Republic of Zambia

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

August 2012

Supported by:

Disclaimer

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Foreword

Zambia started the process of a Technology Needs Assessment (TNA) for climate change adaptation with a stakeholder's meeting in September 2011. A similar process for climate change mitigation was initiated in parallel. I am glad to report that both processes have now been concluded and have resulted in the identification and prioritisation of technologies that Zambia should pursue to help our communities adapt to the hazards of climate change.

With the help of her partners, Zambia was keen to engage in the TNA process because the country has seen the reality of climate change for a number of years now. The rise in the frequency of droughts, floods and extreme temperatures, the increase in the unpredictability of rainfall during the rainy season and the increase in mean temperatures are already wrecking hazard on the livelihoods and general wellbeing of our people. What is worse is that the occurrence of such climatic hazards is projected to increase. All our development efforts and the great score we have made over the past decade risk to be reversed by climate change. Clearly we cannot continue with business as usual.

The Government of the Republic of Zambia has recognized this need for some time now and has been preparing ground for action with regards to climate change adaptation. In 2007, it produced the National Adaptation Programme of Action which identified the nature of climate change hazards that threaten Zambia, the most vulnerable sectors and areas of our country and the kind of interventions needed to help our population adapt to these risks. This was followed by the adoption of the National Climate Change Response Strategy and the Pilot Programme for Climate Resilience in 2011. Our national development plans and other national development documents since 2006 have taken climate change as a crosscutting is that should be taken into account in all our strategies and actions. A lot has already been done to respond to climate change and yet the threat remains huge that more needs to be done with even greater urgency.

In conducting the TNA process, consultation with key stakeholders was the core approach taken at every stage. Stakeholders scored and identified the sectors and technologies that needed to be given priority in devising the needed actions. They went on to identify the barriers that would hinder the diffusion of the selected technologies and specified measures required to overcome the barriers. These stakeholder representatives came from civil society, the private sector, academia and government. The determination and desire to forge our effort together is an indication of how climate change adaptation is such an important national issue and is of great concern to all who work to better the lives of our people.

The TNA process on climate change adaptation has produced four reports which should be read together as the unfolding narrative of its results:

1. Technology Needs Assessment Report This report presents the methodology used in the TNA process, how sectors and technologies were identified and prioritized. For climate change adaptation, two sectors – water and agriculture and food security sectors – received the highest scores and were consequently selected for further analysis. In each of the two sectors, three technologies were ranked highest and taken forward for barrier analysis.

2. Barrier Analysis and Enabling Framework Report It documents the barriers to technology diffusion identified by stakeholders and their root causes. Measures and the enabling framework for technology diffusion in the respective sectors and for each technology are also detailed in this report.

3. Technology Action Plans The TAP report provides the steps and actions required to take forward the identified measures in each sector and for each technology.

4. Project Ideas Report Building on the TAP report, this report develops some specific project ideas for water and agriculture and food security. For the water sector, it is proposed to establish a Pilot Climate Change and Water Access (PCCWA) project meant to enhance access to water in Region I despite the climate change hazards the region is exposed to. For the agriculture and food security, it is proposed that a Pilot Smallholder Climate Change Resilience (PSCCR) Project be established to enhance the resilience of small farmers to climate change hazards. Both are pilot projects from which lessons should be learnt with a view to rollout to other areas, especially Region I where these hazards are increasing in prominence.

This has been a lot of work and I am pleased at its successful conclusion. I am grateful to the stakeholders who participated in the process over a period of nearly two years. I thank our partners, the United Nations Environment Programme (UNEP), the Global Environment Facility, UNEP RISO Centre and ENDA for the financial and technical support rendered to the TNA process in Zambia. I wish to also recognize the work of the Consultant, RuralNet Associates Limited, who facilitated the process and documented the outcomes from the stakeholder consultations into the reports mentioned above.

It remains for all of us to work together to ensure that the results of this intense and long process will not go to waste as has been the case in the past with other processes. The Ministry of Lands, Natural Resources and Environmental Protection has made climate change a top priority in its work. I and my colleagues will therefore work very hard to ensure that the projects identified come to fruition. We need the continued support of everyone.

Hon. Wilbur Simusa (MP)
Minister, Lands, Natural Resources and Environmental Protection

May 2013, Lusaka, Zambia

Acronyms

AC	Alternating Current
ACF	Agriculture Consultative Forum
AIACC	Assessment of Impact and Adaptation to Climate Change
BCR	Benefit Cost Ratios
CBA	Cost Benefit Analysis
CEC	Copperbelt Energy Corporation
CFU	Conservation Farming Unit
CGE	Computable General Equilibrium
COP6	Sixth Conference of Parties
DC	Direct Current
DFZ	Disease Free Zone
DoF	Department of Fisheries
ERB	Energy Regulation Board
EST	Environment Sound Technologies
EWS	Early Warning System
FAO	Food and Agriculture Organization
FFS	Farmer Field School
FNDP	Fifth National Development Plan
GART	Golden Valley Research Trust
GDP	Gross Domestic Product
GDWQ	Guidelines for Drinking Water Quality
GEF	Global Environment Facility
GRZ	Government of the Republic of Zambia
HDI	Human Development Index
HWTS	Household drinking Water Treatment and Safe Storage
HYV	high yielding variety
ICRAF	International Center for Research in Agro forestry
IFPRI	International Food Policy Research Institute
IRWR	Internal Renewable Water Resources
IUCN	International Union for the Conservation of Nature
KWh	Kilowatt hour
LSPC	Luangwa Solar Power Corporation Limited
MACO	Ministry of Agriculture and Cooperatives
MALD	Ministry of Agriculture and Livestock Development
MCDA	Multi-Criteria Decision Analysis
MDG	Millennium Development Goals
MEW	Ministry of Energy
MLGHEE	Ministry of Local Government Housing and Early Education
MLNREP	Ministry of Lands, Natural Resources and Environmental Protection
MLNREP	Ministry of Lands, Natural Resources and Environment Protection
MW	Megawatt

NAPA	National Adaptation Plan of Action
NARDC	National Aquaculture Research and Development Centre
NASCO	National Steering Committee
NCCRS	National Climate Change Strategy Response
NEPAD	New Economic Partnership for Africa's Development
NGO	Non Governmental Organization
NISIR	National Institute of Scientific and Industrial Research
NPV	Net Present Value
NWASCO	National Water and Sanitation Council
O&M	Operations and Maintenance
PCS	Post Construction Support
PLARD	Programme for Luapula and Rural Development
POU	Point Of Use
PPCR	Pilot Programme for Climate Resilience
PV	Photovoltaic
RAP	Rural Aquaculture Programme
RHW	Rainwater Harvesting
SCCI	Seed Control and Certification Institute
SHS	Solar Home System
SMS	short messaging system
SNDP	Sixth National Development Plan
SODIS	solar disinfection
SPCR	Strategic Programme for Climate Resilience
SWM	sustainable water management
TB	Tuberculosis
TNA	Technology Needs Assessment
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children Fund
UNZA	University of Zambia
USCSP	United States Country Programme
USCSP	United States Country Study Programme
WHO	World Health Organization
WSP	Water Supply Plans
ZARI	Zambia Agriculture Research Institute
ZESCO	Zambia Electricity Supply
ZMD	Zambia Meteorological Department
ZNFU	Zambia National Farmers Union

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Executive Summary

Introduction

This report presents a Technology Needs Assessment (TNA) for Zambia for climate change adaptation. A TNA report dealing with climate change mitigation has been issued separately. The Report documents the process followed to prioritize and select technologies for reducing the country's vulnerability to climate change hazards. This is the first deliverable of the TNA process. After this, three more deliverables are expected as follows:

- ***Barrier Analysis and Enabling Framework Report:*** This will analyze the likely barriers to transfer the identified technologies and suggest options to address barriers. It will also propose the enabling framework for technological diffusion for the sectors in which technologies have been identified.

- ***Technology Action Plans (TAPs):*** This will detail the steps needed in each relevant sector and for each technology to diffuse the selected technologies. TAPs will also deal with crosscutting issues.

- ***Project Ideas*** These are brief summary and specific project ideas for each sector that has been prioritized.

The imperative need for Zambia to take steps to adapt to climate change arises from two main reasons. First is that climate change is a reality and there is evidence that this has already started taking hold. It has been observed that "*rainfall seasons in southern Zambia have become less predictable and shorter (most notably in the south-western area), with rainfall falling in fewer, more intense events*" (Government of the Republic of Zambia, June 2011, p.10). Mean annual temperatures have increased, droughts and floods have become more frequent and widespread. These climatic changes are projected to worsen over time.

Second is that the hazards that climate change induces have already started to seriously threaten the country's development and may start complicating Zambia's economic rebound of the last decade. One study suggested that climate variability "*reduces Zambia's GDP growth rate by 0.4 percentage points per year, which costs the country US$4.3 billion over a 10-year period. These losses reach as high as US$7.1 billion under Zambia's worst rainfall scenario*" (Thurlow, et, al, 2008, cited in MFNP, Feb. 2011). Even without such detailed studies, evidence is everywhere of the serious havoc climate change hazards cause on communities around the country. Communities themselves bear testimony to the destruction of crops and livestock, increase in malnutrition, the damage to critical infrastructure including housing and rise in the incidence of diseases. Without steps to adapt to these current and projected climatic changes, the high economic growth rates since 2003 are likely to be checked, may lack inclusiveness at the very least while the current poor human conditions could deteriorate even further.

Realizing the threat to economic progress and human development, the Government of the Republic of Zambia (GRZ) has taken a number of initiatives to prepare the country to adapt to climate change. These include the National Adaptation Programme of Action (NAPA) adopted in 2007, the National Climate Change Response Strategy (NCCRS) and the Pilot Programme for Climate Resilience (PPCR) in June 2011 which takes step to start implementing the NAPA and the NCCRS. In addition, the Sixth National Development Plan (SNDP) that started in 2011 mainstreamed climate change throughout the plan. Civil Society and producer organizations have also taken various initiatives to help their constituents to adapt to climate change.

TNA Institutional Arrangements

The Ministry Lands, Natural Resources and Environmental Protection (MLNREP) is the responsible organization for the TNA project in Zambia. One of its officers is the TNA Coordinator. Two TNA Consultants have also been appointed. Centre for Energy, Environment and Engineering Zambia (CEEEZ) Limited is responsible for mitigation while RuralNet Associates Limited is the consultant for adaptation. The MLNREP has constituted the National Steering Committee to provide oversight to the TNA process.

To allow for stakeholder participation, an Inception Workshop of stakeholders was held in September 2011. At the Inception Workshop, stakeholders selected two sectors out of the five that had been prioritized in the NAPA and other national documents. Shortly after the Inception Workshop, the MLNREP constituted two technical working groups (TWGs), one each for adaptation and mitigation consisting stakeholder representatives. Facilitated by the consultant, the adaptation TWG reviewed information related to climate change, the nature of hazards this induced, and the negative impacts on different social groups and regions of Zambia. The TWG then prioritized technology options and selected three technologies each for agriculture and water sectors for in-depth analysis at the barrier analysis stage.

Sector Selection

The five sectors considered at the Inception Workshop were: (i) Agriculture and Food Security; (ii) Human Health; (iii) Water and Energy; (iv) Natural Resources and Wildlife; and, (v) Infrastructure. These sectors were subjected to scoring and prioritization. First indicators and weights had to be agreed upon. The Workshop adopted weights suggested in the NAPA which had given equal weights to all the indicators. Indicators were grouped into three categories namely, economic, social and environmental.

The results of the prioritization exercise are in Table ES1. Water and energy and agriculture and food security sectors received the highest scores and were thus picked for further consideration. However, as the TNA process proceeded, it was realized that water and energy are better treated as two distinct sectors. Given the overlap between the technologies considered for energy and those being considered by the mitigation group, it was decided to drop the energy sector altogether to avoid duplication

Table ES1: Scores for Sector Ranking

Priority Sector	Total Score Value	Sector Ranking
Agriculture & Food Security	264	2
Human Health	180	3
Water & Energy	280	1
Natural Resources- Wildlife	121	4
Infrastructure	82	5

Technology Prioritization for the Water Sector

Using the TNA Guidebook series for climate change adaptation in the water sector (Elliot, et al, 2011) as the main source, 11 technology options were identified. Fact sheets were drawn by the consultants on each option and these were reviewed by the TWG. They were then prioritized using the MCDA as in the case of sector prioritization. The only difference in this case was that scoring was much more detailed as both the main and sub-indicators were given a score.

The benefits that these technology options provide could be put into two non-mutually exclusive categories. The first are the *water access enhancing technology options*. A number of options listed were meant to enhance access to water likely to become more complex under projected climate scenarios. Some options, e.g. drilling boreholes/tubewells, were meant to provide better access to water directly by increasing the number of water sources. Rainwater collection from ground surfaces and rainwater harvesting from rooftops could also be put in this category.

However, other options enhanced water availability by improving the efficient utilization of the water already available. Three options which do this from the list are: (i) Increasing the use of water-efficient fixture & appliances; (ii) Leakage management, detection and repair in piped systems; and, (iii) Post Construction Support (PCS) for community managed water supplies. Water reclamation and reuse fall under this category but is not widely used in Zambia. These options will reduce the need for new water sources as existing ones are used more efficiently. It is a strategy obviously that needs to be tackled in parallel with those strategies that directly make more water available from new sources.

The second set were *water quality enhancing technology options.* These options target the quality of water and deal with the hazards that create conditions for water contamination. Floods are the hazard mostly in focus here although droughts and extreme heat conditions also pose the risk of water contamination. The main benefit is the reduction in water borne diseases. Under this category of options are: (i) Household drinking water treatment and safe storage (HWTS); (ii) Improving the resilience of protected wells to flooding; and, (iii) Water Safety Plans (WSPS).

The process followed in prioritizing and selecting options was similar to that followed for sectors. Results are provided in Table ES2. The top three technology options from which specific technologies were to be derived were according to their ranking rainwater collection from ground surfaces, boreholes/tubewells for domestic water supply, and improving the resilience of protected wells to flooding. A brief description of the three priority technology options and the specific technologies arising from them are provided below.

- ***Rain water collection from ground surfaces-small reservoirs and micro- catchments:*** The aim of this technology option is to store water for use during seasonal dry periods and where possible during droughts. There are two broad categories. The first is collecting rainfall from ground surfaces utilizing "micro-catchments" to divert or slow runoff so that it can be stored before it evaporates or enters watercourses. However, the volumes tend to be small and are typically to be used by only one household. The second is collecting water from a river, stream or other natural watercourse which gets inundated by rain water flows during the rain season. This often includes an earthen or other structure to dam the watercourse and form "small reservoirs."

- ***Boreholes/tubewells for domestic water supply during drought***: Tubewells are a narrow, screened tube or casing driven into a water bearing zone of the sub-surface. Boreholes are tubewells penetrating bedrock, with casing not extending below the interface between unconsolidated soil and bedrock. A hand-powered or automated pump is used to draw water to the surface or if the casing has penetrated a confined aquifer, pressure may bring water to the surface. The technology option is meant to ensure access to water during droughts or prolonged dry periods. Many hours travelling long distances to collect water, especially by women and children will be saved and potentially applied to more productive activities. To enhance this objective, it is proposed that the boreholes have a *Solar powered pump for water supply photovoltaic system (PVP)* with a particular focus on drought prone regions in Agro Ecological Region I. The solar pump would pump water into an overhead tank which later flows down using gravity.

- ***Improving the resilience of protected wells to flooding:*** This option aims at ensuring good quality water in situations of increased occurrence of floods. It involves enhancing wells at design and construction stages for high resilience to flooding. Wells not properly designed and constructed to provide high resilience to flooding are vulnerable during flooding and may lead to water contamination, collapse of the well or failure by the community to reach the water point when the area gets submerged. The specific technology selected was the building of a concrete apron/collar on the well. This would require changing the design of most wells provided in Zambia by building concrete works on the well and around the well. The concrete rings would form an apron/collar of 1.5 m high and 3.0m in diameter. The slope of the base is 45-degrees, gradual enough to prevent damage to the base during flooding. The wells would be operated with the hand pump.

In order to assess whether these technologies yielded benefits that exceeded their costs or performed better than the baseline scenario, i.e. before their introduction in a community, a basic cost benefit analysis was conducted. Results showed that all the three technologies being proposed yield higher benefits than the baseline scenario and confirmed their selection for barrier analysis.

Technology Prioritization for Agriculture and Food Security

Identification of technology options for agriculture and food security relied on the TNA Guidebook series for climate adaptation for the agriculture sector. These were refined using national documents particularly the NAPA and expert consultations. It resulted in the identification of 19 technology options that were grouped into eight categories.

Options addressed a diversity of challenges and can be grouped into three broad categories depending on the kind of challenges addressed and the envisaged benefits. First are options that sought to ensure a *better management of climate change related risks*. The options related to planning for climate change and variability that build farmers capacity to manage their enterprises better including knowing which varieties to plant at what time play this role. Second are options that promote *sustainable utilization of existing natural resources* that support production. A number of options specifically provide for sustainable utilization of land, water and fisheries. Last are options which focus on *improved production systems* to make these systems more efficient. Although this is important even under a non-climate change scenario, it becomes more important in the context of extreme events that make complicate production even further. Minimising post harvest losses is a focus of some of these technology options in this regard.

After conducting a multi-criteria decision analysis, three options were selected for further analysis regarding more specific technologies: (i) Soil management (conservation farming, land Husbandry and agro-forestry); (ii) Sustainable farming systems (mixed farming); and, (iii) Sustainable crop management (crop diversification and new varieties).

Arising from the selected priority adaptation options of conservation farming, land husbandry and agro-forestry, mixed farming and crop diversification and new varieties, the breakdown of identified specific adaptation technologies associated with each of the three options is presented in Table ES 2. We describe below the specific technologies providing their perceived benefits and drawbacks.

Table ES2: Prioritized Technology Options and the Specific Technologies Identified

Prioritized Technology Options	
1. Conservation farming, land management and agro-forestry	1. Hand-hoe conservation farming
	2. Conservation farming with Ox-drawn rippers
	3. Conservation farming with agro forestry ➲ *Conservation Farming with Faidherbiaalbida (Musangu Tree)* ➲ *Conservation Farming with TephrosiaVogelii (Ububa Tree)* ➲ *Conservation Farming with Sesbaniasesban*
2. Mixed farming	4. Integrated small livestock-fish-poultry-vegetable production system
3. Crop diversification and new varieties	5. Promotion of drought-tolerant and early maturing food crops (cassava, sweet potatoes, millet, sorghum and maize).

➲ ***Conservation Farming Conservation:*** This is meant to address the increase in the incidence of late onset of rains and droughts. Both increase soil erosion and reduce soil fertility. Conservation farming refers to a number of practices that in combination conserve soil, moisture, fertilizer, seeds, energy and time. Basic features include no burning of crop residues, correctly spaced planting basins established before the rains, early planting of all crops, early weeding and rotation with a minimum of 30% legumes in the system. Three types of specific technologies identified here were hand-hoe conservation farming, conservation with ox-drawn rippers and conservation farming with agro-forestry with either *Faidherbia albida*, T*rephrosia vogelii* or *Sesbania sesban*.

➲ ***Mixed Farming*** This is an agricultural system in which a farmer conducts different agricultural practices together such as production of cash crops and livestock. Mixed farming is a good adaptation option for farmers facing climatic hazards. It spreads the risk widely across different enterprises and has an inbuilt mechanism of one enterprise mitigating the risk of the other. Mixed farming is practiced widely in Zambia and there is a very wide range of combinations in which this could occur. However, for the TNA process, an integrated farming system of livestock-poultry-fish-vegetables which is yet to take hold among small and medium farmers in Zambia was proposed for consideration. Specifically further, the proposal is for an integrated farming system of non-ruminants (village chickens and ducks), pigs, goats, fish farming and vegetables.

➲ ***Crop diversification and new varieties:*** This is the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. It addresses climate change related risks which farmers who are dependent on rain-fed agriculture face from planting long maturing varieties. The aim is to enhance plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses.

Over the years, research both in Zambia and outside have established new varieties which are increasingly cognizant of the risks posed by climate change. Considering the rising occurrence of droughts and short rain seasons, the promotion of early maturing and drought tolerant food crops was proposed for consideration. Specifically this is the promotion of new varieties for Zambia's major staple crops of sorghum, millet, cassava, sweet potatoes and maize.

The technologies contained in Table ES 2 were subjected to cost benefit analysis for a reality check. It was found that integrated crop-small livestock-fish-poultry-vegetable systems and promotion of drought tolerant and early maturing varieties for food crops yielded more benefits than the baseline scenario and could thus be recommended to go forward to barrier analysis. Of the number of technologies available under conservation farming, conservation farming with *Faidherbia albida (Musangu Tree)* was selected as it yielded the greatest benefits when subjected to cost benefit analysis.

Summary and Conclusions

The TNA process to arrive at climate change adaptation technologies used the MCDA to first select sectors for consideration. Out of the six sectors that had been considered priority in the earlier documents produced on adaptation, this process selected water and agriculture and food security sectors. This was done at the Inception Workshop. The Workshop had first agreed that the three main categories of indicators – economic, social and environmental – would each carry equal weight.

The Technical Working Group representing key stakeholders in the two sectors sifted through a lot of information to prioritize the proposed technology options for each sector again using the MCDA. After ranking the technology options, the CBA was used as a reality check regarding the feasibility of the technologies to be taken to the barrier analysis stage. This process resulted in six technologies recommended by the TWG to be taken forward to the barrier analysis stage. Table ES3 lists these technologies.

Table ES3: List of technologies to be subjected to barrier analysis

Sector	Adaptation Option	Adaptation Technology
Water	Rain water collection from Ground water surfaces	Small reservoirs and micro-catchments
	Improving the resilience of protected wells to flooding	Building a Concrete Apron/Collar on the well
	Boreholes/Tube wells for domestic water supply during drought	Borehole/ tubewell with overhead tank and a solar powered pump for water supply
Agriculture and Food Security	Conservation farming	Conservation farming with *faidherbia albida* (Musangu tree)
	Mixed farming, land management and agro-forestry	Integrated crop-small livestock-fish-poultry-vegetable production system
	Crop diversification and new varieties	Promotion of drought-tolerant and early maturing varieties for food crops

Chapter 1 Introduction

This is the Technology Needs Assessment (TNA) Report for Zambia as the first deliverable of Zambia's TNA project. The report documents the process followed to prioritize and select technologies for reducing the country's vulnerability to climate change hazards. It follows the framework of technology transfer developed and adopted at the sixth Conference of Parties (COP6). Under this framework, countries are required to conduct a Technology Needs Assessment (TNA) to come up with Environmentally Sound Technologies (EST) to foster both mitigation and adaptation.

1.1 About the TNA project

The TNA process for climate change is now well established and is currently in its second round as a specific project for developing countries with funding from the Global Environment Facility (GEF) and implemented by the United Nations Environmental Programme (UNEP). The project started in 2009 with 15 participating countries selected in early 2010. An additional 21 countries including Zambia were selected in October 2010 for the second round to bring the total number of countries to 36.

The TNA Handbook defines TNA as "*a systematic approach by which to identify, evaluate, and prioritize technological means for achieving sustainable development ends*" (UNDP, 2009: p.5). The two sustainable development ends are climate change mitigation which is *an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases* and adaptation, *an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects* (ibid p. vii). This process is critical because technology is central to issues of climate change either as the cause or as the solution (see Akoi, Nov 2010). Therefore, UNEP is supporting a process that goes beyond a mere prioritization and selection of technologies helping countries to come up with action plans that facilitate the transfer of ESTs by identifying critical barriers to the diffusion of these technologies and propose actions to remove the barriers.

Key steps and deliverables of the TNA project are presented in Figure 1. It is seen that the project begins with the production of the TNA report which shows the process and results of sector and technology prioritization. The second step is to undertake a barrier analysis with a view to coming up with strategies for overcoming the transfer and diffusion of the selected technologies. It is recommended that no more than three technologies be selected for barrier analysis from the priority list. Deliverables 3 and 4 – Technology Action Plans and Project Ideas – both arise from barrier analysis.

