BOTSWANA

TECHNOLOGY NEEDS ASSESSMENT REPORT

CLIMATE CHANGE ADAPTATION

AGRICULTURE SECTOR

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LIST OF ACRONYMS

ASSP	Agricultural Service Support Project
ASWG	Agriculture Sector Working Group
ATO	Adaptation Technology Option
BAEF	Barrier Analysis and Enabling Framework
BCCP	Botswana Climate Change Plan
BCCP	Botswana Climate Change Policy
BCCS	Botswana Climate Change Strategy
BITRI	Botswana Institute of Technology, Research and Innovation
BNBPU	Botswana National Beef Producers Union
BNDP	Botswana National Drought Plan
BOCONGO	Botswana Council of Non Governmental Organizations
BoFA	Botswana Farmers' Association
BoHoC	Botswana Horticulture Council
COP	Conference of Parties
CSA	Climate Smart Agriculture
DAP	Department of Animal Production
DCP	Department of Crop Production
DMS	Department of Meteorological Services
EWS	Early Warning System
GCF	Green Climate Fund
GCM	Global Climate Model
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GoB	Government of Botswana
ICT	Information and Communications Technology
INDC	Independent Nationally Determined Contribution
ISPAAD	Integrated Support Programme for Arable Agriculture Development
KP	Kyoto Protocol
LIMID III	Livestock Management and Infrastructure Development Phase III

MCA	Multi Criteria Analysis
MEWT	Ministry of Environment, Wildlife and Tourism
MoA	Ministry of Agriculture
NARDI	National Agricultural Research and Development Institute
NC	National Communication
NCCSAP	(Botswana) National Climate Change Strategy and Action Plan
NDA	Nationally Designated Authority
NDC	Nationally Determined Contribution
NDE	Nationally Designated Entity
NDP	National Development Plan
PCFA	Pandamatenga Commercial Farmers Association
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SDG	Sustainable Development Goal
SPI	Standard Precipitation Index
TAP	Technology Action Plan
TFS	Technology Factsheet
TNA	Technology Needs Assessment
UCCC	UNEP Copenhagen Climate Centre
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework on Climate Change

Executive Summary

Botswana through GCF funding is updating its technology needs assessment to develop a technology road map for prioritized adaptation technologies to address climate change challenges in the agriculture and water sectors and mitigation technologies in the energy sector. The CTCN is responsible for the execution of the TNA project through UNEP Copenhagen Climate Centre team of international and sector specific national experts.

This TNA report has been prepared as the first part of the process of updating the 2004 TNA which has three reporting stages: Technology Needs Assessment (TNA), Barrier Analysis and Enabling Framework (BAEF) and Technology Action Plan (TAP).

The agriculture sector was prioritized at the project formulation by the Nationally Determined Agency (NDA) and approved by the National TNA Committee. Stakeholder participation and gender mainstreaming in the assessment and prioritization of ATOs was achieved through the constitution of the Agriculture Sector Working Group (ASWG) with 10 stakeholder institutions and 36% female members. The stakeholder institutions were Department of Crop Production, (DCP) Department of animal Production (DAP), Department of Meteorological Services (DMS), National Agricultural Research and Development Institute (NARDI), Botswana Institute of Technology, Research and Innovation (BITRI), Botswana Horticulture Council (BoHoC), Botswana Farmers Association (BoFA), Pandamatenga Commercial Farmers Association (PCFA), Botswana University of Agriculture and Natural Resources BUAN), Botswana International University of Science and Technology (BIUST) and National Beef Producers Union (BNBPU). The heads of the institutions appointed one member each except BoFA who presented two resulting, BUAN who did not nominate and BIUST whose nominee did not participate. The ASWG had six males (60%) and 4 females (40%).

The contracted national agricultural expert reviewed various national, regional and international relevant policies/strategies/plans and technology sources to prepare a potential list of adaptation technologies. The expert also conducted training for members on the TNA process and facilitated the final selection, prioritization and multi criteria analysis (MCA) of the ATOs.

Eleven ATOs were subjected to MCA and were ranked as follows:

Adaptation Technology Option	SCORE	RANK
Integrated Nutrient Management (INM)	8765	1
Livestock Selective Breeding and Species Diversification (LSBSD)	8675	2
Crop Diversification and New Varieties (CDNV)	8555	3
Sustainable livestock health and population management (SLHPM)	8395	4
Rainwater harvesting (RH)	8370	5
Integrated / Ecological Pest Management (IPM / EPM)	8255	6
Conservation Agriculture (CA)	8030	7
Strengthening agrometeorological monitoring and information system (SAMIS)	7770	8
Efficient irrigation technologies for food security (EITFS)	7380	9
National Multiple Hazard Early Warning System (NMHEWS)	6825	10
Index-based Climate Insurance (IBCI)	6211	11

CHAPTER 1. INTRODUCTION

1.1 About the TNA project

The Technology Needs Assessment (TNA) is crucial for an emerging economy like Botswana. The purpose of the current TNA project in Botswana is to assist it with updating the country's TNA process which was first undertaken in 2004 and develop a technology roadmap for prioritized technologies to address climate change challenges in the most critical sectors of the economy. The work is conducted taking into consideration the broader context of the TNA conducted by many countries and recognized by the COP as a key element for technology identification and planning to address climate change challenges. This is to be achieved through the following three outcomes:

- Outcome 1. Institutional capacity and coordination mechanisms in place to govern and coordinate climate action and finance
- Outcome 2: Country Programming process that will contribute to the development of short- and long-term solutions that aid climate change resilience and build the necessary capacity in terms of environmental systems
- Outcome 3: Climate finance strategies strengthened, private sector mobilized, and project pipeline enhanced

These outcomes serve as a guide for the implementation approach in the project as well as the TNA methodology (as laid out in the TNA Step-by-Step Guidance).

The objective of 2004 Botswana Technology Needs Assessment on Climate Change (GoB, 2004) was to identify and assess environmentally sound technologies with synergy between reducing impact of climate change and the rate of GHG emissions and national development objectives. This followed the requirements of GEF funding provided to 92 countries between 2000 and 2004 for the first round of TNAs. Since then, it has become more realistic that adaptation and increasing resilience to the impacts of climate should have more emphasis since Botswana's contribution of global GHG emissions is minimal compared to the developed countries. Therefore, the current TNA initiative funded through CTCN using GCF aims to identify both mitigation and adaptation technologies against climate change and its impacts on the prioritized sectors of energy, water and agriculture. The energy sector will deal with mitigation while water and agriculture will deal with adaptation technologies. The Botswana National Designated Authority (NDA) (Ministry of Finance and Development Planning) and the National Designated Entity (NDE) (BITRI) to the UNFCC collaboratively developed and submitted the current TNA proposal to GCF as detailed in GCF Readiness and Preparatory Support (GCF, 2019). The programme title for the TNA is **"Update the technology needs assessment and develop a technology road map for prioritized technologies to address climate change challenges in the most critical sectors of the economy".**

The TNA project will be achieved through the three TNA steps:

1. To identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities (TNA).

2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies.

3. To develop Technology Action Plans (TAP) including policy briefs specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected /prioritized technologies in Botswana. This section presents the aspects of climate change adaptation for the agriculture sector in Botswana.

1.2 Existing national policies related to technological innovation, adaptation to climate change and development priorities for the agricultural sector

The section reviews the various policy instruments that have been produced after TNA 2004 in relation to climate change adaptation in the agriculture sector. The review will cover national development, agriculture sector and climate change policies These instruments informed the current updating of the Botswana TNA in relation to climate change, and it is hoped the climate adaptation technologies enhance sustainable national development by improving food security and the resilience of the agriculture sector.

1.2.1 National circumstances

Botswana is in the central part of Southern Africa with a land area of 581,730 km^2 of which only 2.58% is water and wetlands and the Kalahari Desert covers 70%. The 2022 population is 2,346,179 compared to 2,024,904 in 2011 a growth rate of about 1.4% (Statistics Botswana, 2022). The climate is subtropical, semiarid to arid with unreliable and poorly distributed rainfall with very hot summers and cool winters. The mean annual rainfall is 416mm, ranging from 250mm in the southwest to 650mm in the north of the country while the mean annual evapotranspiration is 2742mm ranging from 2,300 in the east (Mahalapye) to 3200mm in the west (Ghanzi) (GoB 2021b, Andringa, 1984). The rain season runs from October to April, however, with climate change the onset of the rains is shifting towards December and the unpredictability, frequency and intensity of droughts and floods are increasing.

Botswana is an upper middle-income aspiring to achieve a high-income country status (GoB, 2016) with its economy mainly dependent on minerals and tourism which contribute about 40% to the GDP. The contribution of agriculture to GDP is only 1.95% but the sector supports more than half of the rural population which is dependent on subsistence crop and livestock farming. Even though Botswana is not technically a poor nation, substantial clusters of poverty remain in its rural areas where the poverty rate is as high as 46% and unemployment for the country is at 17.7% (2022_IndexofEconomicFreedom-Botswana.pdf (heritage.org) Causes of Poverty in Botswana – The Borgen Project viewed on 30 June 2022). The poverty incidence rates in cities, urban villages, and rural areas and nationally based on 2015/2016 survey are 5.34%, 14.05%, 37.48 and 20.84%, respectively (Statistics Botswana, 2021.) These figures have increased with the Covid-19 pandemic and the current Russia-Ukraine war which has resulted in increasing prices of fuel, food, and other commodities.

The agriculture sector consisting mainly of livestock and arable crop production is dependent on rainfall. The livestock sector is dominated by the traditional livestock farming characterized by low offtakes, high stoking rates and poor herd management resulting in degradation of range resources. During the 2008-2019 period the livestock (cattle, goats, and sheep) population decreased from 4.4 million in 2010 to 2.4 million in 2019 with cattle population declining form 2.3 million in 2011 to 935,000 in 2019. The Botswana dairy industry is in its infancy and produces about seven million litres of milk annually, while the country needs about 70 million litres annually. The subsector is limited by availability of heat tolerant breeds and local fodder production. The production of cereals and legumes is characterized by low yields due to drought stress, pests, and low soil fertility. As a result, Botswana is a net importer of cereals and grain legumes. During 2008-2019 period, land area planted, and production have declined from 262,000ha and 41,000MT in 2011 to 88,000ha and 3,000MT in 2019 (Statistics Botswana 2019). The horticulture subsector depends on irrigation and the limited water resources have resulted in the development of horticulture clusters mainly around dams, urban wastewater treatment facilities and areas with readily available ground water. The government on 1st January 2022 banned the importation of sixteen vegetables to encourage retailers to buy from local producers. The agriculture sector is, therefore, vulnerable to the impacts of climate change such as droughts, extreme heat and floods as demonstrated by recent events such as 2019 drought.

1.2.2 National development policies, strategies and action plans related to climate change

1.2.2.1 Vision 2036 - Prosperity for All

Botswana's 20-year development framework for the period 2016 to 2036 is driven by Vision 2036 (GoB 2016b) whose theme is 'Achieving Prosperity for All' and aims to move Botswana from an upper middle-income to a high-income country. The four pillars of Vision 2036 are i) sustainable economic development, ii) human and social development, iii) sustainable environment and iv) governance, peace and security. Under sustainable environment the Vision acknowledges the threat of global warming and climate change on desired economic growth and development and the need for climate resilience and disaster risk reduction strategies.

For the agriculture sector, the Vision states "Our country will have a sustainable, technology driven and commercially viable agricultural sector. We will develop a disease-free agricultural sector that optimizes the use of land (and other resources), utilizing technologies and modern farming methods to improve productivity. We will encourage the development of private sector led value chains in the agricultural sector including the production, processing, marketing, and distribution activities".

1.2.2.2 National Development Plan (NDP) 11 Volume 1April 2017–March 2023.

The NDP11 (GoB 2016) is a development blueprint for the period April 2017 to March 2023 whose theme is *"Inclusive Growth for the Realisation of Sustainable Employment Creation and Poverty Eradication*". Climate change mitigation and adaptation is one of the strategies of NDP 11 under the Sustainable Environment Pillar. During NDP11 the Botswana Government has approved and is implementing the climate change policy, its strategy and action plan.

For the agriculture sector, the thrust of NDP11 is for the adoption of "smart agriculture" which is an approach that will help Botswana to transform her agricultural systems towards more productive, efficient, resilient and sustainable systems. The government allocated funding for "smart agriculture" projects such as Pandamatenga Agricultural Infrastructure Project, Zambezi Integrated Agro-commercial Development Project, Chobe-Zambezi Water Transfer Scheme Phase 1 to increase food security by providing water for irrigation of commercial farms.

Sustainable Development Goals Botswana Domesticated SDG Indicators

1.2.2.3 Sustainable Development Goals Botswana Domesticated SDG Indicators

On 25 September 2015, the 193 countries of the UN General Assembly including Botswana adopted the 2030 Development Agenda titled "Transforming our world: the 2030 Agenda for Sustainable Development". The global Agenda has 17 Sustainable Development Goals

(SDGs), 169 associated targets and 232 indicators. Botswana domesticated SDGs indicators are all the global SDGs indicators that are applicable to Botswana. The indicators are also mapped to the relevant pillars of the Botswana Vision 2036 (Statistics Botswana 2018).

The SDGs relevant to the agriculture sector in Botswana are SDG 2 End Hunger whose goal is to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Some of the targets under this SDG include:

- Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality
- Target 2.5: By 2020, maintain the genetic diversity of seeds, cultivated plants, and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote

access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

1.2.2.4 Final Action Plan - National Climate Change Action Plan for Botswana

The National Climate Change Action Plan (NCCAP) for Botswana (GoB, 2018) covers 2018 to 2030 timeframe and identified 11 and 7 key sectors for adaptation and mitigation, respectively. The sectors for adaptation are agriculture (livestock and animal husbandry and arable agriculture) Water

human health, human settlements, forest management, land use and land use change, disaster risk management, biodiversity and ecosystems, infrastructure development, industry and manufacturing and tourism.

For agriculture and food security, the NCCAP has proposed five climate change adaptation interventions as follows:

1. Identify key livestock-focused areas of intervention within existing Climate Smart Agriculture (CSA) programmes, and scale-up such programmes with a specific focus on livestock management.

2. Implement a strengthened livestock disease surveillance and response system to manage outbreaks, thereby maintaining resilience in the livestock sector and protecting the value of Botswana's livestock, with a specific focus on climate related threats and impacts.

