The Republic of Uganda

TECHNOLOGY NEEDS ASSESSMENT REPORT FOR CLIMATE CHANGE ADAPTATION

[January 13, 2020]

Report I: TNA Report for Climate Change Adaptation in the Agriculture, Forestry and Water Sectors of Uganda

This publication is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with Energy Research Centre, University of Cape Town The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP DTU Partnership, UN Environment or Energy Research Centre, University of Cape Town. We regret any errors or omissions that may have been unwittingly made.

Table of Contents

LIST OF TABLES

LIST OF ACRONYMS

CAADP	Comprehensive Africa Agriculture Development Program
CCAFS	Climate Change for Agriculture and Food Security
CCD	Climate Change Department
CDM	Clean Development Mechanism
CGIAR	Consultative Group for International Agricultural Research
CTCN	Climate Technology Centre and Network
DSIP	Development Strategy and Investment Plan
DTU	Technical University of Denmark
EAC	East African Community
FAO	Food and Agriculture Organization
FMNR	Farmer Managed Natural Regeneration
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
IFFM	Integrated Forest Fire Management
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for Conservation of Nature
LVBC	Lake Victoria Basin Commission.
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MCA	Multicriterial Analysis
MoFPED	Ministry of Finance Planning and Economic Development
MoLG	Ministry of Local Government
MWE	Ministry of Water and Environment
NAPA	National Adaptation Plan for Agriculture
NCCAC	National Climate Change Advisory Committee
NCCP	National Climate Change Policy
NCCPC	National Climate Change Policy Committee
NDCs	Nationally Determined Contributions
NDP	National Development Plan
NDE	National Designated Entity
NEMA	National Environmental Management Authority

NPA	National Planning Authority
NPC	National Population Council
NWSC	National Water and Sewerage Corporation
PELUM	Participatory Environment and Land Use Management.
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RWH	Rainwater Harvesting
SAP	Super-absorbent polyacrylate
SNC	Second National Communication
SPR	Sector Performance Report
TAPS	Technology Action Plans
TNA	Technological Needs Assessment
UBOS	Uganda Bureau of Statistics
UDHS	Uganda Demographic and Health Survey
UNCST	Uganda National Council for Science and Technology
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WASH	Water Sanitation and Hygiene

EXECUTIVE SUMMARY

Climate change in Uganda is predicted to cause temperature rise and make rainfall seasonality more erratic, including changes in onset, duration and intensity punctuated with intra-seasonal dry spells. Minimum temperature is projected to rise by 0.8-2.1 and maximum temperature by 1-2.1^{o}C in mid-century. The frequency and severity of extreme events such as droughts, floods and landslides are predicted to increase. Climate change will potentially have adverse impacts on the economy, which is highly dependent on rain-fed agriculture, employing about 72% of the total population. To achieve its development objective of transforming the Ugandan society from "a peasant to a modern and prosperous nation" (NPA 2007), Uganda needs to develop its capacity to respond appropriately to climate change and this requires substantial external support.

Uganda is a Party to the United Nations Framework Convention on Climate Change (UNFCCC), which brings together nations to agree on collective responses for mitigating and adapting to climate change. Being a Least Developed Country with low green-house gas emission levels yet with high vulnerability to climate change, Uganda's climate responses are predominantly focused on adaptation and making the key development sectors more resilient (Uganda's NDC 2016). Based on the National Climate Change Policy (NCCP 2015), climate change is being mainstreamed in working plans and budgets of all government sectors.

Sectors that were identified as most vulnerable to climate change impacts in the NAPA (2007) were prioritised in Uganda's 2nd National Communication (SNC) to the UNFCCC. The highest ranked were the agricultural and agricultural-related sectors including water, forestry, environment and biodiversity. Other vulnerable sectors identified were health, infrastructure and human settlement. Agricultural production is predicted to decrease due to lowering of soil fertility, increased incidences of pests and diseases and post-harvest losses. Degradation in water quality and changes in seasonal water availability are also predicted, with increased incidences of flooding and droughts affecting may other sectors. Forests and wetlands are also vulnerable to increasing pressure due to growing demand for land for human settlement and agricultural production. Potential damage of infrastructure and human settlement will potentially destroy property and livelihoods leading to food and water insecurity and may cause people to migrate.

In all these vulnerable sectors, strengthening of technical and institutional capacity is emphasised to enable comprehensive assessment of vulnerability and implementation of adaptation actions.

The UNFCCC (1992) Article 4 aims to enable developing nations to respond to climate change through commitments made by developed nations to transfer environmentally sound and appropriate technologies. This requires prior assessment of technology needs in light of future climate change scenarios and development priorities (the Bali Plan of Action for Transfer of Environmentally Sound Technologies (UNFCCC 2008). It also involves assessment of potential technical, institutional and financial capacity to develop and use technological responses to climate change, including the capacity to develop, transfer, adopt, adapt and diffuse technology where it is needed.

Uganda received support from the Global Environment Facility (GEF) to conduct a climate Technology Needs Assessment (TNA). The TNA is a country-driven systematic process for identifying, selecting and implementing climate technologies for mitigating or adapting to climate change to support implementation of Uganda's nationally determined contributions (NDCs) and related technology-dependent climate actions at national level. This project is implemented by the UN Environment through UNEP DTU Partnership, Denmark, and coordinated by Uganda National Council for Science and Technology (UNCST), which is the National Designated Entity (NDE) for the Climate Technology Centre and Network (CTCN).

The TNA involves three steps: technology identification and selection, identification and analysis of framework and barriers hindering the deployment or diffusion of prioritized technologies; and designing of technology action plans (TAPS). The process is participatory involving relevant stakeholders to enable ownership of the process and ensuring that identified climate technologies are in line with national development and climate adaptation priorities. The National Team also includes the UNCST, consultants, a steering committee and relevant stakeholders in the various sectors. The stakeholders to be engaged in the TNA process are those in national institutions involved in climate change policy-making, including the Ministry of Water and the Environment (MWE), the National Climate Change Policy Committee (NCCPC), the National Climate Change Advisory Committee (NCCAC), composed of technical persons from relevant government sectors, with representatives from the private sector, civil society, academia and district authorities, the Parliament Standing Committee on Natural Resources, the Climate Change Department (CCD), the Ministry of Finance Planning and Economic Development (MoFPED), the National Planning Authority (NPA) and the Ministry of Local Government (MoLG).

This report presents the process followed in the identification and selection of technologies for climate change adaptation. Sectors considered for climate adaptation technology were those considered as most vulnerable in NAPA (2007), ranked according to the high magnitude of climate-change risks and low capacity to cope. These included water, agriculture, health, forestry, infrastructure and disaster-risk management. At the TNA project inception workshop, stakeholders prioritized Agriculture, Forestry, and Water sectors for climate-adaptation technology transfer.

Potential climate adaptation technologies in the water, agriculture and forestry sectors were identified **(Table 1)**. Technology identification was based on:

- Potential to enable adaptation to projected climate change scenarios
- Priority in the national development documents
- Appropriateness, applicability/acceptability – based on national development priorities
- Experience in using the technology based on what has been tried - status of implementation for example at pilot or rollout stage, etc.
- Potential scale and replicability – geographical area and number of people impacted
- Co-benefit
- Accessibility to material, expertise and capacity to establish and operate.

Fact sheets on each of the identified technologies were developed and shared with stakeholders. Stakeholders who actively participated in technology identification and selection were from Ministry of Water and Environment (MWE), the academia, civil society, and the National Agricultural Research Organisation (NARO). They were engaged in a workshop where the TNA process was introduced and during break-out sessions which were done according to the agriculture, water and forestry sectors, more in-depth discussion of potential adaptation technologies was conducted, guided by the fact sheets. Stakeholders also recommended additional technologies in the case of agriculture and forestry (marked by * in **Table 1**).

Table 1. Technologies identified for Climate Adaptation

Water	
	Water channeling
	Rooftop rainwater harvesting
	Surface runoff harvesting
	Construction of new das and rehabilitation of old ones
	Deep well water channeling
	Household water treatment and safe storage
	Community irrigation
Agriculture	
	Crop breeding for tolerance to adverse climatic conditions
	Crop diversification and precision farming
	Community irrigation systems
	Ecological pest management
	Culture based fisheries and aquaculture
	Responsive agricultural extension
	App for targeting Soil and water conservation technologies to appropriate conditions and estimating outcomes
	Livestock breeding for cattle and goats
	Climate insurance
	Seed and grain storage
	Agro-meteorology & market Information access & use by farmers*
	Value addition and processing of produce*
Forestry	
	Integrated wildfire management
	Enrichment planting for restoration of natural forests
	Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism
	Application of tissue culture to hasten massive propagation/multiplication of tree seedlings
	Advancing biotechnology to produce hybrids which are adapted to Uganda's climatic conditions
	Application/use of drones in forest management for effective monitoring
	Promotion of bamboo value chains – production and processing/ value addition and marketing
	Forest products management to increase resilience to temperature rise/ humidity change and insect/ disease vulnerability – wood/ biomass product seasoning, treatment/ protection, dimensions

Integrated pest management in forest plantations
Integrated forestry-crop-livestock systems
Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration
Diversification in forest species plantations
Use of hydrogels and hydro-absorbents to advance adaption to prolonged droughts impacting on forest plantations

Using the multi-criteria analysis tool provided by the TNA support team, stakeholders then agreed on criteria for ranking the technologies considering potential climate scenarios to reduce vulnerability or increase resilience, economic, social and environmental costs and benefits. Criteria were given weights according to relative importance. Technologies were allocated scores (from 0 being least desirable to 100, the most desirable) for each criterion, which were then multiplied by the weight of the criteria. Therefore, for costs, scores tended towards 100 if they were low and towards zero if they were high. For benefits, scores tended towards 0 if they were low and towards 100 if they were high. Total scores for each technology were used to rank the technologies considered to be of highest priority. The top-ranked climate adaptation technologies in the water, agriculture and forestry sectors are presented in **Table 2**.

This method enabled selection of technologies that were likely to provide high benefits and which could be implemented with low cost. The weakness in this method is that the prioritised technologies turned out to be not so different from business as usual. This could have resulted from situations where cost criteria were also given high weights as was often the case, leading to low ranking of technologies that were considered too costly for the country even if they would have potentially enabled the country to achieve more in enabling climate change adaptation.

Table 2. Technologies prioritised for Climate Change Adaptation

Water
• Deep well extraction • Rainwater harvesting • Surface runoff harvesting
Agriculture
• Responsive agricultural extension • Community irrigation systems • Crop breeding for climate change adaptation
Forestry
• Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration; • Integrated pest management in forest plantations through promoting mixed-species plantations; • Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism

CHAPTER ONE: INTRODUCTION

Climate change in Uganda is predicted to cause temperature rise and make rainfall seasonality more erratic, including changes in onset, duration and intensity punctuated with intra-seasonal dry spells (NAPA 2007; Lyon and DeWitt 2012). Minimum temperature is projected to rise by 0.8-2.1°C and maximum temperature by 1-2.1°C in mid-century (Second National Communication, SNC). The frequency and severity of extreme events such as droughts, floods and landslides are predicted to increase. Currently, the frequency of droughts has increased from every 20 years to every 5-16 years. The snow cover on the Rwenzori Mountain has receded (MAAIF DSIP, 2010). This will potentially have adverse impacts on the economy, which is highly dependent on rain-fed agriculture (Uganda National Development Plan 2015/16-2019/20). To achieve its development objective of transforming the Ugandan society from "a peasant to a modern and prosperous nation" (NPA 2007), Uganda needs to develop its capacity to respond appropriately to climate change and this requires substantial external support, including financial, institutional and technical capacity development

Uganda is party to the United Nations Framework Convention on Climate Change (UNFCCC), which brings together nations to agree on collective responses for mitigating and adapting to climate change. Being a Least Developed Country with low greenhouse gas emission levels yet with high vulnerability to climate change, Uganda's climate responses are predominantly focused on adaptation and making the key development sectors more resilient. It has also developed plans and actions for a low-emission development pathway and a National Climate Change Policy (NCCP, 2015). Article 4 of the 1992 UNFCCC aims to enable developing nations to respond to climate change through commitments made by developed nations to transfer environmentally sound and appropriate technologies. This requires prior assessment of technology needs in light of future climate change scenarios and development priorities (the Bali Plan of Action for Transfer of Environmentally Sound Technologies, UNFCCC 2008). It also involves assessment of potential technical, institutional and financial capacity to develop and use technological responses to climate change, including the capacity to develop, transfer, adopt, adapt and diffuse technology where it is needed.

1.1 ABOUT THE TNA PROJECT

The Technology Needs Assessment (TNA) is a country-driven systematic process for identifying, selecting and implementing climate technologies for mitigating or adapting to climate change to support implementation of Uganda's nationally determined contributions (NDCs) and related technology-dependent climate actions at national level. It is a participatory process involving all relevant stakeholders to ensure understanding, acceptability, support and implementation. Rooted in the Poznan Strategic Program on Technology Transfer and the Paris Agreement (2015), the TNA plays a key role in promoting and facilitation technology development and transfer, supporting developing countries to identify appropriate technology options and implement them for their climate response.

In Uganda, the TNA project seeks to support identification and implementation of potential technologies for climate adaptation and mitigation prioritised in the national policy and investment plans. It is implemented by the UN Environment through UNEP DTU Partnership, Denmark, and coordinated by Uganda's National Council for Science and Technology (UNCST), which is the National Designated Entity (NDE) for the Climate Technology Centre and Network (CTCN). The TNA Team in Uganda is made up of the Uganda National Council for Science and Technology (UNCST), consultants for climate adaptation and mitigation, sector working groups and the steering committee. At the TNA inception workshop, stakeholders prioritised the Agriculture, Water and Forestry Sectors for climate change adaptation and the Energy Sector for mitigation. Consultants reviewed national development and climate policy documents, identified potential technologies and in consultation with the UNCST agreed on the top 7 for the water sector, 12 for the agricultural sector and 13 for the forestry sector, for which fact sheets were developed. These were shared with stakeholders in a workshop where focus groups used multi criteria analysis to select the top three in each sector. The identification and selection of technologies through TNA provides a starting point for a variety of national projects and programs for accessing support for technology transfer and implementation. The capacity and tools gained from the consultative TNA approach can be applied for strengthening other aspects of national development planning.

1.2 EXISTING NATIONAL POLICIES RELATED TO CLIMATE ADAPTATION TECHNOLOGIES

1.2.1 National Circumstances.

Uganda is located in East Africa (1.3733° N, 32.2903° E) with a total area of 241,550 km^2, of which 41,743 km^2 is open water and swamps. Mean annual rainfall is between 400-2200 mm across the country and falls mostly in two seasons (March to June and October to December), except in the Northern region which receives a single rainy season (March to October). The North-eastern regions are relatively drier than other regions of the country. Weather patterns are influenced by the inter-tropical convergence zone (ITCZ), while inter-annual differences in rainfall are driven by monsoons and the teleconnection phenomena (El Nino Southern Oscillations). Because of its topographic characteristics such as mountain ranges, large rivers and lakes, climatic patterns vary widely across the country (USAID 2013). Total population is 38.8 million, 21% of the population are between the ages of 18 years and 35 years old, and 72.8% dwell in rural Uganda (National Population Council 2018; UBOS 2018). The country is classified among the Least Developed Countries (LDCs)with 21.4% of the population living below the national monetary poverty line in 2016/17 (World Bank 2016; UBOS 2018) and likely to increase in cases of extreme climatic and market shocks. Poverty is more concentrated in rural areas especially in northern and eastern Uganda where nutrition, education and sanitation are generally poor.

The economy of Uganda is highly dependent on rain-fed agriculture, which contributed 24.8% to the national GDP in 2013/14 and employed about 72% of the total population (UBOS and MAAIF 2011; Uganda National Development Plan, NDP II 2015). About 38% of the youth are engaged in agriculture, forestry and fishing (UBOS 2018). Agriculture is predominantly in the form of smallholder farming and although rainfall and soils are generally suitable for agriculture, productivity of crops, livestock and fisheries is below potential due to poor agronomic practices, and low access to modern technology especially for women farmers (Fermont and Benson 2011; NDP II 2015). Although Uganda is committed to the Maputo Declaration of the Comprehensive Africa Agriculture Development Program (CAADP), which recommends allocation of 10% of the total national budget to agriculture, the allocation to the sector was only 3% in 2013 (Second National Communication 2014). The population in the drier areas is chronically food insecure.

Coping mechanisms farmers resort to, have long term negative implications. Environmental degradation is also rampant with loss of forest cover from 24% in 1990 to 18.3% in 2005 and an estimated loss of 4 to 12% of GDP annually due to soil erosion (World Bank 2018). Consequently, agroecosystems and rural livelihoods are fragile, exacerbated by weak extension services and limited private sector engagement to provide quality inputs and credit services (World Bank 2016). Regional demand for agricultural produce is growing, however farm profitability is very low due to limited capacity and access to modern technologies and limited value addition. Mobile phone technology is not being utilised to its potential in transferring information due to limited internet coverage, low access to electricity (World Bank 2018) and prohibitive connectivity taxes.

Water resources are underdeveloped with cycles of runoff losses during rainy seasons and water scarcity during dry seasons. Irrigation is practiced by less than 1% of farmers and only 3% of the irrigable area is equipped (UBOS 2010; MAAIF 2011). Access to piped clean water is only 66% in rural areas and 74% in urban areas in 2017/2018 (Uganda Water and Environment Sector Performance Report 2018). Ordinarily about 55% of women and children in rural households spend on average 30 minutes a day collecting water (UDHS 2018). Diseases due to poor water quality e.g., cholera and typhoid, still take a heavy toll on the country's economy.

1.2.2 National Policies and Actions Related to Climate Change

The development framework of Uganda is based on Vision 2040 (NPA 2007), which aims to transform the country from "a peasant to a modern and prosperous nation". The country has developed international partnerships for climate action including ratifying the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Uganda is party to the East African Community climate change policy. It aims to follow a low carbon development pathway linked to green growth and sustainable development goals and has put in place the policies and measures for coordinated mitigation and adaptation to climate change impacts. At the national level, Climate change is led by the Climate Change Department under the Ministry of Water and Environment. The Ministry of Water and Environment has pursued accreditation as a National Implementing Entity for Climate Change in order to access the Adaptation Fund and the Green Climate Fund.

Uganda's Nationally Determined Contribution (2016) prioritises adaptation to climate change. Uganda developed a multi-sectorial National Adaptation Programme of Action (NAPA 2007) to communicate and implement immediate needs for climate change adaptation. To operationalise this, various actions have been taken including a National Adaptation Plan for Agriculture, 2018, which systematically assessed Uganda's climate vulnerability status and prioritized the most vulnerable sectors for special focus in designing national climate response. The National Climate Change Policy (2015) and Climate Change Bill (2017) were also developed to ensure a coordinated approach to climate change resilience in all sectors while ensuring a low carbon pathway to sustainable development (MWE 2015). In addition, the Uganda Strategic Programme for Climate Resilience (2017) reflects the national climate change adaptation priorities and is based on analytical studies on the viability of agricultural insurance, building rural community resilience through conservation and protection of catchment areas, strengthening hydrometeorology and early warning systems, assessing urban resilience and infrastructure, assessing the capacity of the national climate resource centre and assessing capacity needs for climate monitoring and climate resilience action planning. Climate change was built into the National Development Plan II (2015/16-2019/20) and is being mainstreamed in working plans and budgets of all government sectors. The National Climate Change Policy (2015) is aimed at ensuring national development that is climate change resilient (Uganda National Development Plan 2015/16-2019/20). Climate change mainstreaming has started with five priority sectors: agriculture, water, infrastructure, energy and lands. A checklist and guidelines for doing so were developed (MWE SPR 2018) and the structures are being established. Working with the CGIAR research program on Climate Change Agriculture and Food Security (CCAFS), Uganda is mainstreaming climate change into national agriculture plans (MAAIF DSIP 2010). Climate change is also being mainstreamed into the policies of the Ministry of Health, including water and sanitation, environmental health, control of communicable diseases and control of disease vectors. Climate change is also a key component of the National Disaster Preparedness Policy and Management (2010). Actions have been initiated towards strengthening climate change mitigation and adaptation including implementation of various climate-response projects, building of climate change into research, education and awareness creation, and systematic observations especially in meteorology, pest and disease surveillance. The strengthening of

human, scientific, technical and institutional capacity are key priorities mentioned in Uganda's Second Communication to the UNFCCC.

1.3 VULNERABILITY ASSESSMENTS IN THE COUNTRY

1.3.1 Overview of Existing Vulnerability Assessments

Climate change in Uganda is predicted to cause temperature rise and make rainfall seasonality more erratic, including changes in onset, duration and intensity punctuated with intra-seasonal dry spells (NAPA 2007; Lyon and DeWitt 2012). Nationwide, rainfall amount is not likely to change significantly for the 2015-2045 period (USAID 2013; Mubiru et al. 2018). However, rainfall distribution is likely to change over space and time. In the mid-western region, Mt. Elgon area and the region extending from Rwenzori mountain to southern shores of Lake Kyoga, however, rainfall is projected to increase[1] (Second National Communication SNC 2014), while around Lake Victoria shores, it is predicted to decrease by about 20% (IPCC 2014). Rainfall may increase during December, January and February (a typically dry season), which may affect perennial crops and post-harvest activities (USAID 2013). In Northern Uganda, rainfall is predicted to decline by 50-150 mm per annum (Funk et al. 2012). The current wet season from March to May might shift forwards in time or the September to November rains, may extend (NEMA 2010). The duration of the drought period will potentially become more pronounced (months to accumulate 50 mm rainfall) mostly in the South western region (3 months) during April-October, and in the north-eastern region (4 months) during October-April (SNC 2014), Increased incidences of floods and prolonged drought are predicted for Lake Victoria, south western northern and Teso regions. In the mountainous regions of Rwenzori, Elgon and south-western Uganda, landslide incidences are likely to increase (USAID 2013; SNC 2014; Broeckx et al. 2018; Jacobs et al. 2017)

With regards to temperature, the IPCC Fifth Assessment Report (IPCC AR5) predicts an increase of up to 2.5°C in the next 80 years (IPCC 2014). Trend analysis of 1900-2009 shows an increase of 0.2°C/y (Funk et al. 2012). Regional trend analysis has also confirmed an increase in temperature (e.g. Mubiru et al. 2018). Minimum temperature is projected to rise by 0.8-2.1°C and maximum temperature by 1-2.1°C in mid-century (Second National Communication 2014).

[1] Projections from the AGMIP team in collaboration with the Goddard Institute for Space Studies of the National Aeronautics and Space Administration (NASA) of the United States of America.

These changes will mainly increase the drying up in the drier regions in the north eastern and south western areas. Climate change is predicted to cause loss of grazing lands, loss of soil fertility and biodiversity, water shortage, increased wild fire outbreaks, reduced crop and livestock productivity, and escalation of pests and diseases of crops, livestock and humans (NAPA 2007). This may lead to increased poverty, limiting the country's potential to achieve its development aspirations.

1.3.2 Strategic Themes and Recommendations Coming from These Assessments

Strengthening of technical and institutional capacity is emphasised to enable comprehensive assessment of vulnerability and implementation of adaptation actions. The capacity of the country to conduct long-term measurements to monitor climate change and minimise its impact is inadequate due to limited technical capacity and financing. The Department of Meteorology needs to be enabled to provide timely weather and climatic information on which appropriate adaptation responses depend. More experts are needed to design protocols and appropriate indicators for assessing climate-change vulnerability and the effectiveness of intervention options. Community engagements need to be strengthened in identifying appropriate adaptation options and assessing their effectiveness in different contexts. Management processes of the various public institutions also need to be assessed for potential gaps that pose potential risks in the face of climate change. Key activities that need strengthening include research, systematic observation, training, education, awareness creation and ensuring that national level plans are linked to actions in the decentralised local governments. The National Adaptation Plan (2007) was developed and in the agricultural sector, a climate-smart agriculture program (2015-2025) was developed.

1.3.3 Adaptation Priorities Identified:

- Strengthened Early Warning System in the Department of Meteorology and the Climate Change Unit to ensure that weather and climatic data is monitored, analyzed and the information disseminated in good time to stakeholders.
- Improved surveillance of pest and disease epidemics for humans crops and livestock, disaster preparedness and implementation of appropriate response systems
- Increased financial support for research to develop technologies and breed varieties of crops and livestock that are tolerant to rising temperature, drought and floods.

- Documentation and dissemination of indigenous knowledge of well-tried adaptation practices.
- Awareness creation about climate change and the interventions needed.
- Bottom up and participatory designs of adaptation responses that are relevant to the different contexts and different gender needs.
- Building of technical capacities of officials in supporting climate change activities.
- Restoration of a functional agricultural extension and advisory services to transfer of technologies between agricultural researchers and farmers.
- Mainstreaming of climate change in all sector policies, plans and programs
- Development and enforcement of regulations byelaws and ordinances for the conservation of water sources, soils, forests and wetlands.
- Diversification of livelihood options to increase resilience in regions which will be most affected by drought and floods.
- Strengthening of credit providing services at village levels
- Ensuring water supply to key economic sectors.

1.4 SECTOR SELECTION

1.4.1 Expected Climate Change Impacts on Sectors Vulnerable to Climate Change

1.4.1.1 Introduction

Sectors that are most vulnerable to climate change impacts identified through stakeholder consultation during the development of the NAPA (2007) were prioritised in Uganda's 2014 Second National Communication (SNC). The highest ranked are the agricultural and agricultural-related sectors in water, environment and biodiversity (Orindi and Eriksen 2005; MWE 2007). Other vulnerable sectors identified were health, infrastructure and human settlement (MAAIF DSIP 2010; USAID 2013).

1.4.1.2 Expected impacts of climate change in vulnerable Sectors

Agriculture

Drought, floods and landslides will take a heavy toll on soil fertility leading to reduced crop productivity and availability of pastures (Funk et al. 2012). The reduction in production of crops

due to pests and diseases is about10-20% in fields and 20-30% after harvest (SNC 2014). A rise in temperature and atmospheric CO_2 concentrations can potentially alter insect pest populations and feeding rates affecting crops in the field and after harvest (Karuppaiah and Sujayanad 2012). Increasing drought and rising temperature tend to accelerate the rate at which pests and disease-causing pathogens mate, the severity of damage they cause to crops and livestock and to expand or alter their range and migration patterns (Maxmen 2013). The rising temperature will potentially depress fish productivity and species composition (IPCC 2014; FAO brief 2018). Increased drought and floods are also predicted to increase livestock diseases in the south western region (NAPA 2007). Reduced land productivity may lead to expansion of cropland into forests and wetlands and migration of humans and livestock, potentially leading to conflicts as was observed in the 1991 drought (Funk et al. 2012).

Water

The rise in annual temperature of 1.3^{o}C observed between 1960 and 2014 is associated with increased frequency of extreme events such as drought, floods and mudslides (Niang et al. 2014; NDC 2016). With increasing temperature, water quantity will increase in seasons of high rainfall intensity, leading to increased runoff and flooding (Lake Victoria Basin Commission; USAID 2018). However, in seasons of prolonged droughts, water quantity is likely to reduce affecting water levels and flows and causing scarcity for production and domestic consumption. Flooding may affect water quality due to increased flow of sediments and other pollutants into water bodies, potentially increasing the risk of vector- and water-borne diseases (SNC 2014; NDC 2016; Lake Victoria Basin Commission; USAID 2018). Increased water surface temperature also increases algal blooms especially in cases of high nutrient loading in water systems (FAO 2018).

Fisheries

A rise in surface water temperatures is likely to affect fish breeding leading to low production (O'Reilly et al. 2003). Degradation of water quality due to soil erosion and other contaminants and extreme seasonal changes in water levels will potentially affect water-based ecosystems and reduce fish stocks and change species composition (FAO 2018).

Forestry

Climate change combined with rapid population growth are likely to put more pressure on forests due to growing demand for wood fuel for energy purposes and land for crop production, livestock grazing and settlement (SNC 2014).

Health

The potential destruction of physical and health infrastructure due to floods and landslides is likely to affect human lives through disruption of livelihoods, displacement of people, poor nutrition, poor sanitation, increased water and vector-borne diseases and psychological stress. Diseases likely to increase include cholera, diarrhoea, malaria and hepatitis E. Damage to physical infrastructure may lead to loss of lives and injuries exacerbated by limitation of accessibility for treatment. During droughts, dry dusty air may lead to increased respiratory diseases and poor access to good nutrition and clean drinking water. Climate change may shift the geographical distribution of disease pathogens due to changing environmental conditions to human and livestock populations that have no prior exposure and low immunity (SNC 2014).

Infrastructure

Floods and waterlogging will cause costly damage to infrastructure including roads, bridges and power transmission lines. The most vulnerable areas are shores of Lake Kyoga and Lake Victoria and the valley of the Albert-Nile as well as the lowlands of south western and Eastern Uganda (SNC 2014).

Human settlement

An increase in flood and mudslide incidences pauses a threat to human settlements, property and livelihoods in the prone areas (Heinrich 2010). Increased incidences of prolonged drought also lead to loss of livestock, crop failure and food insecurity, forcing communities to migrate. Displacement of people is an expensive challenge with psychological harm to the affected populations. The acceptance of displaced people in new communities is also difficult and may lead to conflict.

1.4.2 Process and Results of Sector Selection

In the NAPA (2007) a participatory rural appraisal tool was used with stakeholders from all sectors to prioritise sectors for climate change responses. Sectors were ranked according to the magnitude of risks climate change causes and also according to their capacity to cope. Since water is key in driving the major sectors for the national economy and since water resources will be affected by climate change, ranking of key sectors for climate adaptation was made based on water resources occurrence and accessibility. Agriculture (including crops, livestock and fisheries) was ranked highly as facing the highest climate related risks and yet with very low coping capacity (NAPA 2007). Health and nutrition also scored highly on risks and relatively low of coping capacity. Other sectors prioritised for reducing vulnerability and addressing adaptation were forestry, infrastructure (with an emphasis on human settlements, social infrastructure and transport), water, energy and disaster risk management.

In the National Development Plan (2015/16-2020/21), sectors are grouped as primary growth sectors, complementary sectors, social sectors and enabling sectors. These sectors were first ranked according to their contribution to the Gross Domestic Product (GDP), livelihoods/employment, export earnings and food security. Primary production sectors considered were crop livestock fisheries, forestry and tourism. Complementary sectors were transport and energy. Social sectors were health and nutrition, water and sanitation. Enabling sectors were water resource management, meteorology, environment and disaster preparedness (SNC 2014). Since the Uganda NDC prioritises climate adaptation, the highly ranked sectors were then assessed based on risks of climate change depending on geographical extent, potential risks, and intensity of impact on human livelihoods and wellbeing.

Considering that land and land use were ranked highest in the Poverty Elimination Action Plan (PEAP) 2004 of Uganda and the global Millennium Ecosystems Assessment (MEA) 2005, Uganda's NDC (2016) prioritised land use-based sectors for climate change adaptation. At the inception workshop for Technology Needs Assessment held by Uganda National Council for Science and Technology, stakeholders prioritized Agriculture, Forestry, and Water sectors for climate-adaptation technology transfer.

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

Climate change policy making in Uganda is led by the Ministry of Water and the Environment (MWE). The National Climate Change Policy Committee (NCCPC) coordinates policy implementation. It brings together ministers from various departments at national level and is chaired by the Prime Minister. The National Climate Change Advisory Committee (NCCAC), chaired by the Minister of Water and Environment, supports the NCCPC with coordination and technical information input. The NCCAC is composed of technical persons from relevant government sectors, with representatives from the private sector, civil society, academia and district authorities. Oversight of climate change policies, programmes, actions and budgetary allocation is provided by the Parliament Standing Committee on Natural Resources. Climate change awareness and actions are promoted by the Parliamentary Committee on Climate Change.

The implementation of the Climate Change Policy is led by the Climate Change Department (CCD) in the MWE, which is the focal point and secretariat for the UNFCCC and the Designated National Authority for the Clean Development Mechanism (CDM) projects. The CCD is an information hub for climate change and ensures mainstreaming of climate change concerns in relevant government institutions. It advises and monitors the implementation of climate policy and strategy. Policy implementation of climate change is also supported by the Uganda National Meteorological Authority, Ministry of Finance Planning and Economic Development (MoFPED), National Planning Authority (NPA) and Ministry of Local Government (MoLG). Other government departments agencies or authorities implement relevant climate change actions prescribed in the policy through their designated focal points.

2.1 NATIONAL TNA TEAM

The TNA project in Uganda was coordinated by the Uganda National Council for Science and Technology (UNCST), which spearheaded the formation of the TNA team constituting the Steering Committee, the consultants and the sector working groups. The UNCST is the National Designated Entity for the Climate Technology Centre and Network (CTCN). The UNCST and consultants selected relevant stakeholders for the TNA by considering people in agriculture, water, forestry, climate change and environment:

- With mandate to make decisions –government, development partners and private sector
- Who represented interest groups - civil society academia, farmers,
- With technical capacity and likely to play key roles in climate technology and innovation
- With strong capacity to streamline gender in environment and climate processes

Some stakeholders had already shown keen interest in the TNA inception workshop and in responding to the call for TNA consultants. Balanced gender representation in the different sector working groups was also considered. Individuals were selected from existing relevant working groups, including the Water and Sanitation working group, Water and Environment working groups, Forestry working group, and a civil society platform PELUM (Participatory Environment and Land Use Management). In addition, a climate financing subgroup and a media communication representative were considered for engagement in the TNA process. A total of 32 stakeholders were selected for the technology identification and prioritization step (Annex II a.). Stakeholder engagement and recruitment into the TNA process continues and a list of potential other stakeholders for next steps is also given in Annex II b.). Invitation to the steering committee and sector working group membership to participate in the TNA process was led by the UNCST.

In consultations with UNCST, consultants developed the long lists of technologies with justifications from key national development and climate change documents. The consultants then developed facts sheets for the agreed long list based on the template from the TNA website. The major challenge in developing fact sheets was the scarcity of information on costing, gender and market considerations.

2.2 STAKEHOLDER ENGAGEMENT PROCESS FOLLOWED IN THE TNA-OVERALL ASSESSMENT

Stakeholders were engaged through a two-day technology prioritization workshop convened by UNCST. The concept note of the prioritization workshop was developed through consultations between the consultants and the UNCST. Due to budget constraints, the same workshop included the prioritization of both the adaptation and mitigation technologies. High level/policy level persons and some development partners were invited for the first day for information and buy-in and to pave the way for next TNA steps where they would be needed. However, they were not able to attend. The gender expert was also not available for the workshop.

Stakeholders were reintroduced to the TNA project, its rationale and planned process. The need for effective representation was emphasized for enabling realistic identification, selection and implementation of climate technologies for reducing greenhouse Gases (GHG) emissions (mitigation) and/or vulnerability to Climate Change (Adaptation). There were concerns about TNA being top-down and not engaging the grassroots communities enough to get a true picture of climate challenges experienced and some of the local technologies and innovations available. Weaknesses in policy implementation, inadequate business development, the rapid population growth and limited longevity of good initiatives were also highlighted as things to consider in the TNA process.

Participants were then introduced to the technology long lists and the rationale for identification of the technologies for national adaptation. The Intergovernmental Panel on Climate Change (IPCC, 2000) definition of technology as "a piece of equipment, technique, practical knowledge or skills for performing a particular activity, components of which include: hardware, software, and orgware" was also presented to help participants understand the broad considerations in developing the technology long lists. The multi-criterial analysis (MCA) methodology was introduced for technology prioritization.

In focus groups constituting sector working groups, stakeholders were given printed copies of the technology fact sheets and were guided through them by the consultants. Copies of fact sheets were also shared with stakeholder by email. The potential for each technology to contribute to climate change adaptation and Uganda's development agenda and potential challenges and opportunities in its adoption and implementation were discussed. Stakeholders contributed to the fact sheets by making corrections, providing additional details and recommending relevant documents for the future TNA steps. Stakeholders then agreed on criteria for technology prioritization broadly grouped into costs, benefits and climate impacts, and allocated weights to them. Using fact sheets as reference and expertise of the stakeholders in the various thematic areas, the technologies were scored according to the criteria.

2.3 CONSIDERATION OF GENDER ASPECTS IN THE TNA PROCESS

Gender aspects were considered in constituting the thematic working groups and gender experts were invited to the prioritisation workshop. The team of consultants includes two women and two men. The constitution of sector working groups included 2 women and 2 men in agriculture, 4 women and 3 men in water and 1 woman and 2 men in forestry. A gender expert from the Parliamentary Forum on Climate Change, who is also a member of Uganda's Gender negotiation team at COP, was at the meeting for the 2 days. She mainly participated in the Water Sector working group. Gender awareness as applied to Technology Needs Assessments across the 3 sectors was conducted as part of the content in the respective presentations made by the consultants. Thus, they underscored the implications and the need for gender analyses in the value chain of technology development. Furthermore, stakeholders in the workshop also raised gender considerations especially among grass root technology users. It was noted that gender differences would be considered more comprehensively in the Barrier and Enabling Framework Analysis stage of the TNA.

