THE GOVERNMENT OF THE REPUBLIC OF MALAWI

TECHNOLOGY NEEDS ASSESSMENT REPORT - ADAPTATION

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MINISTRY OF NATURAL RESOURCES,
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MALAWI TECHNOLOGY NEEDS ASSESSMENT REPORT – ADAPTATION

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FOREWORD

Climate change remains one of the major threats to Malawi's development and people's livelihoods. Over the last few decades, the country has experienced an increase in magnitude and occurrence of climate related disasters such as floods and droughts almost in all districts including cities of Lilongwe and Blantyre. In order to tackle such climate change threats in a systematic manner, the National Climate Change Management Policy (NCCMP) was formulated. The Policy got approved and adopted by the Government of Malawi in 2016. The NCCMP 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 policy and legal framework for a pragmatic, coordinated and harmonized approach to climate change management.

The Government of Malawi is aware of the importance of technology in managing impacts of climate change. Technology Needs Assessment (TNA), an initiative that originated from the fourteenth Conference of Parties (COP 14) to the United Nations Framework Convention on Climate Change (UNFCCC), is a country-driven set of activities directed mainly at the identification, selection and implementation of climate change mitigation and adaptation technologies. Also, the TNA tracks the evolving needs of developing countries for new equipment, techniques, practical knowledge and skills. In Malawi, the TNA is aligned with National Climate Change Management Policy under priority area 3.4: Research, Technology Development and Transfer, and Systematic Observation. Under this priority area, the Policy highlights the role and contribution of technology and its transfer in the management of climate change. The TNA therefore provides a link between National Climate Change Management Policy and other policies and strategies to achieve Malawi's overarching development plan presented in the Malawi Growth and Development Strategy III. Due to the crossing cutting nature of climate change and its related impacts on national developmental sectors, the TNA also provides a framework for implementation of national sectoral priorities, strategies and plans which are related to climate change.

The process of developing Technology Needs Assessment Report for Malawi in the adaptation (water and agriculture) and mitigation (energy and forestry) sectors involved stakeholder participation, ensuring gender inclusion at very stage. The implementation of the prioritised climate technologies in the TNA reports will require a collaborative approach of all stakeholders including government, Non-Governmental Organisations (NGOs), civil society, Faith Based Organisations (FBOs), the private sector and academia. It is my sincere hope that the TNA Report will serve as a shop list of climate change technologies which are key for climate resilient building of the economy and livelihoods of Malawians while ensuring reduction in greenhouse gases.

Patrick C.R. Matanda

Principal Secretary for Natural Resources, Energy and Mining

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The EAD appreciates efforts of the international TNA Review team comprising Sara Laerke Meltofte Traerup from UNEP DTU Partnership, Debbie Sparks and Jiska De Groot from University of Cape Town, in guiding the TNA Project at various stages. The EAD team that facilitated this TNA Report comprises the following:

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(iv). Mr. Evans Njewa
(v). Mr. Patrick Mkwapatira
(vi). Mrs. Hannah Siamme and
(vii). Mr. Lyson Kampira (from National Commission of Science and Technology of Malawi).

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Tawonga Mbale-Luka
Director of Environmental Affairs

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ACRONYMS AND ABBREVIATIONS

BAEF = Barrier Analysis and Enabling Framework
COP = Conference of the Parties
CTCN = Climate Technology Centre and Network
DRM = Disaster Risk Management
DTMA = Drought Tolerant Maize for Africa
EAD = Environmental Affairs Department
DCCMS = Department of Climate Change and Meteorological Services
DODMA = Department of Disaster Management Affairs
EAD = Environmental Affairs Department
ERC = Energy Research Centre
ESTs = Environmentally Sound Technology
EWG = Expert Working Group
FLR = Forest Landscape Restoration
GDP = Gross Domestic Product
GCF = Global Climate Fund
GEF = Global Environment Facility
GoM = Government of Malawi
ICLAF = Integrated crop-livestock-aquaculture-forest
IFM = Integrated Flood Management
IRBM = Integrated River Basin Management
MCA = Multi-Criteria Analysis
MFERP = Malawi Floods Emergency Recovery Project
MGDS = Malawi Growth and Development Strategy
NAIP = National Agriculture Investment Plan
NAP = National Agriculture Policy
NAPA = National Adaptation Programmes of Action
NCCMP = National Climate Change Management Policy
NDC = Nationally Determined Contributions
NDRM = National Disaster Risk Management
NRS = National Resilience Strategy
NSCCC = National Steering Committee on Climate Change
NTCCC = National Technical Committee on Climate Change
PPA = Policy Priority Area
PPDAA = Public Procurement and Disposal of Asset Authority

RBM = Reserve Bank of Malawi
RWHAM = Rainwater Harvesting Association of Malawi
TAPs = Technology Action Plans
TNA = Technology Needs Assessment
UNFCCC = United Nations Framework Convention on Climate Change
UCT = University of Cape Town
UDP = UNEP DTU Partnership
UNDP = United Nations Development Programme
UNEP = United Nations Environment Programme
WEMA = Water-use Efficient Maize for Africa

EXECUTIVE SUMMARY

This Technology Needs Assessment (TNA) report presents the environmentally sound technologies which have been prioritised for addressing climate change impacts in the agriculture and water sectors in Malawi. The prioritised technologies would form a basis for a portfolio of environmentally sound technology (EST) projects and programmes designed to reduce vulnerability and enhance resilience of the two key sectors to current and future impacts of climate change in Malawi.

The agriculture and water sectors are most important for Malawi in terms of driving economic growth and contributing to socio-economic development of the country. Over the last ten years, the agriculture sector, for example, has consistently generated the highest contribution to gross domestic product (GDP) of the country. It has contributed, on average, 20.1 percent of the country's GDP, followed by the Wholesale and Retail trade sector (15.8%), the Manufacturing sector (9.1%), the Real Estate activities (8.0%), and the Forestry and Logging sector (7.3%), (RBM, 2019). Considering the linkages of agricultural production and processing with input supply, trade and transport service, the broader agri-food system contributes 44 percent to GDP and generates 74 percent of local employment in Malawi (GoM, 2017). This is a significant contribution to the national economy and livelihoods of Malawians.

Despite the agriculture sector being key to the country's economy, the sector's productive capacity is largely being undermined by climate change impacts and risks. Malawi's agriculture is largely rain-fed and its productivity is sensitive to climate related changes and events. The 2015 floods and 2016 drought are good cases for illustration. Following floods in 2014/15 agriculture season, the country's cereal yields declined to as low as 1.6 tonnes per hectare from 2.2 tonnes per hectare in the previous agriculture season (2013/2014), representing a 28.3% decline in production. The subsequent drought of 2015/2016 growing season resulted in a further decrease in cereal yields to as low as 1.3 tonnes per hectare, representing a further 15.3% decline in production (see table below). The number of people requiring food aid sharply increased from the national average of 1.5 million in the previous five years to 6.8 million in 2016 due to these extreme climate events (GoM, 2016d).

Cereal production per unit area in Malawi between 2008 and 2017
(Data s*ource*: World Development Indicators (https://knoema.com/atlas/Malawi/Cereal-yield)

Year	**Cereal yield** (kg/hectare)	**Year**	**Cereal yield** (kg/hectare)
2017	1,903	*2012*	2,087
2016	1,347	*2011*	2,094
2015	1,591	*2010*	1,907
2014	2,218	*2009*	2,124
2013	2,069	*2008*	1,599

In order to restore and enhance the contribution of the agriculture and water sectors to the country's economy and livelihoods, the National Agricultural Policy (NAP) (GoM, 2016) and its subsequent operationalization plan – the National Agricultural Investment Plan (NAIP) (GoM, 2018) - provides clear direction and guides all players in the agriculture sector towards accelerating agricultural transformation in the face of climate change. The NAIP recognizes climate change as the main challenge in the agricultural transformation process and the *Plan* has prioritized building resilience of agricultural systems as a key program for the 5 year period of its implementation (2017/18 – 2022/23). The prioritized adaptation technologies presented in this report would therefore contribute towards the Government's efforts to reduce the vulnerability of the agriculture sector to climate change impacts and build resilient livelihoods and production systems as outlined in the NAIP.

Ten climate adaptation technologies for each of the sectors were identified and taken through the prioritization process using a participatory Multi-Criteria Analysis (MCA). A gender responsive approach was mainstreamed in the prioritisation process through inclusion of gender-related criteria to help prioritise climate technologies that could contribute to promotion of gender equality and economic empowerment of women and girls. Through the MCA process, the ten climate technologies for each sector were ranked from the highest to the least priority technologies. In each sector, the top three climate adaptation technologies were selected to become the priority climate change adaptation technologies in the agriculture and water sectors in Malawi. These technologies are presented in the Table below:

Climate technologies prioritised for adaptation in the agriculture and water sectors in Malawi.

Sector	**Priority (rank)**	**Adaptation Technology**
Agriculture	1	*Landscape restoration for improved land productivity*
	2	*Integrated crop-livestock-aquaculture-forest production systems*
	3	*Community-based agricultural extension*
Water	1	*Rainwater harvesting*
	2	*Integrated river basin management*
	3	*Integrated flood management*

<u>Prioritised climate technologies in the agriculture sector</u>:

1. *The Landscape restoration for improved land productivity* is a technology of regaining ecological functionality across deforested or degraded landscapes. Recent studies show that Malawi loses an estimated 29 metric tons of soil per hectare each year (GOM, 2001). This has made croplands less productive and more vulnerable to climate change impacts. *Landscape restoration* technology has potential to restore productivity of the degraded croplands and support increased food security, resilience and enhanced biodiversity.

2. *An integrated crop-livestock-aquaculture-forest production systems* is a technology which integrates four different production systems within the same area or farmland in order to maximize its production capacity. The interplay between the production systems generates mutual benefits. In addition, a diversified portfolio of production systems ensures increased resilience of the farming households from climate change and variability. This is because if one production system fails due to drought or climate induced pest infestation, the farmer will still survive on yield from the other production systems.

3. *Community-based agricultural extension* is a technology based on the idea of providing specialized and intensive technical training to 1 or 2 people in a community to become rural extension agents. The technology will enhance the effectiveness of the *lead farmer* approach, an approach currently being used to accelerate technology dissemination in Malawi. Most of the technical training which the *lead farmers* receive is informal or conducted during meetings and this affects their effectiveness in discharging their duties and roles as rural extension agents.

Prioritised climate technologies in the water sector:

1. *Rainwater harvesting* is a technology through which rainwater is captured from rooftops, road drainage and culverts; and stored in storage tanks or reservoirs for use during dry periods when water is scarce. Malawi has a large seasonal variation in rainfall such that during the dry season (May – Oct), water shortage is experienced, while during the rainy season (Nov – April) the country receives intense rainfall with a monthly average of 196 mm (GoM, 2006). According to Rainwater Harvesting Association of Malawi, the country loses 18 million m^3 of rainwater yearly through runoff. The *rainwater harvesting* technology has potential to collect and store this water for future use.

2. The *integrated river basin management* is a technology which integrates surface and ground water systems, land and natural vegetation, and people who directly or indirectly use or benefit from the services of the river basin. The interplay of these components enhances management and conservation of the river basin to sustainably supply freshwater for different purposes of the basin. The technology has the potential to maintain and restore productivity of the degraded river basins and build them to become resilient to climate change impacts.

3. The *Integrated Flood Management* is a flood management technology which integrates land and water resource development in flood-prone areas. The technology aims to minimize damages and losses associated with floods, and maximize the net benefits from the use of floodplains for agriculture. The technology mitigates flood damages and flood losses through: i) reduced physical exposure of human settlement, assets, infrastructure and ecosystems to flood hazards such as restricting any form of development in floodway, ii) reduced asset vulnerability by adopting building guidelines that meet resiliency design standards, e.g. flood proofing and, iii) improved disaster preparedness through increased access to flood hazards information in the form of awareness, early warning systems, emergency shelters and evacuation routes.

The three priority climate technologies for each of the two sectors i.e. agriculture and water, would further be analyzed in the next stages of the TNA process to form the basis for a portfolio of environmentally sound technology (EST) projects and programmes for addressing climate change impacts in the agriculture and water sectors in Malawi.

CHAPTER ONE: INTRODUCTION

1.1 About the TNA project

Technology Needs Assessment (TNA) is a set of country-driven activities leading to the identification, prioritisation and diffusion of environmentally sound technologies for mitigation and adaptation to climate change. It is a long-standing process under the United Nations Framework Convention on Climate Change (UNFCCC). Since 2001, more than 80 developing countries have undertaken TNAs to assess their technology needs to address climate change. The concept of TNA was formalized under the UNFCCC process in 2001, when in Marrakesh Conference of the Parties (COP) 7 established the technology transfer framework. One of the originating themes of the framework is the TNA.

The TNA process has constantly evolved and may be broken into two distinct rounds. Between 2001 and 2008, the first round of TNAs focused on supporting developing countries to develop a clearer understanding of their technological needs and priorities for reducing greenhouse gas emissions and adapting to the adverse impacts of climate change. The Global Environment Facility (GEF) provided financial support for these TNAs, with the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP) supporting the country projects. Malawi participated and the country developed its first TNA in 2003. The processes followed by various countries in developing these TNAs were diverse and, for the most part, the end results lacked implementable actions.

The second round of TNAs commenced in 2009 and continues until present. This round has placed a greater emphasis on implementation, on supporting countries to translate their identified technology needs into implemented projects and programmes. In this way, the TNA process evolved to have three broad benefits. It supports participating countries to:

1. Identify technological means to address climate change and accelerate national development;

2. Build national capacity to support national sustainable development;

3. Create technology action plans to achieve implementation and demonstrate technology viability.

Support for TNAs in this round has come through GEF's Poznan Strategic Programme on Technology Transfer. The GEF programme has funded TNA global projects implemented by UNEP in partnership with the Technical University of Denmark (this partnership is known as *UDP*). The TNA global project has established regional centres to provide technical support to national TNA teams in the implementing countries. These regional centres are recognized climate change expert institutions in their respective regions. Countries in Anglophone Africa, which Malawi is part, are supported by the Energy Research Centre (ERC) of the University of Cape Town (UCT) in South Africa.

The TNA global project phase I ran from 2009 to 2013, with 36 developing countries participating. Between 2014 and 2018 the UDP implemented the GEF-funded TNA Global Project, Phase II, which provided financial and technical support to 27 countries to conduct TNAs. In 2016, the GEF Council approved a TNA Global Project, Phase III, to support further 23 developing countries from small island developing states and least developed countries. This Phase III started in 2018. The countries in African Region that participated in the three phases of the TNA global project are presented in **Table 1**. Malawi is participating in the current phase III of the global TNA Project alongside other African countries listed in **Table 1**.

Table 1: List of countries of Africa region already participated or is currently participating in the phases of the TNA global projects (2009 – 2019).

Region	**TNA Phase I (2009 – 2013)**	**TNA Phase II (2014 – 2018)**	**TNA Phase III (2018 – 2021)**
Africa	Code d'Ivoire Mali Morocco Senegal Ghana Mauritius Rwanda Sudan Zambia	Burkina Faso Burundi Gambia Madagascar Mauritania Mozambique Seychelles Swaziland Tanzania Togo Tunisia	Benin Central Africa Republic Djibouti Guinea Niger Eritrea Liberia **Malawi** Uganda Sao Tome & Principe

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

1.2.1 The Malawi Growth and Development Strategy III

The Malawi Growth and Development Strategy (MGDS) III (GoM, 2017) is a development blueprint for Malawi for the period 2017 to 2022. The MGDS III aims to improve productivity, turn Malawi into a competitive nation, and develop national resilience to shocks and hazards. To achieve this, agriculture, water development and climate change management have been identified as among the 5 key priority areas the Strategy is focusing on. Realising that climate change has adverse impacts on the agriculture sector, a number of strategies have been proposed including adaptation and mitigation of climate change impacts. Adaptation will enhance preparation for and negate the effects of climate change, thereby reducing vulnerability of communities and ecosystems. The environmentally sound technologies identified through this TNA process will contribute to this end, by reducing vulnerabilities and increasing community and ecosystem resilience to the impacts of climate change.

1.2.2 Malawi’s National Resilience Strategy

The National Resilience Strategy (NRS) (GoM, 2017a) is 15-year national agenda aimed at putting vulnerable households on a more sustainable path by strengthening their resilience to seasonal predictable shocks, and extreme shocks such as drought and floods, which are expected to increase owing to climate change. The NRS is composed of four complementary pillars; each of the pillars contains a package of interventions that in combination contributes to resilient people, resilient agriculture, and resilient environment. Through this TNA process, the required enabling framework conditions and their associated implementation plans for the transfer and diffusion of the stated interventions in the NRS can be developed for successful implementation, thereby contributing to attainment of the desired outcomes of the NRS.

