SWAZILAND

TECHNOLOGY NEEDS ASSESSMENT REPORT 1

CLIMATE CHANGE ADAPTATION

Revised Draft 15 June 2016

Prepared by Deepa Pullanikkatil (PhD), CANGO

Table of Contents

List of Tables

List of Figures

ACRONYMS

ABS	Access and Benefit Sharing
ACC	Anti-Corruption Commission
CBFIM	Community-based Fire Management
CDM	Clean Development Mechanism
CITES	Convention on International Trade of Endangered Species
COP	Conference of Parties
COSPE	Co-operation for the Development of Emerging Countries
DFID	Department for International Development (UK)
DNA	Designated National Authority
DRM	Digital Radio Mondiale
DRR	Disaster Risk Reduction
EPR	Emergency Preparedness and Response
ERC	Energy Research Centre
EST	Environmentally Sound Technology
EW	Early Warning
EWS	Early Warning System.
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HASSP	Harmonised Seed Security Project
IACG	Inter Agency Consultative Group
IFAD	International Fund for Agricultural Development
INDC	Intended Nationally Determined Contributions
IRBM	Integrated River Basin Management
IRD	International Relief and Development
IWRM	Integrated Water Resources Management
JICA	Japanese International Cooperation Agency
KDDP	Komati Downstream Development Project
LUSIP	Lower Usuthu Smallholder Irrigation Project
MCA	Multi Criteria Analysis
MDG	Millennium Development Goals
MEPD	Ministry of Economic Planning and Development
MHUD	Ministry of Housing and Urban Development
MNRE	Ministry of Natural Resources and Energy
MTEA	Ministry of Tourism and Environmental Affairs
MTRD	Ministry of Tinkhundla and Regional Development
NAMA	Nationally Appropriate Mitigation Actions
NAP	National Action Programme

NCCC	National Climate Change Committee
NCCSAP	National Climate Change Strategy and Action Plan
NDMA	National Disaster Management Agent
NDS	National Development Strategy
NEWS	National Early Warning Systems
NGO	Non-Governmental Organization
NWP	National Water Policy
PAWD	Partnership for African Water Development
SADP	Smallholder Agricultural Development Project
SARUA	Southern African Regional Universities Association
SCCF	Special Climate Change Fund
SEA	Swaziland Environment Authority
SHIP	Swaziland Smallholder Irrigation Project
SIDA	Swedish International Development Agency
SNL	Swazi Nation Land
SNTC	Swaziland National Trust Commission
SNTC	Swaziland National Trust Commission
SWALGA	Swaziland Association for Local Government Associate
TAP	Technology Action Plans
TCP	Technical Cooperation Programme
TFCA	Transfrontier Conservation Areas
TNA	Technology Needs Assessment
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP DTU	United National Environment Programme and Denmark Technical University
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WFP	World Food Programme

Executive Summary

Swaziland has experienced the impacts of climate change, which has affected many of its economic sectors. Erratic rainfall patterns have already begun to affect crop yields in recent years. It is anticipated that Swaziland's economy will be affected by climate change and key sectors that need to adapt to climate change include land, agriculture, water, forests and health. The country faces many capacity and technology constraints in addressing climate change challenges. There is low level of awareness of the threats and opportunities of climate change; limited human resources; low technological capacity; and inadequate availability of the financial resources to address climate adaptation. Technology plays an important role in managing the impacts of climate change and in this regard, the Technology Needs Assessment (TNA) project can play an important role in Swaziland. The TNA helps identify as well as prioritise climate technologies for key sectors in the country.

The Ministry of Tourism and Environmental Affairs (MTEA), Department of Meteorology (DOM) spearheaded the TNA project with the support from the United National Environment Programme and Denmark Technical University partnership (UNEP DTU Partnership). The purpose of the TNA project was to assist Swaziland to identify and analyse priority technology needs. This formed the basis for identifying and prioritising a portfolio of environmentally sound technology (EST) projects and programmes to facilitate the transfer of, and access to ESTs and know-how. This in turn helps in the implementation of Article 4.5 of the UNFCCC Convention, to which Swaziland is party to (UNFCCC, 2015).

The TNA process in Swaziland began with extensive stakeholder engagement in 2015. The sector prioritization process involved brainstorming on country development priorities and discussion of sectors which are most vulnerable to climate change and likely to affect long term national development. It was decided to prioritize water, agriculture and forests and biodiversity sectors for the TNA process under climate change adaptation. Stakeholders felt that these sectors contribute significantly to the development priorities of the country and are likely to be affected adversely by climate change. It is imperative that the country build resilience in these three sectors to enable adaptation to climate change impacts and adopting environment friendly and climate compatible technologies that address stresses in these sectors. Technologies that would help in climate change adaptation for the sectors were listed for all three sectors. Stakeholders further prioritised three technologies per sector, which would undergo further analysis and be developed into technology action plans. In the water sector, technologies prioritized were integrated river basin management, rooftop rainwater harvesting and wetland restoration. For the agriculture sector, livestock and poultry selective breeding, conservation agriculture and micro and drip irrigation were prioritised. For the forestry and biodiversity sector, agroforestry, conservation of genetic resources and alien invasive species management were prioritised. Further to this prioritization, the TNA process will develop Concept Notes for attracting funding to implement selected technologies in priority areas of national relevance.

Report I
Technology Needs Assessment Report

Chapter 1 Introduction

1.1 Background of TNA project

Technology transfer has been under focus since the Rio Summit in 1992, where issues related to technology transfer were included in Agenda 21 as well as in Articles 4.3, 4.5 and 4.7 of the United Nations Framework Convention on Climate Change (UNFCCC). These were subsequently discussed in the Conference Of Parties (COP) 1 in Berlin and COP 4 in Buenos Aires with Decision 2/ COP4 requiring GEF to provide funding to developing country Parties to enable them to identify and submit to the COP, their prioritized technology needs in particular sectors of their national economies which are conducive to addressing climate change and minimizing its adverse effects. The Technology Needs Assessment (TNA) process originates from the Poznan Strategic Programme on Technology Transfer established at the Fourteenth Conference of the Parties (COP 14). In 2010, a TNA was undertaken in Swaziland, however it focused only on mitigation and it was decided that Swaziland will participate in second phase of TNA. The first phase of global TNA activities concluded in 2014 and TNA Phase II was initiated in November 2014 with 26 countries in Asia, Africa, Latin and Central America and Europe invited for participating in this second Phase, including Swaziland (ERC, 2015).

The Ministry of Tourism and Environmental Affairs (MTEA), Department of Meteorology (DOM) spearheaded the Technology Needs Assessment project in Swaziland with the support from the United National Environment Programme and Denmark Technical University partnership (UNEP DTU Partnership). The purpose of the TNA project was to assist Swaziland to identify and prioritise technology needs, which formed the basis for a portfolio of environmentally sound technology (EST) projects and programmes to facilitate the transfer of, and access to ESTs and know-how in the implementation of Article 4.5 of the UNFCCC Convention (UNFCCC, 2015). Hence TNAs are central to the work of Parties to the Convention on technology transfer and present an opportunity to track an evolving need for new equipment, techniques, practical knowledge and skills, which are necessary to mitigate GHG emissions and/or reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change.

The main objectives of the TNA project are:

1. To identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities;
2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies; and
3. To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries.

Further, the TNA process will develop Concept Notes for attracting funding to implement selected technologies in priority areas of national relevance.

The TNA Process in Swaziland began with a National Inception Workshop which was held on 24th of March 2015 at Mountain Inn, Mbabane. The TNA is coordinated by the Department of Meteorology and consultants for this project were Dr. Mduduzi Mathunjwa (mitigation) and Dr. Deepa Pullanikkatil (adaptation). The consultants participated in a methodology training workshop in Arusha, Tanzania from 22nd to 24th June 2015. The methodology used for the TNA process includes Multi Criteria Analysis (MCA) with extensive stakeholder participation at every stage of the needs assessment. Furthermore, methodology training, a stakeholder consultation for prioritization of sectors was done at Royal Villa, Ezulwini on 13 July 2015. Here stakeholders selected three sectors for adaptation; namely Water, Agriculture and, Forests and Biodiversity. Furthermore, the consultants developed factsheets for technologies in each sector which were distributed to stakeholders via e-mail. A workshop on prioritizing technologies was held at Simunye Country Club from 20th to 21st August 2015 where stakeholders prioritized three technologies per sector using the MCA method. This report provides information regarding the TNA process and outputs in Swaziland for adaptation to climate change.

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

Swaziland has experienced the impacts of climate change, which has affected many of its economic sectors. Erratic rainfall patterns have already reduced crop yields in the past, as noted in the Swaziland Annual Vulnerability Assessment and Analysis Report (Government of Swaziland, 2012a). The Second National Communications (Government of Swaziland, 2012) prepared by Department of Meteorology under the Ministry of Tourism and Environmental Affairs (MTEA) states that a number of sectors will be affected by climate change in Swaziland including land, agriculture, water, forests and health, and it also elucidated many capacity and technology constraints that the country faces in addressing climate change challenges. A study by Southern African Regional Universities Association (SARUA) made mention of sectors including energy, water and industrial processes, agriculture, land use change and forestry, waste, health and socio-economic sectors, that will be adversely affected by climate change (Urquhart and Lotz-Sisitka, 2014). To respond to these challenges, Swaziland has taken several steps including development of policies and regulations and establishing organizations and committees to coordinate efforts on tackling climate change. Furthermore, it has also been implementing projects and programmes on climate change adaptation and mitigation, which are geared towards achieving objectives of the UNFCCC (Government of Swaziland, 2014).

The actions towards managing climate change in Swaziland began in 1992 with the establishment of the Swaziland Meteorological Services. In the same year, Swaziland participated in the Rio Earth Summit and became Party to the UNFCCC. It was a milestone for the country and in 1992, the Swaziland Environment Authority Act was also passed by Parliament, putting in place a parastatal responsible for environmental matters. In 1994, the country ratified the International Convention on Biodiversity. The UNFCCC convention as well as the United Nations Convention to Combat

Desertification (UNCCD) were ratified in 1996. The following year, a number of major milestones were achieved with regard to signing of soft laws. The Flora Protection Act was gazetted in 1997 and the Swaziland Environment Action Plan was also developed that year. The Convention on International Trade in Endangered Species (CITES) of Wild Flora and Fauna was also ratified in 1997. The year 1997 saw Swaziland taking a major step in planning its development by formulating the National Development Strategy (NDS) and Vision 2022 which articulated a vision of seeing Swaziland as a developed country in the future. In year 2000, the National Environment Policy was approved and a National Greenhouse Gas inventory was completed in year 2000. In 2001, The National Action Programme of the Convention to Combat Desertification and the Rural Water Supply and Sanitation Sector Policy were approved.

In year 2002, the National Forest Policy, the Swaziland Biodiversity Strategy and Action Plan and the Tourism Policy and Strategy, and the National Environmental Health Policy were approved and the Environment Management Act was gazetted and in the same year, Swaziland prepared the First National Communication. In 2003, the Water Act was gazetted, the Mining Policy, the National Forestry Programme, The Swaziland National Solid Waste Management Strategy and the Rural Resettlement Policy were approved. In 2004, the Alien Invasive Strategy Action Plan, the National Framework on Biosafety were formulated and in the same year, a National Capacity Self-Assessment Report on National Capacity Needs, Constraints and Priorities for the Implementation of Climate Change, Desertification and Biodiversity Conventions was produced. In 2005, an Assessment of the Status of Access and Benefit Sharing (ABS) of Genetic Resources in Swaziland and the Integrated Water Resource Management (IWRM) Plan and Water Efficiency Plan were formulated. The Kyoto Protocol was ratified by Swaziland in 2006 and in the same year, Department of Meteorology became the Designated National Authority (DNA) for Clean Development Mechanism (CDM) in the country. In 2010, the MTEA along with DOM established a multi sectoral National Climate Change Committee (NCCC) comprising of various sectors and members from both Government and non-governmental agencies. The first Technology Needs Assessment (TNA) for Swaziland was also done in 2010, however it focused mostly on climate change mitigation issues. In 2012, the National Development Strategy was reviewed. In 2015, Swaziland joined many countries in developing the Intended Nationally Determined Contributions (INDC), which were to be discussed at the COP 21 in December 2015. This is also the year when Swaziland joined 26 other countries in the second phase of Technology Needs Assessment. The timeline of these major events are pictorially depicted in Figure 1.

Besides the establishment of the NCCC and DNA, Swaziland has developed a National Climate Change Policy which is awaiting approval from Parliament. In harmony with the country's Vision 2022 that incorporates environmental sustainability in her quest to achieve sustainable development and poverty eradication, a National Climate Change Strategy and Action Plan (NCCSAP) was developed in 2014. The NCCSAP provides information regarding the country's priorities for climate change management. Both these instruments will ensure that climate change is mainstreamed in national development policies and programmes. Furthermore, the food security and agricultural sector policies, biodiversity conservation and management policy, natural disaster and emergency policy, national biofuels strategy and action plan, national energy policy implementation strategy have

included climate change considerations and adaptation and mitigation measures have been included in national action plans. The Technology Needs Assessment (TNA) conducted in 2010 identified technologies for climate change mitigation and reported that there were both mitigation and adaptation measures available to address the key impacts of Climate Change in Swaziland. However, since this document was skewed towards mitigation, Swaziland joined Phase II of TNA process to conduct another TNA in 2015 and this report is part of TNA Phase II. At the same time, the UNFCCC has been supporting Swaziland to participate in some of the UNFCCC programmes such as the adaptation panel and the Nairobi Framework Programme on adaptation and the Poznan technology transfer programme.

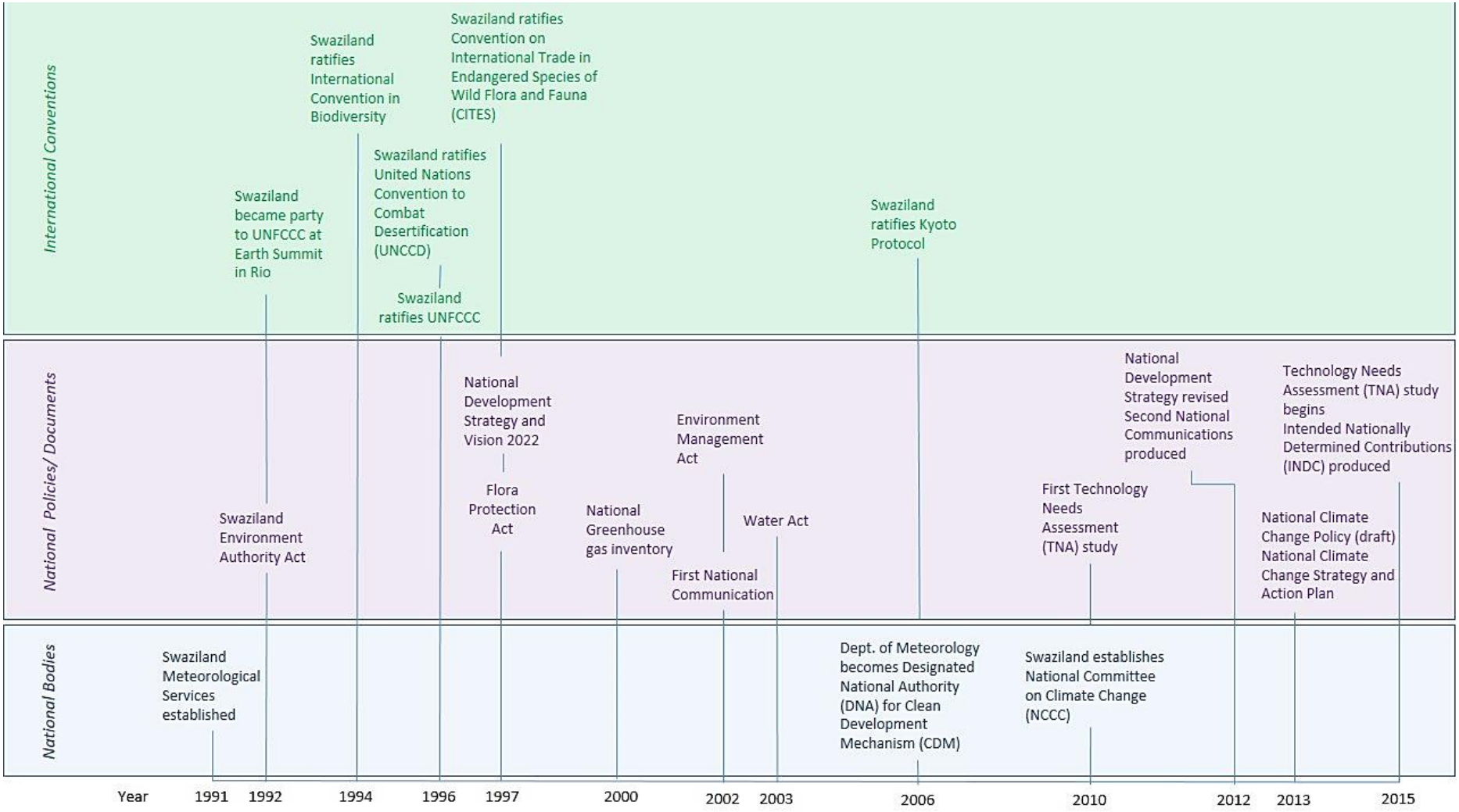

Figure 1 Timeline of events for Swaziland with regards to environment and climate change management

1.3 Vulnerability assessments in the country

Swaziland is a middle income landlocked country and has a land area of 17,363 sq.km (Manyatsi and Mhazo, 2013). It is surrounded by the Republic of South Africa and the Republic of Mozambique. The land is classified into six physiographic zones: Highveld, Upper Middleveld, Lower Middleveld, Western Lowveld, Eastern Lowveld and Lubombo Range (Sweet and Khumalo, 1994). The country has a population of 1.268 million, with a predominant agriculture based economy and 63% of people live in poverty (World Bank, 2014). The country is endowed with natural beauty and cultural heritage, and is a popular tourist destination. The broad climatic characterization of Swaziland is subtropical with wet hot summers and cold dry winters (April-September) and the country is highly vulnerable as it lies at the transition of major climatic zones and is prone to a number of hydro-meteorological hazards, with drought being the most common, which is likely to be exacerbated by climate change. The country is affected by climate change and is committed to managing its environment and economic growth and to address the global challenge of climate change. It is imperative that the country adapts to the changing climate, build resilience and reduce vulnerability in order to survive and develop in these circumstances. Swaziland's Second National Communication to the UNFCCC has reported significant increase in temperatures and varying rainfall patterns. Climate change is said to affect many sectors including energy, water, industry, agriculture, forestry, waste management, health sectors (Urquhart and Lotz-Sisitka, 2014). The urgent need for enhancing adaptation is mentioned in the Second National Communication by the Minister of Tourism and Environmental Affairs; "For Swaziland, adaptation is not an option but is a necessity; however, there is still need for strengthening institutional and human resources for the country to adapt to the impacts of climate change" (Government of Swaziland, 2012).

Swaziland has experienced increase in overall temperatures and varying rainfall patterns due to climate change. The frequency of extreme weather events have also increased in Swaziland (Manyatsi *et al*., 2010). Droughts were reported in the years 1983, 1992, 2001, 2007 and 2008, while cyclone Domonia in 1984 and floods were reported in 2000 (Brown, 2010; Gamedze, 2006; Manyatsi *et al*., 2010; Oseni and Masarirambi, 2011). Between years 1961 to 2000, annual mean temperature has increased by 3 ^{o}C and rainfall patterns have changed with delayed onset of rains (Government of Swaziland, 2014). It is predicted that in future the country will be faced with overall warming and drying, with increase in extreme weather events such as droughts as well as floods (UNDP, 2015). This has implications for the economy and the people. Furthermore, the country is vulnerable, mainly due to its undiversified economy, as it is dependent on food imports, have limited land area (being landlocked geographically) and have a weak private sector (UNCCD Secretariat, 2006). It is predicted that temperature rise will continue while rainfall patterns will change with extreme fluctuations, while overall rainfall may remain the same (Government of Swaziland, 2014).

Climate change is also causing extreme weather events such as droughts and floods. Table 1 presents the natural disasters related to climate change such as droughts, windstorms, hailstorms and floods that have occurred in the past in Swaziland. These have impacts on various sectors and livelihoods. High temperatures are likely to lead to high evaporation and drying thereby reducing water availability, thus impacting agriculture, forest plantations and indigenous forests. A drier scenario

may also trigger forest fires. Agriculture will be adversely affected when rainfall patterns are erratic (Urquhart and Lotz-Sisitka, 2014). This will also affect biodiversity and species decline may be experienced, while warmer temperatures may increase vector borne diseases such as malaria. Water resources may be affected negatively with snowballing impacts on food, availability of water and health of ecosystems (Government of Swaziland, 2014). Therefore, it is vital that the country must put in place measures to adapt to this changing climate and secure future water supplies.

Table 1 Climate Change related disasters in Swaziland from 2001 to 2011.

Hazard	Year	Number of people affected
Drought	2001	347,000
	2007	410,000
	2008	287,634
	2009	256,283
	2010	170,000
	2011	88,511
Strong winds/Windstorms	1984	632,500
	2005	1,150
	2006	6,535
	2010	1,000
	2011	+ 200 families
Hailstorms, thunder and lightning	2000	No data
	2011	+ 200 families
Floods	2008	272,000

Source: National Multi-Hazard Contingency Plan 2012-2013 (Government of Swaziland, 2012b).

Droughts in the past were severe (years 1983, 1992, 2001, 2007 and 2008) and in 2007, about 40% of the population was faced with acute food and water shortages. Incessant lightning during rainy seasons, cyclone Domonia in 1984, and torrential rains and floods in 2000 are some of the other hydro-meteorological hazards in recent years (Government of Swaziland, 2012b; Manyatsi, 2011). These aspects contribute to increasing vulnerability in Swaziland in various sectors, with the most apparent one being agriculture.

The most recent Vulnerability Assessment and Analysis Report (Government of Swaziland, 2014) stated that the agricultural sector performance, particularly crop production remains highly vulnerable to the effects of climate variability. Heavy storms and dry spells affected productivity in this sector, and hence the country has been investing in climate smart technologies to improve productivity. Rainfall patterns have been changing, according to the report, January 2014 experienced dry spells and February received below average rainfall, while above average rainfall was experienced in March 2014, in the high and middle veld. Figure 2 shows how temperatures and rainfall patterns have changed in the past in Swaziland. Temperature patterns have changes, however, rainfall patterns are not showing a big difference (see figure 2).

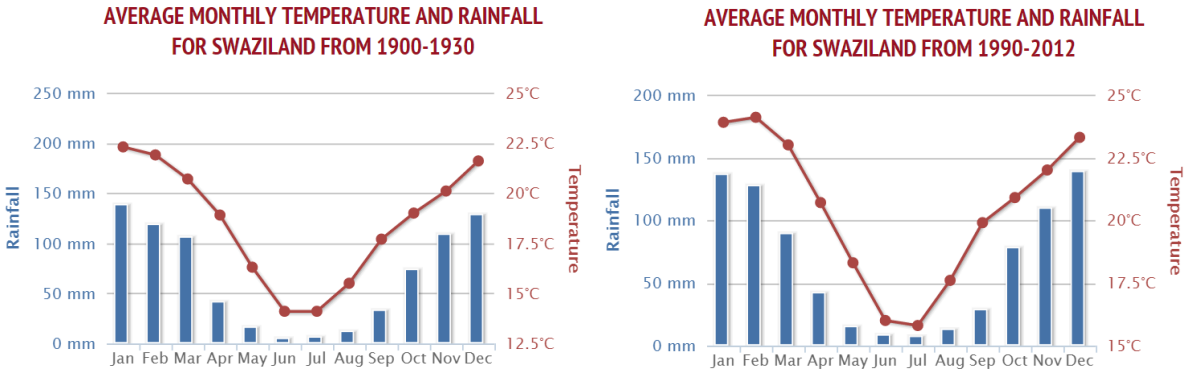

Figure 2 Average Monthly temperature and rainfall patterns for Swaziland comparing 1900-1930 and 1990-2012
(Source: World Bank.org, 2014)

Poor cold storage and post-harvest losses contribute to increased vulnerability in farming households. Mortality rates of livestock has been high in 2014, according to the report (Government of Swaziland, 2014). It appears that the Lubombo region is more vulnerable as dependence on self-employment and social grants is high in that region when compared to the other regions. Another factor that exacerbates vulnerability is lack of paid employment. Unemployment in the country is 29% and is 64% among the youth aged between 15 to 24 years. Migration in search of jobs is also common in the country, especially rural to urban migration. Vulnerability is also high in households where orphan hood is higher, as the report notes that approximately 19% of children are orphans in Swaziland (Government of Swaziland, 2014). According to the Vulnerability Assessment and Analysis Report, rural households experienced a number of shocks including weather related (drought, irregular rains and prolonged dry spells), health related (such as illness of family member) and market related (food price increase and unemployment) in all regions. These shocks have an impact on the ability of the rural household's to provide for their food and nutritional requirements in all the regions with the Lubombo regions reporting a higher percentage followed by the Shiselweni region. To cope with the shocks, households rely on low nutrition value and less preferred food and selling of productive assets which have a negative impact on their food security. Nationally, in terms of nutrition, the report states that the prevalence of stunting in Swaziland is 31 % and 1% of the under-five children are wasted, whereas 6% are underweight (Government of Swaziland, 2014). World Bank, estimates that about 63% of the population of Swaziland live below the national poverty line (World Bank, 2014). Vulnerability is driven by poverty and unemployment as well as limited adaptive capacity (Government of Swaziland, 2012).

Sectors that are affected by climate change have been highlighted in the National Climate Change Strategy and Action Plan 2014-2019 (Government of Swaziland, 2013). These include agriculture and food security, water resources, biodiversity and ecosystems, health and human settlements, which will need to adapt to climate change (Government of Swaziland, 2012). As solutions, the document identifies five strategic focus areas, namely:

1. Integration of climate change adaptive and mitigative measures into the various sectoral policies and national development planning and budgeting;

2. Promotion of development of adaptation and mitigation actions that contribute to achievement of sustainable development and eradication of poverty;
3. Provision of mechanisms for mobilizing and accessing support for technology development and transfer, capacity building and financial resources from the international community and other sources;
4. Building awareness and understanding of climate change among various stakeholders through education, training and public awareness; and
5. Strengthening legal and institutional framework for effective coordination and implementation of climate change adaptation and mitigation actions, programmes and initiatives.

Swaziland is constrained by a number of challenges to effectively deal with climate change. These include weak human resource capacity, poor climate data collection and management systems and framework and low levels of funding for climate change related activities (Urquhart and Lotz-Sisitka, 2014). There is low level of awareness of the threats and opportunities of climate change; limited human resources; low technological capacity; and inadequate availability of the financial resources to address climate adaptation. There is need for capacity development, training, enhanced and better resourced research, technology development and innovation, and mainstreaming climate change into policy and ensuring implementation through awareness raising and enforcement (Urquhart and Lotz-Sisitka, 2014). Technology plays an important role in managing the impacts of climate change and in this regard, the TNA project is a necessity for Swaziland. The following chapters will provide information on how the sectors and technologies were chosen for the TNA.