3. Expand the reach of Botswana's existing Climate Smart Agriculture (CSA) programmes, with a specific focus on increasing resilience in production systems and subsequently production (outcome), during climate change and subsequently improved livelihoods (impact), e.g., job creation and market access,

4. Provide low-cost credit (concessionary loans), rebates, and other financial incentives to farmers and farming clusters for the purchase and use of solar-power water pumps and biogas digesters.

5. Invest in expanded and advanced agricultural early warning systems across all farming regions in Botswana, including the strengthening of watercourse flow gauge network and integration of weather alerts, with integration with ICT and radio-based technologies (e.g., mobile phone alerts) for dissemination of early warnings and climate information services.

1.2.2.5 Botswana National Communications to UNFCCC

Botswana is party to the United Nations Framework Convention on Climate Change (UNFCCC) and its related implementation mechanisms, including the Kyoto Protocol (KP), Paris Agreement and

Conference of Parties (COP). As required by UNFCCC, Botswana has put in place an organization structure for coordination of climate change with the Ministry of Environment, Wildlife and Tourism (MEWT) through the Department of Meteorological Services (DMS) in charge of coordinating all climate change related matters. The government submitted National Communications (NCs) to UNFCCC in 2001 (GoB 2001), 2011 (GoB,2011) and 2019 (GoB, 2019). In these documents, several technologies for climate change mitigation and adaptation were proposed. The implementation of the proposed adaptation technologies varied from full, partial or no implementation depending on the sectors.

NC 1 of 2001 and NC 2 of 2011 proposed the following adaptation technologies for the agriculture sector: adaptations to changes in growing season length, development of heat tolerant and drought resistant crops, intensify irrigation systems, changes in ploughing methods, develop agricultural infrastructure, adaptations to changes in crop productivity, seed and fertilizer provision, early warning systems, use of greenhouse/nets, drought mitigation, reducing livestock numbers and improving animal productivity. NC3 of 2019 has proposed conservation agriculture, nitrogen fertilizer application and plant population in cowpea, breeding for adapted animals, fodder production, supplementation, destocking, livestock mobility, improved herd health, development of sustainable water sources for livestock, and wildfire control and management. The focus of these technologies is to ensure the resilience of farmers especially the small scale and vulnerable ones and for national food security.

1.2.2.6 Nationally Determined Contributions (NDC) of Botswana to UNFCC

Botswana submitted to UNDP the Botswana INDC (GoB, 2016) and the Updated Nationally Determined Contribution of Botswana (Draft) NDC 2 (GoB, 2022). The Updated NDC covers adaptation, mitigation, as well as cross-cutting measures to increase the resilience of Botswana to climate change and contribute to the global effort to reduce GHG emissions. The sectors for adaptation measures in NDC2 include meteorological services, water, livestock, crop production, biodiversity and ecosystems and human health sectors. In total, there are 35 measures that will be grouped into larger (sectoral and partly even cross-sectoral) programmes to facilitate their implementation. The development of the TNA could play a vital role in identifying appropriate technologies, their required enabling framework conditions and preparing for their implementation plans for their transfer and diffusion.

1.2.2.7 The Botswana Climate Change Policy

The Botswana Climate Change Policy (BCCP) (GoB, 2021) was approved in 2021 and its vision is "Botswana through Vision 2036 strives to be a society that is sustainable, climate resilient, and whose development follows a low carbon development pathway, in pursuit of prosperity for all". The policy aims to mainstream sustainability and Climate Change into development planning and in so doing, enhance Botswana's resilience and capacity to respond to existing and anticipated Climate Change impacts. The policy also promotes low carbon development pathways and approaches that significantly contribute to socio economic development, environmental protection, poverty eradication and global goal for reduction of Green-house-Gases (GHG) from the atmosphere and SDG's. To this effect, the

TNA Project directly contributes to the realization of the objectives of the BCCP by coming up with appropriate adaptation technologies for the water and agriculture sectors.

1.2.2.8 Botswana National Drought Plan (BNDP)

Botswana as signatory to the United Nations Convention to Combat Desertification (UNCCD) signed and ratified the Convention in 1995 and 1996 respectively following the Rio Convention of 1992 in Brazil. Since climate change is expected to increase drought frequency and severity, the government has also put in place the Botswana National Drought Plan (BNDP) (GoB, 2021b). A key element of the BNDP is to boost the resilience of people, communities, and ecosystems against

drought by being prepared and acting early. For the agriculture sector the Plan has recommended adaptation measures such as animal and crop insurance, planting early maturing and drought tolerant crop varieties and species and drought tolerant animal breeds and species.

1.2.2.9 National Policy on Agricultural Development

The National Policy on Agricultural Development (GoB, 1991) was developed following the first comprehensive Agricultural Sector Assessment/Review Study conducted in 1988. The study evaluated the performance of the sector and its contribution to socio-economic goals, identified sectoral policy issues and constraints and provided policy recommendations to improve the sector's contribution to the economy in general and the rural population in particular. The study showed that the agricultural sector was characterised by cyclic performance due to erratic rainfalls and that the arable was more sensitive to climatic changes than the livestock subsector. The main causes of poor performance of the agriculture sector were identified to be: 1. Poor soils and erratic rainfall, 2. Poor management (this was the most significant factor contributing to poor performance), 3. Lack of appropriate technology, 4. The pricing system of grains, 5. Unproductive labour force – mostly unskilled, 6. Lack of diversification, 7. Non-targeted use of government subsidies, 8. Water availability, 9. High cost of energy and 10. Poorly developed physical infrastructure especially roads.

The policy was approved by the Botswana National Assembly 15th February 1991 and mainly addressed the poor performance of the sector to ensure "increase in productivity to acceptable levels with minimum adverse effects on resources and the environment". On technology development, the policy emphasized on concerted effort in providing the farming community with technology necessary to ensure efficient production under the country's agroecological conditions. The components of the technology included management practices in both livestock and arable sectors that will minimize the adverts effects of drought, high yielding and livestock together with the necessary inputs and management systems. Even though the policy does not specially mention climate change adaptation technologies, the measures suggested are aimed at improving the resilience of the sector to the effects of climate change.

1.2.2.10. Ministry of Agriculture Strategic Plan 2017-2023

The MoA strategic plan was developed to implement the NDP 11 (2016 -2023) key indicators for the sector of food security with its four dimensions of availability (adequacy and affordability of food), access, stability and utilization. The overall objective of the plan was "To ensure availability of adequate food supplies at national and district levels through a sustainable combination of domestic production, imports, reserves and effective distribution and marketing while creating sustainable, long term productive employment"

The plan does not directly address issues of climate change adaptation and mitigation in the three strategic themes: 1. Knowing the sector, 2. Enhancing agribusiness environment and 3. Develop the sector. However, there are aspects of the plan that will address adaptation to climate change as detailed below.

Under Theme 1. Knowing the sector, the plan will promote research and development resulting in technological improvements including the use of biotechnology to ensure growth in agricultural productivity. The research focus areas will be integrated pest management, high yielding and pest and drought tolerant crop varieties and animal breeds, livestock health and management and nutrition. To achieve these, the MoA will: 1. Establish NARDI, 2. Develop research agenda for domestication of indigenous food, 3. Upgrade agricultural research infrastructure and 3. promote a system of participatory research adapted to the needs of producers

Under the Theme 2. Developing the sector, sections 3.3 Sustainable use of agricultural resources and 3.4 Irrigation development will contribute to climate adaptation. Under sustainable use of agricultural resources, the strategic plan will promote 1. Conservation, management and sustainable utilisation of plants and animals including fish, 2. Climate smart agricultural technologies, 3. Controlled environment production and 4. Fodder production. Under irrigation the plan will promote: 1. Irrigation and 2. Efficient utilisation of water used for agricultural production

The current TNA process will hopefully identify adaptation technologies that will address some of the issues above to improve the resilience of the agriculture sector and the farmers in particular

1.3 Vulnerability assessment of the agriculture and other sectors in Botswana

1.3.1 Overview of existing vulnerability assessments

Botswana is one of the most drought prone countries in the world and climate change is worsening the situation by reducing mean annual rainfall, delaying the onset of rains, and raising the temperatures. According to GoB (2021b), Botswana has experienced single-year and multi-year droughts (in bold) since the 1950s as follows:1959/60 **1961-1965**, 1969/70, 1972/73, 1978/79, **1981-87**, 1991/92, **1993-1996**, 2001/02, **2004-2006,** 2007/08, **2011-2013**, 2015/16 and 2018/19. The figures show that the return period between droughts has shortened indicating increased frequency of drought. Botswana's 2050 climate scenarios have been constructed based on representative concentration pathways (RCPs) of 4.5 and 8.5 using global climate models (GCMs) and regional climate models (RCMs) ensemble and seasonal and annual precipitation, mean, maximum, and minimum temperature, drought, and extreme precipitation as inputs. The 2050 climate scenario predicts that Botswana will be hotter (an increase of 1.3 to 2.7ºC) and drier (GoB 2021b GoB, 2021c). This will generally reduce crop yields by decreasing suitable area for growing finger millet, dry beans, and maize while that for sorghum is projected to greatly increase. The increased aridity is expected to reduced livestock productivity due to deterioration and total loss of range resources. The declining rainfall and rising temperatures will also reduce availability of surface and ground water for irrigation of crops and drinking water for animals.

1.3.2 Strategic themes and recommendations coming from these assessments

According to Updated Nationally Determined Contribution of Botswana (GoB 2022), lack of human and institutional capacity and financial resources are major constraints to the implementation of both adaptation and mitigation measures across all sectors. Hence, strengthening of technical and institutional capacity to enable comprehensive assessment of vulnerability and implementation of adaptation actions is critical. The Department of Meteorological Services (DMS) and the Early Warning System (EWS) needs to be strengthened to provide timely weather, climatic information, and a wider range of climate-related threats, on which appropriate adaptation responses depend. It is also important to strengthen the sector-mandated ministries and committees responsible for implementation of climate change related activities namely, Ministry of Minerals and Energy, Ministry of Transport and Public Works and Ministry of Agriculture, the Parliamentary Portfolio Committee on Wildlife, Tourism, Natural Resources and District Development Committees. There is also need for funding of research, systematic observation, training, education, awareness creation and mainstreaming of climate change into all development activities.

1.3.3 Adaptation Priorities Identified

The Botswana Climate Change Policy (GoB 2021a) has identified and prioritized the following sectors for climate change adaptation measures based on their vulnerability:

1. *Agriculture and food security*: The unpredictability of rainfall, frequent droughts and extreme heat events in Botswana are viewed with most concern as most rural communities derive their livelihoods from rainfed small scale crop and livestock production. Most commercial arable farming is also dependent on rainfall because of limited water sources for irrigation.

2. *Water:* Availability of water for domestic and economic purposes determines the economic growth of any country. The varied and low rainfalls have largely affected most sectors of the economy especially major economic drivers such as agriculture, mining, and wildlife. Climate change is predicted to further reduce the already low water resources in Botswana, hence the need for water efficiency and conservation measures.

3. *Human health*: Climate change will negatively affect human health directly through

increased temperatures, drought, and floods and indirectly through its effect on the spread of water borne, water related, and vector borne diseases and malnutrition, hence the need for measures to reduce vulnerability and increase resilience to such impacts.

4. *Human settlements*: Development of sustainable and resilient human settlements to withstand adverse impacts of climate change with a low carbon footprint without compromising the living conditions of Batswana in rural and urban areas.

5. *Forest Management*: To increase the integrity and sustainability of Botswana forest and ensure that the threats of human and induced interventions are minimized for forests to achieve their dual role of climate change adaptation and mitigation.

6. *Land use and land use allocation*: Sustainable land use and land use allocation to minimize anticipated conflict stemming from climate variability and extreme weather events that result in migration of human settlements, livestock, and wildlife in search for suitable land and environment for socio-economic purposes.

7. *Disaster risk reduction*: Climate change impacts are likely to increase vulnerability to disaster

risk factors such as heatwaves, veldt fires, floods and droughts which will increase pressure on resource allocation towards disaster risk management. Thence the need for comprehensive approaches to disaster risk reduction programmes and plans to enhance societal adaptive capacity and capability

8. *Biodiversity and ecosystems*: Promotion of sustainable use of biodiversity and effective management of ecosystems, as well as promotion of equitable sharing of benefits from natural resources for increased adaptation and resilience to climate change impacts.

9. *Infrastructure Development*: Development of sustainable and climate resilient infrastructure such as buildings, roads, dams, water reticulation systems and electricity connections that can withstand climate change impacts such as floods and extreme heat events

10. *Gender*: Mainstreaming gender into development planning to ensure that climate change response measures are gender sensitive particularly the recognition of youth, women, children, and people living with disability and that such measures reduce their vulnerability to climate change impacts

The Updated Nationally Determined Contribution of Botswana (GoB 2022) climate ambition towards 2030 has prioritized 7 sectors for adaptation namely meteorological services, water, livestock, crop production, biodiversity and ecosystems and human health sectors.

1.4 Sector selection and overview

1.4.1 An Overview of projected climate change and its impacts in agriculture

Botswana has adopted a multi-faceted governance approach to tackle adaptation to the threats of climate change and build resilience to its impacts. The main climate change threats are droughts, floods and extreme temperature events which can further negatively affect the key sectors of the economy such as water, agriculture, and health. Adaptation to climate change and resilience to its impacts have been mainstreamed in NDP 11 (GoB, 2016a), Vision 2036 (GoB, 2016b), Botswana Climate Change Strategy (BCCS) (GoB, 2018a), Botswana Climate Change Policy (GoB 2021a) and NDC3 (GoB, 2022).

Predicted more frequent droughts, delayed onset of the rain season, higher temperatures, floods, and wildfires due to climate change will reduce animal and crop productivity in Botswana. Temperature is expected to increase by 1.3 to 2.7°C while rainfall will decrease in some regions and increase in others. Vulnerability assessment of livestock and rangeland indicated a decline in beef cattle and dairy cattle production by 2050 under RCP 4.5 mainly due to poor rangelands and high temperatures, respectively (GoB, 2019). Crop vulnerability assessment studies showed yield increases or decreases depending on the risk factor, crop species and region. In general, C3 crops like cowpeas will increase in yield with increasing temperature with Maun region having the highest increase of 55%. Among the C4 plants the highest average yield reduction was observed from the maize (-15%) and sorghum (-37%) crop in the

Francistown Region under RCP 6.0. while the highest increase in yield (+37%) was from pearl millet after incorporating stover in the soil from the Maun region(GoB, 2019). In general, increasing drought, floods and rising temperature tend to accelerate the rate at which insect pests and pathogens reproduce, the severity of damage they cause to crops and livestock and to expand or alter their range and migration patterns (Maxmen, 2013, Gupta et al., 2017).

