# UNDERSTANDING AGRICULTURAL SYSTEMS VULNERABILITY TO CLIMATE CHANGE: THE CASE OF BOTSWANA IN THE LIMPOPO RIVER BASIN


2023

EXECUTIVE SUMMARY REPORT


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The full research report can be found <u>here</u>.

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# Introduction

**In 2022, the World Meteorological Organisation (WMO) released the *State of the Climate in Africa 2021* report, which highlighted that 2021 was the third hottest year on record for Africa with the air temperature between 0.45⁰C and 0.86 ⁰C above the 1981 – 2010 average. With an increase in droughts, predictions for the next three years (from 2022) suggest that 230 million people will face water scarcity and over 460 million people will live in water-stressed locations (Khanyi, 2022).**

Countries which already fall in desert zones are at significant risk. Botswana, a landlocked country in Southern Africa, is mainly covered by the Kalahari Desert and shares much of its water resources with neighbouring countries (Du Plessis & Rowntree, 2003). The key reliance on mainly rain-fed crop and livestock agriculture in Botswana (Ministry of Environment, Natural Resources Conservation and Tourism, 2019) combined with expected changes in climate patterns make Botswana vulnerable to climate change (Mackett, 2021).

2 0 2 1

3rd Hottest Year

on record for

B o t s w a n a

## Botswana

Botswana has made significant efforts to understand its exposure and sensitivity to climate change, aiming to adapt to the predicted changes. For instance, the country has

- Ratified the Paris Agreement, the 2030 Agenda and the United Nations Framework Convention on Climate Change (UNFCCC).
- Produced the Third National Communications Report in 2019 outlining a need for developing a national mitigation strategy and action plan that will guide the implementation and operation of the mitigation plans for the country (Ministry of Environment, Natural Resources Conservation and Tourism, 2019).
- Released their National Adaptation Framework (Ministry of Environment, Natural Resources Conservation and Tourism, 2020) where they propose to design and implement a sectoral National Adaptation Plan, which is currently in progress.
- The World Bank published a climate risk country profile for Botswana (The World Bank, 2021) which emphasised the need to enhance Botswana's adaptive capacity by enhancing investment in weather stations and expanding the country’s national hydro-meteorological monitoring system for observational data of changes.

Botswana ranked 89th out of 181 countries in the 2020 Notre Dame Global Adaptation Initiative (ND-GAIN) Index for vulnerability with a score of 48.3 - scores range from 75.4, highest rank to 26.7 as lowest (ND-GAIN, 2021). Over a nineteen-year period, Botswana has decreased its vulnerability to climate change by increasing its national readiness through increased economic investment. Botswana however scored low on agriculture capacity and social readiness, indicating that while Botswana is showing potential for responding effectively to climate change, the need for adaptation is still high.

# Agriculture in Botswana

Even though climate change alters and puts stress on global, regional and local weather patterns and climates in many different ways (Abbass et al., 2022; Arnell et al., 2019; Loubere, 2012), the consensus is that the productivity of agriculture is likely to decline because of high temperatures and drought-related stress (Altieri et al., 2015). Currently, the agricultural sector in Botswana produces 2% of Gross Domestic Product (GDP) but is one the biggest employers (next to the diamond industry), of the labour force (UN Botswana, 2021). Around 70% of the households in the rural areas of Botswana derive part of their livelihoods from rain-fed agriculture through farming practices (SADRI, 2021). This means they are vulnerable to increasingly variable rainfall patterns and temperature extremes (Mackett, 2021).

**70%**

of rural households rely partly on rain-fed farming

## ND-Gain index

**The ND-GAIN Country Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience.**

Agricultural capacity: the average of the 2 best scores (lowest vulnerability scores) out of the amount of fertilizer use, amount of pesticide use, ability to equip agriculture area with irrigation, and the frequency of tractor use. The indicator reflects a country's capacity to acquire and deploy agriculture technology.

Social readiness score: the social factors that enhance the mobility of investment to be converted to adaptation actions. Indicators include social inequality, Information and communication technologies (ICT) infrastructure, education and innovation.

The current dependence on rain-fed agricultural practices is one of the most prominent reasons for the country's vulnerability (World Bank, 2021). No wonder, the Government of Botswana (GoB) has set out various priority areas including 'food' and 'agriculture' for the period 2023-2028.

## Agriculture is the second largest employer of the labour force in Botswana

Notably, the country introduced a ban on the import of certain fruits and vegetables from South Africa as an incentive to increase local production (Thukwana, 2022).

Given the recent emphasis on local food production in Botswana, it is necessary to understand the risks of climate change against the capabilities of the agricultural sector (IAEA, 2022; Thukwana, 2022). The agricultural challenges in Botswana are particularly stark among the vulnerable groups with higher exposure levels, and often low adaptive capacities (Mugari et al., 2020).

# Smallholder farmers at risk

Small holder farmers are likely to be the most vulnerable as they constitute the majority of rural populations and they are highly dependent on subsistence agriculture.