CHAPTER THREE: TECHNOLOGY PRIORITISATION FOR THE WATER SECTOR

3.1 KEY CLIMATE CHANGE VULNERABILITIES IN THE WATER SECTOR

Climate change is predicted to cause temperature rise and alter rainfall seasonality and intensity. The increase in temperature by 0.8-2.1^{o}C (minimum) and 1-2.1^{o}C (maximum) by mid-century (SNC 2014), is likely to accelerate evapotranspiration in vegetation and evaporation from water and soil surfaces. This is likely to increase the frequency of droughts and cause lowering of water levels in surface and ground water sources in cases of prolonged dry seasons especially in areas that receive low rainfall. The potential outcome of this is crop failure, death of livestock, trekking of women and children for long distances in order to supply water for domestic use, consumption of unsafe water, migration of populations and conflict between communities over resources as was experienced in 1991-2000 when droughts were more frequent than usual (NAPA 2007). The most vulnerable regions are the north-eastern and south western parts of the country. Seasons of reduced rainfall may lead to reduced levels of Lake Victoria and outflows into the River Nile, thus disrupting hydro-electricity generation. Reduced surface water availability may drive increases in ground water abstraction. Boreholes, which provide water to three quarters of the rural population from ground water sources (SPR 2018), are especially vulnerable to receding water tables.

Rainfall intensity is predicted to increase in Northern and West Nile sub-regions (UNMA 2019) with potential to cause flooding in valleys, and increased soil erosion, and landslides in mountainous areas. Flooding often leads to contamination of water sources because of poorly constructed toilet facilities (2016 UDHS 2018) and poor waste management, with potential dangers of water-borne diseases including dysentery, hepatitis E, cholera and typhoid (CDC 2015). Soil erosion causes land degradation and sedimentation of water sources downstream reducing volumes of surface storage and seepage to recharge underground storage. Valleys of mountainous areas and lake shore especially around urban centres are susceptible to flooding and degradation of water quality (SNC 2014). Rising water temperatures are predicted to affect species biodiversity of freshwater animals and plants.

Erratic rainfall leads to uncertainty in implementation of the farm calendar resulting in losses in agricultural production. Irrigation could potentially be used to overcome this. However, the

infrastructure for irrigation is poorly developed. Of the 3,030,000 ha of potential irrigable area only 15,000 ha (0.5%) is under irrigation (MWE SPR 2018). When this option becomes available, a sharp increase in demand for water for production will potentially increase (MWE SPR 2018).

Key focus areas

- Technologies to reduce contamination of water sources and ensure access to safe water
- Technologies to harvest and conserve water to minimise water scarcity during drought seasons
- Abstraction of surface and ground water for domestic use and production (including crops, livestock, fisheries, energy, industry etc.).
- Transfer of water from places of abundance to places of scarcity
- Management of wetlands and watersheds including integrated water resource management, to minimise soil erosion, mudslides and sedimentation of water sources and reservoirs (NAPA).

3.2 DECISION CONTEXT

3.2.1 Existing Programmes/ Policies to Reduce Climate Change Vulnerabilities

Climate change adaptation priorities are mainstreamed in the draft water policy and bill. The MWE set aside 3% of water protection budgets for protection of water sources and training staff in mainstreaming climate change in work plans and budgets. Environment officers from local governments and academic institutions were trained in sustainable land management, land restoration and linkages to climate change. A guide was developed to mainstream climate change and drought resistance into the Water and Sanitation sub-sector Planning (MWE 2014). Forest restoration and tree planning were supported to reduce vulnerability in flood-prone areas (Directorate of Water Resources Management 2009; MWE 2013).

Some key projects for climate change adaptation in the water sector include the Adapting to Climate Change in Lake Victoria Basin (UNEP 2016), which focuses on building technical capacity for climate change adaptation and supporting policy and actions for adaptation. It is supported by Adaptation Fund through UNEP (2016). Another project is the Climate Resilient Institutional and Public Sanitation Project working on construction of sanitation facilities e.g.

Enviro-loos, Cesspits and Lined Ventilated Improved Pit latrines, Community WASH structures and formation of Health clubs in schools (MWE Brief undated). The Clean Development Mechanisms Project on GHG mitigation through municipal waste management also seeks to control and protect water catchments from point source pollution as an adaptation co-benefit (World Bank 2010). The IUCN Global Species Project is mapping a critical sites network for freshwater biodiversity in the Lake Victoria Catchment (Evans and Miriti 2017)

3.2.2 How Key Focus Areas are Aligned to Development Efforts

Key focus areas are aligned with major development efforts including improving access to clean and safe water for all, enhancing water for production monitoring and managing water quantity and quality, and water resource management (**Table 3**).

Table 3. Alignment of key focus areas with development efforts in the Water Sector

Key focus area for climate change adaptation	*Government development efforts**
Water resources management	Catchment-based management in the four Water Management Zones, development and implementation of water source protection guidelines, wetland demarcation and management participation in transboundary water resources management.
Water resources monitoring and information services	Strengthening water resources monitoring and information services and setting up a water resources institute to understand variability of water quantity due to climate change and to guide water allocation; water resources forecasting and modelling.
Water for production:	Increasing availability of water for production by harvesting rain water and exploiting the potential of ground water to enable diversification of farm production and reduce vulnerability to drought incidences. The National Irrigation Policy 2018 targets to increase the area of irrigated farmland by 1,500,000 ha by 2040.

Water quality management	Development and implementation of the National Water Quality Management Strategy and development of water quality guidelines and standards, strengthening of the water resources regulatory framework, development of reservoir regulation and dam safety guidelines, development and implementation of a water quality monitoring system and implementation of the strategy for compliance and enforcement of water laws and water permit conditions.
Access to clean and safe water for all	Various water and sanitation programmes are implemented at district and national levels including a strategy for one safe water source per village or cell which has so far covered 66% out of a total of 57,974 villages in the country. Programmes for provision of safe water sources are implemented in rural and urban areas. In urban areas, implementation is through partnership with the National Water and Sewerage Corporation (NWSC), using metered piped water. Comprehensive water supply, sanitation and hygiene water master plan are being developed for areas that are most vulnerable to water contamination including refugee settlements, lake shores and urban settlements.

*Information drawn from the Water Sector Performance Report (2018).

3.3 OVERVIEW OF EXISTING TECHNOLOGIES IN THE WATER SECTOR

- *Catchment-based integrated water resource management* is implemented in four Water Management Zones in catchments of Aswa, Albert Nile, Maziba, Awoja, Mpanga, Semliki, Lokok, Lokere and Rwizi to improve water conservation. This includes catchment and wetland demarcation, planting of trees, restriction of activities near water source. Catchment-based management is also implemented in transboundary water resources management programmes, notably the Nile Basin Initiative, and East African Community (EAC)/Lake Victoria Basin Commission. Catchment-based management frameworks are now getting integrated with wetland management and forest management plans.
- *Surface water and groundwater stations* for monitoring water levels are being converted from manual to real-time telemetry to collect daily data in different lakes, rivers and groundwater aquifers, to understand variability of water quantity due to climate change and to guide water allocation. Ground water monitoring needs to be strengthened. Technologies for water resources forecasting and modelling are also implemented.
- *Roof top rainwater harvesting for domestic use* has been in practice for long, but its exploitation is far below potential, contributing only 0.4% of the water sources in rural areas (SPR 2018). The biggest challenge is low access to affordable storage tanks (Blanchard 2012).
- *Earth dams and valley tanks* for storing runoff to reduce soil erosion, reduce sedimentation of water bodies and reservoirs downstream and enable deep water seepage for ground water recharge. Construction of valley tanks has been concentrated mainly in the drought prone regions especially the cattle corridor. The total number of facilities in 2017 was 1,230 (MWE 2018). Valley tanks enable availability of water in the long term and can be used for fish farming. However, valley tanks are disproportionately concentrated in cattle areas. The rate of degradation of these facilities is high due to direct watering of livestock leading to ground compaction and degradation in the neighboring areas, increased soil erosion and high sedimentation rates. They are also exposed to surface evaporation. Due to poor operation and management structures, valley dams are prone to vandalization.

- *A network of stations and laboratories monitoring water quality*, tracking human activity in water catchments, effluent discharge from sewerage and industry and the quality of drinking water from point sources
- *Spring protection* by constructing a protective wall around water points where ground water is brought to the surface: Springs provide water for 21% of rural households (SPR 2018), but they are prone to contamination. The MWE constructed 167 protected springs to ensure access to safe water.
- *Piped water systems* including metered water and public standpipes in urban areas. Piped water is powered by gravity flow or electrical pumping. Piped water coverage is generally still very low at only 7% countrywide by 2013 (Residential piped water in Uganda, World Bank study 2018). In urban areas, piped water coverage reached 83.7% in 2017. In rural areas coverage of piped water has only reached 11% (SPR 2018).
- *Bulk water transfer systems* seek to channel water from locations where it is abundant to where it is scarce. It has great potential of redistributing water from the many lake and river sources to drier parts of the country. It is, however, considered to be very expensive.
- *Small-scale irrigation schemes* are being constructed especially in drought-prone districts of Sembabule, Kiboga, Mubende, Luweero, Nakaseke and Nakasongola. Abstraction of water from ground water is powered by electrical pumping, from hydro, diesel, solar or windmill (E.g., Karamoja) sources (MWE SPR 2018).
- *Gravity flow schemes* enable abstraction of water from high altitude rivers and springs to communities. This is feasible in 21 districts and can benefit large rural populations (Wobusobozi et al. 1995).
- *Shallow wells fitted with hand pumps* provide clean water for about 24% of the population. They make up about 17% of the water technologies in Uganda (Uganda National Report, Water Supply Atlas 2017).
- *Deep boreholes* are the most commonly used technology in Uganda supplying 44% of the rural population with safe and clean water (SPR 2018). This saves communities from having to use wood to boil water to purify it for consumption. Boreholes save women and children from trekking long distances to collect water for domestic use. Boreholes are also used for collecting water for livestock. The challenge is that they break down and need to be rehabilitated from time to time.

3.4 ADAPTATION TECHNOLOGY OPTIONS FOR THE WATER SECTOR

Potential climate change adaptation technologies in the water sector were identified from desk review of the following key development documents taking into consideration development priorities and predicted climate change and its impacts. Vision 2040 (NPA 2007), the NAPA (2007), the NDP II (NPA 2015), the Uganda NDC (2016), the Ministry of Water and Environment Sector Performance Report (2018), the Disaster Preparedness Policy (2010), peer reviewed reports and publications and fact sheets in the data base of the TNA website.

Criteria for identifying potential technologies were:

- Priority in the national development documents
- Appropriateness, applicability/acceptability – based on national development priorities
- Potential to enable adaptation to projected climate change scenarios
- Experience in using the technology based on what has been tried - status of implementation e.g. at pilot or rollout stage, etc.
- Potential scale and replicability – geographical area and number of people impacted
- Co-benefit
- Accessibility of material, expertise and capacity to establish and operate

1) Water channeling

Bulk water transfer aims at supplying quality and adequate amounts of water all year round for multi-purpose use by conveying large quantities from places of plenty to places of scarcity. It includes channeling from rivers, lakes and reservoirs. It may cover long distances involving a network of reservoirs and pipes/channels /canals. It can potentially reduce risks of crop failure, livestock death related to prolonged drought, and enable enterprise diversification and provide water for domestic use. It can also enable reclamation of some drylands for farming (Kyeyune 2017).

2) Rooftop rainwater harvesting (RWH)

Rainwater is still the safest and most economical source of drinking water available in most rural areas. With average rainfall of 500-1200 mm a year, rooftop water harvesting could provide clean water for a wide number of households, but this resource is poorly exploited. Rainwater harvesting (RWH) through roof catchments is being promoted by the water sector in Uganda

because it is affordable and manageable by communities especially in water stressed areas both at household and institutional levels. Rainwater harvesting systems can be applied from small to large scales. They comprise of a roof, a storage tank and a means such as guttering to connect one to the other. Other possible components are filters or 'first-flush' diverters. As an adaptation measure, it will eliminate the need for the energy and chemicals used to produce pure drinking water, improve agricultural production when water is used for livestock and irrigation of gardens leading to better nutrition (Danert and Motts 2009).

3) Surface runoff harvesting

Surface runoff water harvesting is the collection, accumulation, treatment or purification, and storing of storm water for its eventual reuse for domestic water supply and irrigation of crops in the dry season (Hatibu et al. 2006). The system also traps soil from being eroded by water. Surface runoff water harvesting is done at micro and macro level. Micro-catchment rainwater harvesting systems are designed to collect runoff from a catchment area of 10–500 m^2, within the farm boundary. The runoff water is usually guided into a type of infiltration enhancement structure and used to irrigate plants. Commonly micro-catchment techniques include pitting, contouring, terracing, furrowing and micro-basins supplemented with mulching, reduced tillage (Biazin et al. 2012). Macro-catchment rainwater harvesting systems collect runoff or river flow from large areas including manmade surfaces, such as roads, parks, gardens and playing fields into reservoirs. Earthen bunds or embankments are built from soil excavated from within the reservoir or bricks and cement to increase storage capacity and a spillway or weir allows controlled overflow when storage capacity is exceeded. Harvested water can be used for irrigation thus reducing the risk of total crop failure. Trapped water seeps into the soil and recharges ground water storage (Practical Action Technical Brief undated).

4) Construction of new and maintenance of old dams

Dams provide multiple benefits to the communities in Uganda but are mostly used for livestock, watering in drought-prone areas in the cattle corridor and in northern and eastern districts. Improving dam construction by covering to reduce evapotranspiration and channeling or pumping of water for livestock into troughs will improve the water quality and reduce degradation of land and vegetation around dams (Mugerwa et al. 2012 and MWE SPR 2018).

5) Deep well water extraction

Deep well water extraction involves digging and drawing water from underground using containers or pumping it through sunk pipes. Most commonly, it involves a vertical bore hole with a diameter of 100 to 600 mm, within which an extraction pipe is placed that has a perforated section (filter) and sand trap, surrounded by filter gravel. Borehole coverage is still not sufficient yet established ones have too many users per point are not well maintained and dry up during drought events (MWE SPR 2018). As an adaptation technology, it will increase access to water in dry periods, reduce negative impacts on public health, preventing epidemic diseases e.g. diarrhea, relieve pressures on surface water sources.

6) Household water treatment and safe storage (HWTS)

Household water treatment involves a water sanitation and hygiene system including evaluation of water sources, regular testing of water quality to ensure that water quality meets minimum standards, construction of clean storage tanks and filtering, use of chemicals or boiling (MWE SPR 2018). Safe storage can be constructed in a way that is impervious to contaminants and using material that is non-corrosive and easy to clean (Mintz et al. 1995).

7) Community irrigation

Community-based irrigation schemes are co-owned and managed by the community and cover an area of 200 ha or less (Seleshi 2003). The infrastructure includes water reservoirs, canals, pipes and drainage channels. Areas near permanent water bodies do not need reservoirs. The infrastructure, operations and maintenance plus water distribution are the sole responsibility of the community (Wanyama et al. 2017).

3.5 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION

Multi-criteria analysis was used in deciding, which technologies to prioritize to enable objectivity and build consensus among stakeholders with divergent views. According to the MCA guidance on Adaptation the following steps were followed.

1) Identification of the criteria for technology prioritization

The following criteria for technology prioritization were developed through discussions with stakeholders in the water sector working group with experience and knowledge from

government, civil society and private institutions. They were guided by the key template of the technology fact sheets that were shared by the consultant to determine the suitable and appropriate criteria for technology prioritization. Criteria for technology prioritization were based on their potential to reduce vulnerability or enhance resilience to climate change, and their potential social, economic and environmental benefits as well as cost implications **(Table 4)**.

Table 4. Criteria for analyzing technologies for climate adaptation in the Water Sector

Consideration	Criterion	Explanation
Economic benefit	Size of beneficiaries	Number of women, men and youth gaining from the technology. Regional area that the technology covers. Intensity of the challenge that the technology solves
	Capacity to increase water use efficiency	Ability of the technology to increase the output obtained per unit of water used. Ability to save time, energy and avoid risks in accessing and using water. Ease of increasing scale of distribution and replicating the technology.
	Income and market potential	Increased income or reduced costs/risks at local and/or national level.
Social benefit	Social benefit	Congruence of the technology with existing social norms and cultures, increasing employment, catering for needs of women, men, children and the youth, inclusiveness of indigenous knowledge in establishment an operation.
	Food/water/health security	Potential to increase food production, nutrition and post-harvest handling; potential to improve water quality and quantity; potential to improve human and livestock health and avoid disease increases that may occur due to climate change.
	Gender inclusiveness	Inclusion of men women and youth in the process, establishment and operation of the technology; consideration of how the technology addresses needs

		of different genders
	Employment potential	Potential for the technology to create jobs from direct engagement or to create environment for job creation and new livelihood options.
Environmental benefit	Minimization of land degradation	Low negative environmental footprint e.g., less earth movement, less pollution of water, soils, air, sound etc.
	Restoration of habitat	Potential to recover degraded area leading environmental co-benefits
Climate benefit	Reduced vulnerability or improved resilience to climate change	Potential of the technology to enable society or the economy to avoid, overcome or withstand climate change e.g. projected increase in temperatures
Economic Cost	Investment cost	Cost of construction / establishment of the technology infrastructure including purchase of equipment, land acquisition, electrical/mechanical power purchase and hiring of technical manpower.
	Operation and maintenance	Availability and ability to purchase equipment parts, availability of energy sources to ensure functionality.
	Ease of implementation	Availability of human, organizational, policy and financial capacity to establish and operate the technology.

2) Scoring of criteria

Criteria were assessed by allocating scores of 0 (not favorable) to 100 (very favorable) to costs and benefits **(Table 5)** following the logic recommended in the MCA guidebook.

Table 5. Logic for scoring criteria in evaluating technologies

Category	Cost	Benefit
Very low	76-100	0-25
Low	51-75	26-50
Medium	26-50	51-75
High	0-25	76-100

3) Weighting of the criteria

Stakeholders allocated weight to each criterion (adding to 100) according to urgency, importance in contributing to development priorities, applicability and suitability of the technology for adapting to climate change **(Table 6)**.

Table 6. Weighting of criteria for the Water Sector

Size of beneficiaries	14
Capacity to increase water use efficiency	6
Income and market potential	7
Social benefit	4
Food/water/health security	5
Gender inclusiveness	4
Employment potential	3
Minimization of land degradation	8
Restoration of habitat	8
Reduced vulnerability or improved resilience to climate change	14
Investment cost	14
Operation and maintenance	6
Ease of implementation	7
Total	**100**

3.6 RESULTS OF TECHNOLOGY PRIORITISATION FOR THE WATER SECTOR

Using expert opinion, scores were assigned to the technologies against each criterion **(Table 7**). The scores were multiplied by the weight assigned to each criterion (**Table 8).** The total weighted score for each technology was then summed up. The technologies were then ranked according to their total weighted score **(Table 9**). Three technologies were prioritized and these were:

1. Deep well extraction
2. Rooftop rainwater harvesting
3. Surface runoff harvesting.

Table 7. Criteria scores for technologies in the Water Sector

Technology	Costs		Benefits								Climate	Others	
			Economic		Social				Environmental				
	Investment	Operation & maintenance	Size of beneficiaries	Capacity to increase water efficiency	Food and health security	Sensitivity to existing norms	Gender inclusive ness	Employment potential	Minimize land degradation	Restore habitat	Reduce vulnerability and resilience	Ease of implementation	Income and market potential
Rooftop rainwater harvesting	97	95	65	80	70	98	90	30	85	30	40	90	95
Bulk water channeling	40	50	75	85	95	45	80	95	90	50	85	45	50
Surface runoff harvesting	95	75	50	95	50	50	80	30	80	80	80	60	65
Deep well extraction	60	85	90	98	75	35	70	60	55	50	95	65	70
Household water treatment and safe storage	70	90	60	90	80	60	30	20	60	50	10	70	90
Community irrigation systems	30	60	63	95	60	25	85	70	90	80	80	50	55
Construction of new and maintenance of old dams	20	50	80	60	50	55	25	40	70	85	70	30	50

Table 8. Weighted scores for technologies in the Water Sector

Technology	Cost		Benefits								Climate	Others		Total	Rank
Criterion weight	**14**	**6**	**14**	**6**	**5**	**4**	**4**	**3**	**8**	**8**	**14**	**7**	**7**	**100**	
	Investment	**Operation & Maintenance**	**Size of beneficiaries/ market potential**	**Capacity to increase efficient water use**	**Food, water & health security**	**Sensitivity to existing norms and cultures**	**Gender inclusiveness**	**Employment potential**	**Minimize land degradation**	**Restoration of habitat**	**Reduced vulnerability, increased resilience**	**Ease of implementation**	**Income & market potential**		
Rainwater harvesting	1358	570	910	480	350	392	360	90	680	240	560	630	665	7285	2
Water channeling	560	300	1050	510	475	180	320	285	720	400	1190	315	350	6655	4
Surface runoff	1330	450	700	570	250	200	320	90	640	640	1120	420	455	7185	3
Deep well extraction	840	510	1260	588	375	140	280	180	440	400	1330	455	490	7288	1
HWTS	980	540	840	540	400	240	120	60	480	400	140	490	630	5860	6
Community irrigation	420	360	882	570	300	100	340	210	720	640	1120	350	385	6397	5
Construction of new & maintenance of old dams	280	300	1120	360	250	220	100	120	560	680	980	210	350	5530	7

Table 9. Ranking of technologies in the Water Sector

Technology	Total score	Rated technology in descending order
Deep well extraction	7288	1
Rainwater harvesting	7285	2
Surface runoff	7185	3
Water channeling	6655	4
Community irrigation	6397	5
HWTS	5860	6
Construction of new and maintenance of old dams	5530	7

CHAPTER FOUR: TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

4.1 KEY CLIMATE CHANGE VULNERABILITIES

Rising temperature will potentially increase evapotranspiration and intensify water scarcity during drought periods, resulting in reduction in crop and pasture production. Uganda fish production is from fresh water sources which have low buffering capacity and are very sensitive to climate variability. An increase in water temperatures is also likely to depress freshwater vegetation, reduce fish production, change species composition and increase risk of fish diseases and parasites (FAO 2010; Souchon and Tissot 2012; Dell, Pawar and Savage 2013). The increased surface evaporation may result in lowering of water levels of lakes, exposing breeding grounds and reducing fish production (MAAIF DSIP, 2010). The impact of climate change on fisheries in Uganda is predicted to be moderate compared to global changes. However, its interaction with poor fishing practices, introduction of non-native species, habitat destruction and lake pollution may worsen the situation (FAO 2018). Increased temperatures also affect reproduction of livestock (SNC 2014).

The rising temperature and droughts are likely to depress the productivity of key crops, notably coffee, maize and cereals in general. A combination of erratic rainfall and increased temperature will likely lead to crop losses in the field and after harvesting due to increased disease (e.g., red-berry disease in Robusta coffee, leaf rust disease in Arabica coffee, fungal diseases and aflatoxin degradation of grains maize diseases) and pest attack (e.g., fall army worm, aphids etc.). Of the major crops, vulnerability to climate change is relatively lower in matooke and beans and even lower in cassava, sweet potatoes and sorghum (USAID 2013). However, climate change is likely to increase diseases in such crops (e.g. banana bacterial wilt and black sigatoka disease, cassava mosaic, cassava brown streak, potato blight etc.) and their pests (e.g., banana weevils, nematodes etc.) (World Bank 2018).

Change in rainfall seasonality is predicted to increase events of prolonged droughts and intense rainfall leading to crop failure and livestock death. Intense rainfall increases soil erosion and landslides and loss of soil fertility. It also leads to flooding, rendering land especially in valleys and adjacent to water bodies unusable for long periods. Increased incidences of floods will potentially lead to yield loss of sweet potatoes, simsim and groundnuts in the Northern and Teso region (USAID 2013). Flooding also destroys infrastructure and given that storage of agricultural produce is rudimentary, the destruction of road access to markets and points of consumption potentially cause

great losses. Road destruction also reduces farmers' access to advisory support services and inputs. The erratic and unpredictable weather patterns are likely to disrupt farm calendars with high potential losses and frustration to farmers.

Focus areas for climate adaptation technologies

- Tolerance to prolonged drought conditions in crop and livestock production
- Soil and water conservation
- Disease, vectors and pest resistance and control
- Improving water supply by strengthening the irrigation system
- Strengthening information systems for early warning and disaster preparedness
- Agricultural insurance
- Improved agricultural advisory services
- Improving crop storage
- Demarcation and restoration of degraded farmland

4.2 DECISION CONTEXT

The focus areas are aligned with the following key priorities of the Agriculture sector (MAAIF 2018):

- Strengthening research to generate climate change resilient technologies and practices; showcasing, training farmers and promoting investment in these technologies.
- Strengthening the agricultural extension system – single-spine agricultural extension
- Controlling agricultural pests, vectors and diseases
- Improving precision in agricultural production, value addition and processing to minimize wastage and loss
- Increasing availability of water for agricultural production especially in drought-prone areas.
- Increasing access to credit to enable fertilizer access for farmers and far-input traders.
- Improving access to high quality seed and planting material
- Establishing storage for agricultural produce
- Increasing fish stocks in major water bodies

Other technologies highlighted in NDP II include restoring wetlands, zoning drought prone areas, expanding climate information and early warning systems, diversifying livestock, fighting invasive species, managing rangelands, utilizing indigenous knowledge, managing natural resources,

operating a database system for ENR integration and national accounting and payments for ecosystem services (MAAIF 2018).

4.3 OVERVIEW OF EXISTING TECHNOLOGIES IN THE AGRICULTURAL SECTOR

Existing technologies in the Agriculture Sector are numerous. They are broadly categorized here, but the list is by no means exhaustive. The challenge is that the coverage of the technologies to the areas where they are needed is not sufficient and the support provided to farmers and researchers to adapt such technologies to their contexts and benefit from them is limited.

- Crop and livestock breeding
- Small and large-scale irrigation schemes
- Soil and water conservation technologies: terracing, contouring, conservation tillage,
- Soil fertility enhancement technologies
- Pest, disease and vector surveillance and control including industrial chemical and ecological-based options
- Weather monitoring and information systems
- Agroforestry
- Agricultural insurance
- Early warning and disaster preparedness
- Precision agriculture
- Soil fertility improvement
- Biotechnology and tissue culture
- Mixed farming
- Tillage technologies including the hand hoe, tillage and draught animals

4.4 ADAPTATION TECHNOLOGY OPTIONS FOR THE AGRICULTURE SECTOR

1. Crop breeding for tolerance to adverse climatic conditions:

Crop biotechnology enables development and promotion of varieties with climate adaptation traits such as tolerance to floods and drought, resistance to pests and diseases, early maturation, and long shelf-life. Techniques include selecting and promoting varieties with desirable traits, plant cuttings, tissue culture, applied breeding and genetics, gene isolation and genomics, genetic modification, phenomics; molecular mapping; molecular biology molecular markers etc. (Arora et al. 2011).

2. Crop and livestock diversification and Precision farming:

Smallholder farms often involve a number of plant and livestock species in a small land area. Precision farming aims to increase efficiency by matching agricultural inputs and practices to the exact need of crops grown in specific ecological and climatic conditions. Precision farming uses sensors, GPS mapping tools, low-cost accessible satellite data, data-analytics software and robots. Modification of equipment/ machinery for fertilization, pesticide application and irrigation may be needed for small holding farms (Swinton and Lowenberg-Deboer 2001; Maisiri et al. 2005).

3. Community Irrigation Systems:

Community-based irrigation schemes are co-owned and managed by the community and cover an area of 200 ha or less. The infrastructure operations and maintenance plus water distribution are the sole responsibility of the community. Equipment needed includes pumps, pipes, sprinklers, channels and drip lines etc. Community-based irrigation fuses local organizational capital and indigenous knowledge into small-scale irrigation systems thus ensure sustainable and equitable allocation of water, which is responsive to prevailing local climatic and social conditions (Wanyama et al. 2017).

4. Ecological Pest Management:

Climate change is predicted to alter the prevalence, intensity and severity of crop and animal pests. Measures to control this risk need to be designed in a way that avoids inappropriate use of agrochemicals that pose risk to human and environmental health. Ecological pest management seeks to predict and avert the risk of pests and diseases and the risk of the various control measures to human and environmental health (Tshernyshev 1995).

5. Culture- Based Fisheries and Aquaculture:

To ensure resilience to climate shocks, a healthy balance of fish stocks and species diversity must be maintained. Culture based fisheries and aquaculture are technological interventions that can help to build up fish stocks (De Silva 2003; Dey and Prein 2006).

6. Responsive Agricultural Extension:

Agricultural advisory and extension services are crucial in transferring and adapting technologies to farmers' contexts, and providing feedback for further research depending on technology performance. How this extension system can be effective requires full consultation with farmers crop and livestock farmers and what their adaptation needs are in the different ecozones. The system must

connect well with private businesses for supply of seeds, feeds and fertilizers, produce protection, storage and processing, financial and insurance services (Davis 2008). This system also needs to use available technology by incorporating existing mobile-phone based apps and translating existing information into local languages using diagrams, videos etc. (Asenso-Okyere and Mekonnen 2012).

7. App for targeting soil and water conservation technologies to appropriate conditions and estimating outcomes:

An app providing a portfolio of soil and water conservation technologies and supporting farmers in deciding the most appropriate one for their context has great potential in controlling soil erosion, loss of soil fertility and water. The portfolio includes options such as mulching, crop rotation, fallowing, practices for water retention and maintaining soil structure, contour farming, bench terraces, grass strips, minimum soil disturbance e.g. basin planting and ripping, contour hedgerows and retention ditches, agroforestry, and drip irrigation. The app uses a simple program that can be accessed via a mobile phone using simple queries and drop-down menus of options. It can generate suitability maps for technology selection giving due consideration for vulnerable areas including swamps and along river banks, hilltops, steep slopes and areas under semi-nomadic shifting agriculture. This can be supplemented with organized farmer- group learning through physical meetings and demonstration as well as through radio broadcasting (Namirembe et al. 2015).

8. Livestock breeding for cattle and goats:

Breeding climate resilient livestock in relation to tolerance to increased temperatures and drought (affecting food conversion, weight gain, reproduction, increased risk of diseases and pest incidences) (FAO 2005). Efforts to introduce climate resilient breeds may involve tradeoffs with productivity. Decentralized establishment of local artificial insemination points enables innovation that responds to the local climate context.

9. Climate insurance:

Seasonal predictability is likely to change especially onset and intensity of rainfall. These will increase risks to agricultural production, including diseases, pests, input and commodity prices. Insured farmers can access credit more easily from financial institutions and can therefore purchase inputs for improved technologies for production (AIC presentation undated; Nabwiiso 2018).

10. Seed and grain storage:

Human capacity and systems of crop handling and storage need to adjust to improve preparedness for climate change impacts. A system is needed to purchase seed and grains from farmers at competitive prices, store them safely and redeploy them where/when needed. This will potentially minimize losses from physical degradation, pests and diseases, help farmers avoid food insecurity, selling at low prices in times of bumper harvests (Musoke 2018).

4.5 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION

Multi-criteria analysis was used in deciding which technologies to prioritize in the Agriculture sector following the same steps as in Section 3. Criteria for prioritization of agriculture technologies for climate change adaptation **(Table 10)** were assessed by allocating scores of 0 (not favorable) to 100 (very favorable) to costs and benefits **(Table 5).**

Table 10. Criteria for analyzing technologies for climate adaptation in the Agriculture Sector

Consideration	Criterion	Explanation
Economic benefit	Improved livelihood	Consistency of income flow/ household assets and capabilities.
	Macro economy	Employment, competitive markets, price stability, trade and export earning
	Trigger private investment	Potential for companies, financial organizations, or other investors, to finance investment
Social benefit	Poverty reduction potential	Ability to improve standards of living, better housing, accessibility of financial services
	Reduced drudgery and acceptability	Ability to reduce labor demand from for women and men. Alignment with cultural norms, inclusiveness of needs of different sections of society, enhancement of food, livelihood and employment security.
	Improved food security	Potential to enhance food security
Environmental benefit	Contribution of technology to protection of soil and water	Ability of technology to prevent soil loss, improve soil fertility and prevent water loss and contamination.

	Protection of biodiversity	Ability to maintain ecosystems in the locality
	Reduction of pests and diseases	Ability to prevent occurrence and mitigate spread of pests and diseases
Climate benefit	Reduced vulnerability and improved resilience to climate change	Potential of the technology to enable society or the economy to avoid, overcome or withstand climate change e.g. projected increase in temperatures
	Reduced emissions	Ability to reduce pollutants such as carbon dioxide, nitrogen oxide, and other hydrocarbons
Institutional or implementation advantage	Ease of implementation	Availability of human, organizational, policy and financial capacity to establish and operate the technology. Congruence of the technology with existing social systems.
	Replicability and ability to impact at large scale	Potential feasibility to spread technology where it is needed. Number of beneficiaries.
Cost	Establishment and operation	Equipment, human expertise, energy sources, land and organizational resources needed to set up technology, and operate the technology
	Social cost	Threat to cultural norms and local cohesiveness, inclusiveness of needs of different sections of society, threat to food. livelihood and employment security.
	Cost of building human capacity to generate and operate the technology	Existence of trained professionals, ease of passing on skills to other people to run the technology
	Environmental cost	Threat to biodiversity, risk of increasing adverse climatic effects.
Political support	Coherence with development policies	Contribution of the technology to current development priorities.

Weighting of the criteria

Stakeholders allocated weight to each criterion (adding to 100) according to urgency, importance in contributing to the applicability and suitability of the technology for adapting to climate change **(Table 11)**. Technologies were allocated scores for each criterion as described in Section 3.

Table 11. Weighting of criteria for the agriculture sector

Criterion	Weight
Establishment and operation (EO)	8
Social cost (SC)	5
Cost of building human capacity to generate and operate the technology (HC)	8
Environmental cost (EC)	6
Improved livelihood (L)	5
Macro economy (ME)	5
Trigger private investment (PI)	5
Poverty reduction potential (PR)	4
Reduced drudgery and acceptability (DR)	5
Improved institutional capacity, networking, cross learning (IC)	5
Improved food security (FS)	8
Contribution of technology to protection of soil and water (S&W)	4
Protection of biodiversity (B)	3
Reduction of pests and diseases (P&D)	5
Reduced vulnerability and improved resilience to climate change (R/VR)	8
Reduced emissions (ER)	2
Ease of implementation (EoL)	5
Replicability and ability to impact at large scale (R/S)	5
Coherence with development policies (DP)	4
Total	**100**

4.6 RESULTS OF TECHNOLOGY PRIORITISATION

Scores assigned to the agricultural technologies are in **Table 12** and their weighted values in **Table 13**. From total weighted score, the three technologies that ranked highest were:

1. Responsive Agricultural Extension
2. Community Irrigation Systems
3. Crop breeding for climate change adaptation

The participants prioritized and ranked the technologies for adaptation in agricultural sector in descending order as in **Table 14.**

Table 12. Criteria scores for technologies in the Agriculture Sector

Technology	Costs				Benefit										Climate		Others		
					Economic			Social				Environmental					Institutional/ implementation		
Criteria#	EO	SC	HC	EC	L	ME	PI	PR	DR	IC	FS	S&W	B	P&D	R/VR	ER	EoL	R/S	DP
Crop Breeding for CC adaptation	50	80	60	50	75	55	67	70	60	50	80	65	60	90	98	75	80	75	95
Crop Diversification and Precision Farming	30	50	20	93	75	70	50	70	35	30	80	70	80	80	80	65	30	50	45
Community irrigation systems	40	80	70	59	80	80	20	90	70	90	90	85	80	60	98	85	60	80	65
Ecological Pest Management	60	80	50	92	65	45	60	65	0	30	80	90	90	100	75	55	60	65	50
Culture Based Fisheries and Aquaculture	70	70	70	50	75	87	83	70	70	40	68	65	78	40	70	10	30	45	50
Responsive Agric. Extension	40	65	80	100	50	95	0	80	60	90	90	75	60	95	95	60	75	89	90
Soil & water conservation App	70	85	80	100	40	65	20	40	50	60	65	90	75	55	70	65	50	65	55
Breeding cattle, goats, poultry & fish	50	50	60	50	70	70	40	65	50	50	70	65	60	90	85	80	70	70	75
Climate insurance	30	75	30	100	75	30	70	90	65	65	85	20	20	40	90	50	35	70	55
Storage seed, grain	20	60	30	93	75	70	90	80	65	70	90	0	50	70	90	55	35	60	50
Agro-met. & market Infor access & use *	20	50	20	90	60	60	50	70	68	70	70	50	55	75	85	55	50	90	50
Value addition and processing *	20	30	50	75	80	80	80	75	75	60	75	5	65	70	85	55	40	50	55

See Table 11 for explanation of abbreviations

*Additional technologies suggested by sector working group team members during the scoring exercise. No fact sheets were developed for this and the scoring was based on expert opinion

Table 13. Weighted scores for technologies in the Agriculture Sector

Technology	Costs				Benefits										Climate		Others			Total	Rank
Weight	**8**	**5**	**8**	**6**	**5**	**5**	**5**	**4**	**5**	**5**	**8**	**4**	**3**	**5**	**8**	**2**	**5**	**5**	**4**		
Criteria#	**E & O**	**SC**	**HC**	**EC**	**L**	**ME**	**PI**	**PR**	**DR**	**IC**	**FS**	**S & W**	**B**	**P & D**	**R/ VR**	**ER**	**EoL**	**R/S**	**DP**		
Crop Breeding for climate change adaptation	400	400	480	300	375	275	335	280	300	250	640	260	180	450	784	150	400	375	380	7014	3
Crop Diversification and Precision Farming	240	250	160	558	375	350	250	280	175	150	640	280	240	400	640	130	150	250	180	5698	12
Community irrigation systems	320	400	560	354	400	400	100	360	350	450	720	340	240	300	784	170	300	400	260	7208	2
Ecological Pest Management	480	400	400	552	325	225	300	260	0	150	640	360	270	500	600	110	300	325	200	6397	5
Culture Based Fisheries and Aquaculture	560	350	560	300	375	435	415	280	350	200	544	260	234	200	560	20	150	225	200	6219	7
Responsive Agricultural Extension	320	325	640	600	250	475	0	320	300	450	720	300	180	475	760	120	375	445	360	7415	1
App for Soil and water conservation	560	425	640	600	200	325	100	160	250	300	520	360	225	275	560	130	250	325	220	6425	4
Breeding of cattle, goats, poultry & fish	400	250	480	300	350	350	200	260	250	250	560	260	180	450	680	160	350	350	300	6380	6
Climate insurance	240	375	240	600	375	150	350	360	325	325	680	80	60	200	720	100	175	350	220	5925	10
Storage seed, grain	160	300	240	558	375	350	450	320	325	350	720	0	150	350	720	110	175	300	200	6153	8
Agro-met. & market Infor access & use by farmers*	160	250	160	540	300	300	250	280	340	350	560	200	165	375	680	110	250	450	200	5920	11
Value addition and processing of produce*	160	150	400	450	400	400	450	300	375	300	600	20	195	350	680	110	200	250	220	6010	9

See Table 11 for explanation of abbreviations

Table 14. Ranking of technologies in the Agricultural Sector

Technology	Total score	Rated technology in descending order
Responsive Agricultural Extension	**7415**	**1**
Community irrigation systems	**7208**	**2**
Crop Breeding for climate change adaptation	**7014**	**3**
App for Soil and water conservation	6425	4
Ecological Pest Management	6397	5
Breeding of cattle, goats, poultry & fish	6380	6
Culture Based Fisheries and Aquaculture	6219	7
Storage seed, grain	6153	8
Value addition and processing of produce	6010	9
Climate insurance	5925	10
Agro-met. & market Infor access & use by farmers	5920	11
Crop Diversification and Precision Farming	5698	12

CHAPTER FIVE: TECHNOLOGY PRIORITISATION FOR THE FORESTRY SECTOR

5.1 KEY CLIMATE CHANGE VULNERABILITIES IN FORESTRY

The forestry sector in Uganda comprised the following tenure categories as described in the National Forestry Policy of 2001 (MWLE 2001): Central Forest reserves (constitute 15% of the total forest cover); forests in wildlife and national parks (constitute 15% of the total forest cover); forests on private and community forests (constitute 70% of the total forest cover).