1.4.2 Process and results of sector selection

The BCCS (GoB 2018) and Final Action Plan (GoB 2018) identified and prioritized the vulnerable sectors and their strategic adaptation action plans, programmes, and projects to achieve Botswana's vision of being a society that is sustainable, climate-resilient, and whose development follows a low carbon development pathway, in pursuit of prosperity for all. The strategy was cognizant of the fact that climate change will have economy-wide impacts with implications for Botswana's socio-economic growth, and the possibility that the country's objective of prosperity for all as articulated in its Vision 2036 and its achievement of the global Sustainable Development Goals (SDGs) will be jeopardized. Agriculture and food security and water are key to the economic, political, and social stability of any nation and are the most vulnerable to climate impacts especially drought and extreme temperatures. The BCCP (GoB, 2021a) prioritized ten (10) sectors for adaptation and seven (7) for mitigation.

However, the sectors for the current Botswana TNA were pre-selected during the GCF Readiness and Preparatory Support Proposal stage (Green Climate Fund, 2019). For adaptation only the top 2 (Agriculture and Water) out of the 10 sectors were prioritized. For mitigation, three subsectors under energy were prioritized mainly for reduction of GHG emissions. These were: Energy, including renewable electricity, Energy efficiency, the built environment, and Industrial processes. There were no consultations with stakeholders on sector selection for adaptation and mitigation due to limited time for the TNA project.

CHAPTER 2. INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

2.1 National and International TNA team

Botswana's TNA project is based at the Ministry of Environment, Wildlife and Tourism (MEWT). The Botswana Department of Meteorological Services (DMS) are the focal point for coordinating the TNA. The main Botswana TNA project team includes a National TNA Focal Point, three national sectoral experts (One mitigation expert, and two adaptation experts), including international technical experts (3 experts). The Botswana TNA project team works with sectoral working groups in the selected sectors. Furthermore, the team consults with relevant stakeholders throughout the process. Figure 1 shows the institutional arrangements of the stakeholder involvement in the TNA process.

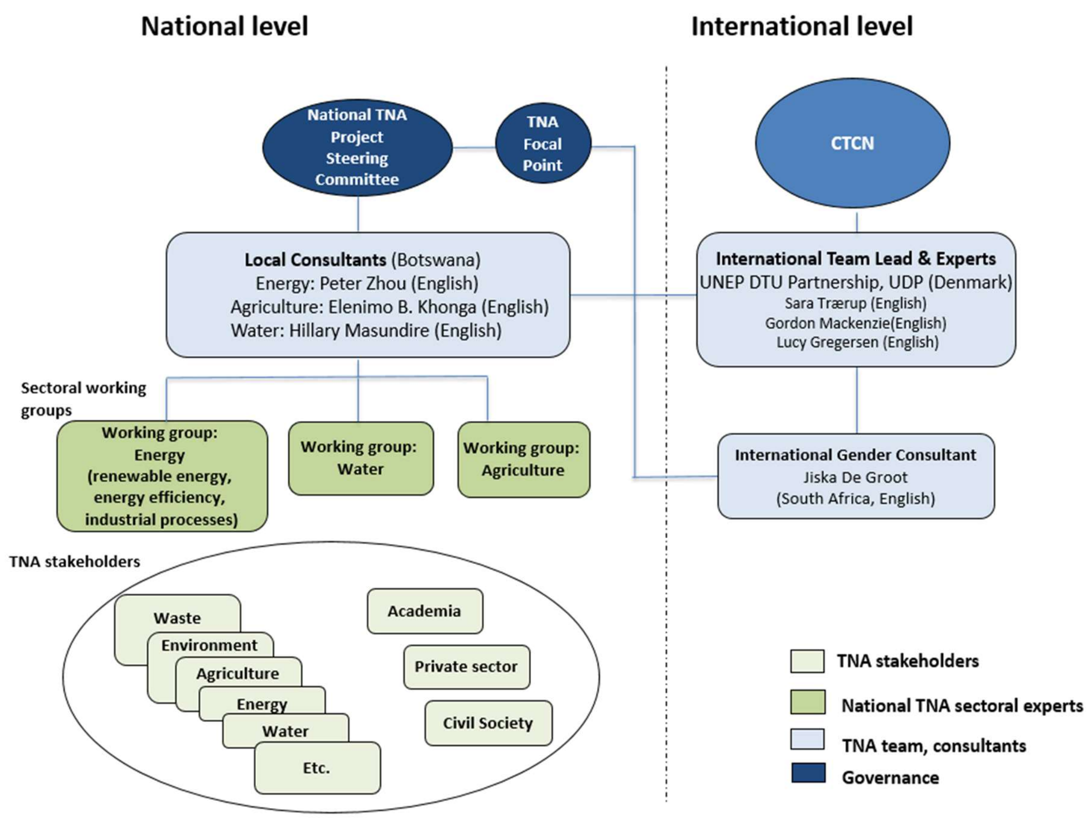


Figure 2. Institutional Structure for the TNA project

National TNA Focal Point

The Botswana DMS designated Mr. Maikutlo Mokakapadi as the TNA Focal Point. He is the focal point for the overall coordination and management of the TNA process nationally and is responsible for facilitating the project, and most importantly, communicate with national stakeholders, and communicate with UNEP Copenhagen Climate Centre (UNEP CCC), Climate Technology Centre & Network (CTCN), Nationally Designated Authority (NDA) to the GCF within the Ministry of Finance and Development Planning, and the Nationally Designated Entity (NDE) to the UNFCCC Technology Mechanism within the Botswana Institute for Technology Research and Innovation (BITRI).

National TNA Committee

The National TNA Committee is the guiding body of the project. The key objectives of the committee are to:

- Provide relevant data and info to the TNA
- Be active in the TNA process
- Oversee implementation
- Ensure validation of the deliverables based on agreed timelines
- Coordinate with the broader stakeholders within priority sectors as necessary

The National TNA Committee comprised of members responsible for policy making from all relevant ministries as well as key stakeholders from the private sector. Special consideration was given to gender balance, vulnerable groups, and appropriate representation throughout the process of the TNA Committee formation. The Committee will be chaired by the Permanent Secretary – Ministry of Environment, Wildlife and Tourism (MEWT). It is suggested that the TNA Focal Point, a representative of the NDE to the UNFCCC Technology Mechanism and representative of the NDA to the GCF are members of the Committee as they will work in close collaboration with the national TNA team and other experts and relevant stakeholders towards the implementation of the TNA project.

The National TNA Committee Consists of representatives from the following organizations presented in Table 1 below.

Table 1 National TNA Committee Members

Organization	Type of Stakeholder
1. Dept. of Energy	Government Institution
2. Dept. of Water and Sanitation	Government Institution
3. Dept. of Project and Infrastructure Planning	Government Institution
4. Dept. of Animal Production	Government Institution
5. Dept. of Agricultural Research Statistics and Policy Development	Government Institution
6. Dept. of Agricultural Research	Government Institution
7. Dept. of Crop Production	Government Institution
8. Ministry of Finance and Development Planning (NDA)	Government Institution
9. Dept. of Waste Management and Pollution Control	Government Institution
10. Ministry of Labour and Home Affairs	Government Institution

11. Ministry of Education and Skills Development	Government Institution
12. Ministry of Local Government	Government Institution
13. Botswana Climate Change Network	Network of Community Based Organizations, Non-Governmental Organizations, Research, and Private Sector
14. Botswana Energy Regulatory Authority	Government Institution
15. Solar Industries Association Botswana	Private Sector
16. BOCONGO	Non-Governmental Organizations

National and International Consultants

The selection of the national and international consultants by the CTCN for implementing the project, was done following competitive international bidding using the UNON procurement process. The team of national and international consultants that were selected, consists of the UNEP Copenhagen Climate Centre (formerly UNEP DTU Partnership) as the international technical experts, Ms. Jiska de Groot as the gender expert, and Mr. Peter Zhou as the national mitigation expert, Mr. Hillary Masundire as the national adaptation expert covering the water sector, and Mr. Elenimo Khonga as national adaptation expert covering the agriculture sector.

The adaptation and mitigation national experts are responsible for consulting relevant stakeholders; identifying and prioritizing technologies for specific sectors; leading the process of analyzing with stakeholders and sector working groups; participating in capacity-building workshops; working in close partnership with the national focal point, sector working groups, and stakeholders; and preparing the TNA and TAP (incl. barrier analysis) reports.

Sectoral Working Groups

To ensure extensive stakeholder participation, a sectoral working group was established for each priority sector. To facilitate strategic decision-making and cross-sectoral co-operation, the sectoral working groups were established under the National TNA Committee. The objective of the working groups was to provide inputs to: Identify prioritized sectors, identify, and prioritize technologies and validating final selection thereof, development of TAP (incl. barriers), and review of TAP for each sector.

Each sectoral working group consisted of representatives from the government ministries, private sector, academia, climate change experts and civil society. Tables 2 presents the composition of the agriculture adaptation sectorial working group.

Table 2 Adaptation sectoral working group for the agriculture sector

Institutions	Name of representative	Gender	Type of Stakeholder
1. Department of Crop Production, Ministry of Agriculture	Ms. Tshepho Matsuokwane replaced by Ms. Evelyn Ramontshonyana	F*	Government Institution
2. Department of Animal Production, Ministry of Agriculture	Mr. Thatayaone R. Oageng	M	Government Institution
3. National Agricultural Research and Development Institute (NARDI)	Dr Odireleng Molosiwa	M	Parastatal Organization - Research
4. Botswana Institute for Technology Research and Innovation (BITRI)	Prof Nyaladzi Batisani	M	Parastatal Organization - Research
5. Botswana Horticulture Council	Mr. Mogomotsi Moatswi	M	Private Sector
6. Botswana Farmers Association	Ms. Diane Sibanda	F	Private Sector
	Ms. Botsalano Coyne	F	Private Sector
7. Pandamatenga Commercial Farmers Association (PCFA)	Mr. Ryan Neal	M	Private sector
8. Botswana International University of Science and Technology	Prof G. Mengistu Did not participate	M	Parastatal organization - Academia
9. Botswana University of Agriculture and natural Resources	Not appointed	-	Parastatal organization - Academia
10. Botswana National Beef Producers Union (BNBPU)	Mr. Mpho Molokwe	M	Private sector
11. Department of Meteorological Services	Ms. Pearl Gosiame	F	Government Institution

**Gender participation of 60% males and 40% females*

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

After undertaking a stakeholder mapping, the initial stakeholder engagement was done through a Project Kick-Off Meeting held on 27th January 2022. The stakeholders were consulted regarding the rationale for the mitigation and adaptation sector selection, and gain input on the composition of each sectorial working group as well as the National TNA Committee.

The Project Kick-Off Meeting was attended by stakeholders from government, civil society, and the private sector.

Formal communication was sent in the form of official letters to the identified stakeholders to nominate a focal point who will be representing the respective organization in the National TNA Committee. The same was done at the level of the sectorial working groups.

Stakeholder engagement included a mix of bilateral and technical working group meetings and stakeholder workshops to identify and prioritize technologies. Due to the on-going COVID-19 pandemic mostly online meetings were conducted to minimize the risk of infection.

The agriculture sector stakeholder engagement was facilitated by the national consultant through one face to meeting and three virtual meetings. In between meeting stake holders were engaged online as they read documents and provided feedback when required to do so. Table 3 presents the key stakeholder engagement processes for the agriculture sector.

Table 3 Key stakeholder engagement process for the TNA project

Meeting/Workshop	Date and venue	Participants	Main Discussion Points
National TNA Kick-Off Meeting	27th January 2022, Virtual meeting	National TNA Committee and other relevant stakeholders from across the mitigation and adaptation sectors.	• Discussion on the composition of the National TNA Committee and sectorial working groups. • Workplan of the national TNA Committee. • How can gender aspects be mainstreamed into TNA process.
First Agriculture Working Group	22nd February 2022, Aquarian Tide Hotel	Agriculture Working Group members	• Training session for members on the TNA process
Second Agriculture Working Group meeting	7th April 2022, Virtual meeting	Agriculture Working Group members	• Selection of long list of adaptation technologies options (ATOs) • Training on multi-criteria analysis
Third Agriculture Working Group meeting	20th April 2022, Virtual Meeting	Agriculture Working Group members	• Finalization of list of ATOs and criteria for use in MCA • Assigning weights to criteria

			• Scoring of ATOs against criteria using MCA template • Ranking of ATOs
Fourth Working Group Meeting	15th August 2022	Agriculture Working Group members	• Conducted Sensitivity test following agreed adjustments of criteria weight • Final ranking of ATOs

2.3 Consideration of Gender Aspects in the TNA Process

Gender is considered a key aspect of the TNA process and was considered throughout the different stages of preparing the setup of the project and of this report. This was guided by the TNA Guidance for Gender Responsiveness (De Groot, 2018). In terms of the composition of the agriculture sector working group there were 7 males (64%) and 4 females (36%) (Table 2). The nomination of the WG members was done by the organizations after being sensitized about the importance of gender balance. Gender was also considered in the choice of adaptation technologies and their criteria for prioritization in the MCA to ensure that the final list of technologies will be inclusive of women and youth in their implementation.

CHAPTER 3 TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

Agriculture is an important source of the livelihoods of communities despite its contribution of 2% to the GDP in Botswana. Given that the agricultural sector is highly vulnerable to weather related production shocks, it is imperative that the sector adapts effectively to climate change to increase resilience of farmers, and the national economy in general. In this regard, adaptation technologies are important, and this chapter will focus on the technology prioritization for the sector.

3.1 Key Climate Change Vulnerabilities in the Agriculture Sector

Botswana is a semiarid country with frequent droughts and erratic and poorly distributed rainfall. Climate change is making the situation worse by increasing temperatures and delaying the onset of the rain season. These changes are making agriculture to be a risky business and making farmers to be vulnerable to climate change impacts. For optimal crop and livestock production optimal levels of water, temperature and soil nutrients at specific growth stages are critical. Changes in climate have necessitated the need for breeding for drought and heat tolerant crop varieties and livestock breeds or introduction of heat and drought tolerant species of crops and livestock.