1.2.3 Malawi’s National Climate Change Management Policy

Malawi’s National Climate Change Management Policy (NCCMP) (GoM, 2016a) has outlined six priority areas for climate change management in order to reduce vulnerability of the Malawi population and promote community and ecosystem resilience to the impacts of climate change. The priority area 3.4 of the NCCMP recognizes the need for technology development and transfer as well as research in order to achieve this long-term goal for climate change management. To this effect, the TNA Project forms the bedrock and directly contributes to the realization of the objectives of the NCCMP.

1.2.4 Malawi’s National Adaptation Programmes of Action

Malawi’s National Adaptation Programmes of Action (NAPA) (GoM, 2006) identifies six priority interventions for adaptation across several productive sectors of the economy, including agriculture. These priority interventions are considered urgent; and they respond to immediate needs to cope with impacts of climate change, for which further delay will increase people’s vulnerability. The prioritised interventions of NAPA focus on reducing the vulnerability of rural communities and increasing their adaptive capacity to adverse effects of climate change, whilst TNA provides a framework for environmentally sound technology transfer and diffusion to that will help to achieve the NAPA’s goals.

1.2.5 The Nationally Determined Contribution

Malawi submitted its Nationally Determined Contribution (NDC) (GoM, 2015a) in the lead up to the Paris Agreement on climate change. Malawi is committed to pursuing policies and measures that slow and eventually reverse GHG emissions from deforestation and forest degradation, and increase removals through afforestation and promotion of farmer managed natural regeneration on the cultivated landscapes. Malawi’s NDC includes also adaptation actions that will make productive sectors of the economy (e.g. agriculture and water) resilient to adverse impacts of climate change. Such actions include, for example, promotion of forest landscape restoration of the degraded landscapes. The development of the TNAs could play a vital role in identifying appropriate technologies, their required enabling framework conditions and preparing for their implementation plans for their transfer and diffusion.

1.2.6 The National Forest Landscape Restoration Strategy

The National Forest Landscape Restoration (FLR) Strategy (GoM, 2017b) provides strategic direction to enable Malawi place 4.5 million hectares of the country's degraded lands and forests under active restoration by 2030. The FLR Strategy outlines priority opportunities and interventions that can translate the potential of restoration into multiple benefits such as improved food security, increased biodiversity, improved water supply, job creation, income, carbon sequestration and enhanced resilience to climate change. The FLR Strategy is of explicit relevance to the TNA process. The environmentally sound technologies (ESTs) identified and prioritised through this TNA process will form part of the interventions under the FLR process.

1.2.7 The National Agriculture Policy

The National Agriculture Policy (NAP) (GoM, 2016) aims to increase national agricultural production, productivity and real farm income. The NAP recognises that climate change and weather variability can have devastating effects on agricultural production and productivity. As such Priority Area 3.6 of the NAP focuses on establishing a diversified portfolio of agricultural production risk management instruments and technologies to reduce the impacts of the climate related changes and events. These instruments and technologies may include, for example, increased use of irrigation and promotion of tolerant crop varieties. The TNA process provides a prioritised list of environmentally sound technologies and their enabling framework conditions to enhance their transfer and diffusion. The TNA, therefore, directly contributes to the achievements of the NAP goals.

1.2.8 The National Water Policy

The National water Policy (GoM, 2005) aims to guide the sustainable management and utilisation of water resources, in order to provide water of acceptable quality and of sufficient quantities, and ensure availability of efficient and effective water and sanitation services that satisfy the basic requirements of every Malawian and for the enhancement of the country's natural ecosystems. The environmentally sound technologies (ESTs) identified and prioritised through this TNA process will directly contribute to the achievement of sustainable and integrated water resources management and development that make water readily available and equitably accessible to and used by all Malawians in pursuit of their human development and socio-economic advancement, and enhancement of the country's natural resources *(Priority Area A: Water resources management and development)*. In addition, the ESTs will contribute to improved water of acceptable quality for human and ecosystem use, and to sustainable provision and utilisation of water in households, industries, agriculture, fisheries, hydro-power and for other uses.

1.2.9 The National Disaster Risk Management Policy

The National Disaster Risk Management (NDRM) Policy (GoM, 2015) aims to sustainably reduce disaster losses in lives and in the social, economic and environmental assets of individuals, communities and the nation. Two of the six Policy Priority Areas (PPA) of the NDRM Policy are of explicit relevance to the present TNA. These include: i) Development and strengthening of a people-centred early warning system (PPA 3) for effective disaster preparedness and response. This is to reduce the possibility of injury and loss of lives and livelihoods, and take measures to limit damage to property and environment; ii) Reduction of underlying risks (PPA 5) which involves, among other things, sustainable management of the environment and natural resources. This aims at increasing the resilience of the poor and most vulnerable to disasters. Through the TNA process, appropriate technologies will be identified and prioritized that enable realization of the two Policy Priority Areas of the NDRM Policy.

1.3 Vulnerability assessments in the country

Table 2 shows historical, current and projected (future) climate data for Malawi (*Source*: USAID/Malawi, 2013).

Table 2: Historical, current and future temperature and rainfall data in Malawi (*Source*: USAID/Malawi, 2013)

Climate variable	**Historical climate data**	**1997 – 2011 climate data**	**2020 – 2060 projected climate**
Temperature	12°C - 32°C	13°C - 33°C	To increase by 1.75°C – 2.5°C
Rainfall	725mm – 2500mm	630mm – 1650mm	Late onset; and early cessation of rains

The climate data in **Table 2** shows an increase in temperature, both in terms of maximum and minimum temperatures, over the years between 1997 and 2011 (13°C – 33°C) from the long-term average for the country (12°C – 32°C). The October and November temperatures for the period between 2020 and 2060 are projected to be warmer than the historical averages, with an increase of between 1.75°C and 2.5°C. The data confirms the increase in temperatures in Malawi from the historical climate data.

The rainfall data in **Table 2** shows a reduction in mean annual precipitation received in Malawi for the period 1997 – 2011 (630mm to 1650mm) from the historical annual average of 725mm – 2500mm. In addition, the empirical rainfall data observed during the same period (1997 – 2011) showed prevalence of drier conditions during the months of November and December, and the rainfall becoming less in March and April (USAID/Malawi, 2013). The projected rainfall pattern (2020 – 2060) showed a similar trend (Table 1). This suggests a shift in rainfall pattern in the country, i.e. late onset and early cessation of the rainy season.

The impacts of these climate related changes and events on Malawi’s socio-ecological systems are already evident. For example, Malawi’s agriculture is largely rain-fed and its productivity is sensitive to climate related changes and events. The 2015 floods and 2016 drought are good cases for illustration. Following floods in 2014/15 agriculture season, the country’s cereal yields declined to as low as 1.6 tonnes per hectare from 2.2 tonnes per hectare in the previous agriculture season (2013/2014), representing a 28.3% decline in production. The subsequent drought of 2015/2016 growing season resulted in a further decrease in cereal yields to as low as 1.4 tonnes per hectare, representing a further 15.3% decline in production (**Table 3**). For these climate related extreme events, the Government needed in excess of US$500 million for humanitarian food and recovery (GoM, 2015 & 2016).

Table 3: Cereal production per unit area in Malawi between 2008 and 2017 *(Data source*: World Development Indicators (https://knoema.com/atlas/Malawi/Cereal-yield)

Year	**Cereal yield** (kg/hectare)	**Year**	**Cereal yield** (kg/hectare)
2017	1,903	*2012*	2,087
2016	1,347	*2011*	2,094
2015	1,591	*2010*	1,907
2014	2,218	*2009*	2,124
2013	2,069	*2008*	1,599

While Malawi continues to be threatened by climate change, an opportunity exists to proactively adapt to current and future climates. The TNA programme provides a framework to reduce vulnerability of populations and promote community and ecosystem resilience to the impacts of climate change. This is achieved through identification of prioritized adaptation technologies in the priority sectors of the economy and, these prioritized technologies are further analyzed to form a portfolio of environmentally sound technology (EST) projects and programmes for implementation.

1.4 Sector selection

Due to their sensitivity to climate change impacts, the Agriculture and Water sectors were prioritized for TNA adaptation in Malawi. The prioritization of the two sectors was also informed by the Malawi Government's desire to achieve sustainable agricultural transformation and water development that is adaptive to climate change impacts, while enhancing ecosystem functionality upon which the agriculture sector depends for sustainability (Priority Area No. 2 of the MGDS III).

The MGDS III recognizes that agriculture remains key for Malawi in terms of driving economic growth and contributing to socio-economic development of the country. However, the sector's productive capacity is largely being undermined by climate change impacts and risks. The MGDS III has therefore put in place a number of adaptation strategies to address climate change impacts on the agriculture and water sectors. The adaptation strategies in the MGDS III are envisioned to enhance preparation for and negate the effects of climate change on agriculture and water, thereby reducing vulnerability of communities and ecosystems.

The agriculture and water sectors were also reported as priority climate technology sectors in Malawi by the Incubator Programme of the Climate Technology Centre and Network (CTCN) in Malawi (CTCN, 2018). The Incubator programme was designed to identify and enlist priority climate technology sectors, stakeholders and climate that would form a concept for submission to the Global Climate Fund (GCF).

CHAPTER TWO: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

2.1 National TNA team

Malawi adapted the existing climate change institutional structures for the implementation of the TNA process. **Figure 1** presents the adapted structure.

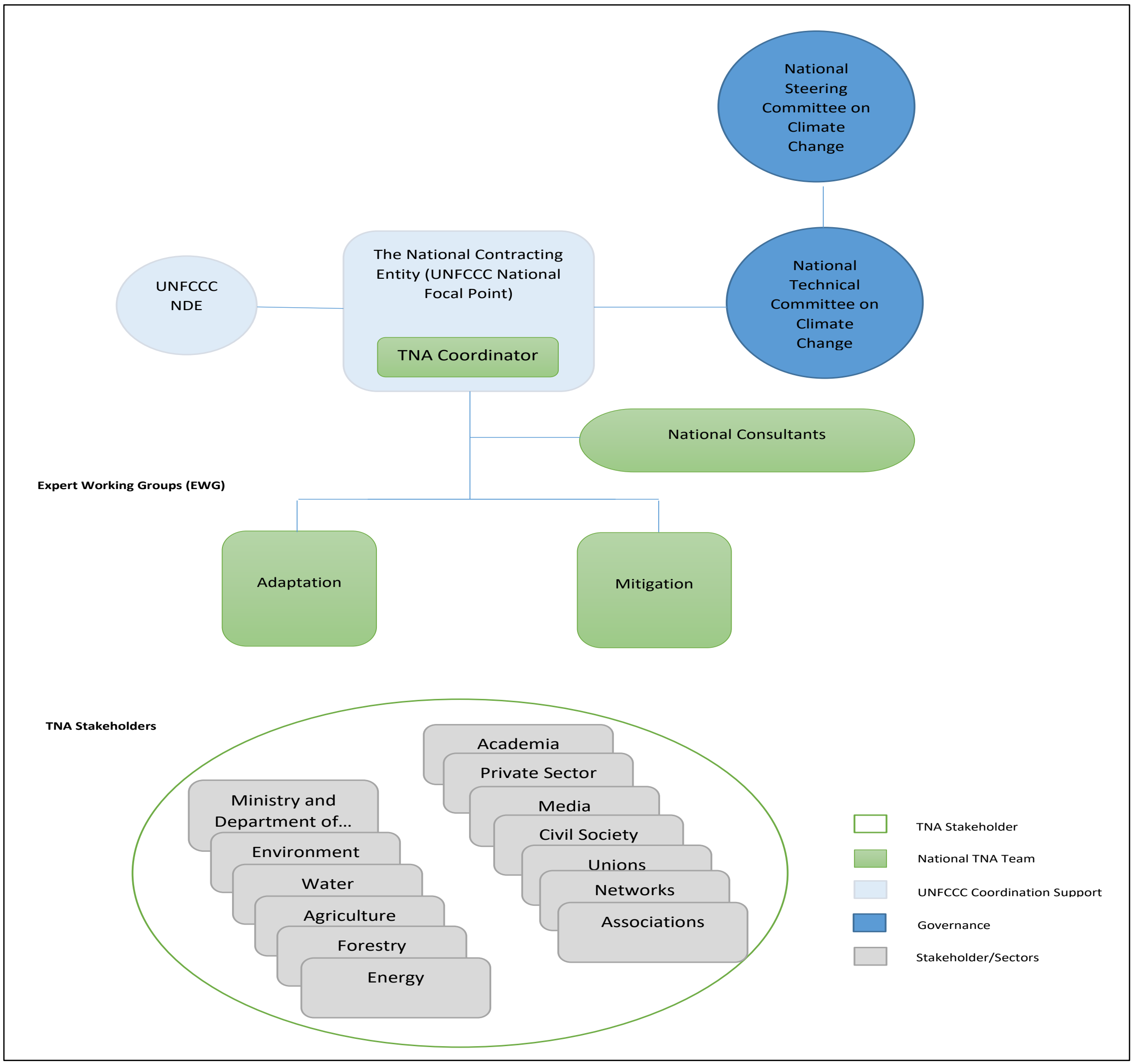

Figure 1: Malawi’s institutional arrangement for managing the TNA process

The structure in **Figure 1** shows linkages between different entities for managing TNA in Malawi. The entities include:

1. *National Steering Committee on Climate Change (NSCCC)* - provides a cross-sectoral coordination of TNA process. NSCCC is chaired by the Ministry of Finance and Development Planning and its Secretariat is housed at the Ministry of Natural Resources, Energy and Mining where the National Contracting Entity (UNFCCC Focal Point) is based. The NSCCC members include controlling officers from Government Ministries responsible for climate change related initiatives.

2. *National Technical Committee on Climate Change (NTCCC)* - A committee providing technical oversight of the climate change management related projects, including TNA. It provides technical guidance to the NSCCC. The committee is chaired by the Department of Climate Change and Meteorological Services.

3. *Secretariat for implementing the TNA project and TNA Coordinator* – The Environmental Affairs Department (EAD) is the implementing entity and the Secretariat for the TNA project. The Secretariat provides administrative support and coordination of the TNA project stakeholders, including the national consultants. The Secretariat also liaises with the UNEP DTU Partnership (UDP) and the Regional Centre (Energy Research Centre, University of Cape Town) to ensure that the TNA project and its deliverables are completed to the highest quality and standards.

4. *Expert Working Groups (EWGs)* – These are stakeholder platforms through which the project is implemented. There are two EWGs, i.e. Adaptation and Mitigation. The membership of the EWGs includes stakeholder institutions shown in **Figure 1**.

5. *National TNA Consultants* – Are national experts hired to support the TNA process. The selection of the National Consultants went through national procurement processes guided by the Public Procurement and Disposal of Asset Authority (PPDAA). The key TORs for the National Consultants included the following:

    i. identifying and prioritizing technologies for the priority sectors through a participatory process with the broad involvement of relevant stakeholders and experts and the development of the TNA report;
    ii. leading the process of barrier analysis and development of an enabling framework for the prioritized technologies and development of the barrier analysis and enabling framework (BAEF) report;
    iii. development of a Technology Action Plans (TAPs) and awareness materials on the outputs of the TNA process in Malawi such as policy briefs;
    iv. training the EWG members (Adaptation) on the Multi-Criteria Analysis (MCA) process. This was key in the prioritization of climate technologies in the priority adaptation sectors.

2.2 Stakeholder engagement process followed in the TNA – Overall assessment

The TNA project utilized members of the Expert Working Groups and other invited experts from the local councils, utility companies and the media. These formed a group of key stakeholders for the TNA process. These stakeholders were engaged in the TNA process at different meeting platforms, and these included; i) the Project Inception Workshop, ii) National Technical Committee on Climate Change (NTCCC) Meeting, and iii) Technology Prioritization Workshop.

The Inception Workshop

The inception workshop for the TNA project was held at Sunbird Lilongwe Hotel on 06th November 2018. Members of both the Adaptation and Mitigation EWGs and potential consultants attended the inception meeting (**Figure 2**).

Figure 2: Stakeholders who attended the TNA inception workshop (*Photo credit:* Chris Manda)

At the inception workshop, the international TNA team from the UDP in Denmark and the Energy Research Centre (ERC) of the University of Cape Town in South Africa introduced the TNA project, its processes, desired outcomes and timelines. The one-day inception workshop was followed by a meeting of the potential national consultants. The participants were briefed of the recruitment processes for the National Consultants for the TNA project.

The National Technical Committee on Climate Change (NTCCC) Meeting

On 15th November 2018, the TNA project was introduced to the members of the NTCCC at its meeting held at the Golden Peacock Hotel in Lilongwe (**Figure 3**).

Figure 3: Members the NTCCC meeting (*Photo credit:* Chris Manda)

A presentation was made by the TNA Coordinator on the TNA process and the expected outcomes, implementation structure, and timelines for implementation of the project.