Uganda's forest cover status has followed a drastic negative trend during the last 30 years. Thus, it reduced from 24 to 9% of the total land area in 1990 and 2015 (MWE 2017). This is largely attributed to key drivers of deforestation and forest degradation as described in the National Reducing Emissions from Deforestation and Forest Degradation (REDD) + strategy for Uganda (MWE 2017) including: expansion of commercial and subsistence agriculture; unsustainable harvesting of tree products, mainly charcoal, firewood and timber; expanding human settlements including growing numbers of refugees; free-grazing livestock; wild fires; artisanal mining operations and oil exploration.

The reported climate change and variability impacts (*such as: prolonged droughts, unreliable rainfall patterns, flooding*) (MWE 2015) exacerbate the forestry sector that is already facing huge pressures through provision of ecosystem services and forest products to the burgeoning Uganda population, with an annual growth rate in Uganda of 3.3%. Thus, Uganda is estimated at 45 and 61 million Ugandans currently/now and by 2030, respectively (National Population Council 2018).

Whereas there is no comprehensive national climate change vulnerability assessment for Uganda across all the sectors including forestry, the reported (NAPA 2007) vulnerabilities in the forestry sector in Uganda include the following:

a) emergency and proliferation of trees pests and diseases;
b) increased risk to destruction of forest from wild fires due to prolonged droughts;
c) Increased encroachment on forests and forest land by community due to escalating land degradation and food insecurity among households with forest landscapes.

5.2 DECISION CONTEXT

Uganda as a country has made progress with various achievements in the policy, legislative and institutional framework in respect to advancing climate change adaptation across sectors with aim of reducing the vulnerabilities described in section 5.1. However, what remains is required investments

at different levels for effective implementation of these policies and strengthening of institutional capacity to effective respond to the emerging climate change impacts.

Some of the outstanding achievements are enlisted as follows:

1. The Uganda Vision 2040 (NPA 2007);
2. The National Development Plan II (NPA 2015);
3. Development and implementation of the National Adaptation Programmes of Actions, (2007);
4. Development of the Uganda National Policy on Disaster Preparedness and management
5. Development of the climate change policy, (MWE 2015);
6. Development of the draft National Climate change bill, (2017);
7. Establishment of the Climate Change Department in 2008 and the National Metrological Authority in 2012;
8. Development of the National Adaptation Plan for Agriculture, 2018;
9. Development of the National Climate Smart Agriculture Program, 2015-2025 (MAAIF & MWE (2015);
10. Development of the climate change mainstreaming guidelines in 2014 (MWE 2014);
11. Targeted capacity building and training for climate change adaptation by various stakeholders both Government and Non-Government. This started in the early 2000 and is continuously being implemented at the national, local and community levels;
12. Establishment of the National Council of Science and Technology in 1990;
13. Establishment and operationalization of the Ministry of Science, Technology and Innovation in 2016;
14. Establishment of the Parliamentary Forum on Climate Change;
15. Establishment of the Parliamentary Committee on Climate Change in 2019;
16. The approval of the National Forestry Policy in 2001
17. The National Forestry and Tree Planting Act, (2003;
18. National Reducing Emissions from Deforestation and Forest Degradation (REDD) + strategy for Uganda (MWE, 2017 and FIP, 2017);
19. The approval of the Uganda National Forest Stewardship Standards in 2018 (NFSS 2018);*-
20. The draft bamboo strategy and guidelines;
21. The Farm Income Enhancement Program II (2015);
22. The Sowlog Production Scheme Grant III, (2016);
23. The National Environment Act, (2018);

24. The Forest Landscape Restoration (FLR) Opportunities report (MWE 2016);
25. The Uganda National Green Growth Strategy, 2017/18-2030/2031 (NPA 2017);
26. The Nationally Determined Contributions for Uganda (NDC 2016)

5.3 OVERVIEW OF EXISTING TECHNOLOGIES IN THE FORESTRY SECTOR

The following are some of the existing technologies in the forestry sub-sector, identified through a process described:

1. Integrated wildfire management;
2. Enrichment planting for restoration of natural forests;
3. Promoting Forest based enterprises e.g. bee keeping/apiary, butterfly farming, fruit trees production, ecotourism;
4. Application of tissue culture to hasten massive propagation/multiplication of tree seedlings;
5. Advancing biotechnology to produce hybrids which are designed to be adaptable to future anticipated conditions due to impact of climate change in Uganda.
6. Promoting community woodlots for biomass energy production;
7. Application/use of drones in forest management for effective monitoring;
8. Promotion of bamboo value chains – production and processing/value addition and marketing;
9. Promoting improved chainsaws to advance efficiency in timber logging;
10. Promoting portable sawmills for onsite timber processing to advance efficiency;
11. Promoting phytosanitary practices for diseases and pest control;
12. Integrated pest management in forest plantations;
13. Use of hydrogels and hydro-absorbents to advance adaption to prolonged droughts impacting on forest plantations;
14. Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration;
15. Intercropping in forest plantations;
16. Diversification in forest plantations;
17. Integrated forestry-crop-livestock systems;
18. Use of forest residues for biomass energy;
19. Growing Trees for food i.e. pomo-culture;
20. Promoting energy saving stoves

5.4 ADAPTATION TECHNOLOGY OPTIONS FOR FORESTRY SECTOR

1. ***Integrated wildfire management****:*

According to ITTO (2019), Integrated forest fire management (IFFM) comprises a systematic approach to forest fire management. It encompasses both the traditional efforts of fire prevention and fire suppression as well as the use of prescribed fire as a tool, community involvement, and forest law enforcement. IFFM if applied effectively by forest responsible bodies will prevent destruction of trees and forest by wild fires during prolonged droughts as a result of climate change and variability in various parts of the country across the different forest landscapes. Besides, the technology and approach was identified as a strategic option in Uganda's National strategy for Reducing Emissions from Deforestation and Forest Degradation for reducing the impacts of wild fires on forests (MWE, 2017).

2. Enrichment planting for restoration of natural forests:

According to Neufeldt, (2015), Enrichment planting is a strategy for increasing the planting density (i.e. the numbers of plants per hectare) in an already growing forest stand. It is a common technology/practice used for increasing the density of desired tree species in secondary forests for purposes of forest restoration and enhancement of overall value of the forest in terms of productivity. It's done through planting of high value timber native/natural tree species in existing but degraded secondary forests (Paquette et al., 2009).

3. Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism:

The technology is community based and established with the buffer zones and within the protected forests so long as it has minimum negative impacts on the forest in terms of degradation. Thus, overall the selected enterprises must be promoting forest restoration and conservation and at the same time improving the livelihoods of the forest adjacent communities through income generation and food security (Frey et al., 2019). The technology is largely managed by the forest adjacent communities after they are equipped with the requisite knowledge and skills to management the enterprises efficiently and effective.

4. Application of tissue culture to hasten massive propagation/multiplication of tree seedlings:

Tissue culture involves rapid multiplication of clean and healthy planting materials in controlled environment. It takes a shorter time as compared with the common practice of nurturing planting materials through nursery bed.

5. Advancing biotechnology to produce hybrids which are adapted to Uganda's climatic conditions:

Biotechnology is applied in various disciplines (crops, livestock) targeted at development improved varieties and or breeds (FAO, 1995). Equally, its applicable to develop clones which are more productive for generation of timber and other forest products; resistance to pests and diseases. This is therefore a great opportunity, which can be tapped into for development of appropriate tree species clones that adapted to the local climate conditions in Uganda. Besides, the impacts of climate variability and change are already visible and impacting on the forestry sector in Uganda.

6. Application/use of drones in forest management for effective monitoring:

According to Newcome, (2004) drones (such as the small fixed-wing aircraft) were initially developed for military use. However, they are increasingly being deployed in civilian applications, including mapping, monitoring and managing habitats and natural resources. Various reports indicated that often, drones also referred to as, *'remotely piloted aerial vehicles'* have been used in the mapping and monitoring fires and forest stands (Casbeer et al. 2006). The drones were recently introduced technology in Uganda and by far have been used in the documentation of proceedings of social events through taking automated aerial photo graphs.

7. Promotion of bamboo value chains – production and processing/value addition and marketing;

According to Lobovikov, et al. (2005), Bamboo is a major non-wood forest product and wood substitute. It is found in all regions of the world and plays an important economic and cultural role. Bamboo is an ancient woody grass widely distributed in tropical, subtropical and mild temperate zones. It is a major non-wood forest product. There are about 1200 species of bamboo (Lobovikov, et al. 2005). It is an integral part of forestry, but it is also widely spread outside forests, including farmlands, riverbanks, roadsides and urban areas. In Uganda bamboo grow naturally in some of the following regions: the highlands of Kigezi (Bwindi, Mghahingha and Echuya, Mt. Rwenzori); the eastern highlands (Mt. Elgon, Mt. Kadam, Mt. Moroto); in Buganda Region (Mabira and Kifu forests); in the Northern Region (Agoro-Agu, Lokung Forest Reserve) and others. In these regions, it often grows wildly but among the protected species in the natural forests (NFA, 2014).

Bamboo can be promoted to contribute to restoration of degraded forest landscapes in Uganda. Besides, it provides various products which add value in contributing to adaptation and building resilience to climate change impacts – as these provide alternative livelihoods and incomes to

communities and stakeholders involved in the bamboo value chain (INBAR, 2014). Thus, bamboo is fast growing and can be transformed into various products for: housing, crafts, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics, oil, gas and charcoal (for fuel and as an excellent natural absorbent), it is also a healthy vegetable (the bamboo shoot). Thus, bamboo industries are now thriving in Asia and are quickly spreading across the continents to Africa and America (INBAR, 2014).

8. Forest products management to increase resilience to temperature rise/humidity change and insect/disease vulnerability – wood/biomass product seasoning, treatment/protection, dimensions:

This involves promoting access and application of efficient and effective technology in timber harvesting and processing will contribute to adaptation in the forestry sector, but also open up employment and income generation opportunities through advancing the timber value chain and industry. Some of the technologies especially for the private smallholder tree growers are: portable saw mills;

9. ***Integrated pest management in forest plantations****:*

It involves application of integrated approaches, which complement each for effective pests and diseases management and control. Pimentel (1986) described integrated pest and diseases management as a control method that includes judicious use of pesticide and non-chemical technologies – all of which are based on sound ecological principles. It consists of two basic elements including: a decision and action process. The actions/responses for pest/diseases management/control may consist of one or more ecologically, economically and socially acceptable tactics designed to reduce pest populations to non-damaging levels (Ciesla 1982).

10. Integrated forestry-crop-livestock systems:

According to Yadav, (2014), Integrated Forestry-crop-livestock systems involve integration of forest, crop and livestock enterprises managed within the same system. It consists of a great variety of crops, including perennial fruit and timber/fodder trees and different species of livestock on the same piece of land.

11. Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration:

FMNR is a simple technique/practice of systematically regenerating mainly tree species in the natural from living tree stumps, roots or seedlings. It involves a process of selecting healthy and

vigorous natural seedlings and removing unwanted ones through proper pruning. It started in West Africa, motivated by the severe drought of mid 1970s that prompted innovative farmers working with a development agent called Tony Rinaudo to develop specific techniques for regenerating trees from existing stumps of indigenous trees – combined with low-cost soil and water conservation techniques (ICRAF 2013). It promotes regeneration of degraded forest landscapes. Thus, it's a low-cost sustainable landscape restoration technique aims to improve the productivity of agricultural lands while increasing tree cover and biodiversity.

12. Diversification in forest species plantations:

This involves forest plantation with mixed tree species stands as opposed to common pure stands. It requires the right selection of the tree species which can co-exist and is applicable in both plantation and natural forests (Jactel et. al. 2005).

13. Use of hydrogels and hydro absorbents to advance adaption to prolonged droughts impacting on forest plantations:

Hydrogels have abilities of absorbing and retaining water. They have been reported as used in establishment of tree seedlings and transplants in the arid regions and in increasing plant survival and overall dry weights, particularly for less drought tolerant tree species (Orikiriza et al. 2013). They can absorb and store water up to 400 times their own weight, and consequently, reduce water stress for the trees (Bouranis et al. 1995). Examples of hydrogels include: STOCKOSORB and super absorbent polyacrylate (SAP) hydrogel amendment.

The detailed technology fact sheets are **attached in a separate document**. Besides, the fact sheets were used as key reference materials that provided additional information to the participants during the TNA prioritization workshop for informed decision making.

5.5 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION

Multi-criteria analysis was used in deciding, which technologies to prioritize to enable objectivity and build consensus among stakeholders with divergent views. According to the MCA guidance on Adaptation the following steps were followed:

The following criteria for technology prioritization were developed through discussions with stakeholders in the water sector working group with experience and knowledge from government, civil society and private institutions. They were guided by key template of the technology fact sheets that were shared by the consultant to determine the suitable and appropriate criteria for technology

prioritization. Criteria for technology prioritization were based on their potential to reduce vulnerability or enhance resilience to climate change, and their potential social, economic and environmental benefits on the one hand while taking into consideration cost implications (Table 14).

Table 15. Criteria for analyzing technologies for climate adaptation in the Forestry Sector

Consideration	Criterion	Explanation
Economic benefit	Size of beneficiaries	Number of women, men and youth gaining from the technology. Regional area that the technology covers. Intensity of the challenge that the technology solves
	Employment and increase in income	Potential for the technology to create jobs from direct engagement or to create environment for job creation, new livelihood options and income generation
	Market potential	Potential market demand of the technology and associated products
Social benefit	Reduced labor burden for both men and women	Congruence of the technology with existing social norms and cultures, increasing employment, catering for needs of women, men, children and the youth, inclusiveness of indigenous knowledge in establishment an operation.
	Food/water/health security	Potential to increase food production, nutrition and post-harvest handling; potential to improve water quality and quantity; potential to improve human and livestock health and avoid disease increases that may occur due to climate change.
	Gender inclusiveness/fairness in pricing and inclusion in decisions	Inclusion of men women and youth in the process, establishment and operation of the technology; consideration of how the technology addresses needs of different genders
Environmental benefit	Minimization of land degradation	Low negative environmental footprint e.g. less earth movement, less pollution of water, soils, air, sound etc.
	Restoration of habitat	Potential to recover degraded area leading environmental co-benefits
	Reduced pollution	

Climate benefit	Reduced vulnerability or improved resilience to climate change	Potential of the technology to enable society or the economy to avoid, overcome or withstand climate change e.g. projected increase in temperatures
Economic Cost	Investment cost i.e. cost of equipment/land	Cost of construction / establishment of the technology infrastructure including purchase of equipment, land acquisition, electrical/mechanical power purchase and hiring of technical manpower.
	Operation and maintenance/skills enhancement	Availability and ability to purchase equipment parts, availability of energy sources to ensure functionality.
	Ease of implementation/fuel and energy	Availability of human, organizational, policy and financial capacity to establish and operate the technology.

Weighting of the criteria

Stakeholders allocated weight to each criterion (adding to 100) according to urgency, importance in contributing to the applicability and suitability of the technology for adapting to climate change (**Table 16**). Technologies were allocated scores for each criterion as described in Section 3.

Table 16. Weighting of criteria for the Forestry Sector.

Criterion	Weight
Cost of equipment/land	15
Cost of skills enhancement and or maintenance costs	10
Cost of fuel and energy to run/use the technology	5
Size of beneficiaries from the technology	5
Market potential for the technology	12
Creation of employment opportunities and increased incomes from the technology	8
Contribution to food/water/health	4
Fairness in pricing and inclusion in decisions	3
Reduced labor burden for both men and women	3
Land restoration	5

Reduced pollution	3
Improved habitat	7
Contribution to climate resilience	20
Total	**100**

Key reactions and feedback by participants on the forestry sector TNA presentation

During the plenary discussions, the participants reacted to the presentation by raising additional technologies including the following:

(i) Use of forest residues for biomass energy
(ii) Growing trees for food i.e. pormo-culture
(iii)Promoting energy saving cooking stoves

Key reactions and feedback by participants on the selected technologies for prioritization

During the group work session, the participants provided feedback that out of the 13 technologies identified for the forestry sector, some of them are in the early stages of development, thus still at pilot stage and on-farm. Therefore, the participants felt that it is too early to up-sale and out-scale these technology through the TNA project initiative. These technologies included the following:

(i) Diversification in forest plantations;
(ii) Use of hydrogels and hydro-absorbents to advance adaption to prolonged droughts impacting on forest plantations.

Therefore, 11 out of the 13 technologies were prioritized by the participants using the MCA tool. These are listed as follows:

1. Integrated wildfire management;
2. Enrichment planting for restoration of natural forests;
3. Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism;
4. Application of tissue culture to hasten massive propagation/multiplication of tree seedlings;
5. Advancing biotechnology to produce hybrids which are adapted to Uganda's climatic conditions;
6. Application/use of drones in forest management for effective monitoring;
7. Promotion of bamboo value chains – production and processing/value addition and marketing;
8. Promoting portable sawmills for onsite timber processing to advance efficiency;

9. Integrated pest management in forest plantations
10. Integrated forestry-crop-livestock systems;
11. Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration.

5.6 RESULTS OF TECHNOLOGY PRIORITISATION.

Using expert opinion, the scores were assigned to the technologies against each criterion detailed in **Table 17.** The scores were multiplied by the weight assigned to each criterion presented in **Table 18**. The total weighted score for each technology was then summed up. Based on this the 3 most important technologies are:

1. Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration;
2. Integrated pest management in forest plantations through promoting mixed species plantations;
3. Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism.

Participants prioritized the identified adaptation technologies for the forestry sector based on the MCA tool giving them order of importance as listed in **Table 19**.

Table 17. Criteria scores for technologies in the Forestry Sector

Technology	Costs			Benefits									
				Economic			Social			Environmental			Climate related
Criteria	Equipment/ land	Maintenance/ skill enhancemnet	Fuel/ enegry	Size of beneficiaries	Market potential	Employment/ increased income	Food water health security	Fairness - pricing /inclusion in decisions	Reduced labour burden men & women	Land restoration	Reduced pollution	Improved habitat	Climate resilience
Integrated forestry crop-livestock system	43.75	26.25	71.5	80	90.5	92.75	86	43.5	25	84	64.5	75.25	89.75
Portable sawmill equipment for value addition	22.5	21.25	16.25	47.5	36.5	15	10	46.25	75.75	33.75	32.5	15	23.75
Drones for M&E in Forestry	7.5	13.75	16.25	10	54.5	18.75	29.5	69.5	84.5	29.5	79.25	23.25	36.67
Forest based enterprises	50	38.5	65.5	84.75	92.33	92.67	82	62.33	65	85.33	70.33	74.67	73
Farmer natural regeneration for trees and forestation	83.25	81.25	95	87.75	54.5	26.25	78.5	77.5	82.25	91.5	83	87.25	93.75
Biotechnology to produce hybrids adapted to Uganda,s climate	16.25	13.75	30	83	82.25	75	74.75	80	18.75	72.25	83.75	82.5	89.25
Enrichment planting for forest restoration	64.75	57.5	46.25	62.5	37.75	43.75	52.5	70	55	82.5	78.75	81.25	82.5
Intergrated pest management in forest management	73.75	80	67.5	78.75	73.75	66.25	68.75	71.67	47.5	78.75	75	76.25	73.75
Tissue culture to hasten massive propagation/multiplaication of tree seedlings	31.25	26.67	22.5	78.75	83.75	68.75	75	78.75	29	76.25	78.75	71.25	82.5
Promotion of bamboo and bamboo value chains-processing and marketing	42.5	72.5	38.75	80	82.5	82.5	68.75	77.5	41.25	70	73.75	68.75	82.5
Integrated wildfire management	31.25	41.25	25	60	68.75	62.5	67.5	77.5	27.5	69.75	79.5	75	76.25

Table 18. Weighted scores for technologies in the Forestry Sector.

Technology	Costs			Benefits									Climate	Total	Rank
Weight	**15**	**10**	**5**	**5**	**12**	**8**	**4**	**3**	**3**	**5**	**3**	**7**	**20**		
	Equipment / land	**Maintenance/ skill enhancement**	**Fuel/ enegry**	**Size of beneficiaries**	**Market potential**	**Employment/ increased income**	**Food water and health security**	**Fairness in pricing and inclusion in decisions**	**Reduced labour burden for both men and women**	**Land restoration**	**Reduced pollution**	**Improved habitat**	**Climate resilience**		
Integrated forestry crop-livestock system	656.25	262.5	357.5	400	1086	742	344	130.5	75	420	193.5	526.75	1795	6989	4
Portable sawmill equipment for value addition	337.5	212.5	81.25	237.5	438	120	40	138.75	227.25	168.75	97.5	105	475	2679	11
Drones for M&E in Forestry	112.5	137.5	81.25	50	654	150	118	208.5	253.5	147.5	237.75	162.75	733.33333	3046.583	10
Forest based enterprises	750	385	327.5	423.75	1108	741.33	328	187	195	426.67	211	522.667	1460	7065.917	3
Farmer natural regeneration for trees and forestation	1248.75	812.5	475	438.75	654	210	314	232.5	246.75	457.5	249	610.75	1875	7824.5	1
Biotechnology to produce hybrids adapted to Uganda's climate	243.75	137.5	150	415	987	600	299	240	56.25	361.25	251.25	577.5	1785	6103.5	8
Enrichment planting for forest restoration	971.25	575	231.25	312.5	453	350	210	210	165	412.5	236.25	568.75	1650	6345.5	6
Intergrated pest management in forest management	1106.3	800	337.5	393.75	885	530	275	215	142.5	393.75	225	533.75	1475	7312.5	2
Tissue culture to hasten massive propagation/multiplaication of tree seedlings	468.75	266.67	112.5	393.75	1005	550	300	236.25	87	381.25	236.25	498.75	1650	6186.167	7
Promotion of bamboo and bamboo value chains-processing and marketing	637.5	725	193.75	400	990	660	275	232.5	123.75	350	221.25	481.25	1650	6940	5
Integrated wildfire management	468.75	412.5	125	300	825	500	270	232.5	82.5	348.75	238.5	525	1525	5853.5	9

Table 19. Ranking of technologies in the Forestry Sector

Technology	Total score	Rated technologies in descending order
Farmer natural regeneration for trees and forestation	**7824.50**	**1**
Intergrated pest management in forest management	**7312.50**	**2**
Forest based enterprises	**7065.92**	**3**
Integrated forestry crop-livestock system	6989.00	4
Promotion of bamboo and bamboo value chains- processing and marketing	6940.00	5
Enrichment planting for forest restoration	6345.50	6
Tissue culture to hasten massive propagation/multiplaication of tree seedlings	6186.17	7
Biotechnology to produce hybrids adapted to Uganda's climate	6103.50	8
Integrated wildfire management	5853.50	9
Drones for M&E in Forestry	3046.58	10
Portable sawmill equipment for value addition	2679.00	11

CHAPTER SIX: SUMMARY AND CONCLUSIONS

Climate change will potentially have adverse impacts on the economy, which is highly dependent on rain-fed agriculture and employs about 72% of the total population. Being a Least Developed Country (LDC) with low greenhouse gas emission levels yet with high vulnerability to climate change, Uganda's climate responses are predominantly focused on adaptation and making the key development sectors more resilient (Uganda's NDC 2016). Sectors ranked highest as the most vulnerable to climate change in the NAPA (2007) were the agricultural and agricultural-related sectors including water, forestry, environment and biodiversity. Climate extremes are also likely to affect health, infrastructure and human settlement by damaging property and livelihoods leading to food and water insecurity and people migration. In all these vulnerable sectors, strengthening of technical and institutional capacity is emphasised to enable comprehensive assessment of vulnerability and implementation of adaptation actions.

Based on the UNFCCC (1992) Article 4 aiming to transfer environmentally sound and appropriate technologies from developed to developing countries, Technology Needs Assessment (TNA) project identified and selected climate adaption technologies. Through consultations with stakeholders from key national institutions leading climate change, the Agriculture, Forestry, and Water sectors were prioritized for climate-adaptation technology transfer. Coupled with review of major national development and climate response documents, technologies were prioritized using a multi-criteria analysis in accordance with the TNA procedures. The technologies prioritized for climate change adaptation are listed in **Table 20**.

Table 20. Technologies prioritised for Climate Change Adaptation

Sector	**Technology**
Water	• Deep well extraction • Rainwater harvesting • Surface runoff harvesting
Agriculture	• Responsive agricultural extension • Community irrigation systems • Crop breeding for climate change adaptation
Forestry	• Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration; • Integrated pest management in forest plantations through promoting mixed species plantations; • Promoting Forest based enterprises e.g. bee keeping/apiary; butterfly farming, fruit trees production; ecotourism

Recommendations

- Stakeholders recommended consideration of local technologies, which have not yet been documented need boosting, operationalization and transfer.
- Cost estimates were difficult to come by in the available literature and this gap needs to be taken into consideration in the next steps for TNA. Technical support is needed to support technology costing.
- The potential for ongoing climate change processes to contribute to or benefit from TNA needs to be further elaborated on to ensure value addition from the TNA process.
- In retrospect, the reverse scoring of costs in the MCA and the tendency for stakeholders to allocate high weights to them, systematically disadvantages the technologies that the country cannot afford and results in ranking of technologies that tend towards business as usual. This needs to be reconsidered or revised.
- The TNA process has enabled identification of key potential adaptation technologies, which can be supported through other initiatives if not prioritized for TNA.
- Understanding the adaptation technologies that fit different contexts and what drives decisions especially in agriculture, requires use of local agroecological knowledge, geospatial and socio-economic maps and modelling.

LIST OF REFERENCES

AIC undated. The Uganda Agriculture Insurance Scheme. https://iiu.ac.ug/images/Agricpresentation.pdf. Accessed on 8th November 2019.

Arora I. V. Bargali S. S. & Rawat J. S. (2011). Climate change: Challenges, Impacts and Role of Biotechnology in mitigation and adaptation. *Progressive Agriculture, 11*(conf), 8-15.

Asenso-Okyere K. & Mekonnen D. A. (2012). The importance of ICTs in the provision of information for improving agricultural productivity and rural incomes in Africa. *African Human Development Report. UNDP Sponsored research Series*.

Biazin B. Sterk G. Temesgen M. Abdulkedir A. & Stroosnijder L. (2012). Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa–a review. *Physics and Chemistry of the Earth, Parts A/B/C, 47, 139-151*. http://www.rainfoundation.org/wp-content/uploads/2017/10/RWH-and-management-in-rainfed-and-agricultural-systems-in-sub-Sahara-Africa.pdf. Accessed on 8th November 2019

Blanchard J. P. (2012). Rainwater Harvesting Storage Methods and Self Supply in Uganda. https://scholarcommons.usf.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=5175&context=etd Accessed on 12th July 2019

Bouranis D.L. Theodoropoulus A.G. Drossopoulus J.B. 1995. Designing synthetic polymers as soil conditioners. *Communications in Soil Science and Plant Analysis, 26: 1455–1480.*

Broeckx J. Maerterns M. Isabirye M. et al. (2018). Landslide Susceptibility and Mobilization Rates in the Mount Elgon Region, Uganda. https://link.springer.com/article/10.1007/s10346-018-1085-y Accessed on 1st October 2019

Casbeer D.W. Kingston D.B. Beard R.W. McLain T.W. (2006). Cooperative Forest Fire Surveillance using a Team of Small Unmanned Air Vehicles. *Int. J. Syst. Sci. 2006, 37, 351–360.*

CDC (Centers for Disease Control and Prevention) (2015). Public Water Systems. https://www.cdc.gov/healthywater/drinking/public/water_treatment.html Accessed on 1st August 2019

Ciesla, W.M. 1982. IPM: New approaches to old problems. *American Forests* 88(2): 40-44, 51-52.

Danert K. & Motts N. (2009). Uganda Water Sector and Domestic Rainwater Harvesting Sub Sector Analysis.

Davis K. (2008). Extension in Sub-Saharan Africa: Overview and assessment of past and current models, and future prospects. *Journal of International Agricultural and Extension Education*, *15*(3), 15-28.

Dell, A. I., Pawar, S., & Savage, V. M. (2014). Temperature dependence of trophic interactions are driven by asymmetry of species responses and foraging strategy. *Journal of Animal Ecology, 83(1), 70-84.*

De Silva S. S. (2003). Culture-based fisheries: An under-utilized opportunity in aquaculture development. *Aquaculture*, *221*(1-4), 221-243.

Dey M. M. & Prein M. (2006). Community-based fish culture in seasonal floodplains. *NAGA, WorldFish Center Quarterly*, *29*(1-2), 21-27.

Directorate of Water Resources Management (2009). Climate Change Response Strategy and Action Plan. December 2009.

Evans A.K. Miriti (2017), A Critical Sites Network for Freshwater Biodiversity in the Lake Victoria Catchment. https://www.africangreatlakesinform.org/link/critical-sites-network-freshwater-biodiversity-lake-victoria-catchment. Accessed on 22nd November 2019

FAO (2005). Livestock sector brief Uganda. http://www.fao.org/ag/againfo/resources/en/publications/sector_briefs/lsb_UGA.pdf. Accessed on 15th September 2019

FAO (2010). The State Of The World Fisheries And Aquaculture. http://www.fao.org/3/a-i1820e.pdf. Accessed on 15th September 2019

FAO (2018). Brief on fisheries, Aquaculture and Climate Change in the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) http://www.fao.org/3/a-i5871e.pdf Accessed on 15th September 2019

FAO (2018). Impacts of Climate Change On Fisheries And Aquaculture. *Synthesis of current knowledge, adaptation and mitigation options.* http://www.fao.org/3/i9705en/i9705en.pdf Accessed on 15th September 2019

FAO (1995). Agricultural Biotechnology in the Developing World. Food and Agriculture Organization. Rome.

FAO (2018). Nature-Based Solutions for Agricultural Water Management and Food Security. http://www.fao.org/3/CA2525EN/ca2525en.pdf Accessed on 15th September 2019.

Fermont A. & Benson T. (2011). Estimating yield of food crops grown by smallholder farmers. *International Food Policy Research Institute, Washington DC, 1-68.*

Frey, G. E., Cubbage, F. W., Holmes, T. P., Reyes-Retana, G., Davis, R. R., Megevand, C., . . . Chemor-Salas, D. N. (2019). Competitiveness, certification, and support of timber harvest by community forest enterprises in Mexico. *Forest Policy and Economics*, 101923. Funk C. Rowland J. Eilerts G. White L. Martin T. E. & Maron J. L. (2012). A Climate Trend Analysis Of Uganda. *US Geological Survey Fact Sheet, 3062(4).*

Hatibu N. Mutabazi K. Senkondo E. M. and Msangi A. S. (2006). Economics of rainwater harvesting for crop enterprises in semi-arid areas of East Africa. *Agricultural Water Management, 80(1-3), 74-86.*

Heinrich Böll Stiftung, East and Horn of Africa. (2010). Climate Change Vulnerability and Adaptation Preparedness in Uganda. Retrieved from https://www.boell.de/sites/default/files/assets/boell.de/images/download_de/worldwide/Uganda_Climate_Change_Adaptation_Preparedness.pdf Accessed on 30th September 2019

ICRAF (2013). World Agroforestry Centre. Farmer Managed-Natural regeneration. *How to regenerate pasture and farmland on a low budget. Nairobi.*

INBAR (International Network for Bamboo and Ratan) (2014). Bamboo: A strategic resource for Countries to reduce effects of climate change. Policy synthesis report 1. Beijing.

IPCC (Inter-governmental Panel on Climate Change) (2014). AR5 Synthesis Report – Climate Change 2014 -https://www.ipcc.ch/report/ar5/syr/. Accessed on 12th November 2019

ITTO (International Tropical Timber Organization) (2019), Integrated forest fire management. https://www.itto.int/sustainable_forest_management/fire_management/. Accessed on 19th November 2019

Jacobs L. et al. (2017). Landslide Diversity in the Rwenzori Mountains (Uganda). https://link.springer.com/chapter/10.1007/978-3-319-53498-5_10#citeas Accessed on 15th September 2019.

Jactel, H, E Brockerhoff, and P Duelli. (2005). A Test of the Biodiversity – Stability Theory: Meta-Analysis of Tree Species Diversity Effects on Insect Pest Infestations, and Re Examination. In Forest Diversity and Function: Temperate and Boreal Systems, edited by M. Scherer-Lorenzen, Ch. Körner, and E.-D. Schulze. Vol. 176. Berlin/Heidelberg: Springer-Verlag.

Karuppaiah V. & Sujayanad G. K. (2012). Impact of climate change on population dynamics of insect pests.

Kyeyune M. (2017). Uganda: Leaders Ask Government to Invest in Bulk Water Project. http://greenghanaian.org/uganda-leaders-ask-government-to-invest-in-bulk-water-project/ Accessed on 24th July 2019

Lake Victoria Basin Commission USAID (2018). Lake Victoria Basin Climate Change Adaptation Strategy and Action Plan 2018- 2023. https://www.climatelinks.org/sites/default/files/asset/document/2018_USAID-PREPARED_Lake-Victoria-Basin-Adaptation-Strategy-Action-Plan.pdf Lobovikov, M., Paudel, S., Piazza, M., Ren, H. and Junqi, W. (2005). World Bamboo Resources. A Thematic study prepared in a framework of global forest resources. Food and Agriculture Organization. Rome. http://www.fao.org/3/a-a1243e.pdf

Lyon B. and DeWitt D. G. (2012). A recent and abrupt decline in the East African long rains. *Geophysical Research Letters*, *39*(2).

MAAIF (2010). Agriculture Sector Development Strategy and Investment Plan: 2010/11-2014/15. https://nutrition.opm.go.ug/wp-content/uploads/2017/05/Agricultural-Sector-Development-Strategy-Investment-Plan.pdf. Accessed on 22nd July 2019

MAAIF (2011). Ministry of Agriculture Animal Industry and Fiseries. National Agriculture Policy.

MAAIF (2018). Guildelines for use of Production and Marketing Grant by Local Governments for FY 2018/19.

MAAIF and MWE (2015). Uganda Climate Smart-Agriculture Country Program 2015-2025. Kampala. https://hdl.handle.net/10568/76225. Accessed on 13th November 2019

Maisiri N. Senzanje A. Rockstrom J. & Twomlow S. J. (2005). On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system.

Mintz E. D. Reiff, F. M. & Tauxe, R. V. (1995). Safe Water Treatment and Storage in the home: *a practical new strategy to prevent waterborne disease*. *Jama*, *273*(12), 948-953.

Mubiru D. N. Radeny M. Kyazze F. B. Zziwa, A. Lwasa J. Kinyangi J. & Mungai C. (2018). Climate trends, risks and coping strategies in smallholder farming systems in Uganda. In *Climate Risk Management 22 (2018) 4–21.*

https://www.sciencedirect.com/science/article/pii/S2212096316300821. Accessed on 8th August 2019

Mugerwa S. Kayiwa S. & Egeru A. (2012). *Status of Livestock Water Sources in Karamoja Sub-Region, Uganda.* http://article.sapub.org/10.5923.j.re.20140401.07.html. Accessed on 8th August 2019

Musoke R. (2018). Uganda: Maize Everywhere, but No Store Anywhere. https://allafrica.com/stories/201802210142.html Accessed on 9th august 2019

MWE (2013). Ministry of Water and Environment. Climate Change Policy. Costed Implementation strategy for the National Climate Change Policy. Kampala.