3.1.1 Vulnerability of arable agriculture subsector.

a) Arable crop production subsector

Rain-fed crop production of cereals, pulses, and oil crops by the traditional sector in Botswana is increasingly vulnerable to the impacts of climate change. Annual yields of sorghum, maize, millet, beans/pulses, groundnuts, and sunflower for the period 2008 to 2019 have generally been declining with the steepest declines during 2015 and 2019 when Botswana experienced severe droughts as shown by standard precipitation indices of -2.2 and -2.3, respectively (Table 4.) (Statistics Botswana 2021, GoB 2021b). Land preparation depends on the onset of rains around October/November and the recent trend of delayed onset of rains to November/January has resulted in the decline of land prepared and planted respectively, from 279,000 and 227,000 ha in 2008 to 117,000 and 88,000 ha in 2019. This is because farmers are not ready to take the risk of planting crops very late as the rains may stop before crop maturity or may be affected by cold temperatures. The annual crop production figures are as erratic as the rainfall and were the lowest in 2019.

The most appropriate climate change adaptation technologies for the crop sector are those that will enable crops to survive drought and heat conditions during the growing cycle. These include use of supplementary irrigation during drought periods, use of crop varieties that are early maturing and tolerant to drought and crop residue management to reduce soil surface temperatures and evaporation.

b) Horticulture subsector

Production of vegetables and fruits in Botswana is dependent on availability of adequate and quality ground, surface and treated wastewater. The main horticultural crops are cabbage, tomatoes, bell pepper, potatoes, greens and oranges and they all meet 60% of the nation's demands. Horticulture farmers are grouped into small (less than 5ha), Medium (5-10ha) and large (more than 10 ha) scale farmers and the majority are located in the eastern part of the country where the soil, water availability and weather are more favourable (Botswana's horticultural value chain (fmb.co.bw)). The crops are grown in the open, under shed net or greenhouse and water is supplied through drip or sprinkler irrigation systems. Few farmers are using hydroponics and aquaponics. In January 2022 the government banned importation of most horticultural produce which has led to an increase of production as more small-scale farmers shifted to medium-scale production.

Table 4. Land area ploughed, planted and harvested, production and drought trends from 2008 – 2019

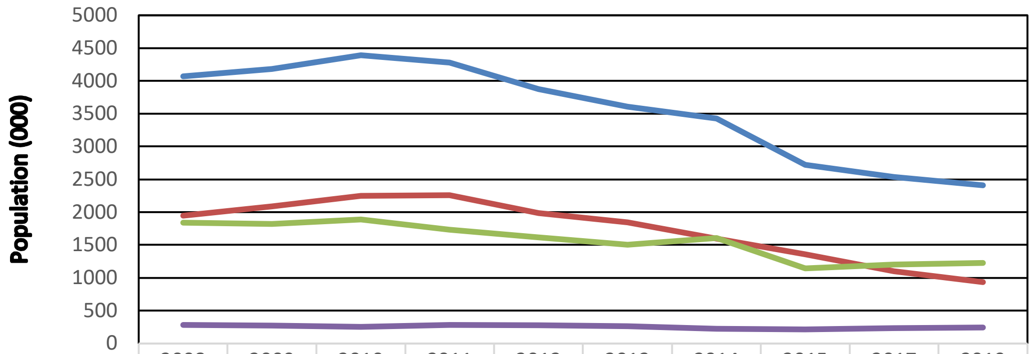
Area (000 HA) / Production (000 MT	2008	2009	2010	2011	2012	2013	2014	2015	2017	2019
Land area ploughed	279	327	259	273	261	259	273	260	135	117
Land planted	227	256	239	262	244	246	255	158	127	88
Land harvested	126	181	159	174	103	108	196	64	93	23
Production*	16	27	23	41	18	10	53	48	23	3
Yield/ha planted	0.07	0.11	0.09	0.16	0.07	0.04	0.21	0.30	0.18	0.03
SPI#	1.3	1.2	-0.3	0.4	-1.2	-1.2	2.2	-2.2	-0.4	-2.3

Source: Statistics Botswana 2021and GoB, (2021b)
* *Production: Combined yields for sorghum, maize, millet and beans/pulses*
\# *SPI: Standard Precipitation Index*

The horticulture subsector is vulnerable to drought, extreme temperatures and hailstorms and flooding caused by climate change. Frequent droughts are reducing the yields of ground water since the aquifers are not recharged. This is also increasing the cost of drilling boreholes as the depth to find water increases. Floods and hailstorms cause damage to the crops and infrastructure such as shed nets and greenhouses. The subsector requires adaptation technologies such as efficient water use irrigation systems, green energies for pumping water, salt tolerant varieties of crops, crop protection, protected environments against extreme temperatures and hailstorms, crop insurance and desalination of poor-quality ground water using reverse osmosis technology at farm level.

3.1.2 **Vulnerability of the Livestock subsector**

Livestock in Botswana comprises cattle, goats, sheep, donkeys/mules, horses, pigs, ostriches, chicken, and others but the main ones are cattle, goats, and sheep. Figure 2 shows the declining trend in the population of the main livestock in Botswana from 2008 to 2019. The total population declined by 40.8% while cattle, goats and sheep individually declined by 52%, 33% and 14%, respectively. The decline can be attributed to the frequent and severe droughts Botswana has experienced during the period since birth and offtake rates have remained the same, but the mortality rates have generally increased in the three species. In cattle the birth rate ranged from 39.1% in 2017 to 44.9% in 2008, offtake rate was 5.6% in 2010 to 7.3% in 2017 and the mortality rate ranged from 16.7% in 2015 to 23.5% in 2008 (Statistics Botswana, 2021). The trend shows that cattle are more susceptible to drought and high temperatures than goats and sheep and appropriate technologies are those that increase heat tolerance in cattle, species substitution from cattle to small stock or indigenous wildlife species or game farming. Supplemental feeding for livestock in time of drought is another technology which can reduce vulnerability of the livestock sector. In addition to drought, livestock disease outbreaks such as foot and mouth disease (FMD) have contributed to the population decline in some years. The FMD outbreaks are likely to increase with climate change as range resources become limited increasing livestock-wildlife encounters for disease transmission.



	2008	2009	2010	2011	2012	2013	2014	2015	2017	2019
Total	4067	4183	4390	4279	3877	3606	3430	2717	2535	2407
Cattle	1944	2087	2249	2260	1986	1845	1597	1360	1100	935
Goats	1841	1824	1889	1736	1615	1500	1606	1143	1200	1229
Sheep	282	272	252	283	276	261	227	214	235	243

Figure 2. Botswana cattle, goats and sheep population trends from 2008 to 2019
Source: Statistics Botswana (2021)

3.2 Decision context

Botswana has been implementing policies, programmes, and measures to help the agricultural and related sectors adapt to climate change and to reduce their vulnerability. The rural economy is largely based on livestock farming hence increased mortality due to a combination of heat stress, reduced availability of drinking water, increased distances to water livestock, as well as greater spread of diseases contribute to vulnerability. Rain-fed crop production is the main economic activity for the livelihood of the rural population and the impacts of droughts and changes in the onset and length of the growing season are becoming more frequent and serious. As seen in Table 5 above crop yields are decreasing in response to the above events.

Food and nutrition security and sufficiency have been at centre of various policies, programmes and NDPs. Vision 2036 envisions Botswana's agriculture to be "*sustainable, technology driven and commercially viable*" by having *"a disease-free agricultural sector that optimises the use of land (and other resources) utilising technologies and modern farming methods to improve productivity".* The NDP 11 (GoB 2016) highlights unsustainable agricultural practices which must be addressed for the sector to be resilient to the impacts of climate change. These include land degradation, due to overstocking, loss of productive arable and livestock grazing land, diminishing soil productivity and natural resource base (woodlands, forests and aquatic systems) that support poorer communities. Additionally, total dependence on rain-fed agriculture and poor soil increased vulnerability of farming systems and predisposed rural households to food insecurity and poverty, by eroding their productive assets and weakening their coping strategies and resilience to climate change. To address the situation NDP11 has provided funding for three agricultural support schemes (ISPAAD, LIMMID III and ASSP) to improve productivity and drought resilience and three agricultural cluster projects to improve commercial farming (Pandamatenga Agricultural Infrastructure Project, Zambezi Integrated Agro-Commercial Development and Chobe-Zambezi Water Transfer Scheme Phase 1)

3.3 Overview of Existing Technologies in the Agriculture Sector

There are several existing technologies for the traditional and commercial livestock, dryland crop and horticulture subsectors which aim to optimize production under the semiarid conditions of Botswana.

3.3.1 Existing technologies in the livestock subsector

There are two main types of livestock production systems (LPS): Communal LPS where animals graze in unfenced communally owned and managed grasslands and commercial LPS where animals graze in fenced freehold or leased grasslands with exclusive rights to grazing resources (Tsopito, 2014). The communal LPSs are divided into cattle post areas (CPA) where the grazing area with one or more boreholes is far from the village or town and the village grazing areas (VGA) or peri-urban areas where animals graze from the village and surrounding areas and may use municipal water for watering the animals. The communal LPS account for over 80% of the cattle population in Botswana.

The current technologies include:

- Use of drought tolerant indigenous beef cattle breeds such as Tswana or improved Musi, Tswana goats and sheep for the communal LPS farmers
- Shifting from cattle to small stock (sheep and goats)
- Shifting from commercial livestock farming to game farming
- Supplemental feeding with crop residues and nutrients especially during the dry season
- Herd health to cover disease surveillance and control
- Sustainable livestock populations to minimize range degradation

Most of these technologies have not been fully diffused and adopted by the traditional livestock sector due economic, social, and cultural challenges and may need further support. The commercial LPS farmers use more superior breeds and sustainable management practices which are costly and beyond the reach of most traditional or communal farmers.

3.3.2 Existing technologies in the arable crop and horticulture production sectors

Arable farmers are grouped based on farm size into subsistence (≤ 16ha), emerging (16-150ha) and commercial (≥1500ha). For a long time, traditional farmers practiced broadcasting where a mixture of indigenous cereal, legume and melon seeds were sown together during ploughing after adequate rainfall as insurance against total crop failure. This technology has almost been replaced by row cropping of individual crops in monocultures or intercrops. Programmes such as ISPAAD first introduced in 2008, has incentivised farmers to adopt modern technologies by providing free seed, fertilizer, cluster fencing, potable water, draught power to commercialise agriculture in Botswana. The technologies include use of hybrid seed, use of fertilizer, weeding, row planting, secondary and tertiary tillage (https://www.yumpu.com/en/document/read/36210051/new-ispaad-guidelines-ministry-of-agriculture). Conservation agriculture has also been adopted especially by commercial farmers to conserved soil moisture and structure and reduce GHG emissions from traditional tillage systems. However, this has necessitated the use of specialized tillage equipment and IPM technology to manage increased pest and disease outbreaks associated with the accumulation of crop residues on the soil surface. Large scale irrigation for field crops is being implemented by few large-scale farmers in Pandamatenga.

The horticulture sector depends mainly on availability of water and infrastructure for protected environment for crop growth. The sector generally requires substantial initial investment in irrigation systems, greenhouses and shed netting depending on the crop to be grown. The current technologies include:

- Drip irrigation of crops in open fields, or greenhouse/she net,
- Hydroponics
- Solar pumping of water for irrigation
- Use of grey water for horticulture production

3.3.3 Integrated farming system (livestock-crop farming)

Traditionally, crop and livestock production activities had different designated land use areas to reduce conflict. However, on 21st February 2013, Presidential Directive CAB 2(B)/2013 (GoB, 2013) approved integrated farming on agricultural land. According to the directive Integrated Farming is practicing the various agricultural enterprises (arable, small stock, beef, etc), which are compatible and support each other in an enclosed parcel of land. The obvious advantage of integrated farming is that it allows the landholder to concentrate production efforts on a single piece of land, thus saving the farmer labour and costs in developing more than one piece of land.

3.4 Adaptation Technology Options for the Agriculture Sector and their main adaptation benefits

Adaptation technology options (ATOs) are all potential technologies currently not available or are not fully diffused to address climate change impacts identified through literature review and expert consultations. Two lists of potential ATOs for the agriculture sector were initially prepared by the Local Consultant using desk review of relevant national documents and the UDP Guidebook by Clements at al., (2011). The national documents reviewed were:

- Botswana Initial National Communication to UNFCCC (NC1) (GoB 2001)
- Botswana Technology Needs Assessment on Climate Change Final Report 1 (GoB 2004),
- Botswana Second National Communication to UNFCCC (NC 2) (GoB 2011)
- First Nationally Determined Contribution of Botswana (NDC 1) (2016)
- Final Action Plan - A National Climate Change Action (GoB, 2018)
- National Climate Change Action Plan (NAP) 2018 and Updated Final Botswana Climate Change Strategy (GoB, 2019a)
- Botswana's Third National Communication to The United Nations Framework Convention on Climate Change (GoB, 2019b)
- Draft Updated Nationally Determined Contribution of Botswana (GoB, 2022),

UDP Guidebook (Clements et al., 2011) has 22 generic ATOs for the agriculture sector as listed in Table 5. From the national documents, 52 potential adaptation measures, technologies and actions were identified and listed in Table 6. The two lists were shared with ASWG members, and each member was requested to select and rank the top 15 ATOs from the generic list which covered aspects of those from the national documents. The ASWG then met on 22nd February 7th and 22nd April 2022 to come up with an agreed prioritized list of 10 to 15 ATOs. The first meeting was face to face while the last two meetings were virtual due to logistical challenges when UDP changed to UCCC and the COVID-19 pandemic.

Eleven (11) ATOs (Table 7) were finally agreed upon by the ASWG using expert judgement and the consultant prepared a technology fact sheet (TFS) for each ATOs (Appendix 1). A TFS is a brief (1-2 pages) description of a technology which provides one's audience with compelling information to be able choose or reject a technology. A typical TFS template covers the following topics:

- **Introduction**
- **Technology characteristics**

- **Country specific applicability and potential (**capacity, scale of application and time horizon-short /medium/long term)
- **Status of technology in country (a**vailability of technology)
- **Climate change mitigation/adaptation benefits**
- **Benefits to economic / social and environmental development**
- **Financial Requirements and Costs (c**apital, operating and other costs)

The 11 FTSs were shared with the ASWG members together with the 11 ATOs 2 weeks before conducting multi-criteria analysis (MCA).