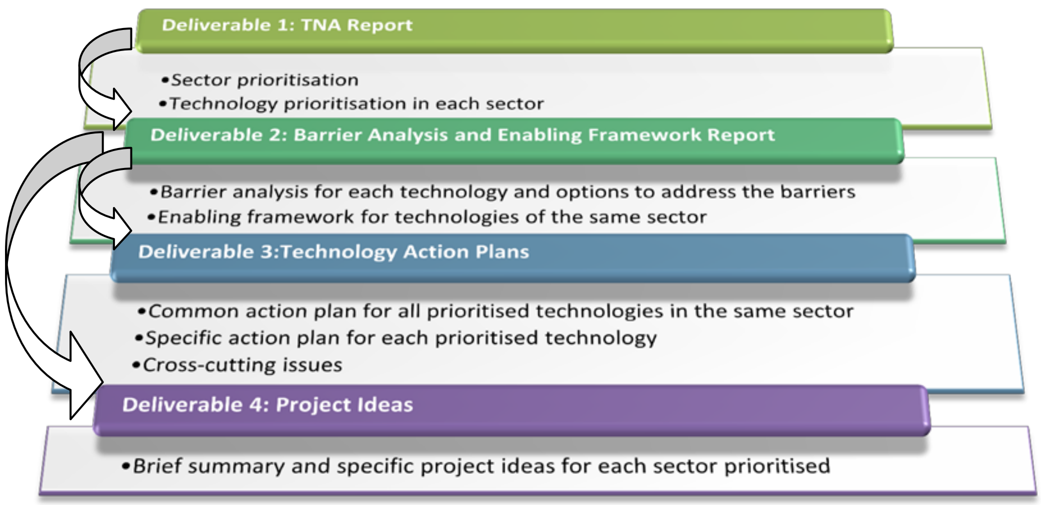

Figure 1: Contents of the Main Country Deliverables from the TNA Project

1.2 Existing national policies about climate change adaptation and development priorities

In view of the risk that climate change poses to economic development and improvement in social conditions, the Government of the Republic of Zambia (GRZ) has with the support of its international partners initiated a number of programmes to help different sectors adapt to the anticipated adverse events. The NAPA which was adopted in 2007 is perhaps the most visible in outlining the course of action the country needs to take to reduce the impact of climate change key sectors. It assessed the impact of climate change in Zambia and proposed a range of adaptation measures to climatic hazards in four sectors, agriculture and food security, human health, water and energy, and natural resources.

The NAPA was followed in 2010 by National Climate Change Response Strategy (NCCRS) "*developed to support and facilitate a coordinated response to climate change issues in the country*" (GRZ, September 2010). The NCCRS states the goal, vision and objectives of a climate change response strategy in Zambia. It also recommends an institutional framework. The Pilot Programme for Climate Resilience (PPCR) inaugurated in June 2011 is a partial actualization of the NAPA and the NCCRS. It focuses on the Kafue and Barotse sub-basins of the Zambezi river basin. Some of the aims are mainstreaming climate change in local area development plans, increasing the resilience of key infrastructure and strengthening GRZ capacity to manage climate change interventions. It is projected to cost US$110 million.

Besides these three initiatives, there are now many other actions on climate change response. Many policies now take note of climate change. Sector ministries in their activities are increasingly taking on board climate change related issues. This is particularly because the Sixth National Development Plan (SNDP) attempted to mainstream climate change in the plan and allocated funds to help tackle the expected hazards. There are a number of civil society organizations working on climate change related issues. Producer organizations such as the Zambia National Farmers Union (ZNFU) are implementing projects to help their members adapt to climate change. The private sector is also being courted to become more aware of climate change and take advantage of funding opportunities promoting green development. All this is a good indication that the country has awakened to the reality that climate change is a big development problem that needs to be tackled very urgently.

The need for adaptation in Zambia is driven by the fact that the country is already facing serious adverse effects of climate change that are threatening her development prospects and could complicate further the efforts to improve social conditions of the people. Available evidence indicates that these adverse effects will get worse in the medium to long term. The context for adaptation to climate change should therefore be understood from Zambia's development story, the challenges it faces to better human conditions and how climate change has potential to scuttle the chances for more inclusive growth.

Table 1: GDP Growth in Selected Industries, 2000 – 2011

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	GDP % (2011)
Total GDP	3.6	4.9	3.3	5.1	5.4	5.3	6.2	6.2	5.7	6.3	7.6	6.6	100
Agriculture	1.6	-6.0	-6.3	8.0	6.1	-4.0	3.0	-2.7	1.9	12.3	6.6	7.7	19
Mining & Quarrying	0.1	14.0	16.4	3.4	13.9	7.9	7.3	3.6	2.5	15.8	15.2	(5.2)	4
Manufacturing	3.5	4.2	5.7	7.6	4.7	2.9	5.7	3.0	1.8	2.5	4.2	7.2	8
Elect, Gas & Water	1.2	12.6	(5.2)	0.4	(1.7)	5.4	10.5	1.0	(1.2)	6.8	7.4	8.2	3
Construction	6.5	11.5	17.4	21.6	20.5	21.2	14.4	20.0	8.7	15.6	7.4	8.2	22

Source: Central Statistical Office, www.zamstat.gov.zm and MFNP, Economic Reports (*various*)

Zambia's GDP increased at an average rate of 5.5% per year between 2000 and 2011 (see Table 1). The economy started to grow in 1998 after a long period of decline and stagnation going back to 1975 when prices of copper fell sharply. At that time, copper exports constituted more than 90% of the country's foreign earnings. Zambia's economy started to grow again in 1998 but grew much more rapidly from 2003 heralding the longest period of sustained economic growth since independence in 1964.

The high growth sectors have been mining at an annual average of 7.9% since 2000 and construction at an average of 14.4%. Manufacturing, although sluggish in comparison, has also performed well growing at an average rate of 4.2%. Despite this high growth, poverty has remained stubbornly high. The reason is that the agriculture sector which has the highest potential for inclusive growth given that 67% of the country's labour force is in the sector has performed relatively poorly with growth averaging 2.4%.

The slow progress in reducing poverty is perhaps for Zambia the most visible struggle in improving the country's social conditions. Although the incidence of extreme poverty dropped between 1996 and 2006,[1] it seems that the momentum to poverty reduction that picked up from 1998 was lost between 2004 and 2006 just when economic growth was beginning to accelerate. Other social development indicators point to some progress in recent years but that there is still a long way to go before Zambia can make a clear dent on the decline in human development which began to deteriorate after 1975 (GRZ and UNDP, 2011). The Human Development Index (HDI) declined continually in the 1990s from 0.495 in 1990 to 0.431 in 2000 (GRZ and UNDP, 2007 and 2011). Thereafter it started to rise and was 0.481 in

[1] The Central Statistical Office is yet to release the latest poverty figures based on the 2010 survey.

2007. But Zambia is still classified as a low human development country. She has been lagging behind other countries in making progress in human development such that, when compared to other African countries that had similar HDI as Zambia's in 1975, the first year for which HDI has been calculated in the global Human Development Reports, Zambia though making progress was by 2007 still lagging behind these countries.

1.3 Climate change and key impacts in Zambia

Assessment of historical trends reveals that "*rainfall seasons in southern Zambia have become less predictable and shorter (most notably in the south-western area), with rainfall falling in fewer, more intense events*" (GRZ, June 2011, p.10). There has been a general increase in the mean annual temperature and a decrease in the amount of rainfall. The incidence of droughts and floods were occurring once every 2.3 years and 5 years respectively between 1991 and 2011. The coverage of these two adverse climatic incidents has been rising as more people and more areas are being affected. "*The 2006/07 flood, for example, affected 41 districts in nine provinces, and the 2004/05 drought left nearly two thirds of Zambia with little or no rainfall*" (ibid, p.10). There has been an increase in the number of hot days per year and a decrease in the number of cold days.

Projections are that average annual temperature will increase between 1.2-3.4% by 2060 and 3-5% by 2100 and the number of hot days and nights will rise by 15-29% and 26-54% respectively while the number of cold days will drop so significantly that they will become very rare (ibid, pp.10-13). Average annual precipitation is not projected to change significantly but rainfall is expected to become more variable. Nevertheless, precipitation levels are expected on average to drop for the early part of the rain season (October to December) and increase for the next part of the rain season (December to May). What this means is that extreme events – droughts and floods – are likely to increase.

The cost of climate change is also already being felt and complicating the economic rebound noted above. It is to be feared that, without adaptation to climate change, both economic growth and progress in human conditions will be reversed. According to a study by IFPRI, increased climate variability "*reduces Zambia's GDP growth rate by 0.4 percentage points per year, which costs the country US$4.3 billion over a 10-year period. These losses reach as high as US$7.1 billion under Zambia's worst rainfall scenario*" (Thurlow, et, al, 2008, cited in MFNP, Feb. 2011). The authors arrive at this by developing a CGE model based on the results of the historical climate data and a hydro-crop model to estimate the impact of climate variability on crop yields over the past three decades. Agriculture is found particularly vulnerable, losing on average 1 percentage point in GDP growth due to climate variability. This goes up to 2 percentage points under worst rainfall scenarios such as occurred between 1985 and 1995 when the country experienced recurrent droughts. Overall, climate variability is said to keep 300,000 people in poverty by 2016 and would rise severely if the 1985 to 1995 rainfall conditions were to prevail.

Numerous studies have documented the struggles that communities go through when hit by these adverse events. The Zambia Vulnerability Assessment Committee (ZVAC) documents on an annual basis how floods, droughts or simply poorly distributed rainfall ravage livelihoods. Agriculture livelihoods have been shown to be the most sensitive suffering crop and animal losses. However, impacts cut across other sectors as well. The National Adaptation Programme of Action (NAPA) documents many other costs including reduction in fish stocks, increase in diseases, poor water quality, soil erosion, decrease in soil fertility, destruction of infrastructure, loss of human life and reduced energy production leading to decline in industrial production (MTENR, Table 2.2). Box 1 in the words of the victims themselves provides a glimpse of the social impacts of extreme events how they tighten the noose on the victims by unleashing multiple effects at the same time. Vulnerable households find it difficult to recover quickly once hit by such shocks.

Chapter 2 Institutional Arrangement for the TNA and the Stakeholders' Involvement

2.1 National TNA team

Figure 2 provides the structure of the national TNA team. MLNREP is the responsible organization for the TNA project in Zambia and has appointed one of its officers as TNA Coordinator to be the focal person for the project. He is responsible for the ongoing administration of the project and keeping contact with all players. In addition, the TNA Coordinator is the immediate supervisor of the TNA Consultants. Centre for Energy, Environment and Engineering Zambia (CEEEZ) Limited is the consultant responsible for mitigation and RuralNet Associates Limited is the consultant for adaptation.

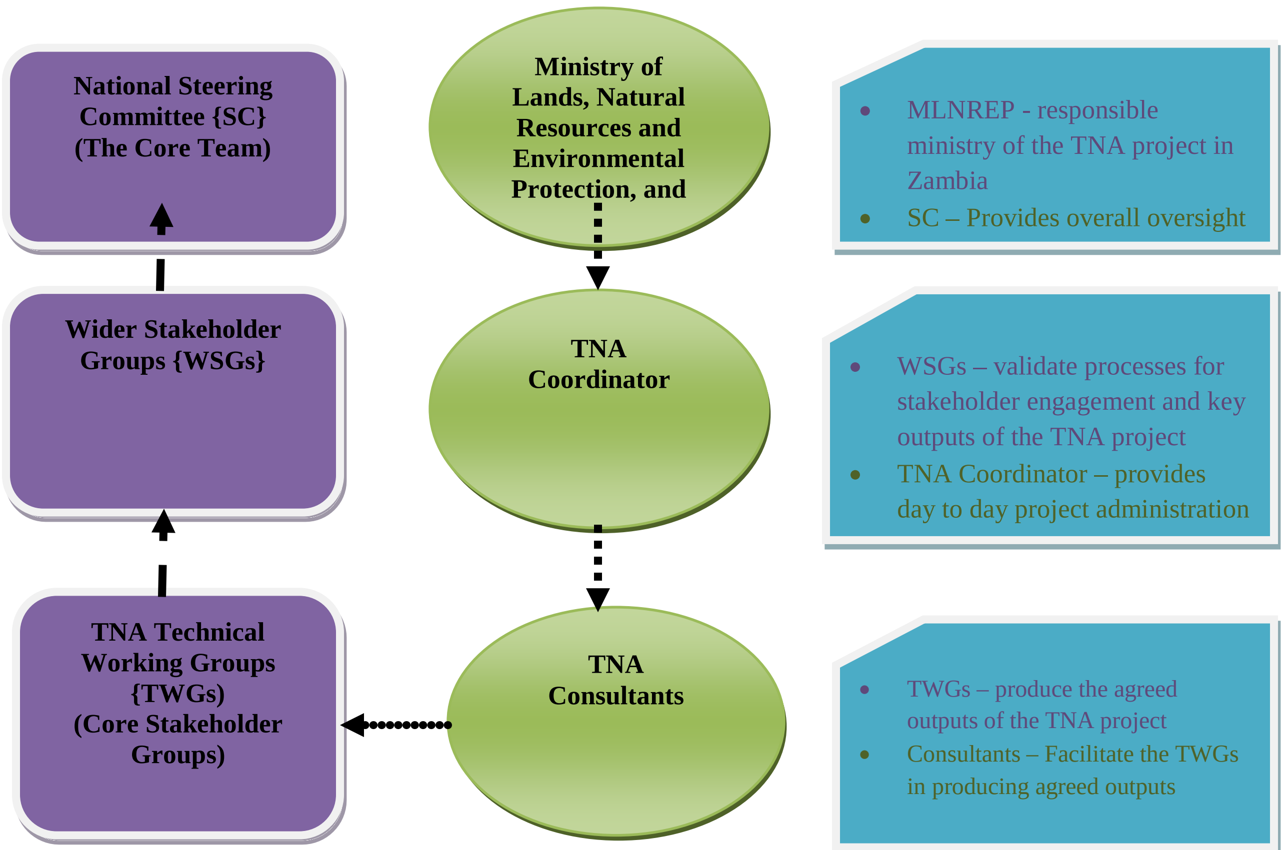

Figure 2: The National TNA Team

MLNREP constituted two technical working groups (TWGs), one each for mitigation and adaptation. Annex II is a list of members of the adaptation TWG. It is seen that the adaptation TWG constituted representatives from the private sector, civil society organizations, quasi-government organizations and government agencies. In coming up with the list, MLNREP took into account the two sectors that had been selected for further study and the special focus of the particular organization. TWG members were selected mostly from the organizations that were represented at the inception workshop and were presumed to have come to understand the TNA process although some organizations absent at the workshop but were deemed critical to the process such as the Zambia Agriculture Research Institute (ZARI) were co-opted.

The consultants, main role was to facilitate the TWGs come up with well informed decisions regarding the selection of technologies. They explained the methodology to the TWG members based on which sectors and technologies were selected. Consultants also provided the necessary information on climate change impacts and the relevant technologies to help adaptation which were summarised in technology fact sheets. They also helped the TWG put together the relevant report before consolidation into a single report. This is presented to the wider stakeholders group which takes the form of workshops. For the TNA, two such workshops were envisaged, the inception workshop mentioned earlier and the validation workshop that took place at the end. However, for Deliverable 1 (see Figure 1) to be legitimized as a national document, it needed to be endorsed by the Steering Committee, an inter-ministerial committee of decision makers on issues of climate change constituted as the highest body in the TNA process to adopt the various outputs.

2.2 Stakeholder Engagement Process followed in TNA – Overall assessment

The TNA Handbook suggests that this be done in five steps. However, as explained in what follows, the process was done in six steps. A brief explanation of the steps is provided below.

- *Step 1: Analysis of the Country's Development Process* This was done by a review of various documents and literature to provide Zambia's past and projected development context from the perspective of climate change. An additional objective was to provide a basis for the identification of the criteria and indicators for decision making in subsequent steps. A number of key documents were reviewed key ones which are pointed out in Chapter 1. The NAPA particularly was identified as a key document to build on with respect to the identification of priority sectors and technologies. In addition, semi-structured interviews with sector experts were conducted.

- *Step 2: Identification of Sectors* Through the literature review conducted in Step 1 and specifically the NAPA and PPCR, the TNA arrived at the following sectors for consideration: (i) Agriculture and Food Security; (ii) Human Health; (iv) Water and Energy; (v) Natural Resources and Wildlife; and, (v) Infrastructure. Informed by the NAPA, the SNDP also prioritizes these sectors. These had been prioritized in the earlier country studies on responding to climate change. A principle of the TNA process is to build on the outcome contained in national documents. Adopting sectors that were already prioritized in these documents was thus the right starting point.

- *Step 3: Prioritization of Sectors* Despite the list of priority sectors, selection of a few sectors from the list for which technologies were to be prioritized and selected needed to be done. This is because national teams were encouraged not to work on too many sectors at the same time given the available resources and the time involved. For this purpose, the MLNREP organized an inception workshop in September 2011. Stakeholders were identified through a stakeholder mapping exercise by the TNA Coordinator and other officers in the MLNREP. The inception workshop also intended to introduce the TNA process to a wider audience as well as agree on the criteria and indicators for prioritizing sectors and technologies.

Through the process described in slightly more detail in Chapter 3, two sectors were selected for carrying forward, i.e. agriculture and food security and water and energy sectors. Agriculture and food security sector includes the following sub-sectors: crops, livestock and fisheries and aquaculture. Water and energy are usually considered as one sector in Zambia perhaps mainly because administratively they fall under one ministry, the Ministry of Energy and Water (MEW), perhaps arising from the heavy reliance of electricity generation on water. For example, the Zambia Electricity Supply Corporation (ZESCO) holds 50% of the water rights of the Kafue river – Zambia's second largest river. However, as the TNA process proceeded, it was found that having water and energy as one sector was too broad and hindered a proper identification of technologies for adaptation. It was therefore decided to split these into the water and energy sectors. Energy was subsequently dropped because of the overlap in the options prioritized with those identified by the mitigation team.

- *Step 4: Identification of Environmentally Sound Adaptation Options and Technologies.* This step was undertaken by the adaptation TWG. A slight departure to the process recommended in the TNA Handbook is that the TWG considered first the identification and prioritization of adaptation options before identifying and prioritizing actual technologies. Adaptation options were defined as broad responses that minimize or overcome the impact of climate change hazards. Adaptation technologies were taken as the equipment, techniques, practical knowledge or skills to meet development priorities through reduction of the vulnerability of sectors to promote sustainable livelihoods and minimize the extent of and adverse impact of climate change (UNDP, 2009: p.vii).

  This means that the concept of adaptation options is broader than that of adaptation technologies and constitutes strategies, policies and technologies themselves. For example, strengthening the early warning system is an adaptation option which could be achieved through new policy measures, particular strategies, new or modified systems or specific technologies as defined above. At this stage of the TNA, the main interest was to relate technologies to options. Options were thus regarded as a specific field of technologies for climate change adaptation. This was important in order to move systematically and to allow the working group to consider a range of technologies that addressed particular adaptation objectives.

  Possible options and technologies for both agriculture and food security and water sectors were sourced from various documents but most particularly from the NAPA, TNA sector guides and websites such as TechWiki. Other sources included interviews with sector experts and suggestions by the TWG members. Chapter 4 provides further details on this process.

- *Step 5: Prioritization of Adaptation Options Using Multi-Criteria Decision Analysis (MCDA)* The TWG prioritized the identified adaptation options using the MCDA. It is defined as a "*a technique used to support decision making which is based on the evaluation options on the criteria, and makes trade-offs explicit*" (UNDP and UNFCCC, p.vii). It is a useful tool in situations of multi-stakeholders and multiple and conflicting objectives. Before the MCDA could be applied, the TWG agreed on the scoring criteria and indicators grouped in three categories, economic, environmental and social. After this prioritization process, three adaptation options were selected for each of the two sectors as detailed in Chapter 5.

- *Step 6: Prioritization of Adaptation Technologies Using Cost Benefit Analysis:* The TWG decided that moving from adaptation options to the prioritization and selection of technologies required a more quantitative basis for prioritization and selection of technologies. It adopted the use of cost benefit analysis (CBA) in the place of the MCDA for this purpose. The CBA is a systematic way of calculating and comparing benefits and costs to see whether the former outweighs the latter as the basis for assessing whether a project, policy, decision, etc, makes economic sense. It requires that all costs and benefits are listed and expressed in monetary values. The costs and benefits would have to be predicted over a period of time, e.g. 5 or 10 years. A net present value (NPV) is calculated by summing up discounted net benefits over the period. The rationale for discounting the sum of net benefits is to cater for the perceptions that benefits are more valuable in the present than in the future. This is a view that would resonate strongly in highly deprived societies where people live on the margins and to survive the day makes more sense than to hope for the benefits of years down the line. There is no firm science about which discount rate to adopt. Therefore, a sensitivity analysis is often done to check how the NPV performs at two or more discount rates.

At this preliminary stage, it was difficult to be comprehensive about the costs and benefits about each technology as this required much more information than currently in possession of the TWG. This is because the list of technologies was still too long for a detailed study to be carried on each one of them within the available resources and time frame. For example, where a technology brings about a reduction in the number of days a household uses in an enterprise, we see clearly that the household benefits from this reduction through lower costs. However, there could be additional benefits as the household applies the time it saves on other enterprises generating additional benefits. More information is required to follow through these loops than was available. Therefore, what was done in this step is only partial cost benefit analysis exclusively focused on the performance of the technology with respect to direct inputs and outputs with no social, environmental and other costs and benefits considered. More comprehensive analysis will be done at barrier analysis stage on the fewer number of technologies selected.

Chapter 3 Sector Selection

As already stated above, five sectors were considered because they were identified as sectors most vulnerable to climate change in the NAPA and the NCCRS as follows:

1. Agriculture and Food Security;
2. Human Health;
3. Water and Energy;
4. Natural Resources and Wildlife; and,
5. Infrastructure.

Below we provide some brief description of the five sectors focusing particularly on their perceived vulnerability to climate change. We state in advance that agriculture and food security and water and **energy sectors were the prioritized sectors although water and energy were split into two sectors and** later on the water sector was selected for more detailed consideration. Hence in what follows below we provide more details on these.

3.1 An Overview of Expected Climate Change and Impacts, Sectors Vulnerable to Climate Change

3.1.1 Water Sector

Zambia is endowed with abundant water of generally good quality (both surface and ground water). The main water bodies are within the watersheds of the Zambezi and Congo rivers with their tributaries of Luapula, Chambeshi, Kafue and Luangwa rivers, and Lakes Tanganyika, Bangweulu, Mweru and Mweru wa-Ntipa including the man-made lakes of Kariba and Itezhi-Tezhi. Water quality varies but is generally considered good for both surface and ground water. Given this, Zambia does not have the serious water constraints other Southern African countries are beginning to face (MFNP, Feb 2011). In 2001, Zambia's Internal Renewable Water Resources (IRWR) was estimated at 7,377 m^3 per capita and was only second to Angola in Southern Africa. Flows from other countries, principally Angola raised renewable water to 9,676 m^3 per capita with only 2% withdraws.

Despite Zambia having abundant surface water resources, communities living in arid parts of the country in Agro-ecological Region I experience severe water shortage during the hot dry season. Floods and high temperatures are the other climatic hazards that have adverse impacts. Examples of the adverse impacts these climate change generate include the following:

- Droughts reduce water quality as it lowers water tables in wells and boreholes. This triggers high incidences of water borne diseases.
- The floods reduce the water quality as the floodwaters carry pollutants and fecal matter into the water bodies.

The Water, Gas and Energy sector directly contributed 3.1% to Zambia's GDP in 2011 (See Table 1).[2] However, its contribution is much more significant than this figure would indicate given that water and

[2] As pointed out already, this is treated as a single sector in national documents and national statistics report their combined contribution to GDP.

energy are essential to the viability of all the other sectors. The Vision of the water and sanitation sub-sector in the Sixth National Development Plan (SNDP) is thus spelt as: "*a Zambia where all users have access to water and sanitation and utilise them in an efficient and sustainable manner for wealth creation and improved livelihood by 2030*" (GRZ, 2011a)

The SNDP recognizes the challenges climate change poses to the water sector. In the SNDP, climate change is thus treated as a cross-cutting issue for all sectors and a very serious problem that could reverse the gains. The SNDP includes specific objectives to deal with climate change adaptation and are as follows for the water sector (ibid, p.15):

1. To achieve sustainable water and resource development for social and economic development
2. To strengthen capacity for disaster risk management, mitigation and adaptation to effects of climate change

3.1.2 Energy Sector

Zambia is richly endowed with a wide range of indigenous energy sources, particularly woodlands and forests, hydropower, coal and renewable sources of energy. Petroleum is the only energy resource that is currently wholly imported. With respect to hydropower, Zambia is ranked among the top 10 African countries with the highest potential estimated at 6,000 MW but having an installed capacity of only 1,681 MW and a demand of 1,740 MW which is however increasing rapidly (ZESCO, 2013). There are efforts to expand installed capacity by at least another 870 MW within the next few years. The World Bank observed that access to electricity stood at only 13% in the second half of first decade of the 21st Century, down from over 20% a decade and a half earlier (World Bank, 2008). In contrast, Sub Saharan Africa on average had access well over 30%. Furthermore, access is clearly skewed in favor of Zambia's urban areas and those with relatively high incomes.

Projected impacts of climate change on energy generation suggest that the ZESCO would lose US$2.5-5.8 million/year by early to mid-century. Unfortunately for Zambia, most of power generation takes place in the Kafue river basin which also accounts for about 40% of the country's population, most of its industrial production and nearly all of its commercial agriculture. Reduced water flows as a result of droughts has potential to ignite serious conflict in demand for water between power generation and for other uses. The case is not helped by the fact that a big proportion of the hydropower potential is actually located at the tip end of the Kafue river basin, near the Kafue river's confluence with the Zambezi.