1.4 Sector selection

Sectors and areas most vulnerable to climate change in Swaziland have been listed in key national documents such as the NCCSAP (Government of Swaziland, 2013). These are agriculture and food security, water resources, biodiversity and ecosystems, health, human settlement, energy, natural hazards and preparedness, climate change-induced migration and conflicts and climate risk management. The Second National Communication to the UNFCCC (Government of Swaziland, 2012) has identified several vulnerable sectors including agriculture, forestry, biodiversity, water, energy, industry and mining and health. These sectors are vulnerable to climate change and need adaptation measures. Having referred to national documents and research on climate change, in particular the National Climate Change Strategy and Action Plan, ten sectors or areas of focus for climate change adaptation were presented to stakeholders during the sector prioritization workshop held on 13th of July 2015. These were then prioritised and three sectors selected in the TNA process for Swaziland.

1.4.1 An Overview of Expected Climate Change and its Impacts in Sectors Vulnerable to Climate Change

It is now considered ‘unequivocal’ that the global climate is changing and its impacts have been felt globally. Sustainable development in Swaziland is at risk to the impacts of climate change, as many sectors are affected including ecosystems, health, water, forests, agriculture, economic activities and

physical infrastructure. This section describes the sectors and explains how climate change may impact on them, beginning with the most important one - agriculture. The National Development Strategy and Vision 2022, is the highest level policy document in the country and envisions "By the Year 2022, the Kingdom of Swaziland will be in the top 10% of the medium human development group of countries founded on sustainable economic development, social justice and political stability" (Government of Swaziland,1999). Environmental management and agricultural development have been recognised in the document to be key in achieving this vision. Both are necessary for adapting to the impacts of climate change, which will affect many sectors including agriculture.

Agriculture sector: The agricultural sector could be impacted by climate change both directly and indirectly. Direct impacts from temperature precipitation changes, increased variability in weather and extreme conditions (heat waves, hail storms, wind storms) will affect the agricultural sector (Government of Swaziland, 2012, Government of Swaziland, 2013). Indirect impacts include changing crop-weed competition dynamics, range changes of pests and pathogens, less-cold winters allow increase in pests and decreased biodiversity in natural ecosystems. According to the 2012 Swaziland Annual Vulnerability Assessment and Analysis Report (Government of Swaziland, 2012a), erratic rainfall affects agriculture, causes declining production and has serious implications for food security. Climate change in Swaziland is anticipated to lead to overall warming and drying and frequency of floods and droughts may increase with an increase in their intensities too. Agriculture will be hard hit, with yields of staple food crops such as maize, sorghum and beans likely to decrease, thereby threatening national food security (UNDP, 2013).

Agriculture has a direct impact on household vulnerability, which, under projected changes in climate, is likely to increase in Swaziland (FARNPAN, 2015). The Second National Communication for Swaziland to UNFCCC (Government of Swaziland, 2012) states that climate change will affect production of crops and livestock. Studies have already shown that climate change and variability has negatively affected livelihoods for most subsistence farm households in the Lowveld through low agricultural productivity (Nxumalo, 2012). Up to 40% of such households still rely on food aid (Manyatsi *et al*., 2010). Studies have shown that although awareness about climate change was there, however, not all households responded by adapting or reducing the negative impact and they continue relying on rain fed agriculture (Shongwe *et al*., 2014). The farmers interviewed in the study who were adapting to climate change adopted various copying techniques and methods including use of drought tolerant varieties, early and late planting, minimum tillage, crop rotation, intercropping, mulching and irrigation. The study called for government support to adopt anticipatory or proactive adaptation strategies rather than the currently used reactive strategies (Shongwe *et al*., 2014). FARNPAN (2015) notes that a major challenge in climate change adaptation in Swaziland is the lack of empirical climate and agronomic data which could help in provision of targeted adaptation solutions and policies. Adaptation to climate change may include shifting planting periods, growing of drought tolerant crops, and raising suitable crops in appropriate regions.

Swaziland produces many agricultural products that it exports to neighbouring countries and the global markets (Table 2). Climate change affecting agricultural yield (Manyatsi and Singwane, 2013) is detrimental to the economy of Swaziland as agricultural exports will be affected. Although

Swaziland is a net importer of food, fuel and machinery, nevertheless agriculture exports are important for the country's economy and the sector has to adapt to changing climate. In this regard, it may be necessary to change planting times to adjust with changing rainfall patterns (Urquhart and Lotz-Sisitka, 2014). A recent FAO/WFP report states that extended dry periods have affected farming and maize yields were half of their average levels in the year 2015 and Swaziland continues to import maize (FAO/WFP, 2015). Solutions for agriculture to adapt to climate change include crop management adjustments including crop diversification, use of improved crop varieties and other technologies which will be discussed further in the next section.

Table 2 Export of agricultural produce from Swaziland 2007-2011

	Units	Export Quantity					Export Value, 1000 US$				
Produce		**2007**	**2008**	**2009**	**2010**	**2011**	**2007**	**2008**	**2009**	**2010**	**2011**
Unrefined sugar	tonnes	877,705	206,869	197,129	283,962	264,841	152,490	121,829	103,410	133,213	135,157
Refined sugar	tonnes	24,003	83,656	68,472	56,972	33,012	12,117	43,922	39,519	32,138	20,646
Grapefruit	tonnes	15,496	14,184	9,494	13,073	17,478	3,494	12,131	7,143	10,975	15,837
Vegetable produce for animal feed	tonnes	17,473	17,473	17,473	17,473	17,473	6,296	6,296	6,296	6,296	6,296
Oranges	tonnes	31,017	15,772	14,017	11,968	12,866	3,204	11,200	9,028	9,127	10,068
Sugar Confectionery	tonnes	9,681	8,500	8,500	8,500	8,500	11,502	10,100	10,100	10,100	10,100
Prepared fruit	tonnes	1,939	11,201	9,772	9,441	8,232	2,968	16,330	12,892	12,495	12,066
Bananas	tonnes	8,075	6,000	7,000	7,500	7,500	727	550	600	700	700
Chocolate products	tonnes	7,043	7,043	7,043	7,043	7,043	8,276	356	356	356	356
Prepared foods	tonnes	379	379	379	379	6,178	823	823	823	823	36,432
Other sugar products	tonnes	5,571	5,571	5,571	5,571	5,571	9,934	9,934	9,934	9,934	9,934
Food Wastes[1]	tonnes	5,527	5,527	5,527	5,527	5,527	1,709	1,709	1,709	1,709	1,709
Pineapples Candy[2]	tonnes	897	2,957	3,164	2,809	1,947	1,136	3,947	3,816	3,294	2,566
Beer of Barley[3]	tonnes	257	685	1,278	1,084	1,362	394	599	1,163	1,119	1,375
Potatoes Flour	tonnes	1,167	1,167	1,167	1,167	1,167	3,535	3,535	3,535	3,535	3,535
Cattle	Head	317	1,100	1,100	1,100	1,100	130	140	150	150	150
Pet Food	tonnes	834	834	834	834	834	258	258	258	258	258
Chickens	1000 Head	792	792	792	792	792	442	442	442	442	442
Groundnuts Shelled	tonnes	745	745	745	745	745	246	246	246	246	246
Hen eggs, in shell	tonnes	579	579	579	579	579	552	552	552	552	552

Source: Food and Agricultural Organization, 2015.

[1] Sweetened forage and preparations used for animal feed such as wine lees, argol.
[2] Fruit pulp prepared in water
[3] Beverage made from barley. Both alcoholic and non alcoholic.

Livestock is important for Swaziland and adaptation to climate change can be achieved by providing support to traditional breeding through development of pastoral facilities and securement capacities in grazing areas, increase productivity of livestock by development of agriculture/livestock integration and support to village poultry farming.

With respect to arable agriculture, technologies such as drip irrigation, efficient sprinklers, re-use of wastewater, water harvesting technologies and other irrigation optimization, and water management techniques will help this sector adapt effectively. Capacity building initiatives such as training in farming technologies, strengthening of agricultural data collection and expanding micro credit, can go a long way to help the agricultural sector. Development of early warning systems and developing flood maps and areas prone to drought or livestock disease can also help (Government of Swaziland, 2013). The NCCSAP recommends mainstreaming climate change into agricultural policy, strategy and action plans and enhance adoption of sustainable land management practices (Government of Swaziland, 2013). There is need to enhance agricultural research, technology development, innovation, strengthen extension services and promote risk management and insurance (Government of Swaziland, 2013).

Forestry

The forest sector is very significant for Swaziland, as it provides jobs for 16-18% of Swaziland's work force and contributes about 26% of the country's revenue through export of timber (Dlamini, 2006). In Swaziland, there are a number of plantations including pine plantations as well as indigenous forests, which satisfy human needs for timber, recreation and provide habitats for wildlife. According to Swaziland's Second National Communication (Government of Swaziland, 2012), the country may be much drier posing potential changes to ecosystems and it is anticipated that the drier Acacia savannah is expected to be dominant. The forestry sector is also affected by climate change as forests are vulnerable to water availability (drought and waterlogging), changes to species composition especially increase in invasive species, pests and pathogens and decrease in pollinators. The country is already faced with the challenge of spread of invasive alien species, which take over farming and grazing land and also consumes water. In 2005, the government declared invasive species a national disaster and committed $1.4 million to their eradication and management (USAID, 2007). Grasslands and Lebombo bushveld are therefore likely to be affected with loss of their bio climate area. Higher temperatures will cause higher evaporation and increase in demand for water in forests. Extended droughts may lead to reduced forest productivity, land degradation and loss of soil fertility, as well as forest fires. Drier areas with higher temperatures may be affected by forest fires and result in smoke haze, pollution, loss of seedlings and biodiversity. Solutions include fire monitoring, afforestation, providing corridors for migration of species, removal of invasive alien species and managing pests. In a drier situation, frequency of forest fires may increase thereby affecting ecosystem functions. Forest fires will also affect biodiversity and contribute to species loss (SEA, 2014). Forests act as a carbon sink and therefore have a clear role in mitigation, but also have a role to play to improve livelihoods which help with adaptation. Forests help humans adapt by providing a safety net and buffer in times of shock to reduce vulnerability through provision of medicinal plants, mushrooms, wood and other forest products.

Water

The water sector will also be affected by climate change in many ways. Water quality and availability will be affected with consequent impacts on water supply, ecosystem services, hydropower generation, human health (through water borne and hygiene related diseases triggered by limited availability of clean water) as well as resource depletion for species that need water (like fisheries) (Government of Malawi, 2012; Ziervogel *et.al*., 2014). Surface flows in rivers and streams are likely to have greater variation, with lower base-flows in the dry season, potentially resulting in water shortages for domestic, industrial and agricultural use. Groundwater reserves, which are an important source of water for many rural communities, may be reduced as a result of increased rainfall intensity and concomitant increases in surface runoff (UNDP, 2013). The Second National Communication (Government of Swaziland, 2012) states that runoff changes are expected in Swaziland's rivers, namely Usuthu, Mbuluzi and Ngwavuma. Reduced water availability will affect industrial productivity, agriculture and households due to climate change (Manyatsi and Singwane, 2013). Productivity in key industrial processes such as timber, fruits and agriculture related industries (e.g. sugar production) may be affected by climate change. Furthermore, extreme weather events is likely to impact on worker productivity due to indirect impacts on their health. In the agriculture sector, water availability for irrigation will be reduced. At household level access to water is indispensable for adaptation through benefits of hygiene, sanitation, economic growth through use of water for agriculture and improved health. Besides reduced water flow in rivers, water availability may be affected due to dry spells, and in dry conditions, people may resort to using contaminated water sources thus triggering disease outbreaks such as cholera.

Table 3 Dams in Swaziland, their capacity, use, surface area, date established and source river

No.	Name of Dam	Capacity ($1000m^3$)	Use	Surface area ($1000m^2$)	Date established	River system
1	Maguga	332,000	Hydropower and irrigation	10,420	2001	Komati
2	Mnjoli	153,000	Irrigation	14,800	1980	Mbuluzi
3	Sand River	50,330	Irrigation	698	1965	Komati
4	Luphohlo	24,000	Hydropower	120	1984	Usuthu
5	Hendrick Van Eck	9,865	Irrigation	145	1969	Usuthu
6	Sivunga	5,920	Irrigation	120	1972	Usuthu
7	Nyetane	6,780	Irrigation	137	Raised 1992	Usuthu
8	Hawane	2,750	Irrigation	70	1984	Mbuluzi
9	Lavumisa	345	Irrigation	27	1996	Pongola

Source: FAO (2015a).

In Swaziland water withdrawal is predominantly for irrigation and construction of dams have increased water storage capacity in the country for irrigation and hydropower generation. Swaziland has a number of dams established since 1965 (Table 3) dependant on the Komati, Mbuluzi, Usuthu and Pongola river systems. With climate change bringing drier scenarios, it is imperative to reduce wastage of water and improve efficiency in order to have continued access to water for irrigation, hydropower generation and domestic use. Technologies for increasing water use efficiency (such as drip irrigation), deploying integrated planning and practices within and between sectors, modelling water and climate scenarios, recycling, water reuse, rainwater harvesting and alternative supply sources are all useful in a climate constrained world. Solutions proposed for the water sector in the NCCSAP include mainstreaming climate change into water sector policies and plans, enhancing holistic management through Integrated Water Resources Management (IWRM) and enhancing risk management and early warning (Government of Swaziland, 2012).

Biodiversity and Ecosystems

Climate change is expected to affect biodiversity and ecosystems in many ways. Swaziland is home to many endemic species and there are several species of flora and fauna that are under threat of extinction as indicated in Table 4. Swaziland has about 2,600 species of flora having social, economic and cultural value (USAID, 2007). Biotic systems provide food, materials and medicines, store and release fresh water, absorb and detoxify wastes and satisfy human needs for recreation and wilderness. Biodiversity and ecosystems will be affected by climate change and this would result in species loss which can result in disruption of natural ecosystems, which provide an array of services that ultimately support human well-being. According to the Second National Communication and Swaziland National Trust Commission (SNTC) (2015), several flora and fauna species have already faced extinction (Table 4).

Table 4 Endangered and threatened species of fish, amphibians, birds and mammals in Swaziland

	Scientific name	**Common name**
Fishes	*Barbus cf. neefi*	Sidespot barb
	Chiloglanis bifurcus	Incomati suckermouth/rock catlet
	Astatotilapia brevis	Orange fringed largemouth
	Barbus brevipennis	Shortfin barb
Amphibians	*Pyxicephalus adspersus*	
	Hyperolius semidiscus	Yellow-striped reed frog
Birds	*Gyps coprotheres*	Cape vulture
	Grys carunculata	Wattled crane
	Anthropoides paradisea	Blue crane
	Balearica regulorum	Crowned crane
	Ardeotis kori	Kori bustard
	Scotopelia peli	Pels fishing owl
	Buphagus africanus	Yellowbilled oxpecker
	Hirundo atrocaerulea	Blue swallow
Mammals	*Sigmoceros lichtensteinii*	Lichtenstein's hartebeest
	Acinonyx jubatus	Cheetah

	Lycaon pictus	African wild dog
	Diceros bicornis minor	Hook-lipped (black) rhinoceros
	Manis temminckii	Pangolin
	Cercopithecus mitis	Samango monkey

Source: Swaziland National Trust Commission, 2015.

The State of Environment Report for Swaziland (Government of Swaziland, 2012c) states that climate change will adversely impact biodiversity and ecosystems with westerly shifting of ecosystem boundaries and increases in aridity in the eastern parts of the country. Species extinctions may be experienced due to changed climate and due to lack of corridors for migration for animals and inability of plants to migrate species, and as a result some species with low populations may even get extinct. Ecosystem services will be affected when there are changes to the ecosystem as a whole. Ecosystems and, animal and plant species have to adapt to the changing climate and there is need for monitoring of species loss to understand how changes in ecosystems are occurring. Adaptation for this sector can be enhanced through provision of corridors for migration of species, promotion of ecosystem-based approach to biodiversity conservation, removal of invasive alien species and promoting ecosystem-based approach to biodiversity conservation through data collection and information dissemination (Government of Swaziland, 2012c).

Health

The health sector will likewise be impacted by climate change, and health impacts of heat waves and extreme weather events (floods, droughts) will increase many vector, food and water-borne diseases. Predictive models have shown that under different climate change scenarios, there would be a net increase in the geographical range of potential transmission of malaria, dengue fever, yellow fever and several types of encephalitis (Ziervogel *et al*, 2014; Government of Swaziland, 2012c). Manyatsi and Singwane (2013) identify under-nutrition as an impact of climate change due to poor food production. Government of Swaziland (2012b) states that it is necessary to project health impact of climate change by analysing future risks and impacts under climate change on public health. Furthermore, most vulnerable populations and geographical areas need to be identified for targeted assistance. Other emerging infectious diseases may also increase due to changing weather and climate patterns (Urquhart and Lotz-Sisitka, 2014). Health infrastructure and services need to cope with increased diseases induced by climate change. To help this sector to adapt effectively, it is useful to establish preventive measures and surveillance systems, improve disease surveillance systems, improve preparedness and emergency response, develop and implement an early warning system and promote domestic water treatment systems (Government of Swaziland, 2012).

Human Settlements

Human settlements will similarly be affected by climate change and variability. Impacts of extreme weather events such as floods can impact negatively on unplanned settlements, and buildings with poor construction are the most vulnerable. Houses that lack insulation exposes families to discomfort due to temperature variations. Human settlements are expected to be affected with climate change if they are positioned in risky areas, for example flood prone areas. Construction on flood plains is a

hazard and with climate change, frequency of floods may increase posing a risk to those settlements. In order to effectively adapt in this sector, interventions such as developing and implementing land use plans and regulations that take into account climate related risks is highly recommended. Additionally, strengthening and expanding building design standards and codes to cover all areas taking into account climate-related risks will help reduce vulnerability. Improving settlements of communities living in climate change risk prone areas and relocating settlements from climate change high risk prone areas also will help in this regard (Government of Swaziland, 2012b).

Energy

Energy sources and systems are affected by climate change, directly and indirectly. Swaziland's local generation capacity is mainly from hydropower and biomass. Both these sources of energy are heavily reliant on precipitation. Climate change affects rate of erosion and subsequent siltation rates affecting dams and rivers. Enhancing conservation of ecosystems which support energy production and use and enhancing access and use of clean energy sources and technologies, are adaptation measures. The National Climate Change Strategy and Action Plan suggests enhancing conservation of ecosystems which support energy production and use and enhancing access to clean energy technologies in the country (Government of Swaziland, 2013).

On the other hand, the energy sector is also important for climate change mitigation. Energy sector contributes emissions that cause climate change, especially due to transport (vehicles) and manufacturing activities. With changes in weather including heat waves there is likely to be high demand for energy for cooling needs and energy infrastructure may not be able to cope with the increasing demand. With climate change affecting water supply, and hydropower generation will be adversely affected. Energy sector has potential for climate change mitigation, however, for adaptation, energy security (i.e. ensuring communities have sufficient access to energy services) is of paramount importance. Having access to energy and clean sources of energy (less polluting for users) helps communities become more resilient to climate change through improving their productivity and reducing their time spent on collecting (say) firewood for their energy needs as well as avoiding negative health impacts from indoor air pollution.

Climate induced Migration and Conflicts

Climate induced migration and conflicts are said to increase with the changing climate. By 2050, it is estimated that adverse effects associated with global climate change will result in the displacement of between 50 and 200 million people (from Government of Swaziland, 2013). Seasonal migration in times of scarcity like drought is a continuous phenomenon. A combination of environmental change, resources capture and population growth decreases the per capita availability of natural resources, particularly the poorest that depend on these natural resources for survival. Both scarcity and abundance of environmental resources can exacerbate existing tensions and contribute to conflict between families and communities. Adaptation measures can include the development and implementation of a risk management strategy to protect citizens from climate change induced migration, to enhance the capacity of local institutions to address climate change induced migration related conflicts through cooperative conflict resolution and management approaches that take into

account gender and to expand the understanding and recognition of potential migration issues through better analysis, better data and better predictions (Government of Swaziland, 2013).

Disaster Risk

Climate change increases disaster risk by changing the magnitude and frequency of extreme events. It also changes average climatic conditions and climate variability, thus affecting underlying risk factors and it generates new threats which might never have been experienced or dealt with in the region. Both adaptation and disaster risk reduction, poverty reduction and sustainable natural resource management are essential components of reducing vulnerability to hazards and climate change. Mainstreaming disaster risk reduction into national planning processes, enhancing early warning systems and building resilience in every sector is imperative. It is important to note about trade-offs between adaptation and mitigation, where an adaptation intervention may end up producing more climate change inducing emissions. An example is the use of air conditioners that help people cope with heat waves, however if the air conditioners are using unclean sources of energy such as coal based power, it contributes to more green-house gases, and ultimately further climate change. Some adaptation measures may have co-benefits for mitigation, for example planting trees for income generation, will help sequester carbon. Swaziland needs to strengthen national capacity to prepare and respond to disasters (Government of Swaziland, 2013) and setting up the Disaster Management Authority in the country is a step in the right direction. Table 5 shows the sectors likely to be impacted by climate change, according to several national documents.

Table 5 Documents that indicate sectors to be affected by climate change

No.	Document	Sectors prioritized/affected by climate change
1	National Climate Change Strategy and Action Plan (2014-2019)	Agriculture and food security Water resources Biodiversity and ecosystems Health Human settlements Energy Natural hazards and preparedness Climate change induced migration and conflicts Climate risk management
2	Third National Communication to UNFCCC Government of Swaziland, (under preparation)	Energy Water and Industrial Processes Agriculture Land use change and Forestry Waste Health
3	Second National Communication to UNFCCC, Government of Swaziland, 2012	Energy Industrial Processes Agriculture Land Use, Land Use Change and Forestry

		Waste
4	First National Communication to UNFCCC, 2002	Agriculture Natural resources Water Public health Biodiversity
5	State of Environment Report, 2012	Biodiversity Ecosystems Forests Water Agriculture Land use and land conditions Human health
7	Swaziland: A Framework For National Development Strategy (NDS) Review, 2013	Agriculture Education Health Water & sanitation
8	Strengthening University Contributions To Climate Compatible Development In Southern Africa- Swaziland Country Report, Urquhart and Lotz-Sisitka, 2014	Energy Water and Industrial Processes Agriculture Land use change and Forestry Waste Health

A comprehensive list of sectors was taken from these documents and presented to stakeholders for the sector prioritization. This is discussed in the next paragraphs.

1.4.2 Process and results of sector selection

Sector prioritization was done at a workshop (13th of July 2015) where the TNA project was presented to the stakeholders. Stakeholders undertook a brainstorming session which was facilitated by the Department of Meteorology where they prioritised three sectors for climate change adaptation and identified technologies for inclusion into factsheets in each sector. The consultant presented ten sectors based on review of key national documents including the National Climate Change Strategy and Action Plan (Government of Swaziland, 2013). The ten sectors were:

1. Agriculture and food security
2. Forestry
3. Water resources

4. Biodiversity and ecosystems
5. Health
6. Human settlements
7. Energy
8. Natural hazards and preparedness (hazards such as drought, hail, diseases management)
9. Climate change-induced migration and conflicts
10. Climate risk management (integration of climate risk into national planning) (Government of Swaziland, 2013).

Stakeholders then discussed these sectors in the plenary and prioritized three from the ten listed. They were prioritized by answering questions given in table below.

Table 6 Questions asked during brainstorming of sector prioritization

Num.	Questions
1.	Is the sector a priority for Swaziland in terms of sustainable development?
2.	Is there potential for reducing risks, threats and vulnerabilities with regard to climate change?
3.	Does the sector have scope for using climate compatible technologies?
4.	Would addressing climate change in the sector be beneficial for the country (e.g. Would it create jobs, have social benefits etc.)
5.	Would addressing climate change in the sector address needs of vulnerable groups, gender, and cultural appropriateness?
6.	Are there technologies that are mature for implementation in Swaziland for that sector?
7.	Does the sector have scope for benefits in economic and environmental areas?

Using these questions, participants were able to come up with three priority sectors which have potential for climate change adaptation viz: water resources, agriculture and forestry, biodiversity and ecosystems. Forestry and biodiversity & ecosystems were separate sectors, however, they were combined into one sector due to overlaps and prioritised as the third sector for the TNA. The stakeholders further identified some technologies that could help each of the three sectors to achieve adaptation. Factsheets were developed for the identified technologies for discussion in the technology prioritization workshop.

Chapter 2 Institutional arrangement for the TNA and the stakeholder involvement

Climate change management in Swaziland began with participation at the Earth Summit in 1992, when the National Meteorological Service Act of October 1992 established the Department of Meteorology in 1993 under the Ministry of Tourism and Environmental Affairs. Swaziland ratified the UNFCCC and Kyoto Protocol and the Department of Meteorology has the responsibility to domesticate the convention and treaty and lead climate change activities in the country. The National Climate Change Committee drives and oversees the climate change agenda in Swaziland. Other bodies related to environmental management include Ministry of Natural Resources and Energy, Sectoral Ministries such as those responsible for water and agriculture, Swaziland National Trust Commission, Swaziland Environment Authority (SEA) and the recently established National Disaster Management Authority. Town Councils, Municipalities, Universities, Research Centres, River Basin Authorities, development partners and Non-Governmental Organizations (NGO), all have a part to play in mainstreaming climate change into their work and developing appropriate strategies. In the TNA process, the Department of Meteorology leads the process and stakeholders from various sectors, academia and private sector were invited to contribute to the technology identification and prioritisation. The full list of stakeholders involved in the TNA is provided in Annex II.

2.1 National TNA team

A National TNA team was set-up by the Ministry of Tourism and Environmental Affairs to oversee implementation of the project. It comprises the TNA Coordinator, the National Committee on Climate Change which includes the Director of Department of Meteorology and the Consultants for Adaptation and Mitigation. Also a TNA Steering Committee was established comprising of high level officials from Government departments.

The National TNA Team was the main decision making body for the project, and the TNA Coordinator was responsible for overall overseeing of the project and the national focal point. The National TNA team was composed of a stakeholders (sectoral experts) and adaptation and mitigation consultants and technical working groups (Figure 2). The TNA coordinator facilitated the different groups, and managed the overall TNA process. The Coordinator also facilitated communication with the Working groups, NCCC, National Consultants and stakeholder groups, assisted in the formation of networks, and compilation of information, coordination and communicating all project products. The stakeholders provided inputs to the TNA through selection of sectors and technologies as well as discussing which technologies are most suited to the country situation. Technical assistance was provided by UNEP/DTU and Energy Research Centre (ERC). The consultants (who worked closely with the TNA Coordinator) analysed country specific information and information provided by UNEP/DTU to come up with country specific analysis, analysed and synthesised the information in accordance with TNA guidebooks provided by UNEP/DTU. The stakeholders were central to the TNA process as they participated in discussions for prioritising sectors and technologies, which was

key to national consultation and inclusive technology prioritisation. The TNA Help Desk provided assistance for countries in undertaking the TNA project.