Table 5. Generic adaptation technologies options for the agriculture sector

Technology Category	Technology
Planning for Climate Change and Variability	1. National Climate Change Monitoring System
	2. Seasonal to Interannual Prediction
	3. Decentralized Community-run Early Warning Systems
	4. Climate Insurance
Sustainable Water Use and Management	1. Sprinkler and Dripping Irrigation
	2. Fog Harvesting
	3. Rainwater Harvesting
Soil Management	1. Slow-forming Terraces
	2. Conservation Tillage
	3. Integrated Nutrient Management
Sustainable Crop Management	1. Crop Diversification and New varieties
	2. New Varieties through Biotechnology
	3. Ecological Pest Management
	4. Seed and Grain Storage
Sustainable Livestock Management	1. Selective Breeding via Controlled Mating
	2. Livestock Disease Management
Sustainable Farming Systems	1. Mixed Farming
	2. Agro-forestry
Capacity Building and Stakeholder Organization	1. Farmer Field Schools
	2. Community Extension Agents
	3. Forest User Groups
	4. Water User Association

Source: Clements et al., 2011

Table 6. Agriculture adaptation technology options, measures and actions proposed in national documents and their status in Botswana

National Document	Adaptation option	Status in Botswana
First Technology Need Assessment (TNA) Report (GoB 2004)	1. Conservation tillage	Needs diffusion
	2. Animal breeding for methane abatement and high productivity	Not available
	3. Reduction of livestock numbers to optimize pastures and reduce GHGs	Needs diffusion
Botswana Initial National Communication to UNFCCC (NC1) (GoB, 2001)	1. Adaptations to changes in growing season length	Needs diffusion
	2. Development of heat tolerant and drought resistant crops	On-going
	4. Intensify irrigation systems	Needs diffusion
	5. Changes in ploughing methods	Needs diffusion
	6. Develop agricultural infrastructure	On-going
	7. Adaptations to changes in crop productivity	Needs diffusion
	8. Seed and fertilizer provision	On-going
	9. Early warning systems	Needs diffusion
	10. Use of greenhouse/nets	On-going
	11. Drought mitigation	On-going
Botswana Second National Communication to UNFCCC (NC 2) (GoB, 2011)	1. Reducing livestock numbers	Needs diffusion
	2. Improving Animal Productivity	Needs diffusion
	3. Ionophores	Not available
	4. Probiotics	Not available
	5. Improved Forage Quality	Needs diffusion
	6. Manipulating livestock Nutrient Composition for Reduction of GHG	Not available
	7. Animal Breeding	On-going
	8. Livestock Methane Vaccine	Not available
	9. Conservation Tillage	Needs diffusion
	10. Tractor Operation and Selection	Needs diffusion
First Nationally Determined Contribution of Botswana (NDC 1) (GoB, 2016)	1. Improve genetic characteristics of the livestock breed such as Musi breed	On-going
	2. Improve livestock diet through supplementary feeding	On-going
	3. A switch to crops with the following traits: Drought resistant, tolerant to high temperatures and short maturity	Needs diffusion
National Climate Change Action Plan (NAP) 2018 and Updated Final Botswana Climate Change Strategy (GoB, 2019a)	1. Identify key livestock-focused areas of intervention within existing Climate Smart Agriculture (CSA) programmes, and scale-up such programmes with a specific focus on livestock management	Needs diffusion

	2. Implement a strengthened livestock disease surveillance system to manage outbreaks, thereby maintaining resilience in the livestock sector and protecting the value of Botswana livestock with a specific focus on climate related threats and impacts	On-going
	3. Expand the reach of Botswana's CSA programmes, with a specific focus on increasing resilience in production systems and subsequently production (outcome) in the midst of climate change and subsequently improved livelihoods (impact) eg job creation and market access	Needs diffusion
	4. Provide low-cost credit (concessionary loans) rebates, and other financial incentives to farmers and farming clusters for the purchase and use of solar power water pumps and biogas digesters	Needs diffusion
	5. Invest in expanded agricultural early warning system across all farming regions in Botswana, including the strengthening of watercourse flow gauge network and integration of weather alerts with integration with ICT and radio -based technologies (eg mobile phone alerts) for dissemination of early warning and climate information services	Needs diffusion
Botswana's Third National Communication to UNFCCC (NC3) (GoB, 2019b)	1. Conservation agriculture	Needs diffusion
	2. Nitrogen fertilizer application and plant population in cowpea	Needs diffusion
	3. Breeding for Adapted Animals	On-going
	4. Fodder production	On-going
	5. Supplementation	On-going
	6. Destocking	Needs diffusion
	7. Livestock mobility	On-going
	8. Improved herd health	On-going
	9. Development of sustainable water source for livestock	Needs diffusion
	10. Wildfire Control and Management	On-going
Second Nationally Determined Contribution of Botswana (NDC 2) (GoB, 2021)	1. Heat-resistant livestock breeds	On-going
	2. Destocking/strict observation of stocking rates	Needs diffusion
	3. Herding and directed area grazing for health and range management	Needs diffusion

	4. Rehabilitation of degraded lands	Needs diffusion
	5.Emergency forage storage and distribution system	On-going
	6. Promote game farming as a heat- and drought-tolerant alternative to livestock farming	Needs diffusion
	7. Continued development of and switch to crops with the following traits 1) drought resistant, 2) tolerant to high temperatures and 3) short maturity	Needs diffusion
	8. Conservation agriculture, with specific focus on those living in poverty, female-headed households and ethnic minorities	Needs diffusion
	9. Integrated Pest Management (IPM)	Needs diffusion
	10. Integrated Soil Management (ISM) to reduce synthetic fertilizer use	Needs diffusion
	11. Agroforestry	Needs diffusion

Table 7. Reviewed and prioritized adaptation technology options for the agriculture sector

Technology	Description	Adaptation benefits
1. Crop diversification and new varieties (CDNV)	The technology involves the breeding and promotion of crop varieties, landraces and introduction of species which are early maturing, drought tolerant, pest and disease resistant and high yielding for food security and resilience to the effects of climate change. A diversified portfolio of crops ensures that farmers do not suffer complete ruin when disasters occur. Similarly, diversification can manage market price risks, on the assumption that not all products will suffer low prices at the same time.	Use of drought/heat tolerant and early maturing crops is critical for the resilience of the agricultural sector and food security in Botswana. Crop diversification reduces the risk of total crop failure in the event of unforeseen climate events. For instance, if one crop fails due to drought or climate induced pest infestation, the farmer will still survive on production from the other crops
2. Efficient irrigation technologies for food security (EITFS)	Efficient irrigation system that provides water to crops using sprinkler or drip irrigation and uses renewable energy to power the pumping of water from water source such as dams, rivers, or boreholes	The technology supports farmers to adapt to climate change during drought periods by using limited water resources efficiently to rescue the crops and enabling them to plant even if the onset of the rain season is late. Use of renewable energy for pumping can help reduce GHG emissions.

3. National Multiple Hazard Early Warning System (EWS)	The technology involves the establishment or expansion of the National EWS to serve multiple sectors such as drought, fires, groundwater availability, insect pest and disease outbreaks and health.	This technology provides reliable prediction of weather- and climate-related hazards to enable governments, communities and individuals to plan for and put measures for minimizing the negative impact of hazards such as drought, floods and wildfires.
4. Strengthening agrometeorological monitoring and information system (SAMIS)	The technology involves the use of agrometeorological data to forecast pest and disease outbreaks and final annual agricultural production. The technology requires installation of modern Real-Time, On-Demand Automated Agromet Stations throughout the country and a data processing centre for production of agrometeorological forecasts. Individual farmers can also have the stations for on-farm forecasts of disease and pest outbreaks.	Functional AFS is critical for the resilience of the agricultural sector because the data is useful for predicting potential losses caused by climate change events enabling farmers to take necessary adaptive actions and governments to prepare for disaster relief programmes
5. Conservation Agriculture (CA)	Conservation Agriculture encompass several technologies that promote minimum soil disturbance, maintenance of a permanent soil cover, and diversification of plant species to enhances biodiversity and natural biological processes above and below the ground surface to improve water and nutrient use efficiency and crop production. The technology may involve one or a combination of any of the following conservation tillage, mixed farming, and agroforestry.	Unpredictability of rainfall and increasing temperatures may affect soil moisture levels leading to crop losses. Conservation agriculture technologies reduce risks and impacts of climate events thus building resilience of farmers. Some of the technologies also mitigate against climate change by reducing GHG emissions and sequestering carbon through reduced use of inorganic fertilizers and fossil fuels in crop production.
6. Rainwater harvesting	The technology involves inducing, collecting, storing, and conserving rainwater from local surface runoff for domestic and agricultural use in arid and semi-arid regions. The rainwater catchment areas include rooftops of buildings, rock surfaces and ground surfaces and storage devices include above- or below- ground storage tanks.	In Botswana the rain seasons are becoming more unpredictable with less poorly distributed rainfall and high temperatures resulting in low levels or no water in reservoirs and rivers. Rainwater harvesting represents an adaptation strategy for people

		living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture.
7. Livestock selective breeding and species diversification	The technology involves systematic breeding of animals that are resilient to climate change effects and introduction of new species and livestock farming systems. Use of new species includes promotion of game farming to replace livestock or combination of livestock and game species and switching from cattle to small stock.	Selective breeding through controlled mating enables farmers to use breeds of animals that are more resistant to the impacts of climate change and reduces the risk of losing animals and income to climate change impacts. Indigenous ruminant and non-ruminant wildlife species are generally more tolerant to stresses such as diseases, drought and heat than popular exotic livestock species such as cattle
8. Sustainable livestock health and population management	The technology involves strategies of maintaining healthy livestock populations with minimal range degradation and desertification under increasing drought conditions due to climate change. These include culling or destocking and enforcement of sustainable stocking rates, promoting a switch from cattle to small stock for traditional farmers, improved cattle post and ranch husbandry practices such as herding, directed area grazing and diet supplementation, increased extension campaigns for buy-in by traditional livestock farmers and livestock disease management	The technology enables recovery of the range and minimum animal losses during drought periods. For example, improved cattle post and ranch practices ensure that animals are directed to graze in alternating areas to allow range recovery and indigenous small stock breeds are generally more tolerant to drought stress and need less grazing area than cattle so encouraging farmers to switch to small stock is an adaption to climate change
9. Index-based Climate Insurance	The technology involves farmers buying insurance against crop and livestock loss due to extreme events of climate change such as drought and floods. Index based insurance assessment does not require on site verification but is based on severity of the hazard such as drought and flooding	Crop losses in years of extreme climatic events can cause extreme financial hardship on commercial farmers and starvation for subsistence farmers. Climate insurance is an adaptation safety net for farmers in years of crop/livestock loss due to climatic events as farmers are

		compensated for the losses incurred.
10. Integrated Pest Management (IPM)	The technology involves the use of multiple and compatible tactics to maintain pest populations below economic injury levels with minimum injury to people, animals, plants and the environment. IPM integrates crop management (variety selection), soil management (agronomy) and pest (pathogens, insects, weeds, birds etc) management for optimal plant health.	IPM contributes to climate change adaptation and resilience by providing a healthy and balanced ecosystem in which the vulnerability of plants to pests and diseases is decreased. By promoting a diversified farming system, the practice of EPM builds farmers' resilience to potential risks posed by climate change, including losses caused by new pests and diseases.
11. Integrated Nutrient Management (INM)	The technology involves the integration of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. It covers soil testing for nutrient deficiencies/toxicities, appraisal of soil fertility management practices, assessment of cropping practices and participatory farmer led INM technology development	Harsh climatic conditions are a major cause of soil erosion and the depletion of nutrient stocks. By increasing soil fertility and improving plant health, INM can have positive effects on crops and increase resilience of farmers to the impacts of climate change

3.5 Criteria and process of technology prioritisation

3.5.1 Capacity building on MCA

Multi-criteria analysis (MCA) was used to objectively rank the 11 ATOs from the most to the least important and to build consensus among the stakeholders with divergent views. Multi criteria analysis is a structured framework for comparing several adaptation technologies across multiple criteria. A major benefit of using MCA for prioritizing adaptation technologies is the ability to include the preferences of stakeholders involved in the process, emphasizing the importance of having appropriate representation of stakeholders during the prioritization process. Members of the working group were initially trained on the steps in the MCA process as detailed in Trærup and Bakkegaard, (2015) during a virtual meeting held on 7th April 2022. Each step was thoroughly discussed and illustrated using practical examples with the MCA calculator.

3.5.2 MCA Process for prioritization of ATOs

According to Trærup and Bakkegaard, (2015) the following stepwise approach was used in the prioritization of the identified 11 ATOs in Table 8 above.

1. Identification of the criteria for technology prioritization

Criteria for technology prioritization are grouped into costs and benefits. The cost criteria are subdivided into three:

- capital or initial
- operational and maintenance
- other costs associated with the technology transfer.

The benefit criteria are subdivided into six:

- political/institutional
- environmental
- social
- economic
- climate related and
- technology related

Table 8 shows 19 generic criteria according to their groups and subgroups (Trærup and Bakkegaard, 2015). Based on the generic criteria the consultant prepared and shared with the group ten criteria for review. Some of the criteria combined two or more of the generic ones. Discussions on the criteria were guided by the template of the TFSs as presented above. After thorough discussions, the criteria presented in Table 9 were adopted for use in the MCA

Table 8. Generic criteria for prioritization of ATOs

Category	Subcategory	Criteria
Costs	Capital	Minimize cost of set-up
	Implementation and maintenance	Minimize cost of implementation and maintenance
	Others	Minimize other types of spending
Benefits	Institutional / political	Coherence with national adaptation plan and development goals
		Ease of implementation
	Environmental	Protect biodiversity
		Protect of environmental resources
		Support ecosystem services
	Social	Reduce poverty
		Reduce inequity
		Improve health
		Preserve cultural heritage
	Economic	Encourage private investment
		Improve economic performance
		Create jobs
	Climate Related	Reduce direct GHG
		Potential to reduce vulnerability and build climate resilience
	Technology Related	Rapid rate of technology diffusion
		Efficiency of technology compared to other alternatives (maturity and effectiveness)

Table 9. Criteria for prioritizing ATOs for the agriculture sector

Consideration	Criterion and its explanation
Costs	1. Capital cost (**CC**)- Costs of setting up the technology which include cost per unit of technology, costs of importation, installation, human expertise, energy sources, land and organizational resources needed.
	2. Operational and other costs (**OOC**) -These include operation and maintenance, human expertise, maintenance of emergency food stocks, supporting of conflict resolution management support, social and environmental costs.
Economic benefit	3. Improved economic performance and private investment (**IEPPI**) - Improved agricultural productivity, changes in markets for agricultural products and potential for companies, financial organizations, or other investors to finance investment
	4. Job creation and improved livelihoods (**JCIL**) - Number and types of potential jobs to be created and consistency of gender balanced income flow/ household assets and capabilities especially for women and the youth
Social benefit	5. Poverty and inequity reduction potential (**PIRP**) - Ability to improve standards of living, food security, better housing, accessibility of financial services especially for vulnerable communities, women, and youth
	6. Potential to improve health and preserve cultural heritage (**PIHPCH**) - Reduced undernourishment, morbidity and mortality in vulnerable groups reduced drudgery of labor demand from women and men and alignment with cultural norms and indigenous knowledge in agriculture
Environmental benefit	7. Protection of biodiversity, environmental resources, and ecosystem services (**PBERES**) - Ability of technology to maintain the local ecosystem with its biodiversity, reduced soil and water loss and reduced incidence of pests and increase activities of beneficial species such as pollinators
Climate related benefit	8. Reduced vulnerability, improved resilience and reduced emission (**RVIRRE**) - Ability of the technology to reduce vulnerability and build climate resilience; and reduce greenhouse gas (GHG) emissions as a co-benefit.
Institutional and political benefit	9. Ease of implementation and coherence with development policies (**EICDP**) - Availability of enablers (human, organizational, policy and financial capacity) to establish and operate the technology and coherence of the technology with existing social systems and development goals
Technology related benefits	10. Technology efficiency and its adoption rate by stakeholders (**TEARS**) - Ease of diffusion and in-country accessibility of the technology and efficiency and effectiveness of the technology in achieving the desired results

2. Scoring of criteria against ATOs

Using the logic in the MCA Guidebook (Trærup and Bakkegaard, 2015), the criteria were assessed by allocating scores of 0-100 (0 not favorable, 100 very favorable) to the cost and benefit criteria (Table 10). Each member was requested to score the ATOs against the criteria and the average scores were combined. The group together made decisions on the final score for each criterion to come up with the scoring matrix.