3.1.3 Agriculture and Food Security Sector

The Agriculture Sector in Zambia is a major contributor to the country's economy accounting for between 18 – 20% of Zambia's GDP according the Ministry of Finance's various economic reports. and it is a source of livelihood for the majority of the population and absorbs about 73% of the labour force

(GRZ, 2008). Agriculture is very important in terms of income and employment creation for rural women who constitute 65% of the total rural population.

Zambia has a total land area of 75 million hectares (752,000 square Km) and 58% (42 million hectares) is classified as medium to high potential for agricultural production. In terms of water resource, the country has one of the best surface and underground water resources in Africa, with many rivers, lakes and dams as seen above. This, with the addition of high potential underground water aquifers in many areas offers excellent prospects for irrigation. However, these water bodies are largely unexploited. Of the country's irrigation potential conservatively estimated at 423,000 hectares, only about 50,000 hectares are currently irrigated (Ibid, p.6).

The country has a sub-tropical climate with three distinct seasons namely; the hot and dry, the cool dry and rainy season (GRZ, 2007). Rainfall ranges between 800 mm to 1,400 mm annually, making a large part of the country suitable for the production of a broad range of crops, fish and livestock. It is estimated that only 14% of the total land with agricultural potential is currently being utilized.

The sector faces many challenges that undermine its ability to be the main driver of economic development and a meaningful provider of incomes and employment to the country. Farmers struggle with diseases and pests, high input prices, an unsupportive macro-economic environment and sector policies. In the recent past the sector has been faced with the negative effects of climate change especially in Agro-ecological Regions I and II.

The SNDP vision for the agriculture sector is "*an efficient, competitive, sustainable and export-led agriculture sector that assures food security and increased income by 2030"*(GRZ, 2011).This is supposed to be achieved by promoting crops, livestock and fisheries production through higher commercialization. Unfortunately climate change is threatening the country's potential to realize its vision for the agriculture sector in the coming years. Achievement of MDG 1 and MDG 2 on poverty and hunger respectively is particularly at risk of being missed but the non-progress in agriculture has adverse implications for all the other MDGs. Therefore, adaptation measures to climate change are urgent for Zambia to achieve her development objectives. Agriculture in particular desperately requires adapting to climate change due to its extreme vulnerability to the same. As seen in what follows below, the agriculture sector is mainly affected by an increased occurrence of droughts and floods, extreme temperatures (hot and frost) and delayed on-set of the rain season which have a negative impact on crop, livestock and livestock production.

The vulnerability of the agriculture sector to climate change varies from one agro-ecological region to another. Zambia has three main agro-ecological regions. The details of the three regions are provided below.

- **Region I.** This region receives less than 800 mm of rainfall annually and constitutes 12% of Zambia's total land area. It consists of loamy to clayey soils on the valley floor and coarse to fine loamy shallow soils on the escarpment. It covers the Southern Province and part of Eastern and Western Provinces and part of which is the Gwembe Valley. The Region is suitable for production of drought resistant crops like cotton, sesame, sorghum, and millet and has the potential for production of irrigated crops but has limited potential for cassava cultivation. Region I is also suitable for extensive cattle production but the valley parts of the region, being on a low altitude and consequently hot and humid, are not suitable for cattle rearing because of tsetse flies. Climate change has been evident in Region I over the years. The historical rainfall patterns in Region I indicates a decreasing trend of annual rainfall (GRZ, 2007). Region I is considered a drought-prone/risk area.

- **Region II.** The Region receives between 800 to 1000 mm of annual rainfall and constitutes 42% of the country's land mass. It is sub-divided into two sub-regions, namely Region IIa and Region IIb. Region IIa covers the Central, Lusaka, Southern and Eastern plateaus of the country and generally contain fertile soils. Permanent settled systems of agriculture are practiced. A variety of crops are grown including maize, tobacco, cotton, sunflower, soybeans, irrigated wheat, groundnuts and other arable crops. This area is also highly suitable for flowers, paprika and vegetable production. Region IIb covers Western Province and consists of sandy soils. It is suitable for production of cashew nuts, rice, cassava and millet, as well as vegetable and timber production. The Region is highly suitable for beef, dairy and poultry production. However, climate change has been evident in Region II by increased frequency and degree of 'below average' rainfall in the 2000s compared to the previous decade (ibidi, p.6).

- **Region III.** The Region receives more than 1,000 mm and up to 1,500 mm of rainfall annually and constitutes 46% of the country's total land area comprising the Copperbelt, Luapula, Northern and North-Western Provinces. With the exception of the Copperbelt, the Region is characterized by highly leached acidic soils. It has good potential for production of millet, cassava, sorghum, groundnuts, and beans. Some coffee, sugarcane, rice, pineapples are also grown in this area. The agricultural potential of the Region can be enhanced by application of lime, and its perennial streams can be utilized for small-scale irrigation. Increased exploitation of fisheries resources and introduction of fish farming offer good opportunities for development. In terms of climate change, Region III had annual rainfall that was varying slightly below and above the average value during the period 1981-1990 (ibid, p.7). However, the period between 1990 and 2000 had an increase in dry episodes with six occurrences of annual rainfall below average.

Below, we describe the effects of climate change in the different sub-sectors of agriculture.

Crop Production: The key climate change hazards affecting small and medium scale farmers in crop production are droughts and floods. Droughts besides damaging crops also create the loss of crop land and water shortages in communities. Floods on the other hand create excessive precipitation that leads to water logging, soil erosion and hindrance to field operations (see Box 1). Again these effects result in crop failure. Besides frequent droughts and floods, the increase in the occurrence of extreme temperature has been noted for their adverse effects on crops. The agricultural sector in sub-Saharan Africa is predicted to be especially vulnerable to climate change because this region already endures high heat and low precipitation, provides the livelihoods of large segments of the population, and relies on relatively basic technologies, which limit its capacity to adapt (Centre for Environmental Economics and Policy in Africa, 2006, p.7).

Livestock Production: The rise in the frequency of droughts and floods is also a major concern to livestock producers. Droughts lead to loss of grazing land, decreased livestock feed and water shortages for animals. Ultimately animals get malnourished and there is a higher incidence of livestock diseases. During drought periods, households dependent on cattle are very vulnerable. In such moments, these farmers tend to resort to distress selling to avoid losing their animals completely as well as to mitigate for the general effects of droughts including crop loss as seen above.

There is an obvious relationship between extreme temperature and livestock productivity. When temperatures are high, the population of livestock reduces and when the temperature is low, the population of livestock increases. According to the Assessment of Impact and Adaptation to Climate Change (AIACC) Study with the Gwembe Valley as a case study, the greatest correlation between climatic indicators and livestock population was observed in cattle (Assessment of Impacts and Adaptation to Climate Change, 2002). As temperatures rose, the cattle population reduced, and as they fell, the population increased. In the same vein, when rainfall increases, livestock productivity improves on account of increased availability of pasture leading to good nutrition and enhanced immunity to diseases.

Fish Production*:* Zambia has rich fisheries in her 11.5 million hectares of open water, swamps and flooded areas, producing about 65,000 MT of fish in 2006. In Southern Africa, Zambia was only third to Angola and Madagascar in terms of per capita kilograms of fish produced that year. Fisheries production is a major source of protein especially for households living close to water bodies like lakes, rivers and swamps. The majority of fishers in Zambia are small scale fishers using traditional and basic fishing technology. Their activity is particularly vulnerable to extreme heat, drought and floods. Extreme heat has the effect of reducing fish stocks in natural water bodies. Drought has similar effect as extreme heat. According to the United States Country Programme (USCSP) study on fisheries, lower rainfall reduces nutrient levels in rivers and lakes and impacts negatively on fish breeding activity as well as depletion of fish species in the long-term. The most vulnerable species are breams and sardines (GRZ, 2007). On the other hand, floods tend to increase fish loss due to poor sunlight. By and large, floods and droughts pose similar problems to the fishing communities.

As seen above, the negative impacts of Climate change on agriculture are diverse. All the sub-sectors of the agriculture sector are adversely affected. Producers (small, medium and commercial farmers) are all very vulnerable, especially small scale farmers. Their resilience is extremely low because they produce at very low scale in the first place and have few resources to help them recover quickly. Since the producers are inter-linked with other actors in the value chain, the adverse impacts of the hazards inevitably affect actors like input suppliers, intermediaries (processors, wholesalers, retailers) and consumers (local and foreign) through various transmission mechanisms.

3.1.4 Natural Resources, Wildlife and Forest

This abundant water is thus able to support many of the Zambia's natural resources that directly depend on water resources including forests, wildlife, fisheries, aquatic species and wetlands besides domestic, agriculture and industrial use. As a result Zambia is one of the best forested countries in Southern Africa with forest cover in 2000 being 42% of the country's total surface area exceeded only by Angola and Zimbabwe within the Southern Africa region.[3] With available water and forests, wildlife flourishes in the 19 national parks which constitute 30% of the country's total area.

A major concern is the unsustainable exploitation of Zambia's natural resources - the high rate of deforestation (one of the highest in Africa), overfishing, poaching, etc. Climate change is complicating the situation. The PPCR observes that droughts force wildlife migrations exposing them to poaching and predators (GRZ, 2011). Floods could have similar effects on some wetland animals. With their habitat flooded they are forced to unfamiliar habitats where they are much more vulnerable. Climate related effects of low rainfall, high temperature and less rainy days, not only retard tree growth but also increase the predominance of bush fires in a situation where regeneration becomes more difficult.

3.1.5 Infrastructure Sector

A study on the analysis of constraints to inclusive growth observed that infrastructure development has contributed very little to Zambia's growth since 2001 when she began to post high growth rates (Ministry of Finance and National Planning, 2010). Most of infrastructural growth has been attributed to improvements in quality rather than increase in the stock of infrastructure dominated by developments in mobile telecommunication and roads. The study observed further that the contribution to the revival of growth due to improvements in both stocks and quality of infrastructure is lower than that of the SADC and Africa. Citing the World Bank, contribution to Zambia's per capita GDP growth due to infrastructure development was estimated at a meager 0.6% for the period 2001-05 compared to 1991-95.

Climate change may be adding significantly to Zambia's infrastructure deficit. Floods in particular wreck extensive damage to existing infrastructure whenever they occur (see Box 1 as an example) costing the country huge sums to replace. Less obvious but nevertheless contributing to infrastructure development challenges are higher temperatures which create conditions for bush fires, already a problem in Zambia even in the best of circumstances, which along the way wreck damage to infrastructure.

3.1.6 Health Sector

[3] From the Encyclopedia of the Earth (www.eoearth.org) based on FAO data

There is a very strong link between climate change and health. "*We had an outbreak of diarrhoea, malaria, rash and children were falling sick frequently. It is like all these diseases were unveiled by the heavy rains*", testified the people of Vwavwa in Sinazongwe recounting the impacts of the 2009/10 floods (see Box 1). Water borne diseases already have some of the highest incidences in Zambia. Floods may lead to contamination of the water sources as faecal matter or other contaminants are deposited into water courses from the sudden increase in water. Malaria has the highest morbidity in Zambia and becomes more widespread as mosquito breeding places increase with floods. Cholera outbreaks have been shown to rise with spikes in temperature just before the onset of the rains. The dust caused by drier conditions due droughts, shorter rain seasons or the dislocation of earth by sudden increase of water causing dusty conditions when it dries up may lead to a rise in eye sores and respiratory diseases.

The concern is that Zambia's health systems are fragile and are not coping well with the current disease burden. The Zambia National Human Development Report 2011 paints a grim picture of the health service delivery system in Zambia (UNDP, 2012). Existing staffing levels are deemed inadequate to meet the health demands of the population. This has resulted in high staff-patient daily contact ratios which compromises the quality of service delivery. Drug availability was shown to be inadequate and erratic. In rural areas especially, many people have to travel long distances to get to a health centre which is worse when their case needs to be attended to at a referral centre.

It can therefore be expected that climate change will put further pressure on an already struggling health system as the disease burden increases. Indirect impacts may arise from damage to infrastructure important in the delivery of health services such as roads and the compromised immune systems as the climate change undermines the nation's food security.

3.2 Process, criteria, and results of sector selection

During the inception workshop for the TNA Study held on 14th September 2011 at Mulungushi International Conference Centre in Lusaka, 16 stakeholders joined the Adaptation group during a breakaway session while the rest went to the mitigation group. As pointed out above, five sectors were selected for consideration, having been identified as priority sectors in the NAPA and the NCCRS as follows: (i) Infrastructure; (ii) Agriculture &Food Security; (iii) Human Health; (iv) Water & Energy; and, (v) Natural Resources -Wildlife & Forest. These sectors were then proposed for scoring and prioritizing.

The adaptation breakaway group began by the stakeholders approving weights. It adopted weights suggested in the NAPA which treated all the indicators equally. Therefore, the weights adopted are as shown the Table 2 below.

Table 2: Weights to Scores for Prioritising Sectors

Indicator	Marks Obtained	Weight	Total
Economic		33.33	
Environment		33.33	
Social		33.33	
Total		100	

The main and sub indicators for assessing the sectors were then presented to the stakeholders as shown in Table 3 below. These were then explained in detail.

Table 3: Main and Sub- Indicators for Assessing Sectors

Indicators	1 Weakly Important	3 Less Important	5 Moderately Important	7 More Important	9 Extremely important
Economic • Contribution to the country's development goals as expressed in the SND and Vision 2030 • Contribution to achievement of MDGs • Synergies with MEAs • Cost effectiveness (capital and operating cost relative to alternatives) • Market potential of technologies (commercial availability, replicability, applicability, adaptability, promotion of SMEs and potential scale of utilization)					
Environment • Reduce negative impacts on the environment • Enhance environmental integrity • Contribution to MDGs					
Social • Reduce poverty to enhance adaptive capacity • Impact on wealth • Impact on health • Improvement to local infrastructure • Improved livelihoods • Contribution to MDGs					

The Scoring Sheet for Ranking Sectors for Climate Change and Adaptation was presented to the stakeholders as shown in Table 4 below. Although sub-indicators were provided, stakeholders were nevertheless not asked to score the sub-indicators but use them as a guide to arrive at the overall score they gave to the main indicator.

Table 4: Scoring Sheet for Ranking Sectors for Climate Change and Adaptation (Please tick as appropriate)

Sector	Indicator	1	3	5	7	9
		Weakly Important	Less Important	Moderately Important	More Important	Extremely important
Agriculture & Food Security	**Economic**					
	Social					
	Environment					
Human Health	Economic					
	Social					
	Environment					
Water & Energy	Economic					
	Social					
	Environment					
Natural Resources-Wildlife	Economic					
	Social					
	Environment					
Infrastructure	Economic					
	Social					
	Environment					

The results of the prioritization exercise are given in Table 5. Water and energy and agriculture and food security sectors received the highest scores and were thus picked for further consideration with respect to technology needs assessment.

Table 5: Scores for Sector Ranking[4]

Priority Sector	Total Score Value	Sector Ranking
Agriculture & Food Security	264	2
Human Health	180	3
Water & Energy	280	1
Natural Resources- Wildlife	121	4
Infrastructure	82	5

The stakeholders were then encouraged to discuss the scoring. After much debate, it was concluded that the scores and resulting rankings were a true reflection of the vulnerability of sectors and their impact on the country's population. Water and Energy were key for any other sector, for instance the agriculture sector depended on the water sector to perform well.

[4] Weighting here and in the other MCDA results was dispensed of because this did not affect the ranking of sectors given that all indicators were to be given equal weights.

Chapter 4 Technology Prioritization for the Water Sector

4.1 Climate Change Vulnerability and Existing Technologies and Practices in the Water Sector

This section draws heavily on the options in the TNA Guidebook series for climate change adaptation in the water sector (Elliot, et al, 2011). These options were nevertheless scrutinized for their relevance to Zambia through a literature review and expert advice. Most of these options are already being utilized in Zambia as good practice but are rarely looked at from climate change adaptation which is where the value of the Guidebook is at its strongest.

Table 6: Proposed Adaptation Technologies for Water

1	Boreholes/Tubes wells for domestic water supply during drought
2	Household Drinking Water treatment and Safe storage (HWTS)
3	Improving the Resilience of protected wells to flooding
4	Increasing the use of Water-efficient fixture & Appliances
5	Leakage Management, Detection and Repair in piped systems
6	Post Construction Support (PCS) for Community managed Water Supplies
7	Rainwater Collection from Ground surfaces-Small Reservoirs and Micro-catchments
8	Rainwater Harvesting from Rooftops
9	Water Reclamation & Reuse
10	Water Safety Plans (WSPS)

The Guidebook listed 11 options but 1 was found not relevant to Zambia. Table 6 lists the relevant options for the water sub-sector. We provide below a brief description of each of the listed adaptation technologies for the water sector.

- ***Boreholes/Tube wells for domestic water supply during drought:*** The main objective of this option is to address the problem of water shortage during droughts. It is supposed to ensure access to good quality groundwater preventing reliance on alternatives that yield poor quality water supply particularly during droughts and the dry seasons which under the new climate scenario tend to be frequent and prolonged respectively. This option is supposed to reduce on the time spent to travelling to distant water points. It is an option most valuable to rural communities but can be complimentary to urban water supply systems. Increasing access to groundwater for both potable and non-potable water is a key strategy for ensuring domestic water supply during droughts.

  This could be done by sinking or deepening of tubewells and/or boreholes. Tubewells may consist of a narrow, screened tube or casing driven into a water-bearing zone of the subsurface. The term tubewell is sometimes used synonymously with borehole. However, boreholes are more specifically defined as *tubewells penetrating bedrock, with casing not extending below the interface between unconsolidated soil and bedrock*. Cost, location, groundwater table, the desired yield and other factors determine the choice of the actual technology and the drilling methods employed.

  Salient features of tubewells include (Water Aid, 2006):

i. Plastic or metal casing (usually 100-150 mm diameter);
ii. In unconsolidated soils, a “screened” portion of casing below the water table that is perforated;
iii. A “sanitary seal” consisting of grout and clay to prevent water seeping around the casing; and,
iv. A pump to extract the water.

- ***Household drinking Water Treatment and Safe Storage (HWTS):*** The main objective of this option is to improve water quality which gets compromised in times of droughts, high precipitation on account of extreme heat and floods as recounted in Chapter 1. Treating drinking water through boiling is too expensive for most households especially those without electricity connection and have to rely on alternative energy although boiling is effective in eliminating the pathogens.

  The ideal situation would be good piped drinking water from a centralized treatment plant and a good secure water source. However, this is not the case for the majority of Zambians. For households or point of use (POU), drinking water treatment and safe storage provides a means to improve the quality of their water by treating it within the home. Popular treatment technologies include chemical disinfectants, coagulants, ceramic filters, biological sand filters, solar disinfection (SODIS) or ultraviolet disinfection processes, and combined products with both coagulant and disinfectant, e.g. Procter and Gamble PUR product (Sobsey, 2002). These technologies are able to improve the chemical quality of water and hence reduce waterborne diseases.

- ***Improving the resilience of protected wells to flooding:*** This option aims at ensuring good quality water in situations of increased occurrence of floods. It involves enhancing wells at design and construction stages for high resilience to flooding. Wells not properly designed and constructed to provide high resilience to flooding are vulnerable during flooding and therefore subject to the following:

i. Infiltration of contaminated waters;
ii. Failure to access wellhead due to flood waters;
iii. Soil becoming saturated eventually leading to collapsing of hand dug wells.

The salient features of all protected wells include the following (Water Aid Bangladesh, 2006):

i. A concrete apron to direct surface water away from the well;
ii. A sanitary seal (normally clay, grout, and concrete) that extends at least 1-3m below ground to prevent infiltration of contaminants; and
iii. A method to access water that enables it to be sealed following use. Hand pumps can be fitted to most wells (including hand dug wells) to improve convenience and decrease the likelihood of contamination.

- ***Increasing the use of water-efficient fixture & appliances:*** This option aims at reducing water wastage and hence reduced cost of water supply for utility companies since customers are using water more efficiently. Water efficient appliances include dishwashers and clothes washing machines, toilets, showerheads and faucets. It might also include the use of gray water from the sink for toilet flushing.

Making the efficient appliances available on the market might not be sufficient to promote these appliances. This could be supplemented by: setting up new standards to enforce the use of water efficient products; the certification of water efficient products; and, granting tax incentives for the purchasing and replacing of old fixtures.

- ***Leakage management, Detection and Repair in piped systems:*** The purpose is to ensure that the cost of water delivery on account of leakages is reduced. The option improves the ability of the water utility companies to attend to leaks and repair them on time. At the same time it prevents the loss of leakage volume which might translate into huge costs

  In Zambia, common causes of leakage in addition to aging pipes include poor network design and construction, damage to exposed pipes and leakage at poorly sealed connections. Currently this system is only used by the large utility companies in cities whilst those in the peri-urban and rural districts rarely have it. Leakage in distribution systems is a major problem for water utilities as many distribution lines were installed many years ago.

  Large water main breaks can cause sensational damage and draw media attention, but those catastrophic failures only account for about 1% of water lost to leaks (USEPA, 2009). However, minor leaks though little, if not attended to, could lead to a loss of millions of litres of water over time. Usually neglected, the management, detection and repair of small leaks in a distribution system are therefore critical functions of system operation and maintenance.

- ***Post Construction Support (PCS) for Community-managed Water Supplies:*** The main purpose of this adaptation option is to build capacity and ensure that the rural water supply interventions are community driven and all encompassing. *PCS is typically carried out through government programs, municipalities, multilateral donors, and various NGOs. Types of PCS include, but are not limited to* (Wattington, et al, 2009):

  i. Technical training for water system operators
  ii. Technical and engineering support, including provision of technical manuals
  iii. Financial and accounting assistance (e.g. setting tariffs)
  iv. Help settling disputes (e.g. bill payment or water sources)
  v. Help with maintenance, repairs and finding spare parts
  vi. Help finding external funding for O&M, expansion or repairs
  vii. Help assessing the sufficiency of supply for expansion or in the case of drought
  viii. Household visits to residents to discuss water system use, etc.

- ***Rain water collection from Ground surfaces-small Reservoirs and Micro-catchments:*** The main purpose of this option is to improve water availability for both domestic use and agriculture production during drought periods. It is meant to deal with evapo-transporation (evaporation plus transpiration of water taken up by plants) and rainwater running off into the rivers before it has been put into use. This is the main way the rainwater is lost.

  In Zambia, rural water supply comprises mostly of dams, small weirs, boreholes and shallow wells. Rainwater harvesting activities are primarily for agricultural production and are therefore coordinated by the Ministry of Agriculture & Livestock Development. NGOs are also involved in dam and weir rehabilitation and wells dug adjacent to dams for domestic water use.

The two main categories of this options are: (i) Collecting rainfall from ground surfaces; and, (ii) Flood water harvesting (collecting flows from a river, stream or other natural watercourse).

- ***Rainwater Harvesting (RHW) from Rooftops:*** The main purpose of this option is to reduce the huge rain water losses due to evaporation, transpiration, run-offs and drainage that take place during the rainy season. It is an adaptation strategy for the rural communities and has been practiced in Zambia at household level. It is being promoted in many parts of the world as a way of supplementing domestic and institutional water supply. Both small and large scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams (Clements, et al, 2011, p.50). Increased availability of plastic has reduced the cost of implementing these technologies. In most developing countries, RWH is used to collect water for potable and other household uses.

  The key important features of rooftop RWH systems include:

  i. Collection surface where the rain lands;
  ii. Transporting system of gutters and pipes
  iii. Containers to store the water for future use.

- ***Water reclamation and Re-use:*** The main objective to ensure that reclaimed water is only used in those applications where potable water is not required. Water reuse is the use of treated wastewater (or reclaimed water) for a beneficial purpose whilst Water reclamation is the processing of wastewater. The term-reclaimed water is used interchangeably with the often more culturally acceptable term recycled water (Asano, 2007).

  In water reclamation, the water is reusable and is of the required water quality standards. This would mean a change in the existing piping so that both lines for portable water and that of reclaimed water co-exist. The advantage is that aquatic ecosystems would be protected since the demand and diversion of freshwater would decrease. In addition, by reclaiming the water, the nutrients and other contaminants entering the waterways would reduce which would necessarily reduce the cost of treating water. This technology utilizes the same treatment technologies as conventional wastewater treatment, including disinfection basins, different designs of filtration basins, secondary clarifiers and membranes.

- ***Water Supply Plans (WSPs):*** This option aims at improving through the identification of threats to water safety at all stages – transport, treatment and distribution of drinking water. It differs with the traditional method where the emphasis is on the end product and treatment. There is reduction in the costs incurred in the traditional method where the sampling has to be done during the distribution system. The main advantage is that most issues are dealt with before the water is delivered to the consumer. WHO's Guidelines for Drinking Water Quality (GDWQ) third edition which is the basis for current water quality standards in many countries around the world describes WSPs collectively as a systematic and integrated approach to water supply management based on assessment and control of various factors that pose a threat to the safety of drinking water (WHO, 2008).They are made up of three separate activities:

- *System assessment*: This stage involves the identification of the potential hazards to water quality and health at key steps or locations. These points should be within the boundaries of a water supply chain.