The level of impacts and coping strategies of populations to climate change is dependent on socio-cultural norms, individual socio-economic status, ability to access resources, poverty, and gender. The livelihoods of communities in Botswana have, over the years, evolved within variable climatic conditions and therefore adapted over time by employing various responses to survive. However, in recent decades, increasing environmental stresses have placed Botswana under more vulnerable conditions, undermining the livelihoods of smallholder farmers in the area (Dube & Sekhwela, 2007; Batisani & Yarnal, 2010; Moseley, 2016). Coping and adapting better to changing climatic conditions increases resilience to current and future climate change and is, therefore, a crucial first step in coping and adapting to current and future climate change.

## Proportion of Population living below the International poverty line

# 16.1%

Pre-pandemic (UN Botswana, 2021)

Even among an already vulnerable group of smallholder farmers, women are even more disadvantaged and are in a more vulnerable position when it comes to adaptation due to gender-based roles within their society (Mackett, 2021; Peters, 1983). There are attempts in recent literature to examine the link between adaptive capacity and socio-economic development, both globally and to a certain degree within the Southern Africa context. However, there is a lack of research examining socio-economic determinants of adaptation strategies by smallholder farmers in Botswana (Mogomotsi et al., 2020).

## Case Study – Limpopo River Basin

**Recently, the Limpopo Basin has been identified as a key source to meet the country's future water needs (World Bank, 2021), which makes it an important area of study.**

**However, due to climate change, the Limpopo River Basin may experience more frequent flooding and droughts, affecting livelihoods, agricultural productivity, and ecosystem health (Petrie et al., 2015). As such, the basin presents an interesting case to examine climate risks, adaptive capacities to better understand what is needed for climate change adaptation in this area. This basin is transboundary - its river is shared by the riparian states of Botswana, Mozambique, South Africa and Zimbabwe. The basin is very densely populated and covers major towns/cities such as the capital – Gaborone (Figure 1).**

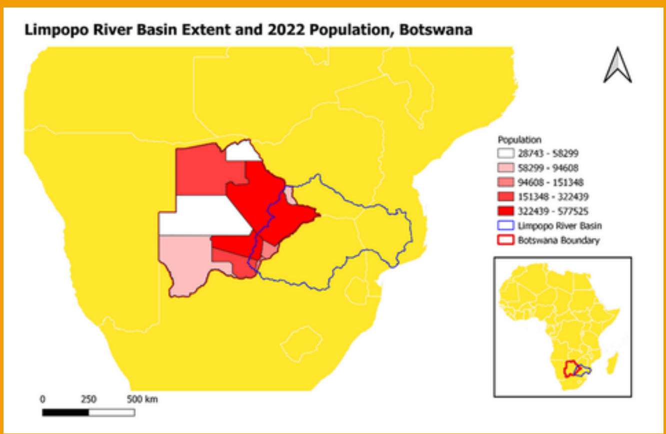



Figure 1 The extent of the LImpopo River Basin and population distribution in Botswana

**Rainfall in the basin is highly variable, making farming very difficult under drought conditions (World Bank, 2021). Growing water demands and fluctuating temperatures combined with less predictable rainfall patterns threaten livelihoods of smallholder farmers in the area.**

# The challenge

This project built on existing information elaborating historic trends and future climate change effects on agriculture based on recommendations from the Third National Communication Report (Ministry of Environment, Natural Resources Conservation and Tourism, 2019), The National Adaptation Framework (Ministry of Environment, Natural Resources Conservation and Tourism, 2020) and the World Bank Report (World Bank, 2021). This report highlights various vulnerabilities and attempts to contribute to the wider understanding of how the adaptive capacity of small-scale farmers can be enhanced through participatory knowledge sharing and acquisition.

Furthermore, the report demonstrates the relevance/value of stakeholder participation in climate change adaptation planning and implementation.

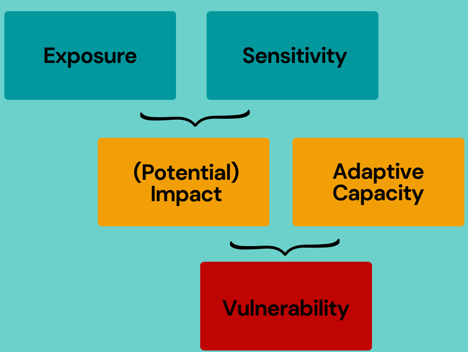
## Lima Adaptation Knowledge Initiative:

### Closing knowledge gaps to scale up adaptation

**The Lima Adaptation Knowledge Initiative (LAKI) is a joint action pledge under the Nairobi work programme between the UNFCCC Secretariat and UN Environment through its Global Adaptation Network (GAN).**

**The LAKI identifies and prioritizes climate change adaptation knowledge gaps for specific subregions and sectors/themes. In Southern Africa, including Botswana, 16 key knowledge gaps were identified and this project focused on knowledge gap 3 – 'Lack of knowledge on the sensitivity of agro-ecological zones across the sub-region to historic and future climate change'. Lack of data and lack of actionable knowledge (e.g., in need of repackaging existing knowledge) were identified as key constraints in this regard**

## Terminologies




This project aimed to better understand the vulnerability of small-holder farming in Botswana, using the above framework (Glick et al., 2011).