Table 10. Logic for scoring criteria in evaluating technologies

Score category	Costs	Benefits
Not applicable to ATO	0	0
Very Low	76-100	1-25
Low	51-75	26-50
Medium	26-50	51-75
High	1-25	76-100

3. Weighting of the criteria

The ASWG allocated weight to each criterion (adding to 1 or 100%) according to its urgency and importance in contributing to development priorities, applicability, and suitability for climate change adaptation. This was done to normalize the scores to express the relative importance of each criterion with respect to the other criteria. Table 11 shows the agreed weights for the ten criteria

Table 11. Weights allocated to criteria for MCA

Consideration	Criteria	Weights
Costs	1. Capital cost (**CC**)	30
	2. Operational and other costs **(OOC)**	15
Economic benefit	3. Improved economic performance and private investment (**IEPPI**)	10
	4. Job creation and improved livelihoods (**JCIL**)	10
Social benefit	5. Poverty and inequity reduction potential (**PIRP**)	5
	6. Potential to improve health and preserve cultural heritage (**PIHPCH**)	5
Environmental	7. Protection of biodiversity, environmental resources, and ecosystem services	5
Climate related	8. Reduced vulnerability, improved resilience and reduced emission (**RVIRRE**	10
Institutional and political benefit	9. Ease of implementation and coherence with development policies (**EICDP**)	5
Technology related benefits	10. T Technology efficiency and its adoption rate by stakeholders (**TEARS**)	5
Total		100

4. Combined score and weight for overall ranking of ATOs

Using the MCA calculator template, for each criterion its score was multiplied by its weight to get the overall score used in the ranking of the ATOs. The ATOs were ranked in descending order from the highest overall score to the lowest.

5. Sensitivity Test of Results

A sensitivity test was conducted on 20 July and 15 August 2022 whereby the members were given a chance to review the ranking by adjusting the weights giving compelling justification. The final agreed weights were inputted into the MCA calculator to get the final ranking of ATOs.

3.6 Results of technology prioritisation for the agriculture sector

Tables 12 and 13 show the initial MCA prioritization results and Tables 14 and 15 show the final ATO rankings after conducting the sensitivity test. The adjustment of weights did not change the final ranking of the ATOs. The final ATO prioritization resulted in the following top four ATOs:

1. Integrated Nutrient Management (INM) with an overall score of 8765. The technology involves the integration of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. It covers soil testing for nutrient deficiencies/toxicities, appraisal of soil fertility management practices, assessment of cropping practices and participatory farmer led INM technology development. Botswana soils are generally low in fertility and INM will have positive effects on crops and increase resilience of farmers to the impacts of climate change.

2. Livestock Selective Breeding and Species Diversification (LSBSD) with an overall score of 8675. The technology involves systematic breeding of animals that are resilient to climate change effects and introduction of new species and livestock farming systems. Use of new species includes promotion of game farming to replace livestock or combination of livestock and game species and switching from cattle to small stock. This will increase the resilience of farmers by ensuring that some species or breeds survive in case of drought or high temperature events.

3. Crop Diversification and New Varieties (CDNV) with an overall score of 8555. The technology involves the breeding and promotion of crop varieties, landraces and introduction of species which are early maturing, drought tolerant, pest and disease resistant and high yielding for food security and resilience to the effects of climate change. A diversified portfolio of crops ensures that farmers do not suffer complete ruin when disasters occur.

4. Sustainable livestock health and population management (SLHPM) with an overall score of 8395. The technology involves strategies of maintaining healthy livestock populations with minimal range degradation and desertification under increasing drought conditions due to climate change. These include culling or destocking and enforcement of sustainable stocking rates, promoting a switch from cattle to small stock for traditional farmers, improved cattle post and ranch husbandry practices such as herding, directed area grazing and diet supplementation, increased extension campaigns for buy-in by traditional livestock farmers and livestock disease management. The technology enables recovery of the range and minimum animal losses during drought periods, thus increasing farmer resilience to climate change effects.

The ranking of the rest of the ATOs in decreasing order were:
5. Rainwater harvesting (RH) with an overall score of 8370
6. Integrated / Ecological Pest Management (IPM / EPM) with an overall score of 8255
7. Conservation Agriculture (CA) with an overall score of 8030
8. Strengthening agrometeorological monitoring and information system (SAMIS) with an overall score of 7770
9. Efficient irrigation technologies for food security (EITFS) with an overall score of 7380
10. National Multiple Hazard Early Warning System (NMHEWS) with an overall score of 6825 and
11. Index-based Climate Insurance (IBCI) with an overall score of 6211

The top 3 or 4 prioritized adaptation technologies will be developed into technology action plans after validation and barrier analysis.

Table 12. Final scores and weights of criteria before sensitivity test

ATO	Costs		Benefits							
			Economic		Social		Environ-mental	Climate	Institutional & Political	Technology Related
	CC	OOC	IEPPI	JCIL	PIRP	PIHPCH	PBERES	RVIRRE	EICDP	TEARS
Crop Diversification and New varieties (CDNV)	70	90	95	80	100	90	80	90	90	70
Efficient Irrigation Technologies for Food Security (EITFS)	60	20	95	80	95	90	80	100	80	60
National Multiple Hazard Early Warning System (NMHEWS)	60	95	70	60	60	70	70	70	60	60
Strengthening Agrometeoro-logical Monitoring and Information System (SAMIS)	70	95	80	70	80	80	70	80	70	70
Conservation Agriculture (CA)	85	80	80	70	80	80	80	85	90	85
Rainwater Harvesting (RH)	80	95	80	70	90	95	70	80	90	80
Livestock Selective Breeding and Species Diversification (LSBSD)	80	85	80	90	95	95	80	90	80	80
Sustainable Livestock Health and Population Management (SLHPM)	80	80	80	90	80	90	90	90	80	80
Index-based Climate Insurance (IBCI)	55	15	70	50	80	80	71	80	70	55
Integrated / Ecological Pest Management (IPM / EPM)	80	90	70	70	90	90	90	80	80	80
Integrated Nutrient Management (INM)	95	80	70	90	90	80	90	90	85	95
Criterion Weight	30	15	10	10	5	5	5	10	5	5

Table 13. Final ATO ranking before sensitivity test

ATO	Costs		Benefits								Total Score	Rank
			Economic		Social		Environ-mental	Climate	Institutional & Political	Technology Related		
	CC	OOC	IEPPI	JCIL	PIRP	PIHPCH	PBERES	RVIRRE	EICDP	TEARS		
Integrated Nutrient Management (INM)	2850	1200	700	900	450	400	450	900	425	450	8750	**1**
Livestock Selective Breeding and Species Diversification (LSBSD)	2400	1275	800	900	475	475	400	900	400	475	8500	**2**
Crop Diversification and New Varieties (CDNV)	2100	1350	950	800	500	450	400	900	450	450	8450	**3**
Sustainable Livestock Health and Population Management (SLHPM)	2400	1200	800	900	400	450	450	900	400	425	8400	**4**
Rainwater Rarvesting (RH)	2400	1425	800	700	450	475	350	800	450	450	8350	**5**
Integrated / Ecological Pest Management (IPM / EPM)	2400	1350	700	700	450	450	450	800	400	425	8275	**6**
Conservation Agriculture (CA)	2550	1200	800	700	400	400	400	850	450	350	8000	**7**
Strengthening agrometeorological Monitoring and Information System (SAMIS)	2100	1425	800	700	400	400	350	800	350	425	7950	**8**
Efficient Irrigation Technologies for Food Security (EITFS)	1800	300	950	800	475	450	400	1000	400	425	7825	**9**
National Multiple Hazard Early Warning System (NMHEWS)	1800	1425	700	600	300	350	350	700	300	400	7725	**10**
Index-based Climate Insurance (IBCI)	1650	225	700	500	400	400	355	800	350	400	6875	**11**
Criterion Weight	30	15	10	10	5	5	5	10	5	5		

Table 14. Final weights of criteria after sensitivity test

ATO	Costs		Benefits							
			Economic		Social		Environ.	Climate	Institutional & Political	Technology Related
	CC	OOC	IEPPI	JCIL	PIRP	PIHPCH	PBERES	RVIRRE	EICDP	TEARS
Crop Diversification and New (CDNV)	70	90	95	80	100	90	80	90	90	90
Efficient Irrigation Technologies for Food Security (EITFS)	60	20	95	80	95	90	80	100	80	85
National Multiple Hazard Early Warning System (NMHEWS)	60	95	70	60	60	70	70	70	60	80
Strengthening Agrometeorological Monitoring an Iinformation System (SAMIS)	70	95	80	70	80	80	70	80	70	85
Conservation Agriculture (CA)	85	80	80	70	80	80	80	85	90	70
Rainwater Harvesting (RH)	80	95	80	70	90	95	70	80	90	90
Livestock Selective Breeding and Species Diversification (LSBSD)	80	85	80	90	95	95	80	90	80	95
Sustainable Livestock Health and Population Management (SLHPM)	80	80	80	90	80	90	90	90	80	85
Index-based Climate Insurance (IBCI)	55	15	70	50	80	80	71	80	70	80
Integrated / Ecological Pest Management (IPM / EPM)	80	90	70	70	90	90	90	80	80	85
Integrated Nutrient Management (INM)	95	80	70	90	90	80	90	90	85	90
Criterion weight	20	13	5	12	12	7	7	10	7	7

Table 15. Final scores and weights of criteria after sensitivity test

ATO	Costs		Benefits								Total Score	Rank
			Economic		Social		Environ-mental	Climate	Institutional & Political	Tech Related		
	CC	OOC	IEPPI	JCIL	PIRP	PIHPCH	PBERES	RVIRRE	EICDP	TEARS		
Integrated Nutrient Management (INM)	1900	1040	350	1080	1080	560	630	900	595	630	8765	1
Livestock Selective Breeding and Species Diversification (LSBSD)	1600	1105	400	1080	1140	665	560	900	560	665	8675	2
Crop Diversification and New Varieties (CDNV)	1400	1170	475	960	1200	630	560	900	630	630	8555	3
Sustainable livestock health and population management (SLHPM)	1600	1040	400	1080	960	630	630	900	560	595	8395	4
Rainwater harvesting (RH)	1600	1235	400	840	1080	665	490	800	630	630	8370	5
Integrated / Ecological Pest Management (IPM / EPM)	1600	1170	350	840	1080	630	630	800	560	595	8255	6
Conservation Agriculture (CA)	1700	1040	400	840	960	560	560	850	630	490	8030	7
Strengthening agrometeorological monitoring and information system (SAMIS)	1400	1235	400	840	960	560	490	800	490	595	7770	8
Efficient irrigation technologies for food security (EITFS)	1200	260	475	960	1140	630	560	1000	560	595	7380	9
National Multiple Hazard Early Warning System (NMHEWS)	1200	1235	350	720	720	490	490	700	420	560	6885	10
Index-based Climate Insurance (IBCI)	1100	195	350	600	960	560	497	800	490	560	6112	11
Criterion weight	20	13	5	12	12	7	7	10	7	7		

CHAPTER 4. SUMMARY AND CONCLUSION

The aim of the current GCF funded TNA project is to update the technology needs assessment and develop a technology road map for prioritized technologies to address climate change challenges in the energy, water and agriculture sectors which are critical in the development of Botswana. The report has reviewed the first TNA report of 2004 which emphasized mitigation technologies against climate change in the three sectors. Following vulnerability assessments, the emphasis has now shifted more towards adaptation and increased resilience to climate change impacts of drought, extreme heat, and floods on the various sectors of the economy.

Various policy instruments were reviewed, and they guided the participatory selection and prioritization of the adaption technology options for the agriculture sector. Structures to ensure stakeholder participation in the TNA process were established. These were the National TNA Committee with representation from 16 government and non-government institutions and agriculture sector working group with representation from ten institutions.

Climate adaptation technology options for the agriculture sector were assessed and prioritized in a participatory manner by ASWG members. A long list of ATOs identified through desktop review by national expert were reviewed and eleven (11) were selected by the stakeholders because of their potential to reduce vulnerability and enhance resilience of the sector to current and future impacts of climate change in Botswana. A participatory Multi-Criteria Analysis (MCA) tool was used to prioritize the ATOs using two (2) cost-related and eight benefit-related criteria. Each ATO was scored using 1-100 score where 1 was low and 100 was high. The criteria were each assigned weights form 1-100 and overall score for each ATO was product of the score and weight. The overall score of all 10 criteria per ATO was used to rank the ATOs. A sensitivity test was conducted where the criteria weights were adjusted but the results remained the same. SA gender responsive approach was mainstreamed in the selection of the ASWG and the ATO prioritization process by including criteria to enable prioritization of technologies that could contribute to the promotion of gender equality and economic empowerment of women and youth.

Based on their overall MCA scores, the ranking of the ATS were as follows:

1. Integrated nutrient management (INM),
2. Livestock selective breeding and species diversification,
3 Crop diversification and new varieties and
4. Sustainable livestock health and population management
5. Rainwater harvesting (RH)
6.Integrated / Ecological Pest Management (IPM / EPM)
7. Conservation Agriculture (CA)
8. Strengthening agrometeorological monitoring and information system (SAMIS)
9. Efficient irrigation technologies for food security (EITFS)
10. National Multiple Hazard Early Warning System (NMHEWS)
11. Index-based Climate Insurance (IBCI)

The ranking results will be subjected to validation process by the National TNA Committee and once approved the top four ATOS will be subjected to further participatory analysis in the next stages of the TNA process.