MWE (2013). Ministry of Water and Environment. Framework And Guidelines For Water Source Protection *Volume 1: Framework for* Water *Source Protection.* https://www.mwe.go.ug/sites/default/files/library/Vol.%201%20-%20Framework%20for%20Water%20Source%20Protection%20FINAL.pdf. Accessed on 22nd July 2019

MWE (2013). Ministry of Water and Environment. Framework And Guidelines For Water Source Protection *Volume 4: Guidelines for Protecting Water Sources for Multipurpose Reservoirs.* https://www.mwe.go.ug/sites/default/files/library/Vol.%204%20-%20Guidelines%20for%20Protecting%20Multipurpose%20Reservoirs%20-%20FINAL.pdf. Accessed on 22nd July 2019

MWE (2014). Ministry of Water and Environment. Guidelines for integration of Climate Change in Sector plans and budgets. Kampala. http://ccd.go.ug/wp-content/uploads/2018/04/National-Climate-Change-Mainstreaming-Guidelines-.pdf. Accessed on 22nd July 2019

MWE (2016). Ministry of Water and Environment. Uganda State of Forest Report. Kampala. http://www.mwe.go.ug/sites/default/files/State%20of%20Uganda%27s%20Forestry-2015.pdf. Accessed on 23rd August 2019

MWE (2016). Ministry of Water and Environment. Forestry Landscape Restoration Opportunity Assessment for Uganda. Kampala. https://portals.iucn.org/library/sites/library/files/documents/2016-076.pdf. Accessed on 23rd August 2019

MWE (2017). Ministry of Water and Environment. National Reducing Emissions from Deforestation and Forest Degradation (REDD) + strategy for Uganda. Kampala. https://www.mwe.go.ug/sites/default/files/Uganda%20National%20REDD%2B%20Strategy_0.pdf. Accessed on 23rd August 2019

MWE (2017). Ministry of Water and Environment. Uganda National Report, Water Supply Atlas. https://www.mwe.go.ug/sites/default/files/library/Atlas%202017_1_Introduction.pdf. Accessed on 12th November 2019

MWE (2018). Ministry of Water and Environment Water and Environment Sector Performance Report 2018. https://www.mwe.go.ug/sites/default/files/library/SPR%202018%20%20FINAL_0.pdf. Accessed on 17th July 2019

MWE Brief (undated). Ministry of Water and Environment Brief on The Climate Resilient Institutional and Public Sanitation Project. https://www.mwe.go.ug/sites/default/files/library/BRIEF%20ON%20THE%20CLIMATE%20RESILEINT%20%20INSTITUTIONAL%20AND%20PUBLIC%20SANITATION%20PROJECT.pdf Accessed on 22nd November 2019

MWLE (2001). Ministry of Water, Lands and Environment. National Forestry Policy, (2001).

Maxmen A. (2013). Crop pests: under attack. *Nature, 501*(7468), S15.

Nabwiiso S. (2018). Uganda Confirms National Agriculture Insurance Scheme To Start Next Year. https://www.busiweek.com/uganda-confirms-national-agriculture-insurance/. Accessed on 8th November 2019

NFA, (2014). National Forestry Authority. Project proposal for promoting community-led commercial bamboo farming and sustainable management of naturally occurring bamboo in Uganda. Kampala.

Namirembe S. Nzyoka J. M and Gathenya J. M. (2015). A guide for selecting the right soil and water conservation practices for small holder farming in Africa. http://old.worldagroforestry.org/downloads/Publications/PDFS/TM17511.pdf. Accessed on 12th November 2019

NAPA (National Adaptation Program of Action) (2007). National Adaptation Program of Action on Climate Change in Uganda.

http://www.preventionweb.net/english/policies/v.php?id=8578&cid=180. Accessed on 22nd August 2019

National Adaptation Plan for Agriculture MAAIF (2018). National Adaptation Plan for Agricultural Sector. November 2018.https://www.agriculture.go.ug/wp-content/uploads/2019/09/National-Adaptation-Plan-for-the-Agriculture-Sector-1.pdf. accessed on 12th November 2019

National Population Council (2018). State of Uganda Population Report. Kampala. http://npcsec.go.ug/wp-content/uploads/2013/06/SUPRE-2018-.pdf. Accessed on 22nd August 2019

NCCP (National Climate Change Policy) MWE (2015). Ministry of Water and Environment. National Climate Change Policy. Kampala.

NDC (Nationally Determined Contribution) MWE (2016). Uganda's Nationally Determined Contribution https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Uganda%20First/INDC%20Uganda%20final%20%2014%20October%20%202015.pdf. Accessed on 20th September 2019

Neufeldt, H. (2015). Forestry Technologies for adaptation and mitigation of climate change. World Agroforestry Centre. Nairobi.

Newcome L. R. (2004). Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles; *American Institute of Aeronautics and Astronautics, Inc.: Reston, VA, USA.*

Niang I. Ruppel O. C. Abdrabo M. A. Essel A. Lennard C. Padgham J. & Urquhart P. (2017). Climate change 2014: impacts, adaptation, and vulnerability. *Part B: regional aspects.*

NFSS (2018). National Forest Stewardship Standard for the Republic of Uganda. Kampala. https://www.mwe.go.ug/sites/default/files/National%20FSC%20Forest%20Standard_Uganda.pdf. Accessed on 10th November 2019.

NPA (2017). National Planning Authority. Uganda's green Growth Development Strategy, 2017/18-2030/2031. National Planning Authority, Kampala. http://npa.ug/wp-content/uploads/2017/11/Uganda-GGDS-FINAL.pdf. Accessed on 10th August 2019

NPA (National Planning Authority) (2007). Uganda Vision 2040. National Planning Authority. Kampala. http://npa.go.ug/wp-content/themes/npatheme/documents/vision2040.pdf. Accessed on 10th August 2019

NPA (National Planning Authority) (2015). The Second National Development Plan. National Planning Authority. Kampala. http://npa.ug/wp-content/uploads/NDPII-Final.pdf. Accessed on 10th August 2019

O'Reilly C. M. Alin S. R. Plisnier P. D. Cohen A. S. & McKee B. A. (2003). Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. *Nature, 424(6950), 766.*

Orikiriza L.J.B Agaba H Eilu G Kabasa J. D. Worbes M. Hüttermann A (2013). Effects of Hydrogels on Tree Seedling Performance in Temperate Soils before and after Water Stress. *J. Environ. Protect. 4: 713-721*

Orindi, V. A., & Eriksen, S. (2005). Mainstreaming adaptation to climate change in the development process in Uganda.

Pimentel, D. 1986. Status of integrated pest management. In: Pimentel, D. *Some aspects of integrated pest management*. Department of Entomology, Cornell University, Ithaca, NY.

Republic of Uganda (2010). The National Policy for Disaster Preparedness, 2010. https://www.ifrc.org/docs/IDRL/Disaster%20Policy%20for%20Uganda.pdf Accessed on 12th November 2019

Republic of Uganda (2017). Climate Change Bill, 2017. https://www.pelumuganda.org/download/2018-the-draft-national-climate-change-bill-emerging-issues-recommendations-for-integration-into-the-proposed-law/. Accessed on 12th November 2019

Seleshi Y. (2003). *Community based small scale irrigation types and importance in poverty alleviation.*http://www.iwmi.cgiar.org/assessment/files/pdf/publications/WorkshopPapers/SSI_YILMA%20Sileshi_Presentations.pdf. Accessed on 8th November 2019

SNC (Second National Communication) (2014). Uganda Second National Communication to the United Nations Framweork Convention for Climate Change. https://unfccc.int/resource/docs/natc/uganc2.pdf. Accessed on 1st october 2019

Souchon Y. & Tissot L. (2012). Synthesis of thermal tolerances of the common freshwater fish species in large Western Europe rivers. *Knowledge and Management of Aquatic Ecosystems, (405), 03.*

Swinton S. M. & Lowenberg-Deboer J. (2001, June). Global adoption of precision agriculture technologies: Who, when and why. In *Proceedings of the 3rd European Conference on Precision Agriculture* (pp. 557-562). Citeseer.

Tshernyshev W. B. (1995). Ecological pest management (EPM): general approaches. *Journal of applied entomology*, *119*(1-5), 379-381.

UBOS and MAAIF. (2011). Uganda Census of Agriculture (UCA) 2008/09 at a Glance. https://www.ubos.org/wp-content/uploads/publications/03_2018UCAGlance.pdf. Accessed on 16th July 2019

UBOS (2018). Uganda Demographic Health Survey. https://www.ubos.org/wp-content/uploads/publications/07_2018UDHS_2016_FInal.pdf. Accessed on 19th July 2019

UBOS (2018). 2018 Statistical Abstract. *Uganda Bureau of Statistics.* https://www.ubos.org/wp-content/uploads/publications/05_2019STATISTICAL_ABSTRACT_2018.pdf. Accessed on 25th July 2019

Uganda Strategic Programme for Climate Resilience 2017. http://ccd.go.ug/wp-content/uploads/2019/10/Uganda-Strategic-Programme-for-Climate-Resilience_May_2017.pdf

UNEP (2016) Adapting to Climate Change in Lake Victoria Basin-- Burundi, Kenya, Rwanda, Tanzania and Uganda. https://www.adaptation-fund.org/wp-content/uploads/2015/08/UNEP_Burundi_Kenya_Rwanda_Tanzania_Uganda_proposal_combined.pdf. Accessed on 8th November 2019

UNFCCC (2008). Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007. https://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf. Accessed on 11th October 2019

United Nations (1992). United Nations Framework Convention on Climate Change (UNFCCC). *Article 4-Committments. FCCC/INFORMAL/84 GE. 05-62220 (E) 200705.* https://unfccc.int/resource/docs/convkp/conveng.pdf. Accessed on 13th November 2019

UNMA Act (2012). Uganda National Meteorological Authority Act. Parliament of Uganda. Kampala. http://extwprlegs1.fao.org/docs/pdf/uga158640.pdf. Accessed on 12th October 2019

USAID (2013). Uganda Climate Change Vulnerability Assessment Report. https://www.climatelinks.org/sites/default/files/asset/document/ARCC-Uganda%2520VA-Report.pdf. Accessed on 6th August 2019

Wanyama J. Ssegane H. Kisekka I. Komakech A. J. Banadda, N. Zziwa, A. and Mucunguzi D. B. (2017). Irrigation development in Uganda: constraints, lessons learned, and future perspectives. *Journal of Irrigation and Drainage Engineering*, *143*(5), 04017003

WHO and INHWTS. (2011). National Household Water Treatment and Safe Storage Strategies and Integrated Household Environmental Health Interventions. http://www.health.go.ug/MoH/docs/Environmental_Health_Report.pdf. Accessed on 23rd June 2019

WHO (2013). Household Water Treatment and Safe Storage Manual for Participant. http://www.wpro.who.int/environmental_health/documents/docs/Household_Water_Treatment_Safe_Storage_PARTICIPANT.pdf. Accessed on 23rd June 2019

Wobusobozi N. Pieter R. & Herbert N. (1995). Suatainability of Water and Sanitation Systems: *The gravity flow schemes programme in Uganda*. In E Rural Water Supply and Sanitation. Kampala. https://wedc-knowledge.lboro.ac.uk/resources/conference/21/Wobusobo.pdf. Accessed on 9th August 2019

World bank (2010), Uganda Shows Way on Scaling up Carbon Mitigation. *Press release on 26th July 2010, Press release No. 2011/038/AFR*. https://www.worldbank.org/en/news/press-release/2010/07/26/uganda-shows-way-on-scaling-up-carbon-mitigation. Accessed on 22nd November 2019

World Bank (2016). Uganda Poverty Assessment 2016: Fact Sheet. https://www.worldbank.org/en/country/uganda/brief/uganda-poverty-assessment-2016-fact-sheet. Accessed on 31st July 2019

World Bank. (2018). Closing the Potential-Performance Divide in Ugandan Agriculture*: Fact Sheet.* https://www.worldbank.org/en/country/uganda/publication/closing-the-potential-performance-divide-in-ugandan-agriculture-fact-sheet. Accessed on 19th June 2019World Bank Group. (2018). Residential Piped Water in Uganda. http://documents.worldbank.org/curated/en/753451545258513387/pdf/133114-PUB-PUBLIC-9781464807084.pdf. Accessed on 6th August 2019.Yandav, Y. (2014). Farming-Forestry-Livestock-Linkages: A Component of Mountain Farmers' Strategies (Nepal). Sustainable Mountain Agriculture, Volume 1. DOI: 10.3362/9781780443546.00. Accessed on 18th November 2019.

ANNEX I: TECHNOLOGY FACTSHEETS FOR WATER, AGRICULTURE AND FORESTRY SECTORS

a. WATER SECTOR TECHNOLOGY FACTSHEETS

1. Rooftop Rainwater Harvesting	
Introduction	Rainwater is relatively safe and most economical source of drinking water available in most rural areas. From a survey in Kabarole, rural mean daily water consumption is about 10 litres per capita. Rooftop RWH through roof catchments is being promoted by the water sector in UG because it is affordable and manageable by communities especially in water stressed areas both at household and institutional levels. Average rainfall 500-1200mm in Uganda
Institution and organizational requirements	Ministry of Water and Environment through National Water and Sewerage Corporations is key in upscaling RWH-a revolving fund approach mentioned in the W&E SPR2015/16. The rural water department strategy on improving water supply to the water-stressed areas needs be operationalized. Ministry of Local Government, district and municipal leaders, City Council Authorities (KCCA) would play a key role. Ministry of Agriculture and Animal Industry and Fisheries is a key beneficiary of RWH. More than 800 RWH water sources were established by CSOs in 2016. Private sector and development partners are also major players.
Size of beneficiaries	Mainly low-income communities. Access to clean water is 65% in rural areas, 75% in urban areas. Each RWH tank of 10m3 serves 6 persons/y.
Operation and maintenance	Key activities are promotion, sensitization, advocacy training, tank distribution, maintenance. Rain water harvesting systems are easy to operate and involve low cost. Maintenance includes cleaning the tank and inspection of the gutters, pipes, taps and other conveyance systems. Cleaning should take place before the start of each major rainfall season with regular inspections. MOH recommends a cement mortar jar that has a lid on the top to prevent contamination; a tap for easy access to water; and a drainage plug for easy cleaning.
Advantages	● Affordable: Easy to install and operate. ● Long life span of over 10 years ● Enhanced water security ● Reduction in the time spent carrying water from point sources ● Increase in household water consumption wherever it was previously constrained by the effort of collection. ● The quality of the collected water is usually quite high although it drops following the arrival of the first rains after a dry season due to dust on roofs.
Disadvantages	● Water-related insect vector disease e.g. mosquito breeding may increase. ● Expensive storage systems, not affordable for many households

	● Depending on seasons may not provide sufficient water ● Overflows during times of abundance ● interlocking block tank design requires more skill levels than exists in rural Uganda. ● Doesn't apply to some roofing systems
Capital costs	
Cost of implementing adaptation options	Roof water harvesting system comprises a roof, a storage tank and a means such as guttering of connecting the one to the other. Other possible components are filters or 'first-flush' diverters In the Sector Investment Plan rainwater harvesting is costed at UGX 2.09 bn countrywide. In Uganda, the cost of a rainwater tank constructed from burnt bricks or concrete blocks isUS$ 0.06 per litre followed by corrugated iron sheets at US$0.08 per litre, then pot jars at US$ 0.10 per litre; the most expensive being PVC tanks at US$ 0.27 per litre. Per litre tanks costs are UGX 76 for Tarpaulin tank, UGX 110 for Ferrocement tank, 150 UGX for corrugated iron tank, UGX 161 for mortar jar, UGX 173 for ISSB, UGX 322 for crest tank, UGX 400 for Polyfibre Tank and 451 UGX when using burnt bricks. Plastic is slightly cheaper Guttering accounts for about 25% of the total system cost
Additional cost to implement extra unit	Convenient first flush device must be integrated. Roughly the first flush to be may be taken to be 2 mm rainfall and the volume is obtained by multiplying this by the area of the roof. 2. Storage must be tightly lidded and all entry points must be closed by a mesh to prevent entry of mosquitoes and eggs. 3. It is preferable to allow the water to stand for some time before drawing. The bacterial count is more at the bottom. Some rapid testing methods like H2S test methods are useful in the field for indicating presence of biological contamination. The safest methods of treatment are exposure to UV & boiling
Development impacts, indirect benefits	
Economic benefits	● Investment; manufacturing the parts needed e.g. gutters, pipes, pumps, taps, dam sheets etc. ● Savings are made on money spent by the government in supplying food during prolonged droughts and in alternative water infrastructures installation for remote areas. ● Reduced cost - watering the garden, clean the car or flush it down the toilet
Social benefits	● Households and small-scale farmers are able to not only feed their families better, but also earn extra income from selling their produce at local markets. ● Improved health from accessing clean water, improved hygiene ● Ownership of the technology, therefore sustainability. • Children and women saved from collection of water in slippery sloping areas. Saved time can be put to other productive use.

	• Improved agriculture production when water is used for livestock and irrigation of vegetable gardens leading to better nutrition • Community organizations to manage water sources and share knowledge • Reduced conflict • Exclusive water source. Not shared with animals
Environmental benefits	• Eliminates the need for the energy and chemicals used to produce pure drinking water • Reduces need for pumping of mains water, and the energy use, pollution and CO2 emissions that go with it • Reduces demand on rivers and groundwater • Using water to wash cloths reduces the amount of detergent used and reduces water pollution from these compounds • Large-scale collection of rainwater can reduce run-off and therefore the risk of flooding
Local context	
Opportunities	• There exist two separate intensive rainfall seasons/year countrywide which make rain water harvesting optimum • Rainwater harvesting is one of the key priority areas in Uganda's second communication to UNFCC and NDP. • 62% of households in ug have iron roofs and are potential beneficiaries (UNBS, 2009/10). • Opportunity is created for micro-enterprises to manufacture and supply of water storage tanks. • Communal water harvesting is feasible
Barriers	• Initial costs can be prohibitive for low income families. • Use of Grass thatched houses • Rural farmers experience financial challenges to build the tanks • Technical challenges to build the related harvesting infrastructure • If they are poorly constructed, the tanks can suffer from algae growth and pest invasion. • May involve high initial investments and/or labour requirements for maintenance • Tax has been put on these tanks • Plastic tanks aren't durable. Ferro cement tanks are recommended
Market potential	Rainwater harvesting systems can be applied from small to large scales. With an average of 80 inches of rainfall

	a year, Uganda is an ideal location for rainwater harvesting as a primary source of clean water. RWH can be optimally used as means to alleviate the shortage in water supply in water scarce areas. Companies are installing low-cost water tanks in Uganda for example HYT thus employment creation. Rural water department has constructed over 1000 rainwater harvesting tanks in Bududa, katakwi, apac, kwania. 20,000-30000litres. Trained women in constructing the tanks
National status of the technology	1% of the population is served by rainwater tanks (public tap-28%, protected springs-47%, shallow wells-14%, deep boreholes-10%)
Timeframe	Short term: 3 years or less. Begin immediately if resources are available.
Acceptability to local stakeholders	Technology well known and accepted by population. It is an optimal technology, affordable and manageable by the low-income community members both at household and institutional levels, for improving access to safe water

2. Deep well water extraction in the dry season	
Introduction	Deep well water extraction involves digging and drawing water from underground using containers or pumping it through sunk pipes. Ground water is used to meet domestic water (and livestock) needs especially for rural communities. Borehole is the most common approach for deep well water extraction. Borehole coverage is still not sufficient yet established ones keep breaking down and getting abandoned for various reasons. Existing boreholes are described in the NDPII as overstretched with too many users where piped water access has not reached. Frequent droughts have resulted in lowering of the water table in dryland areas e.g. the cattle corridor, leading to drying of boreholes. (NAPA). New technical skills are needed of drilling for deeper intrusion into the ground in order to extract water more efficiency. A deep well consists of a vertical bore hole with a diameter of 100 to 600 mm, within which an extraction pipe is placed that has a perforated section (filter) and sand trap, surrounded by filter gravel. The depth of the deep well depends on the required filter surface and the ground-water level, and takes ground-water sinking into account. With a longer and deeper filter, the drainage volume will increase. The rising pipe and the filter are mainly made of high-density polythene or PVC. The filtering material is determined by the soil texture. Where electricity is available an underwater pump can be used to bring the water to a height at which it can be drained using a discharge pipe. Water can also be extracted using a vacuum pump at ground level. The diameter of the bore hole and the filter are determined by the diameter of the pump, which is in-turn dependent of the

	desired extraction volume. In Uganda, most boreholes are in rural areas and are hand-pumped. About 9 000 boreholes, typically drilled to a depth of 60 to 90 meters, are equipped with hand pumps. Useful life of deep-well piston hand pump is 6−12 years. Yielding is 0.25−0.36 liters/ s at 25 meters and 0.18−0.28 liters/s at 45 meters depth.
Institution and organizational requirements	Mandated government institutions are MWE, NWSC, and Local governments International development partners, NGOs, and the private sector also contribute.
Size of beneficiaries	Community level beneficiaries including villages, schools, health centers and markets
Operation and maintenance	Preventive maintenance normally includes checking that the pump is functioning, such as cleaning the pump and pump site daily. Every week the pump should be greased and once a month all parts of the pump stand should be checked. Small repairs consist of replacing bearings, seals and washers and straightening bent pumping rods. Once a year, the entire pump should be dissembled for a check, the parts cleaned with clean water and the pump stand repaired by concrete. Corroded pump rods have to be replaced. A galvanized steel pump rod needs to be replaced every five or six years under normal conditions. Riser pipes made of galvanized iron should be removed and checked. Major repairs include replacing the piston, foot valve, cylinder, pump rods, rising main, and pump handle.
Advantages	• It is often most practical and economical to obtain and distribute; the water-bearing stratum from which it is drawn usually provides a natural storage at the point of intake. • Low per capita cost • Water contamination is relatively low compared to surface runoff • Creates employment opportunities for the locals • Cost effective, self-sufficient asset and a long-term investment: as a long -term asset it can last at least 10 to 15 years. • Deep-water extraction represents an uninterrupted supply of water without relying on the municipal supply.
Disadvantages	• Energy costs for pumping water to the surface • Ground water is often high in mineral content and may contain contaminants that make it unsuitable for direct domestic consumption without purification. • Engineering works are expensive • Possible long-term degradation of water quality from possible saline intrusion • Possible lowering of the water table

Capital costs	
Cost of implementing adaptation options	Costs are mainly on experts, labor and material such as extraction pipe, filtering material, pump, discharge pipe, level indicator, and clay pellets/bentonite.
Development impacts, indirect benefits	
Economic benefits	• Helps avoid interruption of significant socioeconomic activities during dry periods, for example when used for irrigation. • Increasing income generation through the sale of high value crops, good quality dairy products from healthy livestock, diversification of income generating options such as bee keeping (which is successful where there's water and plants).
Social benefits	• Increasing access to water in dry periods. • Reducing negative impacts on public health, preventing epidemic diseases e.g. diarrhea. • Reducing risks women and children face when they have to walk long distances to fetch water • Convenient source of water for institutions with concentrated populations such as schools, hospitals, prisons etc. • Availability of irrigation water has improved food security • Supplying fresh water, adding to the deficit in water balance in dry periods. • Reducing negative impacts on public health, preventing epidemic diseases. • Reducing the burden and time commitment that women spend hauling water, allowing them to participate in other income-generating activities. • Local people settle in their camps for longer, allowing for decisions that require consistency such as education for children. • Stable access to potable drinking water. On the downside, it takes rainwater and surface water longer to replenish a deeper well. When a deep well goes dry, it tends to stay dry for several months.
Environmental benefits	• Relieves pressures on surface water sources as there is growing population • Reduces risks of pollution and degradation. • Drought resistance. • Reintroduction of some trees and plants. Fosters agricultural diversification.

Local context	
Opportunities	• Borehole wells are key in Uganda's push for rural water access • Ministry of Water and Environment (Conditional grant utilization agreement for financial year) 2018-2019 • The Republic of Uganda Ministry of Water and Environment Assessment of Groundwater Investigations and Borehole Drilling Capacity in Uganda • The republic of Uganda ministry of water and environment National water and sewerage corporation consultancy services for design review and construction supervision of Mbale water Supply and Sanitation Project July 2018
Barriers	• Lack of hydro-geological data. • Arsenic and fluoride contamination in deep wells. • Low community awareness on sanitation. • Maintenance of the Boreholes requires technical capacity which is not easily available. • Requires pumping and associated energy supply (and costs) for larger volumes, though solar water pumps are becoming increasingly viable • Requires knowledge of local geological conditions and assessments of chosen drilling sites • Poorly coordinated well development can cause and create risk of over-abstraction leading to a lowering of groundwater table • In areas with high climate variability (floods and droughts), tube wells and boreholes are at risk of being contaminated during flood events.
Market potential	High potential in rural areas, where there is no centralized water supply system. Appropriate in dry areas or constantly flooded areas. In Uganda, the government depends on contractor-constructed boreholes which in turn provide employment opportunities for Borehole drilling/construction companies. (They contracted under the 'turnkey contracts') • Selling of water to communities • Private companies benefiting from selling pumps
National status of the technology	Total water withdrawal of the country increased from 300 million m^3 in 2002 to 637 million m^3 in 2008 (Republic of Uganda, 2010).Deep well water extraction has been popular for daily life in rural areas and significant amount of work on development of water and sanitation in Uganda has so-far been done however a lot still needs to be done in this sector so as to consolidate the gains that have been already registered.

Timeframe	No information found
Acceptability to local stakeholders	One borehole has the capacity to supply between (1200 Ltrs to 2000 Ltrs) of water per-hour, implying; (100 families) can be able to each have access to (120 Ltrs) of water daily from a single borehole during the 12 hours in a day. This therefore means that if each village in Uganda requires 2 well maintained / rehabilitated boreholes.

3. Household water treatment and safe storage	
Introduction	Access to safe water for drinking and domestic use in sufficient quantity for rural and urban households as well as schools and hospitals is a key development objective. Vulnerable areas to unsafe water include northern and eastern districts with low access to water; urban and rural areas where frequent flooding occurs; valleys of mountainous areas where landslides are frequent, areas with low latrine coverage; and refugee settlements and host communities in Arua, Adjumani, Ntoroko, Yumbe, Kiryandongo, Lamwo, Kyegegwa, and Moyo. MWE carried out water quality assessments on rural and urban water sources and found that 60-87% and 64% of the improved water sources in the urban and rural areas respectively, complied with the national standards for drinking water with respect to E. coli. HWTS could potentially be an effective emergency response intervention in case of floods and other natural disasters, epidemic outbreaks caused by cholera. The government ensures availability of water sources for drinking and domestic use. It also regulates rates of abstraction and controls and ensures the treatment of the discharge of substances that may have adverse impact on water sources. Interventions include understanding the risks and regulation of harmful behaviors on waste disposal and open defecation and management of waste and sewage. Activities include: • Developing and enforcing policies for ensuring water safety standards and HWTS. • Assisting, regulating, coordinating, monitoring and evaluating the efforts of all those involved in HWTS. • Developing a water supply, sanitation and hygiene water master plan for at least every district. • Evaluating water sources, regular testing of water quality. Supporting local universities and research institutions in conducting research on innovative HWTS solutions for local populations. • Building capacity to support the successful implementation of safe and effective HWTS options at the national, regional, district and local levels. • Awareness creation to change behavior of communities (e.g. waste disposal, hand washing and open

	defecation), industries, farms, and institutions such as hospitals. • Using engineering, policy and capacity building approaches in ensuring high standards of water safety for drinking and domestic use. Construct, repair and maintain existing water sources. • Constructing and maintaining engineering works to divert waste away and avoid contamination of water sources. Protecting and conserving natural resources including wetlands and forests to minimize soil erosion and improve water purification.
Institution and organizational requirements	Ministry of water and environment, Directorate of Water, District Local Governments, Municipal Councils, National Water and Sewerage Corporation; Civil Society Organizations e.g. the WASH Project including UNICEF, Uganda Red Cross, UNHCR Government has an essential role and significant responsibilities in optimizing the impact of household water treatment and safe storage (HWTS). Media organizations; Schools; Hospitals; Water officials and Extension officers.
Size of beneficiaries	According to the Water Supply Sector Performance Report in June 2010, the national safe water coverage for rural water supply was estimated at 65%, giving an average of 302 persons per improved water point across rural Uganda. In 2018, the number of boreholes was 40223, shallow wells 21567, protected springs 28908, tap stands 19885 and harvest tanks 20187. These serve a total of 27,425,472. The number of people without any improved water supplies at all is very high. The access of school pupils to clean drinking water is low with a pupil: stance ratio at only 71:1, well below the recommended national standard of 40:1 in schools.
Operation and maintenance	An overall masterplan is needed to make the interventions needed to ensure safe water for all. Programs should include creating demand for HWTS, Supplying the required HWTS products and services to meet the demand; and Monitoring and continuous improvement of programme implementation.
Advantages	• Minimizes the risk to human health from using water from the piped system • Household water treatment allows people to use a wide array of water sources that may be more convenient and accessible, even though they are of poor quality, such as rivers, ponds, streams and canals. • They are simple to operate and maintain and generally require only part-time stuff. • They are very effective at removing disease-causing organisms (pathogens) from wastewater. • Water Softening disinfects, removes iron and manganese, reduces tastes and odors, reduces total solids content, and removes radioactivity and reduces excessive soap use and scaling.
Disadvantages	• Odor can become a nuisance when water comes from anaerobic sources

	• Household water treatment techniques are not very effective at removing heavy metals from wastewater. • high costs for maintenance of pumps or treatment equipment due to high rate of wear and tear • Costly storage units and softening chemicals • The high pH associated with lime softening tends to form hypo chlorate as the dominant free chlorine residual, which is less powerful disinfectant than other free chlorine residuals. • The high pH may also increase tri halomethane levels in the water. • If the water is not properly stabilized after treatment, then corrosive water may be produced which will corrode the distribution system.
Capital costs	
Cost of implementing adaptation options	Latrine construction is about 48,816UGX per capita according to UNICEF expenses in the WASH project. Per capita cost for rural water supplies was UGX 246,663 (68 USD) in 2018. Average cost per beneficiary of the new water and sanitation scheme (USD) per capita in FY 2017/18 was USD 58. Water treatment costs include chlorine cost at $0.30 for a 500-mL bottle of 0.5% sodium hypochlorite solution, (Mukwano Industries, Kampala, Uganda). Water vessel cost $3.50 (Multiple Industries, Kampala, Uganda) including the 20-liter polyethylene vessel with a spigot.
Additional cost to implement extra unit	Unknown
Development impacts, indirect benefits	
Economic benefits	• When health-cost savings are included, implementing HWTS can actually result in net savings to the public sector. • HWTS can be a low-cost option for these households to provide safe drinking-water, even if they are using contaminated sources
Social benefits	• HWTS increases resilience to water quality degradation by enabling users to improve water quality at the point of use. • Reduce water borne disease such as diarrhea. • Removes chlorine resistant parasites that can be fatal to people living with AIDS • Children are protected from opportunistic infections
Environmental benefits	Strengthening environmental protection and sanitation to preserve unpolluted water and clean environment; Avoiding polluting water resources in order to protect ecosystems
Local context	

Opportunities	HWTS is prioritized in NAPA.
Barriers	• High cost • Ignorance about the appropriate water treatment required. • Low access to material to water treatment • Infrequent testing • Low coverage of laboratories for testing water and low access to information about water safety. • Poor enforcement of water safety standards • General poor access to water in water stressed regions.
Market potential	Improving quality, business efficiency and governance of water works
National status of the technology	The Uganda Water Supply Atlas of the MWE indicates that out of the 57,974 villages, only 66% (38,200) have valid safe water sources. Safe water coverage in the large towns stands at 77 % while piped sewerage is estimated at 6 %. The rest of the inhabitants rely on on-site sanitation facilities. Safe water coverage in the small towns has significantly increased from 55 percent to 60 percent. In urban areas, the number of NWSC domestic connections is 284,861, equivalent to 22% access to safely managed water. In small towns not supplied by NWSC access is estimated at 3%. This results in an overall value of 20% access to safely managed water in 2018. Government is to construct piped water supply systems in Rural Growth Centers (RGCs) to replace the currently overstretched hand-pumped borehole service technology.
Timeframe	Short term: approximately 3 years or less
Acceptability to local stakeholders	Awareness and education needed to overcome cultural barriers and aversion against historical methods of enforcing hygiene and sanitation. Government officials acknowledged that their work on HWTS is still at a very early stage; however, the concept is now being embraced by the government with plans to carry out research into appropriate technologies, and approaches to promotion, investment and uptake by users. Expansion of safe water storage capacity is not happening fast enough due to limited private sector players (investors and CSO).

4. Surface Runoff Water Harvesting	
Introduction	In order to offset the projected rainfall reduction and unpredictability that comes with climate change, farmers have to practice moisture conservation farming practices to sustain moisture in agricultural systems in drought-prone parts of Uganda. Surface runoff water harvesting is the collection, accumulation, treatment or purification, and storing of storm water for its eventual reuse for domestic water supply and irrigation of crops in the dry season. Micro-catchment rainwater harvesting systems are designed to collect runoff from a catchment area of 10–500 m^2, within the farm boundary. The runoff water is usually guided into a type of infiltration enhancement structure and used to irrigate plants. Commonly micro-catchment techniques include pitting, contouring, terracing, furrowing and micro-basins supplemented with mulching, reduced tillage. Macro-catchment rainwater harvesting systems collect runoff or river flow from large areas including manmade surfaces, such as roads, parks, gardens and playing fields into reservoirs. Earthen bunds or embankments are built from soil excavated from within the reservoir or bricks and cement to increase storage capacity and a spillway or weir allows controlled overflow when storage capacity is exceeded.
Institution and organizational requirements	Government Agencies (Ministry of Agriculture, Animal Industry and Fisheries; Ministry of Water and Environment; District Local Governments) and non-governmental organizations.
Size of beneficiaries	No information found
Operation and maintenance	• Construct dams or reservoirs or tanks • Convey water from dams to farm filed using pipes or canals or channels. The irrigation efficiency of micro dams can turn out to be low if water is lost during conveyance from the dams to individual fields. Simple drip-irrigation kits have been widely regarded as efficient. • Reduce the evaporation by constructing a thatch over the tank • Do not let water-plants grow in the tank as these will increase water loss through evapotranspiration • Fence around the tank for the security of children & domestic pets. • Still waters breed disease transmitting vectors, therefore fish which prey on mosquito larvae e.g. ‘Korali’- Oreochromis mossambicus should be introduced into the tank. • Clean water tank when empty by removing all soil deposits and other waste.

Advantages	• Designing and installing surface runoff collection systems can provide sustainable jobs for the economy of the future • surface water harvesting can provide an independent water source in areas where other water sources are unavailable • Increase the productivity of arable and grazing land by increasing the yields and by reducing the risk of crop failure • Harvesting techniques are relatively cheap to implement and can therefore be a viable alternative where irrigation water from other sources is not readily available or too costly.
Disadvantages	• Rain water is insufficient during below-average seasons. • The common traditional open rain water ponds have a short lifespan due to seepage (except for rock catchment dams) and evaporation. • There is loss of storage caused by siltation • Pollution problems due to the garbage collected from the running water leading to diseases if not properly treated • If water is stored on the surface there shall be loss of agricultural land • There is possible harm to fauna and flora adapted to running waters and wetlands. • Once the running water is directed poorly it can cause damage of property, farms • Water from general urban runoff carries a mix of pollutants, including untreated sewage, soil, fuel oils, industrial process chemicals and solid waste
Capital costs	
Cost of implementing adaptation options	Construction of storage tanks includes trenching; filling with sand and excavation materials; excavation, earth transportation to landfill, clearing and ground leveling with concrete. Materials include, cement, clay lime, polythene sheets Pipework, Valves, Stopcock, filters, pumps and electricity. A project budgeted for runoff harvesting at UGX 2,690,000 to cater for excavation and covering of ponds if they were to harvest 35,000 liters. Maintenance cost of cleaning the pond should also be considered.
Additional cost to implement extra unit	Uncertain
Development impacts, indirect benefits	
Economic Benefits	• Availability of additional water for irrigation will not compete with that for other uses. • This water can also contribute to productive and economic livelihood purposes.