- *Monitoring*: This component involves the designing of a priority and a specific plan for monitoring and controlling the hazards as they have already been identified during the system assessment.

- *Management*: This involves the action and correcting of any issues that were in the previous stage.

4.2 Adaptation Options for the Water Sector and Their Main Adaptation Benefits

Based on Table 7, it is possible to categorize the water sector adaptation options into two broad areas from the view point of the problems they tackle: (i) Water access enhancing adaptation options; and, (ii) Water quality adaptation options. We describe these two aspects in turn and thereby provide an overview of the benefits of the options identified in the water sector in Section 4.1.

- ***Water access enhancing adaptation options*** Most of the options discussed in Section 4.1 are meant to enhance access to water, an issue likely to become more complex under projected climate scenarios. Droughts, prolonged dry seasons and evapo-transporation due to extreme heat are bound to make access to water more difficult. A number of adaptation options identified deal with this issue directly by making more water available from new sources. Drilling boreholes/tubewells is one strategy which from an adaptation view point could be especially applied in areas identified as most vulnerable to droughts such as in Agro-ecological Region I. Other options are rainwater collection from ground surfaces and rainwater harvesting from rooftops.

  Other options enhance water availability not through new water sources but by enhancing the efficient utilization of water already available. The most obvious and already in use in Zambia are: (i) Increasing the use of water-efficient fixture & appliances; (ii) Leakage management, detection and repair in piped systems; and, (iii) Post Construction Support (PCS) for community managed water supplies. Water reclamation and reuse fall under this category but is not widely used in Zambia. These options will reduce the need for new water sources as existing ones are used more efficiently. It is a strategy obviously that needs to be tackled in parallel with those strategies that directly make more water available from new sources.

- ***Water quality enhancing adaptation options:*** These are options that target the quality of water and dealing with hazards that create conditions for water contamination. Floods are the hazard mostly in focus here although droughts and extreme heat conditions also pose the risk of water contamination. The main benefit is the reduction in water borne diseases. Under this category of options are the following: (i) Household drinking water treatment and safe storage (HWTS); (ii) Improving the resilience of protected wells to flooding; and, (iii) Water Safety Plans (WSPS).

Table 7: Summary of Descriptive Benefits of Identified Adaptation Technology Option for the Water Sector

Technology Options	Adaptation Problem Being Addressed	Likely Beneficiaries	Other Descriptive Benefits
Boreholes/tubes wells for domestic water supply during drought	- Inadequate access to safe water during droughts.	- Households not connected to piped water supply especially in rural and peri-urban areas	- Helps to reduce time spent to travelling to distant water points. - Able to compliment urban water supply systems.
Household drinking water treatment and Safe storage (HWTS)	- Contamination of water during times of droughts, extreme heat and floods	- All households but especially those without electricity connection	- Reduction of water borne diseases likely to increase with rise in climate change hazards
Improving the Resilience of protected wells to flooding	- Reduced water quality due to floods	- Households relying on wells for water	- Reduction of water borne diseases likely to increase with rise in climate change hazards
Increasing the use of Water-efficient fixture & Appliances	- Water wastage which exacerbate water shortages during droughts or extended dry seasons	- Households connected to piped water supply systems	- Efficient utilization of water leading to reduced costs for water utility companies
Leakage Management, Detection and Repair in piped systems	- Water wastage on account of leakages that exacerbate water shortages during droughts or extended dry seasons	- Households connected to piped water supply systems	- Improves the ability of water utility companies to attend to leaks and repair them on time - Prevents loss of leakage volume which might translate into huge costs
Post Construction Support (PCS) for Community managed Water Supplies	- Constant breakdown in community water systems exacerbating water problems caused by droughts and prolonged dry seasons	- Rural and peri-urban communities	- Strengthened capacity for community-led water systems
Rainwater Collection from Ground surfaces-Small Reservoirs and Micro-catchments	- Inadequate water availability during drought	- Farming communities	- Reduction in evapo-transporation - Reduction in rainwater loss by running off into the rivers before it has been put into use
Rainwater Harvesting from Rooftops	- Inadequate water availability during drought	- Households with appropriate roof types	- Supplementing domestic and institutional water supply
Water Reclamation & Reuse	- Inadequate water availability during drought and prolonged dry seasons	- Households connected to piped water	- Protection of aquatic ecosystems as demand and diversion of freshwater decrease. - By reclaiming the water, the nutrients and other contaminants entering waterways reduce which in turn reduce the cost of treating water.
Water Safety Plans (WSPS)	- Threats to water safety at all stages – transport, treatment and distribution – likely to worsen during climate hazards such as flooding	- All households but especially those connected to piped water	- Reduction in the costs incurred in traditional method as sampling is done during the distribution system. - Most issues dealt with before water is delivered to consumer.

These two categories are not mutually exclusive. Technologies that make more water available for new sources could actually help to enhance water safety by reducing competition for water whose quality increases by the mere fact that it is now being handled by less people or that by reverting to optimal levels of extraction allows for adequate recharge and water remains of good quality at all times. Conversely, some water enhancing technologies can indirectly play the role of enhancing access to water. Examples are technologies that improve the resilience of protected wells which could guard against damage to these vital installations during flooding and continue to ensure water availability.

4.3 Criteria and process of technology prioritization

The process followed in prioritizing and selecting options was similar to that followed for sectors explained in Chapter 3. To reiterate:

1. **Agreeing on Indicators** – The TWG first debated the question of indicators during its second meeting. Small changes were made to sub-indicators under each of the three main indicators, i.e. economic, environment and social. The refined list of indicators is presented in Table 8.

Table 8: List of Indicators for Scoring Technology Options

Economic Criterion	
1	Impact on economic growth
2	Impact on MDGs
3	Synergies with Multi-lateral Environmental Agreements (MEAs)
4	Cost effectiveness-economically sustainable
5	Promotion of SMEs
6	Increased productivity
Environment Criterion	
1	Reduce negative impacts on the Environment
2	Enhance environmental integrity
3	Impact on MDGs
Social Criterion	
1	Reduce poverty to enhance adaptive capacity
2	Impact on Wealth creation (including income distribution)
3	Improvement on Health and Nutrition
4	Improvement on Local Infrastructure
5	Improved livelihoods
6	Impact on MDGs

2. **Agreeing on Weights** – The agreement made at the inception workshop was reiterated that all indicators receive equal weights.

3. **Scoring Indicators for Each Technology Option**–The members of the TWG were then given a number of scoring sheets for each option to be scored**.** The scoring sheet was the same as used at the Inception Workshop. The only difference being that these were now being used to score the options recounted in Chapter 3. The process was explained again as a number of TWG members were not at the Inception Workshop having been co-opted later for their perceived expertise and relevance to the process. This time, the TWG also scored each individual indicator in all the three categories which were then summed up. Given the large volume of sheets to be filled in, members were asked to take the forms back with them and fill the sheets over a course of the following few days. RuralNet Associates Limited then went around their offices to collect the forms to tabulate the results.

4.4 Results of technology prioritization

The results of the scoring exercise carried out above are indicated in Table 9. The top three technology options were (i) rainwater collection from ground surfaces; (ii) boreholes/tubewells for domestic water supply; and, (iii) improving the resilience of protected wells to flooding.

Table 9: Prioritized Adaptation Options for the Water Sector

Rank	Adaptation Option	Economic	Environment	Social	Total score
1	Rainwater collection from ground surfaces	314	181	330	825
2	Boreholes/Tubeswells for domestic water supply during drought	322	151	349	822
3	Improving the Resilience of protected wells to flooding	284	165	334	783
4	Increasing the use of Water-efficient fixture & Appliances	302	159	297	758
5	Household Drinking Water treatment and Safe storage (HWTS)	286	129	316	731
6	Leakage management, Detection and Repair in piped systems	290	149	290	729
6	Post Construction Support (PCS) for Community managed Water Supplies	288	141	300	729
8	Water reclamation & reuse	293	155	272	720
9	Water safety Plans (WSP)	274	159	276	709
10	Rainwater Harvesting from Rooftops	250	127	272	649
11	Ground & surface water monitoring system	216	125	214	555

Below we provide further and more specific details on the options, moving in the process from the broad adaptation concepts discussed above to the actual technology to be taken forward for in-depth analysis. It is observed that in the case of the water sector, unlike the agriculture and food security sector discussed in Chapter 5, the three priority adaptation options led to a specific technology rather than multiple technologies considering the prevailing practice in Zambia as the details provide below.

4.4.1 Rainwater collection from ground surfaces – Small reservoirs and micro-catchments

As already seen above, the rainwater collection from ground surfaces technology option aims at storing water for use during times of rainfall failure, either for seasonal dry or drought periods. This diverts or slows runoff to store it before it evaporates or enters watercourses. The equipment is simple to install and operate. Collection and storage infrastructure can be natural or constructed and take many forms. Three of these were considered.

- ***Installing below ground tanks, i.e. cisterns and excavations*** (either lined for water proofing or unlined) into which rain water is directed from the ground surface. However, volumes of these are typically small and are usually used by one household or an institution like a school or health clinic. The technology was considered unlikely to get wide coverage.

- ***Recharging groundwater aquifers by directing water down an unlined well***. Groundwater recharge is also an added benefit of unlined reservoirs as stored water will infiltrate permeable soils during storage and eventually reach the groundwater table. However, to be effective this technology needs to be combined with the sinking of tube wells or boreholes considered below as communities will not access the water that has gone underground without a well or borehole. Fortunately tube well and borehole technology was listed among the priority technologies and is discussed below.

- ***Collecting water from a river, stream or other natural watercourse.*** This often includes an earthen or other structure to dam the watercourse and form "small reservoirs." The earthen bunds or embankments are typically built from soil excavated from within the reservoir to increase storage capacity. A spillway or weir allows controlled overflow when storage capacity is exceeded. Most small streams in Zambia are seasonal and dry up during the dry season. Constructing a dam on some part of the stream helps to store water for use during the dry season or during dry spells.

For reasons given above, only the technology of collecting water from a natural watercourse using small reservoirs was proposed for consideration. The cost of a typical project for a small dam, i.e. below the depth of 10m, is estimated at US$284,000, for a medium dam (between 10 to 15m depth) US$378,000.00 and US$1,133,000.00 for a large dam.[5] Annual maintenance cost was assumed at 10% of the total investment cost.

4.4.2 Boreholes/Tube wells for domestic water supply during drought

Borehole/tube well with overhead tank and a solar powered pump for water supply. There is no national standard borehole specification for Zambia. The handbook entitled "*Borehole Standard Construction and Details 2002*" indicates that finished diameters should be 4 inch for hand pumps and 6 inch for motorized units. In practice, most specifications are 4 inch diameter casing in a 6.5 inch (165 mm) diameter hole but Danida and German Government funded projects both currently specify 8 inch (312 mm) diameter drilled boreholes and the current JICA-funded programme formation, specifies drilled diameters of 7.8 inch (200mm) to 9.75 inch (250mm)[6].

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[5].Interview with Mr. Albert Chongo, Water Engineer, Water Board, March 2012
[6]Ibid

In Zambia, the boreholes are usually fully cased to the bottom irrespective of the natural rock lining. Since this design is to supply the water even during the drought, the depth would be 100m. The Danish Government through Danida and UNICEF intends to construct 3,650 water points each by 2015. It is a target of the National Rural Water Supply and Sanitation Programme, (NRWSSP) in Zambia to construct 10,000 new water points by 2015.

To enhance the productivity of the community, it is proposed that the boreholes have a *Solar powered pump for water supply photovoltaic system (PVP)*. In this system, the women and children would not spend time operating the hand pump. The time would then be used in other productive activities. This particular technology involves the application of solar energy to deep well water pumps for water supply in drought prone zones. The water pump is powered by solar and might involve pumping the water into an overhead tank which later flows down using gravity. Drought causes the lowering of the ground water level causing a number of communities to have no access to portable water supplies. The PVP technology involves solar water pump drawing water from the water source, well or borehole into the overhead tanks. The water then comes down from the overhead tank to the pipes by gravity. The piping distance is dependent on the distance from the water source to the points of use. The PVP equipment mainly comprises:

- PV generator which generally constitutes one or more polycrystalline photovoltaic solar module;
- Inverter which converts direct current (DC) into alternating current (AC). This is not applicable when the pump is for DC;
- Pumping system, this could be DC or AC; and,
- Overhead tank for water storage.

Estimated unit cost of technology of protected wells is US$ 12,000 with 10% annual maintenance cost.[7]Some of the benefits of the technology include better access to water for irrigation and other uses such as watering livestock. It also increases the productivity of women as they now access water near their homes. The drawbacks include high installation costs and that the technology is not usually applicable to deep boreholes and high water consumption rates. Diesel pumps are best applied in such cases.

4.4.3 Improving the resilience of protected wells to flooding

Building a Concrete Apron/Collar on the Well: This involves constructing a different design to that of the normal wells. An apron/collar would be built at the mouth of the well so that it is less vulnerable during flooding. This improves the well and hence the water is protected even during the floods. It would involve changing the design of most wells by building concrete works on the well and around the well. Concrete rings would form an apron/collar of 1.5 m high and 3.0m in diameter. The slope of the base is 45-degrees, gradual enough to prevent damage to the base during flooding. The wells are usually operated with the hand pump.

The water affairs department has been encouraging the communities to site the wells in locations which are not prone to flooding. The site for the wells is very important so that the well is on the hydraulic gradient (uphill) against the pit latrines. This is very important so that animal and human waste do not

[7] Interview with Mr. Albert Chongo, Water engineer, Water Board, March 2012

contaminate through the surface transport of fecal pathogens during the flooding. International organizations like UNICEF, SNV and Care have been promoting this in flood prone rural districts.

The floodwaters will not only contaminate drinking water sources but also lead to the destruction of water and sanitation systems, increasing the risk for water-borne diseases such as cholera during the rain season. This technology therefore reduces the vulnerable during flooding. Community health and economic activity require continuity of safe water supply. Sealing and elevating wells can prevent both contamination of drinking water and loss of physical access to the wellhead.

The estimated unit cost of technology of protected boreholes is US$ 15,000 with 10% annual maintenance cost.

4.5 Cost Benefit Analysis

It remained to show whether the benefits of these technologies exceeded their costs through a basic cost benefit analysis. Table 10 below gives the results of cost-benefit analysis for technologies in the water sector. We must, however, describe briefly the concept of cost benefit analysis and how to go about it.

4.5.1 A Brief Explanation of Cost Benefit Analysis

Cost benefit analysis is a method widely used to assess the desirability of a given action, which could be a policy, project or programme, on the basis of whether the benefits outweigh the costs. Across a range of alternatives, the idea is to select a choice that offers maximum benefits at least cost. To do this, it is possible to rank the benefit cost ratios (BCR) of alternative actions and then choose an action with the highest ratio. This introduces some realism in the technologies taken forward for barrier analysis.

Applying CBA to the prioritization of technologies for climate change adaptation followed the steps recommended by the UN Framework Convention on Climate Change as given below (UNFCCC, 2011).

- **Agree on an Adaptation Objective:** This means that for each technology, we needed to define an objective whose attainment was quantifiable in monetary terms. Adaptation objectives for each technology were taken from background discussions during the TWG meetings as well as expert consultations made by the facilitators.

- **Establish a Baseline:** This required that we define the situation without adaptation to which we then contrast the costs and benefits of the adaptation technologies being proposed. We will then be comparing "with" and "without" adaptation situations. Each adaptation technology, therefore, is contrasted with a conventional technology (baseline scenario) and benefits and costs for both are calculated and contrasted.

- **Quantify and Aggregate Costs and Benefits of the Adaptation Intervention:** Both direct and indirect costs and benefits of adaptation are supposed to be included. This way, we could arrive at additional costs and benefits that the adaptation technology would entail. Comprehensiveness is the key and it requires a very detailed investigation of the intervention. It is important to point out here that the indirect costs and benefits such as arising from the social change that arises as a result of change in the use of technology have not been included as these will be the focus of the barrier analysis. As required, some estimation regarding avoided costs as a result of climate change have been included.

- **Compare the aggregated Costs and Benefits:** This is the core of the CBA approach. To do this, we need to reduce these aggregated costs and benefits into a single variable that will serve as comparator between technologies. For our purposes, we adopted two variables, i.e. the net present value (NPV) and the benefit cost ratio (BCR). There are other variables that could be used such as the other widely used variable known as the internal rate of return (IRR) or the Modified Internal Rate of Return (MIRR) but the NPV and the BCR were deemed sufficient for our purposes and for keeping the exercise as simple as possible.

  The NPV is defined as "*the difference between the present value of cash inflows and the present value of cash outflows*".[8] In our case, all the costs associated with adopting a given technology represent outflows while benefits are inflows. Future expected inflows and outflows have to be converted in their present value on the premise that a ZMK1 today is worth more than the ZMK1 in future. There are two basic requirements to this understanding. First, the inflows and outflows need to be summed up over a period of time. We have used a 10 year period because a 5 year period (which is the other period normally used) is too short for climate change adaptation purposes while going beyond 10 years although desirable means that figures begin to become less reliable.

  Second, a discount rate must be selected to discount the future values of costs and benefits. There is no science to guide what rate is selected which is left to intuition and expert perception regarding what present value beneficiaries or sponsors of the technology would put on the present inflows and outflows compared to their future value. In order to avoid making decisions based on a very biased choice of a discounting rate, the tendency is to perform sensitivity analysis with two or more discount rates used instead. In the calculations, we used discount rates of 5% and 10% although the summary below is based on the latter. A negative NPV means that the technology or any other intervention is not beneficial.

  The BCR on the other hand is the ratio of the benefits of a technology in this case expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs are expressed in discounted present values. This means that the BCR takes things a step further than the NPV and provides a summary of the overall value of money for the adaptation technology.

From Table 10, it is seen that all the three technologies being proposed yield better results than the baseline scenario whether seen from the BCR or the NPV view point. This means that we are on firm ground in selecting these technologies for barrier analysis.

[8]see http://www.investopedia.com/terms/n/npv.asp#ixzz1sTrlbKbt

Table 10: Summary Results of Cost-Benefit Analysis for the Water Sector Selected Technologies

Name of adaptation Technology	Benefit Cost Ratio (BCR)		Net Present Values (NPVs)		Data Sources
	Conventional	Adaptation	Conventional	Adaptation	
1. Rain water collection from Ground water surfaces(Small reservoirs & micro catchments)	0.97	1.05	($1,879)	$5,216	• Rob Dyer, The Mvula Trust - Promotion of rainwater catchment in Southern Africa, Durban, South Africa • Interview with Mr. Feston Sikanga, Water Engineer, Water Board, Lusaka
2. *Improving the resilience of protected wells to flooding* (Building a Concrete Apron/Collar on the well)	0.44	1.78	($25,000)	$69,465	• Interview with Mr. Chimwanga Maseka, Programme Manager, SNV,July 2012, Lusaka; Dr Mpamba, Assistant Director, Water Department, July 2012, Lusaka • Rural Water Supply Network (RWSN)[9]
3. Boreholes/Tube wells for domestic water supply during drought (Borehole/ tube well with overhead tank and a solar powered pump for water supply)	0.01	0.03	($803,163)	$390,744	• NFU, Solar Photovoltaic Briefing,UK 2010 • UNEP/GEF Zambia: Renewable Energy based Electricity Generation for Isolated minigrids • Interviews with Mr. Gabriel Chingwe, Director, Luangwa Solar Power Corporation, March 2012, Lusaka; Mr. Chimwanga Maseka, Programme Manager, SNV,July 2012, Lusaka; Dr. Mpamba, Assistant Director, Water Department, July 2012, Lusaka.

[9] http://www.rwsn.ch/prarticle.2005-10-856177177/prarticle.2005-10-26.7220595116/prarticle.2005-11-15.8234616177/prarticle.2009-11-16.1112810268/

Chapter 5 Technology Prioritization for Agriculture and Food Security

5.1 Climate Change Vulnerability and Existing Technologies and Practices in the Agriculture and Food Security

5.1.1 A Brief Description of Adaptation Options in Agriculture and Food Security

The TNA Guidebook series for climate adaptation puts adaptation options for agriculture into eight categories as in Table 11 (Clements, op cit). The TNA process for Zambia adopted these eight categories as a good starting point. From the NAPA, the TNA Guidebook on adaptation, other national documents and discussions with various experts, 19 adaptation sub-options for the agriculture and food security sector in Zambia were identified (seen again Table 11). We refer to these as sub-options because they are still not specific enough to be called technologies. The identified options and sub-options are described in slight detail below indicating what climate change challenges they address, how they help to foster resilience in the Zambian context, the current status of the option in Zambia and their pros and cons within the Zambian context.

Table 11: Proposed Adaptation Options for Agriculture and Food Security

Category for Adaptation Option	Adaptation Sub-Options
Planning for Climate Change and Variability	1. National Climate Change Monitoring System
	2. Decentralized Community-run Early Warning Systems
Sustainable Water Use and Management	3. Rainwater Harvesting
	4. Promotion of short-furrow or furrow-basin flood irrigation
	5. Establishment of water rights that are supportive of sustainable agriculture development
Soil Management	6. Conservation Tillage
	7. Promote sustainable utilization of wetlands and dambos
Sustainable Fisheries Management	8. Promotion of community fish ponds for small scale farmers as a way of increasing the fish resources
	9. Introduction of chorkor smoking kilns for fishers in all viable fisheries (reduction of post-harvest losses)
	10. Use of legitimate and legal fishing gears in a bid to support the efforts of restocking the lakes, rivers and dams
Sustainable Crop Management	11. Crop Diversification and New Varieties
	12. Construction of improved granaries for small scale farmers (reduction of post-harvest losses)
Sustainable Livestock Management	13. Selective Breeding via Controlled Mating
	14. Livestock Disease Management
	15. Promotion of feed conservation practices during dry season for livestock farmers
Sustainable Farming Systems	16. Mixed Farming
	17. Agro-forestry
Capacity Building and Stakeholder Organization	18. Farmer Field Schools
	19. Community Extension System

Source: Clements, et al, Op cit; Government of the Republic of Zambia, 2007

5.1.2 Planning for Climate Change and Variability

The objective of planning for climate change and variability is to build the capacity required to efficiently manage climate impacts before and after they occur. It is a form of risk management which involves gathering data on climatic conditions and disseminating the information to a wide range of stakeholders. These systems should particularly capture the current and forecast future climatic conditions. This should strengthen the capacity of stakeholder, especially farmers, to ascertain the ideal crops to cultivate at any given point in time.

➲ ***National Climate Change Monitoring System:*** This integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate. A historical record of spot measurements is built up over time which provides the data to enable statistical analysis and the identification of mean values, trends and variations (Ibid, p.36). The systems address the problem of uncertainty in predicting and forecasting climatic hazards in Zambia. The better the information available, the more climate change can be understood and the more accurately future conditions can be assessed at both local and national level.

The systematic observation of the climate system is usually carried out by national meteorological centres and other specialized bodies. The Zambia Meteorological Department (ZMD) is mandated with the responsibility of climate/weather monitoring in the country. It has the mandate to establish and maintain: (i) meteorological stations; (ii) meteorological systems/networks; (iii) weather forecasting system; and, (iv) collaboration with relevant research institutions. In order to achieve its mandate, ZMD has a total of 41 meteorological stations spread across the 10 provinces of Zambia. These stations record weather measurements and send them to ZMD headquarters in Lusaka where the data is processed and disseminated to members of the public through the media. ZMD collaborates with a number of institutions such as the MALD, ZESCO, University of Zambia (UNZA) and other research institutes like the Zambia Agriculture Research Institute (ZARI).

Consultations with ZMD highlighted two critical constraints that constantly affect the realization of ZMD's mandate:

- *Inadequate human resources*: ZMD has very few staff qualified to carry out research. Of the 188 staff spread across Zambia, the majority are in administrative rather than professional positions.

- *Obsolete monitoring equipment*: Equipment is archaic and does not help to meet the demands of the modern ICT world. In most cases, old model radios (*HFSSB Radio System*) are used to transmit data from meteorological stations to the ZMD headquarters. Old radios are affected by weather patterns and as such the information which should be transmitted within 15 minutes (in accordance to global standards) takes approximately 1 hr 20 minutes.

Thus ZMD needs modern and automatic equipment to facilitate fast communication. Furthermore, the department should be restructured and qualified staff be recruited in a bid to make ZMD more efficient. The main challenge of a well modernized national climate monitoring system is that it is expensive to set up such a system. Currently, insufficient financial resources are allocated to the ZMD. The consequence is the obsolete equipment in use by ZMD as well as inadequate staffing at the department.