Expert Working Group (EWG) Technology Prioritization Workshop

Members of the EWG met at Matundu Lake Shore Resort in Salima from 17th to 19th September 2019 to review and prioritize the proposed technologies for adaptation in agriculture and water sectors. The 1st day of the meeting was spent on training the participants on Multi-Criteria Analysis (MCA) as a tool for the prioritization process (**Figure 4**).

Figure 4: EWG members undergoing training on MCA at the Technology Prioritisation Workshop (*Photo credit:* Mathew Malata)

The last two days of the workshop concentrated on members of the EWGs prioritizing climate technologies using the MCA tool (**Figure 5**).

Figure 5: EWG members prioritizing climate technologies using MCA tool (*Photo credit:* Mathew Malata)

2.3 Consideration of Gender Aspects in the TNA process

A gender-responsive approach was adopted in the identification and prioritisation of the selected climate technologies. In developing the factsheets for each identified adaptation technology, gender-related issues were identified, assessed and integrated into the factsheets to enable the TNA team gather sex-disaggregated background information as base information for selecting and prioritising gender-responsive climate adaptation technologies.

Furthermore, to ensure gender issues are fully mainstreamed in the TNA process, the gender criteria were developed and used in prioritisation process to assess the potential of each technology option to contribute to promotion of gender equality and reduce gender inequality, and promotion of economic empowerment of women and girls. **Table 7** of Chapter three and **Table 16** of Chapter four contain gender criteria that were used in the prioritisation process. At the scoring and weighting stage of the prioritisation process, the gender-related criterion were scores of not less than 5 to reflect the strength of the technology in achieving gender equality.

CHAPTER THREE: TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

3.1 Key Climate Change Vulnerabilities in the Agriculture Sector

As temperatures rise and precipitation becomes erratic, and as water becomes less regularly available, agriculture becomes a risky business. Many agricultural crops (e.g. maize, groundnuts, pigeon peas, cowpeas, sorghum, and soybeans) require specific quantities of water and certain temperature ranges at specific stages of their growth. Changes in climate have already been reported to affect crop growth during different stages of these crops.

For example, maize yields are reported to decrease with higher temperatures (Lobell et al., 2008 and 2010; C. Ringler, 2010). Sensitivity to heat is intensified in drought conditions, and maize growing in sites with mild temperatures can be negatively affected by warming in the absence of sufficient levels of moisture in the soil (Lobell et al., 2011). Empirical studies have also shown that the combination of heat with longer periods of drought has the potential to impact plant development in both vegetative and reproductive phenological stages of groundnuts. The negative impact of elevated temperature and reduced water on groundnuts concurs with the work of Vara Prasad et al. (2003) where it was shown that groundnuts suffer significant reduction in yield due to abiotic and biotic stresses and soil infertility.

These empirical findings explain the yield reduction observed in cereal crops in years when Malawi experiences increased temperatures and erratic rainfall. For instance, from 1985–2005, maize yields in Malawi averaged approximately 1.3 tons per ha. In 2003/2004, crop production was adversely affected by the late onset of rains and a prolonged dry spell that occurred at a critical stage in crop development, particularly in the southern region of the country (USAID/Malawi, 2005). During the 2004/2005 growing season, drought had a devastating effect on maize yields, and the national average yield fell 40 percent below the long term average, to 0.76 tons/ha. In November 2005, five million Malawians (or 38 percent of the population) were in need of food aid (*ibid*).

Furthermore empirical studies have shown that different crops are affected differently, and to a different degree, by changes in weather patterns due to climate change (Lobell et al., 2011). Some crops may withstand a late rainy season onset better than others, for example, with moderately reduced yield in some cases and greatly reduced yield in others. The answer to climate change will not be for farmers to plant a specific crop during a specific time period, but rather to build the adaptive capacity that farmers will need to allow them to face a very uncertain climate future. Agricultural diversification and intensification would be important in enhancing resilience to climate change impacts.

3.2 Decision context

Agriculture is the most important sector of Malawi's economy. Over the last ten years, the agriculture sector has consistently generated the highest contribution to gross domestic product (GDP) of the country, generating, on average, 20.1 percent of the country's GDP. **Table 4** shows sectoral contribution to GDP of Malawi's top 5 sectors. The **Table 4** shows that the agriculture sector surpasses all other sectors. Considering the linkages of agricultural production and processing with input supply, trade and transport service, the broader agri-food system contributes 44 percent to GDP and generates 74 percent of local employment in Malawi (GoM, 2017a). This is a significant contribution to the national economy and well-being of Malawians.

Table 4: Sectoral contribution to Malawi's gross domestic product (GDP) (*Source:* Reserve Bank of Malawi, 2019).

Sector	Percent (%) contribution to GDP
1. Agriculture	20.1
2. Wholesale and Retail	15.8
3. Manufacturing	9.5
4. Real estate activities	7.9
5. Forestry and logging	6.7

Malawi's agricultural production is concentrated on one main food crop (maize) and one main cash crop (tobacco). Maize is by far the most dominant crop grown by almost every farmer in Malawi and accounting for about 50% of the entire planted area. As the main source of food, maize has been at the centre of agricultural policies and public expenditures for decades. Tobacco has been the major cash and export crop since the 1980s, accounting for between a quarter and a half of Malawi's exports. Initially restricted to estates, smallholder production now accounts for 95% of the total tobacco production.

In order to sustain the contribution of the agriculture sector to the country's economy and livelihoods, the 2016 National Agricultural Policy (NAP) and its subsequent operationalization plan – the National Agricultural Investment Plan (GoM, 2018) - provides clear direction and guides all players in agriculture sector towards accelerating agricultural transformation in the face of climate change. The NAIP recognizes climate change as the main challenge in the agricultural transformation process and it has prioritized building resilience of agricultural systems as a key program for the 5 year period of its implementation (2017/18 – 2022/23). The prioritized adaptation technologies presented in this report will therefore contribute towards the Government's efforts to reduce the vulnerability of the sector to climate change impacts and build resilient livelihoods and production systems as outlined in the NAIP.

3.3 Overview of Existing Technologies in the Agriculture Sector

In response to changes in local climatic conditions, farmers in Malawi are changing their farming practices to suit the observed changes in the local climatic variables (USAID/Malawi, 2013). For instance, farmers are changing the dates for planting their crops and they are making use of selected seed for shorter cycle crops. In addition, some farmers are using conservation agriculture as a strategy to conserve soil moisture and to increase crop yields, particularly during periods of erratic or reduced rainfall. In districts along the Lake Shore of Malawi farmers are taking steps to protect and regenerate trees such as *Msangu* (*Faidherbia albida)* on their cultivated fields in order to conserve soil moisture and replenish both nutrients and organic matter on cultivated soils (Garrity et al., 2010). **Figure 6** shows the *Msangu* trees growing on cultivated landscapes in Salima district.

Figure 6: *Faidherbia albida* trees in a cultivated farmland in Salima (*Photo credit:* Google)

Table 5 summarises the farming activities that are impacted by climate change and the responses the smallholder farmers are taking to avert or reduce the impacts and ensure adequate crop harvest is acquired and retained at the household. The table shows that the major farming activities impacted by climate change are those related to planting and harvesting, storage and processing, and transport/trading of the agricultural crops. These farming activities are in general impacted by rising temperatures, erratic rainfall and drought, heavy rains and flooding, and strong winds. Different adaptation measures are taken to address these impacts on particular farming activities as presented in **Table 5**. Some of the farming practices, e.g. *replanting* after the crops are destroyed by dry-spell or floods, make farmers incur additional costs in their farming.

Table 5: Farming activities impacted by climate change and adaptation strategies taken by farmers (*Source*: USAID/Malawi, 2013)

Activity	**Climate Change Impact**	**Adaptation Strategies**
Planting and harvesting agricultural crops	Rising temperatures and erratic rainfall contribute to crop destruction and lower yields	i. Changes in dates of planting ii. Replanting iii. Increased cultivation of improved/hybrids varieties iv. Increased cultivation of drought resistant varieties v. Crop diversification (to cassava, sorghum, cotton) vi. Addition of winter cropping and dry season vegetable gardens vii. Increased demand for irrigation viii. Increased use of small scale irrigation (i.e. watering cans); stream diversion
	Climate impacts on soil fertility – lower yields	i. Expansion of cropping to *dambos* and river banks ii. Increased use of conservation agriculture iii. Afforestation: in-field tree regeneration iv. Improved husbandry methods, such as use of compost, organic vegetative and animal manure as fertilizer
	Heavy rains at the end of season damage crops or trigger pests	i. Increased planting of sugarcanes and bananas at field edges (to prevent wash away by rains) ii. Premature harvesting
	Wind and flooding damage crops	i. Increased planting of trees and sisal near field boundaries and riverbanks
Storage and processing	Rising temperatures engender pests and disease (e.g. locusts and termites)	i. Shorter storage periods ii. Early selling (with lower profits)
Transport/trading	Heavy rains and flooding make roads to/from markets impassable.	i. Not selling their crops (loss)

3.4 Adaptation Technology Options for the Agriculture Sector and Their Main Adaptation benefits

The adaptation technology options in the agriculture sector were identified through desk review of relevant national and sectoral documents such as the Malawi Growth and Development Strategy III (GoM, 2017), the National Resilience Strategy (GoM, 2017a), the National Agriculture Policy (GoM, 2016) , the National Agriculture Investment Plan (GoM, 2018), the Malawi's Nationally Determined Contributions (GoM, 2015a), the National Adaptation Programmes of Action (GoM, 2005), the Malawi Incubator Programme (CTCN, 2018), and other relevant initiatives and reports in the agriculture sector. **Table 6** lists the adaptation technologies that were identified and offered for review and prioritisation at the expert working committee meeting that took place in Salima from 17th – 19th September 2019. The factsheet for each of the identified technologies are presented in Annex 4.

Table 6: Adaptation technology options reviewed for the Agriculture Sector.

Technology	Description	Adaptation Benefits
1. Solar powered drip irrigation	An efficient irrigation system that supplies water to the root zone of the plant, and uses solar energy to power the water pump from the water source such as lakes, rivers, wells or boreholes.	The technology supports farmers to adapt to climate change by providing efficient use of water supply. In seasonal droughts, the technology reduces water evaporation losses by providing the necessary water resources direct to the plant.
2. Biotechnology	A technology that generates new crop varieties that are resistant to pests and disease damage, and they are high yielding under variable climatic and soil factors, e.g. early or late maturing maize varieties.	The technology has led to the development of genetically modified crops that have adaptive capacities in vulnerable climatic conditions especially tolerance to drought and pest damage. Examples include: the drought tolerant maize for Africa (DTMA); the water efficient maize for Africa (WEMA).
3. Crop diversification for increased resilience	The technology involves growing different types of crops in a given farm or area so that when one crop fails due to climate related events, the farmers will benefit from the others	A diversified portfolio of crop varieties grown on a farm or region ensures increased resilient from climate variability and changes. For instance, if one crop fails due to drought or climate induced pest infestation, the farmer will still survive on production from the other crops.
4. Landscape restoration for improved land productivity	A technology that helps to regain ecological functionality across degraded landscapes for enhanced human wellbeing.	The technology will result in increased resilience of the farming systems to droughts and other climate shocks.

5. Livestock production systems	An integrated technology that can help adapt the entire livestock production system will enhance the resilience of the livestock sector.	The technology will enhance resilience of the livestock sector to impacts of climate change and make the sector become a means of future food and income insurance against climate and weather-associated risks.
6. Community-based agricultural extension and farmer field school	A technology based on the idea of providing specialized and intensive technical training to 1 or 2 people in a community who then promote a variety of appropriate technologies and provide technical services with occasional support and review from a supporting organization	The technology contributes to climate change adaptation and risk reduction by building the capacity of communities to identify and select appropriate strategies in response to observed impacts of climate variability on local livelihoods.
7. Integrated crop-livestock-aquaculture-forest (ICLAF) production systems	A technology that integrates four different productive systems within the same area in order to maximize its production capacity to meet people's needs and requirements.	The technology ensures increased resilient of the farming systems and people's livelihoods from climate change impacts. If one productive system fails due to drought the farmer will still survive on production from other productive systems.
8. An integrated early warning system	This technology combines indigenous and modern approaches to forecasting possible future occurrence of a natural phenomenon such as floods, droughts, pest and disease incidences, or simply the on-set or cessation of the rainy season.	Accurate and precise weather data is important for advance planning of farming calendar i.e. when to prepare land, when to plant, when to expect to harvest and possible yield levels. This makes the farmer become climate-smart.
9. System of Rice Intensification (SRI)	It is a rice production technology which uses minimal irrigation water to keep the soil just at or below saturation and the rice seedlings are singly spaced and typically hand weeded. SRI has been especially successful among resource poor farmers with small rice farms of 1/3 hectare.	As the technology provides efficient use of available water in rice production, SRI makes rice production systems become resilient to dwindling water availability as a result of climate change. Furthermore, the income from sales of additional rice yield stabilizes household income and contributes to the households becoming resilient to climate change impacts.
10. Integrated pest management (IPM)	IPM is a broad-based approach that integrates practices for economic control of pests. It aims to suppress pest population below the economic injury level.	With climate change contributing to increasing pest pressures, integrated pest management provides farmers with sustainable options to manage the pest populations in an economic manner.

3.5 Criteria and process of technology prioritisation

3.5.1 Capacity building on MCA

The MCA process started with training the members of the Expert Working Groups on the use of Multi-Criteria Analysis (MCA) in the prioritisation process. Each step of the MCA process was thoroughly discussed and illustrated using practical examples. The MCA calculator was also introduced. The MCA process generated interest and nearly all participants actively participated in the discussions. This took nearly the entire day to ensure that all participants were conversant with the MCA process.

3.5.2 MCA process in prioritisation

A *stepwise* approach was used in the prioritisation of the identified adaptation technologies.

Step 1: *Adaptation technology options* – The adaptation technology options presented in **Table 6** and their respective factsheets (as presented in Annex 3) were made available to members of the Expert Working Group for use in the prioritisation process.

Step 2: *Evaluation criteria* - A pre-determined list of criteria for evaluating each adaptation option was also provided to the participants for review. After thorough discussions, the criteria presented in **Table 7** were adopted. The criteria were organised and clustered under costs and benefits in order to facilitate the scoring process. Costs were broken down into capital costs and operating costs of the technology. The benefits were broken down into economic, social, environmental, climate related, technology and institutional related benefits. Each of the technologies was assessed against these criteria (**Table 7**).

Table 7: Evaluation criteria used in the MCA prioritisation process.

Criteria Category	**Criteria**
Costs	1. *Capital costs* – Cost of setting up the technology – often incurred during start-up phase.
	2. *Operating costs* – costs of maintenance and implementation of the technology.
Benefits	3. *Economic benefits* – the ability of the technology to improve local economy; catalyze private investment; economically empower women and girls; and create jobs.
	4. *Social benefits* – ability of the technology to reduce poverty; improve health, especially of women and girls; contribute to gender equality and reduce inequality; and preserve cultural heritage.
	5. *Environmental benefits* – ability of the technology to protect the environment and/or biodiversity.
	6. *Climate-related benefits* – ability of the technology to reduce vulnerability and build climate resilience; and reduce greenhouse gas (GHG) emissions - as a co-benefit.
	7. *Technology-related benefits* – ease of diffusion and in-country accessibility of the technology; and efficiency and effectiveness of the technology in achieving the desired results.
	8. *Institutional-related benefits* – ease of implementation (enablers), and coherence with national goals.

Step 3: *Scoring the technologies* – The scoring was done using the interval scale method. An interval scale of 0 to 100 was established. A score of 0 was associated with the least performance and 100 with that which performs best on a particular criterion. The advantage in the use of interval scale was that differences in scores among technology options have consistency within each criterion. **Table 8** provides the score descriptions and **Table 9** offers the scores for each technology.

Table 8: Descriptions of the scores used in the MCA process.

Score	**General Description**
0	Information on technology does not apply to a particular criteria
1 - 20	Extremely weak performance, strongly unfavorable;
21 - 40	Poor performance, major improvement needed;
41 - 60	An acceptable or above level;
61 - 80	Very favorable performance, but still needs improvement;
81 - 100	Clearly outstanding performance which is way above normal.

Table 9: Score matrix of the technology options on each criterion.