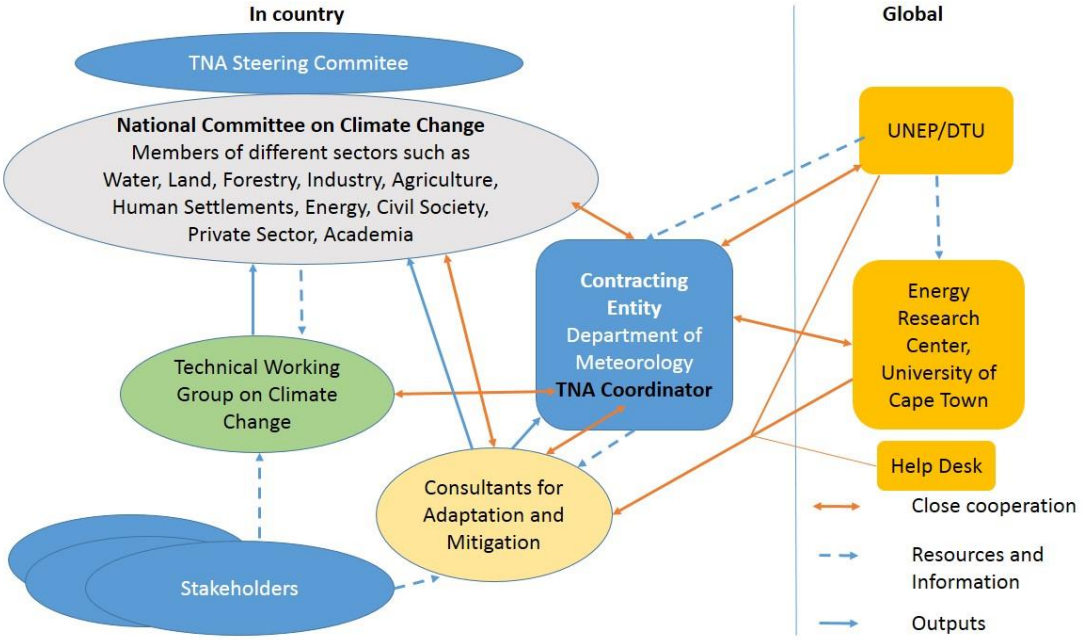

Figure 3 Organization of the national TNA process in Swaziland

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Stakeholders were involved in the TNA from the beginning in accordance with the training provided in Arusha, Tanzania in June 2015 and in accordance with a guidebook provided by UNEP/DTU (PÍa, 2015). The following steps were followed in stakeholder engagement in Swaziland:

1. A list of stakeholders was compiled during the training in Arusha (June, 2015) and invitations were sent to all the stakeholders for the inception and sector prioritization workshops. The list included representatives from Ministries and sectors such as water, biodiversity, agriculture, energy, health, industry, academia, civil society and representatives from municipalities and city councils were also invited.
2. On 13th of July 2015, an inception workshop for TNA was held and at this workshop, stakeholders prioritised sectors for TNA. The ten sectors that were presented to stakeholders were deliberated and discussed. Then stakeholders choose three sectors for which technology factsheets could be developed. They also guided consultants on which technologies to focus on.
3. Stakeholders were sent factsheets of all technologies suggested for sectors prioritised, via e-mail before the technology prioritization workshop.
4. Stakeholders prioritised technologies during the technology prioritization workshop held between 20 and 21 August 2015.

Based on the sectors prioritized and technologies prioritised as well as information from MCA exercise, the TNA report was prepared.

Figure 4 Some of the participants at the Sector prioritization workshop

Figure 5 Stakeholders at the workshop for prioritization of technologies

Stakeholder engagement had many benefits in Swaziland during the TNA. The stakeholders pointed out ongoing projects using technologies for climate change adaptation and some technologies that did not work in the country, thus helping the consultants focus on technologies that were suited to the local context. For example it was agreed to exclude flood mapping as it was not a major issue for Swaziland and rather include technologies such as alien invasive species management. The stakeholders also recommended the inclusion of indigenous knowledge in technology adoption. Furthermore, the TNA technologies prioritization was a useful input into the development of the Intended Nationally Determined Contributions (INDC) report for Swaziland. All the prioritised technology needs were also included in the INDC document, thereby aligning the national INDC process with the TNA. Images of ongoing projects in agriculture are provided in the photo essays in Appendix.

Chapter 3 Technology prioritisation for Water Resources

Water resources was considered very important for Swaziland as they support other sectors such as agriculture, industry and tourism. Climate change will impact the water sector in many ways. Water quantity, quality and availability will be affected and this will adversely impact water supply, ecosystem services, hydropower generation, and also loss of habitats for aquatic species (like fisheries). Human health is also affected through water borne and hygiene related diseases triggered from limited availability of clean water due to climate change. To respond to climate change, stakeholders considered adopting technologies that will promote water conservation, efficiency, improved quality and availability of water. Stakeholders listed the technologies to be developed into factsheets for the TNA and these were Artificial groundwater recharge, Rainwater harvesting through rooftops and dams, Wetlands restoration, Sand dams, Integrated River Basin Management, Water recycling and reuse, Leakage Detection in water supply schemes and Efficient water use technologies (drip irrigation, efficient sprinklers). The factsheets which contain detailed information on the technologies and how they help in climate change adaptation are provided in Annex I.

3.1 Key Climate Change Vulnerabilities in Water Sector

Swaziland has a number of rivers and underground aquifers which are currently being used for its water supply needs. The combined mean discharge for all the rivers leaving the country is 144m^3/s or 4.5 million m^3/annum. Over the years, the country has been able to store 765,000 m^3 per annum, which represents 17 percent of the available renewable water resources. This water is stored in major dams and reservoirs located in different parts of the country (Government of Swaziland, 2012d). The Government is engaged in efforts to develop more dam infrastructure to capture available water resources. The water sector is seen as an engine for development which ensures sustainable economic prosperity and helps in poverty eradication in the country through various interventions. This is in line with the vision of the water sector, which is: “national economic prosperity and social upliftment through equitable, productive and optimum utilisation of water resources while ensuring environmental sustainability” (Government of Swaziland, 2009). But, this is one sector that will be affected by climate change and scenarios have been modelled in the country where annual run-off has been projected to decrease within a range of 2% to 6% in a normal year and even higher in dry years. In addition, demand for Swaziland’s available fresh water is already almost outstripping available supply and under stress (Seetal and Quibell, 2003) and it is expected that there will be intermittent droughts due to low precipitation and floods due to intense rainfall and higher flows (Government of Swaziland, 2009).

According to the Annual Vulnerability Assessment & Analysis Report 2014, access to water is an important part of household livelihood security (Government of Swaziland, 2014). Most people in Swaziland have access to improved water sources such as piped water and boreholes. Because of the dry spells and drought in some communities, many face ongoing water challenges. Some boreholes have dried up and some communities continue to use unprotected water sources such as rivers and man-made dams. This increases the risk of waterborne diseases. According to the Millennium Development Goals Report 2012, Swaziland is on track with achieving its water supply targets,

however, several schools still lack access to water and sanitation (Government of Swaziland, 2012d). With the challenges of climate change, it is imperative that the water sector must adapt to the impacts. This calls for the need for water conservation, efficient use, and recharging of water resources, and ultimately providing benefits for sustainable development. These were the factors that helped in listing technologies in this sector. The technologies that were suggested by stakeholders during the sector prioritization workshop address each of the needs. For example, need for water saving is addressed by sand dams, artificial groundwater storage, water recycling, reuse, rainwater harvesting and leakage detection technologies. Environmental benefits will accrue with integrated river basin management and wetlands protection technologies. All these can help the water sector adapt better to climate change.

3.2 Decision context and overview of technologies in Water sector

Water is a key factor in socio-economic development for Swaziland and the country has a number of policies that assist in managing water resources in the country. The Water Act, No 7 of 2003, provides guidance regarding water permits, borehole drilling, effluent control and extraction of water for water supply needs. There are also standards for water quality and effluent discharge. The Swaziland National Water Policy (NWP) sets out the vision, intention and strategy of the Kingdom of Swaziland on the development and management of water resources. The NWP is based on the concept enshrined in the National Development Strategy (NDS), whereby the goal is poverty eradication and economic prosperity (Government of Swaziland, 2009). Swaziland also has an Integrated Water Resources Management and Water Efficiency Plan (2007) which helps in moving from a fragmented approach to a more inclusive and integrated approach where human and ecosystem needs are considered in managing water resources. The plan led to the piloting of a number of initiatives including the IWRM Demonstration project in Swaziland implemented by the Swaziland Water and Agricultural Development Enterprise (SWADE) (SADC, 2009). Further to this, the Integrated Water Resources Master Plan developed with the assistance of Global Water Partnership was able to provide strategic guidance to decision/policy makers, water managers and water users on how best to manage and develop the country's water resources within the national and regional frameworks.

The National Water Authority governs the overall development and management of water resources in Swaziland and uses a bottom up approach, as it involves small and large scale water users and work together with Government to guide planning for water resources. There are also River Basin Authorities established as part of ecosystem approach and decentralized management of water. Manyatsi and Brown (2009) noted that Swaziland's five river basins are shared with neighbouring countries (Mozambique and South Africa), making the country subject to international agreements and protocols. The Joint Water Commission established by the Government of Swaziland and the Republic of South Africa, the Komati Basin Water Authority established by the Government of Swaziland and the Republic of South Africa, and the Tripartite Commission established by the Government of Swaziland, the Republic of Mozambique and the Republic of South Africa are all helping in managing these transboundary water resources. Swaziland has implemented and is planning to implement as number of projects and programmes on reducing vulnerabilities in the water sector and these are listed in Table 7.

Table 7 Projects and programmes in water sector

No.	Name of Project	Donor/Partner	Description of project
1	Lower Usuthu Smallholder Irrigation Project (LUSIP) (2003-ongoing)	International Fund for Agricultural Development (IFAD), Global Environment Facility (GEF)	The objectives of the LUSIP-GEF are to reduce land degradation, biodiversity loss and mitigate climate change through the application of sustainable land management practices which will contribute to mitigation of, also adaptation to, climate change. LUSIP's goal is the "Reduction of poverty and sustained improvement in the standard of living of the population of the project area through commercialization and intensification of agriculture" (GEF, 2012). One of the key activities of this project is development of irrigation which helps with adaptation.
2	GEF-SCCF project on adapting national and trans boundary water resource management in Swaziland to manage expected climate change (2013–2016)	Ministry of Natural Resources and Energy (MNRE) - Department of Water Affairs (DWA) and UNDP, funded by GEF-Special Climate Change Fund	This project focuses on Incomati, Umbeluzi and Maputo Rivers and incorporates climate risks into Integrated Water Resources Management (IWRM). Pilot projects on community level adaptation, including practices that increase infiltration, rainwater harvesting, risk management, adaptation planning and knowledge generation are some of the elements.
3	Sustainable Watershed Management (Future project)	Projects under the Aligned National Action Programme (NAP) of Swaziland for the United Nations Convention to Combat Desertification	This project helps water resources adapt to climate change. The project focuses on groundwater, invasive alien species control, community based land and rangeland rehabilitation, sustainable use of wetlands and spring protection, restoration and rehabilitation of natural forests and woodlands. It also looks at development of forest environment, community based eco-tourism, documentation of traditional/indigenous knowledge on soil and water conservation, artificial recharge of ground water and national rainfall water harvesting. All these are climate change adaptation techniques.
4	IWRM	As part of the PAWD	The project aimed to revitalize and to set up

	demonstration projects	(Partnership for African Water Development) program, the Swaziland Country Water Partnership embarked on an IWRM demonstration project to test how IWRM principles could actually be applied on the ground.	management rules for the Mvutjini earth dam in KaLanga. As a result of the project the earth dam was fenced and trees cleared, animal drinking troughs built, boreholes were installed, an organized gardening scheme was created and sanitary facilities were built. The local community was also given training and education and involvement of stakeholders from governmental bodies, NGOs and local dwellers was ensured through community meetings (Van Koppen *et al*., 2009)
5	Clean the rivers project	Moss Foundation	This project has been ongoing since 2010 and diverts river water into wash stations for women in villages where previously they used to wash clothes in the river bed. The project has advantages of providing women with dignified and clean access to water and a washing facility as well as has environmental benefits as washing is no longer done in the river bed and waste water from wash stations are filtered through a filtration system before being discharged into nature. The area surrounding the wash stations are planted with trees that provide shade to the women (see photo essay on this project).
6	Rainwater harvesting	Several organizations such as UNICEF, Palm Foundation	Rainwater harvesting from rooftops of households and institutions such as schools to augment water supply. Rainwater harvesting helps households adapt to climate change primarily through diversification of household water supply and increased resilience to water quality degradation. Harvesting rainwater helps reduce the pressure on surface and groundwater resources by decreasing household demand. With climate change affecting rainfall patterns, storage of rainwater can provide short-term security against periods of low rainfall and the failure or degradation of other water supplies. Water scarcity impacts of hindering economic development and affecting human health and well-being, can be reduced using this technology

In addition to the listed projects in Table 8, there are several water supply and irrigation projects that have been on going in the country. These projects have identified that public participation, participatory approaches, local level infrastructural development, targeting vulnerable groups, being gender sensitive, enhancing community leadership, transparency in financing, improving coordination amongst supporting agencies and sharing knowledge are some of the success factors. These are good principles that will help in improving the water sector and also helping with climate change management. The NCCSAP recommends, prioritizing the implementation of Integrated Water Resources Management (IWRM) and enhancing risk management and early warning systems, in addition to mainstreaming climate change into sectoral policies and plans for the water sector. Protecting catchment areas, promoting groundwater recharge, rainwater harvesting, recycling and reuse and water saving technologies are suggested in the NCCSAP (Government of Swaziland, 2014).

3.3 Adaptation Technology Options for Water Sector and their main Adaptation benefits

There are a number of technologies that can help the water sector adapt effectively to climate change. These are listed in table below and further details are provided in factsheets in Annex I. Some images of existing projects are provided in photo essays in Chapter 6.

Table 8 Water sector technology options for Swaziland and how they help in climate change adaptation

No.	Technologies	Adaptation benefit
1	Artificial groundwater recharge	With climate change, water stress is expected and recharging groundwater aquifers helps ensure water demand is met during dry seasons and helps in ecosystem restoration. It also aids in conservation and storage of excess surface water for future requirements and helps improve the quality of existing groundwater through dilution. In Swaziland demand for water has led to drilling of boreholes to tap groundwater and it was reported by stakeholders that in many areas, especially in the Lowveld, boreholes have dried up, indicative of the need for replenishing groundwater through this technology.
2	Rainwater harvesting through rooftops and dams	Rainwater harvesting helps households to adapt to climate change through diversification of household water supply and increasing resilience to water quality degradation. Harvesting rainwater from rooftops is simple and inexpensive technology that helps reduce pressure on surface and groundwater resources by decreasing household demand. With climate change affecting rainfall patterns, storage of rainwater can provide short-term security against periods of low rainfall and the failure or degradation of other water supplies.
3	Wetlands restoration	Wetland restoration involves planting of wetland plants and providing fencing around wetlands to protect them. With climate change, frequency of extreme weather events such as floods will increase. Wetland rehabilitation and restoration helps maintain its ecological functions of flood control and biodiversity maintenance. Restoration of wetlands helps build ecosystem resilience as well as resilience of humans through hazard mitigation and biodiversity and micro-climate preservation.

4	Sand dams	Sand dams are steel reinforced concrete walls built across a seasonal sandy riverbed. It collects river sand and forms an underground reservoir which can be used by community through pipes from an infiltration gallery. They are a cost effective way of harvesting rainwater and providing communities with a clean, local and reliable source of water, especially during dry periods. Sand dams store water below ground and supply water year round in a clean manner as contamination, evaporation and parasite infestation is minimized. These will help communities access water during dry spells and the dam provides environmental benefits of replenishing groundwater as well as allowing vegetation to thrive along river banks.
5	Integrated River Basin Management (IRBM)	IRBM is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources. Since most of Swaziland's rivers are transboundary, there is need for river basin level management which allows for regional integration and uses an ecosystems approach. Climate change cuts across many sectors and water supply directly and indirectly affects sectors such as agriculture, industry, tourism and socio-economic sectors, hence in managing water resources integrated approach of IRBM is useful.
6	Water recycling and reuse	Climate change will create stress for water, hence water recycling and reuse will be a good way of meeting demands as well as utilising resources in a sustainable manner. Water reclamation and reuse employs same technologies as conventional wastewater treatment. Recycling and reuse of water helps protect aquatic ecosystems by decreasing the diversion of freshwater, as well as reducing the quantity of nutrients and other toxic contaminants entering waterways.
7	Leakage Detection	Controlling water leakage using water meters, acoustic detectors, chemical marking etc. helps prevent loss in water supply and conserve water resources in the wake of climate change induced stresses. This technology controls loss of water through leaks and reduces need for maintenance of water systems through early detection. Using this technology is a way of conserving water resources which is essential due to pressures caused by climate change.

Source: Climatetechwiki, 2015, UNDP, 2016.

As indicated in Table 8, the technologies listed above have adaptation benefits and were suggested by stakeholders as they felt these technologies were mature for Swaziland and would receive expert as well as political support, since they contribute to efficient use, water saving and provide multiple benefits (social, economic and environmental). These were developed into factsheets and further prioritised during the technology prioritization workshop.

3.4 Criteria and process of technology prioritisation

Technology prioritization was done at a workshop held between 20-21 August 2015 where criteria for prioritizing technologies was developed by stakeholders and multi criteria analysis was used to prioritize technologies. The steps for undertaking the MCA followed by stakeholders was as follows:

1. **Identify the options.** This is list of technologies for the sector which were provided to stakeholders and information presented in the form of factsheets.
2. **Identify the criteria.** Stakeholders chose various criteria for each sector. For instance, for the water sector they chose water efficiency, capital costs, job creation, maturity, environmental sustainability, social acceptability and gender equity. These were chosen after deliberations and discussions of what were most important for the country in terms of achieving their development goals as well as improving resilience to climate change. Water efficiency was chosen as a criteria because with climate change southern Africa is expected to face water stress and therefore efficient use of water is needed. Technologies which had high capital costs were not preferred, while technologies that created jobs, were environmentally sustainable and socially acceptable were preferred. Maturity was a criteria used because technologies which were already mature for use in Swaziland were preferred due to ease of implementation. Environmental sustainability was another selected criteria due to the fact that all technologies chosen should be environment friendly and not cause pollution. Also stakeholders took into account that adaptation technologies ought not result in increased GHG emissions which would need mitigation efforts. Furthermore, they felt technologies which were accepted socially and allowed no gender bias were preferred.
3. **Weighting.** Assign weights for each of the criteria to reflect their relative importance to the decision. Stakeholders weighed their criteria according to importance by allocating percentages to each criteria. For example, in the water sector, high weightage (30%) was given to environmental sustainability and water efficiency (20%). This was chosen by stakeholders in a participatory manner by debating the importance of the criteria.
4. **Overall value calculation.** Combining the weights and scores for each of the options to derive and overall value. This was done by the consultant after entering the values of ranks and weightages into the Excel based MCA tool.
5. **Examination of the results.** The results were presented to the plenary and discussed.

An important feature of Multi Criteria Analysis (MCA) is its ability to use the expert judgment of the stakeholders e.g. within the setting of a sectoral working group in TNA. This includes establishing targets and criteria, estimating relative importance of weights and in judging the contribution of each technology to each performance criterion. The stakeholders arrived at a collective decision and prioritized three technologies per sector. The MCA Excel based tool provided by UNEP DTU Partnership was used for the MCA exercise.

Figure 6 Working group participants prioritization and ranking technologies

3.5 Results of technology prioritisation

Stakeholders conducted a technology prioritization session where they selected three technologies per sector for climate change adaptation. For the water sector the criteria for ranking technologies were water efficiency, capital costs, job creation, maturity, environmental sustainability, social acceptability and gender equity.

Rationale for criteria selection:

Water efficiency was chosen as a criteria because stakeholders felt that with changing climate putting stress on water resources, technologies chosen should encourage efficient use of water. Overhead sprinklers result in a lot of water wastage due to evaporation and wind dispersal, whereas a technology like drip irrigation has high water efficiency. Capital costs was chosen as a criteria and projects with high capital costs were not preferred. This is due to difficulty in sourcing for finance and also in up scaling. Job creation was a criteria which stakeholders felt was important as technologies that created jobs would boost the economy and address the unemployment issue in the country. Maturity of the technology was important as some technologies may not be commercialised and thus have investment risk for Swaziland. Environmental sustainability was another criteria which stakeholders felt was important as adaptation requires not only addressing human needs but also ensuring environmental resilience is improved. Social acceptability was needed as many technologies have failed as they were not socially acceptable. Gender equity was also a criteria because technologies should be friendly for use to both genders to be widely acceptable.

Highest weight was provided for environmental sustainability (30%), followed by water efficiency (20%) and capital costs and job creation were given equal weight (15%). Stakeholders then ranked each of the technologies based on each of these criteria. The weighted scores were compared and

three technologies were chosen which had highest scores. The rankings and weightages for each sector during the technology prioritization process are provided in Table 9.

Table 9 Technology rankings for Water sector

Option/Criterion	Water efficiency	Capital costs	Job creation	Maturity	Environmental sustainability	Social acceptability	Gender equity
Units	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5
Preferred value	High	Low	High	High	High	High	High
Weights	20%	15%	15%	5%	30%	10%	5%
Artificial groundwater recharge	5	3	3	2	5	4	5
Integrated River Basin Management	5	4	4	4	5	5	5
Leakage Detection	5	5	3	2	5	3	3
Rooftop Rainwater Harvesting	4	2	1	5	5	5	5
Sand dams	5	5	4	2	4	4	5
Water recycling and reuse	5	5	4	2	4	1	1
Wetland restoration	5	4	3	4	5	4	5
Water efficient technologies	5	5	3.5	2	5	4.5	5
Long distance water transfer	4	5	3	1.5	3.5	3.5	1
Earth dam lining	3.5	5	4	2.5	3.5	3	1.5

It is to be noted that “Long distance water transfer” and “Earth dam lining” were two technologies that were brought up at the technology prioritization workshop by stakeholders. These did not have factsheets and were not part of the list developed during the sector prioritization list, when technologies to be developed into factsheets were itemised. The stakeholders who had suggested these technologies explained to the participants, the key aspects of the technology. However, both these technologies scored low in final weighted scores, hence it was agreed by the workshop participants that were not to be developed into factsheets. The Table 10 provides final weighted scores and

technologies prioritized. Integrated River Basin Management got the highest score followed by artificial ground water storage and wetland restoration technologies.

Table 10 Prioritized technologies for water sector and weighted scores

Rank	Option	Weighted Score %
1	**Integrated River Basin Management**	**87.3**
2	**Artificial groundwater recharge**	**83.2**
3	**Wetland restoration**	**78.6**
4	Water efficient technologies	77.0
5	Leakage Detection	67.5
6	Rooftop Rainwater Harvesting	65.0
7	Sand dams	47.0
8	Water recycling and reuse	45.7
9	Long distance water transfer	16.3
10	Earth dam lining	12.1

The technologies that scored the highest are technologies that Swaziland needs in order to assist the water sector to adapt effectively to climate change. Stakeholders noted that groundwater maps have not been created for Swaziland due to lack of adequate data. However, they stated that in many areas of the country, drying of boreholes and lowering of water tables have been experienced. Hence prioritizing groundwater recharge will be beneficial for the country. The three top prioritised technologies would be developed into technology action plans with further stakeholder engagement at a later stage in the TNA project. They are Integrated River Basin Management, Artificial groundwater recharge and Wetland restoration. They are explained in detail in the factsheets provided. IRBM provides tools for managing river basins. In Swaziland, there are several rivers which are transboundary in nature and can benefit from this technology. Using an ecosystems approach in river basin management can help in improving environmental health through providing adequate water for ecosystem functions and conserving vegetation and thereby biodiversity and habitats. The second technology prioritised, artificial groundwater recharge, helps improve water supply which in turn helps improve health and hygiene as well as opportunities for generating income through using the water for irrigation and industry. There is opportunity to do groundwater recharge in Swaziland at various scales. The geology of the country and terrain makes it a suitable technology to use. For the Swazi context, wetland restoration is highly important, with Swaziland's most important cultural event the reed dance requires reeds extracted from wetlands. Besides its cultural significance, restoring wetlands allows it to continue its ecological functions such as flood control and habitats for biodiversity. Medicinal plants extracted from wetlands can help in improving health. Micro climate around wetlands and its aesthetic qualities have eco-tourism potential and can have healing effects for humans. Opportunities for income generation through sale of products derived from wetlands such as reeds used for thatching and basket weaving. In Swaziland there are several wetlands and if properly utilized can provide socio-economic benefits as well as environmental benefits.

Chapter 4 Technology prioritisation for Agriculture Sector

Agriculture is the mainstay for Swaziland's economy and contributes 11% to the Gross Domestic Product (GDP) of the country (Food and Agricultural Organization, 2015). Given that the agricultural sector is highly vulnerable to weather related production shocks, it is imperative that the sector adapts effectively to climate change. In this regard, adaptation technologies are important and this chapter will focus on the technology prioritization for the agriculture sector.

4.1 Key Climate Change Vulnerabilities in Agriculture Sector

Swaziland is prone to hydro-meteorological disasters, with drought being most common, according to Manyatsi and Mhazo (2014). Downscaled global climate change models (GCMs) predict a temperature rise of 1 to 1.5 oC across Swaziland for the years 2000 and 2050, and a reduction of up to 200mm in annual rainfall over much of the country (Manyatsi *et al.*, 2012). The high rate of poverty and large number of subsistence farmers that depend on rain fed agriculture, compromises their ability to adapt to climate change. The El Niño weather phenomenon has been associated with reduced rainfall levels and Swaziland experienced this in year 2015, when poor crop production was experienced. In 2014/15, a prolonged dry spell between January and March had a severe impact on yields and it reduced production by 31% (Food and Agricultural Organization, 2015). With climate change, extreme weather events, dry spells, higher temperatures and climate induced risks such as increased pests and higher evaporation will all affect agriculture, livestock included. Swaziland has reported 25.6% under five years stunting rate, which is indicative of poor nutrition. The Times of Swaziland (14 August 2015) noted that due to poor harvesting practices, Swazi farmers lost about E41.2million (equivalent to $3.1million) or 16,000 tonnes of maize (Maziya, 2015). Swaziland needs to improve the capacity of its small scale farmers, particularly in the light of climate change. Therefore, technologies such as irrigation and improved land management are vital for the sector to effectively adapt and ensure food security in the country. This is discussed in further detail below.