### Exposure

The nature and degree to which a system is exposed to significant climatic variations.

### Sensitivity

The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change.

### (Potential) Impacts

The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability.

### Adaptive Capacity

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

### Vulnerability

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

(IPCC, 2022).

# Our Approach

Climate change is a complex problem that requires overcoming knowledge fragmentation with respect to ecological, economic, and socio-cultural aspects.

This project applied a transdisciplinary approach to assess vulnerability to climate change and identify measures from ecological and social dimensions. 'Ecological' sensitivity and its related elements extend to the exposure, sensitivity, and potential impacts of climate change, whilst the 'social' dimension focuses on the adaptive capacity to climate change (see Figure 2).

The transdisciplinary approach prompted the application of mixed methods i.e. quantitative assessment to evaluate the ecological dimension and qualitative assessments to understand the social dimension. This methodology allowed synergistic collaboration and enabled trans-disciplinary insights to be tailored to the needs of the specific stakeholders in question including smallholder farmers.

## Relevant SDGs

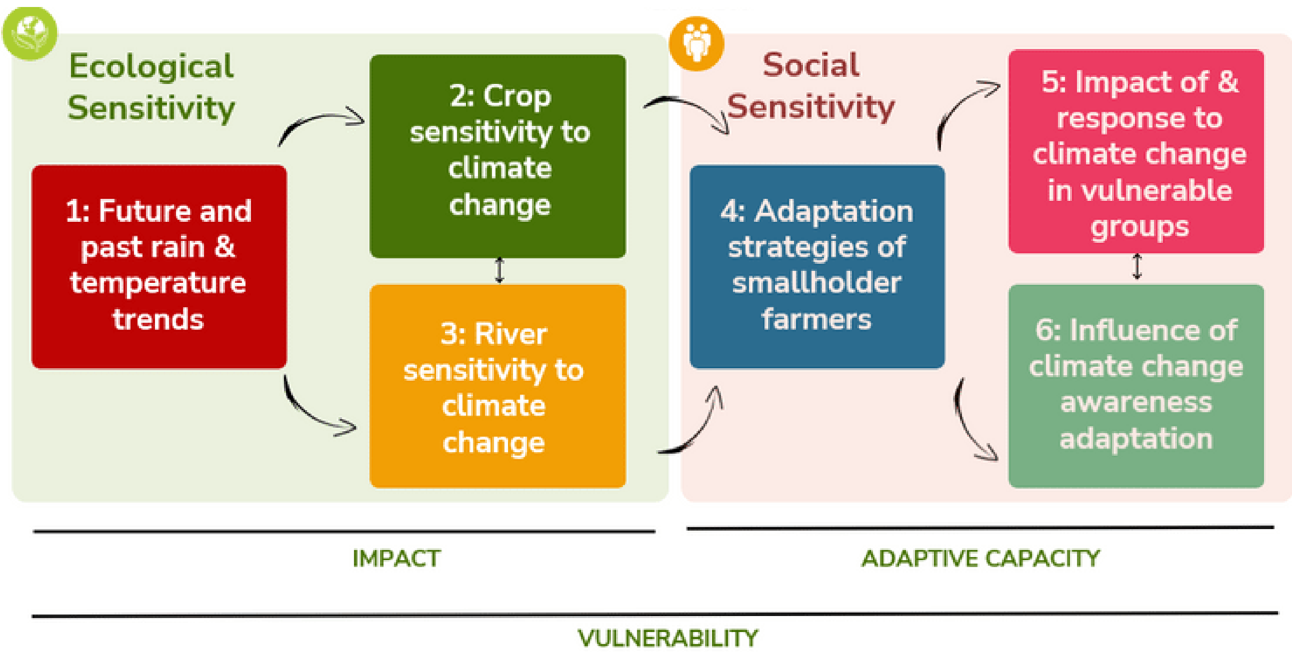




Figure 2 The breakdown of the research aspects of the project

# Conceptual framework

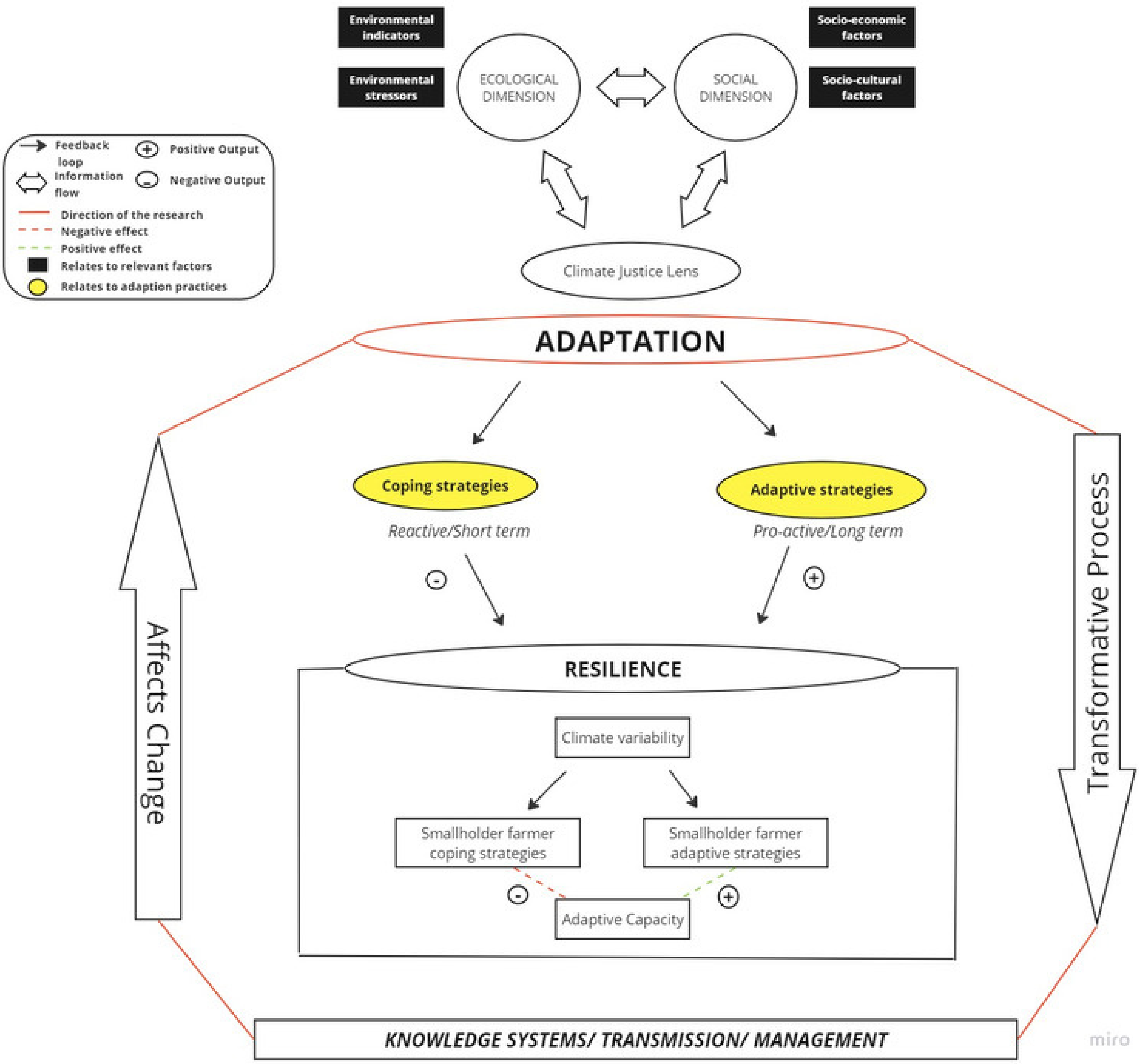


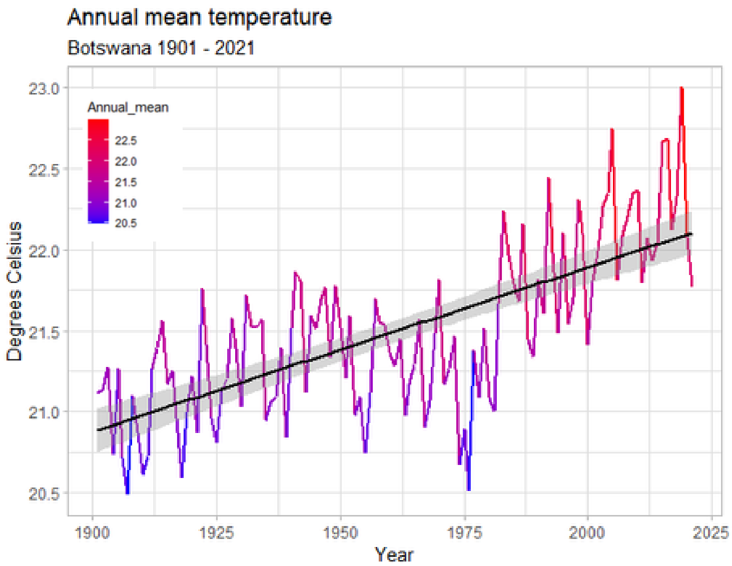

Figure 3 The conceptual framework of climate change vulnerability in agriculture

The conceptual framework was created under the key term of adaptation. The focus hereon enabled the team to develop their understanding of the vulnerability component. This allows for climate change to be visualised through equality and human lens by instilling considerations for gender equality, equity, transparency, inclusivity, and accountability.