Technology Options	**CRITERIA**							
	COSTS		BENEFITS					
	Capital cost	Maintenance cost	Economic	Social	Environ ment	Climate related	Technology related	Institutional
1. Solar powered drip irrigation	80	100	60	40	100	100	80	80
2. Biotechnology	80	80	80	80	60	60	60	60
3. Crop diversification for increased resilience	80	100	20	80	80	100	80	80
4. Landscape restoration for improved land productivity	60	80	100	100	80	100	40	60
5. Livestock production systems	60	60	100	100	60	100	60	80
6. Community based agricultural extension	80	100	60	60	60	100	60	60
7. Integrated crop-livestock-aquaculture-forest (ICLAF) production systems	20	80	100	100	60	100	60	80
8. Integrated early warning system	80	80	60	60	60	100	80	60
9. Systems of Rice Intensification	60	60	60	80	60	60	60	80
10. Integrated pest management (IPM)	60	60	60	60	80	100	60	60

Each score in the matrix of **Table 9** reflects a perceived relative contribution of that criterion towards the choice of a particular technology. For example, a score of 80 of solar powered irrigation on the environment as presented in Table 8 implies that the technology has very favourable performance on the environment, though it can further be improved.

Step 4: *Normalizing or weighting the scores* - The scores generated in step 3 were normalised or weighted in order to express the relative importance of each criterion with respect to the other criteria. The weighting coefficients were derived from the relative importance the panelists attached to each criterion with respect to the others in achieving the desired outcome. The sum of the weighting coefficients was set to equal to 1 or 100%. **Table 10** provides the weighting coefficients as determined by the panelists of the expert working group.

Table 10: Evaluation criteria used in the MCA prioritisation process.

Criteria Category	**Criteria**	**Weighting Coefficient**
Costs	1. Capital costs	0.15
	2. Operating costs	0.05
Benefits	3. Economic benefits	0.18
	4. Social benefits	0.20
	5. Environmental benefits	0.12
	6. Climate-related benefits	0.15
	7. Technology-related benefits	0.10
	8. Institutional-related benefits	0.05
Total		1

The weighting coefficient for each criterion, as presented in **Table 10**, was multiplied by its corresponding scores presented in **Table 9**. The resulting weighted scores were summed up for each technology option to derive an overall score value. The aggregation of the weighted scores was conducted using the MCA calculator. The results of the aggregation of the weighted scores are given in **Table 11**.

Table 11: Overall scores for each of the technology options

TECHNOLOGY OPTIONS	**CRITERIA**									
	COSTS		BENEFITS							
	Capital cost	Maintenance cost	Economic	Social	Environment	Climate related	Technology-related	Institutional	Total Score	Technology Rank
1. Solar powered drip irrigation	1200	500	1180	800	1200	1500	800	400	7580	**4**
2. Biotechnology	1200	400	1440	1600	720	900	600	300	7160	**8**
3. Crop Diversification for increased resilience	1200	500	360	1600	960	1500	800	400	7320	**6**
4. Landscape restoration for improved land productivity	900	400	1800	2000	960	1500	400	300	8260	**1**
5. Livestock production systems	900	300	1800	2000	720	1500	600	400	8220	**2**
6. Community based agricultural extension	1200	500	1440	1200	720	1500	600	300	7460	**5**
7. Integrated crop-livestock-aquaculture-forest (ICLAF) production systems	300	400	1800	2000	720	1500	600	400	7720	**3**
8. Integrated early warning system	1200	400	1080	1200	720	1500	800	300	7200	**7**
9. Systems of Rice Intensification	900	300	1080	1600	720	900	600	400	6500	**10**
10. Integrated pest management	900	300	1080	1200	960	1500	600	300	6840	**9**
Criterion weight (weighting coefficients in %)	**15**	**5**	**18**	**20**	**12**	**15**	**10**	**5**	**100**	

3.6 Results of technology prioritisation

Table 12 presents the results of the technology prioritisation following the MCA process. The adaptation technologies presented in **Table 12** are ranked on the basis of their priority as determined by their total scores generated through the prioritisation process.

Table 12: Prioritised adaptation technologies in agriculture sector

Rank	**Technology**	**Total Score**
1	Landscape restoration for improved land productivity	8260
2	Livestock production systems	8220
3	Integrated crop-livestock-aquaculture-forest (ICLAF) production systems	7720
4	Solar powered drip irrigation	7580
5	Community-based agricultural extension	7460
6	Crop diversification for increased resilience	7420
7	Integrated early warning systems	7320
8	Biotechnology	7200
9	Integrated pest management	6840
10	Systems of Rice Intensification	6500

The first three priority technologies are: i) *Landscape restoration for improved land productivity*, ii) *Livestock production systems* and, iii) *Integrated crop-livestock-aquaculture-forest (ICLAF) production systems*. While the three prioritized technologies can go a long way in increasing national resilience to climate change impacts, the "*livestock production systems*" technology cannot go far enough to reduce the social vulnerability of the poorest and most vulnerable households in Malawi. Its target group is limited and focuses mainly on progressive cattle farmers. For this reason, *Community-based agricultural extension,* a technology ranked 5 on the priority list, was identified as being broad, inclusive and cross-cutting, and focuses on addressing social vulnerability of the target groups. The technology was therefore selected by the stakeholders to be among the top 3 technologies for barrier analysis in phase 2 of the TNA process.

The final list of the prioritised technologies for adaptation in Agriculture sector is therefore presented in **Table 13**.

Table 13: Broader and cross-cutting impact technologies for adaptation in agriculture sector in Malawi

Priority	**Adaptation Technology**
1	Landscape restoration for improved land productivity
2	Integrated crop-livestock-aquaculture-forest (ICLAF) production system
3	Community-based agricultural extension

The landscape restoration for improved land productivity is a technology of regaining ecological functionality and enhancing human well-being across deforested or degraded landscapes. Malawi continues to experience overwhelming land degradation due to combined effects of human activities and natural processes. Recent studies show that Malawi loses an estimated 29 metric tons of soil per hectare each year (GoM, 2001). This has made croplands less productive and more vulnerable to climate change impacts. *Landscape restoration* technology has potential to restore productivity of the degraded croplands and support increased food security, resilience and enhanced biodiversity.

An integrated crop-livestock-aquaculture-forest (ICLAF) production system is a technology which integrates four different production systems within the same area or farmland in order to maximize its production capacity. The interaction between the production systems generates mutual benefits. In addition, a diversified portfolio of production systems ensures increased resilience of the farming households from climate variability and changes. This is because if one production system fails due to drought or climate induced pest or disease infestation, the farmer will still survive on yield from the other production systems.

The community-based agricultural extension is a technology or a model which is based on the idea of providing specialized and intensive technical training to 1 or 2 people in a community who then promote diffusion and provide technical backstopping of appropriate adaptation technologies within their communities. The models of extension based on government services are not sufficient to enhance diffusion of adaptation technologies because of the necessity to respond to local context of climate change impacts and their adaptation needs, which are often not understood by extension agents trained for work in high potential areas. The *community-based agricultural extension* model will enhance the effectiveness of the *lead farmer* approach, an approach currently being used to accelerate technology dissemination in Malawi. Most of the technical training that lead farmers receive is informal or conducted during meetings and this affects their effectiveness in discharging their duties and roles as rural extension agents.

3.7 Conclusion

The study was set up to identify and prioritise climate technologies that would reduce vulnerability and enhance resilience of the agriculture sector to current and future impacts of climate change in Malawi. Ten adaptation technologies were identified and taken through the prioritisation process using participatory Multi-Criteria Analysis (MCA) tools. A gender responsive approach was mainstreamed in the prioritisation process through inclusion of gender-related criteria to help prioritise climate technologies that could contribute to promotion of gender equality and particularly economic empowerment of women and girls.

Through the MCA process, the ten climate technologies were prioritised and ranked from the highest to the least priority technologies. The three climate adaptation technologies, i.e. *i) Landscape restoration for improved land productivity*, *ii) An integrated crop-livestock-aquaculture-forest (ICLAF) production system;* and *iii) Community-based agricultural extension* were selected to become the priority climate change adaptation technologies in the agriculture sector in Malawi. These technologies would further be analysed in the next stages of the TNA process to form the basis for a portfolio of environmentally sound technology (EST) projects and programmes for

CHAPTER FOUR: TECHNOLOGY PRIORITISATION IN THE WATER SECTOR

4.1 Key Climate Change Vulnerabilities in the Water Sector

Malawi is generally considered to be rich in water resources, which are stored in the form of lakes, streams, rivers, reservoirs, and aquifers (Wada et al., 2012). The surface water covers 21% of the country's territorial area of about 118,500 km². The underground water is widespread and its occurrences are associated with two major sources: the basement complex - extensive but low yielding aquifers (0.2 - 4 litres/sec) and cover largely the plateau areas of the country, Shire Highlands, the Upper Shire Valley, the Lilongwe - Kasungu Plains, and the South Rukuru River Catchment; the alluvial aquifers – high yielding (10 litres/sec) and they are localized in Lakeshore Plains and the Shire Valley.

Historically, Malawi's water resources have exhibited a high sensitivity to changes in climate system. These water resources are considered vulnerable to climate change due to extensive reliance on precipitation as the principle source of their availability and the exposure of the surface water to increased temperatures that enhance evapotranspiration (Bates et al. 2008). Along with the rise in temperature, climate change has affected the hydrological cycle altering precipitation variabilities, soil moisture, surface runoff and water yield[1] (*ibid*). Between 1967 and 2019, Malawi experienced seven major droughts and 22 incidences of flooding, which heavily impacted many people in the country (GoM, 2019). The January 2015 floods, for example, were the most devastating and affected over 1.1 million, displaced 230,000 and killed 106 people (World Bank, 2016). The floods also affected infrastructure (including roads, rail, bridges and homes), crops, and increased incidences of water borne diseases (diarrhea, cholera and malaria).

Furthermore, erratic rains, extended dry periods, and increased evapotranspiration, combined with increased demand for water for different uses, are increasingly exerting stress on freshwater availability and rapidly turning Malawi's historical water abundance into water stressed country. Between 1972 and 2017, freshwater resources per capita in Malawi declined from 3,321 m³ in 1972 to 866.7 m³ in 2017 (**Table 14**).

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[1] Water yield is the sum of the surface runoff, lateral inflow, groundwater inflow, transmission loss, and pond abstraction (Adhikari et al. 2016).

Table 14: Climatological and hydrological conditions (1990s) in Malawi (*Source*: AQUASTAT (https://knoema.com/atlas/Malawi/Internal-renewable-water-resources-per-capita)

Year	**Freshwater/capita/year** (m³/inhabitant/year)	**Year**	**Freshwater/capita/year** (m³/inhabitant/year)
2017	866.7	*1992*	1659.0
2012	1003.0	*1987*	1988.0
2007	1166.0	*1982*	2489.0
2002	1343.0	*1977*	2868.0
1997	1555.0	*1972*	3321.0

According to Falkenmark (1986), a threshold of 1,000 m³ and 500 m³/inhabitant of freshwater correspond to the water stress and water scarcity levels, respectively. With the 2017 per capita water value (866.7 m³), Malawi can be classified as a water stressed country. The Food and Agriculture Organization (FAO) of the United Nations recommends 1,000 m³ of water per inhabitant as a minimum to sustain life and ensure agricultural production in countries with climates that require irrigation for agriculture (FAO 2003). Malawi is an example under this category.

In terms of future impacts, Stocker et al. (2013) reported that climate change is projected to intensify the water cycle. At a country level, using the downscaled climatological data from six general circulation models under the most extreme future emission scenario, Adhikari et al. (2016) showed that the northern region of Malawi will generally have increased precipitation in the mid of the century (2050s). The increases may lead to increased soil and nutrient loss, and the region might be more prone to stormy rains, landslides, and floods. The southern region of the country may face increased water stress and the region may be more prone to droughts. The adaptation measures should address these changes to reduce the vulnerability of the impacted population.

4.2 Decision Context

Climate change is expected to further shift precipitation regime in Malawi away from its long-term norms (Adhikari et al., 2016), with the possibility to change their intensity, magnitude, and frequency. Recent observable events indicate that the frequency of extreme weather events in the country has increased – more droughts and floods have occurred in the last two decade (1999 – 2019) than in the past three decades before (1969 – 1999) (GoM, 2019). The impacts of these are often be most severely felt by poor and socially excluded groups, whose capacity to adapt to both rapid- and slow-onset climate change impacts is more limited. These include women, girls, older people, and children. Although these groups – like their more advantaged counterparts – are already adapting to climate-induced changes, these efforts are often undermined by their limited assets. For example, increasing water stress can dramatically increase the labour burden associated with water collection by women and girls in rural areas, thereby limiting them from engaging in economic activities.

Climate change is also exerting increasing pressure on Malawi's aquatic ecosystems and infrastructure to the point of threatening to erode hard-worn developmental gains. This is particularly with the floods that are affecting the country more frequently and destroying infrastructure and property (GoM, 2019). Furthermore, climate change may lead to unplanned displacement and affect patterns and rates of migration. Most displacement related to extreme weather events has, to date, been temporary. However, if climate change renders certain areas uninhabitable (for example, if they become too dry, or too frequently flooded) such migration may increase in scale and lead to permanent resettlement within and outside Malawi's borders.

Avoidance of these impacts in Malawi calls for decisive responses and firm determination for the water sector to adapt climate change and variability. To adapt to climate change the Government of Malawi, its development partners, and all households face the dilemma of what to do first, what to do differently, and how much to invest in different adaptation interventions. The MGDS III, the National Climate Change Investment Plan, the National Resilience Plan, and the Nation Adaptation Plan provide guidance on these important challenges. However, the TNA provides the framework for prioritizing the suggested adaptation technologies, analyzing the barriers, and offering an enabling framework for technology transfer and diffusion to achieve the stated adaptation objectives.

4.3 Overview of Existing Technologies in the Water Sector

Water has a multiplicity of uses and these may include consumptive use (e.g. agriculture); non-consumptive use (e.g. domestic use for washing and sanitation with wastewater discharged back to the environment); waste disposal (water used to dispose of different kinds of wastes); navigation and transport; environmental services (e.g. sustaining aquatic ecosystems) and nature conservation; recreational and aesthetic purposes (e.g. fishing) and religious and spiritual uses (e.g. baptisms) (World Economic Forum, 2014). With water resources succumbing to impacts of climate change, these important water uses are significantly impacted, threatening economic growth, sustainable livelihoods, and social and spiritual wellbeing of the country.

Local people in Malawi have adopted a number of measures and strategies as a response to dwindling water availability and supply as a result of climate change impacts. For example, as a result of erratic rainfall and extended dry periods, local farmers are changing their farming practices to cope with variations in soil moisture available for crop growth and production (USAID/Malawi, 2013). Some farmers are using drought tolerant maize varieties (e.g. Drought tolerant maize for Africa (DTMA) and/or water-use efficient maize varieties (Water-use efficient maize for Africa (WEMA) for cultivation on their farmlands.

There is large seasonal variation in rainfall in Malawi such that during the dry season (May – Oct), water shortage is experienced, while during the rainy season (Nov – April) the country receives intense rainfall with a monthly average of 196 mm (GoM, 2006). Households in some rural areas of Malawi (e.g. Kamsonga village in Ntchisi

District) are harvesting rainwater from rooftops and store the water in tanks for use when water becomes scarce, especially during the dry season (**Figure 7**).

Figure 7: A household in Kamsonga village in Ntchisi District with a rooftop rainwater harvesting system (Source: https://watercharity.com/conclusion-kamsonga-region-rainwater-harvesting-and-well-project-malawi)

With regards to frequent and severe floods occurring in the country, the government through the Department of Disaster Management Affairs (DoDMA) prepares a *flood response plan* which outlines specific flood management interventions to address the effects of a particular flood event that had just happened. An example of Malawi's flood response plan for the 2019 floods can be accessed at https://reliefweb.int/report/malawi/2019-flood-response-plan-and-appeal.The response plan focusses mainly on recovery efforts of the affected communities by different sectoral departments of the Malawi government and their partners organisations.

In addition, the Physical Planning Department of the Malawi government in collaboration with the DoDMA, through the Malawi Floods Emergency Recovery Project (MFERP), developed disaster risk management land use plans for some selected flood-prone areas in the country (GoM, 2019). These *land use plans* outline specific land use activities and construction standards that can be permitted and enforced in flood-prone areas in order to help reduce damages and losses that future flood disasters could cause to people and their property. Examples of such measures include raising the buildings so that flood waters will go under them; or making the walls of critical buildings, e.g. emergency shelters or health clinics, watertight (flood proof).

4.4 Adaptation Technology Options for the Water sector and Their Main Adaptation benefits

Ten technology options for adaptation to climate change impacts in the water sector were identified through desk review of relevant national and sectoral documents. The documents included the Malawi Growth and Development Strategy III (GoM, 2017), the National Water Policy (GoM, 2005), the Malawi's Nationally Determined Contributions (GoM, 2015), the National Adaptation Programmes of Action (GoM, 2006), the National Resilience Strategy (GoM 2017), the Malawi Incubator Programme (CTCN, 2018), and other relevant reports in the water sectors. **Table 15** presents a list of identified technologies for adaptation in the water sector.

Table 15: Adaptation technology options reviewed for the Water Sector.