	• Supplemental irrigation of rainfed agriculture reduces the risk of total crop failure and improves water and crop productivity and farm profitability.
Socio-Economic benefits	• Enables crop diversification hence improving household diets and food security. • Reduces the burden of fetching water from long distances.
Environmental benefits	• Reduced discharge of water into streams and other downstream water sources • Increased ground water recharge • Reduced soil erosion.
Local context	
Opportunities	Water conservation is of key importance for in land and water management in Uganda's major development strategies including the National Development Plan II 2015/16 to 2019/20, the Uganda Second National Communication UNFCCC 2014, Uganda's INDC 2015, the NAPA.
Barriers	• Possible conflicts over access the water sources. • Negative impacts on the environment and ecosystem in the downstream of the reservoir. • Risks of spreading epidemic for human and animals due to using the same public source of water. • Risks of drowning for humans, livestock and pets. • Difficulty in locating and determining the proper scale of reservoir or public's storage to meet the requirements. • High initial costs for construction and community mobilization, and costly maintenance • Requirement of by-laws to regulate water resource ownership and administration
National status of the technology	Government Agencies (Ministry of Agriculture, Animal Industry and Fisheries; Ministry of Water and Environment; District Local Governments) and non-government organizations have been involved in the construction of valley tanks and dams to provide year-round supplies of water for livestock as well as for domestic use. In the North East, organizations are piloting new technologies such as sand dams, subsurface dams and a number of earth dams. The particular geo-hydrological features of this area require robust technologies that are not affected by flash floods.
Timeframe	Medium term since it has already been initiated: 3-5 years
Acceptability to local stakeholders	Surface runoff is estimated to be 10 – 25 %. Farmers in the area (case study Soroti) are able to sustain their production and reduce the chances of crop failures through the use of small-scale affordable surface runoff irrigation schemes.

5. Construction of new and proper maintenance of existing dams and water reservoirs	
Introduction	Uganda is endowed with water bodies in form of rivers, lakes and wetlands yet irrigation is only 3% of potential and rainfed agriculture persists punctuated with seasonal failure and livestock death due to drought especially in northern and eastern districts. Each year at least 2000 heads of cattle die in Karamoja district and 3000 in Nakasongola district due to drought. Dams provide multiple benefits to the communities in Uganda by providing water for livestock, irrigation and fisheries. However, they are disproportionately located. Where they are concentrated, high livestock grazing intensity leads to rangeland degradation. Because of direct livestock watering, water quality in dams is generally poor due to high sediment loading from soil erosion caused by high grazing intensity and cutting of trees near the dam. Most dams are highly exposed leading to high evapotranspiration rates. Dams are sometimes vandalized due to lack of community consultation and engagement in forming sustainable local maintenance and operational management structures.
Institution and organisational requirements	Different aspects of reservoirs schemes are regulated by MWE Directorates, Water Management Zones, and District Local Government, NEMA oversees and coordinates various environmental concerns in the construction and operation of structures for WfP. Community based organisations, water users' associations.
Size of beneficiaries	No information found
Operation and maintenance	Live fencing helps to reduce silt and prevent livestock access. Desiltation; community capacity building, contouring; mapping of new dams; covering to reduce evapotranspiration; construction of troughs and pumping water to them through pipes; Rehabilitation and maintenance of existing dams needs to go hand in hand with construction of new ones. Needed actions include improved management of water dams, mapping of siting of new dams based on needs, vulnerability to water stress, strengthening of local institutions for water management and building community capacity in maintaining and managing dams. Monitoring and upkeep of dam functionality.
Advantages	• Eco-friendly and socially acceptable • Contributes to stabilizing ground water levels in adjacent land areas. • Allows upkeep of minimum flows during dry seasons which enable the preservation of many aquatic animals and plants during droughts. • Creates new and biologically desirable habitats and to irrigate wetland biotopes or wetland forests.

Disadvantages	• If water source development and maintenance is not carefully planned, there shall be over concentration of water sources in particular locations. In particular, considerate development should take action to carefully locate water sources • Constructing a dam is costly and needs skilled labor • One negative effect of dams is the fact that the artificial lakes created by dams become breeding grounds of disease. This holds true especially in tropical areas where mosquitoes, which are vectors for malaria, and snails, which are vectors for schistosomiasis, can take advantage of this slow flowing water • Dams contribute to changes of the earth's climate. Accordingly, it is because dams generate methane, a greenhouse gas. Methane is emitted from reservoirs that are stratified, in which the bottom layers are anoxic (i.e. they lack oxygen), leading to degradation of biomass through anaerobic processes.
Capital costs	
Cost of implementing adaptation options	The cost of a check dam is about $200-400 for a temporary structure and about $1,000 – 3,000 for a permanent structure depending upon the materials used, and the length and height of the obstruction desired. The government requires sh90b (insert USD equivalent) to build dams across the country annually (New Vision 2013)
Additional cost to implement extra unit	Unknown
Development impacts, indirect benefits	
Economic benefits	Income security due to high value agricultural production and agricultural diversification e.g. Water and trees attract bees.
Social benefits	• Reliable water supply for domestic, micro-irrigation and livestock • Reduction of water dependency risks • Increased community ownership • Improved human and livestock health. • Recharge to ground water, raising the levels of local wells used for domestic and agricultural purposes. • Food security- micro irrigation can be used to diversify crops and increase reliable food production.
Environmental benefits	• Increased water use for Agricultural sector • Wetlands rehabilitation • Increased biomass of herbaceous and woody plants in the area. • Land rehabilitation

Local context	
Opportunities	With about 43,942 km2 of wetlands and open water (18% of total area), Uganda is considered fairly well endowed with water resources. Water storage is a priority in Uganda's INDC 2015, the Framework and Guidelines for Water Source Protection. Water storage is a priority in Ministry of Water and Environment Oct 2015. Uganda's INDC Framework and Guidelines for Water Source Protection
Barriers	• There are two counter-intuitive dynamics that should be considered when expanding reservoirs: supply–demand cycles and reservoir effects. Supply–demand cycles describe instances where increasing water supply enables higher water demand, which can quickly offset the initial benefits of reservoirs. Reservoir effects refer to cases where over-reliance on reservoirs increases vulnerability, and therefore increases the potential damage caused by droughts. Reservoirs meant to alleviate the effects of droughts and water shortages can in fact make them even worse. This is often unexpected. • Lack of community involvement at the time of dam construction; decisions on the construction of the dams are taken by technocrats with minimal consultation with the local communities except for the dams (ponds) constructed near the homesteads. The communities thus perceive themselves as recipients.
Market potential	Water dams are constructed by private companies that provide employment. E.g Omega Contractors who built the dams in kotido, Zimwe Construction Company built dams at Moroto and Nakapiripirit districts, with Norconsult as their consultants.
National status of the technology	Data for 1,336 valley tanks, dams, small and medium scale Irrigation schemes constructed from 2000 - 2018 covered in WfP -Database – MWE. By the end of FY 2017/2018, the cumulative WfP storage was 39.32 million cubic meters**.** Construction works are ongoing for 14 Windmill powered water Supply Systems in Karamoja Sub-region, 9 Valley tanks in the Districts of Otuke, Apac and Katakwi and Mabira Dam in Mbarara District. 4 communal valley tanks in the Districts of Kiruhura, Gomba, Kyegegwa and Kiboga were completed. Small scale Irrigation schemes were established in the Districts of Bugiri, Soroti, Abim, Amuria, Kaabong, Napak, Oyam, Alebtong, Lira, Nwoya, Lwengo, Mbarara. A Regional Pastoral Livelihood Resilience Project implemented by the Ministry with support from IGAD started in 2018 and covers northern districts of Abim, Amuria, Amudat, Bukedea, Katakwi, Kotido, Kaabong, Kween, Kumi, Napak, Moroto and Nakapiripirit. It is estimated that the project will directly benefit 42,000 households in Uganda building dams, boreholes and water tanks for livestock. Rehabilitation of old dams is also ongoing e.g. Ongole, Namatata in Nakapiripirit district, Katabok in Abim district, Bigasha in Isingiro district, Mabira in Mbarara and Acanpii in Oyam district.

Timeframe	Medium term since work is already on-going: 3-5 years
Acceptability to local stakeholders	High Valley dams have strengthened the resilience of rural populations, cattle keepers and agricultural production systems and built the capacities of the communities and commercial farmers to cope with climate change. District leaders have asked the government to substitute the construction of small valley tanks at parish level with multipurpose dams because the valley tanks are said to easily dry up in the dry season e.g. in Karamoja Sub-region.

6. Channeling Network	
Introduction	Bulk water transfer programme aims to supply adequate amounts and quality of water all year round for multi-purpose use by conveying large quantities from places of plenty to places of scarcity. It includes channelling from rivers, lakes and reservoirs.
Institution and organisational requirements	Water for Production (WfP) is a department in Ministry of Water and Environment. Other key institutions include MAAIF, Ministry of Works, Ministry of Housing and Urban Development, and NEMA, NWSC, Local governments, and SLM.
Size of beneficiaries	Communities living in areas experiencing water stress due to seasonal drought. Urban dwellers and rural farmers will also benefit.
Operation and maintenance	Construction of a network of reservoirs and pipes/channels/canals to direct water where it is needed. This may involve long distances. It may include construction of water intake tanks, water treatment tanks, water storage tanks and piping network for distribution. The infrastructure needs to be protected from vandalism, pollution and diversion. Channels will need regular de-siltation to avoid backing up of volumes of water. Communities need to be educated on channel care. Regulations are required to govern channel operation. Electricity is required to pump uphill; downhill flow uses gravity. This program may require purchasing of land for the pipelines and protection of communities and property from risks associated with pipe or dam bursts. Fees may be needed to be collected from users to operate these networks
Advantages	• Improve agricultural productivity of the land • Improves crop productivity and profitability by increasing soil water availability over time • If water channeled from roads is stored in reservoirs or basins, it can be successfully used for supplementary irrigation, thus increasing productivity and lowering risks of crop failure related to dry spells; this also gives an advantage to farmers in the form of higher prices in times of drought

	• It reduces risks of livestock death related to prolonged drought • Reduces the risk of flooding • Allows farmers to grow water intensive crops and keep livestock in area that lack sufficient water • It enables reclamation of some drylands for crop production and livestock rearing.
Disadvantages	• Flooding may happen downstream through meandering sections instead, as flood water is carried there faster. • This strategy can be expensive and high-maintenance especially dredging. • Reduces water availability from source
Capital costs	
Cost of implementing adaptation options	Cost Scenarios; • Erecting huge water reservoirs at high peak rocky Sungira Hill located at the centre of Nakasongola is estimated to cost about UGX 50 billion. • Bulk water transfer for the towns of Kyotera, Kalisizo, Mutukula, Rakai & Lyantonde. UGX 40billion
Additional cost to implement extra unit	Water pipes, good infrastructural system, water pumps
Development impacts, indirect benefits	
Economic benefits	• Consistent income for farmers and increased tax base • Less yield losses from drought • Money saving, money generating
Social benefits	• Leads to improved infrastructure • Food, water and health security • Reduces the time women and children spend ferrying water from long distances.
Environmental benefits	Channelling can harm certain fish species and organisms by transferring them into other water basins. Furthermore, there is a concern that Bulk Water transfer can cause reduction in quality of existing water. Moreover, if it is not planned precisely and comprehensively then it can cause water drought.
Local context	
Opportunities	• Some experiences of bulk water transfer exist through NWSC supported by Danida, World bank, European union • Uganda has large water bodies that are currently underutilized.

	• Increasing supply of hydroelectric power • It can be integrated with road construction
Barriers	• Geographical restrictions • Complex transfer system • High investment costs • Uganda has technical capacity to build the water transfers • Lack or legislation to govern the water transfer • Lack of capacity of users to pay the necessary fees to operate and access the water • Availability of land to channel the water may be challenging. • Harmonizing water network infrastructure with transport and other existing infrastructure requires various sectors especially MAAIF, Ministry of Works, Ministry of Housing and Urban Development, and NEMA • A lack of relevant knowledge • It can transfer pollution that may be harmful to crops and livestock and reduce soil quality • If quality is not regularly tested, it can lead to leaching of nutrients and salinization.
Market potential	Currently NWSC is the institution that's involved with channeling of bulk water to areas in Uganda, most of the customers for this technology being households, institutions and industries. Employment for water pipe suppliers and makers.
National status of the technology	Bulk water transfer has been done by NWSC for urban centres. Water for production is yet to be developed. Bulk water transfer systems will be built to cover long distances and large areas to provide water for multi-purpose use. To mitigate shortages at local level large and medium water reservoirs will be developed II Final
Timeframe	No information found
Acceptability to local stakeholders	Districts with effects of prolonged drought have high demand for bulk water e.g Nakasongola

B. AGRICULTURE SECTOR TECHNOLOGY FACTSHEETS

1. Crop Breeding for climate change adaptation	
Introduction	Climate change is predicted to affect crop productivity mainly due to change in rainfall onset, intensity and distribution. This is likely to affect crops directly and also change the nature, intensity and distribution of crop and livestock pests and diseases. Crop biotechnology can be used for food security and climate adaptation by developing and promoting traits for high productivity, tolerance to floods and drought, resistance to pests and diseases, early maturation, and long shelf-life. Techniques include selecting and promoting varieties with desirable traits, plant cutting, tissue culture, applied breeding and genetics, gene isolation and genomics, genetic modification, phenomics; molecular mapping; molecular biology molecular markers. This requires a programmatic approach.
Institution and organisational requirements	Crop breeding is led by MAAIF the Crop resources department, National Agricultural Research Organization. (NARO) including Plant Genetic Resources Center National Agricultural Research Laboratories Kawanda, National Crops Resources Research Institute, Zonal Agricultural Research Development Institutes, and academia including Makerere University, and Kabanyoro Agricultural Research Institute. The process is supported by the National Agricultural Advisory Services; international support partners e.g. SASAKAWA Global 2000, International Center for Tropical Agriculture, FAO, Feed the Future; seed companies e.g. Victoria seed Limited, FICA Seeds Limited, Mt. Elgon seeds Limited; and NGOs e.g. PROLINNOVA Uganda
Size of beneficiaries	crop breeding is beneficial for areas where production is particularly difficult such as semi-arid or high altitudes places or isolated communities.
Operation and maintenance	In-situ improvement and management of crops: surveying and inventorying crop genetic resources; on-farm management and improvement of crop genetic resources; on-farm crop genetic resource restoration in case of disasters; in situ conservation and management of crop wild relatives. Ex-situ improvement and management of crops: targeted collecting of crop genetic resources; sustaining and expanding ex situ conservation of germplasm; regenerating and multiplying ex situ accessions Sustainable use: broaden the genetic resource base by promoting increased crop diversity, expanding characterization, evaluation, and further development of available genetic resources, crop breeding, genetic enhancement; seed production and distribution Building sustainable institutional and human capacities: Building and strengthening national programmes and networks for crop genetic resources including systems for information monitoring and safeguarding crop genetic resources; Building and strengthening human capacity; strengthening public awareness of crop genetic resources (Adapted from the Second Global Plan of Action for PGRFA, FAO

Advantages	• It enables faster growth rate of crops, • Crops have high tolerance of extreme weather • Increases resistance to pests and diseases • Genetic engineering enables creation of new products • Less infestation of land with weed seed/other crop seeds. • Less disease and insect problem. • The quality seed respond well to the applied fertilizers and nutrients. • Creates Uniformity in plant population and maturity. • Good seed prolongs life of a variety. • Yield prediction of genetically engineered crops is very easy. • Handling in post-harvest operation will be easy. • Preparations of finished products are also better
Disadvantages	• Crop breeding can be expensive and may take a long time. • The nutritional value and palatability maybe compromised • Lack of markets and cultural acceptance of new varieties. • Pathogens can adapt to the new genetic profiles. • The engineered organisms often dominate if realized into the wild, resulting in only a modified species over several generations, reducing the diversity that is available. • This knowledge and technology can be easily abused. • Improved varieties may create new management demands • Low human capacity to integrate improved varieties in existing farming systems. • Crop breeding tends to lead to skewed populations containing disproportionately more individuals of certain traits.
Capital costs	
Cost of implementing adaptation options	The resources required for this project are mainly to facilitate collaborative research- experts (plant breeders, plant physiologists, agronomists and plant biotechnologists) and disseminate findings to farmers.
Additional cost to implement extra unit	No information found
Development impacts, indirect benefits	

Economic benefits	• Increased food security from increased and stable productivity • Reduced investment in irrigation and inputs when well adapted crops are used. • Reduced risk in crop production • Increased nutritional variety • Reduced risk in crop production
Social benefits	• Stable income due to consistent and increased yield per hectare • Employment for seed companies • Resistant plants retard the growth and rate of reproduction of insect pest. • Increased fertilizer use efficiency (reduced cost of production)
Environmental benefits	• Environmentally friendly varieties: Improved varieties resistant to pests require fewer pesticides. • High-yielding varieties: Increase food production per unit area and alleviate pressure to add more arable land to production systems. • Reduced greenhouse gas emissions from agriculture by preventing further land conversion to agriculture and reducing the need for fertilizer
Local context	
Opportunities	Uganda has rich diversity of crops and a good landrace collection is maintained at Botanic gardens and the National Gene bank where over 5000 accessions are being conserved in both active (short term storage 5°C) and base (long term storage -20°C) collections. Uganda adopted the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture at the IV International Technical Conference on Plant Genetic Resources held in Leipzig, Germany, in 1996. The GPA is an action framework aimed at guiding countries in filling gaps, overcoming constraints and facing emergency situations in the field of PGRFA. Strengthening agricultural technology is mentioned as a key climate change adaptation strategy in Uganda's Second National Communication to the United Nations Framework Convention on Climate Change Oct 2014; NAPA and Uganda's INDC. Crop breeding is key in the National Development Plan II 2015/16 to 2019/20. Seeds and Plant Act 2006 is generally a good law which if effectively implemented, can go a long way in ensuring the sustainable availability of affordable quality seed.
Barriers	• High prices of seed due to high production costs. • Poor infrastructure, communication facilities, roads, storage facilities upcountry.

	• Institutional problems-being a government unit the USP is affected by government problems. • Lack of regular release of new varieties and more so hybrids. • Marketing problems- uncertainty of price stability for produce, changes in demands for produce from year to year. • Weak policies. it cannot guarantee the sustainable availability of adequate and affordable quality seed and planting materials. • Delay in enactment of the plants Act. The Seeds and Plant Regulations meant to fully operationalize the Act have never been passed and gazetted. • Government failure to establish and maintain regional seed banks that would aid in effective and efficient research from different region of the country thus a weak national genebank
Market potential	Plant genetic resources are bound to play a crucial role in addressing crop breeding for disease resistance brought about by dynamics of climate. There is high potential for genetic improvement of many neglected and underutilized crops so as to supplement most utilized crops in increasing food security as well as address the issues that would arise in crops due to climatic change.
National status of the technology	Scientists from National Agricultural Research Organization (NARO) have been breeding hybrid varieties of crops such as maize, cassava, rice, sweet potato, banana among others which farmers are growing countrywide. The products of these crops have not been released to farmers because of lack of legal framework which is a requirement in regulating the same. The Biotechnology and Bio-safety bill which was drafted by government in 2012 is still before parliament for debate. A Plant Genetics Resources Centre utilizes an online SESTO Genebank data management tool for public access of information on stored and conserved material. The Centre spearheaded the development of the National Information Sharing Mechanism of PGRFA in Uganda.
Timeframe	No information found
Acceptability to local stakeholders	Demand for improved varieties is high especially in drought-prone areas.

2. Crop Diversification and Precision Farming	
Introduction	Crop diversification ensures resilience against change. It conserves genetic diversity but must match agro-ecological conditions and at the same time address cultural and profitability concerns of farmers. Smallholder farms are diversified, often involving a number of plant and livestock species in a small land area. However, the number of crops that could potentially benefit farmers is very narrow and many species are left out for various reasons, market and cultural. Deliberate promotion of these neglected species requires understanding of their growth needs and their potential benefit to humanity. Precision farming can complement crop diversification by matching agricultural inputs and practices to the exact need of crops grown in specific ecological conditions. Fitting precision farming into smallholder systems will ensure increased production of crops and livestock while improving soil health and avoiding environmental shortfalls that accompany agricultural intensification. It requires understanding variability in the nature of crops and livestock and their changing demands over time as well as biophysical variability (soil conditions - physical, nutrient, moisture and organic matter content - weed characteristics, topography and weather. Agro-ecozones provide a coarse approach towards precision agriculture and can be scaled down by understanding intra-agro-ecozone variations. Precision farming uses sensors, GPS mapping tools, low-cost accessible satellite data, data-analytics software and robots. Modification of equipment/ machinery for fertilization, pesticide application and irrigation may be needed for small holders. The delivery of up-to-date, useful information is extremely crucial. Local technical knowledge can help by-pass the need for many of these very high-tech approaches. Consolidating farmer knowledge into a body that is accessible and transmittable to other farmers enables development of agility in responding to not only bio-physical, but climatic and social variations. All in all, precision farming (PF) can potentially reduce wastage of inputs but it requires education and knowledge, easy and timely availability of necessary inputs, supervision/ monitoring of progress
Institutional and Organizational Requirements	MAAIF will provide oversight and implement policies that enable diversification and precision farming. Inventorying and creating a database of the diversity of crop and livestock species available and their growth demands and potential benefits to humanity requires collecting and processing large amounts of data, broadly across large areas of land and also at the individual farm level. This can be spearheaded by NARO and academic institutions. Indigenous knowledge and satellite imagery and mapping are also crucial – this can be led by the national biomass department. The meteorological department will support the process by providing weather and climatic information and how this varies over space and time. The media can play a key role in delivering information and the extension staff through NAADS can provide technical support to farmers. Private

	companies are also key in ensuring timely accessibility of services and inputs.
Size of beneficiaries group	Precision farming will benefit farmers of high value crops and those with access to urban markets and large-scale farmers to begin with. Farmers in areas with limitations such as insufficient water and steep slopes will also benefit from precision farming. Some elements of the technology must be adopted as a general practice for optimum results and unit costs of certain precision farming techniques would significantly lower with widespread use by farmers. Also, some elements of the technology package- especially crop diversification - have a public-good nature requiring state patronage in its expansion.
Operation and maintenance	• Database of crops and livestock that are potentially of benefit to humanity and their growth needs, potential benefits and locations where they are most suited and their market potential. • Mapping including use of existing agro-ecozone characterization and breaking it further to get variation at parish/village and even farm level. Use of satellite, GPS and local knowledge. • Gathering and timely communication of climate and weather information • Developing comprehensive information and communication network including the media, mobile phones, local agricultural shows, and farmer group networks. Examples of phone apps for providing farmers with information include Wefarm which enables farmers to share information via text message, without the internet, Cowtribe used in Ghana for livestock farmers, AfriScout or the 'shepherd's eye in the sky' used in Kenya for pastoralists and a series of agricultural services apps by the Food and Agricultural Organization. • Pest, disease and weed surveillance • Engaging private sector in ensuring accessibility of farming inputs. Farmers will require subsidies and credit support to access inputs in a timely way. • Train extension workers to provide support
Advantages	• Increased yield and reduced wastage • Reduced vulnerability and improved resilience to climatic and other changes. • Relevance of agricultural production to local environmental and social conditions. • Improved understanding of spatial and temporal needs of crops and livestock. • Improved capacity to adjust and adapt farming practices to change. • It manages price risk, on the assumption that not all products will suffer low prices and at the same time improves nutrition diversity.
Disadvantages	• Initial investment cost can be high - in developed countries, precision farming uses the internet, robotics, big data, artificial intelligence and drones to improve yields.

	• The precision agriculture technology was initially developed for large-scale farms and it was aimed for reducing wastage of inputs. It will require some fiddling to fit it into diverse smallholder systems where inputs are scarce. • The approach is knowledge intensive requiring a functional extension system, educated farmers and a good system of transferring information. • Markets for increased yield may not be sufficient, demotivating farmers. • Increased time investment
Capital costs	
Cost to implement adaptation options	Cost to implement precision farming as a technology will be based on the following services; Soil scanning, Nutrient Samples, Variable Seed, Drone Flights, Yield Mapping, Weather/Soil Moisture Station, Software. Cost to implement crop diversification; Intensive research on quality seeds and appropriate fertilizers to be used, storage and post harvesting processing. Research development, Extension system, capacity building of farmers, acquisition of tools, technologies of relaying information in a timely manner
Additional costs to implement extra unit	Biotechnology and genetic engineering in crops, development of pesticides for emerging pest and diseases
Development impacts, indirect benefits	
Economic benefits	• Increases crop yield. • Quality and efficient use of farm inputs and labor. • Ensure productivity and food security. • Reduces financial risk. • Reduced cost of production. Application of exact quantities and at the right time reduces wastage.
Social benefits	• Minimized health problems from environmental pollution, resulting from indiscriminate agro- input use • Increased returns to resource use and improving the attractiveness of farming, particularly to youth, through adoption of high-tech methods. • reduced uncertainties in agriculture especially among smallholder farmers, increases resilience • It improves soil fertility, controls pests and diseases, and brings about yield stability, nutrition diversity, and health. • Diversified nutrition

	• Availability of safety-net crops and livestock that provide alternatives in case the others fail • Diversified products for marketing
Environmental benefits	• Prevents soil degradation in cultivable land. • Reduction of chemical use in crop production • Efficient use of water resources and other natural resources • Reduce GHG emission as demand driven fertilizer management systems emit low NOx and other gases • Soil and plant species can be automatically optimized through sensors taken from a Decision Support System • local biodiversity especially when farmers grow indigenous crop varieties. • Ecologically feasible
Local context	
Opportunities	Crop diversification is one of the agricultural strategies to implement national agenda highlighted in the documents in the Ministry of Water and Environment Oct 2015. Uganda's INDC Precision farming is implied in: 01 Production and Marketing FY 18-19 Guidelines 2018-19; The Republic of Uganda, OPM, Oct 2010; The National Policy for Disaster Preparedness and Management; NAPA; NAPA Implementation, Challenges and Emerging Lessons Project Report; National Development Plan II 2015/16 to 2019/20. Some NGOs have piloted precision farming so they can be learning points for scaling out across the country. Other countries have advanced well and a lot of this info can be adapted from somewhere else. Maps and satellite images are now easy to access Cheaper technology like drones, mobile phones have GPS too so mapping at farm level can be done quite cheaply.
Barriers	• Shortage of soil and water testing laboratories: there is only one such laboratory located in Mbale, which hinders precision agriculture. • Lack of a functional extension system to implement precision farming. They were replaced by NAADS. • Its knowledge intensive and demands mechanization. However, there are simpler ways of implementing precision farming. • Requires a high level of education for farmers, availability of technologies, purchasing power for inputs, enabling policy environment. • Poor access to information in real time • Compatibility of equipment. Precision farming requires use of large equipment which may not be

	compatible with our smallholder farms • Fragmentation of land holdings and lack of mechanization of agriculture due investment constraints and land holding sizes
Market potential	No information found
National status of the technology	Agro-ecological zones were mapped and available satellite information can be used to understand more detailed variation within; mobile phone coverage with GPS option is wide. Some technological advancements are needed in the area of precision farming especially consolidating local knowledge, ensuring timely access to inputs and information on weather, disease, pests and weeds. The extension system needs improvement. Farmers need to be networked to learn from one another. This work can build upon information from previous work by CTA working with the AGRA, EAFF and Mercy Corps has profiled farmers gauged their information needs, trained extension workers, and farmers to use the information and advice they receive.
Timeframe	3-4 years
Acceptability to local stakeholders	Local stakeholders are interested in producing more yield with less inputs and teaching them how to achieve this needs to be accompanied with the inputs themselves. Information needs to be provided in local dialects in ways that farmers can use. Farmers will need to have quick access to extension support if precision agriculture is to work. Crop diversification on the other hand, is within the cultural methods of farming. Its emphasis here is to counter the view that intensification involves monocrops

3. Community irrigation systems	
Introduction	The area equipped for irrigation is less than 3 per cent of the total potential irrigable area in Uganda estimated at 567,000 hectares. Therefore, by exploiting the irrigation potential, Uganda can be more food secure and export more agricultural products. Irrigable areas are divided into: category A for those near permanent water bodies like lakes and rivers, and category B for areas needing artificial valley tanks or dams. Community-based irrigation schemes are co-owned and managed by the community and cover an area of 200 ha or less. The infrastructure operations and maintenance plus water distribution are the sole responsibility of the community. The majority of community-based irrigation schemes started as informal irrigated areas located on the fringes of swamps and rivers. Labor for construction of these schemes is provided by farmers with financial support from the government and development partners. Workshops have been organized where the communities have been able learn about the equipment needed in irrigation such as pumps, pipes, sprinklers, channels and drip lines. Assumptions: Possibility of replicating coordination in the more organized communities. Communities are organized and have the technical capacity (or extension support) to operate an irrigation scheme. Equipment for irrigation is accessible. Land is available for reservoirs to collect water for irrigation. Policies support irrigation. Electricity/fuel (not effective why not solar) cost is available to pump water into gardens. Farmers, stakeholders, and private sector are involved in irrigation and drainage system development. Government subsidizes irrigation equipment, pumps, sprinklers, tanks… Water sources
Institution and organizational requirements	Local farmers need to be organized and trained in benefits of irrigation, how to construct and operate a community irrigation scheme. Water regulations and ordinances are needed to govern management and access to the irrigation scheme. Key institutions include MAAIF, MWE, department responsible for Agricultural Extension, Local Government, Civil Society Organizations and farmer organizations. The Irrigation and Drainage Section within the Division of Watershed Management in the Department of Farm Development (DFD) within MAAIF provides guidance

	and strategies on irrigation, water harvesting, water conservation and wetland management One of its functions is to provide technical guidance in popularizing farmer-managed smallholder irrigation systems; certified centers and technicians. Cooperatives, collaborative- partnerships of government and stakeholders (farmers groups and associations) refer to Kenyan farmers associations.
Size of beneficiaries	Less than 1 per cent of Ugandan farmers practice irrigation yet many more in the country's 127 districts would benefit from it (UBOS 2010).
Operation and maintenance	• Organizational activities - Community group agreement to develop a management plan for an irrigation system mapping out reservoir and piping/channeling system. The management plan is developed with technical extension support, which also advises on technical specifications of appropriate equipment. Communities fully participate in implementation, monitoring and evaluation of the plan. • Communication and conflict management; management committee, sharing costs, compliance with water regulations, avoiding causing harm to non-members. • Control-structural activities: design, and post-maintenances of the physical structures including reservoir, pipework, etc., regular servicing and repair of equipment, de-silting intakes, Sedimentation Basin, Water Conveyance system (piped or canal) slashing. • Water use activities (allocation and distribution) ensuring good distribution among members, avoiding wastage, contamination etc. • Local government production department should be mandated to monitor on the performance
Advantages	Mobilizes communities to co-invest in irrigation system. Reduces need for administrative expertise, therefore low operational cost These systems are more appropriate for smallholder farmers Increased, stable and diversified production all year-round production. Easy to replicate in other communities
Disadvantages	• High initial cost of irrigation project • Need for strong extension support and may not work where the extension support is weak. • Areas with potential for community irrigation are not delineated • Water needs of crops are not well known and in mixed cropping, the appropriate amount may be difficult to estimate. • Power imbalances in sharing of responsibilities

	• Poor enforcement of existing policies • Conflict amongst members and with non-members • Mis-use of the irrigation system • Weak local technical and institutional capacity to manage the scheme. • Insecurity of equipment
Capital costs	
Cost of implementing adaptation option	The average cost of irrigation development in equipped wetlands is estimated at between US$500 and 1 140/ha. The cost of irrigation development with open channel ranges from US$1 750 to 5 700/ha, while the cost of installation of pressurized irrigation is US$5 400/ha (MAAIF, 2011b). It costs UShs500.000 for a solar powered system which can deliver 20,000 litres of water per day and can irrigate an area of 10 to 15 acres depending on the water source. A coupled pump, which can pump 50 litres per minute (3,000 per hour) costs about Shs379,756 ($100) An imported Chinese version costs more than $360 (about Shs1,367,120). Pumping costs vary according to precipitation, crop water needs, size of the field, pumping lift, and energy price. solar pump brands; lorenzo, grundfos, nastec Piping is estimated at UGX 7M
Additional cost to implement extra unit	
Development impacts, indirect benefits	
Economic benefits	• Increased and stable production Crop diversification and value chain development for high value crops. Increased opportunities towards industrialization Employment and Increased and stable income
Social benefits	Better crop prices for poor farmers. Organized communities can market their produce collectively. Better land productivity. Food security and climate resilience. Time saving. Women and children don’t go to fetch water from long distances Promotes family cohesion. Men become more active participants in production.

Environmental benefits	• Reduced runoff and better ground water recharge. • Year-round ground cover. • minimizing soil erosion. • Diversification of crops and farming options in the farming landscape. • Reduction of water pollution. • Restoration and rehabilitation of degraded ecosystems. • Rehabilitation of degraded watersheds to sustain and enhance water catchment functions. • Improvements in farming practices and soil fertility management.
Local context	
Opportunities	• Irrigation is a key need cited in the 2010 National Policy for Disaster Preparedness and Management, the National Development Plan II 2015/16 to 2019/2020. • Enhances Uganda's commitment in meeting NDC obligations (adaptions)
Barriers	• Low returns from farming because of limited access to reliable marketing channels and unstable prices of agricultural commodities. • Inadequate access to water for irrigation: physical water scarcity in times when it is needed, and costs to abstract the water and deliver it to farms • Unfavorable land tenure systems and management make farmers avoid long-term investments on land. • Lack of coordinated master plan for development of an irrigation infrastructure. • Solar pumps are expensive • Counterfeits of equipment that can't serve for the time of installation
Market potential	Government support may be needed for poor farmers' access to this technology and to build their capacity to access markets.
National status of the technology	Currently, only 15,000 ha out of 3,030,000 ha is under formal irrigation. Irrigation development in Uganda is predominantly surface irrigation (96%). A limited area, less than 4% is under pressurized irrigation (FAO 2015).
Timeframe	5 years for implementation
Acceptability to local stakeholders	Areas that are water stressed such as Soroti, Kiruhura, more in certain times of the year and those that are close to ready market for produce would benefit a lot from this scheme. Communities may need to be re-organised according to water flow and readiness to participate and co-invest. Land tenure issues may be a barrier. Water sharing among communities also needs to be considered to avoid future conflict.

4. Ecological Pest Management	
Introduction	Climate change is predicted to alter the prevalence, intensity and severity of crop and animal pests. Measures to control this risk need to be designed in a way that avoids inappropriate use of agrochemicals that pause risk to human and environmental health. Ecological pest control takes into considerations the natural physical (soil water air) and biotic (plants animals, insects and micro-organisms) entities and how their status and interconnections are affected by measures taken. Ecological pest management seeks to predict and avert the risk of pests and diseases and the risk of the various control measures to human and environmental health.
Institution and organisational requirements	EPM requires farmer to work with scientists and extension workers. With many of the 'public good' activities (e.g. supporting value chains and farmers that are not highly commercial, where there is limited involvement of the private sector), the government of Uganda is expected to be the primary financier. Some of the donors that have, and still continue to support projects related to pest and disease management include the World Bank, USAID Feed the Future, IFAD, European Commission, FAO, Bill and Melinda Gates Foundation, and Embassy of the Kingdom of the Netherlands. A good example of an IFAD-funded project on pest and disease monitoring and management is the CABI-led Plant-wise project.
Size of beneficiaries	Actual economic losses to pests and diseases are hard to find – PARM reports per annum losses from MAAIF as 35-200; 60-80; 8 and; 10 million USD/per annum for banana, cassava, coffee and cotton respectively. The technology is beneficial primarily to farmers, consumers and other stakeholders.
Operation and maintenance	The process includes: • proper identification, assessment and prioritization of pest and disease risks and the site variations in the nature of risk. • consideration of all available pest control techniques • evaluation and selection of cultural, biological and chemical measures to manage diseases, insects, weeds and pests with minimum risks to human health and the environment yet cost-effective and socially acceptable. • early warning to farmers on the likelihood of pest and disease outbreaks • extension advice to enable farmers to select the most effective and economical option Field-level practices are: 1. Crop Management: Selecting appropriate crops for local climate and soil conditions. Practices include: Selection of pest-resistant, local, native varieties and well adapted cultivars; Use of legume-based crop rotations to increase soil nitrate availability for robust plants that better face pests and diseases; Use of cover crops, green manure, intercropping and agro-forestry to reduce infestation of disease pest and weeds; and Use of crop

	spacing, intercropping and pruning to reduce conditions favourable for pest breeding. 2. Soil Management: maintaining soil nutrition and pH levels to provide the best possible chemical, physical, and biological soil habitat for crops. This includes using longer crop rotations; applying organic manures with microbes to improve water absorption and air exchange; Managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests. 3. Pest Management: using beneficial organisms that behave as parasitoids and predators. Practices include: Releasing beneficial insects and providing them with a suitable habitat; Managing plant density and structure so as to deter diseases; Managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests.
Advantages	• Increased and stable yield and income. • Conserved ecosystem • Safety of farm produce from chemical contamination • Reduced expenditure on pesticides. • Diversified crop production and diversified diet • Long-term saving at a national level
Disadvantages	• Knowledge intensive requiring understanding of pest, pathogen and weed behavior and risk level – investment in research, which can be expensive • Requires close interaction farmers, extension system and scientists • Requires good communication infrastructure • Requires close monitoring including a lot of learning by doing in the different contexts. • Some of the required outcomes take time to get realized. • Some desirable systems can break down over time due to the introduction of a change in the requisite conditions • Some approaches may require landscape level transformation of practices before change can be realized and therefore farmers need to be organized to have a common goal. • It may be labour demanding.
Capital costs	
Cost of implementing adaptation options	Costs include research, testing, training, equipment To significantly reduce risk and incidence of pests and disease, three main areas are of central importance: 1) Availability of and response to information on pest/disease occurrence.2) access to pest management support

	services needed by farmers and other value chain actors and 3) capacity of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), including the DCP, to lead and co-ordinate crop pest risk management across the country. Interventions in the above areas provide the three key components of the proposed investment plan, which details a 5-year program with an overall budget of US$23.88 million.
Additional cost to implement extra unit	Additional costs for adaptation include establishment of plant clinics and training of plant doctors, media, Plant health rallies, Farmer field schools comprise of weekly, small group training sessions, commonly focused on pest management, over a whole crop season for a specific crop.
Development impacts, indirect benefits	
Economic benefits	• Motivating large numbers of farmers and those in value addition to remain in business. • Farmers can avoid the costs of pesticides as well as the fuel, equipment and labour used to apply them. • Public and private expenditures are reduced. • Increased yield and profitability of farming. • Reduction in producer's economic risk by the promotion of low-cost and carefully targeted pest management practices. • Proactive avoidance of future pest management crisis; through research directed at potential short, medium and long-term challenges.
Social benefits	• Income. The implementation of EPM is likely to enhance the incomes of farmers as they harvest higher yields of their crops. • Safe crops, soils air and water • Indigenous knowledge integrated in research and used to solve pest problems across a wide scale • Mutual learning between farmers
Environmental benefits	• Reduced contamination of natural ecosystems • Protected interactions between organisms and conservation of biodiversity • Increased protection of organisms that play a key role in pest management
Local context	
Opportunities	Pest and disease control is a key priority in the following national development documents: Second National Communication to the UNFCCC Oct 2014, Production and Marketing Guidelines 2018-19, NAPA, National Development Plan II, The Plant Protection and Health Act, 2016
Barriers	• Agriculture Sector Support Plan (ASSP) budget allocated to crop protection is relatively small and not adequate for the substantial increase in capacity required for EPM.