A divide is made between long term adaptive strategies and short term coping strategies, as short term strategies can have negative long term effects due to its short term scope (e.g. slash and burn practices practiced by some farming communities). However it is argued that they can exist simultaneously and positively reinforce one another as well as resilience in general.

# Findings Ecological Sensitivity

## Past and future temperature and rain




### Observed change

6.39% ↑

Average temperature between 2010 -2020 compared to 1900 – 1910

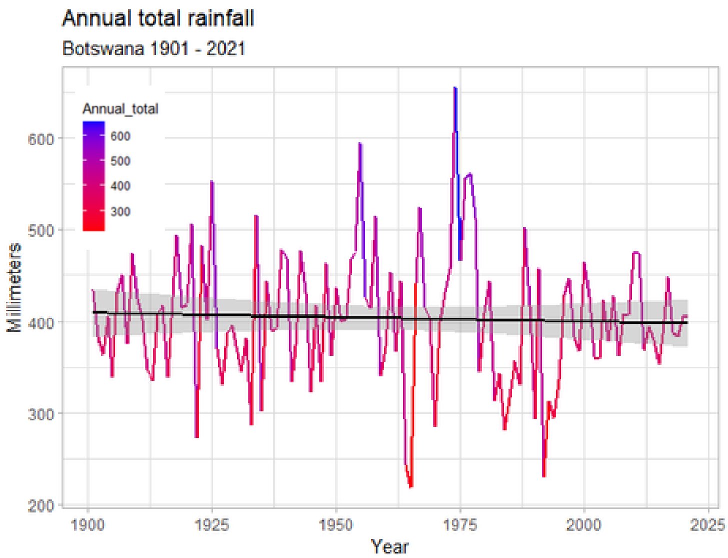
First and last decade of records

### Predicted change

3.11 – 9.75% ↑

Annual temperature between 2040 -2059 compared to 2000 – 2020

Based on different Shared Socioeconomic Pathways (SSPs)




### Observed change

2.42% ↓

Total rainfall between 2010 -2020 compared to 1900 – 1910

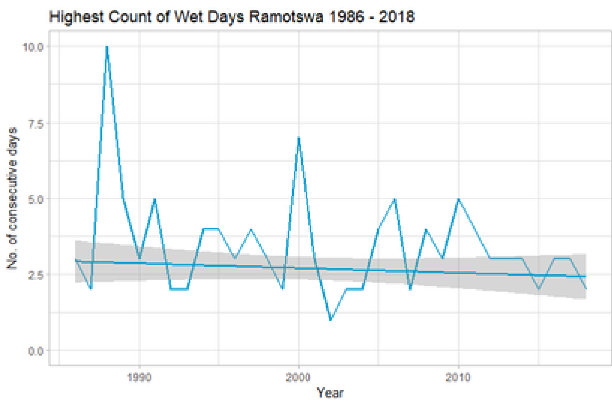
First and last decade of records

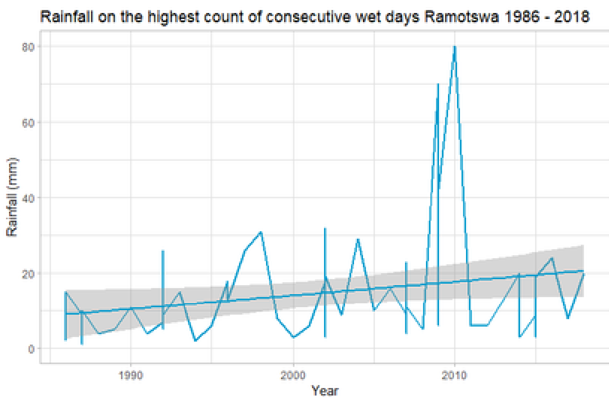
### Predicted median annual change

3.94 – 6.33 mm ↓

Total annual rainfall between 2040 – 2059 compared to 1995 – 2014

Based on different Shared Socioeconomic Pathways (SSPs)



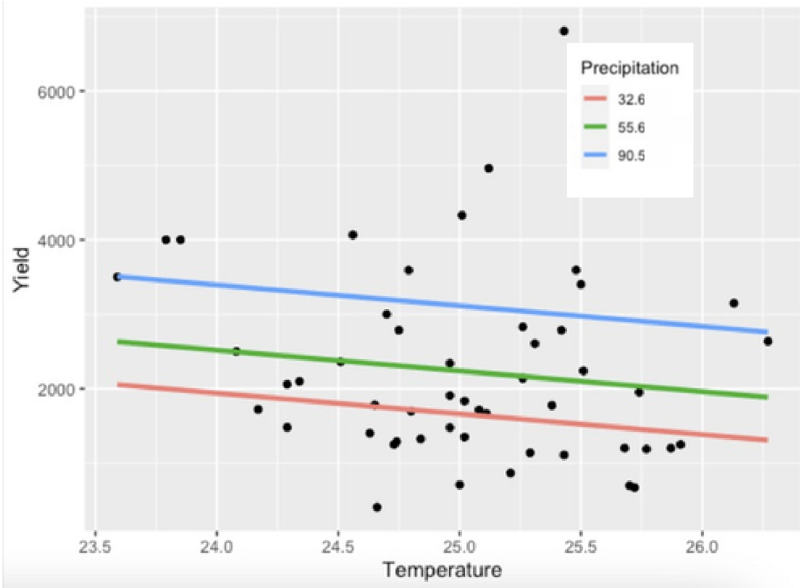




General decrease in highest count of wet days, general increase in rain that falls on those days → General increase in potential flood risk and/or rain harvesting opportunities