Technology:	**Description**	**Adaptation Benefits**
1. Rainwater harvesting	A technology through which rainwater is captured from manmade surface catchments such as rooftops, and road drainage and culverts, and stored in reservoirs or storage tanks for use during dry periods	This technology provides a diversified source of household water supply and a convenient and reliable freshwater supply during seasonal dry periods and droughts.
2. Groundwater abstraction – water borehole drilling	A technology of abstracting water from groundwater source for household use and irrigation through water borehole drilling.	Abstraction of ground water increases water availability for domestic and agricultural purposes. Ground water is relatively less likely to be affected by increased temperatures (evaporation) compared to surface water sources and will therefore be a good water source option especially in arid and semi-arid areas of Malawi.
3. Construction of sand dams	This is a technology where a reinforced rubble cement wall is constructed across a seasonal sandy river to help build up a layer of sand behind the dam wall. During the rainy season, the accumulated sand is water-soaked and retains the water between their grains, thereby making water available for abstraction when the river dries up.	Sand dams will enhance groundwater availability for easy abstraction for household use, drinking animals, and winter cropping when many of the sandy rivers dry out during dry seasons as a result of reduced rainfall and increased evaporation. This is one way of charging the groundwater aquifers
4. Wastewater	This is the reuse of treated wastewater from households,	As climate change projections show general rainfall decrease in

recycling and reuse	communities and industries for home consumption, irrigation, and for industrial activities.	most of the country, re-use of treated wastewater will contribute to the reduction of water shortages occasioned by climate change.
5. Integrated River Basin Management (IRBM)	IRBM is an approach of looking at the whole river basin at a time, understanding different components of the basin, and manipulating how these can work together in order to sustainably supply water for different types of uses in the face of climate change.	IWBM will make the river basins become resilient to these impacts of climate change in many of its forms (e.g. Socio-ecological resilience) through the activities implemented under this broad-based approach.
6. Wetland protection and restoration	A technology that helps to conserve wetlands and restore the degraded ones, thereby enhancing increased availability of shallow waters on the land surface. Wetlands have maintain biodiversity and act as a sponge in regulating water flow thereby controlling floods.	With climate change, it is expected that many wetlands will dry up. Conservation and restoration of wetlands will help build ecosystem resilience as well as resilience of humans who depend on the wetlands for their livelihood and wellbeing.
7. Integrated Flood Management (IFM)	An integrated approach to flood management in order to maximize the net benefits from the use of floodplains and minimizing loss of life and property from floods. It integrates development of land and water resources in a river basin.	With the projected increase in frequency and severity of floods in many flood-prone areas/districts of the country, IFM will make these areas become resilient to negative impacts of flood disasters in many of their forms (e.g. loss of life and damage to property) and maximize use of alluvial-rich floodplains for agriculture.
8. Leakage management, detection and repair in piped water systems	Leaks refer to water lost through leaks on the pipe network before it reaches the customer’s meter i.e Non-Revenue Water (NRW). Detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources.	Quick leak identification and repairs in the piped water network will save the available water from wastage.
9. Water efficient fixtures and appliances	Massive volume of water is lost on daily basis due to use of inefficient appliances and	This technology will help to reduce the amount of water used in households and institutions to

	fixtures in households, offices, industries, hospitals, learning institutions, hotels, etc. Use of water efficient appliances and fixtures can contribute greatly to water conservation, thereby using efficiently the available water resources.	provide the same level of service; consequently contributing to adaptation efforts to the impacts of climate change on reduction of water supply.
10. Construction of multi-purpose dams	This is a technology which combines storing and supplying water for irrigation, industry and human consumption with other uses such as flood control, power generation, navigation, run-off storage and water discharge regulation.	The technology provides flood regulation and protection; increases water and food security; make inland navigation possible on large dams, improving trade and development.

The technologies presented in **Table 15** were offered to members of the expert working group (adaptation) for review at a meeting held from 17 – 19 September 2019 at Matundu Lake Shore Resort in Salima District. Detailed descriptions of each of these technologies are presented in the factsheets provided as **Annex 4**.

4.5 Criteria and process of technology prioritisation

In order to prioritise the adaptation technologies presented in **Table 15**, a set of criteria were locally-validated using the MCA4Climate as the starting framework (UNEP, 2011). The criteria used for evaluating each technology option are summarised in **Table 16.** These criteria were organised and clustered under costs and benefits in order to facilitate the scoring process. Costs were defined as capital costs of the technology. The benefits were broken down into economic, social, environmental, climate related, technology and institutional related benefits.

Table 16: Evaluation criteria used in the MCA prioritization process.

Criteria Category	**Criteria**
Costs	1. *Capital costs* – Cost of setting up the technology – often incurred during start-up phase.
Benefits	2. *Economic benefits* – the ability of the technology to improve local economy; catalyze private investment; economically empower women and girls; and create jobs.
	3. *Social benefits* – ability of the technology to reduce poverty; improve health, especially of women and girls; contribute to gender equality and reduce inequality; and preserve cultural heritage.
	4. *Environmental benefits* – ability of the technology to protect the environment and/or biodiversity.
	5. *Climate-related benefits* – ability of the technology to reduce vulnerability and build climate resilience; and reduce greenhouse gas (GHG) emissions - as a co-benefit.
	6. *Technology-related benefits* – ease of diffusion and in-country accessibility of the technology; and efficiency and effectiveness of the technology in achieving the desired results.
	7. *Institutional-related benefits* – ease of implementation (enablers), and coherence with national goals.

4.5.1 Scoring the technology options

Interval scale method was used in generating scores for each of the technology option based on each of the criteria provided in **Table 16**. An interval scale of 0 to 100 was established. A score of 0 represented a technology that performed the least on a particular criterion, while a score of 100 on the same criterion represented a technology that performed the best. **Table 17** provides the score descriptions and **Table 18** offers the scores generated on each criterion for each of the technologies.

Table 17: Descriptions of the scores used in the MCA process.

Score	**General Description**
0	Information on technology does not apply to a particular criteria
1 - 20	Extremely weak performance, strongly unfavorable;
21 - 40	Poor performance, major improvement needed;
41 - 60	An acceptable or above level;
61 - 80	Very favorable performance, but still needs improvement;
81 - 100	Clearly outstanding performance which is way above normal.

Each score in the matrix of **Table 18** reflects a perceived relative contribution of that criterion towards the choice of a particular technology. For example, a score of 100 of *rainwater harvesting technology* on the *social - criterion* **(Table 18)** implies that the rainwater harvesting technology has a clearly outstanding performance to reduce poverty; especially of women and girls; contribute to gender equality and reduce inequality; and improve health.

Table 18: Score matrix of the technology options on each criterion.

Technology Options	**Criteria**						
	COSTS	BENEFITS					
	Capital cost	Economic	Social	Environment	Climate related	Technology related	Institutional
1. Rainwater harvesting	80	100	100	80	80	100	100
2. Groundwater abstraction – water borehole drills	60	40	100	60	80	80	60
3. Constructing sand dams	40	40	100	80	80	80	100
4. Wastewater recycling and reuse	80	60	40	100	80	20	40
5. Integrated river basin management	80	80	80	80	80	80	100
6. Wetland protection and restoration	40	80	80	100	80	40	80
7. Integrated flood management	40	100	100	100	80	40	80
8. Leakage management, detection and repair in piped water systems	60	40	60	60	80	100	80
9. Water efficient fixtures and appliances	80	60	60	40	80	60	80
10. Construction of multipurpose dams	40	100	80	80	80	60	80

4.5.2 Weighting the scores

The members of the expert working group generated weighting coefficients for each criterion to reflect the relative value the members had attached to each criterion (with respect to other criteria) in attaining a desired result on a particular technology. The sum of the weighting coefficients was set to equal to 1. **Table 19** provides the weighting coefficients.

Table 19: Evaluation criteria used in the MCA prioritization process.

Criteria Category	**Criteria**	**Weighting Coefficient**
Costs	1. Capital costs	0.15
	2. Operating costs	0.05
Benefits	3. Economic benefits	0.18
	4. Social benefits	0.20
	5. Environmental benefits	0.12
	6. Climate-related benefits	0.15
	7. Technology-related benefits	0.10
	8. Institutional-related benefits	0.05
Total		1

The weighting coefficient for each criterion, as presented in **Table 19**, was multiplied by its corresponding scores presented in **Table 18**. The resulting weighted scores were summed up for each technology option to derive an overall score value. The aggregation of the weighted scores was conducted using the MCA calculator. The results of the aggregation of the weighted scores are given in **Table 20**.

Table 20: Overall scores for each of the technology options

Technology Option	**Criteria**								
	COSTS	BENEFITS							
	Capital cost	Economic	Social	Environ ment	Climate related	Technolo gy-related	Institution al	Total Score	Technology Rank
1. Rainwater harvesting	1600	1000	1500	1600	1600	1000	500	8800	1
2. Groundwater abstraction – water borehole drills	1200	400	1500	1200	1600	800	300	7000	6
3. Constructing sand dams	800	400	1500	1600	1600	800	400	7100	5
4. Wastewater recycling and reuse	1600	600	600	2000	1600	200	200	6800	7
5. Integrated river basin management	1600	800	1200	1600	1600	800	500	8100	2
6. Wetland protection and restoration	800	800	1200	2000	1600	400	400	7200	4
7. Integrated flood management	800	1000	1500	2000	1600	400	400	7700	3
8. Leakage management, detection and repair in piped water systems	1200	400	900	1200	1600	1000	400	6700	8
9. Water efficient fixtures and appliances	1600	600	900	800	1600	800	400	6700	8
10. Construction of multipurpose dams	800	1000	1200	1600	1600	600	400	7200	4

4.6 Results of the technology prioritisation

Table 21 presents the results of the technology prioritisation in the water sector following the MCA process. The adaptation technologies are ranked on the basis of their priority as determined by their total scores generated through the prioritisation process.

Table 21: Prioritized adaptation technologies in the water sector

Rank	**Technology**	**Total Score**
1	Rainwater harvesting	8800
2	Integrated river basin management	8100
3	Integrated flood management (IFM)	7700
4	Wetland protection and restoration	7200
4	Construction of multipurpose dams	7200
6	Construction of sand dams	7100
7	Groundwater abstraction – water borehole drills	7000
8	Wastewater recycling	6800
9	Leakage management, detection and repair in piped water systems	6700
10	Water efficient fixtures and appliances	6700

According to the prioritisation results presented in **Table 21**, the three priority adaptation technologies in the water sector are i) “R*ainwater harvesting,* ii) *Integrated river basin management, and* iii) *Integrated flood management*. The three technologies will be taken up to second phase of the TNA process where the barriers for their diffusion will be analysed and enabling framework to promote diffusion will be developed.

The relevance of these prioritised technologies to national context is described below.

4. *Rainwater harvesting:* According to Rainwater Harvesting Association of Malawi (RWHAM), Malawi loses 18 million m³ of rainwater yearly through runoff. Rainwater harvesting has potential to collect and store this water in reservoirs for future use and alleviate water shortages in the face of climate change. The technology is also prioritized in the Malawi Growth and Development Strategy III, the National Water and Agriculture Policies, the National Climate Change

Management Policy, the National Adaptation Programmes of Action, the National Resilience Strategy, and other relevant regulatory mechanisms. The highest priority accorded to this technology is, therefore, inline and consistent with national adaptation priorities of the country.

5. The *integrated river basin management (IRBM)* is a technology that integrates different components of the river basin. The components include both surface and ground water systems, land and natural vegetation, and people who directly or indirectly use or benefit from the services of the river basin. The interplay of these components will enhance management and conservation of the river basin to sustainably supply freshwater for different purposes of the basin. The technology has the potential to maintain and restore productivity many of the degraded river basins in Malawi and build them to become resilient to climate change impacts. The prioritisation of this technology is also supported by national adaptation strategies outlined in the MGDS III, the NAPA, the NDC, the national resilience strategy, and the national water policy.

6. The *Integrated Flood Management (IFM)* is an integrated technology to flood management. It integrates land and water resource development in flood-prone areas and aims to minimize damages and losses associated with floods, and maximize the net benefits from the use of alluvial-rich soils of the floodplains for farming. The technology mitigates flood damages and flood losses through: i) reduced physical exposure of human settlement, assets, infrastructure and ecosystems to flood hazards such as restricting any form of development in floodway, ii) reduced asset vulnerability by adopting building guidelines that meet resiliency design standards, e.g. flood proofing and, iii) improved disaster preparedness through increased access to flood hazards information in the form of awareness, early warning systems, emergency shelters and evacuation routes.

The prioritisation of this technology responds Malawi’s 15-year national agenda (the National Resilience Strategy, 2017) aimed at putting vulnerable households on a more sustainable path by strengthening their resilience to seasonal predictable shocks, and extreme shocks such as drought and floods, which are expected to increase owing to climate change. This is also echoed in the National Disaster Risk Management Policy (2015).

4.7 Conclusion

Chapter four of this TNA report was set up to identify and prioritize climate technologies that would reduce vulnerability and enhance resilience of the water sector to current and future impacts of climate change in Malawi. Ten adaptation technologies were identified and taken through the prioritization process using participatory Multi-Criteria Analysis tools. A gender responsive approach was mainstreamed in the prioritisation process through inclusion of gender-related criteria to help prioritise climate technologies that could contribute to promotion of gender equality and particularly economic empowerment of women and girls.

Through the MCA process, the ten climate technologies were prioritised and ranked from the highest to the least priority technologies. The three climate adaptation technologies, i.e. *i)* R*ainwater harvesting,* ii) *Integrated river basin management, and*

iii) *Integrated flood management* were selected to become the priority climate change adaptation technologies in the water sector in Malawi. These technologies would further be analyzed in the next stages of the TNA process to form the basis for a portfolio of environmentally sound technology (EST) projects and programmes for

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ANNEXES

Annex 1: Work plan for TNA adaptation

DELIVERABLE	ACTIVITY	RESPONSIBILITY	START DATE	END DATE
1. Technology Needs Assessment Report	1.1 Development of Technology Fact Sheets (TFS)	Consultant	Aug’19	Sep’19
	1.2 Expert Working Group meeting to prioritise climate technologies	EAD/Consultant	16-Sep	20-Sep
	1.3 Technology Needs Assessment (TNA) report writing	Consultant	Sep’19	Nov’19
	1.4 Submission of TNA Report to Energy Research Centre (ERC) and UDP for review and feedback	EAD	Nov’19	Dec’19
	1.5 Address of Comments from ERC and UDP	Consultant	Dec’19	Jan’20
	1.6 Approval of TNA Report	NTCCC and NSCCC	Feb’20	Feb’20
	1.7 Submission of TNA Report	EAD	Feb’20	Feb’20
2. Barrier Analysis	2.1 Identification and Analysis of Barriers, and development of enabling framework	Consultant	Dec’19	Jan’20
	2.2 Expert Working Group Meeting to review barriers and enabling framework and provide feedback	EAD/Consultant	Feb’20	Feb’20
	2.3 Development of BAEF Report	Consultant	Feb’20	Mar’20
	2.4 Submission of BAEF Report to ERC and UDP for review and feedback	EAD	Apr’20	Apr’20

and Enabling Framework (BAEF) Report	2.5 Address of comments from ERC and UDP	Consultant	Apr’20	May’20
	2.8 Approval of BAEF Report	NTCCC and NSCCC	Jun’20	Jun’20
	2.9 Submission of BAEF Report	EAD	Jun’20	Jun’20
3. Technology Action Plan (TAP)	3.1 Development of TAP	Consultant	May’20	Jun’20
	3.2 Expert Working Group meeting to review draft TAP	EAD/Consultant	Jun’20	Jun’20
	3.3 Incorporation of comments from EWG	Consultant	Jul’20	Jul’20
	3.4 Submission of TAP to ERC and UDP	EAD	Aug’20	Aug’20
	3.5 Address of comments from ERC and UDP	Consultant	Aug’20	Sep’20
	3.6 Approval of BAEF Report	NTCCC and NSCCC	Sep’20	Sep’20
	3.7 Submission of BAEF Report	EAD	Oct’20	Oct’20
4. Sector Policy Brief	4.1 Development of Sector Policy Brief	Consultant	Sep’20	Oct’20
	4.2 Expert Working Group meeting to review sector policy brief	EAD/Consultant	Oct’20	Oct’20
	4.3 Incorporation of EWG comments on sector policy briefs	Consultant	Nov’20	Nov’20

Annex 2: List of stakeholders involved and their contacts

TECHNOLOGY NEEDS ASSESSMENT (TNA), CLIMATE TECHNOLOGIES PRIORITISATION MEETING, MATUNDU LODGE, SALIMA, 17TH TO 19TH SEPTEMBER 2019