A fully revamped and modernized national climate monitoring system will be expected to provide accurate information on weather patterns and forecast to members of the public including farmers and enhance their climate change preparedness. It should provide farmers with vital information to make decisions regarding what crops to plant, when to plant, the type of varieties to use and when to harvest. Similarly livestock producers would be in a better situation to know what type of animals to rear, what to do about their feed, the likely status of water sources and the kind of diseases they could expect.

- ***Decentralized Community-run Early Warning Systems:*** An Early Warning System (EWS) is a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn of the possible occurrence of a natural phenomenon that could cause disasters. In view of increased climate variability, EWS is becoming more important in improving capacity to adapt to climate change (Ibid, p.50). The community-run Early Warning System (EWS) aims to reduce the inability of farmers to access forecast information on climatic hazards. This option contributes to the climate change adaptation and risk reduction process by improving the capacity of communities to forecast, prepare and respond to extreme weather events. It increases the resilience of small and medium scale farmers to climatic hazards.

  Decentralized community-run Early Warning System does not exist in Zambia although a centralized *Early Warning System* is in place which provides information to MALD to guide crop planning.In 2000 Zambia was selected to participate in a second phase of RANET Project to be coordinated by the ZMD. Its objective was to enhance the living standards of rural communities by way of increasing their access to vital information on health, agriculture, education, environment, weather, natural calamities and other information needed in order to improve their well being and increase their food security[10]. One way in which this objective is achieved is by facilitating acquisition and installation of radio broadcasting equipment for community radio broadcasting stations and provide solar/windup radios to the communities for the reception of the broadcasts.

  In addition, consultations with the coordinator of the Pilot Programme for Climate Resilience (PPCR) indicated that there are plans to put in place a decentralized EWS system which will assess the effects of climate change like precipitation levels and extreme temperatures. PPCR plans to rehabilitate the equipment for measuring rainfall under the ZMD. Within the framework of EWS, the use of cell phone technology to transfer climatic data from the provinces will be promoted. This information from the provinces of Zambia will be verified in order to enhance EWS which will guide farmers regarding what crops to plant and when to plant. It was planned that this EWS could become operational in 2012.

  PPCR also has plans to establish a database that would provide information on the kind of varieties of crops (such as maize) to plant in specific agro-ecological regions. This will assist farmers to know the type of agricultural seed to use for a particular farming season. In the same vein, market information indicating market prices will be developed. There are plans to learn lessons from a mobile platform company/donor called ESOKO based in Ghana, whose primary focus is promotion of farmer information (including weather reports) using short messaging system (SMS) technology (Climate Investment Funds, 2011, p.27).

  The advantage of a decentralized community-run EWS is that it enhances exchange of climate change information within the context of the community. In addition, this adaptation option is not capital intensive to set up. The weakness of the decentralized community-run EWS is its failure to

[10] http://www.meteo-zambia.net/About.htm

forecast droughts. The majority of EWSs were established to prevent or reduce the impacts of climate-related disasters (such as floods and hurricanes). By comparison, the capability of these systems to forecast droughts, extreme colds and heat has been less effective (Clements, op cit). Droughts usually begin slowly and gradually and are not easily visible at the start. Therefore, EWSs are better used with historical data on droughts in order to forecast weather patterns.

5.1.3 Sustainable Water Use and Management

The purpose of sustainable water management (SWM) is to manage the water resources while taking into account the needs of the present and future users. Therefore, the available water resources should be conserved in a manner that does not disadvantage future generations. Zambia has abundant water resources but communities living in arid parts of the country's Agro-Ecological Region I experience severe water shortages during summer (Climate Investments Funds, op cit). It is therefore necessary to improve water availability through adaptation technologies for sustainable water use and management. This is a key strategy for increasing agricultural productivity and securing food. It is against this background that rain water harvesting, furrow-basin irrigation and water rights that are supportive of agriculture development are critical as adaptation technologies in view of the climatic hazards of increased temperatures and drought.

- ***Rainwater Harvesting:*** This is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Both small and large scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams (Clements, op cit, p.50). There are various methods of rainwater harvesting available. These include rock surface, ground surface and roof top. Of these, rock and ground surface are suitable for rural communities whereas the rooftop method is ideal for urban communities with houses made of steel roof tops.

  The adaptation option of rainwater harvesting seeks to address the problem of huge rain water losses due to evaporation, transpiration, run-offs and drainage that take place during the rainy season. This is an adaptation strategy to mitigate against high rainfall variability, both for domestic supply and to enhance crop, livestock and fisheries sub-sectors.

  Rainwater harvesting in Zambia is practiced by a handful of farmers in rural areas. Traditionally, rainwater is harvested either directly in an open bucket or indirectly through shallow wells dug along the riverbanks. The needs of women and men regarding water differ from place to place. Women as compared to men are the main users of water both at household and community level. Water is mainly used for cooking, gardening and agriculture while men usually use water for construction of houses. On account of this, there is need for women to have more control and access to water resource as compared to men.

  Zambia has potential to harvest water that goes to waste during the rainy season. In addition, the country is endowed with massive water bodies and rivers which run all year round but water management is still a problem. This makes agriculture fail to benefit from this potential.

  Rainwater harvesting systems are available in some schools in Zambia. These are mainly roof harvesting systems comprising of a roof catchment, gutters and a tank. The water is usually drawn through a tap from the tank. The water is mainly used for drinking and washing by pupils, teachers and community members. In Eastern Province, MALD constructed a number of different rain water harvesting systems in schools and at individual households. In Southern Province, the Livingstone Sustainable Food Programme also worked with the rural communities in establishing projects in harvesting rainwater. The constructed structures were mainly dams, weirs, and boreholes. The Ministry of Local Government, Housing and Early Education (MLGHEE) with the support from UNICEF has been planning to start pilot projects in 10 districts of the Eastern and Southern Province.

Rainwater harvesting is a low cost technology. Capital costs and maintenance cost are relatively low in comparison to irrigation technology. In addition, the availability of harvested water improves rain fed agriculture. Uncertainty of rainfall associated with arid and semi-arid areas and which likely to even become more prominent with climate change reduces the extent to which users can rely on this source. In addition, water storage containers are not easily available. Some rainwater harvesting technologies such as roof water harvesting systems can only be used during the rainy season when the challenge of water availability is actually not as acute.

- ***Promotion of short-furrow or furrow-basin flood irrigation/Promotion of treadle pumps:*** Short-furrow or furrow basin irrigation is a form of surface irrigation. This system of irrigation involves leading the water from its source (stream, borehole, etc.) to the site. This can be done either by pipe, or by gravity canal if the surface level is below the source. The passage of water through an earth canal always involves some seepage losses, which vary with the soil type and length of canal. Water is usually transferred from the canal to the field by siphon, or pipes may be fitted through the bank of the canal. The short-furrow or furrow-basin flood irrigation is best combined with the promotion of treadle pumps especially for the small and medium scale farmers.

  The problem faced by most farmers is dry soil caused by rapid evaporation because of high temperatures and delayed on-set of the rainy season. This adaptation option of short-furrow or furrow-basin flood irrigation contributes to climate change adaptation and risk reduction process by allowing water to stay trapped for a longer period to moisten the soil in hot dry seasons.

  Short-furrow or furrow-basin flood irrigation is common among small and medium scale farmers in vegetable production. The technologies used are affordable, reliable and can easily be adopted by small scale farmers. In addition, furrow-basin irrigation allows for uniform distribution of water across the whole field, even in cases where the gradient varies or where the flow rate is inconsistent.[11] The drawback is that there is a risk of over irrigating a piece of land and may cause run-offs and soil erosion.

- ***Establishment of water rights that are supportive of sustainable agriculture development:*** Water right in water law refers to the right of a user to use water from a water source, e.g., a river, stream, pond or source of groundwater. In areas with plentiful water and few users, such systems are generally not complicated or contentious. However, in drought-prone areas, especially where irrigation is practiced, such systems are often the source of legal and physical conflict.[12]

  The problem faced by some households in rural areas is the lack of water during dry spells. The scarcity of water resources may cause some households to claim ownership of scarce water resources over others who in return contest this claim leading to conflict. This option contributes to

[11] http://www.fao.org/docrep/w7314E/W7314eOp.htm
[12] http://en.wikipedia.org/wiki/water_right

climate change adaptation risk reduction by allowing community members and farmers to have a regulated way of having constant supply of water for agricultural production.

Zambia is endowed with a lot of water resources. The ownership of all water in Zambia is vested in the President. The responsibility of allocating water is delegated to the Minister responsible for water resource allocation. The Water Act of 1948 empowers the Minister to appoint a Board to allocate water to competing uses. The Water Board administers the provisions of the Act by issuing water rights to all users. Water resources in Zambia is slowly becoming recognized as a strategic commodity, with supply limited in terms of quantity and demand increasing due to population growth and economic development. This has resulted in competition for the limited water resources between domestic, agricultural, environmental and hydropower use.

The Water Board gives water rights based on a fixed amount of water (e.g. 5000 m^3/day) which, with the increase in demand had caused a threat of over allocation on rivers and streams. In order to manage this, water allocation for agriculture (crop irrigation) has been revised to consider among other things climatic factors, water requirements, crop type and rainfall. This has been augmented by the introduction of other tools such as pricing system, metering and more stakeholder participation (Mondoka and Kampata, 2000).

Under the Water Act, landowners have rights to the private and public water on their land free of charge, whether for primary, secondary (irrigation and aquaculture), or tertiary (industry and mechanical) use. Any person who wishes to store or divert water from public streams and waterways for primary, secondary, or tertiary use must obtain permission from the Water Board. Water for industrial, commercial, and urban uses is subject to special permitting requirements.

Water rights help to provide certainty that a water user will have water available in the future. The rights are based on a *priority system* that is used to determine who can continue accessing water when there is not enough water to supply all needs. Those with high priority rights know that they are likely to receive water. Those with low priority rights know that they may not receive water and therefore can plan accordingly. The agricultural producers should be given high priority rights. Water users make economic decisions based on the certainty of their water supply. For instance, farmers who have a high certainty of receiving water are able to plant crops even in dry periods, which can be sold for higher prices.

Water rights also help to protect the environment from impacts that occur as a result of water diversions. The permits usually include conditions to protect other water users and the environment. The water right permitting process can therefore stop environmentally unsustainable projects from starting.

The main drawback is the inadequate institutional capacity to enforce compliance of water rights. Compliance is enforced by imposing sanctions for those who break the regulations. However, the Ministry of Water and Energy Development usually lacks the local information and ability to penalize those who divert water illegally.

5.1.4 Soil Management

The management of soil has a direct link with agricultural productivity. Soils that are considered poor usually have low yields per given area. Climatic hazards like floods and droughts have negative effects on the quality and composition of soils. The type of tillage that a farmer is using can also trigger erosion of soil. Tillage usually exposes the soil to erosion, reduces organic matter content and can increase run-off. It therefore becomes necessary to have a range of soil management adaptation options that can help improve soil fertility such as conservation farming and sustainable use of wetlands.

- ***Conservation Tillage/Farming:*** Conservation Tillage refers to a number of practices that in combination conserve soil, moisture, fertilizer, seeds, energy, time and money (Conservation Farming Unit, 2007). It has a number of basic features which include: no burning of crop residues, correctly spaced planting basins established before the rains, early planting of all crops, early weeding and rotation with a minimum of 30% legumes in the system. Conservation tillage is meant to address the climatic hazard of delayed onset of rains and drought which normally increases soil erosion and reduces soil fertility for both small and medium scale farmers. It also aims at improving fertility and moisture storage.

The adaptation option of conservation tillage is well known and practiced by a number of small and medium scale farmers in Zambia. The main promoters of conservation farming in Zambia have been the Conservation Farming Unit (CFU) of the Zambia National Farmers' Union (ZNFU), the Ministry of Agriculture and Livestock Development (MALD), the Golden Valley Agricultural Research Trust (GART) and the Zambia Agricultural Research Institute (ZARI). Conservation farming is commonly practiced in Agro-Ecological Regions I and II.

In Central and Eastern province, some farmers are integrating conservation farming with agro-forestry. In this regard, tree species like Faidherbia albida (musangu), Tephrosia Vogelii (ububa) and Sesbania sesban are used to promote soil fertility. Sesbania sesban was promoted in Eastern province by the International Center for Research in Agro forestry (ICRAF).

Conservation tillage/farming in Zambia has been shown to help farmers achieve higher yields with less labor, less water and fewer chemical inputs. In addition, soil erosion is minimized. The drawbacks include the fact that the practice entails leaving crop residues in the field which raises the incidence of plant diseases and pest infestation. In some cases, conservation farming has a high dependency on herbicides which increases cost and may not be easily affordable for some small farmers.

- ***Promotion of sustainable utilization of wetlands and dambos:*** A wetland is an area of land that is wet for all or part of the year (e.g. swamps, marsh). It contains some level of water, fed by streams or even underground springs. The water is not deep enough to be a pond, but rarely, if ever, drying out to the damp level of a swamp. They are important habitats for birds, frogs, turtles and are often protected by law.[13]

Wetlands should be managed in a sustainable way. This means that they should yield benefits to the present generation and at the same time maintaining their potential to meet the needs and aspirations of the future generations. This concept is particularly relevant to communities in Africa given their high recognition of the value of wetlands to local communities in meeting various needs.

Climate change may in some cases lead to the drying up of wetlands during drought periods worsened by the use of synthetic (chemical) products like herbicides and fertilizers which have a

[13] http://wiki.answers.com/Q/What_is_a_wetland

negative effect on the bio-diversity of wetlands. Strategies for sustainable utilization of wetlands and dambos are an important option for climate change adaptation and risk management by helping to maintain the bio-diversity of wetlands through sustainable farming practices and use of natural pesticides and herbicides.

According to the FAO, the utilization of wetlands in Zambia is wide spread. The nature, type and location of the wetland determine the intensity and kind of use. In the last 10 to 15 years, growing human population, increased need for food production, income generation and the occurrence of drought have been major factors leading to intensified and diversified utilization of wetlands. They present the opportunity to support a wide range of livelihood activities including crop production, livestock rearing, fishing, gathering of wild products, brick making, craft and building materials and above all water for domestic use, especially in the dry season when wells in the upland areas dry up.

Wetlands are useful for meeting many direct and indirect needs. They are used for dry season grazing, as a source of reeds to weave sleeping mats, baskets, etc, also as a source of fuel wood and timber for building houses.[14]Therefore, wetlands are important to life and should be used in such a way so as to ensure their continued existence and reliability to meet the needs of the next generation. This also implies that chemical fertilizers which have a negative effect on the environment should not be used in the dambos/wetlands.

The utilization of dambos during both the dry and rain seasons adds diversity and increase the possibility of different livelihoods and combinations of livelihoods. This diversity is expressed spatially through activities taking place in different parts of the landscape, temporally (both seasonally and inter-annually) and socially with different user groups (Kokwe, 1995).

Zambia has a number of representative wetlands/dambos that are spread across the three (3) agro-ecological regions of the country.

The main drawback with the use of wetlands and dambos is the pressure that most farmers exert on wetlands on account of the fertile soils found there. This has long term negative effects on the wetlands and dambos' rich bio-diversity. Consequently, farming in the wetlands endangers and destroys their natural habitat.

5.1.5 Sustainable Fisheries Management

Sustainable fisheries management intends to utilize the fisheries resources by taking into account social and economic human needs while maintaining a healthy ecosystem. In order to achieve this, fishing pressure and illegal fishing practices should be reduced to minimal levels. According to the United States Country Study Programme (USCSP) study, the projections of impacts of climatic hazards indicate that lower rainfall would reduce nutrient levels in rivers and lakes, and impact negatively on fish breeding and deplete fish species in the long-term (GRZ, 2007, p 12). In Zambia, many communities that live along the fisheries depend on fishing as a source of food security and livelihood and are therefore likely to be adversely affected unless adaptation measures are taken.

[14]http://www.fao.org/DOCREP/003/X6611e03d.htm

In a bid to adapt the impacts of climate change, the promotion of community fish ponds not only increases the fisheries resources but also reduces the fishing pressure on the major fisheries in Zambia. In addition, the illegal fishing practices can be addressed by enforcing legislation on promoting the use of legitimate and legal fishing gears.

- ***Promotion of community fish ponds for small scale farmers as a way of increasing the fish resources:*** This adaptation option involves constructing fish ponds in communities. A fish pond is a controlled pond, artificial lake, or reservoir stocked with fish in aquaculture. It is important that fish ponds are stocked with species suitable to the local area. Through community fish farming, households that have always depended on fish will still have access to this resource even as the fish stock are depleting on account of climate change and other factors.

  The depletion of fish resources primarily affects the artisan and medium scale fishers especially those that are settled near water bodies like lakes and rivers as their livelihood depends on fishing. If produced on a large scale, the fish resource can generate sufficient household income. In the past, the people of Luapula Province, some parts of Western Province, along the shores of Lake Tanganyika in Northern Province and of Lake Kariba in Southern Province besides the populations living along the country's major rivers depended on fish as the major source of livelihood. Currently, fish stocks have seriously reduced partly due to the effects of climate change and also the use of illegal fishing gear.

  There are various efforts concerning the development of aquaculture in Zambia. According to the NAPA, the Department of Fisheries (DoF) is implementing various projects which include; Farmer-based Aquaculture Training; National Aquaculture Research and Development Centre (NARDC); Rural Aquaculture Programme (RAP); CLIMAFISH and Zambia Japan Cooperation Project on the Ecology and Behaviour of Fish in Lake Tanganyika.

  Rural Aquaculture Promotion (RAP) was developed in 1996 by Peace Corps/Zambia in response to a request from the Department of Fisheries (DoF) for human resource assistance in the aquaculture sector. The purpose of RAP is to help rural families and groups to address their livelihood needs, including HIV&AIDS mitigation, by operating integrated aquaculture as small business ventures that are supported by effective fish farmer organizations.[15]RAP has recorded positive results of increased fish production, yield and incomes of the participating communities in North-Western, Luapula, Northern, Copperbelt, Eastern and Central provinces.

  The main advantage of community fish ponds is its reliance on locally available resources– land, water and man power. This adaptation option also has the high potential for adoption by farmers settled in the plateau regions with minimal fishing activity.

  Fish pond management is an involving task which requires the technical expertise of the fisheries/agriculture extension staff. However, on account of human resource challenges under the MALD and DoF, extension services for aquaculture are limited in most parts of the country.

[15]http://zambia.usembassy.gov/zambia/rapp.html

- ***Introduction of portable chorkor smoking kilns for fishers in all viable fisheries (reduction of post-harvest losses):*** The chorkor smoking kiln is an adaptation option meant to reduce post harvest losses in the fisheries sector. It is an improvement of a traditional fish smoking oven already known and used in Ghana that was readily accepted by women who were practicing traditional fish smoking. It consists of a combustion chamber and a smoking unit with a set of trays. The combustion chamber is rectangular, twice as long as it is wide, divided by a wall down the middle and with two stokes holes in front.

  The fisheries sector could experience post harvest losses on account of poor sunlight caused by climatic variations. The affected category of stakeholders is the small scale fishers who mainly use traditional ways of processing the fish. According to DoF, 30% of the fish caught in Zambia goes to waste through post harvest losses, especially in Luapula Province.

  The DoF in collaboration with Programme for Luapula Agricultural and Rural Development (PLARD) Phase I had plans to introduce portable chorkor smoking kilns for the fishers in Lake Bangweulu of Luapula Province, on a pilot basis in 2003-2004. This was in a bid to promote value addition of the processed fish. The plan was to design a smoking chorkor ideal for both men and women. In this regard, TDAU of the University of Zambia (UNZA) was approached by PLARD Phase I and the design was done. However, with the transition period of PLARD Phase I to II, the promotion of the chorkor has not been done as yet.

  The main advantage of the chorkor smoking kiln is that it is built from locally available resources and is easy to utilize. The use of this smoking kiln is likely to reduce the post harvest losses in the fisheries sector especially during periods when there is no sunlight. A drawback is its heavy reliance on firewood. If the kiln were to be built on a fixed location, it may not be ideal for the fishers who move from place to place especially when it floods. A portable version of the chorkor is therefore ideal for fishing communities in Zambia.

- ***Promotion of the use of legitimate and legal fishing gear in support of restocking the lakes, rivers and dams:*** The depletion of fish resources is a function of climate change and other factors like the use of illegal fishing gears by fishing communities. The use of illegal fishing gears has negatively affected the breeding of fish stocks in the major water bodies of Zambia. The restocking of fish in lakes, dams and rivers is a good plan aimed at increasing fish stock in the natural water bodies. However, unless the use of illegal fishing gears is addressed, such efforts are not sustainable.

  The adaptation option of using legitimate and legal fishing gear is meant to address the problem of reduced fish stocks in the water bodies (rivers, lakes, dams etc). Factors that contribute to reduced fish stocks are both environmental and human. Environmental factors relate mostly to variations in climate and weather patterns. On the other hand, human factors include the use of poisonous herbs (*Tephrosia vogelii-Ububa*) to kill fish, explosives and illegal fishing gear.

  DoF is mandated by law to ensure the preservation of the fisheries resources. Over the years, DoF has been sensitizing the fishing communities on the use of legitimate and legal fishing gear. Collaborative management of the fisheries to promote ownership among communities is also being promoted as part of this sensitization. However, despite these efforts, a number of fishers are still using illegal fishing gear.

5.1.6 Sustainable Crop Management

Sustainable crop management is the managing of crop production in a way that does not negatively affect the ecosystem. This means that sustainable farming practices such as conservation farming coupled with the use of improved seed varieties should be encouraged. It includes measures to reduce post-harvest losses of crops. Crops are negatively affected by climate change through increased salinity, increased temperature, decreased water availability and increased pest and diseases. Responding to these adverse events will require adaptation options such as research on new crop varieties and post-harvest management.

- ***Crop Diversification and New Varieties:*** This option aims at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities (Clements, et al, op cit, p.104). It is meant to address climate change related risks small and medium farmers dependent on rain-fed agriculture face and particularly by planting long maturing varieties. The option also allows farmers to plant crops that demonstrate the qualities of early maturity, crop resilience to disease and greater nutritional value.

  This adaptation option of crop diversification and new varieties is practiced by many farmers in Zambia. In the past, many farmers practiced a mono-culture production of rain-fed maize. MALD is sensitizing farmers to grow crops that best suit their agro-ecological regions. Therefore, many farmers in addition to growing maize are also growing other crops such as groundnuts, beans and vegetables. Agriculture research organizations are helping farmers to identify new varieties that would help adapt to changing climatic conditions. ZARI and GART are in the forefront of developing early maturing varieties of maize, cassava and other crops.

  Although the risk cannot be entirely eliminated, crop diversification and the planting of varieties more appropriate to the changed environment help farmers to reduce the adverse impacts of climate change. In most cases, new crops come with farming practices that are environmentally sustainable. However, this is not without drawbacks. The introduction of exotic crop species by research institutes sometimes escape control and results into unwanted consequences. In addition, crop diversification implies the use of more labour input for the farmer which in certain instances is bound to negatively affect yield per hectare.

- ***Construction of improved granaries for small scale farmers (reduction of post-harvest losses):*** The storage of seed and grain has a direct link to household food security. Most farmers have been using traditional granaries that are susceptible to termite and rat attack and to being soaked by the rains. These exacerbate post harvest losses. The problem of post-harvest losses for small and medium scale farmers can be minimized by improved granaries (storage facilities). They help control the environment in the store house to lower biological damage by insects, rodents and micro-organisms, chemical damage due to acidity development and physical damage through crushing and breaking. A good storage facility has traits that keep the following factors under control: temperature, moisture, light, pests and hygiene.

  Improved granaries increase the availability of grain supplies even during the drought climatic conditions. They maintain the quality of stored food crops, seed and grain so that they last all year round. However, for the grain and seed to last a longer time, cleaning and drying are important measures. Failure to clean and dry the grain can lead to pest infestations. The prevention of pest infestation may require chemical sprays. It is worthwhile to note that some markets do not accept seeds and grains that are treated with chemicals.

Initiatives to help farmers minimize post harvest losses fall directly under the MALD which has for a long time collaborated with other players like the FAO on this. For instance, in 1977 the FAO Action Programme for the Prevention of Food Losses became operational. The general objective was to assist developing countries in planning and implementing their national food-loss-reduction programmes at the farmer/village level. The project was for two years and focused on direct actions to reduce losses in staple foods by the introduction of improved structures or post-harvest equipment, pest-control programmes and capacity building programmes. Currently, MALD through its extension staff continues to play a key role in building the capacity of farmers in post harvest management across the country.

5.1.7 Sustainable Livestock Management

The aim of sustainable livestock management is to improve the condition and health of livestock especially during periods of climatic hazards. Climate change has introduced harsh conditions that impair livestock production, reproductive performance, immune response and feeding regime. It is for this reason that adaptation options such as selective breeding, disease management and feed conservation among many others are critical for the survival of the livestock industry.