# Findings Ecological Sensitivity

## Sensitivity of the yield of common crops to climate variability

### Millet




Increasing temperature ↑

*Correlates with*

Decreasing yield ↓

*with an effect from*

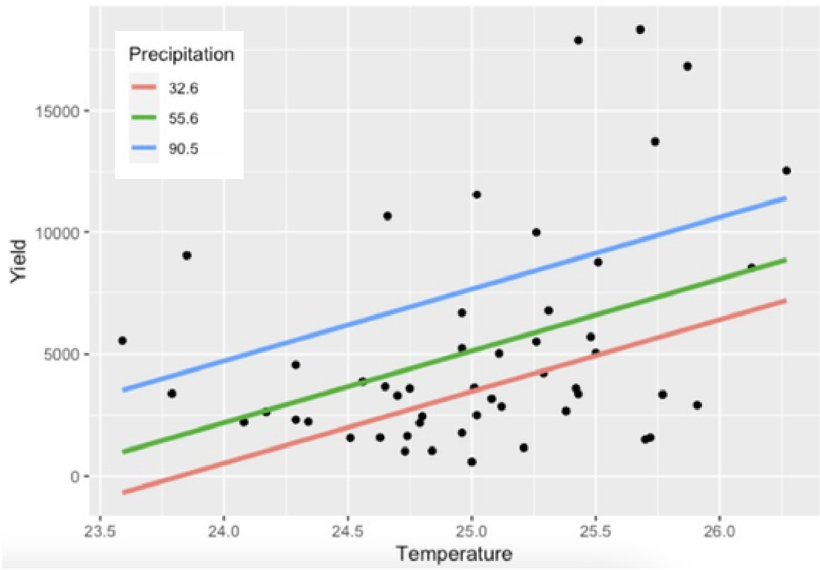
Changing precipitation

22% ↑

Increase in yield with 23mm increase in precipitation at 25°C

Rainy season Sept- April

### Sorghum




Increasing temperature ↑

*Correlates with*

Increasing yield ↑

*with an effect from*

Changing precipitation

40% ↑

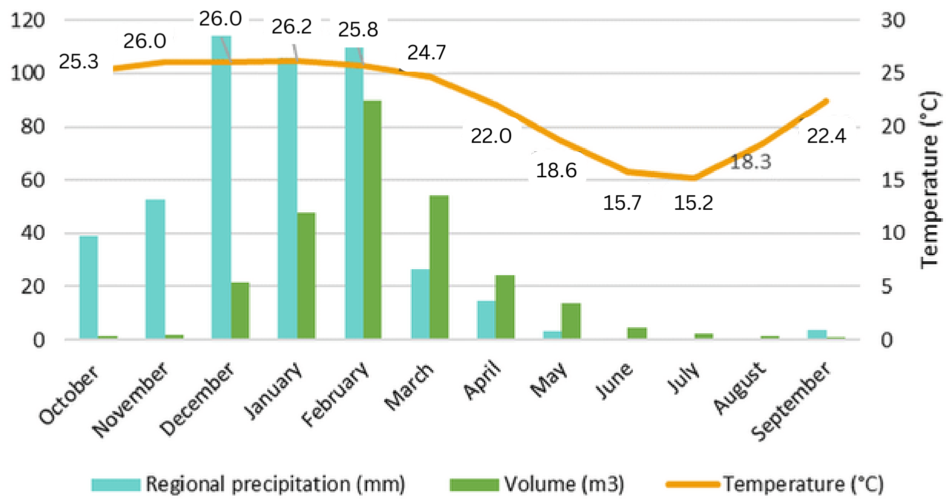
Increase in yield with 23mm increase in precipitation at 25°C

Rainy season Sept- April

→ There is potential to further analyse yields of different crops with changes in temperature and precipitation to identify climate-suitable crops.