NO	NAME	ORGANIZATION	DESIGNATION
1.	Mathews Tsirizeni	LEAD	PM
2.	Henry Utila	FRIM	CFRO
3.	Lawrence Chilimampunga	EGNCO	SEMO
4.	Innocent Nkangala	DAHD	DDLD
5.	Harold Matola	NSO	Statistician
6.	Jullius Ng’oma	CISONECC	Coordinator
7.	Suzgo Kaunda, PhD.	University of Malawi Polytechnic	Consultant - *Mitigation*
8.	Steve Makungwa, PhD.	LUANAR/CASA	Consultant - *Adaptation*
9.	Hannah Siame	EAD	Environ. Officer
10.	Peaches Phiri	Water Resources	DDWR
11.	Micheal Makonombera	EAD	ADEA
12.	Jolamu Nkhokwe	DCCMS	Director
13.	Chimwemwe Yonasi	EAD	Environ. Inspector
14.	Mathew Malata	AEJ	Prophet
15.	Christopher Manda	EAD	EO
16.	Corwell Chisale	Energy Affairs	PEO
17.	Hendrex W. Kazembe	DARS	DDARS
18.	J. Kamoto, PhD.	LUANAR	Deputy Principal
19.	Nelson Ngoma	LWB	Environ. Officer
20.	M. Mkutumula	DODMA	MO
21.	Patrick Mkwapatira	EAD	Environ. Officer
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Annex 3: Technology Factsheets for selected technologies in the Agriculture sector

1. TECHNOLOGY:	SOLAR-POWERED DRIP IRRIGATION FOR EFFICIENT USE OF WATER IN IRRIGATED CROPPING SYSTEMS
Introduction	Irrigation is an agricultural operation, supplying the need of a plant for water. Irrigation is necessary in drier environments where natural rainfall does not meet plant water requirements during all or part of the year. The importance of efficient use of water due to water scarcity is being addressed through development of more efficient irrigation systems such as drip irrigation. Drip irrigation saves water by delivering water directly to the root of the plant one drop at a time. This conserves much of the water that is usually lost through surface runoff and evaporation and gives the soil plenty of opportunity to absorb and hold the valuable water. The technology uses solar energy to power the water pump to pull water from the water sources – including lakes, rivers, wells or boreholes.
Technology Characteristics	A wide range of component and system designs of drip irrigation are available. The choice of a system design depends on topography, field length, and soil texture of the land area earmarked for irrigation. The system can also be used for fertilizer application to the plant root zone. The technology is simple in installation and maintenance.
Country Specific Applicability & Potential	Many parts of Malawi experience droughts as a result of climate variability and changes. This persistently threatens crop growth and productivity, resulting in many households becoming food insecure and exacerbated poverty. Solar powered drip irrigation has the potential to transform crop production in the face of climate change by efficiently providing water to plants from external water sources.
Status of Technology in Malawi	Solar powered drip irrigation technology is being promoted in Malawi through government, NGOs and private initiatives. There is high potential to scale up this technology so that many smallholder farmers are able to benefit from it.
Benefits to Economic/ Social and Environmental Development	A drip irrigation system efficiently provides water to the root zone of the plant thereby increasing available soil moisture for plant uptake for its growth and development. This result in increased crop productivity for household food security and excess for sale to add to household income. In addition, household labour requirement is reduced when automated drip irrigation systems are used. Drip irrigation opens up new land for crop production in areas with permanent or seasonal water scarcity. Additionally, as the technology is adaptable to terrains where other systems cannot work well due to

	climatic or soil conditions, these are also opened up for production.
Climate Change Adaptation Benefits	Drip irrigation technology supports farmers to adapt to climate change by providing efficient use of water supply. In seasonal droughts, drip irrigation reduces demand for water and reduces water evaporation losses by providing the necessary water resources direct to the plant when required.
Financial Requirements and Costs	The estimated costs for the procurement and installation of the drip irrigation system can be in the range of US$15,000 – US$20,000. The costs vary with the design system of the technology and the size and other characteristics of the target area earmarked for irrigation.

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2. TECHNOLOGY:	LIVESTOCK PRODUCTION SYSTEMS
Introduction	While uncertainty in some future climate projections is high, there is little doubt that the future climate will be warmer. Hence, the effects of higher temperature on livestock and their forage is the most certain impact. The predicted changes in climate and weather are likely to result in more variable pasture productivity and quality, increased livestock heat stress, and greater disease/parasite occurrences (Stokes et al., 2010). An integrated technology that can help adapt the entire production system will enhance the resilience of the livestock sector.
Technology Characteristics	An integrated livestock production system consists of components that mitigate the effects of high heat load on livestock. These include: i. Adjusting the environment utilized for care and management of livestock, including, for example, providing shade to ameliorate thermal heat load on the livestock or using sprinklers to wet the animals; ii. Nutritional manipulation strategies which include changing the feeding frequency and time of feeding, and changes in ingredients, e.g. addition of dietary fat to increase energy density, or additional roughage added to cattle diets to reduce heat increment; iii. Animal selection for thermal tolerance or changing the species, e.g. goats rather than cattle. In this case, breeding goals are adjusted to account for higher temperatures, lower quality diets, and greater disease parasite challenges.
Country Specific Applicability & Potential	Temperatures in Malawi are predicted to increase by 0.6-2°C by the 21st Century. This will definitely have an impact on livestock production. Integrated livestock production system as a technology to mitigate the impacts of such heat load has the potential to increase the resilience of livestock sector to such impacts.

Status of Technology in Malawi	The technology is mainly used in dairy farming. However, the larger population of livestock in the country are under extensive grazing systems whose owners have not embraced the technology. Promotion of the technology to these farmers will enhance the resilience of their livestock to the predicted high heat load.
Benefits to Economic/Social and Environmental Development	Livestock provide multiple benefits that include food, clothing, draught, income and employment. The manure from livestock is used in nutrient cycling for soils, thereby enhancing the productive capacity of the land for crop production. However, livestock grazing on fragile landscapes are associated with extensive land degradation. This is ameliorated through proper grazing regimes.
Climate Change Adaptation Benefits	The technology will enhance resilience of the livestock sector to impacts of climate change and make the sector become a means of future food and income insurance against climate and weather-associated risks.
Financial Requirements and Costs	The cost for the technology is estimated in the range of US$2 - 5 million for a period of 5 – 8 years.

3. TECHNOLOGY:	BIOTECHNOLOGY FOR ENHANCED CROP RESILIENCE AND INCREASED PRODUCTIVITY
Introduction	Biotechnology involves breeding for improved performance under environmental stresses. Biotechnology generates new crop varieties that are resistant to pests and disease damage, and they are high yielding under variable climatic and soil factors, e.g. early or late maturing maize varieties.
Technology Characteristics	Biotechnology works through transferring superior genes from one crop to another crop of interest. The technology has been used in such crops as cotton (Bt cotton), cowpeas (Bt cowpea), soybeans, tissue banana culture, etc. and improved yields and pest and disease resistance has been recorded in such crops.
Country Specific Applicability & Potential	Farming in Malawi is risky for smallholder farmers who rely on rainfall to water their crops. These crops are severely affected by frequent droughts and seasonal changes in the on-set and cessation of the rainfall. Insects, particularly stem borers, also have a negative impact on yields, especially during times of drought when they feed on surviving maize and reduce the plants’ ability to use limited water and nutrients. Crop improvement using biotechnology offers a powerful tool to achieve significant drought tolerance, water-use efficiency, and stabilize yields of many of these crops.
Status of Technology in Malawi	The technology is currently being used in the country. For example the Lilongwe University of Agriculture and Natural resources conducted a biotechnology research that resulted in the production

	and promotion of Bt cotton and Bt cowpeas which are resistant to pink bollworm and pod borer pests, respectively. In addition, the tissue culture banana techniques are used at Bvumbwe Agricultural Research Station to produce disease-free (bunchy top virus) tissue culture banana planting materials. These disease-free plantlets are under pilot testing in the country. The government has put in place regulatory mechanisms including biosafety measures to manage biosafety issues associated with the technology.
Benefits to Economic/ Social and Environmental Development	The molecular breeding tools used in Biotechnology have resulted into a 3 to 5 fold increase in crop yields (e.g. drought tolerant maize for Africa - DTMA) and water-use efficient maize for Africa - WEMA). Besides contributing to higher crops yields, disease and pest resistant crops (e.g. Bt Cotton and cowpea) are some direct results of biotechnology. The technology therefore makes a positive contribution in increasing agricultural productivity leading to food and nutritional security in an environmentally sustainable manner. It can be used to increase food production in the face of diminishing land and water resources.
Climate Change Adaptation Benefits	Biotechnology has led to the development of genetically modified crops that have adaptive capacities in vulnerable climatic conditions especially tolerance to drought and pest/disease damage. Some of the biotech products showing longer- term promise for adaptation to climate change include the drought tolerant maize for Africa (DTMA) and the water efficient maize for Africa (WEMA); the Bt Cotton and the Bt Cowpeas; and the tissue culture banana.
Financial Requirements and Costs	The costs are variable depending on the stage of biotechnology, i.e. biotechnology research or promotion of biotechnology products for use by farmers. For example, promotion of tissue culture banana plantlets alone can cost approximately US$200,000.

4. TECHNOLOGY:	LANDSCAPE RESTORATION FOR IMPROVED LAND PRODUCTIVITY, FOOD SECURITY AND RESILIENCE
Introduction	Landscape restoration is an ongoing process of regaining ecological functionality and enhancing human well-being across degraded landscapes. Degraded landscapes are lands that have lost their productivity or capacity to provide services to people and wildlife. These degraded lands are restored to support increased food security, resilience and biodiversity.
Technology Characteristics	This technology embraces maintenance of ecological functionality of the degraded landscapes and human well-being. The actions to include: i) increasing tree cover on degraded croplands and denuded buffer zones of rivers and streams through retention of natural regeneration, direct seeding, and planting of agroforestry trees and shrubs; ii) improving soil structure and protect the soil against erosion and nutrient losses through conservation agriculture (CA) practices that include maintenance of permanent soil cover, minimum soil disturbance, and diversification of plant species; iii) stabilizing soils and increasing infiltration in areas with high rates of rainfall runoff and erosion through terracing, construction of check dams and infiltration ditches; and iv) protecting the existing forest on customary land and in protected areas.
Country Specific Applicability & Potential	Malawi experiences overwhelming land degradation due to combined effects of human activities and natural processes, making the land less productive for agricultural production. For example, Malawi loses 29 metric tons of topsoil per hectare per year due to runoff from rainwater. Landscape restoration has potential to maintain and restore productivity of the degraded agricultural landscapes.
Status of Technology in Malawi	Many smallholder farmers in Malawi practice subsistence farming system with limited use of land productivity enhancing technologies. This has led to increased land degradation resulting in declining crop yields, fuelwood shortages, water scarcity and poor water quality. The effects of these on people include increased food insecurity, vulnerability, and increased water-borne illnesses.
Benefits to Economic/Social and Environmental Development	The following are the benefits of the technology: i. Increased crop yields with decreased dependence on inorganic inputs, reduced soil/nutrient loss; ii. Increased access to forest products (e.g. firewood) for subsistence and sale; iii. Reduced burden on women in collecting fuelwood; iv. Reduced landslide risks during high rainfall events v. Decreased sedimentation of catchments of hydropower infrastructure; vi. Conservation of biodiversity

Climate Change Adaptation Benefits	The technology will result in increased resilience of the farming systems to droughts and other climate shocks
Financial Requirements and Costs	The cost of many landscape restoration projects range from US$6 - & 30 million.

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5. TECHNOLOGY:	INTEGRATED CROP-LIVESTOCK-AQUACULTURE-FOREST (ICLAF) PRODUCTION SYSTEMS
Introduction	Integrated crop-livestock-aquaculture-forest (ICLAF) is an agricultural strategy that integrates four different productive systems within the same area in order to maximize its production capacity to meet people's needs and requirements. The strategy can be implemented using mixed, rotating, or successive crops so that the interaction between each component generates mutual benefits.
Technology Characteristics	ICLAF can be implemented in different ways, with a wide range of crops and a variety of animal or fish species. It can be adapted to regional characteristics, climatic conditions, local markets and farmer's profile, and can be adopted by small, medium and large producers. It can also be used in different configurations, combining two, three or all four components in one productive arrangement. The following configurations can be realized: i. ICL – Crop-livestock (mixed farming); ii. ICF – Crop-forestry (Agroforestry) iii. ICA – Crop-aquaculture iv. ILA – Livestock-aquaculture v. ILF – Livestock-forestry vi. IAF – Aquaculture-forestry vii. ICLA – Crop-livestock-aquaculture viii. ICAF – Crop-aquaculture-forestry ix. ICLF – Crop-livestock-forestry x. ILAF – Livestock-aquaculture-forestry xi. ICLAF – Crop-livestock-aquaculture-forestry
Country Specific Applicability & Potential	The land holding capacity of many smallholder farmers in Malawi is less than a hectare. This entails farmers must maximize production from the same piece of land in order to meet the basic needs of the household. Integrating different production systems on the same piece of land has a potential to meet this requirement.

Status of Technology in Malawi	Some components of ICLAF are already in use in Malawi. For example, some farmers are already practicing integrated aquaculture-agriculture, agroforestry or mixed farming. This requires scaling up and to include other productive systems in order to maximize the returns from the limited available to many smallholder farmers.
Benefits to Economic/ Social and Environ-mental Development	The following are the benefits of the technology: i. Increased production of grains, meat/milk, fish, and tree products from the same area; ii. Greater efficiency in the use of resources and increased energy balance; iii. Increased economic stability through reducing risk and uncertainty by diversifying production; iv. Improvement of the public image of farmers within society. v. Optimization and intensification of soil nutrient recycling; vi. Reduced pressure for opening new lands.
Climate Change Adaptation Benefits	A diversified portfolio of productive systems ensures increased resilient of the farming systems and people's livelihoods from climate variability and changes. For instance, if one productive system fails due to drought or climate induced pest or disease infestation, the farmer will still survive on production from the other productive systems.
Financial Requirements and Costs	The estimated costs may range from US$6-10 million.

6. TECHNOLOGY:	GREATER CROP DIVERSIFICATION FOR INCREASED FOOD SECURITY AND RESILIENCE
Introduction	This technology involves production of a variety of crops in a given farm or area so as to lessen risks from extreme events from climate variability and changes, and fluctuation in market prices. For example, some crops are more drought-tolerant, while others are more resistant to pests and diseases than others. A diversified portfolio of crops ensures that farmers do not suffer complete ruin when the weather is bad and/or when pest/disease infestation occurs. Similarly, diversification can manage market price risks, on the assumption that not all products will suffer low prices at the same time.
Technology Characteristics	The technology can be applied both to individual farmers and to different regions. At a regional or landscape level, the technology is seen as a "shift from the regional or landscape dominance of one crop to regional production of a number of crops which take into account the economic returns from different value-added crops with complementary marketing opportunities.
Country Specific Applicability & Potential	The simplification of cropping systems (e.g. monoculture of maize, tobacco, cotton) have been underway in Malawi for the past 40 to 60 years, accompanied by the growing use of fertilizers and pesticides. This has led to declining yields, increased pest and disease infestation, declined market revenue etc. Crop diversification has potential to transform production systems in terms of both ecological and economic sustainability in the face of climate change in Malawi.
Status of Technology in Malawi	The technology is promoted in Malawi. At a national level, the government is promoting inclusive production of cash crops beyond tobacco. This includes, for example, production of grain legumes. At a household level, mixed cropping has been a traditional cropping system and many farmers are still using the system. Therefore the potential for adoption and scaling up can be hire because the technology is already known in the country.
Benefits to Economic/Social and Environmental Development	A diversified portfolio of crops ensures that farmers do not suffer complete ruin when the weather is bad and/or when pest/disease infestation occurs. Some crops will still survive the event. Similarly, diversification can manage market price risks, on the assumption that not all products will suffer low prices at the same time. The technology also maximizes household labour and irrigation water use, e.g. weeding or water application is done to all crops grown together at the same time. In addition, the technology can promote reduction in the use of pesticides and fertilizer, including the environmental damage resulting from their excessive use.
Climate Change Adaptation Benefits	A diversified portfolio of crop varieties grown on a farm or region ensures increased resilient of the farming systems and people's livelihoods from climate variability and changes. For instance, if one

	productive system fails due to drought or climate induced pest or disease infestation, the farmer will still survive on production from the other productive systems.
Financial Requirements and Costs	The estimated costs may range from US$2 - 5million.