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ANNEXES

Annex 1. List of agriculture sector working group members and their contacts

No.	Name	Gender	Address and contacts
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Annex 2. Technology fact sheets for prioritized ATOs for the agriculture sector in Botswana

1. TECHNOLOGY	INTEGRATED NUTRIENT MANAGEMENT (INM)
Introduction	INM technology involves integrated the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. Rather than focusing nutrition management practices on one crop, INM aims at optimal use of nutrient sources on a cropping-system or crop-rotation basis to encourage farmers to focus on long-term planning and make greater consideration for environmental impacts.
Technology Characteristics	The components of technology include: ➢ Soil testing for nutrient deficiencies/toxicities ➢ Appraisal of soil fertility management practices ➢ Assessment of productivity and sustainability of farming systems ➢ Participatory farmer led INM technology development
Country Specific Applicability & Potential	Botswana soils are generally sandy with low fertility and require application of various nutrients
Status of Technology in Botswana	The technology needs further diffusion by increasing soil testing laboratories, equipment and technical skills. Precision farming needs further development where nutrient application is based on area specific need.
Benefits to Economic/Social and Environmental Development	It is estimated that nitrogen-based fertiliser has contributed an estimated 40 per cent to the increases in per capita global food production in the past 50 years. Nevertheless, environmental concerns and economic constraints mean that crop nutrient requirements should not be met solely through mineral fertilisers. Efficient use of all nutrient sources, including organic sources, recyclable wastes, mineral fertilisers and biofertilizers should therefore be promoted through Integrated Nutrient Management. The current global fertilizer shortage due to the Russia-Ukraine War has demonstrated the need for alternative sources of nutrients
Climate Change Adaptation Benefits	INM enables the adaptation of plant nutrition and soil fertility management in farming systems to site characteristics, taking advantage of the combined use of organic and inorganic nutrient resources to serve the concurrent needs of food production and economic, environmental and social viability. Judicious use of nitrogen inorganic fertilizers can also mitigate against GHG emissions from farming activities.
Financial Requirements and Costs	The main cost associated with Integrated Nutrient Management relates to the purchase and distribution of organic and inorganic fertilisers which are affected by a range of factors such as transport costs and government policies on importation duties. The cost of fertilizers ranges from \$400 to \$700/ton

2. TECHNOLOGY	LIVESTOCK SELECTIVE BREEDING AND SPECIES DIVERSIFICATION
Introduction	The technology involves systematic breeding of animals using traditional controlled mating and or high-tech processes such as in-vitro fertilization to improve productivity and other key characteristics such as thermal tolerance, low quality feed conversion, high kid survival rate, disease resistance, good body condition and animal morphology. Species diversification involves introduction of drought tolerant species including indigenous wildlife in the livestock farming system
Technology Characteristics	Livestock selective breeding uses several techniques such as: ➢ Outcrossing - mating animals not related for 4 to 6 generations, ➢ Linebreeding - mating related animals like half-brother/half-sister, cousins, aunt/nephew ➢ Inbreeding- mating directly related animals, like mother/son, father /daughter, and full brother/full sister To apply this technology, mating pens made of adobe, stone or cattle mesh are required for cattle while small animals can mate in wooden mating pens. Species diversification may involve land use change where small stock like sheep and goats and poultry are kept together with beef and dairy cattle on one farm. This may also involve raising cattle together with game species or changing from livestock to game farming.
Country Specific Applicability & Potential	The use of drought and heat tolerant multi-species livestock farming is an ideal adaptation strategy against losses caused by climate change. Botswana is prone to droughts and the high densities of traditional livestock (cattle) are increasingly degrading range resources. Adoption and promotion of multi-species livestock farming reduces the risk of farmers losing livelihoods in time of drought
Status of Technology in Botswana	Botswana being in a semiarid region has promoted the breeding and introduction of drought and heat tolerant breeds of cattle and small stock. The main breeding thrust for the past decades in Botswana has been to develop a drought-tolerant breed of cattle called the "Musi" breed. Unfortunately, the breed quickly lost the preferred traits through interbreeding and crossbreeding. Work to make it a pure breed is ongoing. Species diversification needs diffusion especially paradigm shift among traditional farmers
Benefits to Economic/Social and Environmental Development	The use of drought and heat tolerant multi-species livestock farming is an ideal adaptation strategy to ensure that farmers do not suffer complete ruin when there is severe drought or disease outbreak climate change. A study conducted in South Africa by Otieno and Muchapondwa (2016) showed that mixed livestock-wildlife farms were less vulnerable to climate change than specialized livestock or wildlife farms but net farm revenue per hectare was higher for specialized wildlife ranches than the other two farm types.
Climate Change Adaptation Benefits	Selective breeding through controlled mating enables farmers to keep animals that are more resistant to the impacts of climate change and hence reduce the risk of losing animals and income while diversifying their income-generating activities by capitalising on higher-quality dairy or fibre production.
Financial Requirements and Costs	The costs and financial requirements will depend on the livestock species and location. In general, controlled breeding is a low-cost technology assuming the candidate animals are already on the farm. In that case the technology only requires mating pens which can cost from $30/pen for stone pens to $200/pen for wire mesh pens. For mixed livestock-wildlife farms the main cost is for erecting special electrified fencing enclosing the wildlife species. Estimated costs are $175,000 for 150 large stock units (LSU) to $1million for 1000 LSUs (Chapter One (wildlifecampus.com))

3. TECHNOLOGY	DIVERSIFICATION OF CROP VARIETIES AND SPECIES FOR FOOD SECURITY AND RESILIENCE
Introduction	Diversification of crop varieties and species technology involves the promotion of crop varieties, landraces and species which are early maturing, drought tolerant, pest and disease resistant and high yielding for food security and resilience to the effects of climate change. The technology considers the different returns from value-added crops with complementary marketing opportunities. A diversified portfolio of crops ensures that farmers do not suffer complete ruin when climate change related extreme events occur, or market prices change if not all products will suffer low prices at the same time. The main emphasis is the introduction of drought-tolerant early maturing varieties of cereals (sorghum, maize, and millet) and legumes (cowpeas, chickpeas and grams)
Technology Characteristics	The technology can be applied both to individual farmers and to different regions. At a regional or landscape level, the technology is seen as a "shift from the regional or landscape dominance of one crop such as sorghum to regional production of several crops which consider the economic returns from different value-added crops with complementary marketing opportunities. New varieties and landraces are developed or sourced, tested, and released to stakeholders by researchers at national, regional and global research institutions and farmers access the planting materials from government institutions or private companies. Farmers may conduct their own on-farm trials to compare existing and new varieties
Country Specific Applicability & Potential	Small-scale farmers in Botswana have been practicing crop diversification for a long time where cereals are grown together with grain legumes, oilseed legumes and cucurbits while large-scale commercial farmers tend to use monocultures of maize or sorghum or legumes. Monocultures have led to increased use of inorganic fertilizers, increased pest outbreaks and higher risks of crop failure due to climate change events. Crop diversification has potential to transform production systems in Botswana in terms of both ecological and economic sustainability in the face of climate change
Status of Technology in Botswana	The technology is promoted in Botswana through the release of non-GMO short-season and drought and pest tolerant varieties of cereals and legumes by the Department of Agricultural Research and seed companies. Drought tolerant nontraditional or neglected crop species such as Bambara groundnuts, green gram, sugar beans, safflower and lentils are being promoted to improve the resilience of farmers.
Benefits to Economic/Social and Environmental Development	A diversified portfolio of crop varieties and species ensures that farmers do not suffer complete ruin when climate change related extreme events occur, or market prices change assuming that not all products will suffer low prices at the same time. The current average grain yield of rainfed cereals in Botswana is about 300Kg/ha and new drought tolerant varieties can significantly improve the yield despite the variable rainfall and pest outbreaks. Some new crop species such as safflower are high value crops with higher income potential especially if there is value addition through oil extraction for export.
Climate Change Adaptation Benefits	The promotion of drought tolerant and early maturing food crops such as sorghum and grain legumes is meant to address the climatic hazards of shifting onset of rain season and frequent and prolonged dry spells. Most small, medium, and large-scale farmers are vulnerable to such climatic hazards because of their dependence on rain-fed agriculture.
Financial Requirements and Costs	The costs vary depending on whether the technology is implemented at farm level or national level. The estimated cost of production of a cereal like maize is $1,000 -$1,300/ha

4. TECHNOLOGY	SUSTAINABLE LIVESTOCK HEALTH AND POPULATION MANAGEMENT
Introduction	The technology involves strategies of maintaining healthy livestock populations which can be sustained by range resources to reduce range degradation and desertification under increasing drought conditions especially under traditional livestock system
Technology Characteristics	Unsustainable livestock populations maintained by traditional livestock farmers under frequent droughts are causing degradation of range resources. The technology will include one or a combination of the following: ➢ Culling or destocking and enforcement of sustainable stocking rates ➢ Promoting a switch from cattle to small stock for traditional farmers ➢ Better cattle post and ranch husbandry practices such as herding, directed area grazing, supplemental feeds and prevention and treatment of diseases ➢ Increased extension campaigns for buy-in by traditional livestock farmers
Country Specific Applicability & Potential	Botswana range resources are fragile especially during the cold and dry seasons when the grasses and browse plants do not regenerate fast and under drought conditions. The Botswana government has been promoting sustainable livestock population but the uptake among traditional farmers has been low because livestock is a measure of one's wealth and status in society. Enforcement of sustainable livestock populations will improve quality of livestock and improved prices at the market at the same time mitigate against GHG emissions
Status of Technology in Botswana	Livestock population management among traditional farmers is being promoted by the government through various programmes and projects. For example, an eight-year GCF-funded project on improved herding and range management covering 3 areas in Botswana has been rolled out in 2021 and is expected to contribute to both farmer resilience and GHG emission reduction.
Benefits to Economic/Social and Environmental Development	Livestock industry in Botswana contributes over 70% of the 2% contribution of the agriculture sector to the GDP. Livestock provide multiple benefits that include food, clothing, draught power, income and employment. The manure from livestock is used in nutrient cycling for soils, thereby enhancing the productive capacity of the land for crop production. However, livestock grazing on fragile range resources are associated with extensive land degradation. This is ameliorated through enforcement of sustainable livestock management.
Climate Change Adaptation Benefits	The technology will enhance resilience of the livestock sector to impacts of climate change and maintain the sector as a major contributor of food security and resilience of livelihoods against climate and weather-associated risks. Current unsustainable high animal population densities in the already fragile semiarid ecosystem will further aggravate the situation and may lead to further range degradation, proliferation of invasive plant species and desertification.
Financial Requirements and Costs	The cost for the technology is estimated in the range of US$ 100 million a period of 10 years (FP158: Ecosystem-Based Adaptation and Mitigation in Botswana's Communal Rangelands | Green Climate Fund)

5. TECHNOLOGY	RAINWATER HARVESTING
Introduction	Rainwater harvesting is a method for inducing, collecting, storing and conserving rainwater from local surface runoff for domestic and agricultural use in arid and semi-arid regions. Both small- and large-scale structures are used for rainwater harvesting collection and storage including water pans, tanks, reservoirs and dams. Rain catchments include rock surfaces, ground surfaces and roof tops. For Botswana, Rooftop rainwater harvesting is ideal for supplying water for homestead backyard gardens in urban and rural areas while pans are ideal for provision of water for livestock
Technology Characteristics	Main components of the technology for watering homestead/backyard vegetable gardens: Catchment area: rooftops of buildings and ground surfaces. Conveyance system: roof gutters and down pipes of building, glides, and surface drains or channels fitted with screens to filter the water Storage devices: under- or above- ground plastic, metal or concrete tanks Water pipes and drippers to supply water to the plants in the garden Solar powered pump: for distribution of water to drips lines. A backyard garden can supply a family with fresh greens and vegetables daily as is a way of addressing food security and health related issues especially among the rural and urban poor during the dry season.
Country Specific Applicability & Potential	Small scale drip irrigation using water harvested from roof tops can provide food and nutritional security in both rural and urban household.
Status of Technology in Botswana	The backyard gardening technology has been promoted in the past 5 years to address food insecurity but was challenged by the high cost of municipal water and annual water use restrictions due to droughts. Rooftop harvesting which is also being promoted will provide a cheaper alternative to municipal water for watering backyard vegetable production. Currently all government buildings in rural areas are required to be fitted with water harvesting facilities.
Benefits to Economic/Social and Environmental Development	The economic benefits of the technology arise from the opportunities that stored water presents for various uses including for irrigation, watering of livestock and fish farming. With minor treatment rainwater is good for domestic use and can alleviate the burden on women and youth of travelling long distances to collect water. Use of the water for irrigation of homestead gardens can improve food and nutritional security of vulnerable communities. In addition, the technology benefits the environment by greatly reducing land erosion and flooding after heavy rains
Climate Change Adaptation Benefits	Rainwater harvesting represents an adaptation strategy for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture. The water can provide a convenient and reliable water supply during seasonal dry periods and droughts. The water can be used to rescue plants during drought spells or for growing off-season vegetables. In addition, use of solar pump and drip irrigation ensures prudent and efficient use of this limited water resource to alleviate water stress during critical stages of crop growth.
Financial Requirements and Costs	The cost for rainwater harvesting varies depending on type and scale of the technology. For household rooftop water harvesting, the initial cost is relatively low since the catchment is already there and the main cost is for the tanks, solar pump and drip irrigation infrastructure. The cost for a household rooftop technology with plastic tanks for a solar powered backyard irrigation system can range from $1000 - $2000.