	• Limited resources for research and extension in Uganda • Technical: lack of studies and complexity of EPM; • Low crop prices yet high cost of EPM • Preference of commercial pesticides by farmers because they are easier to apply and manage • Institutional: poor linkages between research, extension and private sector • Poor understanding of EPM by farmers/extension, lack of EPM specialists. • The common misconception that pesticides are essential for high yields. • Shortage of practices and products as effective as chemical pesticides • The need for smaller diversified operations in EPM which are confusing to adopt rather than the more simplified large-scale specialized operation
Market potential	Increased food safety and reduced contamination of natural ecosystems can increase the branding of products and earn farmers a premium price and open up new export opportunities. As knowledge is gained, packaging and selling of new environmentally acceptable pesticides can be developed leading to new opportunities for local farmers to earn an income. Involvement of farmers and entrepreneurs in experimenting in crop protection.
National status of the technology	Losses due to pests and diseases are estimated at: 10-20% (preharvest); 20-30% (post-harvest); and up to 100% for perishable crops and export crops. Annual losses in the priority crops due to pests are estimated at: US$ 35-200 million (bananas), US$60-80 million (cassava), US$10 million (cotton) and US$8 million (coffee).Currently, in Uganda, little information is gathered to support short or long-term pest management decision-making, which means that responses are often ‘too little, too late’.
Timeframe	The implementation of EPM is long-term
Acceptability to local stakeholders	Increased awareness of farmers through enhancing the extension delivery systems, research and outreach programs will increase multiple adoption. Finally, IPM technologies were found to reduce pesticide use intensity. Indigenous knowledge can play a key role in forming research

5. Culture Based Fisheries and Aquaculture	
Introduction	Fisheries contribute to local livelihoods and export earnings are mainly obtained from Lake Victoria, George, Edward, Albert, and Kyoga, River Nile and a variety of swamps and streams. Climate change will cause changes in water temperature and water availability and flow. This may affect fish species composition, but in order for productivity to remain stable, fish diversity needs to be maintained. High temperature induces masculinization of sexually undifferentiated juveniles of tilapia. Although compared to global changes, the impact on Fisheries is predicted to be moderate in Uganda, its interaction with other bad fishing behaviours notably over-exploitation pollution, habitat degradation may make matters worse. To ensure resilience to climate shocks healthy balance of fish stocks must be maintained. Culture based fisheries and aquaculture are technological interventions that can help to build up fish stocks. Culture-based fisheries (CBF) are practices to enhance fish stocks in waters that don't have enough natural recruitment to sustain a fishery. CBF practices are usually applied in small water bodies such as village dams and irrigation reservoirs. It involves increasing fish production in natural environments by controlling a part of the life history of certain species and transplanting or releasing their seed or fry into the open waters. The juvenile fish, which are produced in hatcheries and are released into waters, are allowed to propagate or forage on natural food supplies. Ownership and management of the stock distinguish CBF as a form of extensive aquaculture. Aquaculture - Industrial and more intensified fish culture - involves the cultivation of aquatic life within controlled environments. There are three types of aquaculture in Uganda: i) rural aquaculture for subsistence is a low or no input system largely dependent on the public sector and friendly farmers for fish seed and advice. ii) small-scale progressive fish farming for income generation. iii) 'emerging commercial fish farming as a business for profit through marketing. Pond culture is the most common; cage culture is only starting. Pond sizes have grown from 50 m^2 to 200 m^2 to more commercial sizes of 500 m^2. Kajjansi Aquaculture Research and Development Center. The major cultured fish types in Uganda include: Nile tilapia, North African catfish, carp, *Tilapia rendalli*, black bass, trout, giant river prawn (*Macrobrochium rosenbergii*) and the red swamp crawfish (*Procambarus clarkii*) A combination of hard and soft technologies would be appropriate depending on location features. • Prediction of water availability in reservoirs with climate change impacts. • Identify alternative means of fingerling stocking. • Develop techniques to identify climate change impacts on fish breeding.

	• Improve breeding techniques to overcome climate change influences. • Effective knowledge dissemination and capacity building
Institution and organizational requirements:	The Minister of State for Fisheries is directly responsible for the aquaculture sub-sector within the Ministry of Agriculture, Animal Industry and Fisheries. The Chief Fisheries Officer, who heads the Department of Fisheries Resources, (Department of Fisheries Resources). There is an Aquaculture Unit headed by a Principal Fisheries Officer. Research institutions, the academia NGOs and the private sector and farmer groups are key players in CBF and aquaculture
Size of beneficiaries group	Aquaculture and CBF farmers in urban and rural communities. People are getting involved in community-based fry-to-fingerling rearing activities. The Ministry of Agriculture, Animal Industry and Fisheries has identified 31 districts as suitable for fisheries and aquaculture development based on both natural and socio-economic factors. These districts are: Mayuge, Jinja, Bugiri, Busia, Mukono, Mpigi, Wakiso, Masaka, Rakai, Mbarara, Bushenyi, Ntungamo, Kasese, Hoima, Masindi, Nebbi, Gulu, Adjumani, Arua, Kamuli, Soroti, Lira, Iganga, Tororo, Pallisa, Mbale, Apac, Kabiramaido, Kabarole, Kamwenge and Kyenjojo. There are currently an estimated 12 000 farmers involved in aquaculture, with about 150 service providers or extension workers employed by local governments.
Operation and maintenance	In CBF, management includes planning of seed stocking (and procurement), monitoring prevailing weather pattern(s) as the key stages of stocking and harvesting are dictated by the water level. Develop appropriate harvesting and related market strategies to minimize negative impacts on farm gate price(s). Build community capacity to develop appropriate, low energy, cost processing techniques as an alternative strategy. Aquaculture involves; • Pond preparation/conditioning – draining and flushing of water; elimination of predators and/or wild species that may eventually compete with the cultured organisms for food and space. • Stocking – stocking with fish fingerlings. • Feeding and/or fertilization provision of supplementary feeds, • Water management – maintaining Water levels for optimal fish growth. In general, a pond water depth of 1 meter is considered best for culture of tilapia, and carps. Maintain pond environment with constant entry of new water from the river or water source (through the supply canal) while draining old water away. • Pond maintenance - fertilization, liming, elimination of pests, stock monitoring, regular maintenance of pond dike and gates • Harvesting. e.g. Tilapia are harvested using seine nets after the pond water is drained to half-level the night before.

Advantages	CBF offer several advantages over more conventional and intensive forms of aquaculture: • Simple technology that is easy for farming communities to learn and adopt. • Very low capital costs, making use of existing infrastructure and natural productivity. • Contributes to the income, food security and nutritional status of rural communities. • Suitable for implementation as a communal activity. • Sustainable, very low greenhouse gas emission food production, with no external power or feed inputs. • Fish growth in ponds can be controlled: the farmers themselves select the fish species they wish to raise. • Effective use of marginal land e.g. land that is too poor, or too costly to drain for agriculture can be profitably devoted to fish farming provided that it is suitably prepared.
Disadvantages	• CBF unpredictable harvests and undefined ownership. • Poor fishing methods and tension. • Overregulation of fish marketing. • Scarcity of fingerling. • Harvesting too much at a go may lead to slumping in prices • CBF may suffer the tragedy of the commons • Aquaculture is very intensive and may face challenges in case of scarcity of feeds, pesticides
Capital costs	
Cost of implementing adaptation options	Obtaining data for fish stocking and appropriate locations to target for CBF, Organizing and building local community capacity in managing CBF, Review existing regulations for CBF and aquaculture management, Establishment of decentralized fish breeding centers. Costs will be estimated for different individual or packages of technological interventions. Measures adopted will vary by location and the economic value of resource to be protected at each location.
Additional cost to implement extra unit	No information found
Development impacts, indirect benefits	
Economic benefits:	• Employment opportunities: for rural communities. (i.e. Doing CBF, Fingerling production, product development, marketing etc.) • Local government revenues through levying of various taxes, levies and license fees • Contribute to poverty alleviation and improvement of livelihoods

	• Economic growth due to exports
Social benefits	• Additional income for farmers • Make available low-cost protein source at affordable price. • Food and nutritional security. • Capacity building at government and community level. • New opportunities for fisheries-related livelihoods • Provides incentives for active management and better governance of common pool resources
Environmental benefits	• No formulated food or other inputs are used in CBF therefore available natural food items are used by the stocked fish species; • No GHG emission in CBF; • No local pollutants and ecosystem degradation; • Minimum use of power; • Minimal impacts on indigenous/endemic aquatic fauna; • Manipulates population and/or food web structure, thus raising fisheries production at low external inputs and degree of habitat modification; • Aids the conservation and rebuilding of depleted or threatened populations; • Provides partial mitigation for ecosystem effects of fishing.
Local context	
Opportunities	• Fisheries development is a priority in National Development Plan II 2015/16 to 2019/20, Fish Agriculture Sector Strategic Plan (MAAIF/ASSP2016/20), Aquaculture Development Strategy (2011), National Aquaculture Development Plan (2011), National Fisheries Policy passed in 2004 and National Fisheries and Aquaculture Policy, 2018 • Regulatory framework exists: The Fish Act (2000), Fish (Aquaculture) Rules 2003 • The Kajjansi Aquaculture Research and Development Center can support the CBF and aquaculture. • With improved market prices for fish, aquaculture has begun to attract entrepreneurial farmers. • Government's concern to fish depletion from water bodies provides good basis for CBF and aquaculture support.
Barriers	Being an Open access fishery, CBF may face • Tragedy of the commons and conflicts amongst users and with governmental authorities

	• poor timing to coincide with the periodic filling of water bodies leads to insufficient production of fish seed quantities leading to unavailability of suitable seed stock especially for carp. • Insufficient knowledge on best practices of suitable preparation of water bodies prior to stocking. • Pollution of the water bodies. • Inadequate capital investment to improve production, processing and marketing.
Market potential	Commercial hatchery operators and a number of grow-out farmers are already exporting fish and fish seed to Democratic Republic of Congo, Kenya and Rwanda. Poor road networks and lack of a railway line have been cited as the major obstacle to wider domestic distribution and availability of fish to Ugandans. Border closure between Rwanda and Uganda caused great losses to fish traders.
National status of the technology	Aquaculture production was 15 000 tonnes of fish (2005) from 20 000 ponds of an average size of 500 m². Production ranges between 1 500 kg per hectare per year for subsistence farmers to 15 000 kg per hectare per year for emerging commercial fish farmers. There were 2 000 farmers who owned nearly 5 000 ponds, with an average pond size of 1 500 m² per pond in 2015.
Timeframe	Medium term: 3- 5-years
Acceptability to local stakeholders	With improved market prices for fish, better relations between government and fisherfolk, CBF will take off and aquaculture will be strengthened. Expansion in aquaculture results in the transformation of the smallholder subsistence ponds into profitable small-scale production units. The technology will be attractive to government, farmers, private businesses, researchers and NGOs engaged in conservation.

6. Responsive Agricultural Extension	
Introduction	Climate change is predicted to deeply impact the agricultural value chain from production, through transportation, processing, storage and consumption. It will affect different crops and livestock differently and will influence certain growth stages more than others. It will also change the way crops and livestock relate to environmental conditions. Pest and disease prevalence will also change requiring farmers and stakeholders along the agricultural value chain to adjust. Emerging market opportunities, farmer innovation and risk management options also need to be made accessible to farmers and other key players. These changes require strengthening of the technical and institutional capacity of the agricultural extension system in Uganda to provide the necessary support in training farmers, disseminating new technologies, assisting farmers to form groups, market their agricultural products and partner with various institutions. In addition to the usual extension methods of trainings, demonstrations, model farmers, radio outreach programs and farm visits,

	extension needs to take advantage of the advances in information technology especially via mobile phones to ensure fast access to appropriate climate information for farmers. The technology rests on activities geared towards strengthening of technical and organizational capacity underpinned to develop knowledge towards climate adaptation that is meaningful and useful to farmers and with their full participation.
Institution and organizational Requirements	Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and the National Agriculture Advisory Services (NAADS), local governments, NGOs and private businesses especially of key commercial crops such as sugarcane, oil palm, tea and cotton. Ministry for ICT for supporting use of mobile phone technology. The existing national extension framework ends at county level with very weak provisions for parish and village levels. Direct contact between farmers and extension officials is therefore very seldom. The initial goal of building farmer groups and farmer organizations to a level where they can fund 50% of the cost of advisory services from private firms, farmer associations or NGOs, has not been successful and a new approach is needed.
Size of beneficiaries group:	All farmers: 78% of the population of Uganda
Operation and maintenance	Development of revised masterplan (policy) for agricultural extension with full consultation with farmers. Inventory of information required for climate change adaptation for crop and livestock farmers in the different ecozones and creating a database of climate adaptation information focusing firstly, on the key focus crops and livestock. These are bananas, beans, maize, rice, cassava, tea, coffee, fruits and vegetables, dairy, fish, livestock (meat), and four strategic commodities, namely, cocoa, cotton, oil seeds, and oil palm. Inventory of support system including private businesses for supply of seeds, feeds and fertilizers, produce protection, storage and processing, financial and insurance services. Building capacity of extension workers and stakeholders in the support system. Deployment of extension workers to cover all ecozones and ensure sufficient access for all farmers. Inventory of existing mobile-phone based apps that are being used worldwide (eg FAO) and selection of options appropriate for Uganda and translating information into local language and diagrams that farmers can use and be able to provide feedback to research and extension
Advantages	• Provides vital access to information for appropriate and timely climate response • ICT-based approach will promote easy transfer of quality information to numerous farmers at the same time • It provides a platform for feedback from farmers that can be used in research development. • It promotes networking and mutual learning among farmers • Technical support is provided in a timely way that helps farmers and stakeholders along the value chain

	avoid losses related to extreme climatic conditions. • Introduces new technologies for future such as new crop, new varieties and new equipment. • Accelerates farm development and potential for farmers to adopt more resilient and profitable approaches.
Disadvantages	• Implementation is costly yet the agricultural sector is allocated only a small portion of the national budget. • It depends on adequate technical expertise being available locally, either from civil society, NGOs, governmental or private entities, and the capacity of a local institution to adequately integrate this information into local know-how. • Farmers need to regain the culture to trust the extension system
Capital costs	
Cost of implementing adaptation options	National costs inclusive of wage, non-wage recurrent and domestic development to MAAIF, DDA, NAGRCBD, NARO, NAADS Secretariat, UCDO, UCDA, District Agricultural Extension, NAADS (Districts), Production and Marketing grant and KCCA Agricultural Grant for 2016/17 was 388.25 UGX Bn
Additional cost to implement extra unit	To be confirmed
Development impacts, indirect benefits	
Economic benefits	• Increase efficiency of resource use overall • Promote rural development and resource conservation • Employment • Boosts agricultural productivity and modernization
Social benefits	• Community participation in institutional development and contribution of their knowledge and observations to knowledge development • Improved food security and resilience against climate shocks. • Increased profitability of learning. • Networking among farmers and with researchers and extension workers. • Increase in Agricultural technical capacity and exposure of farmers and players in the agricultural support system.
Environmental benefits	Integration of environmental concerns in the extension messaging.
Local context	

Opportunities	• The need for responsive Agricultural Extension is expressed in the Production and Marketing Guidelines 2018-19; Uganda's INDC 2015; the National Development Plan II 2015/16 to 2019/20. • MAAIF has an objective to promote agricultural extension systems. • Availability of numerous Non-State Actors in Agricultural extension. These include private sector firms and umbrella organizations, cooperatives, Non-Governmental organization, Development partner projects, training and research institutions. • Technological Advancement. Especially information communications technology (ICT) has created a huge opportunity for e-extension service delivery.
Barriers	• Few resources allocated for staff recruitment, training, transportation, and support for farmer organizations • Untimely release of funds and lack of prior consultations with financing partners before change of design. • Lack of coordination and collaboration. The agricultural extension service in Uganda is fragmented and uncoordinated. Little or no ownership and commitment of the key-actors in the public sector - MAAIF Directorate of Agricultural Extension Services, NARO, and Local Governments and from the Non-State Actor; Non-Government Organization; Donor Projects; Academia and Private Sector Organizations and entities. • Political interference • Poor system of monitoring extension services • Poor quality of information. The subject matter of extension has narrowly focused on primary production which shrinks the opportunities for farmers to earn more from their product • Ineffective extension approaches. Face to face contact is unsustainable in light of inadequate human and financing resources.
Market potential	An effective extension system requires heavy public financing. This will result in development of market opportunities as an outcome.
National status of the technology	Uganda reformed its extension services, to a farmer demand-driven system. This has not worked very well and Uganda needs to consider new models taking into consideration responsiveness to climatic changes in specific location, use of ICT, and participatory options among others.
Timeframe:	Long term: >10 years
Acceptability to local stakeholders	There is a significant increase in the share of farming households sourcing advice from fellow farmers, NGOs/CBOs (community-based organizations), radio and call centers. Extension workers need to work with farmers more intimately using ICT. Mobile phone coverage is now widespread.

7. App for targeting Soil and water conservation technologies to appropriate conditions and estimating outcomes	
Introduction	About 46% of Uganda's soils are degraded and 10% is very degraded. Soil and water conservation (SWC) technologies are required for addressing declining food and commodity production and sustainable use of land in the face of climate change. In Uganda, information to support selection of SWC technologies that are appropriate for climate response in ecological and socio-economic conditions has not been readily available to farmers. An app for supporting farmers with how to target the right SWC technology to the right conditions and what impact to expect involves a tool for assessing a portfolio of SWC. The portfolio includes Mulching, Crop rotation, Fallowing, practices for water retention and maintaining soil structure, Contour Strip Farming, bench terraces, grass strips, Minimum Soil Disturbance e.g. Basin planting and ripping Contour Hedgerows and retention ditches, Agro forestry, and drip irrigation. The app uses a simple program that can be accessed via a mobile phone using simple queries and drop-down menus of options. It can generate suitability maps for technology selection giving due consideration for vulnerable areas including swamps and along river banks, hilltops, steep slopes and areas under semi-nomadic shifting agriculture. This can be supplemented with organized farmer- group learning through physical meetings and demonstration as well as through radio broadcasting. Implementation assumptions: ♦ Land use legislation and broad guidelines developed ♦ Assessment of nationally developed targets for curbing soil loss and conserving water ♦ Technology development by researchers in the Academia and Research institutions ♦ Dissemination through national level media, localized farmer cross-learning including physical meetings and virtual forums on mobile phones, radio and TV as well as through demonstration ♦ Pilots are needed in sample areas of high, medium and low severity. Nationally driven programs to monitor and account for progress towards SWC.
Institution and	Soil and Water Conservation is led by Department of Infrastructural Development (Farm Development),

organizational requirements	Ministry of Agriculture, Animal Industry & Fisheries (MAAIF), Ministry of Water & Environment, Ministry of Energy & Mineral Development, NEMA etc. For setting the agenda, policy development and enforcement. • Research Institutions • Academia will play a key role in modeling and mapping conditions to guide siting of technologies. • Non-Government Organizations e.g., IUCN, IIRR WWF etc., the media as well as donor organizations will play a key role in dissemination. About 1million farmers are targeted under CSA.
Size of beneficiaries Scale	14 million ha of Uganda is cultivable. In 2012, the cultivated area was 9.15 million ha. Cultivated area is degraded mostly due to soil erosion. It is more severe in highlands in the Southwestern Kabale and Kisoro (85%-90% affected), Eastern (Mbale), Western regions (Bundibugyo, Rakai) and Northeastern (Kapchorwa and Kotido, 75% - 80%) which occupy around 25 % of the country's land area and contain 40 % of the country's population. Relatively flat areas have experienced severe sheet and rill erosion (NEAP 1995). Water for production is a limiting resource in the north, a marked dry season affects crop growth. Dry land districts of Moroto, Nakasongola, and Rakai are said to be facing desertification (NEMA 2001).
Advantages	• The App makes SWC information readily available for farmers and helps them decide on the option most suitable for their condition. • Saves time costs by enabling SWC extension workers to interface with many farmers without the need for face to face interaction. • Farmers can provide feedback on their experiences.
Disadvantages	• Many farmers think they know and may not take SWC seriously. • Starting off may entail high knowledge investment. • Farmers need to aggregate into large groups to cause sustainable change. • Impacts of SWC take time. • Profitability may not be realized unless market access is also developed. • It assumes that farmers are literate and tech savvy • The information may need to be translated into local languages, which are quite many.
Capital costs	
Cost of implementing adaptation options	Costs of natural resources degradation in the country estimated at 17% of GDP per year. Cost include research, App development, creating awareness of the App, uploading on mobile phones, monitoring SWC impacts. The Investment framework for Sustainable Land Management Investment Framework was estimated at US$ 245,305,000 for 10 years
Additional cost to implement extra unit	No information found

Development impacts, indirect benefits	
Economic benefits	• Employment and income for the app developers hired as well as the farmers • Increased yield of farmers through the use of the app • More diverse crops grown due to increase in water availability from use of the app
Social benefits	• Improves soil and water conditions may lead to improved food security • Increases provision of water for production • Promotes mutual learning between farmers
Environmental benefits	• Promotes Utilization of degraded land • Increased protection of water catchment areas • Increases in biological activity of soil, bringing the rise in its fertility. • Soil and water conservation reduce soil and nutrient flow which would cause sedimentation and contamination of water bodies downstream
Local context	
Opportunities	Soil and water conservation are mentioned in Uganda Second National Communication to the UNFCCC 2014.
Barriers	• Inadequate investment in sustainable soil management and alternative livelihoods • Poverty and high dependency on extraction of natural resources for income • Insecure land tenure making farmers less motivated in adopting sustainable farming practices. Nomadic pastoralism and shifting cultivation cultures. • High cost of external inputs e.g. fertilizers and water harvesting facilities • Inadequate extension services • Use of rudimentary tools • Inadequate incentives for the private sector to provide services in sustainable soil management. • Investment in SWC may be riskier compared to less risky options such as migration, as returns to any investment in land cannot be relied upon especially in semi-arid environments. • Low education level of farmers
National status of the technology	An agricultural app called ‘Ezy-Agric App’ has been innovated and developed by Ugandans to improve access to agricultural information. The App helps link farmers to genuine suppliers of pesticides and other inputs as well as connect farmers to buyers and traders, among others services. The SWC app can build on this experience.

Timeframe	Medium term: 3-5 years.
Acceptability to local stakeholders	The technologies of SWC are known in general but poorly applied due to lack of guidance on what works where. Farmers will benefit very much from such information. Young farmers are more likely to use this approach because of their knowledge of mobile phone use.

8. Climate insurance	
Introduction	Precipitation in Uganda is predicted to increase in some areas and decrease in others meaning incidences of droughts and floods are likely increase. Seasonal predictability is likely to change especially onset of rainfall. The intensity is also likely to change. These will increase risks to agricultural production, including diseases, pests, input and commodity prices. Insured farmers can access credit more easily from financial institutions and can therefore purchase inputs for improved technologies for production. However, awareness about the agricultural insurance opportunities remains limited for small-scale farmers in Western, Eastern and Northern regions much as such consciousness prevails in central region. What is needed is to align the scattered and fragmented efforts to bring about a robust insurance scheme for farmers especially in regions at most risk of climate change – northern and eastern. Currently, the government is implementing the Uganda Agriculture Insurance Scheme (UAIS) as a pilot project. It seeks to cushion farmers against losses arising from natural disasters related to climate or weather changes. The sum insured can be the farmer's input costs, output (expected yield) or both. It can cover all or some commercial field crops, tree crops or livestock as well as farm assets and equipment including green houses and irrigation facilities. The insurance can consider various climatic perils or specific weather perils **(**e.g. Kilimo Salama**)** that can be measured by a weather station. All the necessary legal Instruments have been worked on. Climate insurance protects farmers from adverse climatic impacts on crop and livestock production as well as prices of inputs and commodities. Farmers pay a premium to cover unforeseen losses in production, sales, equipment loss and failure of infrastructure resulting from flooding. Fluctuations in production are reduced
Institution and organizational requirements	MAAIF, UNFE, UCA, Feed the Future, UNMA, UBA, agribusiness alliance etc. Uganda Insurance Consortium, According to David Muwonge of NUCAFE, high premiums and delays in payouts discourages most farmers from taking up crop insurance
Size of beneficiaries	No information found
Operation and maintenance	• Publicity and awareness creation about climate risks and the benefits of insurance. • Training farmers • Support for farmer group formation. This enables more aggregated and coordinated approaches among farmers and the systems that enable them to access inputs and markets. With scattered farmers, the support

	institutions do not develop. Landscape level impacts like soil erosion can be addressed collectively. Farmers can also invest in community efforts for irrigation and form cooperatives for marketing. Investment requiring a threshold mass of participants can then take off. • Availing government insurance subsidies through insurance companies working with local governments.
Advantages	• Extending Agriculture Insurance to cover the whole country will encourage commercial banks to lend to the agricultural sector, given that the risk associated with agriculture will be mitigated through the Insurance Scheme. • Financial institutions will find less risk in lending to farmers and they will be motivated to use improved technology e.g., appropriate crop/livestock varieties, improved seed, fertilizers and other inputs • Reduced liabilities arising from agriculture shocks; increased income for farmers
Disadvantages	Information imbalance; uncertainty of farmers' risks may demotivate insurers; variation in farmers needs and farm-management decisions.
Capital costs	
Cost of implementing adaptation options	• Cost of agriculture insurance subsidies to the government of Uganda in 2016/17 was UGX 5billion over 5 years. • Money is required to broadcast the information to the farmers and build their capacity to use the facility. Financial institutions also need to be brought on board to understand the farmers' risk and open up more opportunities for farmers to access credit. • Capacity for using weather/climatic information to assess potential risk to the farmer and potential value of the risk so they can decide on appropriate insurance package. • Extension officers are needed to achieve this. • According to WB report the average delivery, loss adjustment, and administration costs amount to a total of 5% of the original gross premium (OGP). Marketing and acquisition costs are 3%, and loss adjustment costs are 2%. • Calculation of the sum of insurance and premium rates to the farmer: The sum of insurance (SI) is calculated using the following formula: SI = ensured area x planned productivity x production forecast price. The premium rates are calculated as percentage of the risk covered by the underwriters based on the information provided by the farmer. The cost of the agricultural insurance for farmers ranges and depends largely from crop culture and number of insured risks.
Additional cost	No information found

Development impacts, indirect benefits	
Economic benefits	• By diversifying loss risks among people and across time, insurance reduces the negative impacts of weather-related disasters. • Enables a timely recovery. • Reduces the financial repercussions of volatility and the uncertainties of decision-making by creating a "space of certainty" within which investments and planning can be undertaken. The payouts help governments to avoid fiscal deficits and costly post disaster loans, and to take prompt action. • Well-designed insurance incentivizes loss reduction and resilience-building activities of households, firms and governments. • Enables productive risk taking on the part of individuals and governments
Social benefits	• Facilitate assessment of loss and damage potential as a prerequisite for identifying needs and policy priorities. • Insurance clients can access timely payouts to purchase food and get back on their feet while avoiding poverty traps. • Protects low income individuals from a variety of desperate coping strategies after loss that include: reducing food consumption, taking children out of school, borrowing money and selling assets.
Environmental benefits	By investing in (re-)construction measures to protect the land and property, a household can keep future damage to a minimum and will enable themselves to recover more quickly after a flood disaster
Local Context	
Opportunities	Uganda set up an agricultural insurance scheme in 2016/17 involving a public private partnership between Uganda insurers association and government of Uganda where farmers pay a subsidized premium and get compensated in case of disaster or failure.
Barriers	• Low capacity and lack of experience in dealing with insurance companies • Poor understanding of risks faced by smallholder farmers by the insurance companies • Poor ability to dissociate direct climatic risks from climate-related risks such as destruction of road infrastructure and therefore prevention of transportation of commodities to market centres; price fluctuations of inputs due to climatic challenges • Low levels of literacy • Extreme poverty levels preventing farmers from having cash for payment of premiums – in-kind options need to be explored.

	• Insurance, as a mechanism, operates most effectively where it is linked to other measures to mitigate the farmer's situation (e.g. improving credit availability, market access, investment into machinery, irrigation equipment and so on). Insurance cannot operate effectively in isolation, and will be regarded as a cost by the farmer. • Lack of information about the insurance opportunity
Market potential	Insurance companies are already in a public-private partnership with government for agricultural insurance
National status of the technology	By March 2019 77000 farmers had accessed agricultural insurance with a value of UGX 6.6bn annually. Before this, farmers were already accessing agricultural insurance through directly participating insurance companies, agro-consortium, district farmer associations and financial institutions.
Timeframe	Short-term since already initiated: < 3 years
Acceptability to local stakeholders	With literacy and awareness raising, it will be acceptable, but more for large scale and livestock farmers. A bit more tinkering may be needed for smallholder mixed crop systems.

9. Seed and grain storage	
Introduction	Smallholder farmers lose a substantial part of their produce due to lack of or poor storage in periods of bumper harvest and face food insecurity in times of scarcity. Farmers are also forced to sell at uncompetitive prices. With climate change, weather events may change and drought seasons may be lengthened, leading to unnecessary loss of human and livestock lives due to poor storage capacity. Storage conditions will also change due to changes in temperature and humidity. Pests and diseases associated with storage are also likely to change in nature, timing, the intensity of damage they cause. Human capacity and systems of crop handling and storage need to adjust to improve preparedness for climate change impacts. A system is needed to purchase seed and grains from farmers at competitive prices, store them safely and redeploy them where/when needed.
Institution and organizational requirements	MAAIF for policy and facilitation of implementation of seed and grain systems, Uganda National Farmers Federation, Ministry of Trade and Industry, Ministry of Commerce, private seed companies, local governments, NAADS for farmer trainings, Uganda National Bureau of Standards to ensure safety from harmful contamination, NARO, Ministry of Disaster preparedness under the office of the prime minister.
Size of beneficiaries	No information found
Operation and maintenance	• Strengthening of the seed and grains storage system at the national and decentralized level. • Public-private partnership in seed handling and management. Development of seed banking. • Funds for purchasing seeds from farmers. • Awareness creation on seed and grains system and the benefits of collective seed storage. • Training of farmers and specialists in seed handling and management. • Organization of farmers into cooperatives. • Construction of decentralized storage facilities with appropriate access to power. • Ensuring quality drying, packaging and storage conditions; Identification of safe chemical dressing for long-term storage. - Some markets will not accept seeds and grains treated with chemicals. • Research in forecasting and developing appropriate responses to changes in climatic conditions on seed and grain harvests, seed handling and storage requirements for different species; seed and grain disease and pest prevalence and severity. Seed harvest forecasting to prepare for handling and storage. • Forecasting of disaster and development of mechanisms for safe transportation where needed.
Advantages	• Stable food availability when and where needed

	• Good distribution of food • Better prices – farmers are not compelled to sell at low prices • Reduced reliance on relief • The establishment of safe, long-term storage facilities ensures that grain supplies are available during times of drought • Avoided wastage and degradation. Grain storage protects the quality, thereby preserving stocks year-round and prolonging the life of the foodstuffs • Farmers can access seed without having to lay out cash. • Reduced physical losses for farmers • In case farmers want their seeds to dry faster, seed storage is a safer option
Disadvantages	• Expensive • May narrow the focus on only crops that are easy to store • May lead to perverse incentive of withholding distribution in speculation of better prices • Highly knowledge and information dependent – uncertainty of climate impact on seed threats and changes needed in storage conditions • Inappropriate storage management may lead to unsafe seed and grains and pest proliferation • Irresponsible timing of distribution may lead to slumping in price • Over-drying of grains can also negatively impact seed quality. • Losses of seeds from insects, rodents, birds and moisture uptake can be high in traditional bulk storage. • Controlling or preventing pest infestation may require chemical sprays. • Some markets will not accept seeds and grains treated with chemicals. • High temperatures hasten the physiological aging of seeds in case they are stored in high temperatures.
Capital costs	
Cost of implementing adaptation options	High initial costs and also quite costly to operate a food and grains storage system.
Additional cost to implement extra unit	A large metallic 1250 litre silo goes for $160, a smaller one (750 litres) goes for $120; the 500 litre plastic silos go $78 while a set of four super grain bags go for $19
Development impacts, indirect benefits	
Economic benefits	• Public and private Investment in seed storage and supply systems including seed bank development.

	• Employment. Jobs in storage systems installation, operation and maintenance. • Reduced expenditures from importation and reduced reliance on relief in times of disaster. • Strengthened capacity to export
Social benefits	• Increased farm profitability due to reduced losses and higher commodity prices. • Improved capacity to handle and store grins • Improved household food security. • Improved health and diets.
Environmental benefits	No information found
Local context	
Opportunities	• Growing regional demand for food grains • Grain and seed storage are key strategies mentioned in the National Policy for Disaster Preparedness and Management 2010; Uganda's INDC 2015; NAPA and the National Development Plan II 2015/16 to 2019/20
Barriers	• Corruption may frustrate the operation of a food and grain system. • High initial costs • Poor inter-sectorial coordination • Ingrained cultural practices of unhygienic drying and storage • Some farmers are not equipped with knowledge on grain storage • Building storage facilities requires a lot of land • Harsh weather can destroy storage facilities especially those made by timber, reeds/ bamboo.
Market potential	High local and regional demand for seed and grain. The East African regional treaties may make regional trade easier and more profitable. An online trading platform 'G-Soko' will be used to help farmers to sell grains at a much competitive price.
National status of the technology	Of the potential harvests of about 4- 5.5 million metric tonnes of maize - and beans obtained per good season, Uganda has capacity to store only about 750,000 metric tonnes with close to 250,000 metric tonnes having been developed in the last four years.
Timeframe	Medium to long term: 3 years or more
Acceptability to Local stakeholders	Organizations have been working with farmers to upgrade storage facilities and provide modern grain processing equipment to ensure their access to markets. About 67,000 rural smallholders in Busoga, Teso, Acholi and western Uganda that suffer the extremes of climatic change have pioneered a method of storing grain in airtight silos — which are basically water tanks of varying size

10. Livestock breeding of cattle and goats	
Introduction	The effects of climate change on livestock are related to the consequences of changes in temperature (affecting food conversion, weight gain and reproduction), rainfall (affecting access to water and pastures), and humidity (affecting disease and pest incidences). Cattle and goats are kept under pastoral and mixed small holder farming systems. The naturally grazed Zebu and Ankole-Watusi cattle, produce high quality beef, but low yields; the Boran are low maintenance, adaptable to dry rangelands low quality feed and is disease resistant; the Brahman are fast growth, tick tolerant and adapted to a wide range of climatic conditions and provide high beef yield; and the Bonsmara produces high yield of beef. There are 12.5 million goats. Goat breeds include the Small East Africa Sea 20-25kg; Mubende 30-35kg; Kigezi 25-30kg; and Boer 60-100kg. Efforts to introduce climate resilient breeds may involves trade-offs with productivity. Decentralised establishment of local artificial insemination points enables innovation that responds to the local climate context. Livestock breeding for disease control, climate resilience and improved production are key priorities mentioned in various national development documents including the National Development Plan II 2015/16 to 2019/20, Uganda's INDC 2015, the National Policy for Disaster Preparedness and Management 2012, and Uganda's NAPA
Institutional and Organizational Requirements:	Ministry of Agriculture, Animal Industry and Fisheries has the mandate for developing and coordinating programs for livestock including regulation of breeding and distribution of superior seed to avoid adulteration. Livestock improvement for climate change adaptation is led by NARO to identify and generate semen and embryos of high quality and monitor climate resilient traits in progeny. The National Animal Genetics Resources Centre & Data bank is also crucial in systematic gathering synthesis and dissemination of livestock information in response to climate change. NAADS, local governments and donor supported programs to: • build capacity of farmers organisations and extension officers in semen/ embryo and calf handling and care. • set up parish-level breeding centres and local pastoral organisations • manage the sharing of improved breeds among villagers Sustainable Land Management for range management The private sector will play a key role in providing breeding, health and nutrition services.