# Findings Ecological Sensitivity

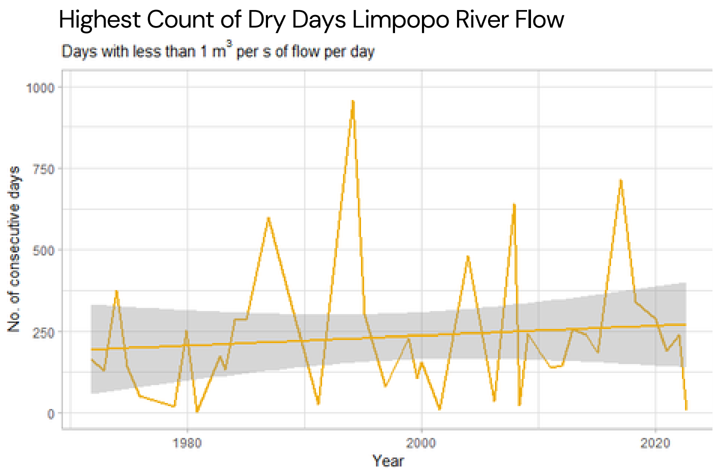
## Sensitivity of water flow of the Limpopo River to climate variability




### Climograph

The average annual flow of the Limpopo River, including temperature and precipitation

Based on observation from 1971 - 2022

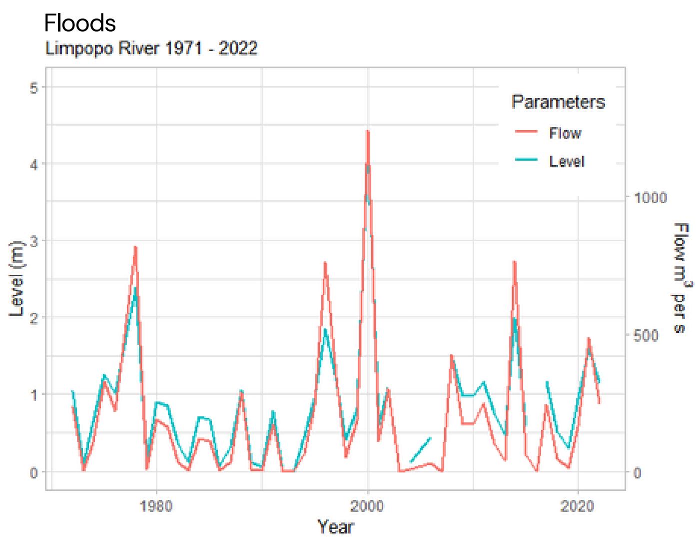



### Dry days

$R^2 = 0.0112$ ↑

Slightly increasing trend in the number of dry days in which the river experiences marginalised to no surface water flow

Based on observation from 1971 - 2022 at the Limpopo River in Botswana, River Gauge A5H006 (-22.56, 28.01) in the Mahalapswe Catchment Area (DWS, n.d.)




### Floods

$R^2 = 0.0043$ ↑

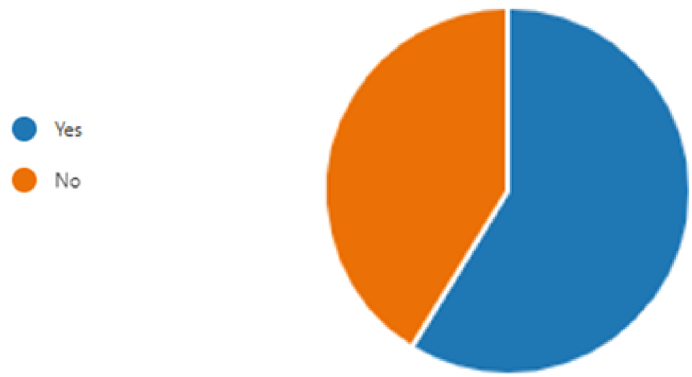
Insignificant but increasing trend in both flood flow and level, meaning that they increase both in intensity and frequency

Based on observation from 1971 - 2022 at the Limpopo River in Botswana, River Gauge A5H006 (-22.56, 28.01) in the Mahalapswe Catchment Area (DWS, n.d.)

# Findings Social Sensitivity

**Based on Smallholder Stakeholder Survey** disseminated via an online tool, targeting one-on-one discussions.

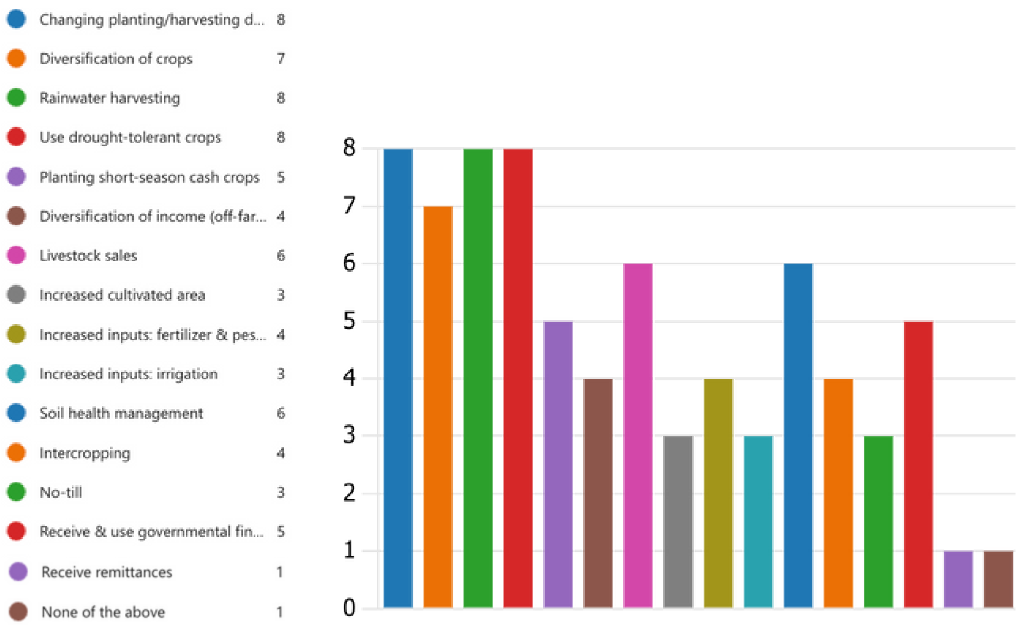
### Disclosure of utilisation of coping/adaptation strategies