4.2 Decision context and overview of existing technologies in Agricultural sector

Swaziland has been implementing projects that help the agricultural sector adapt to climate change and this includes conservation agriculture which was introduced in 2002 by the Ministry of Agriculture with support from Food and Agricultural Organization and the Cooperation of the Development of Emerging Countries (COSPE). Drought tolerant varieties have been introduced through the Harmonised Seed Security Project (HASSP) and it is estimated that 50% of farmers in Swaziland use recycled seeds, which are cheaper than hybrids and have better post-harvesting qualities (Manyatsi and Mhazo, 2014). Maize yields on SNL are very low and are heavily dependent on rainfall. Maize being the staple crop, is widely cultivated in Swaziland. The average yield of maize varies depending on the area with highest yields obtained in the Highveld and moist Middleveld (MOA, 2013). The maize yield on Swazi National Land (SNL) which is communal land where rain fed farming is practised mostly, is 4.42 tonnes per hectare (Dlamini and Masuku, 2011). Maize farming on Swazi Nation Land is mainly for subsistence with little intention for commercial purposes.

Irrigation is used by commercial farmers such as the sugarcane estates, however the small scale farmers reported lack of access to water and high costs to be some of the barriers for lack of adoption

of this technology. Introduction of new crop varieties have been done in the Rural Development Areas to improve diversity and improve production, and these include baby vegetables[4], cassava, Irish potatoes, sorghum, fruit trees, mushrooms, beans and cotton. Use of animal dung as manure and agroforestry are some of the practices also being done in the country. However, unreliable rainfall patterns, persistent droughts and pests and diseases have all affected agriculture in Swaziland.

There are a number of efforts taking place in the country to address food security and enhance productivity in the agriculture sector. These include projects and programmes supported by government and development partners as well as those done by civil society and other players as listed in Table below.

Table 11 Agricultural projects in Swaziland

No.	Name of Project	Donor/Partner	Description of project
1	Food Security in a Changing Environment (2009-2012)	European Commission and Vusumnotfo Ltd.	This project focuses on environmental education and training. It includes elements of sustainable gardening practices through a programming response refined for further roll out. It contributes to poverty reduction in Swaziland, through sustainable food security at family level. Target regions were Northern Hhohho Tinkhundla - 6 communities within Mayiwane, Etimphisini, and Entfonjeni Tinkhundla.
2	Harmonised Seed Security Project (HASSP) (ongoing)	Supported by FARNPAN	The Harmonised Seed Security Project (HaSSP) is a FANRPAN project that seeks to address seed security in the SADC region by aligning country protocols in order to increase availability of and access to quality affordable seed for smallholder farmers. The project aims to increase production and uptake of drought and heat tolerant seeds for use by those at risk. Furthermore, it also helps align seed variety release policies, phytosanitary policies and seed certification policies. It also helps strengthen capacity of government, civil service and other key stakeholders as well as strengthen seed certification facilities.
3	Swaziland Smallholder	Supported by European Commission and	The project helps develop land for irrigation and then assists smallholders, who pool their

[4] Baby vegetables are fully ripe miniature vegetables which have same nutrition as normal vegetables, but take less time to mature, hence in one cropping season multiple harvests are possible.

	Irrigation Project (SHIP) (2009-2012)	implemented by GRM International	land, to become effective farming enterprises.
4	Smallholder Agricultural Development Project (SADP) (2007-2011)	UNDP, IFAD and FAO with support from European Union	The Project aims at improving the incomes and food security of Swaziland's disadvantaged smallholder families, particularly women on Swazi Nation Land (SNL). Includes intervention on agricultural productivity, irrigation and livestock management.
5	Mitigation of negative impacts of climate change in Swaziland (2012-2015)	International Relief and Development	The project provides interventions that aid in climate change adaptation in agriculture and water with outcomes of improved food security, sanitation and hygiene. They have targeted 15 Tinkhundlas[5]. Activities such as conservation agriculture, horticulture, food preservation and trainings on water and sanitation are part of this project.
6	Komati Downstream Development Project (KDDP) (2003-2006)	Government of Swaziland and implemented by Swaziland Komati Projects Enterprise	This project helped smallholder farmers build irrigation infrastructure, intensify production and link with markets.
7	Sustainable Livelihoods, Poverty Alleviation and Alternative Livelihoods (Future project)	Projects under the Aligned National Action Programme (NAP) of Swaziland for the United Nations Convention to Combat Desertification	Although not specifically aiming at climate change adaptation, the activities in this project help communities adapt. The project promoted indigenous chickens, agroforestry and nurseries, mushrooms, bee-keeping, flexi-biogas systems and home gardens, infield water harvesting technologies, goat production and non-timber forest products.
8	Organic Farming (Ongoing)	COSPE	COSPE considers organic agriculture as one of the technologies that can truly adapt and mitigate climate change. The project is implemented in the Lubombo region and target small to middle scale farmers. Processing and marketing of organic produce is also part of this project.

[5] Thinkhundla is a traditional administrative subdivision smaller than a district but larger than a chiefdom. The country has 55 Tinkhundla and 385 Chiefdoms.

In Addition, Ministry of Agriculture is undertaking many activities such as provision of extension services to farmers, agroforestry, conservation agriculture, fodder conservation and equipping farmers with tractors and irrigation facilities.

4.3 Adaptation Technology Options for Agriculture Sector and their main Adaptation benefits

There are many adaptation options in agriculture sector ranging from irrigation to modern biotechnology and these are provided in table below. Table 12 provides a brief description and adaptation benefits of the technologies. However, detailed information for prioritised technologies are provided in the factsheets in annex 1.

Table 12 Adaptation technology options for agriculture sector

No.	Technology	Brief description	Adaptation benefit
1	Conservation agriculture	Conservation agriculture is a form of farming where minimum soil disturbance, maintaining a permanent soil cover through retention of crop residues and growing cover crops, crop rotations and application of integrated pest management strategies help in making farming sustainable.	This technology helps increase ability of soil to store or sequester carbon, enrich the soil, improve soil surface stabilization, reduce leaching of nutrients, decreases evaporation, improve water retention, increase yield and reduce need for tractors to pass on field thereby reducing need for fossil fuels. Conservation agriculture is not widely practised in Swaziland, although some projects do exist. There is scope for small holders and subsistence farmers to adopt this technology. This technology will be replacing conventional tillage farming which is mostly rain-fed.
2	Crop diversification	Crop diversification is addition of new crops in a farm aimed at enhancing crop productivity, improving quality, health and nutritional value and helping with improving crop resilience to diseases, pests and environmental stresses.	Having diversified crops on a farm will increase income on small farm holdings and farmers will be able to withstand price fluctuations. Some plants which are drought tolerant when grown with normal crops, will assist the farmer to mitigate the effects of increasing climate variability. This technology also helps in improving fodder for livestock and depending on the types of crops, decrease pests, diseases and weed problems. This technology will be replacing normal mono-cropping that is practised by most farmers in Swaziland. The advantage in using crop diversification will be to reduce their risk when rainfall patterns

			change.
3	Greenhouse farming	Farming in greenhouse structures and allowing crops to grow in a controlled environment protects crops from pests. Greenhouses are constructed with various materials including glass, plastic sheets and insect proof nets that provide insulation and aeration and capture condensate water from plastic covers.	Farming in greenhouses helps improve yields and reduce risks. Greenhouses allow for increasing planting season, providing better yields, longer season of production and crops that are more resilient to environmental and market risks. This technology is not widely practised in Swaziland and could replace normal tillage farming which is vulnerable to climate and weather fluctuations.
4	Hydroponics	Hydroponics/soilless culture is a technology that can contribute to the preservation of water resources and thus to food security. Using this technology one can control the crop growing environment and avoid uncertainties in the water and nutrient status of the soil.	The technology allows for growth of crops in neutral mediums (such as water) in controlled conditions thereby increasing yields and being less vulnerable to climate change impacts. The technology contributes to climate change adaptation by improving crop productivity thereby aiding in increasing food security and reducing pressure on water resources through water saving. This technology has been piloted in the country but is at very low scale. It is an improvement to normal rainfed farming and aquaculture as it combines both these methods to provide increased yields and reducing risks.
5	Livestock and poultry selective breeding	Selective breeding is a technology that aims to improve the value of animal genetic diversity. This technology can be applied to all types of livestock, including cattle, sheep, goats, pigs and chickens.	Selective breeding of livestock and poultry helps improve animal genetic diversity, productivity of species, health and welfare of animals. The livestock and poultry produced through this method will be sturdier and can withstand shocks such as prolonged dry spells, extreme temperatures, pests and diseases.
6	Micro irrigation	Micro irrigation systems include drip irrigation which target roots of field crops, and sprinklers, which	With climate change, rainfall patterns will vary and dry spells are expected. For agriculture to adapt to these conditions, irrigation is important. Drip irrigation and

		are pressurized irrigation systems that use moving platforms or devices to simulate natural rainfall. Water efficiency for sprinklers is 50-70%, while for drip irrigation it is up to 90% and can also be used in greenhouses, nurseries, orchards and plants in containers. Both systems can be gravity fed or pressurized.	sprinklers provide just the right amount of water and is an efficient technology that will help contribute to improving food security and enhancing food production. Both systems increase crop yield and allow for various types of crops including row, field and tree crops that are grown closely together, such as cereals, pulses, wheat, sugarcane, groundnut, cotton, vegetables and fruits. Swaziland is a mountainous country and both drip and sprinkler irrigation technology is well adapted to a range of topographies and is suitable for all types of soil, except heavy clay. This technology will be replacing rain fed agriculture and inefficient irrigation methods such as overhead sprinklers. Most farmers are dependent on rainfall for crop production and are therefore vulnerable to reduced rainfall and accompanying moisture stress on crops. Micro irrigation systems use water efficiently thereby conserving water.
7	Organic farming	Organic farming is an agriculture system which excludes the use of synthetic fertilisers, pesticides and growth regulators. Instead it promotes the use of crop rotations, green manures, compost, biological pest control and mechanical cultivation for weed control.	It helps in climate change adaptation through improving soil fertility, water retention and yields of crops. The economic benefits of organic farming include low energy and cost of investment. Input costs for seed, fertiliser, pesticides, machinery, and hired labor for example in a rotation system with a leguminous crops are also approximately 20% lower than conventional rotation system. It improves soil fertility. The benefits include health improvement due to reduced pollution of water bodies and soil, with reduction of nitrous gases compared to conventional farming using synthetic chemicals. Improved health helps people adapt to climate change. This has already been practised in Swaziland and could replace farming using synthetic chemicals. Stakeholders felt that

			there is scope for expanding organic farming in the country as the products fetch a higher price on the market and have health benefits.
8	Solar drying	In a solar dryer, produce can be placed in racks without direct exposure to the environment and there is no secondary contamination of the products from rain, dust, insects, rodents or birds. The products are dried by hot air only. The solar energy produces hot air in the solar collectors. A steady stream of hot air into the drying chamber circulating through and over the crop being dried results in continuous and efficient dehydration.	With climate change comes varying rainfall patterns which will affect agriculture and thereby food production. Preserving food and reducing wastage helps in adaptation and solar drying is a technology to dry food at a faster rate without contamination of dust, mould and flies. It helps with increasing food availability during off season period. This technology is not being widely used in the country. It will help improve food security by keeping dry vegetables and fruits available for longer and also reduce wastage. It will replace the practises of wasting excess products which cannot be consumed or sold due to their perishable nature.
9	Fodder conservation	Fodder conservation is conservation and storage of succulent roughage, crop residues or hay. Silage-making is practiced to store and preserve green fodder, when it is available in excess, for later use during scarcity. The fodder conservation process commences with the cutting of the crop. The crop should be at a phase in the growth cycle where vegetative growth and plant sugars are at or near their peak. This will ensure that important feed attributes such as protein, digestible energy, dry matter percentage and digestibility	Fodder conservation improves availability of feed for livestock. Fodder maybe conserved for two purposes, either to act as a long-term drought reserve or to reduce nutritional problems that occur within the year say for example in winter. This improves productivity of livestock. Hay production is the most common fodder conservation practice. Haymaking can be mechanized using rotary mowers, tractors and baling machines. Storing hay also reduces pressure on grazing land. Despite livestock farming being important and widely practised in the country, farmers tend to only depend on grazing to provide food for their livestock. Fodder conservation will help improve livestock food security and therefore improve their health and avoid livestock deaths during lean season when food for animals is not available.

		are at their highest potential at the beginning of the conservation process.	
10	Modern biotechnology	"Biotechnology" means the application of science and engineering in the direct or indirect use of living organisms, or parts or products of living organisms, in their natural or modified forms. "Modern biotechnology" is used to distinguish newer applications of biotechnology, such as genetic engineering and cell fusion from more conventional methods such as breeding, or fermentation.	Benefits of Modern Biotechnology include improved yields, better waste management and value adding of products. Biotechnology can be used as a tool to improve crops and animals yields, thus ensuring food security. It can be used in the industry to produce environmental friendly products such as biofuel and biodegradable plastic materials. This could replace the traditional methods for livestock breeding and reduce diseases in plants. Plants and animals can be improved by selectively breeding for particular traits or by genetic modification. Beneficial traits can be identified visually or by DNA profiling. For example, farmers may want plants with herbicide or insect resistance, tolerance to different growing environments or improved storage, or they may want livestock with better meat and wool or resistance to disease.

Solar drying, fodder conservation and modern biotechnology were technologies brought up by stakeholders in the technology prioritization workshop. These technologies were not initially discussed in the first workshop (sector prioritization workshop) and did not have factsheets developed in the first stage of the project. Since the TNA is a stakeholder driven process, it was accepted that the second workshop discuss these three technologies and include them in MCA exercise. Details regarding the technologies were presented to the forum by the experts who suggested the technologies (academicians and practitioners). Therefore, stakeholders at the workshop were given adequate information about the technologies prior to the MCA analysis. All the technologies in table 12 have elements of water saving, soil improvement, productivity improvement and numerous of benefits including food security enhancement and environmental welfares.

4.4 Criteria and process of technology prioritisation

Criteria for prioritization of technology were income generation, job creation, food and nutrition security, capital costs, sustainable production, gender, maturity, availability and accessibility of implements and level of capacity. These criteria were chosen by stakeholders after deliberations and

discussions. Income generation and job creation were criteria chosen because stakeholders felt that technologies should be carefully chosen which help Swazis to generate income and create employment opportunities. Thus technologies that were capital intensive and mechanized which created less jobs were less desirable. Since the sector under discussion is agriculture, stakeholders felt that technologies that improve food and nutrition security were to be prioritised and hence it was chosen as a criteria. High capital costs for technologies were an impediment to technology use and diffusion, hence "capital costs" were chosen as a criteria but technologies with low capital costs were preferred. Other criteria such as sustainable production was chosen to ensure that technologies remain sustainable for long term. Sustainable production is defined as the creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources. Gender was chosen as a criteria to ensure that technologies are appropriate to both genders and did not favour one against the other. Maturity of technology was a criteria chosen because applicability of technology depends on whether it is commercialised in the country. One of the key indicators of a mature technology is the ease of use including by non-experts. Availability and accessibility of implements will determine diffusion and use of technology. If implements (which are tools and parts of the technology/equipment) have to be imported at a high cost, the technology may not be appropriate for the country. Hence these were also chosen as criteria in the MCA exercise. "Level of capacity" was also taken as a criteria and this meant both institutional and technical capacity to use the technology.

The weightage provided for food and nutrition security was highest at 25%, followed by income generation (20%) and others received weightages of 10% and 5% as indicated in table below. Scores of 1 to 5 were given to each criteria while evaluating each technology and results are provided in Table 13.

Table 13 Technology prioritization in the agriculture sector

Option/Criterion	Income Generation	Job Creation	Food and Nutrition Security	Capital costs	Sustainable production	Gender	Maturity	Availability & accessibility of implements	Level of capacity
Units	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5	Rank 1-5
Preferred value	High	High	High	Low	High	High	High	High	High
Weights	20%	10%	25%	5%	10%	5%	5%	10%	10%
Conservation Agriculture	4	4	5	5	5	5	3	4	3
Crop Diversification	4	4	5	3	5	5	2	2	4
Greenhouse Farming	5	2	5	5	5	5	1	1	1

Hydroponics	5	2	5	5	5	5	1	1	1
Livestock and Poultry selective breeding	5	5	5	1	5	5	2	2	2
Micro irrigation	5	1	5	5	5	5	4	4	3
Organic farming	1	2	5	1	5	5	1	5	1
Solar dryers	3	4	5	1	5	5	1	4	1
Fodder Conservation	5	4	4	2	4	2	1	3	3
Modern Biotechnology	5	5	5	4	3	1	4	4	2

4.5 Results of technology prioritisation

Some sensitivity analysis was done and weightages adjusted after stakeholders saw the weighted scores. Based on weighted scores three technologies per sector were prioritized. Livestock and poultry selective breeding received the highest weighted average score of 82.5%, while conservation agriculture was a close second with 80% and crop diversification received a score of 79.2%. These technologies will be developed into technology action plans for the next stage of TNA.

Table 14 Technologies prioritized in Agriculture sector

Rank	Option	Weighted Score %
1	**Livestock and Poultry selective breeding**	**82.5**
2	**Conservation Agriculture**	**80.0**
3	**Crop Diversification**	**79.2**
4	Micro irrigation - drip and sprinkler	79.2[6]
5	Solar dryers	70.0
6	Greenhouse Farming	62.5
7	Hydroponics	62.5
8	Modern Biotechnology	60.4
9	Organic farming	57.5
10	Fodder Conservation	42.9

The top three prioritised technologies will be developed into technology action plans (Table 14). In Swaziland the Nguni cattle and indigenous varieties are suited for climate variability and been in production for many years. Indigenous knowledge exists about this in farmers of Swaziland. Improved varieties of cattle have a demand in the market, as Swaziland beef is in demand both domestically and for export. Selective breeding has been done for generations by farmers and there is indigenous knowledge about this. Hence it is an accepted technology and modernizing this and creating further awareness will improve adoption. Dairy Management Board and NAMBOARD and private sector may support and invest in this technology, as the benefits are manifold. Swaziland has

[6] Although the scores for crop diversification and micro irrigation were same, sensitivity analysis was not done as stakeholders at the technology prioritization workshop used their judgement to prioritise crop diversification. However, at the validation workshop later on, stakeholders decided to opt for micro irrigation as one of the priorities instead of crop diversification, because the country was going through a drought and they argued that conservation agriculture includes elements of crop diversification.

experienced loss of labour due to HIV and AIDS related illnesses and deaths and using conservation tillage and machines for planting reduces the amount of labour traditionally required in land preparation and weeding. Crop diversification helps in providing a nutritional and diversified diet on the same land. The increased yields due to conservation agriculture can help improve food security.

Chapter 5 Technology prioritisation for Forestry and Biodiversity Sector

Healthy forests and ecosystems are vital to implementation of climate change adaptation and mitigation strategies. Forests and ecosystems provide services which are beneficial to ensuring that livelihoods can withstand shocks of climate change and become resilient. Swaziland prides in being a tourist attraction, which is mostly because of Swaziland's rich biodiversity in its various natural parks where flora and fauna species are abundant. However, this rich biodiversity is at risk of climate change impacts.

5.1 Key Climate Change Vulnerabilities in Forestry and Biodiversity Sector

Forests provide important ecosystem services such as provisioning of food, materials, medicine, have ecological functions of storing water and slowly releasing, detoxifying waste and provides attractions for tourists (Government of Swaziland, 2013). Swaziland has a number of national parks such as Malototja, Hlane, Mkhaya, Milwane and other smaller reserves, which host a number of endangered fauna and flora. Climate change will impact on forests and ecosystems and thereby biodiversity in a number of ways. As temperatures rise and rainfall patterns change with climate change, these biotic systems will undergo change and will shift habitats of species, which may result in loss of biodiversity. Drier and hotter conditions will trigger wildfires. Invasive alien species will find some areas favourable to their growth with the changing climate and due to the fact that they may not have pests that control their growth, their presence will spread rapidly. When forests are affected, the hydrological functions of forests are also affected and in areas where forests have been affected by fire or deforestation by humans, water runoff will be higher, which may cause localised flooding in some areas.

5.2 Decision context and overview of technologies for forests and biodiversity sector

The National Climate Change Strategy and Action Plan (Government of Swaziland, 2013) recommends an ecosystem based approach to biodiversity conservation and calls for strengthening national forest management and enforcement. There are already in place a number of projects and programmes that support forestry and biodiversity sector and these are listed below.

Table 15 Project and programmes that support forestry and biodiversity management in Swaziland

No.	Name of Project	Donor/Partner	Description of project
1	Environmental Sustainability and Climate Change (2012-2015)	UNDP	The project aimed to enable the development of key national frameworks on adaptation to climate change (ACC) and disaster risk reduction (DRR) as well as those prioritized under environmental sustainability. Drafting the climate change policy was also part of this. The project also aimed to enhance knowledge on climate change adaptation and mitigation factors as translation to actionable interventions as prioritized by the institutions and the vulnerable groups. It strengthens partnerships to drive the integration of climate change in national development, indicating the role of the government, private sector and the civil society.
2	Strengthening National and Community Systems for Effective Disaster Risk Management (2013-2014)	UNDP with partners: National Disaster Management Agency (NDMA); Ministry of Tinkhundla and Regional Development (MTRD); Swaziland Association for Local Government Associate (SWALGA); Ministry of Housing and Urban Development (MHUD); Baphalali Swaziland Red Cross Society; World Vision Swaziland. Funded by JICA.	The project helped in strengthening capacity of the Inter Agency Coordination Group (IACG) for effective emergency preparedness and response (EPR). It also helped in building and strengthening national institutions capacity for effective disaster risk management (DRM) at all levels, as well as building and strengthening capacity of local urban government authorities to develop and implement disaster preparedness and response plans. It supported the development of integrated national early warning systems (NEWS) and establishment of national and regional early warning (EW) situation rooms. Also, the project helped in strengthening regional and community disaster preparedness and response systems.

No.	Name of Project	Donor/Partner	Description of project
3	Strengthening the National Protected Areas System (2012-2014)	UNDP with partners: Ministry of Tourism and Environmental Affairs, Swaziland National Trust Commission (SNTC), Swaziland Environment Authority (SEA), Department of Forestry, Protected Areas, Private Sector, Conservancies Communities. Funded by GEF.	The project helped in Policy reforms and knowledge to enable protected areas expansion and removal of threats through co-management. A landscape approach leading to protected areas expansion, and strengthening of core protected areas functions to address existing and emerging threats to biodiversity is also part of this project. Improving ecosystems and areas of environmental importance such as protected areas is a way of climate change adaptation for ecosystems.
4	Community-based Environmental Management Project in Swaziland in Shiseleweni Region, Ngudzeni and Mhlosheni Areas (2008-2011)	European Union and World Vision	This project focuses on environmental education and training in household sustainable farming in Shiseleweni Region, Ngudzeni and Mhlosheni areas. This includes what type of crops to grow, sustainable agricultural practises and nutritional education. Furthermore education related to caring for the environment, growing trees and preventing erosion were also done.
5	Mitigation of negative impacts of climate change in Swaziland (2012-2015)	International Relief and Development (IRD)	The project provides interventions that aid in climate change adaptation in agriculture and water with outcomes of improved food security, sanitation and hygiene. They have targeted 15 Tinkhundlas. Activities such as conservation agriculture, horticulture, food preservation and training on water and sanitation are part of this project.
6	Strengthening national and local resilience to disaster risks in Swaziland (2008-2010)	UNDP	The project improved livelihoods and food security by enhancing capacity of Swaziland to respond to climate related disasters and risks.

No.	Name of Project	Donor/Partner	Description of project
7	Southern African Regional Climate Change Programme (2009-2014)	DFID, SIDA	The project helped synthesize climate evidence and helped countries in the region to enhance their access to climate finance.
8	Promotion of use of efficient and energy saving woodstoves (2008-2010)	Ministry of Natural Resources and Energy with support from GIZ	Promotion of efficient and energy saving woodstoves to help reduce deforestation and indoor air pollution.
9	Sustainable Livelihoods, Poverty Alleviation and Alternative Livelihoods (Future projects)	Projects under the Aligned National Action Programme (NAP) of Swaziland for the United Nations Convention to Combat Desertification (UNCCD)	Although not specifically aiming at climate change adaptation, the activities in this project help communities adapt. The project promoted indigenous Chickens, agroforestry and nurseries, mushrooms, bee-keeping, flexi-biogas systems and home gardens, infield water harvesting technologies, goat production and non-timber forest products.
10	Eco-Lubombo program	COSPE	COSPE in Swaziland is working on the promotion of conservation in the Lubombo Region through the EcoLubombo Program which seeks to protect the highly rich in biodiversity areas of the Eastern Lubombo. The conservation of forests and biodiversity is a reputed key strategy for the development of sustainable and long-term use of land.

In addition to this, Big Game Parks and others work on conserving wildlife, SNTC have put in place measures to monitor and provide early warning for wildfires, biodiversity monitoring studies have been undertaken by the country and the private sector which is custodian of most of the plantations in Swaziland have management systems in place to manage pests and fires. The country is working on a number of initiatives through international collaboration such as the Technical Cooperation Programme (TCP) Project proposal for Community-based Fire Management (CBFIM) in Swaziland in which the Government of Swaziland is working with FAO and collaborating with the Republic of South Africa and Mozambique on the Transfrontier Conservation Areas (TFCAs) (SNTC, 2015). International collaboration is still needed to improve on awareness of this programme.

5.3 Adaptation Technology Options for Forestry and Biodiversity Sector and their main Adaptation benefits

There are a number of technologies that could be adopted in Swaziland to help forestry and biodiversity sector adapt to climate change. These are provided in table below, with information on how they help with adaptation.

Table 16 Adaptation technologies for forestry and biodiversity sector

No.	Technology	Adaptation benefit
1	Agroforestry	Agroforestry helps improve fertility of soil and thereby productivity of land. It involves the land-use practise that encompasses planting of trees along with crops and also keeping livestock in the same field. It provides multiple benefits including provision of firewood and organic materials that can be used a natural fertilisers. Furthermore, there is provision of forage, improvement in soil fertility and improved water flows as soil structure is improved.
2	Integrated Pest Management	This technology helps increase the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. This is an ecologically based pest management that makes full use of natural and cultural processes and methods, including host resistance and biological control. This technology contributes to climate change adaptation by providing a healthy and balanced ecosystem in which the vulnerability of plants to pests and diseases is decreased.
3	Grazing land management	Sustainable grazing land management is a climate change adaptation technology in the animal husbandry sector and it has environmental and biodiversity benefits too. The technology includes managing fire in grazing lands, increasing productivity through irrigation, rotational grazing, planting grasses and reducing erosion.
4	Rehabilitation of degraded land	Swaziland's land is affected by soil erosion and human activities of deforestation and vegetation degradation. Restoring degraded land helps improve its resilience to climate change and allows for biodiversity to thrive.