Size of beneficiaries group	The key producing areas are found in the "cattle corridor", extending from South-Western to North Eastern Uganda. This corridor covers the districts of Ntungamo, Mbarara, Mpigi, Kiboga, Luwero, Apac, Lira, Soroti, Kumi, Mbale, Moroto, and Kotido (INFOTRADE, 2011) and particularly the Karamoja sub-region in the north. Goat are in farmers in rural areas around Lake Victoria and Lake Kyoga and Southern Uganda.
Operation and maintenance	• Research to understand cattle response to climate change and the trade-offs between tolerance and productivity • Generation and Cryo-preservation of semen and embryos of elite goat and cattle breeds. • Production, storage and distribution of semen/embryo handling kits including liquid nitrogen • Multiple Ovulation and Embryo Transfer (MOET), artificial insemination (IB) or natural insemination (INKA) of local female animals. The superior calves /kids are used as first local seed. • Setting up of Village Breeding Centres (VBC) get, using embryo transfer (ET) • Managing the distribution of improved breeds among beneficiaries • Ensuring timely healthcare and nutrition of improved progeny • Capacity building of artificial insemination technicians, village farmer organisations and extension officers in semen/embryo and calf handling and care: nutrition, disease management, parasite control. • Foster development of breeding community based organisations Monitoring of breeding activities for climate resilience and performance of the progeny.
Advantages	• Reduced loss of livestock in drought and extreme climatic conditions leading to stable livelihoods and income. • Drought tolerant breeds are potentially tolerant to heat having slow metabolic rate and therefore low demand for food and water. • Co-development and promotion of drought resistant pastures.
Disadvantages	• The cost of the technology is high as it involves research not only on the livestock, but also the associated nutrition and disease control requirements. • Breeding requires training as well as inputs, to which smallholders and pastoralists may lack access, or financial resources. • Equipment for transferring superior breeds to rural communities may not be easily available. The process requires a strong extension system with sufficient numbers of well qualified livestock specialists. • Technical and institutional capacity is insufficient to conduct decentralised livestock breeding

	• Information transfer mechanisms are not strong enough to support farmers in decision-making • Livestock insurance has not developed sufficiently to protect farmers from extreme weather losses. • Production costs may increase yet market prices may not offset these increases
Capital costs	
	Farming of breeds adapted to climatic changes comes with additional overhead expenses including immunizations; utilities and repair for animals housing and storage buildings; feed and water; veterinary care and feeding. A government project for livestock genetic resources development for 5 years was budgeted at 17,724,704.1 UGX (in 2002).
Development impacts, indirect benefits	
Economic benefits	• Reduced loss of livestock during extreme climatic conditions, therefor stable livelihoods for pastoralists and stable income for the nation. • Improved need for advisory support at the local level on livestock care may create new employment opportunities. • Increased demand for improved stock may create business opportunity for private artificial insemination specialists, veterinary doctors and researchers.
Social benefits	• Food security • Health security- reduces risk of livestock related diseases. • Less risk of being quarantined • Collaborations between community-based organisations, researchers, farmers, academia and government
Environmental Benefits	• Low dependence on biochemical inputs • Improved capacity in managing drought resistant breeds may improve farmers pasture and water management practices. • Breeding of larger animals with large intakes of food, leads to higher emissions of methane.
Local context	
Opportunities	• Livestock improvement for climate resilience, disease and pest resistance and drought tolerance is mentioned in The National Policy for Disaster Preparedness 2010, NAPA and Uganda's INDC 2015, the National Development Plan II 2015/16 to 2019/2020. • Livestock distribution is a key focus of Operation Wealth Creation

	• The sector has attracted vast investments of over US$ 176 million (UIA Database) from both local and foreign investors. The investments include ranching, meat processing. • Formation of The Uganda Beef Producers Association • Establishment of Two beef plants in Nakaseke and Lyantonde. • Prioritization of importation of new breeds of cattle e.g Tooro Kingdom
Barriers	• The lack of handling kit for semen and embryos • Low Capacity and low distribution of technicians countrywide. • Water is still the biggest challenges of managing livestock especially cattle • Inadequate technical knowledge in handling improved breeds. • Materials used and hiring the technicians is quite costly • A lot of counterfeit drugs on the market
Market potential	The major export markets for the beef products are Kenya, Tanzania, Rwanda, Southern Sudan, D.R. Congo and Burundi. Egypt-Uganda Food Security (EUFS), the private beef processing company exported its first 50-ton shipment of Ugandan beef and forecasts of $50 million in revenue are estimated.
Timeframe	Long term: >5 years
Acceptability to local stakeholders	Livestock especially cattle, symbolize wealth and status and reduction in losses related to climate change are of key importance to all. Local varieties may be preferred for cultural reasons to improved breeds, although this is not likely to be a major hindrance. Programs to create awareness of the dangers of climate change and to disseminate knowledge on the value of improved livestock breeds will help prepare livestock keepers to demand for improved breeds

C. FORESTRY TECHNOLOGY FACTSHEETS

1. **Integrated forestry-crop-livestock systems.**	
Introduction	The Integrated Forestry-crop-livestock systems technology has been tested and documented in brazil and Nepal. According to Yadav, (2014), the system produces food year-round, and provides continuous employment for unskilled labour to tend crops and livestock. The system is highly labour-intensive and depends to a large extent on the available forests and rangelands. Forests are as integral a part of the farming system as arable land and livestock. Forests supply fuelwood, fodder, compost, timber, poles, and food to the system. Thus, crop production, animal husbandry, and forestry constitute the main closely and inseparably integrated components of the mountain farming system. There are some farmers practicing the Integrated Forestry-crop-livestock systems technology in Uganda, but their experiences are not reported and or documented. Integrated Forestry-crop-livestock systems involve integration of forest, crop and livestock enterprises managed within the same system. It consists of a great variety of crops, including perennial fruit and timber/fodder trees and different species of livestock on the same piece of land (Yadav, 2014).
Institutional and organizational requirements	The promotion of the Integrated forestry-crop-livestock systems in Uganda requires collaboration among the mandated institutions in both forestry and agricultural sectors to effectively deliver on the support for such integrated system. The key institutions which will deliver this support based on their mandates are: • Ministry of Water & Environment; the Forestry Sector Support Department; Ministry of Agriculture, Animal Industries and Fisheries. These will provide the required policy guidance. • National Forestry Authority, Uganda Wildlife Authority and Local Government. These provide support in terms of policy & legislative regulation and enforcement. In addition, the local governments provide extension and advisory services. • Private sector – these invest in the technology.
Size of beneficiaries	1000 households
Operation and maintenance	It requires specialized skills in both forestry, crop and livestock management. Thus, specialized labour force with knowledge and skills in these aspects is required and certainly needs regular re-tooling/training.
Advantages	• The system produces food year-round, and provides continuous employment for unskilled labour to tend crops and livestock. • Increased production of meat without opening up of large new areas of land; • Reduced weeding costs, largely because the cattle graze on the weeds;

	• Production of organic manure to fertilization of the trees and reduction of costs associated with use of inorganic fertilizers; • Increased rate of nutrient recycling through application of urine and manure; • Provision of additional income to plantation cultivators through increased productivity per unit of land; and • Savings in foreign exchange on fertilizers and meat imports.
Disadvantages	• Overstocking of livestock on the forest units could result into degradation; • It requires extra effort in terms of planning and management of the specific enterprises with the integrated system.
Capital costs	
Cost to implement adaptation option	The estimated average cost to put in place 1 ha of integrated forestry-crop-livestock system 3000-5000 USD.
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs for specialized skills in tree and forest management, but also livestock management. • The technology provides opportunities for investment in the supply chain for inputs required in both forestry and livestock management, but also provision of associated extension and advisory services at production, value addition and marketing. • Can reduce public expenditure on fertilizers because the system provides fertilizers i.e. livestock manures, which are ploughed back into the tree/forest plantations.
Social benefits	• Income a) Increased profits as result of higher yields and lower profits b) Better distribution and diversification of revenue throughout the year, generating a more balanced cash flow c) Risk mitigation in production and prices due to diversification • The knowledge and skills of the people involved in the implementation of the technology would be enhanced. Overtime they can train others to learn and apply the skills elsewhere the technology can be up-scaled. • The technology provides diversified products from forestry, crop and livestock, which impact of overall health of the community. Besides, it promotes changes in ecosystem structure and function that affect disease risk and transmission.

	• Being an integrated system, it provides opportunities for both genders i.e. male and female. Thus, each gender can be targeted to deliver on skills and chores which meet their needs and capabilities. However, it requires pro-activeness and consciousness to ensure that this is done.
Environmental benefits	It's possible to sustain the farming system with due consideration that the components there in complement each other in terms of nutrient and water flows and utilization as determined by the practices and management. For instance, the livestock manure can be ploughed back to fertilize the trees and or the tree forage/fodder trees can be used to feed the livestock.
Local context	
Opportunities	The community leaving adjacent to the forests can provide the labour (i.e. both skilled and unskilled) to manage the system.
Barriers	• Requires attitude changes with due consideration that forests should and or must be managed without livestock. Thus, targeted training, awareness and exposure in necessary to change these attitudes. • There exist knowledge gaps in respect to the optimum stocking capacity for different livestock types, which can be integrated within per unit hectare of the forests. This requires further research. • It requires proper land use assessment and management planning, which must be done by experts to appropriate location of both forestry and livestock enterprises. Payment for such services could be expensive for smallholders. • The livestock must have adequate availability of fodder in the right quality and quantities for maximum productivity of the livestock enterprise. • Stringent measures are required to avoid the negative effects of livestock on the tree plantation when they graze on the tree forage.
Market potential	The technology has a national wide potential across the different forest landscapes.
National status of the technology	The technology is still practice at small-scale especially among few commercial tree growers in central Uganda. They are trying out this through their own innovativeness and initiative with minimum support and guidance from Government extension services on agriculture and forestry with consideration of the integrated approach.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Uncertain

2. **Diversification in forest species plantations**	
Introduction	Diversification in forest species plantations is not very common in Uganda, much as it has been reported as a potential technology to advance adaptation of forest plantations to climate change and variability impacts on trees and forests. The technology has been tested in South Africa and has resulted in positive results. It can potentially be up-scaled in Uganda with due consideration of the similar tropical conditions. This involves forest plantation with mixed tree species stands as opposed to common pure stands. It requires the right selection of the tree species which can co-exist and is applicable in both plantation and natural forests.
Institutional and organizational requirements	The promotion of the forest diversification technology in Uganda is by the key forestry sector institutions based on their mandates. The following are some of them: • Ministry of Water & Environment and the Forestry Sector Support Department for policy guidance. • National Forestry Authority, and Local Government. These provide support in terms of policy & legislative regulation and enforcement. In addition, the local governments provide extension and advisory services. • Private sector especially the individual tree growers and community forest owners.
Size of beneficiaries	1 400 000 households
Operation and maintenance	Specialized skills needed for effective management of the tree species in the diversified forestry system to deliver on the desired objectives. Thus, specialized labor force with knowledge and skills in these aspects is required and certainly needs regular re-tooling/training.
Advantages	• Pests and diseases control with due consideration that these are mixed stands which limit proliferation of pests and diseases impacting/affecting a specific tree species • The trees species mix can be selected based on the grower's interests • The harvesting time for the forest products can be staggered based on the time of maturity for the selected tree species in the forest mix; • Provides a range of timbers for uses such as rough construction up to high quality joinery.
Disadvantages	There is possible competition among tree species especially if mutually compatible species are not identified;
Capital costs	
Cost to implement	The estimated average cost to put in place 1 ha of diversified forestry is 2000-4000 USD.
Development impacts, indirect benefits	
Economic benefits	• Creation of employment in the management of the various value chains for the diversified tree species in respect to tree nursery management, land preparation, pruning, plantation maintenance and harvesting.

	• It creates investment in forestry production inputs, equipment and production transformation industry
Social benefits	• It increases the income earned and inputs saved through trees protected from pests and diseases. • Stakeholders involved in technology will benefit from the knowledge and skills • It can improve medicinal plant conservation, domestication and propagation. The use of the medicinal plants (especially in cases were indigenous tree species are promoted in the diversification) by the communities has a positive impact on the health. • Much as the technology is applicable for both men and women. It's largely prohibitive for women due to socially and culturally constructed attitudes, for instance women working alone deep in the forest planting trees. Therefore, in order to have effective women participation in the technology applications, such barriers must be broken. Otherwise, women could equally be targeted to participate in value chains or requirements for the technology like management of the tree nursery beds for generation of seedlings which will be used in the technology.
Environmental benefits	• It promotes biodiversity conservation within the forest landscapes; • It enhances the appearance of the forest landscape, creating wildlife habitats.
Opportunities	• There exist forest adjacent communities usually organized as groups/associations which can easily mobilized to participate in the interventions e.g. seedling production thereby reducing the costs • The beneficiaries such as the forest adjacent community groups/associations can contribute to maintenance activities for the plantation • The technology links in well with the Government of Uganda's priorities in respect to forest conservation and land scape restoration.
Barriers	No information found
Market potential	No information found
National status of the technology	No information found
Time frame	No information found
Acceptability to local stakeholders	No information found

3. Promoting forest-based enterprises e.g. bee keeping/apiary; butter fly farming, fruit trees production; ecotourism.	
Introduction	Forest based enterprises are described as enterprises that have a direct linkage and base on the forest, thus their success directly depends on the trees and the forests. The technology has been applied in several countries in the tropics (i.e. east and central Africa) and is reported as effective in building resilience of communities against climate change as it provides alternative livelihoods and reduces over dependence on the of forest adjacent communities. In Uganda the technology has been piloted and promoted by National Forestry Authority and Uganda Wildlife Authority through collaboration with Non-Governmental Organizations and the Local Governments among others. The technology is community based and established with the buffer zones and within the protected forests so long as it has minimum negative impacts on the forest in terms of degradation. Thus, overall the selected enterprises must be promoting forest restoration and conservation and at the same time improving the livelihoods of the forest adjacent communities through income generation and food security. The technology is largely managed by the forest adjacent communities after they are equipped with the requisite knowledge and skills to management the enterprises efficiently and effective.
Institutional and organizational requirements	In Uganda over the years since the forestry reforms in 2001-2003, various forest responsible bodies have promoted forest-based enterprises. Some these are enlisted as follows: National Forestry Authority – has promoted the enterprises in collaboration with the civil society (both local and international) and local governments. This is within the framework and guidelines of collaborative forest management targeting forest adjacent communities living near the central forest reserves Uganda Wildlife Authority has promoted the forest-based enterprises targeting communities living adjacent to the national parks in various parts of the country. Commercial Tree Companies, Private tree growers/members of the Uganda Timber Growers Association have promoted forest-based enterprises within the forest plantation and also targeting participation of the surrounding communities.
Size of beneficiaries	450,000 households
Operation and maintenance	The maintenance of the enterprises can be made easy by training farmers' representatives of the forest adjacent communities.
Advantages	• It allows for generation of multiple forest products, thus some a short and medium terms – especially those from the forest-based enterprises; • It provides the directly dependent forest adjacent communities will alternative income and livelihood

	opportunities, thereby reducing over dependency on the forest resources, hence encroachment on the forest;
Disadvantages	• Management of each of the selected enterprises requires specialized knowledge and skills; • The process of development and implementation of the joint forest co-management framework (i.e. collaborative forest management) within which the forest-based enterprises are promoted is time consuming and costly;
Capital costs	
Cost to implement adaptation option	The average estimated cost to put in place 1 ha of integrated forestry-crop-livestock system 500-2000 USD.
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in seedling preparation, land preparation, plantation, maintenance, harvesting and marketing of products from the forest-based enterprises. • Can create investment in inputs, equipment required for establishment of the various enterprises – apiary, ecotourism, fruit trees. Further investment is in training for generation of specialized skilled labor for effective and efficient management of the enterprises along the value chain i.e. from production, harvesting, storage, packaging and marketing. • Can reduce public and private expenditures in respect to monitoring and surveillance around the forests, because this becomes a shared role between the responsible body and the beneficiary community.
Social benefits	• The enterprises generate additional alternative incomes income through sale of the products. • The stakeholders involved in the application of the community-based forest enterprise benefit from the knowledge and skills associated with their management. • The products (e.g. honey, fruits, mushrooms,) from some of the selected enterprises have positive impact on the nutrition and health in the community when consumed as part of the diet. • The technology promotes participation of both men and women in terms of application. The challenge is that women may not own the enterprises because often few women own the land on which these enterprises are established.
Environmental benefits	Increased biodiversity especially within the forest buffer zones for protected forests.
Local context	
Opportunities	• The technology is well understood by local farmers and the forest adjacent communities;

	• There exist farmers associations/cooperatives which can reduce initial investment costs by sharing the cost of seedling production, • The maintenance of the enterprises can be done by beneficiaries themselves, thus reducing the overall maintenance costs.
Barriers	• Lack of access to transport, handling, processing, and marketing infrastructure, bans/restrictions on timber products, hinders the marketing of forest-based enterprises products and services agro-forestry products and services. • Any of the identified enterprise requires requisite knowledge and skills for effective application and management of the enterprises. Thus, accessing and attracting such knowledge and skills may be expensive by the responsible bodies. • Effective implementation of the enterprises to ensure maximum benefits and desired impacts in terms of improved livelihoods, requires to have value addition and market linkages for the associated products. Unfortunately, these are not yet developed. • The unregulated bush burning and stray livestock destroy regenerated trees, especially in Northern Uganda, yet the ordinances and byelaws for regulation of wildfires are lacking or inadequately implemented.
Market potential	The technology has a national wide potential, thus its applicable in buffer zones along protected forests found in all forest landscapes.
National status of the technology	The technology has been largely tested and promoted in various central forest reserves in the country several by the Non-Government Organization in collaboration with the National Forest Authority. The Uganda Wildlife Authority as well has promoted the technology with communities living adjacent to the National parks in Uganda.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population especially those living adjacent to forests and protected areas/national park.

4. Forest products management to increase resilience to temperature rise/humidity change and insect/disease vulnerability – wood/biomass product seasoning, treatment/protection, dimensions	
Introduction	Over the years, there is progressive investment in forest plantation for timber production in Uganda to bridge the gap and demand for timber nationally and globally. This is being promoted through private sector investments by commercial tree growing companies and also through structured support to private growers through the Sawlog Production Schemes Phase I and currently phase II. However, the forestry industry in Uganda is still by large characterized with low value addition on forest product value chain and industrial development. This is a missed opportunity for advancement of the timber value chain and industry, which would create employment opportunities at the community and local levels and increased income and revenue generation from the timber value chain. For instance, most of the high value timber is exported as raw materials to foreign countries (in Europe, China) and imported back as high value furniture products. The private commercial tree growing companies apply efficient technology and machinery in timber harvesting and processing. However, such technology is expensive and therefore not appropriate and or accessible for smallholder tree growers. There are some small-scale initiatives for processing of timber into furniture and other products for the construction sector locally and nationally. However, these overall apply harvesting and processing technologies that are wasteful and hence less efficient and effective, thereby compromising the overall sustainability of the forestry sector. Besides, the current climate change and variability impacts especially the increasing average temperatures and humidity promote pests and diseases infestation for processed timber resulting into poor quality and destruction of the timber and products, thus negatively impacting on the overall sector performance in terms of revenues from timber trade. Therefore, promoting access and application of efficient and effective technology in timber harvesting and processing will contribute to adaptation in the forestry sector, but also open up employment and income generation opportunities through advancing the timber value chain and industry. Some of the technologies especially for the private smallholder tree growers are: portable saw mills.
Institutional and organizational requirements	The promotion of the forest diversification technology in Uganda is by the key forestry sector institutions based on their mandates. The following are some of them: i) Ministry of Water & Environment and the Forestry Sector Support Department. These will provide the required policy guidance and enforcement. ii) Private sector especially the commercial tree growing companies have applied the technology in timber harvesting and processing.

Size of beneficiaries	2000 households
Operation and maintenance	It requires specialized skills in maintenance of the machines and equipment.
Advantages	The technologies and machinery are more efficient and effective, thus wasting unnecessary wastage during harvesting and processing of timber.
Disadvantages	The required equipment has to be imported. Thus, they may not be affordable for smallholders.
Capital costs	
Cost to implement adaptation option	Estimated cost range for complete set of a portable saw mill costs 2500-5000 USD including shipment costs.
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs for operations of the equipment for harvesting, seasoning of forest products such as timber • Can create investment in forestry production inputs, equipment and production transformation industry
Social benefits	• It increases the income through avoided wastage as a result of improved efficiency and effectiveness in harvesting and processing of timber. • The knowledge and skills of the people involved in the implementation of the technology would be enhanced. Overtime they train others to learn and apply the skills elsewhere the technology can be up-scaled. • Most of the equipment and tools promote participation of women. If the latter is to participate in the utilization of the equipment, then there must be affirmative action to encourage their participation. Besides, the attitude and any other barriers, which limit women from operating the equipment/machines should be broken through massive targeted awareness.
Environmental benefits	It promotes biodiversity conservation within the forest landscapes.
Local context	
Opportunities	Private commercial tree growing companies are already applying some of the technologies and machinery in timber harvesting and processing. Thus, provide opportunity for learning and mentoring.
Barriers	• Upfront costs for purchase of equipment and machinery is high; • The equipment/machines have to imported and they are expensive for majority of the users, especially the smallholder tree growers; • Inadequate skilled labor to effectively operate the equipment and or machines, especially for the smallholder

	tree growers; • The smallholder tree growers have inadequate financing to export the appropriate technology and machinery.
Market potential	The technology has a national wide potential, thus it's applicable in all forest landscapes across the country.
National status of the technology	Equipment and machinery are by large used by commercial tree companies. These are not applicable for smallholder tree growers. Thus, equipment and machines applicable for the latter have not be tested on large scale.
Timeframe	The implementation can start immediately
Acceptability to local stakeholder	Well accepted by the local population

5. Application/use of drones in forest management for effective monitoring and reporting.	
Introduction	GPS, small drones were initially developed for military use, but are increasingly being deployed in civilian applications, including mapping, monitoring and managing habitats and natural resources. Although small drones are not used widely in environmental applications yet, their use is likely to increase rapidly as their prices decrease and the technology becomes easier to use. GPS, small drones were initially developed for military use, but are increasingly being deployed in civilian applications, including mapping, monitoring and managing habitats and natural resources. Although small drones are not used widely in environmental applications yet, their use is likely to increase rapidly as their prices decrease and the technology becomes easier to use. According to Newcome, (2004) drones (such as the small fixed-wing aircraft) were initially developed for military use. However, they are increasingly being deployed in civilian applications, including mapping, monitoring and managing habitats and natural resources. Various reports indicated that often, drones also referred to as, 'remotely piloted aerial vehicles' have been used in the mapping and monitoring fires and forest stands (Ambrosia, et al., 2003, Casbeer et al., 2006, and Hinkley et al., 2011). The drones were recently introduced technology in Uganda and by far have been used in the documentation of proceedings of social events through taking automated aerial photo graphs.
Institutional and organizational requirements	The following key institutions are instrumental in the promotion of the application of the technology in forest monitoring based on their mandates, roles and responsibilities: Forestry Sector Support Department – for policy guidance and regulation of the technology; Uganda Police – Provides licenses for use of the technology; National Forest Authority and the Uganda Wildlife Authority – can apply the technology to support the monitoring and surveillance initiatives in the Central forest reserves, the forest in the national parks, respectively; Uganda Revenue Authority regulates the importation of the technology into the country; Uganda Timber Growers Association and Commercial Tree Growing Companies can use the technology the monitoring and surveillance initiatives in their plantations.
Size of beneficiaries	No information found
Operation and maintenance	It requires specialized skills for maintenance of the saver on a regular basis. These can be outsourced or otherwise staff can be trained to take this as additional role.
Advantages	• It supports and makes forest monitoring and routine patrols easier. Thus, a drone can easily traverse the whole forest faster by taking aerial photographs. Physical monitoring can be done based on the results from analyses of the photos, thus making forest monitoring more effective. • The maintain costs for the drone are much cheaper compared to maintaining a team of forest rangers.

	• They facilitate quick decision making and action/responses as the photographs taken are sent to a centralized server.
Disadvantages	The drone's technology is not easily accessible and can be expensive because they are imported into the country
Capital costs	
Cost to implement adaptation option	The estimated cost of a relatively low cost for tropical forest monitoring is at 2000 USD (Paneque-Gálvez, 2014).
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in the application and use of the technology and the associated supply chain for the technology to the clients who want to use. • It requires investment in capacity building of experts who will manage the technology and also interpret the data collected for decision making for timely implementation of appropriate response actions. • The technology if effectively applied and integrated can reduce on the costs for routine monitoring and surveillance in forests.
Social benefits	• Savings through early response actions implemented based on the results from the monitoring and evaluation reports. • The knowledge and skills of the people involved in the implementation of the technology would be enhanced. These train others to learn and apply the skills elsewhere the technology can be up-scaled. • The technology helps in monitoring and reporting of emerging pests and diseases through taking aerial photos, there informing decision making in respect to implementation of appropriate response actions to manage the pests and diseases. • The technology can easily be applied by both men and women. Thus, either men or women can be employed as laborers in the implementation of the technology. Hence, both genders can equally participate in the supply chain and application for the technology.
Environmental benefits	The operations with the application of the drones is quiet with limited disturbance of wildlife.
Local context	
Opportunities	There are several commercial tree growing companies and individuals who are interested in applying the technology to strengthen their forest monitoring functions.
Barriers	• Poor access to electricity. Often the forests are located in the rural areas where there is limited and or

	irregular aces to electricity thus, this can potentially limit the effective application the technology unless measures for alternative sources of energy are established. • The technology requires practical specialized skills for its effective application/use.
Market potential	The technology has a national wide potential as various forest responsible bodies (e.g. National Forest Authority, Uganda Wildlife Authority, and Private Tree Growers – organized as the Uganda Timber Grower's Association) could be interested in using it.
National status of the technology	In Uganda, drones have been used by the security agencies but also in the entertainment industry for photography and video coverage of wedding functions and parties.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population.

6. Advancing biotechnology to produce hybrids which are adapted to Uganda's climatic conditions.	
Introduction	Biotechnology is applied in various disciplines (crops, livestock) targeted at development improved varieties and or breeds. Equally, its applicable to develop clones which are more productive for generation of timber and other forest products; resistance to pests and diseases. This is therefore a great opportunity, which can be tapped into for development of appropriate tree species clones that adapted to the local climate conditions in Uganda. Besides, the impacts of climate variability and change are already visible and impacting on the forestry sector in Uganda. This is not therefore surprising that the National Forestry Research Institute (NAFORRI) prioritized biotechnology in their strategic plan for the Tree Improvement and Germplasm Research Programme to achieve the following: • Improvement of suitable trees for health, food security and nutrition; • Improvement of appropriate trees for timber (and energy); • Improving trees for pest and disease resistance.
Institutional and organizational requirements	Biotechnology development and promotion as applied to forestry in Uganda is spearheaded by the NAFORRI through its Tree Improvement and Germplasm Research Programme and the National Forestry Authority through National Tree Seed Centre. Other institutions which support this initiative are: The Consultative Group on International Research (CGIAR); and the International Union of Forestry Research Organizations (IUFRO),

	International Tropical Timber Organization (ITTO); Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Regional Universities Forum for Capacity Building in Agriculture (RUFORUM),
Size of beneficiaries	1 400 000 households
Operation and maintenance	The technology requires specialized research skills in the following aspects: Biometrics; tree breeding; Clonal Tree nursery management; Molecular biology/genetics. The maintenance of field sites is enhanced through minimum practical training of host farmers.
Advantages	• Biotechnology hastens the process of genetic breeding. Thus, new tree species varieties and clones can be developed in short period of time compared to the normal plant breeding approaches. • The technology is applicable to all types of tree species. Therefore, it can be tailored to the different needs and priorities of the breeding programs. • Biotechnology can be tailored to the prevailing environmental conditions and changes for instance in respect to climate variability & change and the associated impacts in respect to temperature change, increased pests and diseases. • Overall it contributes to increased productivity, lower costs to consumers, and trees modified for easy processing or specific production values • It helps in the preservation and conservation of the forest biodiversity
Disadvantages	Biotechnological innovations have risks associated to biosafety and the effects of transgenic plants on the resistance of pathogens and on the natural ecosystem, particularly the question of genetic exchange between domestic and wild populations (Sedjo, 2011).
Capital Costs	
Cost to implement adaptation option	No information found
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in seedling preparation, land preparation, plantation, maintenance and harvesting. • It creates investment in capacity building, particularly training of experts in biotechnology. Furthermore, interesting the private sector to invest in tree seeds production industry for the hybrids generated that are adapted to the climate change conditions in Uganda. • The technology will reduce public expenditure on imported tree seeds, which are very expensive and yet may not be adapted to the climatic and ecological conditions in Uganda.

Social benefits	• It increases the income earned and inputs saved through improvements in breed that are fast growing and resistant to climate change and variability. • The knowledge and skills of the people involved in the implementation of the technology would be enhanced. • Helps in the control of pests and diseases especially when pest and diseases resistant. • The technology can easily be applied by both men and women. Thus, either men or women can be employed to provide both skilled and unskilled labor in the implementation of the technology. Hence, both genders can equally participate in the supply chain and application for the technology. Despite this, there are few women in leadership and strategic position in the forestry sector. Therefore, affirmative action should be considered to advance the participation of women in the implementation of the technology.
Environmental benefits	It promotes forest biodiversity conservation.
Local context	
Opportunities	• NAFORRI has the basic infrastructure, which is a spring board to develop and advance the technology; • NAFORRI has already prioritized the technology and thus developed a 10 years strategic plan for the Tree Improvement and Germplasm Research Programme whose key outputs would be achieved through application of the technology (i.e. biotechnology).
Barriers	• Requires specialized technical knowledge and skills for effective application of the technology; • Requires long term research to develop and generate the desired results and outputs
Market potential	The products from the technology has a national and east Africa regional wide potential.
National status of the technology	NAFORRI has already prioritized to promote the technology with some pilots and infrastructure on station, research that is ongoing. The 10 strategic plan Tree Improvement and Germplasm Research Programme underscores the technology and stipulates key outputs and outcome targets. However, there various gaps (e.g. Limited staffing levels to address the strategy and respond to rapidly emerging opportunities; Insufficient infrastructure e.g. Lack of laboratories, stores; and Financial insufficiency to operate and expand the activities of the programme) which need to be addressed to step up the technology.
Timeframe	The implementation can start immediately
Acceptability to local stakeholders	Requires a lot of awareness for the local population to appreciate the benefits of the technology.

7. Enrichment planting for forest restoration and increased productivity and benefits.	
Introduction	Enrichment planting is a strategy for increasing the planting density (i.e. the numbers of plants per hectare) in an already growing forest stand (Neufeldt, 2015). It is a common technology/practice used for increasing the density of desired tree species in secondary forests for purposes of forest restoration and enhancement of overall value of the forest in terms of productivity (Tigabu et al., 2010). It's done through planting of high value timber native/natural tree species in existing but degraded secondary forests (Aide et al. 2000 and Paquette et al., 2009). Thus, it protects the secondary forests as it combines both artificial planting and natural management of the existing forest matrix through mimicking natural gap dynamics. It allows for the maintenance of a vegetation structure composed of different layers and complex assemblages of plants. Overall, it retains the forest character and associated biodiversity and ecological services (Michon et al. 2007). In Uganda enrichment planting has been applied in Northern Uganda and has been being promoted by the International and National Civil Society Organization (i.e. International Union for Conservation of Nature, and World agroforestry Centre) in collaboration with the Ministry of Water and Environment and the district local governments. The technology involves replacement of tree seedlings in degraded forest patches with a purpose of increasing overall value of the forest. The same forest species are replaced and usually, it's applied for natural forest species.
Institutional and organizational requirements	The promotion of Enrichment planting technology in Uganda is being advanced through collaboration between Non-State actors and key forestry sector institutions such as the Forestry Sector Support Department, national Forestry Authority, Local Governments and the Community and Private Forest Owners
Size of beneficiaries	1 400 000 households
Operation and maintenance	It requires knowledge and skills enhancement for identification and selection of wildlings for planting and related management to ensure that they grow properly. This is possible through targeted training of farmers and selected community-based facilitators.
Advantages	• It's a cheap and cost-effective technology, which can be easily adapted and applied by the responsible bodies and forest adjacent communities because wildlings are used as planting materials. These are readily available in the forest and can be easily identified and or selected. Furthermore, the costs involved are reduced because the area to be planted does not require lengthy and widespread clearing and preparation • It promotes biodiversity conservation especially for cases were threatened high value natural trees species are re-introduced.

	• It contributes to forest restoration and enhances the overall forest productivity. Hence, highly valuable timber or non-timber products can produce and sold or used locally for construction or artisanal products sold at markets by the responsible bodies for income generation. • Because enrichment planting is associated with the protection of the primary natural forest and the establishment of the secondary forest, this overall augment the provision of optimal levels of all ecological services.
Disadvantages	• It the seedlings for planting are inadequate and therefore requires investment in tree nurseries for indigenous species for multiplication of the required numbers of seedlings. • Most indigenous tree species take long to mature i.e. 15-25 years
Capital costs	
Cost to implement adaptation option	The estimated average cost of restoring 1 ha of forest through enrichment planting 2000-4000 USD.
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in seedling preparation and nursery management, land preparation, plantation, maintenance and harvesting • Can create investment in forestry production inputs, equipment and production transformation industry
Social benefits	• It increases the income earned through the sale of forest products derived through enhanced productivity. • The stakeholders involved in enrichment planting will benefit from the knowledge and skills. • It can improve medicinal plant conservation, domestication and propagation. The use of the medicinal plants by the communities has a positive impact on the health. • Much as the technology is applicable for both men and women. It's largely prohibitive for women due to socially and culturally constructed attitudes, for instance women working alone deep in the forest planting trees. Therefore, in order to have effective women participation in the technology applications, such barriers must be broken. Otherwise, women could equally be targeted to participate in value chains or requirements for the technology like management of the tree nursery beds for generation of seedlings which will be used in the technology.
Environmental benefits	• Increasing water infiltration and slowing runoff flow, stabilizing and protecting stream banks from erosion, filtering pollutants from runoff water, shading streams for controlling. • Furthermore, it contributes towards conservation of the natural forest biodiversity.

Local context	
Opportunities	• There exist forest adjacent communities usually organized as groups/associations which can easily mobilized to participate in the interventions e.g. seedling production thereby reducing the costs • The beneficiaries such as the forest adjacent community groups/associations can contribute to maintenance activities for the plantation • The technology links in well with the Government of Uganda's priorities in respect to forest conservation and land scape restoration.
Barriers	• It involves specialized skills and knowledge for its application. Therefore, targeting awareness and training for the key stakeholders is required. • The key benefits from enrichment planting realized in the medium term at least five to ten years after establishment. This means that farmers must be prepared to invest in their establishment and management during several years before the main benefits are generated. • Limited access to transport, handling, processing, and marketing infrastructure, bans/restrictions on timber products. • The unregulated bush burning and stray livestock destroy regenerated trees, especially in Northern Uganda, yet the ordinances and byelaws for regulation of wildfires are lacking or inadequately implemented.
Market potential	The technology and the forest products have a national wide potential
National status of the technology	The technology is applicable in all forest landscapes across the country. Currently it's largely applied in the central forest reserves and protected areas managed by the National Forestry Authority and the Uganda Wildlife Authority. Likewise, several community and private forest owners have applied the technology in their plantations.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population.

8. Use of hydrogels to advance adaption to prolonged droughts impacting on forest plantations.	
Introduction	Hydrogels are water-retentive chemicals, thus hydrophilic polymers that have been used for providing a possible solution for conservation irrigation and rainwater in such desert regions. In the process they form gels that absorb many times their weight of water and store it for relatively long period of time. Hydrogels promote soil water-holding capacity thereby reducing the watering requirements for plants, particularly in sandy soils (Ekebafe et al., 2011). It earlier studies, it's reported that hydrophilic polymers reduced nutrient losses from soils, reduced soil salinity, especially in sodic soils, and enhanced plant growth by allowing nutrients, incorporated into the hydrogel matrix, to release to the plant as needed (Shakesby, 2000). In Uganda, the use of hydrogels in advancing adaptation of trees and or forest plantations for adaptation to prolonged was piloted through on-station and field collaborative research that involved National Forestry Research Institute, Makerere University and the Georg August University-Goettingen, Germany. Thus, the study focused on, the effect of super absorbent polyacrylate (SAP) hydrogel amendment to different soil types on plant available water (PAW), evapotranspiration and survival of Eucalyptus grandis, Eucalyptus citriodora, Pinus caribaea, Araucaria cunninghamii, Melia volkensii, Grevil-lea robusta, Azadirachta indica, Maesopsis eminii and Terminalia superba. The experimental trials were established in the dry lands of Nakasongola, Kiruhura, Mpigi and Mubende districts while the green house trials have been setup using the facilities of NaFORRI in Kifu, Mukono and Goettingen University, Germany The results indicated that hydrogel positively influenced tree survival against drought conditions. Thus, it prolonged tree survival compared to the controls. Probably, the soil amendment with SAP decreased the hydraulic soil conductivity that might reduce plant transpiration and soil evaporation (Agaba et al., 2010). Hydrogels are have abilities of absorbing and retaining water. They have been reported as used in establishment of tree seedlings and transplants in the arid regions and in increasing plant survival and overall dry weights, particularly for less drought tolerant tree species (Orikiriza et al., 2013). They can absorb and store water up to 400 times their own weight, and consequently, reduce water stress for the trees (Bouranis et al. (1995). An example of a hydrogel include: STOCKOSORB and super absorbent polyacrylate (SAP) hydrogel amendment.
Institutional and organizational requirements	Some of the institutions which have been involved in the piloting of hydrogels in Uganda are: National Forestry Research Institute, Makerere University and the Georg August University-Goettingen, Germany.