7. TECHNOLOGY:	COMMUNITY-BASED AGRICULTURAL EXTENSION
Introduction	The community-based agricultural extension model is based on the idea of providing specialized and intensive technical training to 1 or 2 people in a community who then promote a variety of appropriate technologies and provide technical services with occasional support and review from a supporting organization. This model has generally experienced a high degree of success in terms of discovering or identifying productivity enhancing technologies, which are then widely adopted.
Technology Characteristics	The technology involves establishing appropriate training entities/centres in the target communities, including development of training modules focusing on local contexts. Communities select candidates against a list of agreed criteria for the training to become rural extension agents. Upon completing the training, the new graduates go back to their communities to provide extension services. Technical experts from the training centre are made available to provide ongoing support to newly trained rural extension agents. Periodic refresher courses are made available to rural extension agents to ensure that they are current in their extension messages.
Country Specific Applicability & Potential	Recent developments in agricultural policy and investment plan have re-emphasized the importance of extension services in Malawi. However, models of extension based on government services are not sufficient to meet the needs of farmers in rural areas. This is due to a number of factors including the necessity to respond to the specific technological needs of farmers in different agro-ecological zones; high transaction costs of reaching remote areas; the need for localised crop and livestock management solutions suited to local conditions, which are often not understood by extension agents trained for work in high potential areas; and the challenge of finding professional extension specialists willing to live and work in remote, and sometimes insecure areas.

Status of Technology in Malawi	The community-based extension model or its variant is not new to Malawi. Lead farmer approach is implemented and promoted nationwide to support government extension workers and accelerate technology dissemination. However, most of the technical training that lead farmers receive is informal or conducted during meetings. This affects their effectiveness in discharging their duties and roles as rural extension agents. The proposed technology has the potential to enhance the effectiveness of the lead farmer approach and provide critical mass of rural extension agents in Malawi.
Benefits to Economic/ Social and Environ-mental Development	Rural agricultural extension programmes can help reduce the costs of providing extension services that emanate from the scale and complexity of centralized systems. Rural extension agents themselves benefit from the accumulation of new knowledge and technical skills and, through this, are able to generate additional income by charging for their services. The strengthening of social and professional networks via this model provides vital access to information and, by working directly with local producers and passing on the acquired knowledge, rural extension agents are building the technical capacity of their communities.
Climate Change Adaptation Benefits	The model contributes to climate change adaptation and risk reduction by building the capacity of communities to identify and select appropriate strategies in response to observed impacts of climate variability on local livelihoods. The model promotes a rural outreach programme that provides assistance to many communities that would otherwise not receive technical support services. As a result of these services, farmers have generally been able to increase crop and livestock production.
Financial Requirements and Costs	External financing will be required to set up training schools for agricultural extension. When the training is carried out by local organizations and farmer facilitators, initial start-up costs may be moderate, but running costs will be much lower. The estimated costs may range from US$2-3 million.

8. TECHNOLOGY:	INTEGRATED EARLY WARNING SYSTEM FOR INCREASED FOOD SECURITY AND RESILIENCE
Introduction	This is a technology that combines indigenous and modern approaches to forecasting possible future occurrence of a natural phenomenon such as floods, droughts, pest and disease incidences, or simply the on-set or cessation of the rainy season. This provides an integrated system of early warning that utilizes both indigenous and modern science.
Technology Characteristics	A modern early warning system is a set of coordinated procedures through which information on foreseeable hazards is collected and analyzed for predicting possible future occurrence of a natural phenomenon. The forecasting and predictions are based on probabilities. However, indigenous knowledge utilizes bio-indicators to make forecasts of the possible weather and climate futures. This is based on local knowledge that has accumulated over time and passed on from generation to generation. This knowledge is embedded within the cultures of different ethnic groups. The greatest gains are possible when the two approaches combine to create new opportunities and cross-fertilize the thinking of the other.
Country Specific Applicability & Potential	Too often the two approaches are viewed as competing rather than complementary. The modern (meteorological) forecasts are regarded superior despite some flaws associated with their predictions. An integrated early warning system will complement the strength of each approach, thereby providing more precise and accurate weather forecasts essential for advance planning of farming calendar and in some instances for disaster preparedness.
Status of Technology in Malawi	The technology is not well developed in Malawi. Each approach exists as separate with meteorological weather forecasts regarded as more superior. Forecasting of weather based on indigenous knowledge continues to be regarded as primitive.
Benefits to Economic/ Social and Environmental Development	A reliable early warning system assists farmers take better decisions on agricultural operations and activities with the following possible resultant benefits: i. Reduction of agricultural losses due to adverse climatic events; ii. Availability of data that can be useful to help the official agricultural planning; iii. Increasing productivity that in some cases can guarantee profits for the producer.
Climate Change Adaptation Benefits	Accurate and precise weather data is important for advance planning of farming calendar i.e. when to prepare land, when to plant, when to expect to harvest and possible yield levels. This makes the farmer become climate-smart.
Financial Requirements and	The estimated cost for the technology may range from US$500, 000 – 800,000.

Costs	

9. TECHNOLOGY:	SYSTEMS OF RICE INTENSIFICATION (SRI)
Introduction	The System of Rice Intensification (SRI) is a low water, labor-intensive technology and uses younger seedlings singly spaced and typically hand weeded with special tools. SRI has been especially successful among resource poor farmers with small rice farms of about 1/3 hectare.
Technology Characteristics	SRI involves three essential principles: plant young seedlings, plant single seedlings, and apply minimal irrigation water to keep the soil just at or below saturation (Uphoff and Fernandes 2002). This creates a favorable growing environment, providing soil water and nutrient conditions that greatly accelerate growth. Research shows that SRI crops show more resistance to pests and diseases, tolerance to drought, lodging, hot spells and cold snaps. The length of the crop cycle, especially time to maturity, is also reduced. The water management technique used in SRI (similar to alternate wet and drying) reduces CO^2 emissions from rice paddies (Uphoff et al 2011, Stoop et al 2002). It is also reported to increase the abundance and diversity of soil organisms by keeping the soil moist but not flooded, aerating the soil frequently and enhancing the soil organic matter content (Uphoff et al 2012).
Country Specific Applicability & Potential	Malawi has a number of rice schemes spread across the country where smallholder farmers are allocated small portions of land for rice cultivation. The farmers mostly use conventional methods of rice production. Systems of Rice Intensification (SRI) technology has a potential to transform rice production and make it a viable business for the smallholder farmers in the face of climate change.
Status of Technology in Malawi	The technology has already shown impact by doubling rice yield from 2.5 to 5.8 metric tons per hectare for those smallholder farmers who have adopted the technology in some rice schemes supported by the African Institute of Corporate Citizenship (AICC). The technology requires scaling up to reach out to many rice farmers in the country.
Benefits to Economic/ Social and Environ-mental Development	Increased rice yield obtained by using the technology will bring more cash income to the family to meet family needs. The households are also assured of food security, which ultimately enhance social cohesion within the family. As a result of controlled irrigation and alternate wetting and drying, SRI technology offers water savings for farmers, especially in water scarce areas.
high Climate Change Adaptation Benefits	As the technology provides efficient use of available water in rice production, SRI makes rice production systems become resilient to dwindling water availability as a result of climate change. Furthermore, the income from sales of additional rice yield stabilizes

	household income and contributes to the households becoming resilient to climate change impacts.
Financial Requirements and Costs	The estimated costs for the technology is in the range of US$0.5 – 1million.

10. TECHNOLOGY:	INTEGRATED PEST MANAGEMENT (IPM)
Introduction	Integrated Pest Management (IPM), also known as Integrated Pest Control (IPC), is a broad-based approach that integrates practices for economic control of pests. It aims to suppress pest population below the economic injury level.
Technology Characteristics	The IPM process starts with monitoring, which includes inspection and identification, followed by the establishment of economic injury levels. The economic injury levels set the economic threshold level, i.e. the point when pest damage (and the benefits of treating the pest) exceed the cost of treatment. This can also be an action threshold level. Once a threshold has been passed by the pest population, action steps are taken to reduce and control the pest. IPM employs a variety of actions including cultural control (e.g. physical barriers), biological controls (e.g. natural predators of the pest), and finally responsible use of pesticides and only at specific times in a pest's life cycle.
Country Specific Applicability & Potential	Pests in agriculture are one of the main challenges limiting agricultural productivity in Malawi. An example is the most recent attach of the fall armyworms (*Spodoptera frugiperda*) on maize crop which have caused tremendous destruction to maize crop in the last two cropping seasons. Efforts to control the pest using pesticides have not yet yielded positive results. IPM has the potential to limit the pest population below the economic levels.
Status of Technology in Malawi	IPM technology has been used in Malawi for several decades and has shown potential to manage pest population to below threshold levels. Malawi has therefore the capacity to manage the technology.
Benefits to Economic/ Social and Environmental Development	Limiting the pest population to economic levels through IPM will enhance productivity in agricultural crops thereby offering food security and additional income from the sale of farm produce. Since IPM sparingly use pesticides, chemical contamination of the environment is reduced.
Climate Change Adaptation Benefits	With climate change contributing to increasing pest pressures, integrated pest management provides farmers with sustainable options to manage the pest populations in an economic manner.

Financial Requirements and Costs	The estimated costs of IPM ranges from US$ 0.3 – 0.5 million.

Annex 4: Technology Factsheets for selected technologies in the Water Sector

1. TECHNOLOGY:	RAINWATER HARVESTING
Introduction	Rainwater harvesting is a technology through which rainwater is captured from manmade surface catchments such as rooftops, and road drainage and culverts, and stored in reservoirs or storage tanks for use during dry periods (Figures 1 & 2). The technology is particularly used in places which receive little rainfall but intense and often seasonal (e.g. arid and semi-arid regions). If properly designed, manmade catchment surfaces can collect large quantities of rainwater and used for different purposes, including washing and drinking, irrigating backyard vegetable gardens, grass, lawns or field crops.
Technology Characteristics	The technology is categorised into two: i) R*ooftop rainwater harvesting* as a system which collects water from rooftop surfaces using gutters and drain the water into the collection vessels through down-pipes constructed for this purpose (Figure 1). As the rooftop is the main catchment area, the amount and quality of rainwater collected depends on the area and type of roofing material.  Figure 1: Rooftop water harvesting ii) *Ground surface rainwater harvesting* – The system collects ground surface runoff into water storage reservoirs or tanks for future use (Figure 2). The reservoirs can vary in size depending on the amount of rainwater from runoff to be stored.
Country Specific Applicability & Potential	There is large seasonal variation in rainfall in Malawi such that during the dry season (May – Oct), water shortage is experienced, while during the rainy season (Nov – April) the country receives a monthly average rainfall of 196 mm. According to Rainwater Harvesting Association of Malawi - RWHAM (2017), Malawi loses 18 billion litres of rainwater yearly through runoff. Rainwater harvesting has therefore potential to collect and store this water in reservoirs for future use and alleviate water shortages in Malawi.

Status of Technology in Malawi	Rainwater harvesting is a known technology in Malawi. Rural households collect rainwater from rooftops when it rains using water buckets for their immediate household use. The technology has been mainstreamed in national policies (e.g. National Water Policy and National Agriculture Policy). Recently, the Rainwater Harvesting Association of Malawi (RWHAM) embarked on a campaign to create a mass movement on rainwater harvesting to adopt the practice at a wider scale to increase water sources.
Benefits to Economic/ Social and Environmental Development	Rainwater harvesting will supplement domestic water requirement during seasonal dry periods and droughts, and provides self-sufficiency to freshwater supply. It reduces the cost of pumping of groundwater; as a result it is less expensive. It provides high quality water, soft and low in minerals, thereby enhancing social acceptability. The technology will have environmental benefits through reduction in runoff which chokes storm drains, avoid flooding of roads, reduce soil erosion in urban areas, and reduce ground water pollution.
Climate Change Adaptation Benefits	Climate change projection for Malawi indicates general rainfall decrease most of the country, which together with population growth is bound to impact serious strains in existing low freshwater endowment in the country. This technology can contribute significantly to reducing climate vulnerability at the household level primarily by diversifying household water supply, and providing a convenient and reliable freshwater supply during seasonal dry periods and droughts.
Financial Requirements and Costs	The cost of a standard 1,000 litre household rainwater jar/tank is approximately US$100 if built according to UN-Habitat manual. The cost of construction of a retainer dam depends on the size of the project and location but estimates for a small dam serving 200 households in about US$75,000.

2. TECHNOLOGY:	CONSTRUCTING SAND DAMS
Introduction	A sand storage dam (commonly known as a sand dam) is a small dam built on and into the riverbed of a seasonal sandy river. Sand dams effectively increase the volume of groundwater available for abstraction as well as prolonging the period in which groundwater is available.
Technology Characteristics	A sand dam is a reinforced rubble cement wall built across a seasonal sandy river. A seasonal river is full of water and even floods in the rainy season. But dries up in the dry season. During the dry season, the sediment from the dry riverbed down to the bedrock underneath the river is dug out and a concrete wall is built across the river using a mixture of rubble and rocks from the river bed and cement (Figure 2).  Figure 2: A sand dam during dry season During the rainy season the river floods and the water deposits heavier sand behind the dam and carries the lighter sediment over the top of the dam.  Figure 4: A sand dam during rainy season Over the next few years, the layer of sand builds up behind the dam wall. The sand is water-soaked during the rainy season and retains a lot of that water between the grains of sand during the dry season. During the dry season local people dig shallow scoop holes into the sand and find water. The sand holds water and prevents it from

	evaporating so quickly. Water can be used for irrigating crops, drinking, cooking, and washing; and for animals to drink.
Country Specific Applicability & Potential	Many rivers in Malawi are seasonal, filling-up during the rainy season and completely drying-out during the dry season. The river beds of these rivers are usually sandy, which have a large water holding capacity. Constructing sand dams will help to hold and store water during the rainy season for use during the dry season. There is therefore large potential for sand dams in the Malawi.
Status of Technology in Malawi	Digging shallow scoop holes into the sand and find water during the dry season has been practiced in the rural and remote areas for decades in Malawi. These have helped to alleviate water problems associated with prolonged dry seasons in these areas. The technology can therefore be easily taken up as many local people have experience of digging shallow scoop holes for water.
Benefits to Economic/Social and Environmental Development	Sand dams are simple, low costs, low maintenance technology that retains rainwater and recharges groundwater. They are the most cost-effective method of water conservation in drylands environments. They provide an improved, local and reliable source of water for communities living in remote rural areas for domestic and livestock during the dry season.
Climate Change Adaptation Benefits	Climate change projection for Malawi indicates general rainfall decrease, which is bound to impact serious strains in existing low freshwater endowment in the country. Therefore sand dams will serve to alleviate the climate change induced water stress in these areas. Sand dams can also contribute greatly to the stabilization of declining groundwater tables (Elliot et al 2011).
Financial Requirements and Costs	The average cost of a sand dam that can last as long as 50 years is estimated at US$ 7,500

3. TECHNOLOGY:	INTEGRATED RIVER BASIN MANAGEMENT (IRBM)
Introduction	Integrated river basin management (IRBM) is an approach of looking at the whole river basin at a time, understanding different components of the basin, and manipulating how these can work together in order to sustainably supply water for different types of uses in the face of climate change. These components of the river basin include both surface and ground water systems, land and natural vegetation, and people who directly or indirectly use or benefit from the services of the basin.
Technology Characteristics	IRBM emphasizes cross-disciplinary coordination of major actors in the river basin to balance or trade-off their expectations from the basin to achieve long-term sustainability. This involves setting up a shared long-term vision for the river basin, agreed by all the major stakeholders, including the inhabitants of the basin. Based on shared solid knowledge of the condition of river basin ecosystem and the socio-economic forces that influence it; appropriate policies, strategies and actions are collectively developed in an integrated manner and implemented involving all major stakeholders.
Country Specific Applicability & Potential	Malawi experiences overwhelming degradation of river basins due to mostly human activities, making the river basins less productive to supply freshwater for different types of uses. For example, the major hydropower station on Shire river basin is under threat due to excessive sedimentation as a result of agricultural activities conducted in the upstream of the River. IRBM has potential to maintain and restore productivity of the degraded river basins.
Status of Technology in Malawi	Integrated approaches have been attempted mainly by water sector people without fully engaging other major stakeholders such as environment, agriculture, forestry and inhabitants of the river basins (local people). The results have been variable. Recently, efforts have been taken to include cross-sectoral approaches in river basin management, e.g. the Shire river basin management program.
Benefits to Economic/ Social and Environ-mental Development	The increased availability of good quality water in sufficient amounts for domestic, agricultural and industrial use (e.g. hydro-power generation) will enhance economic development and wellbeing of the people (e.g. reduced incidences of water-borne diseases). In addition, the IRBM approach ensures that, apart from water quantity and quality of both underground and surface waters, other natural resources (e.g. tree and forest resources, land and land use) are sustainably managed and the needs of the people living in the river basin are adequately taken care of.
Climate Change Adaptation Benefits	Climate change projection for Malawi indicates general increase in floods, water scarcity and droughts. IWBM will make the river basins become resilient to these impacts of climate change in many of its

	forms (e.g. Socio-ecological resilience) through the activities implemented under this broad-based approach.
Financial Requirements and Costs	IWBM are high cost projects. Many of the IWBM projects supported by the World Bank range in excess of US$10 – US$30 million.