		The technology involves construction of erosion control structures, contour ridges, rehabilitating dongas and afforestation as well as reforestation.
5	Fire management	Controlling fire and managing it will help reduce damage to land, biodiversity and infrastructure and also reduce emissions that cause climate change. With climate change, dry spells are expected to increase, thus fires may be triggered and managing it includes setting up fire monitoring towers and using remote sensing for early warning and enhancing response measures for fire fighting.
6	Alien invasive species management	With Climate change, comes temperature and rainfall changes, which may be conducive for growth of alien invasive species. Controlling their growth is essential to maintain a healthy ecosystem as the alien species tend to take over and prevent growth of other indigenous species which have important ecological functions as well as provide important ecosystem services. Growth of these may negatively impact food security. A national strategy has been developed, data collected, maps and photographs collated and awareness raised about the need to remove these species.
7	Afforestation	Increasing forest cover allows for greater water retention, improvement of soil fertility, enhancing habitats for fauna, avifauna, insects and microbes and sequesters carbon. Forests also provide additional income during environmental shocks by producing provisioning ecosystem services such as food, fibre and medicine that communities may sell to adapt to the difficult times.
8	Conservation of genetic resources	Conservation of genetic resources, in particular seeds for farmers, is key to the attainment of household food security. The basic objective of good seed storage is to create environmental conditions that protect the product and maintain its quality and its quantity, thus reducing product loss and financial loss. This helps in climate change adaptation by ensuring feed is available for livestock and seed stock is available in the event of poor harvests due to drought. Improving management of forest genetic resources, research and conservation will help in maintaining genetic resources in the country.

5.4 Criteria and process of technology prioritisation

The criteria used for prioritizing technologies were; environmental sustainability, job creation, ecotourism promotion, maturity, income generation, gender, minimizing genetic erosion, capital cost and supporting indigenous knowledge. For the forestry and biodiversity sector, environmental sustainability was a criteria chosen as stakeholders felt that this was important attribute for the sector. Technologies that promote environmental sustainability in terms of conserving forests and biodiversity would be more suited. Job creation was taken as another criteria, technologies that create

new jobs were good for the country to address its social ill of unemployment. Minimizing genetic erosion was considered as a criteria because some technologies such as genetically modified seeds tend to erode genetic diversity in the country and this needed to be avoided. Ecotourism is an important economic activity of Swaziland and technologies that promote this would be preferred and hence "eco tourism promotion" was chosen as a criteria. Similar to other sectors, gender, maturity, capital cost and income generation were also chosen as criteria for this sector. Income generation was considered important in order to reduce poverty levels and this was differentiated from creation of new jobs. Supporting indigenous knowledge was also chosen as criteria because use of natural resources such as forest resources depended a lot on indigenous knowledge. Highest weightage of 30% was given to the criteria of environmental sustainability. The technologies were ranked from 1 to 5 and total weighted scores calculated as provided in Table 17.

Table 17 Ranking of technologies in Forestry and Biodiversity sector

Option/Criterion	**Environmental sustainability**	**Job creation**	**Ecotourism promotion**	**Maturity**	**Income generation**	**Gender**	**Minimizing genetic erosion**	**Capital cost**	**Supporting indigenous knowledge**
Units	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*	*Rank 1-5*
Preferred value	*High*	*High*	*High*	*High*	*High*	*High*	*High*	*Low*	*High*
Weights	*30%*	*10%*	*10%*	*5%*	*10%*	*5%*	*15%*	*10%*	*5%*
Agroforestry	5	2	1	5	4	2	3	1	3
Integrated Pest Management	5	2	1	5	2	1	4	2	3
Grazing land management	4	2	3	2	4	5	5	3	2
Rehabilitation of degraded land	5	4	5	4	2	1	5	5	3
Fire management	4	4	3	3	2	1	5	3	4
Alien invasive species management	5	4	5	4	3	1	5	5	1
Afforestation	5	5	5	4	5	5	5	3	4
Conservation of genetic resources	5	5	5	3.5	3	4	5	4	5

5.5 Results of technology prioritisation

Stakeholders prioritised afforestation, conservation of genetic resources and alien invasive species management as the top three technologies in this sector. Afforestation got a score of 92.1%, while conservation of genetic resources received a weighted average score of 82.1% and alien invasive species management received a score of 68.3% (Table 18). Since afforestation was ranked higher that rehabilitation of degraded land, stakeholders agreed that afforestation activities should also target degraded land. Soil erosion control can also be done through afforestation and planting of beneficial trees such as fruit trees will improve livelihoods.

Table 18 Technologies prioritized in Forestry and Biodiversity sector

Rank	Option	Weighted Score %
1	**Afforestation**	**92.1**
2	**Conservation of genetic resources**	**82.1**
3	**Alien invasive species management**	**68.3**
4	Rehabilitation of degraded land	67.5
5	Agroforestry	55.4
6	Integrated Pest Management	52.5
7	Grazing land management	37.9
8	Fire management	37.1

Afforestation can help rehabilitate degraded land, improve catchments for rivers and thus assist in enhancing hydropower generation, as well as maintain ecosystem integrity. It also helps rehabilitate degraded lands and therefore, it was prioritised as the first technology in this sector. Conservation of genetic resources was prioritised to combat the threat of genetically modified seeds coming into Swaziland through porous borders. This technology helps in conservation of biodiversity and reduces species extinction. It also helps farmers in building a pool of robust seeds which can withstand varying climatic conditions and thereby help in adaptation. Alien invasive species management is a necessity for Swaziland which have wrought havoc by reducing indigenous biodiversity. Swaziland Environment Authority, which is a government department within the Ministry of Tourism and Environmental Affairs, is responsible for overseeing and monitoring all environmental management activities within the country, regards alien invasive species as problematic and detrimental to biodiversity. Some invasive grasses and weeds tend to outperform and grow well thereby taking over grazing lands where sweet palatable grasses for livestock grow. The area of degraded land is not very high and afforestation activities will help address this in Swaziland and hence it was not prioritised. The top three technologies would be developed into TAPs in the next stage of the TNA process.

Chapter 6 Validation workshop

The validation workshop for TNA report was held on 9th of April 2016. Participants from a wide range of sectors were invited. The consultant presented the report and thereafter participants were divided into two groups, one for adaptation and other for mitigation. In the groups, participants deliberated upon the technologies prioritised and looked at in detail at the factsheets. After the discussions, the groups presented their conclusions. It was decided by the stakeholders to make slight modifications in the technologies prioritised. Under Adaptation for water sector, it was decided to prioritize Rain Water Harvesting to replace Artificial Ground Water Recharge. Then the rooftop rainwater harvesting factsheet was evaluated by stakeholders. They observed that the rooftop rainwater harvesting factsheet which was developed was too narrow in focus, concentrating on only one technology. They wanted to include earth dams construction, sand dams and above ground harvesting of rainwater into the factsheet and rename it "rainwater harvesting" using many methods. This suggestion was however not able to be executed because then the factsheet would become too broad and it would not be effective in identifying barriers and develop TAPs. Hence rooftop rainwater harvesting was retained. Wetland restoration was to be renamed "wetland protection and restoration" in order to include elements of protecting wetlands. This was due to the fact that Swaziland recently experience a severe drought and stakeholders felt that rain water harvesting was not done adequately in the country and is a good technology to be upscaled.

Figure 7 Stakeholders at the validation workshop reviewing the adaptation report

Under agricultural sector, stakeholders felt that crop diversification was an element of conservation agriculture and therefore do not need to be a separate technology. They unanimously agreed that considering the recent droughts, there was urgent need for efficient irrigation water use. Hence it was agreed that mirco and drip irrigation would be a technology that would replace crop diversification in the prioritised list of technologies.

For the Forestry and Biodiversity sector, it was decided to replace Afforestation with Agroforestry due to the fact that stakeholders felt afforestation is better suited as a mitigation technology and Swaziland already has a large part of its areas afforested. Stakeholders made specific edits on the

factsheets and the main report, which helped improve the report further. The first priority was given to agroforestry as it had livelihood benefits, followed by conservation of genetic resources and alien invasive species management. Grazing land management was prioritised under mitigation and hence issues of erosion control would fall under that, thus that technology was not prioritised under adaptation. Final list of technologies retained is given in next section.

Chapter 7 Summary and Conclusions

The TNA process in Swaziland began with extensive stakeholder engagement. The sector prioritization process involved brainstorming on country development priorities and discussion of sectors which are most useful for achieving them. It was decided to prioritize water, agriculture and forests and biodiversity sectors for the TNA process under climate change adaptation. Stakeholders felt that these sectors contribute significantly to the development priorities of the country and are likely to be affected adversely by climate change. It is imperative that these three sectors adapt to climate change impacts and adopting environment friendly and climate compatible technologies that address stresses in these sectors is a step in the right direction. Technologies that would help in climate change adaptation for the sectors were listed for all three sectors and stakeholders further prioritised three technologies per sector, which would be developed into technology action plans. The water sector technology priorities were integrated river basin management, Wetland protection and restoration and Rooftop Rain water harvesting. For the agriculture sector, livestock and poultry selective breeding, conservation agriculture and micro and drip irrigation were prioritised. For the forestry and biodiversity sector, agroforestry, conservation of genetic resources and alien invasive species management were prioritised. These have been indicated in table 19 and will be developed into technology action plans. The next step of the TNA process is to undertake a barrier analysis and develop technology action plans.

Table 19 Technologies retained for Technology Action Plans

Sectors	Technologies
Water	Integrated River Basin Management Wetland protection and restoration Rooftop Rain water harvesting
Agriculture	Livestock and Poultry selective breeding Conservation Agriculture Micro and Drip irrigation
Forests and Biodiversity	Agroforestry Conservation of genetic resources Alien invasive species management

Stakeholders indicated that in general there is need to build capacity on climate change adaptation in Swaziland and mainstreaming of climate change issues into national development. The next steps of TNA process include barrier analysis and development of Technology Action Plans. The results of technology prioritization exercise has been endorsed by the TNA Committee and by stakeholder at the validation workshop held in April 2016.

List of References

Brown, R. 2010. Parliamentary Role and Relationship in Effectively Addressing Change issues, Swaziland. *Climate Journal of Agricultural Studies*. Vol. 2, No. 1, 86-98.

Climatetechwiki. 2015. TNA Factsheets for various technologies. Online publication available at www.climatetchwiki.org Accessed Nov 2015.

Dlamini, T. S. 2006. State of Forest and Tree Genetic Resources in Swaziland. Online publication available at http://www.fao.org/DOCREP/005/AC500E/ac500e01.htm Accessed on 14 September 2015.

Dlamini, D.D., and Masuku, M.B. 2011. Land Tenure and Land Productivity: A Case of Maize Production in Swaziland. *Asian Journal of Agricultural Sciences*, 3(4), 301-307.

Energy Research Center (ERC). 2015. 1st Regional Capacity Building Workshop for the TNA Phase II Anglophone group of countries in Africa. Online publication available at http://www.tech-action.org/-/media/Sites/TNA_project/Regional%2520Workshop,%2520Phase%25202/Africa,%2520June%2520 2015/workshop%2520report%2520arusha17August2015_final.ashx%3Fla%3Dda Accessed on 11 October 2015.

FARNPAN. 2015. Evidence to support climate change adaptation in Malawi, Lesotho and Swaziland. Online publication available at http://www.fanrpan.org/documents/d01776/FANPRAN_evidence_to_support_climate_change_adaption_in%20Lesotho_Malawi_Swaziland.pdf Accessed 7 April 2015.

Food and Agricultural Organization. 2015. Trade Statistics -Crops, Live Stock Products & Live Animal, 2013. Online publication available at http://swaziland.opendataforafrica.org/FAOTS2013Sep/trade-statistics-crops-livestockproducts-liveanimal-2013 Accessed on 9 September 2015.

Food and Agricultural Organization. 2015a. AQUASTAT database - Food and Agriculture Organization of the United Nations (FAO). Website accessed on 7 September 2015.

Food and Agriculture Organization / World Food Programme. 2015. Special Report : FAO/WFP Crop and Food Security Assessment Mission to Swaziland. Online publication available at www.fao.org/3/a-i4797e.pdf Accessed on 2 September 2015.

Gamedze, M. 2006. Climate Change Vulnerability and Adaptation Assessments in Swaziland. Online publication Research Abstract available at http://unfccc.int/files/adaptation/adverse_effects_and_response_measures_art_48/application/pdf/200609_swaziland_iva_abstract.pdf Accessed 1 September 2015.

Global Environment Facility (GEF). 2012. Swaziland and the GEF – Factsheet. Online publication available at https://www.thegef.org/gef/sites/thegef.org/files/publication/Swaziland-%20Fact%20Sheet.pdf Accessed on 12 May 2015.

Government of Swaziland, 2014. National Climate Change Strategy and Action Plan. Ministry of Tourism and Environmental Affairs.

Government of Swaziland. 1999. National Development Strategy and Vision 2022.

Government of Swaziland. 2009. National Water Policy. Ministry of Natural Resources and Energy, Mbabane.

Government of Swaziland. 2012. Second National Communication to UNFCCC. Ministry of Tourism and Environmental Affairs, Mbabane.

Government of Swaziland. 2012a. Swaziland Annual Vulnerability Assessment and Analysis Report. Swaziland Vulnerability Assessment Committee, Mbabane.

Government of Swaziland. 2012b. National Multi-Hazard Contingency Plan 2012-2013. Ministry of Tourism and Environmental Affairs.

Government of Swaziland. 2012c. State of the Environment Report. Swaziland Environment Authority, Mbabane.

Government of Swaziland. 2012d. Swaziland Millennium Development Goals Progress Report 2012. Ministry of Economic Planning and Development, Mbabane.

Government of Swaziland. 2013. National Climate Change Strategy and Action Plan, Ministry of Tourism and Environmental Affairs, Mbabane.

Government of Swaziland. 2014. Vulnerability Assessment and Analysis, Vulnerability Assessment Committee, Mbabane.

Manyatsi A.M. 2011. Application of indigenous knowledge systems in hydrological disaster management in Swaziland. *Current Research Journal of Social Scientist* 3(4): 353-357.

Manyatsi, A. M., Mhazo, N., and Masarirambi, M. T. 2010. Climate Variability and Change as Perceived by Rural Communities in Swaziland. *Research Journal of Environmental and Earth Sciences*, 2(3), 165-170.

Manyatsi, A. M., Masarirambi, M. T., Hachigonta, S., Sibanda, L., and Thomas, T. S. 2012. Southern African agriculture and climate change: A comprehensive analysis-Swaziland.

Manyatsi, A.M and Singwane, S. 2013. Climate Change Adaptation Research in Swaziland. Presentation made at the SADC Regional Workshop on Climate Change Adaptation in Agriculture, Lilongwe, Malawi. Online publication available at http://www.caast-net-plus.org/object/news/717/attach/Presentation_by_Swaziland.pdf Accessed on 1 May 2015.

Manyatsi, A.M. and Mhazo, N. 2013. Comprehensive scoping study of climate smart agriculture policies in Swaziland. Unpublished document.

Manyatsi, M.A and Brown, R. 2009. IWRM Survey and Status Report: Swaziland, Global Water Partnership, Southern Africa.

Maziya, P. 14 August 2015. Maize farmers lose E 41.2m due to poor harvesting. Times of Swaziland, Mbabane.

Ministry of Agriculture. 2013. Agricultural services. Mbabane.

Nxumalo, D. N. 2012. Community-perceived household vulnerability to poverty in Mpolonjeni, Swaziland. Unpublished Master's thesis, University of Venda, South Africa.

SADC. 2009. Lessons learnt from IWRM demonstration projects; Innovations in local-level Integrated Water Resource Development, SADC Secretariat, Gaborone.

Seetal, A.R. and Quibell, G. 2003. Water Allocation- Principles, Priorities & Approaches. Joint Australia-South Africa Workshop on Water resources Management, Melbourne (Australia), 1-5 April 2003.

Shongwe P., Masuku M.B. and Manyatsi A.M. 2014.Factors influencing the choice of climate change adaptation strategies by households: a case of Mpolonjeni Area Development Programme (ADP) in Swaziland. Journal of Agricultural Science, 2 (1), pp.86-98.

Swaziland National Trust Commission. 2015. Swaziland Biodiversity Fauna threatened and red list. Online publication available at http://sntc.org.sz/biodiversity/faunardb.asp Accessed on 9 September 2015.

Swaziland Environment Authority. 2014. Swaziland's Fifth National Report to the Convention on Biological Diversity, Swaziland Environment Authority, Mbabane.

Sweet, R.J. and Khumalo S. 1994. Range Resources and Grazing Potentials in Swaziland. FAO Report, Ministry of Agriculture and Co-operatives, Mbabane.

UNCCD Secretariat. 2006. Implementing the UNCCD in Africa: Ten African Experiences. UNCCD Secretariat, Bonn.

UNDP, 2013. Adapting National and Transboundary Water Resources Management to Manage the Expected Impacts of Climate Change Project, Mission 1 (14-18 October 2013) Report. Online publication available at http://www.sz.undp.org/content/dam/swaziland/docs/thematics/UNDP_SZ_Environment_AdaptingNationalandTransboundaryWaterResources_Mission1Report.pdf Accessed on 9 July 2015.

UNDP. 2015. Adapting Water Resource Management in Swaziland to Manage Expected Climate Change. Online publication available at http://www.undp-alm.org/projects/sccf-swaziland Accessed on 12_3_2015.

UNDP. 2016. As rivers dry up, Swaziland builds dams to harvest water. Online publication available at http://www.undp.org/content/undp/en/home/ourwork/ourstories/as-rivers-dry-up-swaziland-builds-dams-to-harvest-water.html Accessed on 21 March 2016.

Oseni, T. O. and Masarirambi, M. T. 2011. The Effects of Climate Change on Maize Production and Food Security in Swaziland. *American Journal of Agriculture and Environmental Science*, 11(3), 385-393.

UNFCCC. 2015. Articles 4.3, 4.5 and 4.7. Online publication available at http://unfccc.int/ttclear/templates/render_cms_page?NAD_home Accessed on 13_3_2015.

Urquhart P. and Lotz-Sisitka H. 2014. SARUA Climate Change Counts Mapping Study : Swaziland Country Report. SARUA, South Africa.

USAID. 2007. Swaziland: 118/119 Biodiversity and Forest Assessment. Biodiversity Analysis and Technical Support team, USAID Bureau for Africa. Online publication available at http://www.encapafrica.org/documents/biofor/Swaziland2007.pdf Accessed on 9 September 2015.

Van Aalst, M.K., Cannon, T., Burton, I., 2008. Community level adaptation to climate change: the potential role of participatory community risk assessment. *Global Environmental Change* 18, 165–179.

Van Koppen, B., Chisaka, J., and Sibande Shaba, S. 2009. Lessons Learnt from IWRM projects :Innovations in local-level Integrated Water Resource Development, International Water Management Institute.

World Bank. 2014. World Development Indicators, Swaziland. Online publication available at http://data.worldbank.org/country/swaziland Accessed on 2 September 2015.

Zevallos, Pía. 2015. Identification and Engagement of Stakeholders in the TNA process: A guide for national TNA teams. Online publication available at www.tech-action.org Accessed 21 August 2015.

Ziervogel, G., New, M., van Gareren, E.A., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J. and Warburton, M. 2014. Climate change impacts and adaptation in South Africa. WIREs *Climate Change*. Vol. 5: 605 – 620.

Annex I: Technology Factsheets for selected technologies

Water

Technology : Integrated River Basin Management for Swaziland

Introduction	"Integrated river basin management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems." Adapted from Integrated Water Resources Management, Global Water Partnership Technical Advisory Committee Background Papers, No. 4, 2000. IRBM rests on the principle that naturally functioning river basin ecosystems, including accompanying wetland and groundwater systems, are the source of freshwater. Therefore, management of river basins must include maintaining ecosystem functioning as a paramount goal. This "ecosystems approach" is the interdisciplinary technology which integrates all other management and technical methods for sustainable development in a river basin.
Technology Advantages	IRBM has many social, economic and environmental advantages. IRBM ensures that human and environmental needs are met in a sustainable manner, thus avoiding conflicts on access and use of water. It facilitates balanced, harmonious social and economic development plans. Furthermore, it protects the local environment, habitats and landscapes.
Technology Disadvantages	This technology needs myriad skills and data, as well as strong institutional arrangements to make it a success. Swaziland does not have good reliable data which can help with making river basin management plans and there is limited coordination amongst organizations and communities and there is need to devolve responsibilities to lower levels including to community level in order to effectively adopt IRBM systems.
Technology Highlights	The seven key elements to a successful IRBM initiative are: • A long-term vision for the river basin, agreed to by all the major stakeholders. • Integration of policies, decisions and costs across sectoral interests such as industry, agriculture, urban development, navigation, fisheries management and conservation, including through poverty reduction strategies. • Managing water at the basin or watershed: This includes integrating land and water, upstream and downstream, groundwater, surface water, and coastal resources. • Optimizing supply: This involves conducting assessments of surface and groundwater supplies, analyzing water balances, adopting wastewater reuse, and evaluating the environmental impacts of distribution and use

	options. • Managing demand: This includes adopting cost recovery policies, utilizing water-efficient technologies, and establishing decentralized water management authorities. • Providing equitable access: This may include support for effective water users' associations, involvement of marginalized groups, and consideration of gender issues. • Establishing policy: Examples are implementation of the polluter-pays principle, water quality norms and standards, and market-based regulatory mechanisms. • Intersectoral approach: Utilizing an intersectoral approach to decision-making, where authority for managing water resources is employed responsibly and stakeholders are involved in the process. Source: http://www.gwp.org/en/The-Challenge/What-is-IWRM/IWRM-components/
Institutional and organizational highlights	Most of the rivers in Swaziland are shared with its neighboring countries, South Africa and Mozambique. The Komati Basin Water Authority (KOBWA) is a bi-national institution (South Africa and Swaziland). The Usuthu River Basin is shared between Swaziland, South Africa and Mozambique. The Great Usutu River Basin Authority has been proposed. In order to facilitate the development of water resources of common interest, in 1992 the governments of Swaziland and South Africa signed a treaty for the establishment and functioning of the Joint Water Commission. A Tripartite Technical Committee (TCTP), established under the Tripartite Agreements between Swaziland, South Africa and Mozambique, is responsible inter alia for the identification and prioritization of capacity-building challenges and opportunities in the water sectors of the three parties and the establishment of administration areas. The member states of the Southern African Development Community (SADC) signed a protocol on shared watercourses (Protocol on Shared Watercourses in SADC, 2000). The overall objectives of the protocol are to foster closer cooperation for judicious, sustainable and coordinated management, protection and utilization of shared watercourses and to advance the SADC agenda of regional integration and poverty alleviation. The Ministry of Natural Resources and Energy (MNRE) is responsible for assessment, monitoring, management and allocation of water resources in the country. It has several branches responsible for specific activities. The Water Resource Branch (WRB) is responsible for stream flow observation, planning of water resources and control of pollution, while the Rural Water Supply Branch is responsible for water supply and sanitation in rural areas. The Groundwater Unit of the Geological Surveys and Mines Branch is responsible for drilling boreholes and monitoring the withdrawal of underground water. The Swaziland Water Service Corporation, a parastatal organization, is responsible for urban and peri-urban water supply and sanitation. The Swaziland Environment Authority (SEA)

	is responsible for pollution control and allocation of compliance certificates after proponents of development projects have submitted environmental impact assessment reports and comprehensive mitigation plans. The Ministry of Agriculture and Cooperatives constructs small earth dams and assists farmers with the utilization of water resources.
Operation and maintenance	Activities include Flood Control (floodwater storage, flood peak reduction, flood desynchronisation), Water Supply maintenance and operations such as Direct abstraction, Maintenance of river flow, Groundwater recharge. Water quality Maintenance and Purification include Removal of agricultural pollutants, Treatment of mine drainage, Domestic and industrial waste water treatment and Erosion Prevention.
Political endorsement	There is consensus that shared water resources have to be managed. The National Water Act 2011 is supporting this.
Endorsement by experts	Experts recommend IRBM as a useful tool for effective water resources management. This has been successfully used in many countries. Experts from WWF, IUCN, FAO, UNEP all recommend using an ecosystems approach, which is in line with IRBM principles.
Adequacy for current climate change	With climate change water stress is expected. When rivers are shared between countries it becomes even more urgent to have holistic management such as IRBM, especially since climate change will put pressure on water bodies.
Scale/size of beneficiaries	This depends on the size of the river basin and varies from several villages to the whole country.
Implementation costs	Many projects will be implemented as part of IRBM and this includes construction of dams, training and capacity building of water authorities, rehabilitation of ecosystems and data collection and monitoring. Costs vary from project to project depending on how large the river basin is and if it covers many countries. Example is the project "Adapting National and Transboundary Water Resources Management" which is funded by the Global Environment Facility (GEF) through the Special Climate Change Fund (SCCF) and UNDP Swaziland Country Office with resources amounting to US$1.87 million. Co-financing and in-kind contributions have been committed by the Government of Swaziland and the Komati Basin Water Authority (KOBWA).
Operating Costs	This depends on the scale of interventions and has to be calculated on a case by case basis.
Additional costs compared to "Business As Usual"	The cost of deployment and application of technology depends on cost databases, construction coordination model of river basin management, training, labor etc. In addition, the costs of lobbying key decision-makers in government and business, raising awareness among government decision makers and field workers, developing capacity through training activities, setting up River Basin authorities and policy development etc. would be additional costs.
Long term cost (i.e. 10, 30, or	Deterioration of water resources and increased stress due to climate change will be costly for the country, as it will have to augment water supply through other means

50 years) without adaptation	such as groundwater. In 30 to 50 years time, climate change is expected to affect water resources and demand for water will rise with increasing population and economic growth. Therefore, without the intervention of IRBM, the country will face costs for supplementing water supply for its numerous needs.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	There will be maintenance costs and infrastructure construction costs, costs of capacity building and training as well as awareness raising. However, these costs will be offset by the long term benefits from IRBM.
Development benefits – direct benefits	Development benefits include conservation of water, ensuring water demand is met in future, infrastructure such as dams are climate proofed and capacity is built within the country's institutions for effective river basin management. Hydropower generation is a direct benefit.
Development benefits – indirect benefits	With good water management, there will be improved human well-being and economic growth and prosperity.
Environmental Benefits	Ecosystems approach in river basin management will ensure that ecosystem needs are also met. This has benefits for flora and fauna and helps prevent species loss as well as ensure ecosystem services are preserved.
Economic benefits – direct benefits Employment	Training of personnel helps in skills development which can result in increased employment. Furthermore, infrastructure development for river basins will create jobs at various levels from skilled to unskilled. Jobs may vary from ecosystem restoration work such as tree planting, to skilled professional work in infrastructure development and policy, planning and management.
Economic benefits – indirect benefits	Availability of water for all sector will boost economic prosperity in Swaziland. Skills developed in the country will have economic benefits too. IRBM will aid in balancing social and economic benefits, guaranteeing social benefits and equality, avoiding conflicts on the access and use of water and facilitating balanced, harmonious social and economic development plans.
Indirect Social benefits-Income	Increasing availability of water in a sustainable manner and building capacity and skills will help the people through providing opportunities for jobs and entrepreneurship in the river basin (through usage of water for irrigating farms and for small businesses that may need water), thereby increasing incomes in society.
Indirect Social benefits-Education	Capacity building and training in IRBM projects will help improve skills in people. The sites where IRBM projects are implemented can be used as study sites for educative tours.
Indirect Social benefits-Health	Ensuring adequate water supply helps improve health and hygiene. Ensuring ecosystem needs are met helps in attaining health benefits.
Indirect Environmental Health	Ecosystems approach in river basin management will help in improving environmental health through providing adequate water for ecosystem functions and conserving vegetation and thus biodiversity and habitats.
Local context - Opportunities	Swaziland has several rivers and there is scope for IRBM in the country. There are institutions in place and skilled personnel too.
Local context -	Funding may be a barrier. Although some skilled professionals are there, there will

Barriers	be specialized skills needed which may have to be developed through capacity building and training. Since most rivers are trans boundary, there will be need for political endorsement in all countries for an effective IRBM project.
Status	In Swaziland, the Komati Basin Water Authority is helping with integrated management of Komati river basin.
Market Potential	IRBM provides tools for managing river basins. In Swaziland, there are several rivers which are trans boundary in nature and can benefit from this technology.
Timeframe	This depends on scale of IRBM project and cannot be estimated at this stage.
Acceptable to Local stakeholders	This is acceptable to Swaziland government as they are signatory to regional agreements on water resources management. Acceptance amongst communities have to be generated through awareness raising campaigns. Capacity building and training of officials working in relevant water authorities will help garner support for IRBM.
Existing investors supporting this technology	This is a project that has to be implemented with support from many actors and requires funding from development partners. Currently UNDP is funding a study on climate change and impacts on three rivers in Swaziland, such studies will provide evidence and information for effective IRBM.