- ***Selective breeding via controlled mating:*** Selective livestock breeding is the systematic breeding of animals in order to improve productivity and other key characteristics. Selective breeding is an adaptation option that aims to improve the value of animal genetic diversity. This can be applied to all types of livestock including cattle, sheep, goats and pigs (Ibid p.136).

  Livestock is affected negatively when exposed to diseases, extreme heat, extreme coldness and flooding. Adaptation to these harsh climatic hazards is a major concern for livestock farmers. Selective breeding should take into account the key breeding traits related to climate change resilience and adaptation. These include tolerance to disease, extreme temperature, low quality feeding and high survival rate of kids.

  The increased disease burden and loss of livestock is a key problem faced by livestock farmers especially when climatic hazards strikes. Therefore, selective breeding and controlled mating seeks to improve local genetics through cross breeding with heat and disease tolerant breeds.

  MALD and the University of Zambia-School of Veterinary Medicines have played a leading role in selective breeding and controlled mating in Zambia. It is worthwhile to note that Zambia has a weak capacity for high-tech breeding programmes that would increase livestock adaptation to climate change. Common programmes in Zambia are those based on controlled mating methods. The weakness with these programmes is that they tend to promote in-breeding especially among the small scale farmers who are less knowledgeable about good livestock management practices.

  The main advantage of selective breeding is that it has high potential of preserving local and rare breeds which would otherwise be extinct due to climate change. The main disadvantage is that it does not always lead to desirable results of high productivity rates.

- ➲ ***Livestock Disease Management:*** The high incidence of diseases is a key problem in the livestock sector. Transmission is mainly caused by interactions with other animals. Droughts and floods create conditions in which these diseases spread very quickly. For example, when there is a drought, there is a high movement and interaction of animals in search of feed and water. At the same time, reduced feed means that their body conditions become very susceptible to disease. Blackleg, anthrax, foot rot and water borne diseases are some of the diseases whose incidence rises with floods.

  Where there is poor disease management, climate change related hazards are bound to aggravate the situation with farmers suffering serious animal loses, reduction in food security, increase in malnutrition and even animals passing on diseases to human beings. Climate change makes it even more important for livestock farmers to acquire skills for preventing and controlling livestock diseases. Given the importance of livestock to the small farmers, this adaptation option will go a long way to raise farmers' resilience against the climate change hazards.

  Livestock diseases vary from place to place. Common ones include corridor diseases (tick bourne disease), newcastle, lumpy skin, contagious bovine pleuro-pneumonia, foot and mouth, African swine fever etc. In 2009, the University of Zambia (UNZA) was chosen as the Southern Africa's node for livestock research under the New Economic Partnership for Africa's Development (NEPAD). The launch was aimed at strengthening capacity in bio-sciences. The Samora Machel School of Veterinary Medicine at UNZA and the Livestock and Pest Research Centre at the National Institute of Scientific and Industrial Research (NISIR) are jointly hosting the SANBio research centre. The aim of the livestock development node is to initiate and coordinate research and development in applied research aimed at reducing the negative impact of tick-borne diseases, Trypanosomes and their vectors, on livestock production in Southern Africa.

  Consultations with the School of Veterinary Medicines at UNZA revealed that rainfall patterns affect wild life in the Kafue National Park. Wild animals usually move from low lands to high lands which are settlement areas for livestock and human beings. In terms of floods, foot and mouth disease is a naturally occurring disease in buffaloes. The disease is transmitted to livestock and human beings when buffaloes move from lower to higher lands. The option in place to deal with foot and mouth disease in Zambia is vaccination. However, vaccination is not 100% effective.

  In Blue Lagoon and Lochnivar National Park, the Lechwe has tuberculosis (TB). During periods of floods, Lechwe interacts closely with cattle and human beings. For instance, in Namwala District, animals graze side by side with wildlife and this increases chances of cattle contracting TB due to contacts. TB in livestock has the negative effect of down-grading the quality of the meat.

  In 2010, the Government of the Republic of Zambia planned to develop Disease Free Zones (DFZs) in Lusaka, Central and Copperbelt Provinces in order to control major livestock diseases and improve livestock productivity with enhanced provision of infrastructure.[16]

  In December 2011, anthrax broke out in Chama District of Eastern Province mainly due to delayed on-set of the rains. In such periods, animals have to scrounge for pasture and usually pick up the disease from the soil. The option in place to deal with anthrax is mainly by way of sensitizing the community members to avoid contact with diseased animals. In 2012, an allocation of ZMK116

[16] http://famis.comesa.int/com/option.com_news/task.viewarticle/sid.343/Itemid.129/pillar.sps/lang./sectionid./

million under the Poverty Reduction Programme (PRP) was made to help contain an outbreak of lumpy skin disease in Southern Province which by early April had affected 1,627 heads of cattle.[17] Lumpy skin in Southern Province has been re-occurring every four to five years and especially during periods of dry spells.

The main benefit of preventing and controlling livestock disease is increased production and reduced mortality rate. When livestock diseases are managed, wildlife within surrounding areas is likely to have indirect benefits. A drawback to the option is that small scale producers find it difficult to meet the full cost of livestock disease management in situations where the government does not provide subsidies. Furthermore, the use of chemical drugs such as anti-biotics and vaccines is not biologically sustainable and in some cases livestock develop resistance.

- ***Promotion of feed conservation practices during dry season for livestock farmers:*** This adaptation option entails the use of fodder or animal feed especially during the dry season when pasture is scarce. Fodder is any agricultural foodstuff used specifically to feed domesticated livestock such as cattle, goats, sheep, chickens and pigs. It usually consists of crop residue or agricultural and industrial by-products. An example of non-leguminous fodder crops rich in soluble carbohydrates include maize, sorghum, millet, and cultivated grasses. It is evident that all the ingredients used for making fodder are readily available in Zambia.

  During dry spells, most livestock farmers are negatively affected by inadequate livestock feed and water. Feed conservation practices during the rainy season helps to address this problem by ensuring constant supply of livestock feed in the dry season or during dry spells. Given the expectation that climate change will make the frequency of droughts and dry spells to rise, this is an important adaptation option for livestock farmers.

  In Zambia large quantities of crop residue such as husks, straws, legume tops, sugar cane tops, cassava leaves and potato vines are left in the field wasting each year because small-scale farmers lack the knowledge of how to utilize them. In addition, there are many tree species that are ideal for fodder including acacia angustissima, calliandracalothyrsus, gliricidia sepium, leucaenadiversifoli, leucaenaesculenta, leucaenapallida and leucaenaleucocephala. The leafy material of these tree species is harvested and fed to animals. In addition, the small scale farmers need equipment that can be adapted to local conditions to process the crop residues as livestock feed. The option should be simple and easy to use at community and farm household level.

  The main advantage of feed conservation practices is that it ensures availability of ruminant feed stocks during periods when there is low or no pasture. In addition, the conserved feed stores sufficient nutrients to merit use in dry periods. In as much as the level of nutrients differs from those of fresh materials, adequate levels of nutrients are retained. However, conserved feed is only beneficial if it is well preserved and highly digestible and contains proteins. In addition, the main requirements for feed conservation should be harvested at a young stage of growth and it should contain enough sugars for fermentation.

5.1.8 Sustainable Farming Systems

[17] http://allafrica.com/stories/201202090759.html

Farming system is a complex inter-related matrix of soils, plants, animals, implements, labour and capital, inter-dependent farming enterprises. It creates an opportunity for developing diversified models for different types and categories of farmers. Therefore, Sustainable farming systems are the ways of organizing resources depending on the available inputs, outputs and processes, in a manner that does not negatively affect the environment and deplete the resources for future generations.

There are different types of farming systems which include: crops and livestock, crops, livestock and poultry, crops and horticulture, crops using intensive or extensive methods. However, the two main broad categories of farming systems are mono-cropping system (single crop farming enterprise) and mixed farming system. In view of the challenges of climate change, it is important for farmers to resort to agro-forestry and mixed farming system as an adaptation option.

- ***Mixed Farming:*** Mixed farming is an agricultural system in which a farmer conducts different agricultural practices together, such as production of cash crops and livestock (ibid, p.140). The main combination in a mixed farming production system is crop and livestock production. However, in an integrated mixed farming system there are a variety of combinations such as livestock-fish-crop, livestock-fish-poultry and livestock-fish-poultry-vegetable. The main distinct features of such a system include: diversification in the use of production resources, reduction and spread of risks, low use of external inputs, multipurpose role of crops and animals and presence of ruminants such as cattle, goats and sheep and non-ruminants such as chickens, ducks and pigs.

  Mixed farming is a good adaptation option for farmers facing climatic hazards. It has been observed that "*the mixed crop and livestock system predominant in Africa is the most tolerant, whereas specialized crop production is the most vulnerable to warming and lower rainfall*" (Nemachena, January 2009).Partly this is due to the spreading of the risk widely across different enterprises. However, mixed farms also have an inbuilt mechanism for one enterprise to mitigate the risk faced by the other.

  In Zambia, mixed farming of crops and livestock is widespread across all the three Agro-Ecological Regions. However, crop/livestock production activities among small-scale farmers are predominant in Agro-Ecological Region I and II. In this case, the production of one enterprise tends to depend on the other (closed system). Crop production will depend on draught animals for cultivation and animal manure for fertilization of crops. On the other hand, livestock production will depend on crop residues for dry season feeding.

  It is also worthwhile to note that integrated mixed farming systems involving livestock-fish-poultry-vegetable are not common in Zambia. This production system has an advantage of spreading investment across farm enterprises and increasing the resilience of farmers to the negative impacts of climate change. However, most small scale farmers do not have the capital required to engage in an integrated mixed farming system of this nature.

  Mixed farming system is more efficient as compared to specialized crop production system particularly in its intense use of land. It also assists in improving the soil fertility due to the animal manure which is added to the soil. Mixed farming has also the advantage of allowing diversification of risks, using labour more efficiently and providing the much need household income in turn. However, mixed farming is particularly hindered in areas which do not support intensive cropping, e.g. semi-arid areas. This is aggravated by the growth in human population which usually reduces the land for grazing and consequently agricultural productivity is minimized.

- ***Agro-forestry:*** This is an integrated and intensive agricultural production system that includes trees and shrubs as an essential component to achieve environmental, economic and social goals. This means that trees are not incidental to the farm operation but rather contribute to improved productivity, yield, profitability and sustainability.[18] In addition, agro-forestry seeks to protect, conserve, diversify and sustain vital economic, environmental, human and natural resources. Agro-forestry systems can be categorized into three systems: (i) trees with crops; (ii) trees with crops and livestock; and, (iii) trees with pasture and livestock.

  Agro-forestry contributes to climate change adaptation and risk reduction by promoting soil nutrients and reducing soil erosion in a farm land. This reduces the amount of chemical fertilizers that the farmers have to apply to the soil.

  Agro-forestry practices have been part of traditional farming system known as *chitemene* system which is a type of shifting cultivation in which trees are cut, piled and later burnt, with crops grown in the areas covered with ash (Kabwe, 2010).

  Agro-forestry in Zambia is spearheaded by the Ministry of Lands, Natural Resources and Environment Protection (MLNREP), specifically the Forestry Department, and the Ministry of Agriculture and Livestock Development. However, there are various stakeholders who play a role in agro-forestry issues in Zambia. These include the University of Zambia (UNZA), the Copperbelt University , the National Institute for Scientific and Industrial Research (NISIR) and the Zambia National Farmers Union (ZNFU). These key players in agro-forestry formed a National Steering Committee (NASCO) on agro-forestry. NASCO has the mandate of facilitating institutionalization of agro-forestry in research, extension, development and education. The agro-forestry adaptation methods available to smallholder farmers in Zambia include improved fallows, biomass transfer, woodlots, fodder banks and use of indigenous fruit trees. In Zambia, agro-forestry is more commonly used in Eastern and Central Province where ICRAF played a key role in building the capacity of small scale farmers in agro-forestry.

  The common agro-forestry tree species used in Zambia are Sesbania sesban, Tephrosia vogelii, Tephrosia Candida (Madagascar) and Cajanus Cajan (pigeon pea). These tree species have been observed to have a good impact on improving the fertility of the soil and in some cases, acting as pesticides.

  A good feature of agro-forestry is that it increases soil fertility through nitrogen fixation while reducing soil erosion. A barrier to adaption of agro-forestry is that it is a long-term investment that requires more than 1 year depending on the tree or shrub under consideration. Therefore, its main disadvantage is the time it takes to see results. It is also highly labour-intensive.

5.1.9 Capacity Building and Stakeholder Organization

Inadequate and lack of technical agricultural knowledge is one of the main contributing factors for poor productivity and production among small scale farmers. With the advent of climate change, the capacity of farmers needs to be built-up so that they are able to know which production systems are ideal to mitigate the adverse impacts of climatic hazards. There are various ways to build small farmers'

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[18] http://www4.agr.gc.ca/AAFC-AAC/ (Agriculture and Agri-Food Canada)

capacity. These include farmer field schools and participatory extension systems. Farmer field schools and community extension system involves farmers conducting their own field studies, sharing knowledge and experiences, learning with each other and using the field as the primary learning base. In short, the farmers “learn by doing” through comparing different management practices. In addition, the expert farmers can then play an important role in providing extension services to their local communities and liaising with the agricultural experts from time to time. In order to strengthen the resilience of small scale farmers who are vulnerable to climate change, lessons on climate change adaptation can be tailored to suit the needs of the farmers.

- ***Farmer Field Schools:*** The Farmer Field School (FFS) is a method to educate farmers in an informal setting within their own environment. FFS are “schools without walls” where groups of farmers meet weekly with facilitators. They are a participatory method of learning, technology development, and dissemination based on adult learning principles such as experiential learning. The defining characteristics of FFS include discovery learning, farmer experimentation, and group action (Ponniah and Sindu, 2007).

  The capacity of farming communities to respond and adapt to climatic hazards can be built up through the farmer field schools. As an adaptation option, farmer field schools will address the problem of poor and unsustainable farming practices among small and medium scale farmers through group-based trainings at community level. They are a forum where farmers can discuss freely the challenges of soil infertility, crop damage, loss of livestock, pest and weed infestation and livestock diseases, all issues that face serious challenges from climate change. By enhancing the knowledge base of farmers, they will be better able to adapt effectively to climate change impacts.

  The concept of farmer field schools is integrated in the extension system of the MALD. Over the years, FFS have been used in Zambia by players like the government and development agencies. For example, in 2010, World Vision Zambia facilitated a training workshop on System of Rice Intensification using the FFS approach in Musele ADP, Zambia. The other example is that of PLARD Phase I in Luapula Province which in 2009 adapted the *farmer field school* approach naming it the *commodity study group* (CSG) approach. The CSG attracted beneficiary farmers who were later trained by the camp extension officers on various production techniques such as crop rotation and liming. At the same time, demonstration plots were done to give farmers the practical/hands-on experience.

  Farmer field schools are a good approach to communicate effectively to a group of farmers. The adoption of successful trials by farmers is quicker as it is based on personal experience. However, facilitators have to be very patient as the transfer of knowledge and its adoption takes long because these farmers are very risk averse given that they are already engaged in an intense struggle for survival which leaves them with very little margin of error. Low education also plays a role in their slow adaptation.

- ***Participatory Extension System:*** This emphasizes experiential learning and building the capacity of farmers to solve their own problems through experimenting and sharing of knowledge (Government of the Republic of Zimbabwe, June 2010). It is imperative that the farmers should use the knowledge gained to increase productivity and sustainability of their production systems. Small scale farmers have a weak resilience to climatic hazards on account of the use of traditional farming practices. A main problem is the lack of modern knowledge on agricultural practices. Participatory Extension

System helps small farmers to adapt to climate change effects by providing rural farmers with accessible knowledge and information.

The MALD is the major provider of extension services in Zambia with staff in all the 10 provinces. However, the main challenge of the extension system in Zambia is the inadequate camp and block extension officers which has resulted in many agricultural camps not to be manned.

One advantage with participatory extension system is its wide diffusion of knowledge, reaching even farmers that may not be direct beneficiaries. This system also works well in building the confidence of lead farmers in rural communities in facilitating agricultural production. However, a main problem associated with the participatory extension system is the inadequate numbers of camp and block extension officers in Zambia. The other drawback is the high operational cost of the system.

5.2 Adaptation Technology Options for the Agriculture and Food Security Sector and Their Main Adaptation Benefits

From Table 12, it is seen that the technology options discussed in Section 5.1 address a diversity of challenges arising from climate change. This in itself is an indication that climate change has a diversity of adverse effects. Successful adaptation to climate change in the agriculture sector at national level therefore requires promoting different adaptation options at the same time. Prioritization and selection of options as done in the next section does not reduce in importance the options not selected.

Although diverse, it is possible to see three threads running through the different benefits that these technology options confer. The first has to do with better risk management. More clearly, this is achieved by the technology option of planning for climate change and variability. This is meant to create greater awareness of climate change and foster better preparedness to a rise in climate hazards. To be successful, however, farmers need to be in a position where they can take action such as deciding the type of seed to plant in the light of the information received. Technology options, therefore, that focus on increasing farmers knowledge of agriculture generally play this role. Capacity building and stakeholder organization also help in farmer preparedness.

Second are technology options that try to promote the sustainable utilization of existing natural resources that support production. The technology options in Section 5.1 have specifically provided for the sustainable utilization of land, water and fisheries. The idea is that, climate change is likely to compromise the productivity of such natural resources. If they have to remain supportive to sustainable agriculture livelihoods, they should be exploited in a sustainable manner. This is a need that has been recognized owing to many different factors. Climate change merely accentuates this need.

The last thread has to do with improved production systems. The idea here is to make already existing production systems become more efficient because climate change will make it much more difficult to attain today’s level of production with the same level of resources. Some options are targeted at ensuring that post harvest losses are kept to the minimum such as the promotion of improved granaries and the chorkor smoking kiln in fisheries around the country.

Table 12: Summary of Descriptive Benefits of Identified Adaptation Technology Option for the Agriculture and Food Security Sector

	Adaptation sub-options	**Adaptation Problem Being Addressed**	**Likely Beneficiaries**	**Other Descriptive Benefits**	**Drawbacks**
Planning for Climate Change and Variability	1. National Climate Change Monitoring System	- Lack of climate change preparedness	- All farmers	- Help farmers make decisions on crops to plant, the timing of planting, varieties and when to harvest. - Help livestock farmers know type of animals to rear, what to do about their feed, the likely status of water sources and the kind of diseases they could expect.	- System expensive to set up. - Insufficient funding of ZMD - ZMD use of obsolete equipment - Inadequate staffing at ZMD.
	2. Decentralized Community-run Early Warning Systems	- Lack of climate change preparedness	- Small and medium scale farmers	- Increased resilience of small and medium scale farmers to climatic hazards by improving their capacity to forecast, prepare and respond to extreme weather events	- Low capability to forecast droughts which start slowly and
Sustainable Water Use and Management	3. Rainwater Harvesting	- Huge rain water losses due to evaporation, transpiration, run-offs and drainage in the rainy season	- Small and medium farmers	- Can help to mitigate rainfall variability and its negative effect on domestic water supply and crop and livestock production	Some technologies such as roof water harvesting systems can only be used during the rainy season when the challenge of water availability is not as acute.
	4. Promotion of short-furrow or furrow-basin flood irrigation	- Dry soil as a result of rapid evaporation due to high temperatures and delayed on-set of the rainy season	- Small and medium farmers	- Allows water to stay trapped longer to moisten the soil in hot dry seasons - Technologies used are affordable, reliable and easy to adopt by small farmers. - Uniform distribution of water across the whole field	- Risk of over irrigating a piece of land and may cause run-offs and soil erosion
	5. Establishment of water rights supportive of sustainable agriculture	- Water conflicts as a result of scarcity due to droughts and dry spells	- All farmers	- Provides some certainty of water availability in the future and ability for farmers to plan - Permits can include protection of environment that may result from water diversion	- Inadequate institutional capacity to enforce compliance of water rights
Soil Management	6. Conservation Tillage	- Delayed onset of rains, prolonged dry spells, drought that increase soil erosion and reduce soil fertility	- All farmers	- Higher yields with less labor, less water and fewer chemical inputs - Minimization of soil erosion	- May raise incidence of plant diseases and pest infestation. - May lead to high dependency on herbicides increasing cost which may not be affordable for some small farmers
	7. Promote sustainable utilization of wetlands and dambos	- Increase in droughts, shorter rain seasons and high temperatures may lead to drying up of wetlands worsened by the use of synthetic (chemical) products.	- Communiti es living around wetlands	- Present opportunity to support a wide range of livelihood activities including crop production, livestock rearing, fishing, gathering of wild products, brick making, craft and building materials. - Source of water for domestic use, especially in dry season when wells in upland areas dry up.	- Farming in the wetlands where not done in a sustainable may endanger and destroys their natural habitat.

		Adaptation Problem Being Addressed	Likely Beneficiaries	Other Descriptive Benefits	Drawbacks
Sustainable Fisheries Management	8. Promotion of community fish ponds for small scale farmers as a way of increasing the fish resources	- Reduced fish stocks partly due to the effects of climate change	- Artisan and medium scale fishers	- Reliance on locally available resources– land, water and man power	- Fish pond management an involving task requiring expertise of the fisheries extension staff but MALD inadequate staffed with such personnel.
	9. Introduction of chorkor smoking kilns for fishers in all viable fisheries (reduction of post-harvest losses)	- High post harvest losses due to poor sunlight caused by climatic variations	- Small scale fishers using traditional ways of fish processing	- Significant rise in fish production as 30% of the fish caught in Zambia goes to waste through post harvest losses	- Heavy reliance on firewood which may not be environmentally friendly. - If the kiln not ideal for very mobile fishers if built on a fixed location.
	10. Use of legitimate and legal fishing gears in a bid to support the efforts of restocking the lakes, rivers and dams	- Reduced fish stocks in the water bodies due to climate change (high variations in climate and weather patterns) and human factors such as illegal fishing gear and methods	- Artisan and medium scale fishers	- Would permit adequate breeding of fish - Could help restocking exercises to be more effective	- The low capacity of the DoF to enforce legal fishing gear and methods
Sustainable Crop Management	11. Crop Diversification and New Varieties	- Various climate change hazards that affect crop yields	- All farmers	- Could allow farmers grow crops best suited to their agro-ecological zone. - In most cases, new crops come with farming practices that are environmentally sustainable.	- Introduction of exotic crop species may escape control and result into unwanted consequences. - May require the use of more labour input which may reduce yields
	12. Construction of improved granaries for small scale farmers	- Reduction in grain supply in drought climatic conditions.	- *Small and medium farmers*	- Help to maintain quality of stored food crops, seed and grain to last all year round.	Prevention of pest infestation may require chemical sprays. Some markets do not accept seeds and grains treated with chemicals.

		Adaptation Problem Being Addressed	Likely Beneficiaries	Other Descriptive Benefits	Drawbacks
Sustainable Livestock Management	13. Selective Breeding via Controlled Mating	- Low livestock productivity when exposed to diseases, extreme heat, extreme coldness and flooding.	- All farmers	- High potential of preserving local and rare breeds which would otherwise be extinct due to climate change.	- Does not always lead to desirable results of high productivity rates. - May promote in-breeding for small farmers less knowledgeable about good livestock management
	14. Livestock Disease Management	- Increase in livestock diseases as droughts and floods create conditions in which these spread very quickly	- Small and medium scale farmers	- Increased production and reduced mortality rate. - Indirect benefits to wildlife in surrounding areas of livestock disease free areas.	- Small producers may not meet full cost of disease management with no government subsidies. - Use of chemical drugs such as antibiotics and vaccines may not be biologically sustainable and livestock may develop resistance.
	15. Promotion of feed conservation practices during dry season for livestock farmers	- Frequency of droughts and dry spells that make availability of livestock feed scarce during the dry season	- All livestock farmers	- All the ingredients used for making fodder are readily available in Zambia.	- Simple and easy to use to make folder by small farmers may not be easily available.
Sustainable Farming Systems	16. Mixed Farming	- Risks of specialized crop production to climate change hazards	- Small and medium scale farmers	- More tolerant to warming and lower rainfall than specialized crop production - Inbuilt mechanism for one enterprise to mitigate risk faced by another increasing resilience to the negative impacts of climate change - More efficient than specialized crop production system in use of labour and intense use of land. - Assists in improving soil fertility from animal manure added to the soil.	- Most small farmers do not have the capital to engage in an integrated mixed farming system - Not suitable in areas which do not support intensive cropping, e.g. semi-arid areas, aggravated by growth in human population reducing land for grazing
	17. Agro-forestry	- Depletion of soil nutrients and intensification of soil erosion heightened by climate change hazards, droughts, floods etc	- Small and medium scale farmers	- Tree species have good impact on improving soil fertility and, in some cases, acting as pesticides. - Increases soil fertility through nitrogen fixation while reducing soil erosion - Reduces amount of chemical fertilizers farmers need to apply	- Slow adoption by farmers because it takes a long time before results are seen - Highly labour-intensive.