4. TECHNOLOGY:	WETLAND PROTECTION AND RESTORATION
Introduction	Wetlands are areas where water covers soil all or part of the time. Wetlands have important ecological functions of maintaining biodiversity and act as a sponge in regulating water flow thereby controlling floods. They also protect water quality by trapping sediments and retaining excess nutrients and other pollutants such as heavy metals. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion. Wetland restoration relates to the rehabilitation of previously existing wetland functions from a degraded state to an operational state of overall function. Human activities of farming on wetlands, converting wetlands for settlements and allowing livestock to drink water in wetlands, all upset the soil conditions and damage its ecological functions.
Technology Characteristics	The most common feature of all wetlands is that the water table (the groundwater level) is very close to the soil surface or shallow water covers the surface for at least part of the year. Conserving these ecosystems and restoring the degraded ones will provide added value to increased availability of high water table even in the face of climate change. Restoration activities may, for example, include planting wetland plants, restricted conversion of wetlands to other land uses.
Country Specific Applicability & Potential	Key wetlands and other aquatic ecosystems cover about 20% of Malawi’s surface area. These wetlands are mainly used as sources of food and livelihoods for the local inhabitants; they store floodwaters and maintain surface water flow, thereby reducing the incidences of flood events during rainy seasons and enhancing water availability during dry periods. Because of the significant contributions these wetlands offer, the potential for their conversation and restoration can be high in Malawi.
Status of Technology in Malawi	The Lake Chilwa wetland has been designated as both a Ramsar Site (1997) and a Biosphere Reserve (2006). This international recognition provides an opportunity for enhanced conservation and restoration of Malawi’s wetlands. Locally, knowledge and information on biophysical characterization of key wetlands of Malawi is available and these can be used to develop conservation and restoration strategies for these.

Benefits to Economic/ Social and Environmental Development	Conservation and restoration of wetlands will ensure continued supply of ecosystem services in adequate quantities for improved livelihoods and ecological sustainability. Such ecosystem services include health habitats for fish and wildlife, opportunities for recreation and aesthetic appreciation, water purification, flood protection, shoreline stabilization, groundwater recharge and stream flow maintenance.
Climate Change Adaptation Benefits	With climate change it is expected that wetlands will dry up, but this can be accelerated if human activities are also degrading the wetlands. Conservation and restoration of wetlands will help build ecosystem resilience as well as resilience of humans who depend on the wetlands for their livelihood and wellbeing.
Financial Requirements and Costs	Varies according to size and type of wetlands and has to be calculated on a case-by-case basis. Type of wetland to be restored, expertise availability, and consequent chances of success depend on degree of wetland degradation and consequent restoration requirements, intended degree of restoration, land costs if land purchase is required to convert to wetlands, labour costs, transportation distance between seedling source and planting site, seedling mortality rate between collection and planting, cost of raising specific species in nurseries before transplantation and scale of post-implementation monitoring operations.

5. TECHNOLOGY:	CONSTRUCTION OF MULTI-PURPOSE DAMS
Introduction	Multipurpose dams combine two or more functions of traditional single-purpose dams into one hydro infrastructure project. A multipurpose dam may combine storing and supplying water for irrigation, industry and human consumption with other uses such as flood control, power generation, navigation, run-off storage and water discharge regulation.
Technology Characteristics	The construction of multipurpose dams is based on the same principles used for single purpose dams (barriers across a body of water), but additional features may be included to accommodate their different purposes, such as irrigation channels or power generation facilities. Dam designs vary, and the chosen design is agreed upon between planners and construction engineers. Operational management of the multipurpose dams includes flushing out sediments and monitoring selected environmental and socioeconomic variables, amongst other activities.
Country Specific Applicability & Potential	Multipurpose dams are particularly appropriate for Malawi as the multi-functionality of the operations can help meet a number of development goals simultaneously, such as those related to energy, water and food security, and economic development.
Status of Technology in Malawi	Multipurpose dams are not yet available in Malawi. Most dams available in Malawi are single purpose dams, e.g. the Kamuzu I and Kamuzu II dams on Lilongwe River supply water to Lilongwe city for human consumption and industry use.
Benefits to Economic/ Social and Environmental Development	Multi-purpose dams provide flood regulation and protection; increases water and food security; make inland navigation possible on large dams, improving trade and development. Inland navigation is a relatively cost-effective and a less-polluting form of transport. - Provides recreational benefits for local communities.
Climate Change Adaptation Benefits	Provides climate change adaptation through reducing seasonal water stress and improving access to water during droughts.
Financial Requirements and Costs	The estimated cost for multi-purpose dam can range from 200 – 350 million USD.

6. TECHNOLOGY:	INTEGRATED FLOOD MANAGEMENT (IFM)
Introduction	Integrated Flood Management (IFM) is a process promoting an integrated – rather than fragmented – approach to flood management. It integrates land and water resources development in a river basin and aims at maximizing the net benefits from the use of floodplains and minimizing loss of life from flooding. Treating floods as problems in isolation almost necessarily results in a piecemeal, localized approach.
Technology Characteristics	Integrated Flood Management recognizes the river basin as a dynamic system in which there are many interactions and fluxes between land and water bodies, e.g. land use has impacts on water in the river basin; effective management of floods through a best mix of strategies and options; and use of an integrated hazard management – early warning systems and emergency planning, etc. The effective implementation of these requires an appropriate enabling environment for effective participation of all key stakeholders.
Country Specific Applicability & Potential	Recently, Malawi has experienced frequent and severe floods, causing extensive harm and damage to peoples' lives and livelihood sources. For example, the 2015 floods, 523,347 houses were partially or completely damaged representing the largest single sector affected by size of loss and reconstruction needs as well as total numbers of assets and people affected. Integrated Flood Management has a potential to reduce such impacts and maximise the alluvial-rich soils deposited by the floods for crop production.
Status of Technology in Malawi	Flood management interventions have been implemented in Malawi as isolated, individual interventions to address floods as a problem in many flood prone areas. The results of these interventions are variable. For example, the Government of Malawi through the Malawi Floods Emergency Recovery Project (MFERP) has just developed land use plans for disaster risk management in some selected flood-prone trading centres in Malawi.
Benefits to Economic/ Social and Environ-mental Development	Floods are associated with deposition of alluvial soils in the floodplains providing rich soils for agriculture and food security. Through Integrated Flood Management, these floodplains will be maximally utilized. In addition, IFM will make the flood-prone areas resilient to flood damage to property and loss of life.
Climate Change Adaptation Benefits	Climate change projection for Malawi indicates a general increase in floods in many flood-prone areas of the country. Integrated Flood Management will make these areas become resilient to negative impacts of flood disasters in many of their forms (e.g. loss of life and damage to property) and maximize use of alluvial-rich floodplains for agriculture.
Financial Requirements and Costs	Integrated Flood Management (IFM) are high cost projects. Many of the IFM projects supported by the World Bank range in excess of US$50 – US$250 million.

7. TECHNOLOGY:	GROUNDWATER ABSTRACTION – WATER BOREHOLE DRILLS
Introduction	Groundwater abstraction is the process of getting water from the ground source for household use and irrigation (Figure 4).  Groundwater abstraction can be either manual, where water table is high or mechanized usually by using a rotary drilling rig which is able to reach deep aquifers of several hundred meters.
Technology Characteristics	A water borehole is a specially engineered hole in the ground, making provision for water to flow into this hole and allowing for a pump to be installed inside the hole to allow abstraction of water. The two most common borehole drilling methods are the rotary and air percussion (Aqua Earth, 2011). In rotary drilling, a drill bit, made of tough metals such as tungsten, is attached to a length of connected drill pipe and as the drill is rotated the bit grind up the rock. Air percussion technique utilizes compressed air to operate a down-hole air hammer on the end of the drill string that helps to break up the rock formation. The compressed air that is used to operate the down-hole air hammer also blows the crushed rock fragments out of the hole to the surface along with any water that flows into the hole during drilling (Aqua Earth 2011). Typically, a borehole is completed by installing a vertical pipe (casing) and well screen to keep the borehole from caving and help prevent surface contaminants from entering the borehole and protect any installed pump from drawing in sand and sediment.
Country Specific Applicability & Potential	Groundwater is more immune to the effects of climate fluctuation compared to other sources of water, especially surface water. Therefore, groundwater abstraction will be a vital water source option in the face of climate change. The government is encouraging individuals, groups and communities, through development of appropriate policies and provision of financial assistance to utilize groundwater, especially in the areas where surface water is in short supply or unavailable.

Status of Technology in Malawi	Groundwater abstraction is common in Malawi. In many rural and urban areas with shallow water tables, hand-dug shallow wells are important domestic water sources. In most areas, the bore-holes needed to abstract groundwater would require a depth of as much as 40 - 50 m and the cost of sinking such a bore-hole is high. Drilling of boreholes has continued to increase as an option by the government to address increased water demand accession by population growth and supply unreliability occasioned by frequent droughts.
Benefits to Economic/ Social and Environmental Development	Abstraction of ground water increase availability of good quality water for domestic and agricultural purposes. In many cases, water boreholes are drilled closer to homesteads, thereby providing readily available water to women and reducing time spent by women looking for water to family and other socio-economic activities. The abstracted water is usually safe and there is a reduced incidence of water-borne diseases.
Climate Change Adaptation Benefits	Climate change projection for Malawi indicates general rainfall decrease most of the country, which together with population growth is bound to impact serious strains in existing low freshwater endowment in the country. Ground water is relatively less likely to be affected by climate change compared to surface water sources and will therefore be a good water source option especially in arid and semi-arid areas of Malawi.
Financial Requirements and Costs	The costs of drilling new boreholes vary widely depending on many factors such as aquifer depths, design and the difficulty to construct a borehole in a specific geological formation. However, the average cost of drilling and equipping a borehole in Malawi is estimated at MWK4 million (US$5,500).

8. TECHNOLOGY:	WASTEWATER RECYCLING AND REUSE
Introduction	Wastewater reuse is the use of treated wastewater from households, communities and industries for home consumption, irrigation, and for industrial activities. Wastewater includes used water from sinks, dishwashers, washing machines, bath tubs, showers, and flush toilets from households; municipal sewage; and industrial activities (e.g. industrial cooling and processing waters). The wastewater from these sources is treated and reused.
Technology Characteristics	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 (Elliot et al 2011). The extent to which treated wastewater can be reused depends on the level of treatment that has been carried out. For example, after undergoing 1^0, 2^0 or even 3^0 treatments, 100 percent of the microbes in the wastewater load are not removed. In order to destroy these pathogens, disinfection/sterilization will be needed depending on the intent reuse.
Country Specific Applicability & Potential	The 4 major cities in Malawi (Blantyre, Lilongwe, Mzuzu and Zomba) have sewerage treatment facilities and maturation ponds. The treated effluent from these plants can be used for irrigation agriculture and aquaculture farming to supplement food requirements in these urban areas. In addition, many manufacturing industries produce high wastewater effluent discharge which can be treated and reused for cooling and other operation not requiring high quality water, e.g. watering grass. There are also large volumes of wastewater in boarding schools, hospitals, prisons, etc. which once collected and treated for their reuse, they will go a long way in easing the water stress in these institutions. Given the water stress status of Malawi, treating and reusing wastewater for both domestic and industrial will go a long way in easing the water stress.
Status of Technology in Malawi	The reuse of the treated wastewater for agriculture, aquaculture and other purposes is not common in Malawi and the water, after treatment, is usually discharged into the nearby water bodies.
Benefits to Economic/Social and Environmental Development	By treating and using the treated water, additional water source is made available for domestic and agricultural purposes, thus increasing access to water (per capita water availability) for productive and economic activities. The technology is local and less expensive compared to dam or reservoir building, thereby reducing public and private expenditures associated with water infrastructure. The technology will create jobs as this technology will require trained staff to operate and maintain the system.

	In addition, treating and reusing the treated wastewater can result in a reduction in the discharge load on receiving waters, thereby providing a clean and decent environment.
Climate Change Adaptation Benefits	As climate change projections for Malawi show general rainfall decrease in most of the country, this together with population growth is bound to impact serious strains in existing low freshwater endowment in the country. Re-use of treated wastewater will contribute to the reduction of water shortages occasioned by climate change.
Financial Requirements and Costs	The financial implication will mainly be related to the need for expanding treatment works to include a tertiary stage, where it does not exist, and distribution system to the required areas. Estimates for facility serving 200 households is US$ 100,000

9. TECHNOLOGY:	LEAKAGE MANAGEMENT, DETECTION AND REPAIR IN PIPED WATER SYSTEMS
Introduction	Leaks refer to water lost through leaks on the pipe network before it reaches the customer’s meter. Detection and repair of leaks in water systems is an important part of comprehensive strategies to reduce pressure on existing water resources.
Technology Characteristics	This technique uses electronic listening equipment to detect the sounds of leakage. The equipment has a piezoelectric sensor, a high fidelity earphone set, a receiver box and a mechanical component in combination with the sensor power rating. As pressurized water is forced out through a pipe, a leak loses energy to the pipe wall and to the surrounding soil area. This energy creates audible sound waves that can be sensed and amplified by electronic transducers/ piezoelectric sensor. The sound waves are evaluated to determine the exact location of the leak. Audible sound transducer is placed in contact with ground surface to assist in locating where the sound of leakage is loudest.
Country Specific Applicability & Potential	The major problem for piped water provisioning in Malawi is that large amount of water are lost physically in pipe leakages. Common causes of leakage include aging pipes, corrosion of internal and external surfaces of pipe network, poor design (materials selection, sizing, layout), and damage to exposed pipes especially during roads construction, it is worsened if the pipes are on the surface or less than 1 m deep.
Status of Technology in Malawi	The most practiced water leakage identification in Malawi’s National Water Boards is what is called “*Passive observation*”. This method includes: i) Responding to running or spouting water; ii) Responding to low pressure identified by customers or during routine inspections; iii) It is useful to locate only obvious leaks or breaks (e.g. break of sufficient size or duration that water reaches the surface) A leak team goes to the reported pipe network and conducts leak search

	by combing of the whole pipe network to identify any visible leaks. The team sketches the leaks identified and reports this to the leak repair/maintenance team.
Benefits to Economic/Social and Environmental Development	Electronic detection of the water leaks will reduce operational costs of the Water Boards – less travels to the field to repair leaks. The technology will provide quick detection of leaks and repairs can also be done quickly and this reduces water losses, and more water will be available for consumption thereby increasing revenue of the Water Boards. There will also be reduced incidences of water contamination as a result of quick detection and repairs of the leaks on the pipe network
Climate Change Adaptation Benefits	Climate change projections for Malawi show general rainfall decrease in most of the country, this together with population growth and water leakages in the network, is bound to lead to low water supplies to customers. Quick leak identification and repairs will save the available from wastage.
Financial Requirements and Costs	The cost of the technology may range from 0.5 – 1.5million USD

10. TECHNOLOGY:	WATER EFFICIENT FIXTURES AND APPLIANCES
Introduction	In Malawi massive volumes of water are lost on daily basis due to use of inefficient appliances and fixtures in households, offices, industries, hospitals, learning institutions, hotels, etc. Thus the use of water efficient appliances and fixtures can contribute greatly to water conservation efforts as well as adaptation efforts to climate change impacts in water sector.
Technology Characteristics	Water efficient appliances are those appliances that use less water to operate, such as fewer litres of water per flush with a toilet. Water efficient appliances can be purchased or older appliances can be retrofitted to conserve water. The most common water efficient appliances include dishwashers and clothes washing machines; popular fixtures include efficient toilet cisterns, and water saving taps and showerheads. The combined use of water efficient technologies at household could reduce water by 30-40 percent.
Country Specific Applicability & Potential	Inefficient use of water in households, offices, industries, hospitals, learning institutions, hotels, etc. is common in Malawi. Many of these places use water inefficient appliances and fixtures. Thus the technology has a potential to contribute greatly to water conservation efforts as less water will be used to provide the same level of service or to get the same result.

Status of Technology in Malawi	Some buildings in Malawi are installed with water efficient fixtures and appliances, e.g. flush toilets. However, many buildings and constructions have not adopted this technology to enhance efficient water use.
Benefits to Economic/ Social and Environmental Development	Adoption of this technology will drastically reduce water bills for households and institutions as less water will be used to provide the same level of service. The technology will also result in reduction in the loss of water, which will be made available to the consumers
Climate Change Adaptation Benefits	This technology will help to reduce the amount of water used in households and institutions to provide the same level of service; consequently contributing to adaptation efforts to the impacts of climate change on reduction of water supply.
Financial Requirements and Costs	The cost for establishing this technology will differ according to the kind of water efficiency appliance to be used.