Technology : Rooftop Rainwater harvesting for Swaziland

Introduction	Due to climate change, rainfall patterns will change and water stress may be experienced. Hence it is imperative that water be conserved and reused. Collecting rainwater from rooftops is an easy and fairly inexpensive way to increase amount of water availability in a household. The harvested water can be used for a myriad of uses from domestic to irrigation uses, depending on how it is filtered and treated. The range of available rainwater harvesting (RWH) options depends on the quality, cost, and sustainability of other residential water supplies, precipitation patterns, household income, and other factors.
Technology Advantages	RWH helps households adapt to climate change primarily through two mechanisms: (1) diversification of household water supply; and (2) increased resilience to water quality degradation. Harvesting rainwater helps reduce the pressure on surface and groundwater resources by decreasing household demand. With climate change affecting rainfall patterns, storage of rainwater can provide short-term security against periods of low rainfall and the failure or degradation of other water supplies. Water scarcity impacts hindering economic development and affecting human health and well-being, can be reduced using RWH.
Technology Disadvantages	If not properly implemented, growth of algae will occur. There is need for regular maintenance and cleaning or the technology will fail and people will lose faith in it.
Technology Highlights	A rooftop RWH system include: (1) a catchment surface such as the roof of a house for collecting falling rain; (2) a conveyance system of gutters and pipes to move and direct the water; and (3) containers such as tanks to store the water for later use. It is important to protect and maintain water quality in RWH systems and it can be done through filtration/screening, chemical disinfection, or a “first flush” system. First flush systems rejects the first rainwater volume which may contain impurities. Incorporating collected rainwater into the piped system of a residence or for other needs such as watering garden. Harvested rainwater can be used with proper filtration for potable use, or with no treatment for watering gardens and flushing toilets.
Institutional and organizational highlights	In Swaziland RWH systems are promoted by Government, development partners and NGOs. It is important that awareness programs and initial training required should be given by experts. Construction and repairs should be done/managed by households and there must be some training provided in this regard. However, a simple plastic tank RWH system is fairly easy to install with minimal or no training. The Department of Water Affairs can provide technical advice whenever required. Arrangements should be provided to test quality of stored water on a regular basis.
Operation and maintenance	The hard roof of a house or building is the catchment area and care must be taken that the paint on roofs is not toxic. Roofs made out of organic materials are not good for this technology. Gutters and pipes can be of aluminium or PVC.

	Maintenance is required especially to ensure that contaminants present on the roof do not fall into the storage tank. This can be done by closing the downpipe with an end cap or valve and discarding the first flush of rainwater. Chemical disinfectants may be used to maintain water quality. Cleaning of screens and filters is essential. Storage tank should be closed using a lid and should not allow sun light to enter so that algae will not grow. The whole rainwater collecting system should be cleaned at least 2-3 times per year, especially prior to the rainy season and after a long period of dry weather or after strong winds. Catchment surface and gutters have to be kept free of bird droppings, leaves and rubbish. The filter should be changed once in every three months. Mosquitoes can breed in tanks if lids are not provided.
Political endorsement	In principle, this technology is promoting efficiency in water and hence is endorsed.
Endorsement by experts	This is a simple and easy to use technology promoted by experts and used worldwide.
Adequacy for current climate change	With climate change comes erratic rainfall patterns and unreliable water supply. RWH can help augment water supply during dry spells, thus helping households adapt to climate change. Use of RWH for agriculture could complement current irrigation systems for agriculture and would strengthen system resilience. Harvesting rainwater also reduces demand from other sources of water such as surface and groundwater which are affected by climatic variations and assures water supply for various uses in a household.
Scale/size of beneficiaries	Rooftop harvesting of rain water can be done at scale of households, while larger systems can be used in schools, hospitals and other larger institutions. There is need to study how many systems are in place in Swaziland and how many more can be installed.
Implementation costs	A capital cost of US $500 to $1000 is required to build a RWH system for a typical household. The costs can vary according to the size of the buildings or houses to be equipped as wells as the storage capacity required.
Operating Costs	Operating lifetime of a rooftop RWH system is 20 years. Operational costs are minimum aside from regularly changing the filter, cleaning for debris and sediments, and repairs of potential leaks.
Additional costs compared to "Business As Usual"	Cost of installation of gutters, pipes and tanks will be offset by the many advantages of this system.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	Cost of water supply to households in the wake of increased water stress expected from climate change. Loss of income due to unavailability of water during dry spells.
Long term cost (i.e. 10, 30, or	System lasts for about 20 years and costs of maintenance include cleaning of gutters and roof and changing filters every three months. After 20 years system

50 years) with adaptation	may need some major repairs or replacements.
Development benefits – direct benefit	Water resources are less depleted and households are better able to adapt to dry spells with help of harvested rainwater, which also has snowballing positive impacts on health and incomes.
Development benefit – indirect benefits	Improved water security helps food production and household hygiene and health.
Environmental Benefits	RWH helps in reduced ecosystem degradation through preventing siltation and erosion due to reduced runoff and helps to maintain or increase groundwater table, as there would be less reliance on groundwater for household use.
Economic benefits – direct benefits Employment	RWH can increase job opportunities. Farmers using RWH for augmenting irrigation can lower the risk of their crop failures and thereby raise profits.
Economic benefits – indirect benefits	The cost for water supply at a household can be reduced with RWH systems, thereby providing them with extra funds for other economic activities that will improve their wellbeing.
Indirect Social benefits-Income	Using RWH systems for augmenting irrigation in farms can help improve production and thereby income. It also saves the time taken to collect water from distant sources and ensures continuous supply of water if tank is large enough.
Indirect Social benefits-Education	Training of people who will install and maintain RWH systems helps build capacity of human resources in the country.
Indirect Social benefits-Health	Households can improve their health from better sanitation using the additional water available from RWH systems.
Indirect Environmental Health	Using water from clean RWH system reduces waterborne diseases compared to usage of unclean sources.
Local context - Opportunities	Opportunities are greater in areas of Swaziland where water sources are far away or supply is unreliable. Thus investing in RWH in such areas can have time and cost savings, in addition to improved water quality and health gains. In areas where roofs are “hard” (e.g. metal or tile, in contrast to vegetative) the capital costs are lower, and efficiency and water quality are superior. RWH is a valuable potential resource for agricultural production if used for irrigation during dry spells. Storage and use of rain water reduces the risk and uncertainty due to water shortage for crop production and improves production.
Local context - Barriers	Barriers to implementation include inadequate or unsuitable roofing, lack of space for placing storage containers such as tanks. This may not be useful in areas with low rainfall, or less space for keeping storage containers.
Market Potential	Simple household RWH can be implemented effectively with little training or

	capacity building and there is large market potential for this. There are many suppliers of tanks and storage containers and other system components. Operation and maintenance consists primarily of simple cleaning and basic repairs. However, some training for households on how to protect water quality and how to budget for RWH systems will further improve adoption.
Status	Currently there are several RWH systems in use in Swaziland and there is potential for many more. An assessment has to be made to determine exact numbers of RWH systems in the country.
Timeframe	System lasts for about 20 years.
Acceptable to Local stakeholders	This is widely acceptable in Swaziland and suppliers are many who can provide necessary hardware for this technology, as well as assist in installation. Schools that have installed RWH systems have trained youth as well as started gardening projects and used the water for washing hands thereby improving hygiene.
Existing investors supporting this technology	USAID supports Palms for Life to build rainwater harvesting systems in 120 schools. ACAT, IRD and others have implemented rainwater harvesting in Swaziland in communities and institutions such as schools. UNDP supporting Department of Water Affairs in a project called "Adapting Water Resource Management In Swaziland To Manage Expected Climate Change", which includes rainwater harvesting

Technology : Wetland Protection and Restoration for Swaziland

Introduction	Wetlands have important ecological functions of maintaining biodiversity and act as a sponge in regulating water flow thereby controlling floods. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion. Wetland restoration relates to the rehabilitation of previously existing wetland functions from a degraded state to an operational state of overall function. Human activities of farming on wetlands, converting wetlands for settlements and allowing livestock to drink water in wetlands, all upset the soil conditions and damage its ecological functions.
Technology Advantages	Wetland rehabilitation and restoration helps maintain its ecological functions of flood control and biodiversity maintenance. Therefore, wetland creation may also fulfil legal obligations for the compensation of habitats lost through development. It also helps maintain the micro climate and allow vegetation to thrive. Some special vegetation such as reeds and medicinal plants grow on wetlands which have human welfare benefits. Wetlands are aesthetically pleasing. Wetlands can be used for waste water treatment.
Technology Disadvantages	The disadvantage would be the space required for wetlands to maintain their ecological function in cases where there is demand and competition for land for other uses such as farming and human settlements. Wetland restoration needs expertise especially if transplanting wetland plants is needed. However, the advantages far outweigh the disadvantages.
Technology Highlights	Wetland restoration is very specialized and needs skills. Activities include planting wetland plants and providing fencing around wetlands to prevent livestock from entering. There may be need to raising specific species in nurseries before transplantation. There will also be activities related to awareness raising and education.
Institutional and organizational highlights	The organizations that could be involved with wetland rehabilitation and restoration in Swaziland will be Ministry of Tourism and Environmental Affairs, Swaziland Environment Authority, Swaziland National Trust Commission, Development Partners and Civil Society. Awareness raising on wetlands have been done in Swaziland through commemoration of World Wetlands Day. The Water Act of Swaziland promotes the need for protecting water resources including wetlands. In many of Swaziland's regulations (e.g. National Climate Change Strategy and Action Plan), ecosystem approach is recommended and in this approach, maintaining ecological functions of important natural areas such as wetlands comes in. SNTC is managing wetlands that are on protected areas on Swazi National Land.
Operation and maintenance	Wetlands monitoring and continuous environmental education are long term costs. There is no major operational and maintenance costs save the maintenance of fences. The costs of fencing may vary from $1000 to $3000 per km.
Political endorsement	In many of Swaziland's legislations ecosystems approach has already been incorporated and hence indirectly wetland conservation is part of it.

Endorsement by experts	Wetland restoration has been recognized by experts as an important way of maintaining biodiversity and ecological functions of reducing flooding. Around the world wetlands have been used for livelihoods enhancement when it is sustainably used and products such as reeds are extracted and moisture used for farming and livestock watering.
Adequacy for current climate change	With climate change it is expected that wetlands will dry up, but this will accelerate if human activities are also degrading wetlands. Conservation of wetlands helps build ecosystem resilience as well as resilience of humans through hazard mitigation and biodiversity and micro climate maintenance.
Scale/size of beneficiaries	Depends on size of wetland and where it is located. It can benefit small communities to very large populations depending on size of wetland.
Implementation costs	Varies according to size and type of wetlands and has to be calculated on a case-by-case basis. Type of wetland to be restored, expertise availability, and consequent chances of success depend on degree of wetland degradation and consequent restoration requirements, intended degree of restoration, land costs if land purchase is required to convert to wetlands, labour costs, transportation distance between seedling source and planting site, seedling mortality rate between collection and planting, cost of raising specific species in nurseries before transplantation and scale of post-implementation monitoring operations.
Operating Costs	Minimal. Monitoring costs and awareness raising costs may exist and have to be calculated on case-by-case basis.
Additional costs compared to "Business As Usual"	Additional costs may include all the costs indicated above if nothing is being done at all in Swaziland, but if there are some activities already happening (this is the Business As Usual), then to upscale activities or improve the actions will be the additional costs.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	Cost of soil erosion and floods in long term. Cost of loss of biodiversity, loss of income generating opportunities from activities related to flora and fauna of wetlands.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Once restored, long term costs are minimal if wetlands are used properly. Sustainable use of wetlands can be ensured if environmental education and awareness raising can be done in a regular fashion. Thus, costs for environmental education and awareness raising have to be taken into account for long term. Cost of monitoring wetlands will depend on its location and accessibility.
Development benefits – direct benefit	Wetlands can be used as public spaces for recreation and eco-tourism. Wetlands are natural flood control mechanisms and so save in costs of dealing with flood disasters if they are destroyed. Restoration provides a small number of jobs. Other goods and services provided by wetlands, such as the provision of wood, medicinal plants and fibers help in income generation for local communities.
Development benefit – indirect benefits	Restoration provides indirect benefits such as hazard mitigation, biodiversity enhancement and improving aesthetics.

Environmental Benefits	Wetland restoration helps create awareness of environmental issues for people in the area. It protects biodiversity, controls micro climate, allows vegetation to thrive and provides habitats for animals, insects, birds and flora.
Economic benefits – direct benefits Employment	Wetland restoration provides a few specialized jobs and some unskilled labour may be used. Ecotourism is boosted in wetland areas where aesthetically pleasing wetlands attract tourists.
Economic benefits – indirect benefits	Indirect jobs are created from harvesting of wetland resources such as reeds, medicinal plants and small animals and birds for sale.
Indirect Social benefits-Income	Communities can use wetlands for harvesting reeds, medicinal plants and small animals, insects and birds.
Indirect Social benefits-Education	Restoring wetlands in an area helps to raise awareness about their environmental function and serves as an educational opportunity too. The wetland locations can be used in site visits for students.
Indirect Social benefits-Health	Medicinal plants extracted from wetlands can help in improving health. Micro climate around wetlands and its aesthetic qualities can have healing effects for humans.
Indirect Environmental Health	As a result of wetlands acting as a sponge absorbing water during heavy downpours and slowly releasing it during dry season, it allows for small streams downstream to have water flows during dry times, hence providing environmental benefits such as moisture for flora and fauna.
Local context - Opportunities	Opportunities for income generation through sale of products derived from wetlands such as reeds used for thatching and basket weaving. In Swaziland there are several wetlands and if properly utilized can provide socio-economic and environmental benefits.
Local context - Barriers	Communities tend to allow their livestock to graze on wetlands during dry spells which causes negative impacts as soil in wetlands is compacted from trampling by livestock. The importance of wetland restoration needs to be elevated and awareness raised in Swaziland in this regard. Pressure for land causes construction of settlements very close to wetlands.
Market Potential	If communities are made aware of the economic benefits of restoring wetlands, then there is potential for self help groups undertaking this at their own expense. Furthermore, through eco-tourism and sustainable harvesting of products, communities will be able to offset the cost of restoration.
Status	Under the Protected Areas project being implemented by Government of Swaziland and UNDP, wetland protection is included.
Timeframe	This depends on size and type of wetland but generally for benefits to be visible, at least one to six years would be taken and long term monitoring is necessary.
Acceptable to	There is need for awareness raising to enhance consciousness of the importance of

Local stakeholders	wetlands in Swaziland.
Existing investors supporting this technology	Wetland protection and restoration is part of projects implemented under National Environment Fund. Development partners such as EU, UNDP are supporting wetland protection and SNTC is managing projects in protected areas.

Agriculture

Technology : Livestock and poultry management through selective breeding for Swaziland

Introduction	Climate change is expected to create a number of challenges including extreme weather events, and livestock and poultry should be able to withstand shocks such as temperature extremes, drought, pests and diseases. Selective breeding is a technology that aims to improve the value of animal genetic diversity. This technology can be applied to all types of livestock, including cattle, sheep, goats, pigs and chickens. This method helps in the productivity of livestock species as well as improvements in the health and welfare of livestock and other animals.
Technology Advantages	The livestock and poultry produced through this method will be sturdier and can withstand shocks such as prolonged dry spells, extreme temperatures, pests and diseases. The methods of controlled mating are very simple and do not incur high costs. Selective breeding through controlled mating enables farmers to breed animals that are more resistant to the impacts of climate change, such as sudden changes in temperature, prolonged droughts or the appearance of new diseases. It can reduce mortality rates, increase fertility rates, and can also be used to improve the quality of livestock products such as milk and fibre. As a result, livestock producers are at a lower risk from losing animals to climate change impacts and they are also able to diversify their income-generating activities by capitalising on higher-quality dairy or fibre production.
Technology Disadvantages	These programmes usually do not produce immediate improvements. Improvements are usually not seen for at least one growing season, so livestock producers must incorporate long-term planning into production management strategies. Such measures could include: (i) identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and (ii) improving local genetics through cross-breeding with heat and disease tolerant breeds. One of the main limitations of this technology is that selective breeding of certain genes can run the risk of reducing or removing other genes from the overall pool, a process which is irreversible. This can create new weaknesses amongst animals, particularly with the emergence of new pests or diseases. Depending on the animal traits chosen, selective breeding may not always lead to higher productivity rates. Source: http://www.climatetechwiki.org/content/selective-breeding-controlled-mating
Technology Highlights	Selective livestock breeding is the systematic breeding of animals in order to improve productivity and other key characteristics that can help them adapt better to environmental conditions such as thermal tolerance, low quality feed, high kid survival rate, disease resistance, good body condition and animal morphology. Various methods for selective breeding exist, from high-tech and costly processes

	such as in-vitro fertilisation or genetic engineering to more simple low-cost techniques that rely on the selection and controlled mating of animals based on observable characteristics. There are three main approaches to selective breeding: 1) Outcrossing: This involves mating two animals that are unrelated for at least 4 to 6 generations back. Outcrossing improves fitness traits such as reproductive ability, milk production, kid survivability and longevity. 2) Linebreeding: Linebreeding involves mating related animals like half-brother/half-sister, cousins, aunt/nephew, and other more distant relationships. This is usually done to capitalize on a common outstanding ancestor who appears in recent generations of the pedigree. There is a higher degree of uniformity with linebreeding than in outcrossing, and a reduced possibility of harmful genetic defects than inbreeding. 3) Inbreeding: This method involved mating directly related animals, like mother/son, father/daughter, and full brother/full sister (full siblings). This method is used generally to create uniformity and prepotency (the ability of this process to continue) and to force out latent weaknesses from the gene pool. Fitness traits are especially at risk with this breeding scheme.
Institutional and organizational highlights	Government, through the livestock extension department, educates farmers in all aspects of livestock and poultry production. Cattle production in Swaziland can be divided by breeds into a) exotic dairy cattle and b) other cattle (traditional and beef specific cattle). Production, processing and marketing of livestock and poultry is carried out by the private sector in Swaziland
Operation and maintenance	Normal practices of livestock management are required in caring for livestock which have been bred selectively.
Political endorsement	The Livestock Improvement Act 2007 and supporting legislations and policies have endorsed methods that will improve productivity. Helping farm animals adapt to climate change is supported by the Government. There is need for awareness raising of this technology and Government can play a role in providing necessary information to farmers.
Endorsement by experts	This technology has been widely used in many countries and the various methods are endorsed by experts, however specialized knowledge is required.
Adequacy for current climate change	Climate change will create extreme weather events, heat waves and cold waves and therefore sturdier varieties of livestock and poultry are needed. Specific advantages of selective breeding through controlled mating include low input and maintenance costs once the strategy is established, and permanence and consistency of effect. In addition, controlled mating can preserve local and rare breeds that could be lost as a result of climate change-related disease epidemics.
Scale/size of beneficiaries	This can be applied by small scale farmers to commercial livestock production enterprises. The technology varies and can range from simple controlled breeding

	to more advanced in-vitro fertilization.
Implementation costs	The costs and financial requirements will depend on the livestock species and location. However, in general controlled breeding is a low-cost technology. If stones are locally available and can be used to build the mating pens, an average investment would come to around US$ 30. In areas with clay soils, adobe bricks may be used, at an average cost of US$ 90. In many cases, cattle mesh has been the chosen alternative, with an average investment of US$ 200 for each mating pen. (Source: Climatetechwiki.org)
Operating Costs	Maintenance of cattle pens and costs of undertaking selective breeding will vary, but is generally affordable, however advanced technology like in-vitro fertilization may be costlier.
Additional costs compared to "Business As Usual"	Costs of construction of cattle pens and undertaking the breeding activities.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	Cost of livestock deaths when heat waves or cold waves and extreme weather events such as droughts and floods are experienced. These are likely to increase in 30-50 years with the changing climate and therefore livestock should adapt. Furthermore, limited availability of beef leads to higher food prices.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Costs of breeding, construction of cattle pens, costs of awareness raising etc. But these are offset by the gains in reduced livestock deaths and improved production.
Development benefits – direct benefit	Sturdier livestock and poultry will improve availability and quality of meat, which will boost agricultural economy.
Development benefit – indirect benefits	With less imports of meat, the country will benefit in preserving their forex. There is also indirect benefits of improving food security, income for farmers and creation of jobs.
Environmental Benefits	Importance for livestock production will boost the need for improved grazing land management.
Economic benefits – direct benefits Employment	Greater production will create more number of jobs.
Economic benefits – indirect benefits	Increasing number of livestock will also supply dung which can be used for biogas and organic fertilizer.
Indirect Social benefits-Income	Improved varieties and increased production of livestock and poultry will improve incomes for farmers. Other indirect benefits include improved diet and food security.
Indirect Social	Documentation of the indigenous knowledge of livestock keepers about animal

benefits-Education	breeds and breeding should be an integral part of the work of rural development projects, institutions and organisations because it can be a source of information about the existence of breeds that scientists have overlooked and which may have unrecognised advantages and potential. Investments in science and technology for developing new breeds and genetic types also present an opportunity for larger-scale interventions where funding is available.
Indirect Social benefits-Health	Improved livestock health will have nutrition benefits for people in Swaziland, which will improve health. Improved incomes of farmers will also provide them with means to improve household nutrition and health.
Indirect Environmental Health	Reduced livestock deaths have environmental benefits as livestock depends on grazing and therefore managing them will help in sustainable grazing land management.
Local context - Opportunities	In Swaziland the Nguni cattle and indigenous varieties have been suited for climate variability and been in production for many years. Indigenous knowledge exists about this within farmers in the country. It will be relatively inexpensive and easy to spot varieties that are sturdy and implement selective breeding. Many farmers in the private sector have the means to undertake this and therefore there are many opportunities in Swaziland for this. Artificial insemination, embryo transfer and associated biotechnologies have helped to improve breeding in indigenous livestock.
Local context - Barriers	There are knowledge gaps about how breeds react to conditions brought about by climate change. The FAO list many species and local breeds which are already adapted to high temperatures and harsh conditions, or are reported to be resistant or tolerant to various diseases. However, many of these reports are based on anecdotal evidence rather than scientific studies, and the underlying physiological and genetic mechanisms are not well understood. This makes it difficult to predict climate change impacts or develop adaptation strategies for such production systems or breeds.
Status	The livestock sub-sector accounts for about 14% of agricultural output and 1% of total GDP. Selective breeding is being done in Swaziland, however accurate data is not available to determine the status.
Market Potential	Improved varieties of cattle have a demand on the market, as Swaziland beef is in demand both domestically and for export.
Timeframe	This depends on type of livestock or poultry and scale of operations. But benefits should accrue within a few years and productivity will improve with time.
Acceptable to Local stakeholders	Selective breeding has been done for generations by farmers and there is indigenous knowledge about this. Hence it is an accepted technology and modernizing this and creating further awareness will improve adoption.
Existing investors supporting this technology	Dairy Management Board and NAMBOARD and private sector may support and invest in this technology, as the benefits are manifold.