6. TECHNOLOGY	INTEGRATED / ECOLOGICAL PEST MANAGEMENT (IPM / EPM)
Introduction	IPM/EPM involves the use of multiple and compatible tactics to maintain pest populations below economic injury levels with minimum injury to people, animals, plants and the environment. It integrates crop management, soil management and environmental friendly pest control for optimal plant health.
Technology Characteristics	The key components of an EPM approach are: Crop Management such as use of drought and pest tolerant varieties, crop rotation, crop density, crop residue management to reduce inoculum etc Soil Management such maintenance soil nutrition and pH levels to provide the best possible chemical, physical, and biological soil habitat for crops, reduction of soil structure disturbance by use of minimum tillage etc Integrated Pest control such as use of biocontrol agents, use of surveillance to control pests when they reach economic injury levels, planting density and resistant varieties etc
Country Specific Applicability & Potential	Pests in agriculture are one of the main challenges limiting agricultural productivity in Botswana. Examples of the most recent attacks include locust, and the fall armyworm outbreaks which have caused destruction of cereals in Botswana. Efforts to control the pest using synthetic pesticides have resulted in adverse effects on non-target biodiversity.
Status of Technology in Botswana	Aspects of IPM technology have been used in Botswana and have shown potential to manage pest population to below threshold levels. For example, the use of falcons to chase away quelea birds in commercial sorghum farms in Pandamatenga is gaining popularity Botswana has therefore the capacity to manage the technology.
Benefits to Economic/Social and Environmental Development	Limiting pest populations to below economic levels through IPM will enhance productivity in agricultural crops thereby offering food security, additional income from the sale of farm produce and enhance resilience to climate change. Since IPM sparingly use synthetic pesticides, chemical contamination of the environment is reduced thus increasing the strengths and stability of natural systems to reinforce the natural processes of pest regulation.
Climate Change Adaptation Benefits	IPM contributes to climate change adaptation by providing a healthy and balanced ecosystem in which the vulnerability of plants to pests and diseases is decreased. By promoting a diversified farming system, the technology builds farmers' resilience to potential risks posed by climate change, such as damage to crop yields caused by newly emerging pests and diseases.
Financial Requirements and Costs	The technology can be applied at individual farm, community, regional and national level and costs vary accordingly. The estimated costs of national IPM ranges from US$ 5 to $7.5 million.

7. TECHNOLOGY	CONSERVATION AGRICULTURE
Introduction	Conservation Agriculture is farming system that promotes minimum soil disturbance, maintenance of a permanent soil cover, and diversification of plant species to enhances biodiversity and natural biological processes above and below the ground surface to improve water and nutrient use efficiency and crop production. The technology is a component of "climate-smart Agriculture" because it improves productivity, enhances resilience and reduces emissions.
Technology Characteristics	The technology involves one or a combination of any of the following: Conservation tillage (CT)- establishing crops in a field where at least 33% of previous crop's residues are purposely left on the soil surface to conserve moisture and reduce soil erosion. The techniques include: ➢ No-till/ zero tillage where soil is left undisturbed, and seeds are drilled into the soil within residues ➢ Ridge till where crops planted in ridges with minimum removal of residue from previous season ➢ Mulch till where there is limited soil tillage leaving about 33% of residues on the surface Integrated nutrient management (INM): the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. Mixed or integrated farming where farmers combine different crop species, livestock species and, trees to increase income through different sources and to complement land and labour demands across the year
Country Specific Applicability & Potential	Frequent droughts, increasing temperatures and unreliable onset of rains affects soil moisture levels leading to losses and food insecurity. Conservation agriculture has potential to increase productivity and enhance the resilience of vulnerable groups such as the rural poor, women and the youth
Status of Technology in Botswana	The technology is not fully established but components such reduced tillage are being practiced by some commercial farmers and use of compost is being promoted among small-scale farmers
Benefits to Economic/Social and Environmental Development	CA has the potential to increases crop productivity, minimizes erosion and improves soil nutrients thus improving food security at the household and national level. The reduced use of inorganic fertilizers and fossil fuel for tillage mitigates against climate change by reducing emissions. The technology can be implemented among vulnerable rural populations thus enhancing their resilience to the impacts of climate change
Climate Change Adaptation Benefits	Conservation agriculture improves soil moisture by reducing surface runoff and evaporation and improves soil nutrients. A diversified portfolio of crop and livestock species grown on a farm or region ensures increased resilient of the farming systems and people's livelihoods from climate variability and changes. For instance, if one productive system fails due to drought or climate induced pest infestation, the farmer will still survive on production from the other productive system.
Financial Requirements and Costs	The costs for implementation of CA vary depending on the components involved and change of farm implements from conventional ploughs to rippers, chisel ploughs and specialized planters Estimated cost may range from $3-5 million

8. TECHNOLOGY	STRENGTHENING AGROMETEOROLOGICAL MONITORING AND INFORMATION SYSTEM
Introduction	Availability of area-specific agrometeorological and agricultural production data is critical in the development of an agrometeorological forecasting system. An agrometeorological forecasting system is a correlation of weather data and crop growth and yields, incidences of pests and diseases to predict future yields and outbreaks of pests and diseases. Examples of use of the forecasting system include the use of weather forecasts for farm operations such as spraying for control of insect pests and diseases. The technology will entail setting up an agrometeorological monitoring, communication and analysis facilities at national and district level and the institutional and technical capacity on data sharing, archiving, analysis and interpretation of agrometeorological information products to users at all levels.
Technology Characteristics	The technology involves installation of modern Real-Time, On-Demand Automated Agrometeorological Stations in the 25 agricultural districts of Botswana and establishment of a data processing and dissemination of agrometeorological forecasts to users at all levels.
Country Specific Applicability & Potential	Forecasting of potential outbreaks of serious pests like Quelia, locusts, fall army worm and diseases like early and late blight of potato and tomatoes and leaf blight of sorghum will enable farmers to be prepared in the management of the crop health hazards. The information is also critical in decision making of farmers on when to plant or to harvest to minimize losses and for crop insurance purposes
Status of Technology in Botswana	Few agrometeorological stations were available in some of the Agricultural Research Stations in the past, but these were discontinued. The technology is aimed at resuscitating and strengthening agrometeorology forecasting for sustainable agricultural production and as an adaptation to climate change
Benefits to Economic/Social and Environmental Development	Accurate and timely agrometeorological forecasts are critical for the agriculture sector. In Botswana the main economic activity of most of the population is linked to agriculture hence, timely forecast-based farm activities such as planting and pest and disease management can improve yields, household livelihoods and food security. The technology can also facilitate government agricultural planning and disaster preparedness and index-based climate insurance
Climate Change Adaptation Benefits	Accurate agrometeorological forecasting is important for advance planning of farming calendars, disaster preparedness, human disease and pest outbreak surveillance. The technology will enable the integration of national early warning systems, GIS mapping of vulnerable areas, meteorological information on flooding and droughts, as well as the mapping of disease outbreaks
Financial Requirements and Costs	The costs can range from $25, 000 to $30,000 per station

9. TECHNOLOGY	EFFICIENT IRRIGATION TECHNOLOGIES FOR FOOD SECURITY
Introduction	Climate change induced droughts, heat and delayed onset of rain seasons are more frequent in Botswana increasing the vulnerability to food insecurity especially among women and children. Irrigation can ensure guaranteed yields under above conditions by providing water from surface and or ground sources for optimal crop growth. Two main methods of delivering water to the plants are high-pressure sprinkler (and their variants) and low-pressure drip (and their variants) irrigation. Sprinkler irrigation mimics natural rain while drip delivers water to the root zone only.
Technology Characteristics	Irrigation technology consists of surface or ground water source a pump unit powered by solar or conventional electricity, a set of water pipes and sprinklers or drippers to efficiently deliver water to the plants. A wide range of component and system designs of efficient irrigation are available. The choice of a system design depends on topography, field length, soil texture of the land area earmarked for irrigation, the crops to be grown and availability of funds. The technology, especially drip irrigation can also incorporate fertilizer application to the plant root zone.
Country Specific Applicability & Potential	Many parts of Botswana experience droughts because of climate variability and changes.. The technology has the potential to transform crop production in the face of climate change by efficiently providing water to plants from external water sources when rains are delayed or during period of drought. The technology can be adopted by individual farmers or clusters of farmers where government provides infrastructure around dams and wastewater treatment plants such as Dikabeya irrigation scheme and Glenn Valley wastewater irrigation project.
Status of Technology in Botswana	Sprinkler and drip irrigation is popular among horticultural farmers and its use in cereal production is limited. The pumps are powered mainly by electricity from the coal-powered national grid or from diesel engines. Solar powered pumps are now being promoted in the horticulture and livestock sectors for supply of water to crops and livestock. The technology has potential to increase production of traditional dryland or rain fed crops such as cereals, grain legumes and fodder crops.
Benefits to Economic/Social and Environmental Development	Irrigation increases crop productivity resulting in food security at household, community, and national level by enabling the growing of different annual crops throughout the year. This creates jobs at farm as well as at various stages of the value chain. The technology can result in new investments in manufacture/local assembly of equipment for solar power, irrigation system components, inputs and training of local technicians for installation and repair of the system and establishment of agro-processing plants. Environmental benefits include reduced use of GHG emitting fossil fuel for pumping the water, reduced leaching and GHG emission from fertilizers and soil erosion. The technology such drip irrigation can be used by women and youth as it is easy to install and operate.
Climate Change Adaptation Benefits	The technology supports farmers to adapt to climate change and be resilient to its impacts by enabling efficient use of the limited water supply. In seasonal droughts the technology saves water and reduces water losses by providing water direct to the plant when required. The technology also provides farmer with more options on which crops can be grown to increase their income and resilience.
Financial Requirements and Costs	The costs vary with the design of the technology, source of water, crop type and the size and other characteristics of the target area earmarked for irrigation. Initial capital cost of land acquisition and preparation, boreholes / water reservoirs, pipes, solar power panels and inverters, pumps and soil water monitoring equipment are high but operational cost are low. The estimated costs for the technology can be in the range of US$15,000 – US$30,000 /ha

10. TECHNOLOGY	NATIONAL MULTIPLE HAZARD EARLY WARNING SYSTEM (EWS)
Introduction	Multiple Hazard Early Warning System (MHEWS) is a technology that combines indigenous and modern approaches to forecasting possible future occurrence of a natural phenomenon such as the on-set and cessation of the rainy season, floods, droughts, pest outbreaks, wildfires, availability of ground water and human disease outbreaks. Systematic observation of the climate system is usually carried out by national departments of meteorological services and other specialised bodies. They take measurements and make observations at standard pre-set times and places, monitoring atmosphere, ocean and terrestrial systems. Government support through adequate funding for infrastructure, equipment and well-trained scientists is critical
Technology Characteristics	A modern early warning system is a set of coordinated procedures through which information on foreseeable hazards is collected and analysed for predicting possible future occurrence of a natural phenomenon. Basic weather data are collected manually or can be fully automated where data is transmitted through cell phone network to the national data processing centre. Indigenous knowledge, however, utilizes bio-indicators to make forecasts of the possible weather and climate futures. The greatest gains are possible when the two approaches combine to create new opportunities and cross-fertilize the thinking of the other.
Country Specific Applicability & Potential	Modern meteorological and indigenous knowledge EWS approaches both have an important role to play despite the former being considered superior. An integrated early warning system will complement the strength of each approach, thereby providing more precise and accurate weather forecasts essential for advance planning of farming calendar and in some instances for disaster preparedness.
Status of Technology in Botswana	The technology is available in Botswana, but it needs strengthening by funding for: ➢ Strengthening of automated synoptic stations network, ➢ Automatization of rainfall stations, ➢ Improved access to information, ➢ Seasonal to Interannual Prediction (3-6 months weather prediction) to assist in choosing short- and long-term agricultural activities at national, district and local farm level ➢ GIS mapping of vulnerable areas, ➢ Meteorological information/modelling on flooding and droughts
Benefits to Economic/Social and Environmental Development	An accurate MHEWS is invaluable for many sectors, particularly agriculture in Botswana. The technology will assist farmer take better decisions on agricultural operations and activities with the following possible resultant benefits: ➢ Reduction of agricultural losses due to adverse climatic events ➢ Increasing productivity that in some cases can guarantee profits for the producer through decision on what crop and when to plant, livestock populations on the range and when to sell off livestock. ➢ Government agricultural planning and disaster preparedness
Climate Change Adaptation Benefits	Accurate MHEWS is important for advance planning of farming calendars, disaster preparedness, human disease and pest outbreak surveillance. The technology will enable the integration of national early warning systems, GIS mapping of vulnerable areas, meteorological information on flooding and droughts, as well as the mapping of disease outbreaks
Financial Requirements and Costs	The estimated cost for the technology may range from US$200, 000 – $500,000.

11. TECHNOLOGY	INDEX-BASED CLIMATE INSURANCE
Introduction	The technology involves farmers buying insurance against crop and livestock loss due to extreme events of climate change such as drought and floods. Schemes that require on site verification of losses before payment tend to be more costly than those that estimate losses using other means. The technology is more common in developed countries than in developing countries.
Technology Characteristics	There are several types of insurance schemes available to farmers and the most common are: ➢ Named Risk Climate Insurance: Insurance against loss for specific event, for specific amount, loss verified in the field ➢ Multiple Risk Climate Insurance: Insurance against yield loss below 50-70 per cent of expected yield due to any cause ➢ Area/Yield Index Insurance: Insured against yield loss below a certain per cent across a district. Yield changes verified independently on a sample of farms across the district ➢ Climate Weighted Index Insurance: Insurance based on certain climatic conditions being met. If met certain loss of production assumed and compensated for ➢ Normalized Difference Vegetation Index: Based on satellite monitoring of vegetation development of grazing land to compensate livestock farmers ➢ Livestock Mortality Index: Based on independent estimates of livestock mortality rates done by NGOs
Country Specific Applicability & Potential	Farming in Botswana is very risky because of the frequent droughts increasing temperatures and outbreaks of livestock diseases such as foot and mouth. Farmers need a safety net in time of losses and index-based insurance is an ideal strategy for increasing the resilience of farmers
Status of Technology in Botswana	Crop and animal insurance schemes have been in Botswana for over 10 years but the uptake by small to medium size farmers has been lower than by large commercial farmers (Livestock and crop insurance comes to Botswana (thegazette.news)) (http://erepository.uonbi.ac.ke/handle/11295/152913)
Benefits to Economic/Social and Environmental Development	Index-based climate insurance costs to farmers are reduced as no in-situ verifications are made of actual losses. This makes it viable to provide coverage to many small-scale producers for whom it would be unviable to provide standard insurance
Climate Change Adaptation Benefits	Insurance payments can cushion farmers against total economic disaster, thus increasing their resilience to climate change.
Financial Requirements and Costs	The development of indexed linked climate insurance as a commercial product has generally involved the collaboration between interested insurance companies (whether public or private) and facilitated by national or multi-lateral organisations such as the World Bank or regional development banks who have subsidised the costs of development of climate insurance products. Normally farmers would pay for the insurance, either directly or more commonly as an additional financial service associated with a loan. In some cases, the costs of insurance are subsidised by the government, where it is considered strategic for the country to support buffering the impacts of climate change. The cost to livestock farmers in Botswana ranges from \$18-\$25 /animal /annum and for crops \$10-\$15/ha/annum