		Adaptation Problem Being Addressed	Likely Beneficiaries	Other Descriptive Benefits	Drawbacks
Capacity Building and Stakeholder Organization	18. Farmer Field Schools	- Low capacity of small farmers to respond and adapt to climatic hazards due to their unsustainable farming practices.	- Small and medium scale farmers	- Adoption of by farmers is quicker as it is based on personal experience.	- Transfer of knowledge and its adoption still takes long as small farmers are risk averse as they have very little margin of error. - Low education a factor in slow adaptation.
	19. Community Extension System	- Low capacity of small farmers to respond and adapt to climatic hazards due to their unsustainable farming practices.	- Small and medium scale farmers	- Wide diffusion of knowledge, reaching even farmers that may not be direct beneficiaries. - Works well in building the confidence of lead farmers in facilitating agricultural production.	- Inadequate numbers of camp and block extension officers in Zambia. - Has very high operational cost of the system.

5.3 Criteria and process of technology prioritization

The prioritization of technology options for the agriculture and food security sector followed the same process outlined in Section 4.3 above in the case of the water sector.

5.4 Results of technology prioritization

After conducting a multi-criteria decision analysis, three options were selected for further analysis regarding more specific technologies in the agriculture and food security: (i) Soil management (conservation farming, land Husbandry and agro-forestry); (ii) Sustainable farming systems (mixed farming); and, (iii) Sustainable crop management (crop diversification and new varieties). The details are in Table 13.

Table 13: Prioritized Adaptation Options for the Agriculture and Food Security Sector

Rank	Technologies	Economic	Environment	Social	Total Score
1	Conservation Tillage & Land Husbandry	384	203	352	939
2	Mixed Farming	371	175	372	918
3	Agro-forestry	364	199	334	897
4	Crop Diversification and New Varieties	365	158	373	896
5	Establishment of water rights that are supportive of sustainable agriculture development	366	163	353	882
6	Rainwater Harvesting	356	179	342	877
7	Promotion of treadle pumps for irrigation	361	151	356	868
8	Farmer Field Schools (Use of rural note book)	343	169	332	844
9	Use of legitimate and legal fishing gears in a bid to support the efforts of restocking the lakes, rivers and dams	342	165	330	837
9	Participatory Extension System	342	171	324	837
10	Promote sustainable utilization of wetlands and dambos	328	185	322	835
11	Promotion of community fish ponds for small scale farmers as a way of increasing the fish resources	338	131	356	825
12	National Climate Change Monitoring System	343	177	299	819
13	Decentralized Community-run Early Warning Systems	324	165	313	802
14	Introduction of chorkor smoking kilns for fishers in all viable fisheries	298	149	332	779
14	Construction of improved granaries for small scale farmers	314	129	336	779
15	Livestock Disease Management	306	136	336	778
16	Promotion of feed conservation practices during dry season for livestock farmers	300	144	290	734
17	Promotion of Food & Nutrition Management (improvement of Nutrition Centres)	278	116	298	692
18	Selective Breeding via Controlled Mating	252	108	249	609

It is worthwhile to note that the TWG decided to combine conservation agriculture, land husbandry and agro-forestry because these were all thought to address soil management. This therefore, created room for the then fourth ranked option, crop diversification and new varieties, to be selected. The justification for adjustment was to ensure that the adaptation options are varied enough and also in line with the policy direction of the MALD which has placed high premium on crop diversification and new varieties as a strategy for food security and climate change adaptation.

Arising from the selected priority adaptation options of conservation farming, land husbandry and agro-forestry, mixed farming and crop diversification and new varieties, the breakdown of identified specific adaptation technologies associated with each of these three options is presented in Table 14. We describe below the specific technologies providing their perceived benefits and drawbacks.

Table 14: Prioritized adaptation options and specific technologies

Prioritized Adaptation Options	Specific Technologies
1. Conservation farming, land management and agro-forestry	1. Hand-hoe conservation farming
	2. Conservation farming with Ox-drawn rippers
	3. Conservation farming with agro forestry ➲ *Conservation Farming with Faidherbia albida (Musangu Tree)* ➲ *Conservation Farming with* Tephrosia Vogelii (Ububa Tree) ➲ *Conservation Farming with* Sesbania sesban
2. Mixed farming	4. Integrated small livestock-fish-poultry-vegetable production system
3. Crop diversification and new varieties	5. Promotion of drought-tolerant and early maturing food crops (cassava, sweet potatoes, millet, sorghum and maize).

5.4.1 Hand-Hoe Conservation Farming

Hand-hoe conservation farming is widely used because it has low investment costs mostly requiring that farmers change their farming practice. It entails farmers begin their dry-season preparation of a precise grid of permanent planting basins (15 cm x 15 cm) during July when the soil is still moist. This is distinguished from conventional hand hoe farming which usually begins after the first rains in October or November.

The advantage over conventional farming is that the major farming activities and their specific demand for labour are allowed to spread out over a longer period of time. Waiting for the first rains to soften the soil means that a farmer has to do land preparation, planting and begin weeding within a very short period of time. With conservation farming (CF), even with hand-hoe only, by the time of the first rains, the farmer is ready to plant and apply fertilizer and begin to weed as soon as weeds emerge they cannot afford herbicides. Therefore, a farmer using CF can cultivate a larger acreage and manage better the area planted than would otherwise be the case. Other practices associated with CF include; crop residue retention, seeding and input application in fixed planting stations and nitrogen-fixing crop rotation.

Various studies consistently show positive results of hand-hoe CF over conventional farming. First, The Zambia National Farmers Union's (ZNFU) 2011 enterprise budgets show that small scale maize production is only profitable under CF and not under conventional farming whether hand-hoe or ox-cultivation. The gross margin for maize under CF in 2011 was ZMK910,703.99 (USD 171.83) compared to ZMK545,859.99 (USD 102.99) under conventional hoe cultivation. Studies by Haggblade and Tembo (2003) using survey results had also arrived at similar conclusions.

Other advantages of CF over conventional farming in general include its potential to: (i) Minimize soil erosion; (ii) Allow growth of micro-organisms; (iii) Increase soil nutrients; (iv) Reduce requirements for herbicides and fertilizers over time; and, (v) Reduce emission of harmful gases such as carbon monoxide. These qualities make it a good adaptation technology for farmers struggling against the risk of falling productivity due to the harsh environmental conditions resulting from climate change. And yet even more specifically, CF has been shown to do much better than conventional farming under drought conditions or simply rainfall failure at the critical times of plant growth. This is mostly because the planting basins reduce run-off on the planted field by acting as small rainwater harvesting devices.

The main challenge of hand-hoe CF and CF in general has to do with its strict regime in the practices involved. Non-adherence reduces the benefits and some small farmers find it difficult to transit clearly from conventional farming practices to CF in terms of when land preparation begins, the amount of residue retained on the farm and crop rotation. The non-till practice means that weed infestation in the first three seasons may be higher than under conventional farming if farmers do not adopt the use of herbicides. Farmers many times give up CF as a result before the full benefits actually set in.

5.4.2 Conservation Farming with Ox-drawn Rippers

This technology involves dry-season ripping, normally with the locally developed *Magoye Ripper*. The Ripping technology can be classified into shallow and deep ripping. Shallow ripping (0 – 15 cm) involves opening planting lines and is carried out prior to onset of rains. Deep ripping (25 – 30 cm) is mainly for water infiltration, water harvesting and breaking hard pans. This technology is mainly carried out in July/August when there is some soil moisture. It is worthwhile to observe that both the *Hand-Hoe Conservation Farming* and the *Conservation Farming with Ox-drawn Rippers* are commonly referred to as '*Water Conserving Conservation Farming'* because of the positive effect on water infiltration.

The advantage of conservation farming with Ox-drawn rippers over conventional farming is that farmers are more efficient in the utilization of time and deployment of labour over a period of time. The benefits are as stated under hand hoe CF. An additional benefit is that ox-drawn CF lowers crop vulnerability to drought by reducing water requirements by up to 30 percent. It makes better use of soil water and facilitates deeper rooting of crops. These benefits make conservation farming with Ox-drawn rippers to be a suitable adaptation technology especially in drought prone regions I and II by enhancing soil fertility and moisture storage.

The study on conservation farming in Zambia conducted by Haggblade and Tembo (2003) indicates positive results of conservation farming with Ox-drawn rippers over conventional Ox-plowing. The gross margin of high yielding maize variety under CF with Ox-drawn rippers was $130 (ZMK 691,675) per hectare as compared to $59 (ZMK 313,675) per hectare using conventional ox-plowing. The main drawback of conservation farming with ox-drawn rippers is the investment costs of the rippers and animal draught power. Therefore, even though the Magoye Ripper was developed in Zambia, there are no major innovations to ensure that it becomes the equipment of choice to small scale farmers. According to GART 2010 Year Book, the investment cost of the Magoye Ripper and Two Oxen is $849 or ZMK 4,500,000 (Golden Valley Agriculture Research Trust, 2001, p.75). This investment cost is very high for an average small scale farmer in Zambia.

5.4.3 Conservation farming with agro-forestry

Various studies have shown that '*conservation farming with agro-forestry*' yields positive results especially on agricultural production. Some of the CF technologies with agro-forestry include CF with Faidherbia albida (Musangu Tree), Tephrosia Vogelii (Ububa Tree) and Sesbania sesban***.*** The main purpose of conservation farming with agro-forestry is to improve the fertility of the soils.

- ***Conservation Farming with Faidherbia albida (Musangu Tree):*** The main objective of conservation farming with Faidherbia albida is to fertilize the field where food crops like maize are intercropped. There are numerous benefits that are attributed to this farming practice. These include: enhanced food crop yield as a result of intercropping with nitrogen-fixing trees. Faidherbia is an excellent agro forestry tree that contributes to soil fertility. Organic matter, nitrogen and other nutrients are added to the soil as a result of the falling leaves and seed pods. These leaves and seed pods are used as protein-rich livestock fodder, the tree bark as a medicine and the wood for construction. Unlike other trees, Faidherbia albida produces leaves in dry season and defoliates in the rains and this reduces competition for sunshine with the cultivated crop. The root systems and higher levels of organic matter in the soil increases water retention and assists to stabilize the soil against landslides and soil erosion.

  In Zambia, recent observations by Conservation Farming Unit (CFU) in the 2008 growing season found that unfertilized maize yields in the vicinity of Faidherbia trees averaged 4.1 tonnes per ha, compared with 1.3 tonnes in areas beyond the tree canopy. In addition, GART conducted studies on the *effects of crop rotation on the maize grain yield under and away from the canopy of young Faidherbia albida tree* from 2006/7 to 2009/10 farming seasons. The results indicated that significant higher yields were achieved under the canopy than away from the canopy. For instance, the yield of maize under the canopy was 2065 Kg/ha and away from the canopy was 1852 Kg/ha during the 2006/7 farming season.

  The main drawback of conservation farming with Faidherbia albida is that it is a long term investment. The tree requires more than 15 years to fully achieving its benefits on maize production. In view of this, Faidherbia trees are found on less than 2% of Africa's maize area and on less than 13% of its sorghum and millet area. The survival rate of the tree ranges between 15% and 60% in the fields for small scale farmers.

- ***Conservation Farming with* Tephrosia Vogelii (Ububa Tree):** The use of Tephrosia Vogelii has tremendous benefits to farmers. It is useful as a natural insecticide to farmers engaged in vegetable production. Tephrosia Vogelii is also a nitrogen fixing tree which increases organic matter thereby promoting the fertility of the soil.

  A study on the *impact of fertilizer tree fallows in Eastern Province of Zambia* was conducted by World Agro-forestry Centre in 2005. The maize yields after having 2-years Tephrosia Vogelii fallows in farmers' fields (1998-2000) indicated that Tephrosia fallow yielded 3.1t/ha in year 1, 2.4 t/ha in year 2 and 1.3t/ha in year 3. This is in direct contrast to unfertilized maize which yielded 0.8t/ha in year 1, 0.1t/ha in year 2 and 0.5t/ha in year 3. The drawback of Tephrosia Vogelii is that it is classified by the World Health Organization as a moderately hazardous class II pesticide which has a poisoning effect on bio-diversity especially fish.

- ***Conservation Farming with* Sesbania sesban:** The use of Sesbania sesban is beneficial to farmers in various ways. Sesbania sesban is a fast growing tree. On average, it takes 2 – 3 months for the seed to mature and 12 months to flower after sowing. The seeds are easy to propagate and the mature tree can be removed from the field without much difficult. It also has the benefit of fixing nitrogen in the soil and producing high-quality biomass. Sesbania sesban also plays a significant role for farmers engaged in crop and livestock production in that it can be used as green manure and animal fodder. Sesbania sesban is tolerant to saline, alkaline and highly acidic soil conditions. In addition, it helps to fight weeds which are prevalent due to low soil fertility in the field.

A study conducted on *Sesbania fallows for increased maize production in Zambia in 1994/95* by Kwesiga and Baxter revealed that growing Sesbania sesban in depleted fields or on fallow lands for 2 or 3 years and then introducing a hybrid maize crop after the fallow period produced positive results. In addition, a study on the impact of fertilizer tree fallows in Eastern Province conducted by World Agro forestry Centre revealed that maize yields with Sesbania sesban gave positive results. For instance, the maize yields after 2-years Sesbania sesban fallows in farmers' fields (1998-2000) indicated that Sesbania fallow yielded 3.6t/ha in year 1, 2.0 t/ha in year 2 and 1.6t/ha in year 3. This is in direct contrast to unfertilized maize which yielded 0.8t/ha in year 1, 1.2t/ha in year 2 and 0.4t/ha in year 3. The main drawback with Sesbania sesban is that it is difficult to establish seedlings and this requires additional labour days in the production of seedlings.

5.4.4 Mixed Farming

Generally, mixed farming is a good adaptation option for farmers facing climatic hazards. It has been observed that "*the mixed crop and livestock system predominant in Africa is the most tolerant, whereas specialized crop production is the most vulnerable to warming and lower rainfall*"(Namachena, op cit, p.vii). This is mainly because the risks are spread across different enterprises in an integrated mixed farming system. Although mixed farming could take many forms, only one specific model was considered by the technical working group, i.e. the integrated small-livestock-fish-poultry-vegetable-crop production system described below.

Integrated small livestock-fish-poultry-vegetable-crop production system

An integrated small livestock-fish-poultry-vegetable-crop production system operates on the premise of inter-dependency. Crop production depends on the supply of animal manure. Livestock plays a key role fertilizing the fish pond and field crops. The small livestock depends on extensive grazing of natural pasture and crop residues during the dry season. This is a closed system in which waste products from one activity are used as input in the other activity. For example, the waste products from crops and vegetables are used by livestock and fish.

This integrated production system provides various benefits to farmers. For farmers with pigs, there is potential to generate bio-gas energy from the waste of pigs. It helps to maintain the environment in a sustainable way due to recycling of natural resources such as animal waste products and crop residues. In addition, there is an increase in the conservation of water resources. The water that is used by small livestock can also be transmitted to the fish pond and later used to irrigate vegetables.

Therefore, the production system involving non-ruminants (village chickens, ducks and pigs), ponds (fish) and annual cropping with cassava and maize production is a good option for small scale and medium scale farmers in Zambia. The proposal is for small scale farmers to be engaged in the production of non-ruminants such as village chickens, ducks and pigs and ruminants such as goats, coupled with fish farming and production of drought-tolerant cassava and early maturing maize varieties. In addition to this, vegetables can be grown using basic irrigation systems.

Small scale and medium scale farmers can benefit from the sale of pig, fish, ducks and vegetables. The non-ruminants are less location specific than ruminants and have less reliance on the land base. The growth of the poultry and pig industry in Zambia provides an assured market for the small and medium scale farmers.

A study on integrated farming systems for smallholders in India conducted from 1984-2000 indicates that various integrated crop-animal systems gave highest average net returns with high employment days as compared to arable farming systems. For instance, the average net return on 1 hectare irrigated land for arable farming was $236 with 182 employment days in comparison to 1 hectare irrigated land for mixed farming with one crossbred cow was $710 with 559 employment days. The drawback with integrated small-livestock-fish-poultry-vegetable production system is that it is labour intensive and this raises the total cost of labour.

5.4.5 Crop diversification and new varieties

Promotion of drought-tolerant and early maturing food crops (cassava)

Climatic changes exacerbate the loss of crops due to poor moisture content in the soil as a result of poor precipitation and prolonged dry spells. Promotion of drought-tolerant and early maturing food crop varieties helps to reduce the risk of crop loss and enhance crop resilience to disease and harsh climatic conditions. Drought-tolerant and early maturing crop varieties have varied benefits. The main one is that they have a shorter maturity period as compared to traditional crop varieties. They are able to enhance plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses.[19] Improved crop varieties possess resistance to water during wet climatic conditions and heat stress during dry climatic conditions. When new crop varieties are introduced to farmers, environmentally sustainable farming practices such as minimal or no application of chemical fertilizers is emphasized.

In Zambia, various studies show that improved cassava variety has better yields compared to traditional cassava varieties. In 2006, a *study on cassava as drought insurance-food security implications of cassava trials was conducted in Central Zambia* (Barrat, et al, 2006).The yield for high yielding variety (HYV) of cassava was 3 tonnes per hectare as compared to 1.5 tonnes per hectare of local cassava. In 2010, FAO conducted a *study on value chain mapping and cost structure analysis for cassava in Zambia.* The results indicate that the average yield per hectare of early maturing cassava variety was 10.96 tonnes per hectare while the average yield per hectare of various traditional varieties was 4 tonnes. However, drought-tolerant and early maturing crop varieties are not without difficulty when promoting them. The main one is the cautious approach by small farmers to adopting improved crop varieties which they are not familiar with. In addition, the introduction of improved crop varieties by research institutes have at times escaped control and resulted into pests or weeds.

5.5 Cost Benefit Analysis

[19]Techwiki: Crop Diversification and New Varieties

In prioritizing technologies for the agriculture and food security, the TWG was guided by the summary of BCA results in Table 15. The three selected technologies based on NPV are: (i) Conservation farming with Faidherbia albida (Musangu Tree); (ii) Integrated crop-small livestock-fish-poultry-vegetable production system; and, (iii) Promotion of drought-tolerant and early maturing food crops/varieties.

Table 15: Ranked Adaptation Technologies for Agriculture and Food Security

Name of adaptation Technology	**Benefit Cost Ratio (BCR)**		**Net Present Values (NPVs)**		**BCR Rank**	**NPV Rank**
	Conventional	**Adaptation**	**Conventional**	**Adaptation**		
1. Conservation farming, land management and agro-forestry						
➲ Hand Hoe Conservation farming	0.98	1.05	- $ 41.8	$231.8	6	7
➲ Conservation farming with Ox-drawn ripper (Magoye Ripper)	0.49	0.68	- $ 2,318	$ 836	7	4
➲ Conservation farming with Faidherbia albida (Musangu Tree)	12.2	18.6	$ 4,056	$ 6,390	1	2
➲ Conservation farming with Tephrosia Vogelii (Ububa Tree)	2.01	2.77	$130	$233	4	6
➲ Conservation farming with Sesbania Sesban	2.01	3.13	$130	$309	2	5
2. Mixed Farming						
➲ Integrated small livestock-fish-poultry-vegetable production system	2.05	2.88	$ 31,850	$ 51,360	3	1
3. Crop diversification and new varieties						
➲ Promotion of drought-tolerant and early maturing food crops (cassava).	1.45	2.28	$ 510	$ 1,320	**5**	3

Chapter 6 Summary and Conclusions

6.1 Summary of the Outcomes

The TNA process to arrive at climate change adaptation technologies used the MCDA to first select sectors for consideration. Out of the six sectors that had been considered priority in the earlier documents produced on adaptation, this process selected water and agriculture and food security sectors. This was done at the Inception Workshop. The Workshop had first agreed that the three main categories of indicators – economic, social and environmental – would each carry equal weight.

The Technical Working Group representing key stakeholders in the two sectors sifted through a lot of information to prioritize the proposed adaptation options for each sector again using the MCDA. This information was summarized in fact sheets. Additional information particularly relating to the decision context was also provided to the members of the TWG. After ranking the options, Cost Benefit Analysis was used to arrive at the actual adaptation technologies. The use of CBA was also a reality check regarding the feasibility of the technologies being taken to the barrier analysis stage before too much time and resources are invested in in-depth analysis of the said technologies. This process resulted in six adaptation technologies being recommended by the TWG to be taken forward to the barrier analysis stage. Table 15 lists these technologies.

Table 16: List of adaptation technologies to be subjected to barrier analysis

Sector	Adaptation Option	Adaptation Technology
Water	Rain water collection from Ground water surfaces	Small reservoirs and micro-catchments
	Improving the resilience of protected wells to flooding	Building a Concrete Apron/Collar on the well
	Boreholes/Tube wells for domestic water supply during drought	Borehole/ tubewell with overhead tank and a solar powered pump for water supply
Agriculture and Food Security	Conservation farming	Conservation farming with *faidherbia albida* (Musangu tree)
	Mixed farming, land management and agro-forestry	Integrated crop-small livestock-fish-poultry-vegetable production system
	Crop diversification and new varieties	Promotion of drought-tolerant and early maturing food crops/varieties

The technologies are taken from a wide range of adaptation options. Inherent in this is that many issues related to climate change are in focus. This might raise questions as to whether the effort is not being spread too thinly to have any significant impact. In answer to this concern, it is important to view these technologies as merely a start. All the options and technologies that have been considered in this TNA report actually deserve to be taken forward as they would have something to contribute to tackling the urgent issue of climate change adaptation. However, the selected technologies have the merit of reaching a very wide range of users living in the more vulnerable areas. They are bound to have maximum impact at minimal cost. The technologies selected therefore are meant to help make a case for climate change adaptation by quickly demonstrating the benefits of being proactive to the challenge of the rise in the frequency of climatic hazards.

6.2 Some Key Observations on the TNA Process

As pointed out in Chapter 1, the TNA process is now in its second round of implementation and has therefore been well tested in a number of countries. To help countries undertake their TNAs, a revised TNA Handbook was launched in 2010. The TNA process documented here relied on the Handbook together with the guidance provided through 2 regional methodological workshops.[20] Despite this, there were two issues that seriously challenged the process and need to be reflected upon in the way the TNA is conducted in future. These are highlighted here below as they also expose some of the weaknesses of the outcomes of the process.

- ***The TNA as a very complex process:*** This is perhaps the most challenging aspect which the TNA Handbook does not highlight sufficiently. Because this is not acknowledged from the outset, how the implementation can be made simple is not in focus and the TNA team had to learn by doing around this issue. Complexity does not arise so much from the stages through which the process has to go through but the volume of issues that are thrown up whatever one touches. This is also as a result that the TNA process is participatory in nature and no stage moves forward without the decision of stakeholders. Although sector identification and selection proceeded very quickly because of the prior work that had been done during the design of the NAPA and other national processes on climate change, massive information needed to be generated for each adaptation option (32 in total) and technology. Not only did this overwhelm the people facilitating the process who had to research and arrange this information but stakeholders as well who clearly struggled to assimilate the information in order to make informed decisions.

  Related to the complexity is that not adequate time was given to ensure that the TNA process was sufficiently explained to stakeholders. Some highlight of the process was done at the inception workshop but this one day event also had other issues on the agenda to devote sufficient time to the explanation of the process. The four meetings of technical working group were half a day events and each stage was only briefly explained to the stakeholders before they engaged in some exercise leading to one of the many critical decisions that needed to be done – prioritization and selection of adaptation options (done in two meetings) and adaptation and selection of priority technologies (also done in two meetings). This was not helped by perhaps the inevitable inconsistency of some group members given that these are already busy men and women.

- ***Insufficient differentiation of adaptation options and technologies concepts:*** The TNA process as designed appears to move straight from sector to technology prioritization and selection. Applying this process it was discovered that there was an intermediate stage. We deemed these as adaptation options which were distinguished from technologies because they constituted a cluster of actions (strategies, policies, technologies, etc) to meet the challenge of adaptation. The TNA process needed to move backward a bit when stakeholders pointed out that the so called technologies such as renewable energy which were identified and prioritized were too general and we needed to be more specific. This was also pointed out at the second methodological workshop but is not pointed out in the TNA Guide. An extra step was thus created which required addressing adaptation options first before identifying and selecting specific technologies from the prioritized options.

[20]Although the second regional methodological workshop was focused on how to conduct barrier analysis, it also reviewed some aspects of the TNA and received reports from various countries helping the team to review some aspects of the process as a result.

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Annex 1: Technology Factsheets for selected technologies

A. Boreholes/tube wells for domestic water supply during drought

A.1 Introduction

Water shortage for domestic or production due to droughts, prolonged dry spells or extreme heat is one of the most recognisable effects of climate change. Fortunately, Zambia still has a lot of water stored in its underground aquifers to mitigate this impact but many communities have little means to access this water. Increasing access to groundwater for both potable and non-potable water is a key strategy for ensuring domestic water supply in the light of climate change. Boreholes/tubewells where they are promoted could help meet this need.