Technology: Conservation Agriculture for Swaziland

Introduction	Conservation agriculture is a form of farming where minimum soil disturbance, maintaining a permanent soil cover through retention of crop residues and growing cover crops, crop rotations and application of integrated pest management strategies help in making farming sustainable. Conservation agriculture helps promote soil fertility, improve crop yield, improve below ground carbon storage and improve water retention. Conservation agriculture has both adaptation and mitigation benefits. It strives to achieve profitable and sustainable yield levels while concurrently conserving the environment that influences production.
Technology Advantages	Conservation agriculture helps conserve fragile soils, retain organic matter and extend the period of water availability to crops. After harvesting a crop, the residue is left intentionally and using minimal tillage new crops are planted in the mulched soil with at least 30% surface cover. Judicious use of external inputs such as inorganic fertilisers and pesticides are done and this technology saves fuel for large scale farmers for deep ploughing. The goal of CA is to strike a balance between agricultural sustainability and efficient use of natural resources.
Technology Disadvantages	Machinery (such as specialized planter) is required for planting and weeds and cover crops are controlled by a pre-planting application of non-pollutant desiccant herbicides, which can be costly. There is also need for capacity building and training for the technology to be upscaled. Not all crops are suited to be farmed using this technology. Some crops such as ground nuts and ginger may need the soil to be tilled for allowing root growth. This technology can lead to soil compaction, and may not be suitable for irrigated areas. There is a risk of pests and more diseases if residues are not removed, and more chemicals are required for higher weeding effort. Communal grazing disturbs the CA practice (crop residue and cover crop consumed; soil compaction due to livestock movement). Specialized machinery not locally available.
Technology Highlights	The sustainability of CA is enshrined in its three main principles which are; (1) minimum mechanical soil disturbance, (2) maintaining a permanent soil cover through retention of crop residues and growing cover crops, and (3) promoting a healthy soil through practicing crop rotations, cover crops and application of integrated pest management strategies (*Source: Manyatsi, A. 2014. Comprehensive scoping study of climate smart agriculture policies in Swaziland, unpublished report.)*
Institutional and organizational highlights	In Swaziland, Ministry of Agriculture is the responsible authority for agriculture. There is need for greater awareness and capacity building to popularize conservation agriculture. Swaziland's Ministry of Agriculture has been supported by FAO and Cooperation of the Development of Emerging Countries (COSPE) in implementing conservation agriculture, which has elements of conservation tillage since 2002. Swaziland Agricultural Development Programme (SADP),

	International Relief and Development (IRD) and World Vision International have also implemented similar programmes. African Cooperative Action Trust (ACAT) with support from New Partnership for Africa's Development (NEPAD) are preparing a compendium on climate smart agriculture for Swaziland to support Ministry of Agriculture.
Operation and maintenance	Specialised equipment and selective pesticides need to be used. The equipments will need maintenance, similar to conventional machinery.
Political endorsement	In Swaziland conservation agriculture has received substantial attention and a number of studies have been done in the country, however it has not been up scaled. However, the technology is gaining popularity in Africa as shown by the Africa Conservation Tillage Network (ACT). This was established in 1998 to promote conservation agriculture as a sustainable means to alleviate poverty, make more effective use of natural and human resources, and reduce environmental degradation. Conservation tillage has been incorporated into the regional agricultural policies by NEPAD (New Partnership for Africa's Development) and more recently by AGRA (Alliance for a Green Revolution in Africa). A task force has been established, Swaziland National Conservation Agriculture Task Force and include are MoA, COSPE, SNAU, ACAT, UNISWA, World Vision, LUSLM, FAO. FAO is the secretariat.
Endorsement by experts	Conservation agriculture has been accepted by experts worldwide to be a good technology and in countries like Brazil and Argentina, 45-60% of all agricultural land is reportedly managed by conservation agriculture systems. In United States, 15 million hectares, 13 million hectares in Canada and 9 million hectares in Australia are under Zero tillage. ACAT has prepared a compendium on climate smart agriculture which includes conservation agriculture and it is endorsed by experts in Swaziland as a technology that helps farmers adapt better to climate change. FAO has endorsed this technology worldwide.
Adequacy for current climate change	Climate change adaptation is enhanced when soil erosion is reduced, water retention is increased and risk of pest infestation decreased in most cases (however, in some cases crop residue remaining in the field embedded in residues may increase pests), thus increasing yields in crops. Increased yields help farmers adapt better through improved incomes. The co-benefit from this is for climate change mitigation. Land use and land cover change increases emissions when soil is disturbed for agricultural activities. Using conservation agriculture, soil disturbance is reduced, thus storage of carbon increase, which helps in climate change mitigation. Mulching helps in water retention and this type of farming helps improve yields.
Scale/size of beneficiaries	This technology can benefit smallholder farmers to large scale farmers and can be applied in farms of varying hectarage.
Implementation costs	Costs of using machines such as specialized planter/rippers (approximately $2500 to $15,000) and pesticides (sprayers). This depends on scale of operation.

Operating Costs	Maintenance of machines and inputs needed for farming. This depends on size of farm and can vary per farmer.
Additional costs compared to "Business As Usual"	Specialized machines such as planters will be needed compared to traditional methods. Furthermore, pesticides will also be needed.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	Costs of water pollution from increased runoff and erosion, costs of soil loss, costs of decreased yields as compared to conservation agriculture farms, costs of water use and fuel use in tractors.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Maintenance of equipments and costs for inputs will continue over the years. However this will be offset by the increased yields, increased carbon sequestered, savings from less use of fuel, environmental benefits of reduced pollution, less use of water and savings of time and labour.
Development benefits – direct benefit	Since there is need for less labour compared to tillage farming if mechanized planter are used, this will provide farmers with more time to participate in income generating activities which will aid in development. Use of tractors for tillage is no longer required and thus the farmer can save costs of diesel/petrol. Less water is also needed, as this technology reduces evapotranspiration and improves water retention. Increase of carbon storage is also a development benefit as it increases Swaziland's ability to become a carbon sink.
Development benefit – indirect benefits	Less labour time and cost are required under a reduced tillage system due to fewer tillage trips and cultivation operations for seedbed preparation. Generally, reduced tillage systems have lower machinery repair and maintenance costs due to less use of tillage implements. The saved income can be used for other activities which will support development of the country. Sale of machines and inputs will create jobs for vendors.
Environmental Benefits	Increased water retention, reduced pollution, reduced erosion and increased carbon sequesteration are some of the environmental benefits.
Economic benefits – direct benefits Employment	The supply and marketing of machines and pesticides may provide jobs. Increased yields will trigger jobs for farm products vending and food processing.
Economic benefits – indirect benefits	Increased yields will provide improved incomes which can be used for investments that contribute to job creation indirectly. Food processing companies may also benefit from increased yields and may not have to import raw materials.
Indirect Social benefits-Income	Increased yields contribute to increased farm incomes, which can help farmers save money and meet their needs and expanding their economic activities.
Indirect Social	Conservation agriculture provides many educational opportunities where farmers

benefits-Education	may learn about importance of water retention, carbon sequestration and minimum soil disturbance. Climate change adaptation and mitigation benefits from this technology provide lessons for Swaziland. Sites where conservation tillage is practiced may be used for knowledge exchange and practical lessons for students and other farmers.
Indirect Social benefits-Health	Swaziland has experienced loss of labour due to HIV and AIDS related illnesses and deaths and using conservation tillage and machines for planting reduces the amount of labour traditionally required in land preparation and weeding. Crop diversification helps in providing a nutritional and diversified diet on the same land. The increased yields due to conservation tillage can help improve food security.
Indirect Environmental Health	Improved soil fertility, water retention, carbon sequestration and least soil disturbance helps the environment.
Local context - Opportunities	There is opportunity to expand this technology to the arable lands in Swaziland. Both smallholders and commercial farmers will benefit.
Local context - Barriers	There are many barriers to adopting this technology including mindset (tradition, prejudice), knowledge, availability of appropriate machines, availability of adequate herbicides and supportive policies to promote adoption. The largest barrier is the cost of the specialised planters required to penetrate the soil covered with the previous crop. The use of these planters is mainly restricted to richer countries where the fields are relatively large. For growers with small farms, the large amount of hand labour required is a barrier.
Status	Conservation agriculture was introduced in 2002 in Swaziland by the Ministry of Agriculture (MOA) through support from the Food and Agricultural Organisation of the United Nations (FAO) and the Cooperation of the Development of Emerging Countries (COSPE). The Shewula community in the northeast of the country and Kambhoke community in the south were targeted and a roll out programme, to cover the whole country, was implemented in 2006 in which participating farmers were supplied with the necessary equipment and related inputs. However, the current hectarage under conservation agriculture is not known and needs further investigation.
Market Potential	According to World Bank, 175000 hectares of arable land exist in Swaziland. There is scope for expanding conservation tillage in the country. There is also market potential for sale of machines and pesticides for this purpose, however, support from development partners may be needed to reach the smallholder farmers.
Timeframe	For effective benefits to be accrued it may take a few years. Initial investment costs are incurred in the first year, while rest of years only maintenance and costs of inputs are needed.

Acceptable to Local stakeholders	This technology has been used in Swaziland and farmers have seen its benefits. It is generally acceptable, however there may be need to overcome barriers such as funding and equipment needs.
Existing investors supporting this technology	Development partners have been supporting this, such as FAO and COSPE. Farmers themselves need to take initiative to adopt the technology for it to be up-scaled. NGOs that have implemented this include World Vision and IRD. FARNPAN and NEPAD are supporting facilitation of uptake of Climate Smart Agriculture in Swaziland with implementing agency Africa Cooperative Action Trust (ACAT) and they are also documenting good practices. NAMBOARD is implementing a climate smart agriculture project in Swaziland. LUSLM project is supporting 1220 households covering 244 ha in conservation agriculture.

Technology : Micro and drip Irrigation system for Swaziland

Introduction	Agriculture is the mainstay of the Swaziland economy and is critical for the achievement of the overall development objectives of the country. Climate change induced dry spells and erratic rainfall patterns are affecting crop production in Swaziland. Most farmers are dependent on rainfall for crop production and are therefore vulnerable to reduced rainfall and accompanying moisture stress on crops. Irrigation can help farmers in Swaziland to adapt to changing climate and substantially improve food production. The goal of efficient irrigation is to supply each plant with just the right amount of water it needs, thereby reducing wastage of water. Micro irrigation systems include drip irrigation which target roots of field crops, and sprinklers, which are pressurized irrigation systems that use moving platforms or devices to stimulate natural rainfall. Water efficiency for sprinklers is 50-70%, while for drip irrigation it is up to 90% and can also be used in greenhouses, nurseries, orchards and plants in containers. Both systems can be gravity fed or pressurized. Adaptation of this technology promotes sustainable management of energy, water, land, and labor. Under conditions of increased water stress resulting from climate change, the benefits of the technology rises quite significantly.
Technology Advantages	This technology contributes to improving food security by enhancing food production. Both drip and sprinkler irrigation systems use water efficiently and therefore save water by reducing water losses. Water is also distributed more evenly across crops helping to avoid wastage. Both systems increase crop yield and allow for various types of crops including row, field and tree crops that are grown closely together, such as cereals, pulses, wheat, sugarcane, groundnut, cotton, vegetables and fruits. Swaziland is a mountainous country and both drip and sprinkler irrigation technology is well adapted to a range of topographies and is suitable for all types of soil, except heavy clay. Soluble fertilizers may be used in sprinkler systems. Since less water is used at a time, there is less risk of soil erosion because soil disturbance is low. There are secondary benefits from improved crop productivity such as income generation, employment opportunities and food security.
Technology Disadvantages	The main disadvantage is that initial investment cost associated with pumps, pipes, tubes, emitters and installation is higher than other systems. Heavy rainfall episodes may affect drip systems. When farms use mechanized production such as tractors, it is difficult to combine with drip system. Root development may be restricted by the limited soil area wetted. Swaziland is affected by strong winds and efficiency of sprinkler systems may be affected by this as water distribution will be altered by wind. When installed in areas with high temperatures, such as the low veld, water can evaporate at a fast rate reducing the effectiveness of the irrigation. This technology requires a clean source of water and, this is a challenge

	when rainfall is becoming less predictable and water sources are affected by siltation. Mechanized sprinkler irrigation systems have a relatively high energy demand. Regular maintenance inspections are needed to maintain system effectiveness. Although sprinkler systems have moving platforms, labour is nevertheless required to move the system. There may be need to level the land for the systems to work, which is an additional cost. There is a risk of sabotage, vandalism and theft for sprinkler and drip systems.
Technology Highlights	Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops. A drip irrigation system typically consists of pumps or pressurised water system, filtration systems, nutrients application system, backwash controller, pressure control valve, pipes, control valves and safety valves, poly fittings and accessories and emitters. A wide range of components and system design options is available. The wetting pattern of water in the soil from the drip irrigation tap must reach plant roots. Emitter spacing depends on the crop root system and soil properties. Sprinkler irrigation is a method by which water is distributed from overhead by high-pressure sprinklers, sprays or guns mounted on risers or moving platforms. A sprinkler irrigation system typically consists of a pump unit, pipes, lateral delivery system and water emitting devices. Mechanised and manual systems exist. A wide range of sprinkler systems is available for small and large-scale application. When installing micro irrigation schemes, Swaziland must take note of the following factors: • The crop or crops to be cultivated and their water requirements throughout the growing season, • Land tenure issues and the shape and size of the field, as this will determine the range of suitable technologies, investment and labour requirements, • Topography, in particular the location and elevation of the water source relative to the field, land slopes and uniformity, • The water rights and type of water source, whether it is surface water or groundwater and if they are available in sufficient quantity from a locally accessible source. A clean supply of water free of sediment is required to avoid blockage in sprinkler nozzles and crop spoilage, • Available labour force. Where skilled labourers are not available on location, local farmers will require training to install, maintain and repair the various components of the sprinkler system, • The soil profile. Sprinkler irrigation technology is best suited to soils with high infiltration rates so that ponding and surface runoff can be avoided. The application rate of the sprinkler system must therefore be matched to

	the infiltration rate of the most restrictive soil in the field, • Energy requirements of different systems, including the manufacturing, transportation and installation of the various systems. The location of the water source will also affect the need for energy for pumping, • Social aspects such as local preferences, capacity to maintain the system, implications for labour requirements and how these may affect different members of the community, • Financial aspects of the project and funds for maintenance • An understanding of existing health risks is crucial to avoid schemes that may promote water borne diseases, and • An environmental impact assessment should be conducted to fully understand potential impacts of drainage and diverting water resources, amongst others.
Institutional and organizational highlights	Swaziland has several institutions that help manage water resources including for irrigation and these include: • Water user associations are, responsible for managing water systems at community level. • The Water Resources Branch, within the Ministry of Natural Resources and Energy, manages water for irrigation. • Komati Project Co-ordination Unit, within the Ministry of Natural Resources, manages water in Komati River. • Small Irrigation Section (also referred to as a Unit) within the Ministry of Agriculture caters for small-scale farmers including small scale sugar growers, providing design work and extension mainly on irrigated vegetables. • The Rural Water Supply Branch (RWSB) has responsibility for rural water supply and falls under the Ministry of Natural Resources and was setup with donor funding and NGO support during the United Nations Decade of Water and Sanitation. • The Water Services Corporation, within Ministry of Housing and Urban Development (privatized in 1994) facilitates better planning, budgeting, and overall management of urban water supplies. • The sugarcane irrigators and the Swaziland Sugar Association (based in Simunye) have contributed towards the development of water resources legislation and together have built up considerable levels of expertise in water resources management. • The Swaziland Komati Development Project (SKPE) office is located in • Tshaneni, in the northern part of the lowveld.
Operation and	Maintenance of the system mainly relates to regular cleaning of the component

maintenance	parts. Seals on pipes and sprinkler nozzles should be checked to avoid water seepage. During periods when the equipment is not being used, it is recommended to store component parts in a cool, dark place.
Political endorsement	The Government of Swaziland (GOS) has identified the development of smallholder agriculture from subsistence farming to commercialization and intensification farming as the main elements in its policy to alleviate poverty. Irrigation plays an important role in achieving this and is a priority for the Government of Swaziland. Improving irrigation has been mentioned as a priority in various national policies and documents.
Endorsement by experts	This technology has been endorsed by FAO, IFAD and UNDP.
Adequacy for current climate change	Climate change is affecting rainfall patterns and reduction in precipitation in some areas. By its design and working principle drip irrigation best meets the environmental, energy-efficient and resource-saving requirements under climate change. Drip and sprinkler systems are a means for climate change adaptation as they aid in sustainable water use and management, thereby increasing productivity and strengthening the adaptive capacities of people that are heavily dependent on agriculture. When faced with water scarcity, sprinklers and drip irrigation systems allows for efficient use of water and represent an adaptation strategy against scarcity of water.
Scale/size of beneficiaries	This technology can be used in all four regions of Swaziland. Benefitiaries may range from households to several communities depending on scale of irrigation use.
Implementation costs	Depending on the type of system, drip irrigation system ranges from 1000 USD to 3500 USD per hectare. Financing for equipment may be available from financial institutions via leasing operations or direct credit.
Operating Costs	Operational cost for technology will be around 50-100 USD per hectare per year.
Additional costs compared to "Business As Usual"	Investment in the technology and providing training for installation and maintenance.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	• Costs of water pollution from applying fertilizers in normal irrigation schemes, which when done inefficiently, can leach into water. • Cost of land degradation from soil erosion. • Loss of yield from poor soils and water depletion, due to inefficient use of water sources, pollution from excessive fertilizers and erosion. • Crop failure and low yield and low income, field abandonment, affecting livelihood of farmer, food insecurity, wastage of water and less irrigable area

Long term cost (i.e. 10, 30, or 50 years) with adaptation	Additional costs will be needed to provide necessary capacity building activities for local farmers. However, this can be recovered from profits of higher yield and quality of crops. Micro-irrigation can increase crop yield by 30- 40 %.
Development benefits – direct benefit	The harvest increases by 30-40% times, thereby increasing production, food security and incomes. Livelihoods of farmers will be improved and they will be better able to adapt to climate change. It improves water use efficiency and crop yield and quality by providing year round production, more efficient water use and less cost of water.
Development benefit – indirect benefits	Irrigation provides a means for farmers to adapt to changing climate.
Environmental Benefits	• The water efficiency increases, thereby aiding in sustainable use of water resources. • Soil erosion from irrigation is excluded and soil productivity improves as physical, chemical and biological properties are improved. • Use of solar pumps for irrigation have local and global benefits through the reduction of pollutants and emission of green-house-gases and generate CDM credits.
Economic benefits – direct benefits Employment	• Maintenance of irrigation equipment needs skilled labour and use of this technology creates jobs for the skilled labour. • The technology can facilitate gainful employment of the farm family labour throughout the year.
Economic benefits – indirect benefits	• The technology can facilitate participation of women in farming through the operation of the system and carrying out regular maintenance operations. • The overall time spent is decreased as a result of less time spent on irrigating crops and this time saved can be used for other income generating activities. • Contributes to diversification of economic activities which is a priority of the country. Leads to improvement of economic condition of rural population. Leads to efficient use of resources such as land, water and fertilizers.
Indirect Social benefits-Income	Contributes to food security priority by increasing productivity. Leads to increase in income of rural population. Reduces migration to urban areas from rural communities.
Indirect Social benefits-Education	Skills training in irrigation equipment installation and maintenance help in development of human resources in the country.

Indirect Social benefits-Health	Increase food productivity helps improve nutrition and thereby health. Saving of labour provides farmers with time for leisure.
Indirect Environmental Health	Lowered water withdrawal from ground water resources, particularly during more sensitive dry months, drip technology prevents depletion of ground water table and pollution from infusion of saline and other contaminants. Increased use efficiency of chemical fertilizer through fertigation prevents resource waste and development of water pollution problems such as eutrophication. Drip irrigation reduces crop disease pressure as foliage are kept dry.
Local context - Opportunities	• Agricultural production will increase leading to decrease in the dependence of imported agricultural products. • Skills training will create jobs. Sale of irrigation equipments will boost the economy. • The technology can be employed in combination with other adaptation measures. • Intensive agriculture with mixture of crops is possible using this technology and year round production is enabled. • It contributes to efficient water use, reduces requirements for fertilisers and increases soil productivity as well as due to fertigation and reduced need for weed control, requires less labour.
Local context - Barriers	No matter how clean the water looks, a water quality analysis should be completed to determine if precipitates or other contaminants are present that could affect operation of the irrigation system, especially for drip irrigation. The technology for automated and mechanized systems is expensive and needs high amount of initial investment. Some farmers may be put off by the fact that there may be limited market for second hand equipment. Drip irrigation equipment can only be used when field conditions are right. Technical conditions such as soil clay presence, irregular rainfall or steep slopes can increase implementation and maintenance costs or affect drip system efficiency. Furthermore, with climate change affecting water resources, there could be uncertainty in availability of water for irrigation, which may discourage investment in this technology for some. Insufficient skills for installing drip irrigation equipment and high investment costs initially are also barriers.
Market Potential	The technology is suitable for various users from small scale to large scale and can be low-cost gravity-fed or automatic and pressurized. Suppliers are available locally or equipment can be imported from South Africa.
Status	In Swaziland, irrigation is used by farmers in many places from individual farmers to associations and is also supported by NGOs such as COSPE where several farmers benefit.
Timeframe	This technology can be implemented within a short period. Suppliers are available

	locally for this technology.
Acceptable to Local stakeholders	These technologies have already been used in Swaziland and is widely accepted by stakeholders.
Existing investors supporting this technology	African Development Bank, IFAD, UNDP, COSPE, European Commission, NAMBOARD. Several commercial farmers are using this technology.

Forests and Biodiversity

Technology: Agroforestry for Swaziland

Introduction	Agroforestry is a land-use practice that encompasses planting of trees along with crops and also keeping livestock in the same field. This practice helps improve soil fertility. The crops can be grown together at the same time. They can also be grown in rotation, or in separate plots when residue from one are used as fodder for other crops. The trees help in holding the soil, to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall, and to provide shade, construction materials, foods and fuel. In addition to adaptation benefits, agro-forestry also has a function of carbon sequestration.
Technology Advantages	Agroforestry is a technology that improves fertility of soil and thereby productivity of land. It provides multiple benefits including provision of firewood, organic materials that can be used as natural fertilisers, provision of forage, improvement in soil fertility and improve water flows as soil structure is improved. Crops planted along with trees such as Acacia albida provide higher yields. Agroforestry helps the farmer have income for the whole year as they can now derive construction materials (wooden poles) and fuelwood and reduce needs for purchased inputs such as fertilizers.
Technology Disadvantages	Agro-forestry systems require considerable management. Incorporating trees and crops into one system can create struggle for space, light, water and nutrients and can hamper the use of tractors in the field as there are trees growing in between the crops. It is important to manage the land effectively to reduce the competition for resources and maximise the ecological and productive benefits. Yields of cultivated crops can also be smaller than in alternative production systems, however agro-forestry can reduce the risk of harvest failure.
Technology Highlights	Generally, however, agro-forestry systems can be categorised into three broad types: agrosilviculture (trees with crops), agrisilvipasture (trees with crops and livestocks) and silvopastoral (trees with pasture and livestock) systems. Agroforestry practices include: • Alley cropping: growing annual crops between rows of trees • Boundary plantings/living fences: trees planted along boundaries or property lines to mark them well. • Multi-strata: including home gardens and agroforests that combine multiple species and are particularly common in humid tropics such as in South East Asia • Scattered farm trees: increasing a number of trees, shrubs or shaded perennial crops (such as coffee and cocoa) scattered among crops or pastures and along farm boundaries. • It is important to plan the features of soil erosion control, earthworks, and

	gully maintenance, plan spacing of fruit trees according to final spacing requirements and plan a succession of annual or short-lived perennials beginning with the most shade tolerant for the final years of intercropping.
Institutional and organizational highlights	Agroforestry is part of climate smart agriculture which is being promoted by the Ministry of Agriculture. To plan for the use of trees in agro-forestry systems, considerable knowledge of their properties is necessary. Desirable information includes: the climatic adaptations of the species, including adaptations to various soils and stresses; the size and form of the canopy as well as the root system; and the suitability for various agro-forestry practices. The selection of crops also requires knowledge of uses, adaptation, and market opportunities. There is need for creating awareness amongst NGOs in Swaziland to implement this at grassroots level.
Operation and maintenance	Trees will need to be planted in straight lines and pruned from time to time, so that there is ample space for tractors to move in the open space between the trees where crops are grown.
Political endorsement	Agroforestry as a climate smart agriculture practice has been positively received in Swaziland and is being implemented by Ministry of Agriculture in conjunction with organizations such as NAMBOARD.
Endorsement by experts	FAO and other experts have confirmed that agroforestry is a good technology and aids in improving agriculture as well as adaptation to climate change.
Adequacy for current climate change	Agro-forestry can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Trees have an important role in reducing vulnerability, increasing resilience of farming systems and buffering agricultural production against climate-related risks. Trees are deep rooted and have large reserves, and are less susceptible than annual crops to inter-annual variability or short-lived extreme events like droughts or floods. Thus, tree-based systems have advantages for maintaining production during wetter and drier years.
Scale/size of beneficiaries	Agroforestry can be practiced at household levels and community levels.
Implementation costs	Agroforestry at household level or community level does not cost much except for purchase of seedlings, land preparation and capacity building and training of farmers. For large scale agroforestry projects, costs can increase due to construction of community nurseries, seedling production and distribution and installation of plantations and rejuventation of regional forests. Exact costs have to be calculated on a case by case basis.
Operating Costs	There are minimal operating costs except for managing the farm and its products.
Additional costs compared to "Business As Usual"	Purchase of seedlings, investment in training, setting up nurseries and labour during planting of trees.

Long term cost (i.e. 10, 30, or 50 years) without adaptation	Costs of soil erosion from lack of tree cover, costs of fertilizers and water.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Cost of purchase of seedling, planting them, pruning the trees and managing the land. This cost is offset by the benefits accrued.
Development benefits – direct benefit	Agro-forestry has a number of benefits including: • Improving productivity of land • Making maximum use of land and increasing land-use efficiency • Livelihoods diversification • Production of construction materials and firewood and • Reducing the need for fertilizers.
Development benefit – indirect benefits	There are benefits of improved soil fertility and water retention in land which improves productivity of agriculture. Furthermore, increased incomes in farm households will indirectly generate more jobs and investment in development.
Environmental Benefits	Soil fertility improved, water retention improved and biodiversity enhanced through greater vegetative cover.
Economic benefits – direct benefits Employment	Planting of trees, sale of seedlings and produce from the farm provides employment in farming and marketing of produce.
Economic benefits – indirect benefits	Increased yields from crops and sale of firewood, fruits and construction materials from trees will provide enhanced income for farm households.
Indirect Social benefits-Income	Agroforestry provides year round production in the farm and longer production periods require year-round use of labour.
Indirect Social benefits-Education	Agroforestry teaches the importance of managing land in a sustainable way and provides sites for knowledge exchange amongst farmers.
Indirect Social benefits-Health	Improved soil fertility and water retention helps in growth of healthy crops and fruits which will provide adequate nutrition to farm households thereby improving their health.
Indirect Environmental Health	Agroforestry improves soil fertility, water retention and enhances biodiversity, which has positive environmental health effects. Agroforestry reduces the need for chemical fertilizers thusly, reducing water pollution.
Local context -	There is opportunity to practice agroforestry at household level and community

Opportunities	levels in Swaziland. The supply of seedlings is available and technology for agroforestry can be easily taught through community level training sessions.
Local context - Barriers	The use of tractors may be a barrier as farmers may not want to plant trees in their field which they feel may impede the use of tractors. This can be overcome by pruning the trees and allowing adequate space between trees for tractors to move. Another barrier could be inadequate awareness of this technology.
Status	NAMBOARD, LUSLM and Ministry of Agriculture is implementing agroforestry as part of their climate smart agriculture projects in Swaziland. Several hundred households have benefitted from this.
Market Potential	Market of agroforestry products is available as a portion of the country's imports include fresh produce including vegetables and fruits which can easily be grown in Swaziland. Availability of tree nurseries is also adequate and can be expanded in Swaziland to promote agroforestry.
Timeframe	The benefits of agroforestry will take about a year to accrue.
Acceptable to Local stakeholders	Swaziland Agriculture Development Programme (SADP) has established 300 on farm demonstration sites
Existing investors supporting this technology	LUSLM project has supported 689 households with orchards and agroforestry. This was supported by GEF, IFAD and SWADE.