	Other institutions which will promote this technology based on their mandate in terms of research and development include: Uganda Timber Growers Association; Local Governments
Size of beneficiaries	1000 households – especially those involved in commercial tree growing.
Operation and maintenance	It requires specialized skills in application of the technology. Plantation and maintenance can be made easy by training farmers' representatives.
Advantages	• Hydrogels improve the soil water holding capacity thereby increasing water retention for utilization by the trees during the long periods of drought; • They reduce soil nutrient losses, soil salinity, especially in sodic soils, and enhanced plant growth by allowing nutrients, incorporated into the hydrogel matrix, to release to the plant as needed. Thus, overall impact positively of tree and forest productivity;
Disadvantages	• Hydrogels must be applied with a lot of care and in the correct amounts. Otherwise application of an overdose results in plant and or tree mortality; • Hydrogels are not easily available and accessible on the market because they have to be imported.
Capital costs	
Cost to implement adaptation option	No information found
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in execution of the technology especially during the application of the hydrogels. But also management of the supply chain for the hydrogels and associated training and extension and or advisories for their effective application/use. • The technology creates investment in the supply chain for the hydrogels in the country and the related extension and advisory services for its effective use and or application. • Can reduce public and private expenditure on maintenance costs for forest plantations during the dry season.
Social benefits	• Income generated through forest products from trees that survived prolonged droughts through application of hydrogels. But also related income from the supply value chain and extension and advisory services for effective application and or use hydrogels by tree growers and or forest managers. • The stakeholders involved in the application of the hydrogels will benefit from the knowledge and skills. • Health. The positive impact of hydrogels in terms of improving water retention and reducing water stress on trees enables in maintenance of a healthy forest during prolonged droughts.

	• The technology can easily be applied by both men and women. Thus, either men or women can be employed as laborers in the implementation of the technology. Hence, both genders can equally participate in the supply chain for the technology.
Environmental benefits	Hydrogels improve the soil water holding capacity thereby increasing water retention for utilization by the trees during the long periods of drought. Furthermore, they reduce soil nutrient losses, soil salinity and enhance plant growth.
Local context	
Opportunities	The technology will be interested by most of the tree growers whose plantations are affected by prolonged droughts and the associated stress.
Barriers	• The technology is still new and has been piloted in few forest landscapes across the country. Thus, it's difficult to determine the appropriate rates of application for the respective forest landscapes. • It has been tested largely under forest plantations and not on natural forests.
Market potential	The technology has a national wide potential given that water stress during the prolonged droughts affects trees across all the forest landscapes in the country.
National status of the technology	Technology is still at pilot stage and has not been tested widely across all the 7 forest landscapes.
Timeframe	The implementation can start immediately
Acceptability to local stakeholders	Well accepted by the local population.

9. Integrated pest management (IPM) in forest management.	
Introduction	Pests have been reported to attack both natural and plantation forests. Hence, they can damage trees in all stages of development and have negative effects in terms of overall productivity of the trees and forests (FAO, 2001). Under the current climate change and variability impacts, the pests and diseases are even proliferated by the current climate and variability. Thus, consequently and the intensity in terms of severity has increased. IPM technologies have been applied widely applied in agricultural farming systems and have been reported to be plausible. Likewise, these have been applied in forestry. Pimentel (1986) described integrated pest and diseases management as a control method that includes judicious use of pesticide and non-chemical technologies – all of which are based on sound ecological principles.

	It consists of two basic elements including: a decision and action process. The actions/responses for pest/diseases management/control may consist of one or more ecologically, economically and socially acceptable tactics designed to reduce pest populations to non-damaging levels (Ciesla 1982). The decision-making process is informed by the population levels of the pests and whether anticipated resource losses as projected compared to the costs of treatment and its anticipated benefits. Thus, if treatment costs exceed losses, a rational decision may be to not treat and accept the losses. Other consideration is to apply natural control measures within a short period of time and if these are effective, then artificial controls will be unnecessary. Overall, it's important to conduct regular monitoring of the pests and diseases. On another note, the IPM action regime comprise of 2 key strategies that focus on: Prevention or direct control (suppression). Prevention consists of techniques aimed at either reducing the probability of the occurrence of a pest or disease or to create environmental conditions inhospitable for its build-up into damaging numbers. Thus the prevention actions could constitute application of: Regulatory (-prevent introductions of exotic pests and diseases and to prevent their spread once established), cultural (– these create conditions inhospitable for the development of damaging numbers of pests and diseases|) and or genetic techniques – i.e. make use of varieties of host plants that are either more tolerant to damage or less palatable to the pest (FAO, 2001). On the other hand, suppression as direct control of the pests and diseases involves actions/interventions which target the pests directly. Examples in this respect include: various types of biological (i.e. use of natural enemies of a pest or disease to help keep its numbers in check), mechanical (this involves removal and destruction or rapid removal of infested or infected trees with the objective of destroying the pest, e.g. cutting and burning of trees infested by bark beetles or rapid salvage of infested trees and destruction of infested bark at the sawmill) and or chemical methods. The latter involves use of acceptable pesticides either from the ground or by low flying aircraft based on forest management. The above IPM techniques as described have been applied in several countries including Uganda. However, these are applied at small scale and under the current climate change and variability further application and up scaling could require further studies and research for effective application across the 7 forest landscapes in the country. It involves application of integrated approaches, which complement each for effective pests and diseases management and control.
Institutional and organizational requirements	Integrated pest management in forest plantations in Uganda is promoted by both Government and Private Institutions. The responsible Government Institutions responsible for the research and development of plausible

	integrated pests and diseases management techniques in forestry include: The National Forest Resources Research Institute, Makerere University School of Forestry, Environmental and Geographical Sciences. On the other hand, the private sector institutions responsible with promoting the application of the integrated pest and disease management techniques in forest plantations is by large the Uganda Timber Growers Association, community and private forest owners.
Size of beneficiaries (estimate)	1 400 000 households
Operation and maintenance	The application of the integrated pest management techniques and practices in forest plantations requires targeted practical training and continuous backstopping. Furthermore, there must close interaction between the developers and user of the techniques through onsite and on station applied participatory research.
Advantages	• IPM is cheap and cost effective; • It promotes biodiversity conservation; • It allows for ecosystem balance, especially in cases were biological control measures are applied; • The technology has been applied and adapted to the local conditions
Disadvantages	• Biological control measures for IPM have a risk of introducing natural enemy with the forest ecosystem, which could innocuous or beneficial insects in the ecosystem. Thus, this process requires through evaluation of candidate species before release; • It also presents a potential hazard of accidentally introducing hyperparasites, natural enemies of the biological control agents, which might eventually affect the agent's efficacy.
Capital costs	
Cost to implement adaptation option	The estimated average cost of managing pests and diseases for 1 ha of forest through application of integrated pest management is 200-1000 USD.
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in application of the technology through provision of both skilled and unskilled labor. Furthermore, through the supply of pesticides. • It creates investment in forestry through provision of the inputs required in IPM and related supportive equipment to support application of the technology. • Can reduce public expenditure on pesticides, especially in cases were cultural and biological control measures are applied.
Social benefits	• There is increased income from sale of forest products that have been protected from attack and destruction

	by pests and diseases. • The stakeholders involved in IPM benefit from the knowledge and skills. • The technology can be associated with health implications especially when chemical for diseases and pest management are being applied. Therefore, it's important for the workers applying to have protective gear and also follow the industrial prescriptions for proper and effective application, but also take precautionary measures. • The technology can be applied by both men and women in respect to both skilled and unskilled labour. Though affirmative action should be considered in the case of women's participation because often there are few women actively participating in forest management.
Environmental benefits	It promotes biodiversity conservation for both flora and fauna;
Local context	
Opportunities	• The technology is well understood by local farmers; • Its applicable across the 7 forest landscapes in Uganda; • There is peer learning and mentoring that can be tapped among the forest responsible bodies
Barriers	• Inadequate knowledge and application of the IPM especially among the private individual commercial tree growers; • The chemical pesticides are expensive and may not be affordable for smallholders.
Market potential	The technology has a national wide potential. Thus, it's applicable across the 7 forest landscapes in the country and in both natural and plantation forests.
National status of the technology	The technology is already being applied by the different forest responsible bodies (National Forest Authority, Uganda Wildlife Authority, Community Forest Association, Private commercial forest companies) at different scales.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population.

10. Promotion of bamboo value chains – production and processing/value addition and marketing.	
Introduction	Bamboo is a major non-wood forest product and wood substitute. It is found in all regions of the world and plays an important economic and cultural role. Bamboo is an ancient woody grass widely distributed in tropical, subtropical and mild temperate zones. It is a major non-wood forest product. There are about 1200 species of bamboo in some 90 generals. It is an integral part of forestry, but it is also widely spread outside forests, including farmlands, riverbanks, roadsides and urban areas. In Uganda bamboo grow naturally in some of the following regions: the highlands of Kigezi (Bwindi, Mghahingha and Echuya, Mt. Rwenzori); the eastern highlands (Mt. Elgon, Mt. Kadam, Mt. Moroto); in Buganda Region (Mabira and Kifu forests); in the Northern Region (Agoro-Agu, Lokung Forest Reserve) and others. In these regions it often grows wildly but among the protected species in the natural forests. Bamboo can be promoted to contribute to restoration of degraded forest landscapes in Uganda. Besides, it provides various products which add value in contributing to adaptation and building resilience to climate change impacts – as these provide alternative livelihoods and incomes to communities and stakeholders involved in the bamboo value chain. Thus, bamboo is fast growing and can be transformed into various products for: housing, crafts, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics, oil, gas and charcoal (for fuel and as an excellent natural absorbent), it is also a healthy vegetable (the bamboo shoot). Thus, bamboo industries are now thriving in Asia and are quickly spreading across the continents to Africa and America. In Uganda bamboo has a great potential and viability for replacement of wood and industrial raw material for both traditional and modern sectors. Its employment potential is very high with a major work force, which could target the rural poor especially women. Thus, according to the UN Comtrade data base (2016), the annual trade in bamboo from Uganda yielded 304,000 and 203,672 USD for import and export, respectively for the period 2014-16.
Institutional and organizational requirements	In Uganda there are various institutions both Government and Private Sector that have differentiated but equally important roles in respect to promotion of the bamboo value chain. In most cases effective implementation of the roles is required to boost the bamboo value chain for maximum benefits in terms of livelihoods and economic development. The key institutions and their associated responsibilities for advancing the bamboo value chain are summarized as follows: • Ministry of Water and Environment/ Department Environmental Affairs - Supervision, co-ordinate, oversight and reporting the forestry sector including bamboo. Ensure that bamboo budgets are reflected in

	the lead and sectoral ministry's plans, budgets and Provide a stable and enabling work environment • Forest Sector Support Department - Policy formulation and guidance; Supervision of NFA and DLGs on forestry initiate projects, initiate value addition, Advocacy and coordination of Stakeholders and technical guidance • National Forestry Authority - Manage existing bamboo resources in or near CFRs, Establish bamboo plantations, initiate projects, initiate value addition, Advocacy and coordination of Stakeholders and technical guidance • Uganda Wildlife Authority - Manage existing bamboo resources in or near protected areas, Establish bamboo plantations, initiate projects, initiate value addition, Advocacy and coordination of Stakeholders and technical guidance • National Environment Management Authority - Issue EIAs and environmental monitoring, Policy formulation • Wetlands Management Department - Management of Wetlands (and Wetland forests). Provide technical guide on establishing bamboo resources near wetlands • District Local Governments - Represent local Government authorities. Manage Local Forest Reserves • National Research Institutions - Research on aspects of bamboo propagation, technologies, utilization, management, market development and stakeholder issues • Academic Institutions - Training and research on aspects of bamboo management and utilization • Uganda Bureau of Standards - Quality standard setting, monitoring and enforcement, Control of counterfeits • Uganda Industrial Research Institute - Promoting development of bamboo products and value addition technologies • Ministry of Trade & Industry - Policy formulation, Regulation, and control of bamboo trade • Ministry of Finance - Fiscal Policy formulation, National Planning and Financial allocations for the forest control, • Uganda Investment Authority - Attract investors in the bamboo sector and create enabling environment for business • Private Sector Foundation /Uganda Manufacturers' Association - Support private sector members investing in Uganda on advocacy and necessary reforms for growth of business • International Network for Bamboo and Rattan (INBAR) - Provision of advisory, technical services,

	information exchange, research and training to member countries • Local Communities - Provision of indigenous knowledge, participation in establishment, management and utilization of bamboo resources • CSOs and CBOs - Advocacy and citizen empowerment to participate in government and other programmes • Craft makers/Artisans - Buy bamboo materials, manufacture and sell bamboo products • Secondary Manufacturers - Value addition to bamboo raw materials • Traders - Distribution, Promotion and sale of bamboo products
Size of beneficiaries	180,000 households
Operation and maintenance	• It requires specialized knowledge and skills in seedling production. • Plantation and maintenance can be made easy by training farmers' representatives. • Requires specialized equipment in harvesting, processing and value addition. • Responsive training is required for effective utilization of the tools.
Advantages	a. Bamboo is a fast-growing plant/grass. Thus, it matures in period of 3-5 years and is ready for harvesting for use a timber/wood product. b. It can grow and easily adapt to various unfavourable conditions in various forest landscapes across the country. c. It's a self-regenerating plant. Thus, new shoots replace the old ones. d. It allows regular production from the same plant, increasing the frequency at which yields can be generated. e. Several bamboo species are available from other countries (e.g. China) that suit specific value chains. Thus, these can be evaluated based on Uganda's needs and subsequently introduced, tested and promoted. f. There are various countries which have advanced the bamboo value chain with measurable outstanding achievements e.g. in Asia i.e. China, India. Thus, best practices and experiences can be learnt from them by way of benchmarking. g. Bamboo has a great potential for carbon sequestration there contributing to climate change mitigation.
Disadvantages	Bamboo grows so fast and of not properly regulated can become more dominant compared to other forest tree species
Capital costs	
Cost to implement adaptation option	The estimated average cost to put in place and restore 1 ha of bamboo is 250-600 USD

Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in seedling preparation, land preparation, plantation, maintenance, harvesting, transportation, trading. • Can create investment to advance the bamboo value chain through: training; access to production inputs, equipment and production transformation industry
Social benefits	• Increased income from sale of value-added products made from bamboo. Other sources of income will be realized from the various employment opportunities the bamboo value chains present through providing skilled and unskilled labor along the value chain from production, value addition/processing, packaging and marketing. • The beneficiaries involved in the bamboo value chain from production to marketing will improve on various aspects of bamboo production, value addition and processing. • The technology can easily be applied by both men and women. Thus, either men or women can be employed as laborers in the implementation of the technology. Hence, both genders can equally participate in the supply chain and application for the technology. Besides, there are also roles were either gender category is most suited to participate along the value chain.
Environmental benefits	Increasing water infiltration and slowing runoff flow, stabilizing and protecting stream and river banks from detrimental effects of soil erosion and runoff; filtering pollutants from runoff water, shading streams for controlling
Local context	
Opportunities	• The technology is well understood by local farmers, • There exist farmers associations/cooperatives which can reduce initial investment costs by sharing the cost of seedling production, • Maintenance can be done by beneficiaries themselves, • Conservation and reforestation are among the country's priorities.
Barriers	• Need for a change of mindset and attitude in the replacement for use of bamboo products especially in communities where these have not been used before. • Over exploitation/harvest of bamboo especially in the Agoro-Agu central forest reserve landscape in Northern Uganda i.e. comprises of 16 CFRs located across 4 districts – Agago, Lawmo, Pader and Kitgum • There is still great ignorance about the full potential use bamboo and the several products that can be derived from it among the duty bearers and the community

	• Advancement of the technology will require great investment in knowledge and skills and technology transfer from countries, which have already developed the technology. • Lack of clear policy direction and guidance for development of the bamboo value chain in Uganda. Initiatives were started by the Forest Sector Support Department to develop such a policy and related instruments.
Market potential	Bamboo is available in various forest landscapes and regions and already some bamboo products and services are being use at community level but at subsistence level. However, there is great potential for market not only in Uganda but also in the East African region if the bamboo value chain is advanced.
National status of the technology	Bamboo grows naturally in various regions of the country but has not been grown to commercial scale. Some the regions are: the highlands of Kigezi (Bwindi, Mghahingha and Echuya, Mt. Rwenzori); the eastern highlands (Mt. Elgon, Mt. Kadam, Mt. Moroto); in Buganda Region (Mabira and Kifu forests); in the Northern Region (Agoro-Agu, Lokung Forest Reserve) and others.
Timeframe	The implementation can start immediately
Acceptability to local stakeholders	Well accepted by the local population and can easily be up-scaled.

11. Promotion of Farmer Managed Natural Regeneration (FMNR) for forest landscape restoration.	
Introduction	According to Chimsah, (2014), FMNR is a simple technique/practice of systematically regenerating mainly tree species in the natural from living tree stumps, roots or seedlings. It involves a process of selecting healthy and vigorous natural seedlings and removing by cutting off through proper pruning of the unwanted ones. It started in West Africa, motivated by the severe drought of mid 1970s that prompted innovative farmers working with a development agent called Tony Rinaudo to develop specific techniques for regenerating trees from existing stumps of indigenous trees – combined with low-cost soil and water conservation techniques (ICRAF, 2013). It promotes regeneration of degraded forest landscapes. Thus, it's a low-cost sustainable landscape restoration technique aims to improve the productivity of agricultural lands while increasing tree cover and biodiversity (IUCN, 2017). In Uganda FMNR has been used in advancing restoration of forest landscapes in Northern Uganda. Thus, civil society development initiatives in 2017 resulted restoration and better management of over 34 square kilometres under Farmer Managed Natural Regeneration in the Shea Butter belt of Lira, Otuke, Alebtong, Amuria and

	Agago (ENR-CSO network, 2018). The National Forestry Authority has as well applied the same technology in the regeneration of shea nut better in Northern Uganda in Agago and Kitgum districts.
Institutional and organizational requirements	In Uganda FMNR has been promoted by International (e.g. the International Union for Conservation of Nature, World Agroforestry Centre) and local Non-Governmental Organization through pilots to advance forest landscape restoration. However, falls within the mandate of forestry sub-sector institutions such as: Forest Sector Support Department, National Forest Authority; Uganda Wildlife Authority; and the District Local Governments.
Size of beneficiaries	300,000 households
Operation and maintenance	Plantation and maintenance can be made easy by training farmers' representatives. Harvesting can be done using local knowledge.
Advantages	• It's a low-cost technology for forest restoration; • Does not require seedlings as planting materials, thus the trees are managed to regrow natural from the tree stamps • Its applicable to all types of forest landscapes across the country. Thus, can easily be adapted to the landscapes.
Disadvantages	• Increasing water infiltration and slowing runoff flow, stabilizing and protecting stream banks from erosion, filtering pollutants from runoff water, shading streams for controlling. • Furthermore, it contributes towards conservation of the natural forest biodiversity.
Capital costs	
Cost to implement adaptation option	The estimated average cost of restoring 1 ha of degraded forest landscape through enrichment planting 100-2000 USD.
Additional cost to implement extra unit	None
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in land preparation, plantation, maintenance and harvesting • The technology creates investment in forestry production inputs equipment and production transformation industry. • Saves on public and private expenditure costs in respect to management of the trees/forests. This is largely because the trees grown regenerate naturally with minimum inputs in terms of fertilizers.

Social benefits	• It increases the income earned and inputs saved through improvements in the farm resource base and products for sale. • Through increased yields, it provides significant savings for households on fire wood, forage and fertilizer purchase. • FMNR improves local knowledge about the technology and increased income would increase school attendance. • Health. It promotes the conservation of the natural tree species, which are also associated with several attributes in respect to medicinal properties known to treat various ailments in community. • Much as the technology is applicable for both men and women. It's largely prohibitive for women due to socially and culturally constructed attitudes, for instance women working alone deep in the forest planting trees. Therefore, in order to have effective women participation in the technology applications, such barriers must be broken. Otherwise, women could equally be targeted to participate in value chains or requirements for the technology like management of the tree nursery beds for generation of seedlings which will be used in the technology.
Environmental benefits	Increasing water infiltration and slowing runoff flow, stabilizing and protecting stream banks
Local context	
Opportunities	• The technology is easily understood by local farmers in the community; • There exist farmer's associations/cooperatives. These can be used as the entry point for training the farmers within the forest landscapes. • Maintenance can be done by beneficiaries themselves; • The technology promotes forest landscape restoration, which fits within the national priorities and commitments for instance the Bonn Challenge and the Nationally determined contributions for Uganda. Besides in the medium terms it contributes to community climate change adaptations as the restored forest landscape contribute to food security, provision of firewood and regulation of the local community climate.
Barriers	• The technology requires knowledge and skills to facilitate its application by the farmer. Enhancement of such skills requires targeted training and awareness at community levels. • The main benefits of FMNR are realized in the medium term at least five to ten years after establishment; this means that farmers must be prepared to invest in their establishment and management during several years before the main benefits are generated.

	• The farmers must be willing to put a side and commit land for forest restoration with the landscapes. • The unregulated bush burning and stray livestock destroy regenerated trees, especially in Northern Uganda, yet the ordinances and byelaws for regulation of wildfires are lacking or inadequately implemented.
Market potential	The technology is applicable national wide across the 7 forest landscapes and results in the generation of several timber forest and non-timber forest products that have a huge market potential at the local, sub-regional and national levels.
National status of the technology	FMNR technology has already been piloted in Northern Uganda. It can easily be up-scaled to other forest landscapes through the best practices and lessons learnt to-date.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population.

12. Application of tissue culture to hasten massive propagation/multiplication of tree seedlings.	
Introduction Technology characteristics	The Tissue culture technology has for decades been applied in the multiplication of seedlings for several crops in various countries in the world. It's a very effective technology in the production of massive clean and healthy seedlings to effectively meet the demands in the market at the national and sub-regional levels. In Uganda the tissue culture technology is applied in the production of banana and coffee seedlings. It's a highly commercialized technology and is largely private sector led. However, the technology is also applied by academia and research institutions in Agriculture. There is an opportunity to use the technology in the production of tree planting materials/seedlings with due consideration that the demand for tree seedlings is very high as a result of the national campaign for planting of trees for restoration of degraded forest landscapes across the country. In forestry and particularly for tree improvement, tissue culture is applicable through the following ways: (1) Micro Propagation (2) Apical Meristem Culture (3) Embryo Culture (4) Endosperm Culture and (5) Haploid Plants. Tissue culture involves rapid multiplication of clean and healthy planting materials in controlled environment. It takes a shorter time as compared with the common practice of nurturing planting materials through nursery bed.
Institutional and organizational requirements	The tissue culture technology by mandate is promoted by the National Forestry Resources Research Institute in terms of development and application. Thus, there is some existing infrastructure which can be up-graded to meet the requirements and expectations for application of the technology to advance tree seedlings

	multiplication. The private sector can take it for investments to advance mass multiplication of tree planting materials. Besides other responsible bodies like the National Forestry Authority through their Tree Seed Centre can equally take up the technology for multiplication of tree seedlings.
Size of beneficiaries (estimate)	300,000 households
Operation and maintenance	It requires specialized skills for maintenance of the saver on a regular basis. These can be outsourced or otherwise staff can be trained to take this as additional role.
Advantages	• The technology enables multiplication and production of a large number of tree seedlings in a short period of time; • The tree seedlings produced through application of this technology are clean and healthy devoid of pests and diseases; • Because a large number of seedlings are produced, overall it reduces the per unit cost for seedling production; • With due consideration that the seedlings are in a controlled environment i.e. laboratory and green houses, their growth is not affected by climate change and variability, hence they grow faster.
Disadvantages	• It requires very high skilled labor especially those that work in the tissue culture laboratories; • Upfront costs for establishment of the facilities for the technology are high. • Possibility that the technology could be affected by attitude because Ugandan community are used to planting seedling from the common/usual tree nurseries. Thus, changing such attitudes/beliefs requires continuous and targeted awareness.
Capital costs	
Cost to implement adaptation option	Estimated costs of development of planting materials using tissue culture unit based 15,000 – 20,000 USD (based on low cost banana tissue culture unit) (IITA, 2013).
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in seedlings production i.e. both skilled and unskilled labour • It requires in the investment in infrastructure to have the controlled environment to enable growth of the tree seedlings.

	• Reduces on public and private expenditures in respect to purchase of tree seedlings. This is because the cost per unit for production of tree seedlings reduces by application of tissue culture. Besides, costs associated with management of pests and diseases would reduce in the long term because clean planting materials/seedlings.
Social benefits	• Income a) Increased income from sale of tree seedlings; b) Increased income from high value forest (e.g. timber) produced from clean and healthy tree seedlings; • The knowledge and skills of the people involved in the implementation of the technology would be enhanced. Overtime they train others to learn and apply the skills elsewhere the technology can be up-scaled. • The technology helps in production of clean and healthy seedlings thereby preventing further transmission of tree pests and diseases. • The technology can easily be applied by both men and women. Thus, either men or women can be employed as laborers in the implementation of the technology. Hence, both genders can equally participate in the supply chain and application for the technology.
Environmental benefits	The technology prevents and control transfer of pests and diseases, because it's associated with production of clean and healthy seedlings.
Local context	
Opportunities	There is high demand for tree planting material to deliver on the national priorities in respect to forest restoration. Besides, there is also demand for tree seedlings in the region.
Barriers	• It requires very high skilled labor especially those that work in the tissue culture laboratories, which apparently inadequate; • Upfront costs for establishment of the facilities for the technology are high. • Possibility that the technology could be affected by attitude because Ugandan community are used to planting seedling from the common/usual tree nurseries. Besides, the technology could face resistance by the stakeholders who have invested in the common/usual tree nurseries. Thus, changing such attitudes/beliefs requires substantive targeted awareness.
Market potential	The technology has high market potential because there is very high requirements for tree planting materials to advance forest restoration in the different forest landscapes. Thus, the technology is handy in bridging the gap in the production of clean and healthy tree seedlings.

National status of the technology	In Uganda the tissue culture technology is applied in the production of banana and coffee seedlings. It's a highly commercialized technology and is largely private sector led. However, the technology is also applied by academia and research institutions in Agriculture.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	Well accepted by the local population because the tissue culture technology has been applied in the multiplication of bananas and coffee.

13. Integrated wildfire management for fire-smart landscapes.	
Introduction	Forest fire refers to the uncontrolled fire that erupts in the wilderness (UTGA, 2011). They involve combustion of organic material (fuel) that releases a large quantity of energy. Much as fires as often result from human negligence for instance (cigarette butts, camp fires that are not extinguished properly, torching of old grass, hunting of rodents), there are reports indicating that climate change, particularly global warming exacerbates the conditions that raise the risk of wild fires (The Conversion, 2018). Thus, forest fires in Uganda are common through the dry season. The northern and western Uganda regions are reported to be affected by forest fires during this period. The fires destroyed both natural forests in protected areas but also plantation forests on private land. Reports indicate that the forest fires are set by hunters and farmers. They are associated with destruction of biodiversity both flora and fauna and negative impact on overall performance and productivity of the forests. Besides, the process of burning is associated with the release of carbon dioxide into the atmosphere thereby contributing to the greenhouse effect phenomenon and climate change. Besides, overall the gases released compromise the local air quality. According the ITTO, (2019), Integrated forest fire management (IFFM) comprises a systematic approach to forest fire management. It encompasses both the traditional efforts of fire prevention and fire suppression as well as the use of prescribed fire as a tool, community involvement, and forest law enforcement. IFFM if applied effectively by forest responsible bodies will prevent destruction of trees and forest by wild fires during prolonged droughts as a result of climate change and variability in various parts of the country across the different forest landscapes. Besides, the technology and approach were identified as a strategic option in Uganda's National strategy for Reducing Emissions from Deforestation and Forest Degradation for reducing the impacts of wild fires on forests. Some of the applicable technologies include:

	• Forest planning to avoid and control forest fires through proper forest plantation compartmentalization. Thus, avoid single blocks or compartments which are 30 Ha without roads. • Establishment of forest fire breaks within or outside the forest and plantation • Designing special areas for smoking by workers or visitors. These should be properly labelled with sign post clearly condemning and warning passersby not to be reckless with the last bits of their cigarette, but also indicate telephone contacts for responding to emergencies in case of fire outbreaks • Investment in basic firefighting equipment – e.g. rake hoes, beaters and water pumps (double action knapsacks) • Staff training in integrated forest fire management • Sensitization of the community about the dangers of the fires and facilitate process for development of simple bylaws and ordinances for enforcement to prevent fire breakouts • Effective coordination with all key stakeholders i.e. forest reserve or plantation staff, communities, visitors in respect to fire prevention and management • Satellite remote sensing – this can provide cost-effective information about the forest for fire management decisions over large landscape areas. It has been applied to provide data for fire danger rating prediction, fuel and fire mapping, fire monitoring, and fire ecology research (Tian Xiao-rui et al., 2005).
Institutional and organizational requirements	Various institutions in Uganda have differentiated mandates as provided for under the current forest policy and law. They are therefore expected to deliver on various roles and responsibilities in respect to forest management. They include the following: • Forest Sector Support Department – this is for policy formulation and enforcement • National Forest Authority, Uganda Wildlife Authority and Local Governments. These are responsible bodies for forest management of protected areas and hence therefore are expected to protect these forests from fire damage. • Uganda Timber Growers Association – provides training, awareness and extension services in respect to integrated fired management to its members • Commercial Forest Companies - have interest in protecting their forests from fire damage • Private commercial forest owners and community forest owners – have interest in protecting their forests from fire damage • Uganda Police – Fire brigade Department – these respond to fire break outs to prevent destruction • Training and research institutions – for training experts in fire management and also conduct action research

	on integrated forest fire management • Private sector – buy and distribute and sell fire technologies to intending buyers that need them across the country. • Forest adjacent communities – play a community policing role, but also at the forefront of the implementation of community bylaws and or ordinances for controlling forest fires. • Civil Society Organizations – for awareness creation, lobbying and advocacy towards effective forest fire management at different scales.
Size of beneficiaries (estimate)	1 400 000 households
Operation and maintenance	It requires specialized knowledge and skills in application of the technologies by the forest owners. Furthermore, it requires continuous community awareness but also development and enforcement of community bylaws and or ordinances.
Advantages	The technology/approach focuses on addressing the underlying causes of the fire, but also identification of long term and sustainable practical actions to deal with the fires with consideration of: prevention, response, and restoration.
Disadvantages	The actions could be difficult to enforce as it requires involvement and participation of various stakeholders.
Capital costs	
Cost to implement adaptation option	The estimated cost protecting 1 Ha of forest using integrated wild fire management is 2000-10000 USD.
Additional cost to implement extra unit	N/A
Development impacts, indirect benefits	
Economic benefits	• Creation of jobs in proving specialized control of fires and emergency response in case of fires; training of key stakeholders and related awareness creation; maintenance of equipment and tools used in fire control and management; providing labor in establishment of physical fire control and prevention measures/strategies. • Can create investment in fire control measures/strategies; • Training and or targeted capacity building • Can reduce public expenditure on rehabilitation of destroyed forests and property by fires. Furthermore, other public funds for use in response for emergencies for lighting out the fires would be saved.

Social benefits	• There increased incomes to the forest owners when the destruction from wild forest fires and controlled and avoided. Furthermore, the private sector who sell this technological equipment generate income from the equipment sold. • The application of the integrated wild forest fire technologies improves the knowledge and skills of the key stakeholders (e.g. staff of responsible forest bodies i.e. National Forest Authority, Uganda Wildlife Authority, Private commercial forest companies, Private tree growers, targeted and involved. • Once forest fires are avoided and effectively managed, the associated impacts if they happened are avoided, for instance pollution of the local air quality that promotes lung and throat associated ailments. • The technology can easily be applied by both men and women. Thus, either men or women can be employed as laborers in the implementation of the technology. Hence, both genders can equally participate in the supply chain and application for the technology. Besides, there are also roles were either gender category is most suited to participate along the value chain.
Environmental benefits	Avoided damage and loss of forest biomass (i.e. both below and above ground) and associated release of greenhouse gases into the atmosphere. Furthermore, the secondary associated impacts due to forest fire destruction are avoided e.g. loss of useful and beneficial fauna, soil erosion/runoff
Local context	
Opportunities	• The National forestry policy (2001) and legislation, (2003) support the technology through establishment of fire management committees. Furthermore, some districts (e.g. Lamwo) have developed ordinances on regulation of unregulated bush burning in the forest landscapes • The technology is easily adaptable to the community needs and context; • The forest adjacent communities can easily be mobilized to support implementation of the actions • The members of the forest adjacent communities can be trained to support implementation of the integrated fire control and management especially outside the forest
Barriers	• Primitive practices in the community e.g. hunting of rodents using fire; • Limited knowledge and skills in respect to integrated wild forest fire management among key stakeholders • Lack of and or weak implementation of supportive legislative measures to prevent and control fires at the community level i.e. bylaws and ordinances
Market potential	The technology has a national wide potential for application especially across the 7 forest landscapes (as described in the Forest Landscape Restoration Opportunity Assessment for Uganda, MWE, 2016) that are potentially at high risk of forest fires.

National status of the technology	The technology/approach is being applied by the various forest responsible bodies at a small scale, but there is need for scaling it out to other parts of the country with due consideration that the risk of forest fires is increasing.
Timeframe	The implementation can start immediately.
Acceptability to local stakeholders	The technology can easily be adapted by institutions responsible for management of protected areas and forest reserves, but also private owners investing in commercial forest. The forest adjacent communities can accept the technology through rigorous awareness and training.

ANNEX II: LIST OF STAKEHOLDERS INVOLVED AND THEIR CONTACTS

a. The proposed steering committee for TNA

POSITION	INSTITUTION
Permanent Secretary and Chair of Steering Committee	Ministry of Science, Technology and Innovation - MOSTI
Permanent Secretary	Ministry of Water and Environment - MWE
Commissioner Climate Change	Climate Change Department CCD/MWE
Professor	College of Agriculture and Environmental Sciences, Makerere University
Commissioner, Development Assistance and Regional Cooperation/ NDA	Ministry of Finance, Planning and Economic Development - MFPED
Assistant Commissioner Sector Capacity Development	CCD/MWE
Asst. Commissioner Disaster Management	Office of the Prime Minister - OPM
Chief Executive Officer	Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA)
Executive Director	National Environment Management Authority - NEMA
Senior Range Ecologist	Ministry of Agriculture, animal Industry and Fisheries - MAAIF
Chief Executive Officer	Advocates' Coalition on Development and Environment - ACODE
Deputy Executive Secretary/NDE Focal Point	UNCST

b. Sector working groups, consultants and other contributors to technology selection

Sector	Stakeholder	Institution
Agriculture	Brian Semakula, Mr.	Agriculture Technology Centre, MWE
	Damalie Akwango, Ms.	National Agricultural Research Organisation - Secretariat
	Godfrey Nviiri, Mr.	ENRAC, NGO
	Miriam Talwisa, Ms.	CAN- Uganda, NGO
	Susan Nanduddu, Ms.	African Center for Trade and Development (ACTADE)
Water	John B. Kaddu, Prof.	Makerere University
	Julian Auma, Ms.	Water Works, NGO
	Walter Cuccu, Mr.	Water Works, NGO
	Linda Mwesigwa, Ms.	Step-up Standard Limited, NGO
	Semakula Brian, Mr	
	Kaaya Christine, Ms	Parliamentary Forum on Climate Change
	Winnie Grace Onziru, Ms.	Uganda National Bureau of Standards
Forestry	Sam Gwali	NARO – Mukono
	Robert Bakiika, Mr.	Climate Change Department, MWE
	Prossy M. Namulindwa, Ms.	Ndejje University
Consultants	Sara Namirembe, Ms	Climate change adaptation, Water and Agriculture Sector
	Joshua Zake, Mr.	Climate change adaptation, Forestry Sector
Other	Michael Wambi, Mr.	Uganda Radio Network
	Rita Rukundo, Ms.	UNFCCC Regional Coordination Centre

c. Other stakeholders considered for involvement in next steps of TNA for climate change adaptation

Working group	Name
Agriculture sector	Mr. Stephen Muwaya MAAIF
	Mr. Augustine Mwendya Uganda National Farmers Federation
	Director General NARO
	Ms. Edith Kateme National Planning Authority
	Ms. Christine Kaaya Parliamentary Forum for Climate Change
	Chief Executive Officer PELUM
	Representative NaFIRRI
	Representative FAO
Forestry sector	Mr. Xavier Mugumya National Forestry Authority
	Prof. Joseph Obua CAES, Mak
	Dr. Robert Nabanyumya Green Approaches
	Mr. A. Kalema Private Sector
	Dr. Hilary Agaba, NaFORRI
	Chief Executive Officer Uganda Timber Growers Association
Water sector working group	Executive Director National Water and Sewerage Corporation
	Callist Tindimugaya MWE
	Mr. Twinomujuni MWE
	Ms. Ashabrick N. Bamutaze Rural Water & Sanitation Dept, MWE
	Executive Director NEMA
Climate financing	Representative UNFCCC
	Representative ADB
	Representative World Bank