A.2 Technology characteristics

Tubewells consist of a narrow, screened tube or casing driven into a water bearing zone of the subsurface. Boreholes are tubewells that penetrate bedrock, with casing not extending below the interface between unconsolidated soil and bedrock. Tubewells can often be installed by hand-auguring while boreholes require a drilling method with an external power source. A hand-powered or automated pump is used to draw water to the surface or if the casing has penetrated a confined aquifer, pressure may bring water to the surface. A tubewell consists of a plastic or metal casing; usually 100-150 diameter, in unconsolidated soils, a “screened” portion of casing below the water table that is perforated, a “sanitary seal” consisting of grout and clay to prevent water seeping around the casing and a pump to extract the water.

To further enhance productivity, it is proposed that the boreholes/tubewells have a *Solar powered pump for water supply photovoltaic system (PVP)*. In this system, the women and children will not spend time operating the hand pump. The time would then be used in other productive activities. The water pump is powered by solar and might involve pumping the water into an overhead tank which later flows down using gravity. The PVP equipment mainly comprises:

PV generator which generally constitutes one or more polycrystalline photovoltaic solar module;
Inverter which converts direct current (DC) into alternating current (AC). This is not applicable when the pump is for DC;
Pumping system, this could be DC or AC; and,
Overhead tank for water storage.

A.3 Country specific applicability and potential

There is no national standard borehole specification for Zambia. The handbook entitled “*Borehole Standard Construction and Details 2002*” indicates that finished diameters should be 4 inch for hand pumps and 6 inch for motorized units. In practice, most specifications are 4 inch diameter casing in a 6.5 inch (165 mm) diameter hole but Danida and German Government funded projects both currently specify 8 inch (312 mm) diameter drilled boreholes and the current JICA-funded programme formation, specifies drilled diameters of 7.8 inch (200mm) to 9.75 inch (250mm)[21].In Zambia, the boreholes are usually fully cased to the bottom irrespective of the natural rock lining. Since this design is to supply the water even during the drought, the depth would be 100m.

A.4 Status of technology in country

Many organizations have been promoting boreholes to improve rural water supply for more than two decades now. Between 2000 and 2009, there were at least 10 projects related to rural water and sanitation with funding from Germany, Ireland, African Development Bank, Japan, UNICEF and Denmark most of which included the sinking of boreholes. NGOs have also participated actively in ensuring access to underground water in rural areas. The Danish Government through Danida and UNICEF intends to construct 3,650 water points each by 2015. It is a target of the National Rural Water Supply and Sanitation Programme, (NRWSSP) in Zambia to construct 10,000 new water points by 2015.

As a result of these interventions, the rural population with access to improved water sources (mostly boreholes and protected wells) rose from 22% in 1990 to 45% in 2010, i.e. over a period of 20 years (WHO/UNICEF, March 2012). Despite this significant improvement, the need for access to ground water remains high as 55% of the rural population is still without safe water. A large proportion of the rural population still depends on open rivers/streams and unprotected wells for their water supply.

A.5 Benefits to economic / social and environmental development

This technology addresses the problem of water shortage during droughts and dry spells in the rain season. Due to climatic changes such as prolonged drought, ground water resources are negatively affected. This results in inadequate recharging, lowering of water tables and drying of boreholes. Discontinuity of water supply during this period can halt economic development and hinder human health and well being. Those mostly affected by the drought are the rural communities in Zambia who have to travel long distances in order to have access to clean water.

Drawbacks include high installation costs and that the technology is not usually applicable to deep boreholes and high water consumption rates. Diesel pumps are best applied in such cases.

A.6 Climate change adaptation benefits

Drilling of boreholes and tubewells will improve access to groundwater by rural populations. It will prevent reliance on poor quality alternative supplies and reduce man hours spent on travelling to far distance reliable water points. Some of the benefits of the technology include better access to water for irrigation and other uses such as watering livestock. It also increases the productivity of women as they now access water near their homes.

A.7 Financial Requirements and Costs

Interviews with some private suppliers indicate that a 40 to 60 meters solar powered borehole would cost between K40 and K60 million including a 2,000 litres tank and pipes.[22] The cost depends on geographical location, soil type-sandy or rocky and distance to site.

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[22]Interview with Mr. Albert Chongo, Water engineer, Water Board, March 2012, SARO Agriculture Engineering Limited and Mr. Chibesakunda, Commercial Manager, SunPower Africa.

B. Improving the resilience of protected wells to flooding– Building a Concrete Apron/Collar on the well

B.1 Introduction

Protected wells can potentially provide a water supply that is highly resilient to flooding. However, improper design and construction can make them vulnerable during flooding. The key vulnerabilities of wells during flooding are: (1) ingress or infiltration of contaminated waters; (2) lack of wellhead access due to flood waters; and (3) collapse of unlined hand dug wells.

Protected wells can include tubewells, boreholes and (hand) dug wells. Location is another key parameter in assessing the vulnerability of wells to flooding. Constructing drinking water wells in the vicinity of sanitation facilities can lead to contamination through subsurface transport of fecal pathogens, particularly during flooding. Wells should be constructed up the hydraulic gradient (usually uphill) from latrines and animal waste. The minimum recommended distance between a well and a single latrine is 30 m. However, in settlements where latrine density is high, greater distances are often needed.

In addition to protection of wells currently used for drinking water, sealing abandoned wells is also essential to protecting groundwater quality in flood zones. If an abandoned well in not properly sealed, floodwaters that inundate the abandoned well are likely to contaminate both shallow and deep groundwater

B.2 Technology characteristics

This involves constructing a different design to that of the normal wells. An apron/collar would be built at the mouth of the well so that it is less vulnerable during flooding. This improves the well and hence the water is protected even during the floods. It would involve changing the design of most wells by building concrete works on the well and around the well. Concrete rings would form an apron/collar of 1.5 m high and 3.0m in diameter. The slope of the base is 45-degrees, gradual enough to prevent damage to the base during flooding. The wells are usually operated with the hand pump.

B.3 Country specific applicability and potential

There are no national standards and guidelines on borehole and well protection in Zambia. However, good practice for digging wells and drilling boreholes exists. Projects promoting ground water access have adopted their own standards to suit local contexts as there is a lot of variability throughout the country. Good practice entails that water points are located away or protected from burial sites, pit latrines, runoff water, waste disposal, etc. On top of this, the water affairs department has been encouraging the communities to site the wells in locations which are not prone to flooding. The site for the wells is very important so that the well is on the hydraulic gradient (uphill) against the pit latrines. International organizations like UNICEF, SNV and Care have been promoting this in flood prone rural districts.

B.4 Status of technology in country

There is no information regarding the status of the proportion of boreholes and protected wells that can be regarded as resilient to climate change hazards. However, given that awareness to this need has only began to emerge slowly in the last decade, it can be envisaged that a big proportion of the boreholes and wells in flood prone area are vulnerable to contamination and damage due to flooding.

B.6 Benefits to economic / social and environmental development

The technology will reduce the chances of households failing to access potable safe water supplies during floods. It will reduce the time lost traveling long distances to access good drinking water when the water point gets either damaged, contaminated or cannot be accessed because of the floods. Avoiding such loss of time prevents disruption in productive activities and the negative implications this entails. Time loss to morbidity or taking care of a sick relative especially by women due to water borne disease from contaminated water points is also reduced. In the end we have a healthy community able to pursue livelihood objectives of its own choice.

B.7 Climate Change Adaptation Benefits

Overall the technology will reduce disruptions in access to safe water during flooding. The floodwaters will not only contaminate drinking water sources but also lead to the destruction of water and sanitation systems, increasing the risk for water-borne diseases such as cholera during the rain season.

B.8 Financial Requirements and Costs

Estimated unit cost of protected well built to be resilient to flooding is US$3,500. Actual cost however depends on geographical location, soil type-sandy or rocky and distance to site.

C. Rain Water Collection From Ground Water Surfaces – Small Reservoirs and Micro-Catchments

C.1 Introduction

Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Both small and large scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams. There are various methods of rainwater harvesting available which include: rock surface, ground surface and roof top. Of these, rock and ground surface are suitable for rural communities whereas the rooftop method is ideal for urban communities with houses made of steel roof tops.

C.2 Technology characteristics

This type of technology involves two broad categories: (i) Collecting rainfall from ground surfaces utilizing “micro-catchments” to divert or slow runoff so that it can be stored before it evaporates or enter watercourses; (ii) Collecting water from a river, stream or other natural watercourse (sometimes called floodwater harvesting). This technique often includes an earthen or other structure to dam the watercourse and form “small reservoirs.”

C.3 Country specific applicability and potential

In Zambia, rural water supply comprises mostly of dams, small weirs, boreholes and shallow wells. Rainwater harvesting activities are primarily for agricultural production and are therefore coordinated by the Ministry of Agriculture & Livestock. NGOs are also involved in dam and weir rehabilitation and wells dug adjacent to dams for domestic water use.

C.4 Status of technology in country

Rainwater harvesting has been practiced in Zambia traditionally such as through dug out wells along river banks to harvest runoffs. However, it is only recently that there has been awareness of the huge potential that exists for rainwater harvesting in all the regions of Zambia. Specific for micro catchments (small dams and weirs), the Ministry of Agriculture and Livestock Development has been the main promoter among small and medium farming communities.

C.6 Benefits to economic / social and environmental development

The economic benefits of the technology arise from the opportunities that stored water presents for various uses including for irrigation, watering of livestock, fish farming, etc. Besides this is the potential for accessing safe water for domestic use. Environmental benefits include how widespread rainwater storage capacity can greatly reduce land erosion.

C.7 Climate change adaptation benefits

Collection and storage of rainwater can provide a convenient and reliable water supply during seasonal dry periods and droughts. Small reservoirs are typically used in areas with seasonal rainfall to ensure that adequate water is available during the dry season

C.8 Financial Requirements and Costs

The cost of a typical project for a small dam, i.e. below the depth of 10m, is estimated at US$284,000, for a medium dam (between 10 to 15m depth) US$378,000.00 and US$1,133,000.00 for a large dam.[23] Annual maintenance cost was assumed at 10% of the total investment cost. Again, the cost depends on geographical location, soil type-sandy or rocky and distance to site.

D. Conservation farming with faidherbia albida (Musangu tree)

D.1 Introduction

[23].Interview with Mr. Albert Chongo, Water Engineer, Water Board, March 2012

Conservation farming in general refers to practices that in combination conserve soil, moisture, and fertilizer, seeds, energy and time.[24]It has a number of basic features which include: no burning of crop residues, correctly spaced planting basins established before the rains, early planting of all crops, early weeding and rotation with a minimum of 30% legumes in the system. There are many ways to practice conservation farming. The technology proposed here is conservation farming with agro-forestry, specifically the planting of faidherbia albida (Musangu tree) in the fields where crops are cultivated.

D.2 Technology characteristics

Faidherbia is an excellent agro forestry tree that contributes to soil fertility. Organic matter, nitrogen and other nutrients are added to the soil as a result of the falling leaves and seed pods. These leaves and seed pods are used as protein-rich livestock fodder, the tree bark as a medicine and the wood for construction. Unlike other trees, Faidherbia albida produces leaves in dry season and defoliates in the rains and this reduces competition for sunshine with the cultivated crop. The root systems and higher levels of organic matter in the soil increases water retention and assists to stabilize the soil against landslides and soil erosion.

D.3 Country specific applicability and potential

The faidherbia albida tree can grow in most parts of the country but requires many years to fully achieve their benefits on crop production. Therefore, the trees are found on very few farms in Zambia and would require significant sensitization and investment in promotion.

D.4 Status of technology in country

Conservation farming is well known and practiced by a number of small and medium scale farmers in Zambia. The main promoters have been the Conservation Farming Unit (CFU), the Ministry of Agriculture and Livestock Development (MALD), the Golden Valley Agricultural Research Trust (GART) and the Zambia Agricultural Research Institute (ZARI). Conservation farming is commonly practiced in Agro-Ecological Regions I and II.

In Central and Eastern province, some farmers are integrating conservation farming with agro-forestry. In this regard, tree species like Faidherbia albida (musangu), TephrosiaVogelii (ububa) and Sesbania sesban are used to promote soil fertility. Sesbania sesban was promoted in Eastern province by the International Center for Research in Agro forestry (ICRAF). Conservation with agro-forestry is not as wide spread mainly because benefits of agro-forestry only begin to show after years.

D.5 Benefits to economic/social and environmental development

In Zambia, recent observations by Conservation Farming Unit (CFU) in the 2008 growing season found that that unfertilized maize yields in the vicinity of Faidherbia trees averaged 4.1 tonnes per ha, compared with 1.3 tonnes in areas beyond the tree canopy. In addition, GART conducted studies on the *effects of crop rotation on the maize grain yield under and away from the canopy of young Faidherbia albida tree* from 2006/7 to 2009/10 farming seasons. The results indicated that significant higher yields

[24]Conservation Farming Unit (CFU): Conservation Farming and Conservation Agriculture Handbook for HOE Farmers in Agro-Ecological Regions I & IIa - Flat Culture 2007 Edition

were achieved under the canopy than away from the canopy. For instance, the yield of maize under the canopy was 2065 Kg/ha and away from the canopy was 1852 Kg/ha during the 2006/7 farming season.

D.7 Climate change adaptation benefits

There are many environmental benefits of conservation farming of the preservation of soil fertility is the most obvious. Besides this, conservation farming helps minimizing of soil erosion, growth of micro-organisms and reduction of the use of herbicides and fertilizers.

D.8 Financial Requirements and Costs

The unit cost of Faidherbia albida seedlings is ZMK 5000 ($0.93). A total of 100 trees are required for 1 hectare piece of land. Therefore, a total of **ZMK 5,000,000 ($943)** would be an investment cost in Zambia for seedling production[25].

[25] Conservation Farming Unit (CFU), Lusaka, 2012.

E. Integrated crop-small livestock-fish-poultry-vegetable production system

E.1 Introduction

Mixed farming helps to spread out risk among enterprises on the farm. Although this is known and widely practiced among small and medium farmers, mixed farming as a specific response to climate change is rarely considered. An integrated farming small livestock-fish-poultry-vegetable-crop production system is proposed. It is rarely practiced in Zambia although common in some Asian countries like China.

E.2 Technology characteristics

An integrated small livestock-fish-poultry-vegetable-crop production system operates on the premise of inter-dependency. Crop production depends on the supply of animal manure. Livestock plays a key role fertilizing the fish pond and field crops. The small livestock depends on extensive grazing of natural pasture and crop residues during the dry season. This is a closed system in which waste products from one activity are used as input in the other activity. For example, the waste products from crops and vegetables are used by livestock and fish.

E.3 Country specific applicability and potential

Integrated farming can be applied throughout the country. However, it may be hindered in areas which do not support intensive cropping, e.g. semi-arid areas as in Agro-Ecological Zone I. Adoption may also be difficult for many farm households because it is labour intensive, a challenge for households with labour shortages. It therefore can only be suitably promoted alongside strategies to relieve labour constraints at farmsteads.

E.4 Status of technology in country

In Zambia, mixed farming of crops and livestock is widespread across all the three Agro-Ecological Regions. Crop/livestock production activities among small-scale farmers are most predominant in Agro-Ecological Region I and II. However, integrated mixed farming systems involving livestock-fish-poultry-vegetable are not common in Zambia. Most small scale farmers do not have the capital and knowledge required to engage in an integrated mixed farming system of this nature.

E.5 Benefits to economic / social and environmental development

Uses land more intensively and efficiently. It improves soil fertility as animal manure is added to the soil. Allows diversification of risks and uses labour more efficiently. Given the higher land and labour productivity, integrated farming has a much higher potential for the generating of household income.

E.6 Climate change adaptation benefits

The main climate change benefit of mixed farming in general and integrated farming in particular is that farmers have chance to spread their risks across several enterprises. The effects of failure of one enterprise as a result of climate change hazards is somewhat mitigated by the other enterprises that continue to operate. And yet at the same time, the interdependence of enterprises makes them more resilient to climate change hazards.

E.7 Financial Requirements and Costs

The total investment cost for integrated crop-small livestock-fish-poultry-vegetable production system is **ZMK 15,226,900 ($ 2,873)**. The key assumption is contained below. This is under the following assumptions: mixed farming involving production of crops (sorghum & sugar beans), vegetables (cabbages), poultry (10 ducks), small livestock (10 goats) and fish farming (3100 fingerlings); production system engaged by emergent farming household; total costs are 10% more than integrated mixed farming; 1 ha of land under utilization (crop=0.50 Ha, Vegetables=0.25 ha & Fish pond=0.25 ha); land is valued at zero due to unlimited supply in rural areas; farming household spends 5 hrs per day in the field; unit price of labour is $3.3 per day/person; total of 50 man-days; 4 rippers and 8 oxen bought at USD $ 849 (ZMK 4,500,000) per ripper & 2 oxen. The shadow prices ZMK/Kg are as follows: the price of sorghum is ZMK 1,632, sugar beans is ZMK 5,000, cabbage is ZMK 1,200, fish is ZMK 12,000, ducks is ZMK 12,500 and goats is ZMK 5,700 per Kg. The annual production of mixed farming (without synergies & interdependence) is as follows: sorghum (188 Kg), sugar beans (138 Kg), cabbage (7,500 Kg), ducks (20 Kg), fish (1,705 Kg) and goats (525 Kg). Hardware equipment (rippers) depreciates in 10 years. Annual maintenance cost is 5% of hardware technology (4 Rippers & 8 Oxen).

F. Crop Diversification and New Varieties – Promotion of Drought-Tolerant and Early Maturing Food Crops (Cassava)

F.1 Introduction

The promotion of early maturing cassava is meant to enhance resilience of crops to climate change hazards, particularly drought, extreme heat and shorter rain seasons.

F.2 Technology characteristics

This entails promoting 7 varieties of cassava released by the Root and Tuber Improvement Programme between 1993 and 2000 in Agro-Ecological Region I and II where the frequency of droughts is projected to rise due to climate change. The varieties have been developed to mature between 12 to 15 months compared to traditional varieties that took between 24 and 36 months.

F.3 Country specific applicability and potential

In areas where cassava is traditionally grown, its suitability is certain. The short maturing and high yielding varieties were specifically developed and adapted to the northern regions of Zambia. There may be doubts about its adaptability to plateau areas with extremely cold temperatures at times of central Zambia. However, Barrat, et al, (March 2006) report on farm research findings which show that with some modifications to management practices to those recommended in the cassava growing regions where the new varieties where developed, these varieties can do reasonably well in these areas as well.

F.4 Status of technology in country

Cassava is grown in most parts of the country and is a staple food in most parts of Agro-Ecological Region III as well as Zone II in Western Province. Cassava production which was on the decline up to the mid-1990s made a huge leap thereafter as the cost of inputs made farmers to look for crops that required less fertilizers and hybrid seeds. Its better drought resilience qualities compared to other crops like maize was increasingly getting appreciated. It was being promoted by a number of agencies as a food insurance after noting that cassava consuming regions of the country enjoyed relative stable food security status.

F.5 Benefits to economic / social and environmental development

In 2010, FAO conducted a *study on value chain mapping and cost structure analysis for cassava in Zambia.* The results indicate that the average yield per ha of early maturing cassava variety was 10.96 tonnes per ha while the average yield per ha of various traditional varieties was 4 tonnes.

F.6 Climate change adaptation benefits

The promotion of drought tolerant and early maturing food crops (like cassava) is meant to address the climatic hazards of short rainfall periods and prolonged dry spells. The small and medium scale farmers are vulnerable to such climatic hazards because of their dependence on rain-fed agriculture and long maturing food crops. The main benefit of this adaptation option is that it allows farmers to plant crops that demonstrate the qualities of early maturity, resilience to disease and greater nutritional value.

F.7 Financial Requirements and Costs

The total investment cost of cultivation of improved cassava variety using hand hoes on 1 ha plot of land is **$ 151.** The key assumption on how the cost was derived are as follows: 1 ha piece of land by 1 small scale farming household; land is valued at zero due to unlimited supply in rural areas; farming household spends 5 hrs per day in the field; unit price of labour is $2.3 per day/person; total of 78man-days; 10 Chaka hoes bought at USD $ 4.7 (ZMK 25,000) each; yield for local cassava is 4,000 Kg/ha; unit price of cassava per Kg is $ 0.0043 (ZMK 228); chaka hoes depreciate in 2 years; annual maintenance cost is 5% of hardware technology (Chaka hoes).

Annex II. List of Stakeholders Involved

Annex IIa Members of the TNA Adaptation Working Group

Name	Position	Organization
Mwilah Chaloba	Logistics	MMI Logistics
Deauteronomy Kasaro	National REDD Coordinator	Dept of Forestry
Alice Namuyamba Mulozo	Project Manager-ERE	World Vision Zambia
Andrew Bwalya		World Vision Zambia
Abel Musumali	CEO	Green Enviro-Watch
Malita Noole		Green Enviro-Watch
Justin Chuunka	PAS	Ministry of Agriculture and Livestock
Bevy Chabwela	Executive Director	Green Earth Zambia
Chilekwa Mibenge	Environmental Health Officer	Ministry of Health-Environmental Health
Godfrey Sakala	Chief Agricultural Officer	Zambia Agricultural Research Institute (ZARI)
Howard Tembo	Snr. Agricultural Research Officer	Zambia Agricultural Research Institute (ZARI)
Michael K. Kabungo	Assistant Director-CPD	Lusaka City Council-CPD
Howard Samboko	Assistant Town Planner	Lusaka City Council
Lungu M. Richard	Principal Natural Resource Management Officer	MLGHEEEP
Musole Munalula		MLNREP
Allan Dauchi	EMO	MLGHEEEP
Elizabeth Nalwimba		MLNREP
Humphrey Katotoka	Economist	ZNFU
Jack B. Munthali	Environmental Scientist	ZESCO
Bonje Muyunda		ZESCO
Luwita K. Changula	Environmental Scientist	ZESCO

Annex IIb List of People Interviewed

Name	Position	Organization
Mr. Rasford Kalamatila	Climate Change Focal Person	Ministry of Agriculture and Livestock Development (MALD)
Mr. Bistone Mbewe	Programme Officer	Project on Climate Change Adaptation and Variability in Agro-ecological zone I and II in Zambia, UNDP, Lusaka
Mr. Munumi Mumbuwa	Chief Planner	Ministry of Water and Energy Development, Lusaka
Mr. David Chama Kaluba	Coordinator for Pilot Programme for Climate Resilience (PPCR)	Ministry of Finance and National Planning (MoFNP), Lusaka
Dr. Joseph Kanyanga	Chief Meteorologist	Zambia Meteorology Department (ZMD), Lusaka.
Mr. Ngwira	Chief Meteorologist	Zambia Meteorology Department (ZMD), Lusaka.
Mr. Mukufute Matongo Mukelabai	Acting Chief Meteorology Officer	Climate and Advisory, Zambia Meteorology Department (ZMD),Lusaka
Mr. Simukoko		TDAU-UNZA, Lusaka
Mr. Amos Banda		TDAU-UNZA, Lusaka.
Dr. Han'gombe B. Mudenda	Senior Lecturer/ Micro Biology	School of Veterinary, Department of Para Clinical (UNZA), Lusaka.
Dr. Munyinda	Lecturer	School of Agric Science (UNZA)
Mr. Lottie Senkwe	Rural Marketing and Supply Chain Coordinator	International Development Enterprise (IDE) Zambia, Lusaka.
Mr. Kelvin Kaira	Sales and Service Engineer	SARO AGRO INDUSTRIAL Limited, Lusaka.
Mr. Alfred Simfukwe	Technical Sales Manager	Green 2000 Limited (Agriculture Equipment and Know How), Lusaka, Zambia.
Dr. Godfrey Sakala	Chief Agricultural Officer	Zambia Agricultural Research Institute (ZARI), Lusaka.
Ms. Harriet Zulu	Senior Energy Officer-Biomass	Ministry of Energy and Water Development, Lusaka.
Mr. Samuel C. Maango	Technical Expert (DIIP)	National Remote Sensing Centre, Lusaka.
Mr. Ushiwa Choza Chikunga	Assistant Project Manager	Climate Inter-Change Lusaka.
Ms Annie Banda Chandipo	Energy officer-Wind & Mini Hydro,	Ministry of Energy and Water Development, Lusaka
Mr. Silvester H. Hibajene	Director-Strategy and Regulation	Copperbelt Energy Corporation PLC, Lusaka
Mr. Gabriel Chingwe	Director	Luangwa Solar Power Corporation
Mr. Feston Sikanga	Water Engineer	Water Board, Lusaka.
Mr. Chrostopher Kellner	Biogas and Sanitation Expert	Water and Sanitation Association of Zambia
Mr. Teddie Mwale	Energy Expert	Energy Management Systems, Lusaka.
Mr. Chimwanga Maseka	Programme Manager	SNV
Dr. Mpamba	Assistant Director	Water Department, Ministry of Energy and Water