Technology: Conservation of Genetic Resources for Swaziland

Introduction	Conservation of genetic resources arose from the thoughts of gene resource conservation which began in the 1910's by agriculturalists who wanted to use wild relatives of crops in breeding programs. This was in response to the concerns that scientists had that the genetic diversity of plant and animal breeders was rapidly being lost. Conservation of genetic resources is important as even maintaining productivity requires constant input of new genetic material to over-come crop losses due to pests that become pesticide resistant. This also helps with climate change as higher diversity in crops will make the farmer more resilient to changing weather and climate patterns. This also helps improve yields and withstand shocks of climate change. The focus on conservation of genetic resources in Swaziland is in the forestry sector. Both in situ conservation and ex situ conservation can be done but the focus in the country is on in situ conservation.
Technology Advantages	This technology helps in conservation of biodiversity and reduces species extinction. It also helps farmers in building a pool of robust seeds which can withstand varying climatic conditions and thereby help in adaptation.
Technology Disadvantages	If the focus is only on agricultural varieties, the approach is only partially effective because traditional crop varieties, though much more diverse than elite varieties, are themselves much less diverse than wild populations and wild relatives. Farmers may prefer to switch to elite varieties for economic benefits and there may be need for subsidies to promote use of genetically diverse varieties. In Ex situ conservation, seed storage is done in seed banks. However, seeds of many important tropical species are recalcitrant, i.e., difficult or impossible to store for long periods. Many crop plants are clonally propagated. Long term seed storage is not effective, and tissue culture techniques for long-term storage are poorly developed.
Technology Highlights	There are two major alternatives for the conservation of genetic resources and they are in situ and ex situ. In situ conservation refers to the conservation of important genetic resources in wild populations and land races, and it is often associated with traditional subsistence agriculture. Ex situ conservation refers to the conservation of genetic resources off-site in gene banks, often in long-term storage as seed. This was identified as a priority for Swaziland as GMO seeds from South Africa are entering the country illegally.
Institutional and organizational highlights	Although there are institutions involved in conservation and use of forest genetic resources, the country has not established any national coordination mechanism to include different institutions. Forest genetic resource research has not been prioritised in the country, thus there is no research programme. A number of laws have been enacted to support the conservation of forest genetic resources. The existing legislation need to be improved to adequately manage forest genetic resources. Agro-forestry as a means to conserve tree genetic resources has just been introduced in Swaziland and the country has been able to establish the programme through the Swaziland Agricultural Development Programme (SADP)

	with funding from the European Union (EU). The Food and Agriculture Organisation of the United Nations (FAO) is coordinating the funds and projects under the fund.
Operation and maintenance	Ex situ conservation, the conservation of organisms outside of natural habitats, is considered especially suitable for seeds of major crop plants. There is need for data collection and construction of seed banks. Germplasm banks fulfill an important long-term need and their functionality is dependent on the collection, characterization, preservation, and distribution of genetic resources. All these require human resources who are skilled.
Political endorsement	Swaziland is a signatory to a number of regional and international conventions, protocols and agreements. These include the United Nations (UN) Convention on Biological Diversity, The United Nations (UN) Convention to Combat Desertification, the Convention on International Trade in Endangered Species of Wild Fauna and Flora etc. There are also several legal instruments that were put in place as a result of the international and regional conventions, protocols and agreements in which the country is a signatory to. These include The Environment Management Act, 2002, the Flora Protection Act, 2001, the Plant Control Act, 1981 etc. Hence, in line with these regulations and soft laws there is endorsement.
Endorsement by experts	This technology, once too expensive and requiring large research investment, is now widely used and endorsed by experts. This technology helps in conservation of biological resources and helps in land management and agriculture.
Adequacy for current climate change	With climate change, biodiversity will be affected by the changing rainfall patterns and temperature. The need for conservation will increase and there is necessity for preserving genetic resources. Thus, this technology is useful in assisting agriculture, forests and biodiversity in effectively adapting to climate change.
Scale/size of beneficiaries	This depends on scale of operations. However, it is best suited for large scale operations, as the technology requires investments and capacity building. Therefore it is best done at national level.
Implementation costs	The management applications of conservation genetics include inferring relationships to identify units of management and evaluate taxonomy, identifying individuals for estimation of population characteristics, associating environmental features with breaks in genetic continuity, and propagating wild or domesticated stocks. Costs related to this need to be calculated on a case by case basis.
Operating Costs	This needs to be calculated at programme level and is difficult to estimate.
Additional costs compared to "Business As Usual"	There will be costs of establishing seed banks, capacity building, training, awareness raising and data collection. This will be offset in the long run by benefits accrued.
Long term cost (i.e. 10, 30, or 50 years)	The cost of loss of genetic diversity. This will reduce the capacity of sectors such as agriculture, forests and biodiversity to effectively adapt to climate change.

without adaptation	
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Costs of maintaining seed banks, continuous capacity building, training, awareness raising and data collection. This will be offset in the long run by benefits accrued.
Development benefits – direct benefit	The benefits of conserving genetic resources are many. There will be improved productivity in agriculture, forests and biodiversity sectors. This will boost the economy and livelihoods.
Development benefit – indirect benefits	Other related sectors such as tourism will benefit from biodiversity conservation through conservation of genetic resources.
Environmental Benefits	Biodiversity will be maintained. Productivity in agriculture and forestry sector will improve, which will provide ecosystem benefits.
Economic benefits – direct benefits Employment	Forest genetic resources provide employment in the commercial forests. They are also used in addressing poverty in terms of products sold in market and also addressing the food security problems.
Economic benefits – indirect benefits	Commercial forests accounts for diversity of product that earns foreign revenue for Swaziland. The major forestry products are unbleached kraft-pulp which closed down in early 2010, sawn timber, poles for fencing, construction and transmission lines, and sawn timber for furniture making. There are other products from forestry which are non-wood forestry products. These include foliage, medicine, honey, edible fruits and nuts, mushrooms and silk worms.
Indirect Social benefits-Income	Increased species of biodiversity will improve attraction of Swaziland for eco-tourism which will generate jobs and income. Improved productivity in farming will provide social and economic benefits to the sector.
Indirect Social benefits-Education	Collection of data and species names will help form a database for scientists and students who are interested to learn more on this. Parks which are conserved provide study sites for environmental students.
Indirect Social benefits-Health	There is more reliance to medicines derived from forests genetic resources for healthcare by a large population in the country.
Indirect Environmental Health	Forest genetic resources also play an important role in minimizing the effects of climate change and addressing soil erosion problems. Having healthy forests assist in carbon sequestration.
Local context - Opportunities	There is opportunity for Swaziland to improve its conservation of genetic resources. There is also scope to include this into existing conservation measures such as conservation of protected areas programmes.
Local context - Barriers	However, the existing regulations on forest genetic resources are not very specific. The Flora Protection Act, 2001 needs to be reviewed to be in line with the present trends. The trends observed over the past ten years include increase in reliance on forests products for wood fuel, medicines and poverty reduction (through sale of

	forest products and job creation), enforcement of legislation to control access to forest genetic resources, increase in number of community forests and forests destroyed by wild fires. The main driving forces to these trends include over-exploitation of forest resources by human activities, increase in human population, poverty and increase in demand for traditional medicines. Swaziland needs assistance to review the existing legislation so that it can address the emerging trends affecting forest resources. The country needs to improve on capacity building and initiate research programmes. It is also important for Swaziland to address the problem of ex-situ conservation as a matter of urgency and to improve on awareness campaigns on forest resources conservation. A number of forests need to be protected to conserve indigenous plant species constituting the forests. Furthermore, conservation of genetic resources need large funding and capacity, which is inadequate in Swaziland. There is need for support from development partners.
Status	According to the State of Genetic Resources Report for Swaziland, conservation in situ is primarily within existing nature reserves. Nature conservation areas' main focus is conservation of fauna and flora. Four threatened species are included in in situ conservation and these are *Warburgia salutaris, Cyathea capensis, Encephalartos paucidentatus, Encephalartos umbeluziences, Prunus africana, Protea comptonii* and *Protea parvula.* However, data on the number of populations or stands conserved and the total area covered by the targeted species is not available. Conservation ex-situ has not been given the necessary attention in Swaziland. The country is experiencing a serious decline in forest species but the country has not yet formulated programmes to initiate ex-situ conservation of forest species. The Government's initiative to establish a national botanic garden failed because of funding not being sufficient to complete the project. However, government is still sourcing funds to embark on the project. In terms of international cooperation regarding programmes on transfer of seed, Swaziland had not initiated any programme. Seed is sourced within the country except for commercial forest tree species which is sourced outside the country. The country has identified eight tree species for improvement, but there is no capacity to carry out the programme. The species include *Combretum zeyheri, Encemphalartos spp, Englerophytum magalismontanum, Pterocarpus angolensis, Sclerocarya birrea, Syzygium cordatum, Vangueria infausta* and *Ximenia caffra*. There are now six (6) conservation areas that are targeting both plant and wild animal species. Although there are no specific strategies/programmes in place, threatened plant species have been made a priority in terms of conservation in these conservation areas.
Market Potential	When genetic resources are conserved there is improved environmental benefits which help boost eco-tourism.
Timeframe	This depends on scale of programme.

Acceptable to Local stakeholders	This has been implemented in Swaziland and is acceptable.
Existing investors supporting this technology	Organizations such as Swaziland National Trust Commission, Government agencies related to environment and non-governmental as well as eco-tourism agencies support this. In situ conservation of plant diversity in Swaziland is primarily in the form of nature reserves, whose objectives are the conservation of the indigenous flora and fauna. These include Malolotja and Mlawula Nature Reserves, run by the Swaziland National Trust Commission, the parastatal organisation responsible for conservation in the country. In addition to these, there are private nature reserves and game sanctuaries, as well as Hlane Game Sanctuary, belonging to His Majesty the King, and, although their objectives usually do not specifically include the conservation of plant diversity, these areas provide some level of protection to the flora. There are also a number of private farms where a high diversity of flora is protected, although this protection is based on the goodwill of the landowners. Other areas where the flora is protected by default include the sites of royal graves, at a number of localities in the country. There is also legislation which provides protection for certain plant species throughout the country, although enforcement of this legislation is often difficult. (*Source: Swaziland National Trust Commission website*)

Technology: Alien Invasive Species management in Swaziland

Introduction	Alien (non-native) species have been introduced both accidentally and intentionally in Swaziland. Intentional introductions are, and have been, motivated by economic, environmental and social considerations. It is important to control invasive species as their impacts are immense, insidious and usually irreversible, and they may be damaging to native species and ecosystems through loss and degradation of habitats. The cost of reversing their impact is large. Although some species have invaded habitats on their own, human activity such as exploration, colonization, trade and tourism has dramatically increased the diversity and scale of invasions by alien species. Invasive species contribute to land degradation through soil erosion and the drawing down of water resources, reducing resources available to people and indigenous plants. Others produce leaf litter which poisons the soil, suppressing the growth of other plants, and in particular that of the understorey. They may alter the environment in directions that are more favourable for them but less favourable to native species. This could include altering geomorphic processes (soil erosion rates, for instance, or sediment accretion), biogeochemical cycling, hydrological cycles, or fire or light regimes. Swaziland declared a national emergency on proliferation of invasive species in year 2005, as they were said to threaten food security and thus the economy of the country.
Technology Advantages	This is not a sophisticated technology and hence can be implemented at reasonable cost and varying scales. Building capacity of communities to identify alien species and encouraging them to uproot and destroy them will help in this cause. SNTC and its partners have been collecting data, researching, mapping and compiling information materials on invasive species. A number of programmes and projects in Swaziland has already included elements of invasive species control (for example LUSLM).
Technology Disadvantages	Some of the invasive species such as eucalyptus and guava have commercial value and are beneficial to people and so support from communities to control those species may be difficult to receive. The activities of data collection, research and mapping requires specialized personnel.
Technology Highlights	Swaziland has to put in place systems for evaluating the risks and benefits associated with alien species, and for deciding when to use them and when to prevent their introduction or eradicate them. This entails considering the economic, development, environment and human well-being costs and benefits, and recognizing the close relationship between these sectors. Second, Africa faces the challenges of how to translate its policy objectives into effective management practice. When species are identified as a threat, appropriate responses may include establishing systems for their eradication, as well as for controlling and monitoring their introduction. When alien species are used, developing early warning and assessment systems regarding their behavior as well as effective response systems is essential. SNTC, SEA and its partners have already embarked

	on such programmes. Some species such as the eucalyptus provide benefits which thwart the need to completely eradicate them from the country. Controlling invasive species can be done through awareness raising, data collection and mapping, physical removal of species through uprooting and burning and setting up early warning systems.
Institutional and organizational highlights	Swaziland National Trust Commission, Swaziland Environment Authority, Swaziland Livestock Technical Services, All out Africa, Natural History Society of Swaziland and others have been actively involved in collecting data, studying and undertaking programmes to control growth of invasive species. Government of Swaziland in particular the Ministry of Tourism and Environmental Affairs is keenly interested and taking leadership in these matters.
Operation and maintenance	This is a continuous project as invasive species is perpetrated by seeds blown by wind, carried by fauna and deliberately planted by humans. Data collection and mapping need to be done at regular intervals to assess extent of spread of invasive species.
Political endorsement	There is strong political endorsement through the Ministry of Tourism and Environmental Affairs and Government of Swaziland declared an emergency of invasive species, indicative of the solid commitment to this cause.
Endorsement by experts	UNEP has declared that invasive species is a substantial threat to ecosystems. The Millennium Ecosystem Assessment (MA) found that trends in species introductions, as well as modelling predictions, strongly suggest that biological invasions will continue to increase in number and impact.
Adequacy for current climate change	With climate change, temperature variations and rainfall variations may promote growth of some species of alien invasive plants. Due to these species, farmers are losing productive arable land used to produce cash crops and pastures where domesticated and wild animals graze. The sugar and forestry industries are struggling to save their farms from these alien plants and thousands of hectares of developed land with very expensive irrigation infrastructure and bridges. The plants have clearly demonstrated their ability to change permanently our ecosystem and economic development that has taken the country decades to develop. Thus controlling invasive species will help the agriculture, forests and biodiversity sectors and indirectly aid in climate change adaptation.
Scale/size of beneficiaries	This is a national level problem which can be tackled beginning at household level by uprooting invasive species and destroying them. Invasive species such as the Guava are planted by individuals for fruits and therefore there is need for greater awareness raising to prevent people planting the invasive species.
Implementation costs	This varies according to interventions. Conducting research, collecting data and mapping is fairly costly, however, there is no other option, as uncontrolled growth of invasive species will threaten the land, ecosystems, agriculture and thereby economy of the country.
Operating Costs	There will be continuous costs of database updating, regular publishing of research results and maps and activities on the field in awareness raising as well as removal and destruction of invasive species.

Additional costs compared to "Business As Usual"	Costs of data collection, mapping, awareness raising, field activities in controlling invasive species. This will be offset by benefits accrued in prevention of land being taken over by invasive species.
Long term cost (i.e. 10, 30, or 50 years) without adaptation	Loss of arable land, loss of grazing land, lower agricultural productivity and increasing food insecurity.
Long term cost (i.e. 10, 30, or 50 years) with adaptation	Continuous costs of data collection, mapping, field activities, capacity building etc.
Development benefits – direct benefit	Benefit of controlling invasive species is myriad. This includes being able to use land productively, increasing agricultural yields and enhancing biodiversity.
Development benefit – indirect benefits	Habitat loss is prevented and therefore there are benefits to wildlife. This will help the tourism sector.
Environmental Benefits	Habitat loss reduction helps in maintaining biodiversity and use of land for productive purposes such as agriculture. Invasive species usually have excessive water demand compared to indigenous species so controlling them has indirect positive benefits on water resources.
Economic benefits – direct benefits Employment	Invasive species may out-compete native species, repressing or excluding them. Controlling invasive species therefore allows indigenous species to thrive which has multiple benefits of provisioning of productive ecosystem services such as food, fibres and medicinal plants.
Economic benefits – indirect benefits	Invasive species such as the Wattle (originally from Australia, but introduced in Southern Africa for wood fuel security) has the tendency to take over grazing land and convert to bush. When such species which take over arable and grazing land are controlled, the benefits are felt in agriculture and livestock rearing through improved land and yields. Furthermore, Guava which is also an alien species are purposely grown by homesteads for its fruit. The disadvantage of this is that indigenous trees are disadvantaged as they take longer to grow and may slowly reduce in number throughout the country.
Indirect Social benefits-Income	Programmes and projects that control invasive species employ people to physically remove the plants and thus jobs are created. Higher level jobs are created for data collection, research, capacity building and mapping of plants.
Indirect Social benefits-Education	Increased research and data collection as well as mapping of invasive plants help provide botanists and students with more information. Capacity building at village level on types of invasive species and their impacts help increase knowledge amongst communities.

Indirect Social benefits-Health	Removing invasive species and bringing back indigenous vegetation helps in protecting ecosystem services such as food, fibre and medicinal plants derived from indigenous species. Increased yields in agriculture and livestock rearing has nutritional benefits for those who consume them.
Indirect Environmental Health	Invasive species wreak havoc by competing for water resources, taking over arable land and grazing land, and reducing habitats for wildlife and indigenous species. . Invasive species may also affect native species by introducing pathogens or parasites that cause disease or kill native species. Thus removing the invasive species improves environmental health.
Local context - Opportunities	There is opportunity in including control of invasive species into current and ongoing as well as future environmental, forestry, agricultural and water projects in the country. This theme affects all these sectors.
Local context - Barriers	Beneficial invasive plants such as wattle, guava and eucalyptus are used by communities and industries and may may need to be controlled.
Status	The Swaziland National History Society, notes that an invasive species known locally as demonia weed was blown into Swaziland by a cyclone in 1984; this has subsequently rendered large areas of formerly productive agricultural land useless. Currently Swaziland has set in place Alien plant control activities on a continuous basis at Mlawula Nature Reserve, and mapping the distribution of Chromolaena odorata. In 2005, the government declared proliferation of these invasive alien species a national calamity.
Timeframe	This can vary according to scale of programme and could be long term protection and in the short term provide education and control.
Acceptable to Local stakeholders	Local stakeholders understand to some extent the negative impacts of invasive species. The challenge may be for controlling of species which are beneficial to them.
Existing investors supporting this technology	Swaziland National Trust Commission, All Out Africa and Natural History Society of Swaziland are all working towards investigating, compiling data and physically removing these alien species. A project was carried out in 2003/4 by Swaziland Environmental Authority, to compile existing data on alien invasive plants of Swaziland. One product of this project was the creation of an online database of Swaziland's alien/non-indigenous plants, with distribution maps and photographs and illustrations.

Annex II: List of stakeholders involved

Sector prioritization workshop (Royal Villas, Ezulwini, 13 June 2015)

No.	Name of Participant	Institution
1.	Mdumiseni Bhembe	Ministry of economic planning and development
2.	Minky Groenewald	Department of Meteorology
3.	Ncamiso Mavuso	Matsapha Town Council
4.	Mpendulo Simelane	ACAT
5.	Hlobsile Sikhosana	Department of Meteorology
6.	Khetsiwe Khumalo	Department of Meteorology
7.	Sihle Mkhatshwa	Department of Meteorology
8.	Maxwell Sithole	Ministry of Housing and Urban Development
9.	Sabelo Masuku	Matsapha Town Council
10.	Ambrose Dlamini	Ministry of Agriculture
11.	Thabile Dlamini	Swaziland Environment Authority
12.	Phinda Nyambose	Limkokwing
13.	Tengetile Hlophe	PPCU
14.	Sandile Gumedze	SNTC
16.	Ndumiso Ngozo	Montigny
17.	Maxwell Nkambule	SNAU
19.	Bruce Jameson	Moss Foundation
20.	Blessing Dladla	Ministry of Information ,Technology and Communication
21.	Bafana Simelane	Department of Meteorology
22.	Sindy Mthimkhulu	Department of Water Affairs

Technology prioritization workshop (Simunye country club, 20-21 August 2015)

No.	Name of participant	Nationality
1.	Ambrose Dlamini	Ministry of Agriculture
2.	Ntombikayise Fakudze	SEPARC
3.	Teddy Dlamini	Ministry of Agriculture
4.	Nozipho Dlamini	Swaziland National Housing Board
5.	Mbuso Mdluli	RSSC
6.	Bongani Sigudla	Ministry of Health
7.	Phefeni Vilakati	NAMBOARD
8.	Bandzile Mavuso	USA Distillers
9.	Colani Ndzinisa	USA Distillers
10.	Bafana Simelane	Department of Meteorology
11.	Gcina Dlamini	UNDP
12.	Thembinkosi Ndzimandze	Department of Energy
13.	Deepa Pullanikattil	CANGO
14.	Mdumiseni Bhembe	Ministry of Economic Planning and Development
15.	Phinda Nyambose	Ministry of Agriculture

16.	Riyong Kim Bakkegaar	UNEP- DTU
17.	Harmke Immink	Promethium Carbon
18.	Freddy Magagaula	Ministry of Agriculture
19.	Ncamiso Mhlanga	UNDP
20.	Samuel Seyama	University of Swaziland
21.	Zweli Maphanga	Municipal Council of Manzini
22.	Bongani Mamba	Unitrans/ Procurement Agency
23.	Mduduzi Mathunjwa	University of Swaziland
24.	Gcina Dladla	Swaziland Environment Authority
25.	Prince Mngoma	SWADE- LUSLIM
26.	Jabu Myeni	Royal Swaziland Sugar Cooperation
27.	Calsile Mhlanga	Swaziland Environment Authority
28.	Cyprian Ndlela	Swaziland meat Industries
29.	Stella Beghini	COSPE
30.	Diana Earnshaw	University of Swaziland
31.	Bruce Jameson	Moss Foundation
32.	Mzwandile Thwala	Department of Energy
33.	Katie Ross	Promethium Carbon
34.	Dennis Mkhonta	Department of Meteorology
35.	Hlobsile Skhosana	Ministry of Tourism and Environmental Affairs
36.	Minky Groenewald	Department of Meteorology
37.	Khetsiwe Khumalo	Department of Meteorology
38.	Sihle Mkhatshwa	Department of Meteorology
39.	Nhlanhla Nxumalo	Peak Timbers
40.	Nomkhosi Dlamini	Ministry of Agriculture
41.	Abednigo Dlamini	University of Swaziland
42.	Sanelisiwe Mamba	Ministry of Tourism and Environmental Affairs
43.	Glory Mdluli	Ministry of Tourism and Environmental Affairs

TNA Validation workshop (Royal Swazi Spa, 9 April 2016)

No.	**Name of participant**	**Institution**
1.	Hlobsile Skhosana	Ministry of Tourism and Environmental Affairs
2.	Bongani Sigudla	Ministry of Health
3.	Mduduzi Mathunjwa	University of Swaziland
4.	Mvezi Dlamini	Peak Timbers
5.	Nhlanhla Nxumalo	Peak Timbers
6.	Thabile Ndlovu	University of Swaziland
7.	Mduduzi Dlamini	Swaziland Environment Authority
8.	Ndumiso Ngozo	Montigny
9.	Rod de Vletter	Eco- Lubombo
10.	Deepa pullanikkatil	CANGO

11.	Freddy Magagula	Ministry of Agriculture
12.	Mfundo ndlela	Centarl Statistics Office
13.	Jo Ann Sparham	Peekay Investments
14.	Megan Darne	Peekay Investments
15.	Vusi Matsebula	Ezulwini Municipality
16.	Bongani Magongo	Ministry of Agriculture
17.	Calsile Mhlanga	Swaziland Environment Authority
18.	Glory Mdluli	Ministry of Tourism and Environmental Affairs
19.	Mzwandile Thwala	Department of Energy
20.	Bongani Nkhabindze	Swaziland Environment Authority
21.	Qondile Dlamini	Ezulwini Municipality
22.	Sihle Mkhatshwa	Department of Meteorology
23.	John Creamer	USA Distillers
24.	Simelane Bafana	Department of Meteorology
25.	Andile Zwane	Swaziland Standards Authority
26.	Saico Singwane	University of Swaziland
27.	Sizwe mabaso	University of Swaziland
28.	Minky Groenewald	Department of metorology
29.	Phindile Dlamini	Ministry of Agriculture
30.	Khetsiwe Khumalo	Department of Meteorology
31.	Mandla Makhanya	Ministry of Agriculture
32.	Ntokozo Dlamini	Ministry of Agriculture
33.	Hlophe Mbongeni	Swaziland Environment Authotity
34.	Mbhekwa Dlamini	Total Swaziland
35.	Adam Dlamini	Ministry of Agriculture
36.	William Ndlela	University of Swaziland
37.	Sipho Mkhonta	Municipal Council of Mbabane
38.	Jabulani Dlamini	Oil One Swaziland
39.	Johan Smit	USA Distillers
40.	Ariane Labat	European Union
41.	Daniel Khumalo	Cotton Board
42.	Mthunzi Fakudze	Ministry of Public Works and Transport, Roads Department
43.	Nkhosingphile Myeni	CANGO
44.	Phefeni Vilakati	Namboard
45.	Rod De Vletter	Eco-Lubombo Conservancy
46.	Bakithi Mamba	CANGO
47.	Mzwandile Ndzinisa	Ministry of Natural resources and Energy
48.	Khulekani Sifundza	Department Of Energy
49.	Abel Nhleko	Ministry of Agriculture
50.	Delani Dlamini	Ministry of Agriculture
51.	Thamsanqa Nkambule	Ministry of Tinkhundla
52.	Jabulani Tsabedze	Swaziland National Farmers Union
53.	Nonhlanhla Mdlovu	Ministry of Commerce, Industry and Trade

54.	Thabsile Dlamini	Ministry of Agriculture
55.	Sifiso Nzalo	Swaziland Meteoroligal Services
56.	Jabu Myeni	Royal Swaziland Sugar Cooperation
57.	Alfred Muyre	University of Swaziland
58.	Mphumelelo Ndlovu	Swaziland Sugar Association
59.	Mmeli makhanya	Swaziland National Trust Commission
60.	Sipho Simelane	Swaziland Water Services Corporation
61.	Mandla Mdlovu	Ministry of Agriculture
62.	Ntombikayise Dlamini	Ministry of Agriculture
63.	Nozipho Dlamini	Swaziland National Housing Board

Field visits done (further details under APPENDIX)

1. Visit to "Clean the Rivers Project" at Ekupheleni, Engcayini community. Visited wash stations, interviewed community and project implementers Jacob Mamba and Bruce Jameson. Moss Foundation, 8 September 2015.
2. Interview with Professor Absalom Manyatsi at Piggs Peak. 16 September 2015.
3. Visit to Siteki to view drip irrigation sites, Lubombo eco products, conservation agriculture sites, agro ecology project and post harvest storage facility. Bheki Buluga, Project Coordinator, COSPE, 23 September 2015.
4. Visit to Siteki to view hydroponics, vegetable farming under shade net green houses and organic farming center. Mancoba, One Heart Africa, 23 September 2015.
5. Visit to climate smart agriculture site at Mphateni, Nhletjeni and Nkhungwini areas. Drip irrigation, crop diversification, agro forestry, earth dam and holding facility for produce visited. Phefeni Vilakati, NAMBOARD, 24 September 2015.
6. Visit to Permaculture Center at Malkerns. Sam, Guba Swaziland, 25 September 2015.

APPENDIX

PHOTO ESSAYS