**41%**

of respondents say they have no coping/ adaptation strategy in place on their farm (n=17) without examples to learn from

### Observed utilisation of coping/adaptation strategies




**94%**

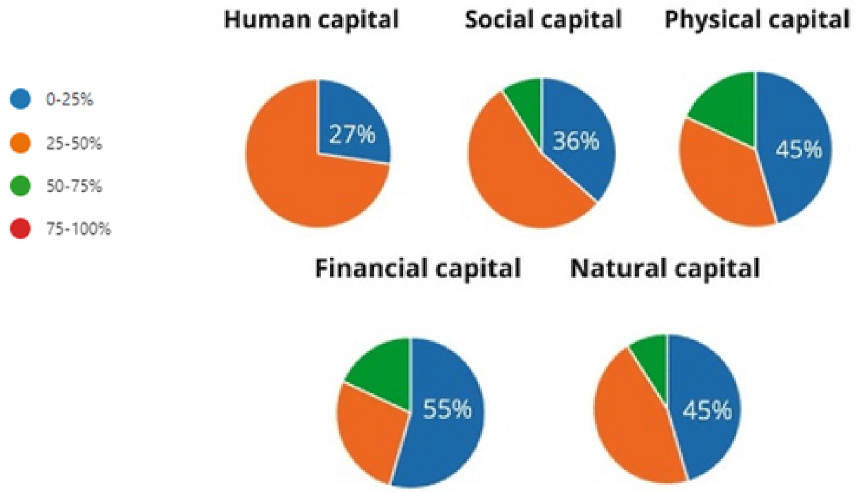
of respondents apply at least one form of coping and/or adaptation strategy on their farm when provided with examples.

Most commonly used strategies included changing planting and harvesting times in response to weather changes and rainwater harvesting, and usage of drought resistant crops.

# Findings Social Sensitivity

**Based on the Smallholder Stakeholder Survey** disseminated via an online tool, targeting one-on-one discussions.

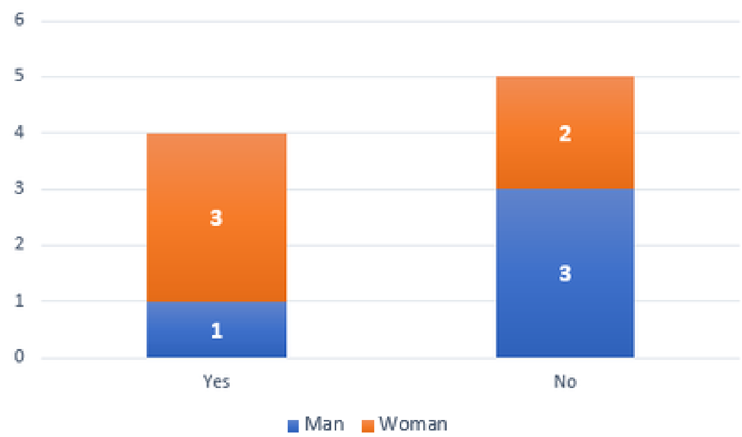
## Access to assets




### Access to financial capital

was the main concern for smallholder farmers.

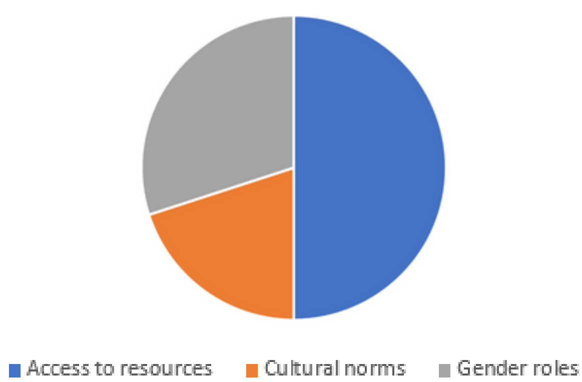
## Perception of adequacy of women's engagement in agriculture




### Different perception

by men and women of whether there is an adequate women's engagement in agriculture

## Barriers to gender equality in agriculture




### Access to resources

Main barrier for female smallholder farmers (education, capital, land).

# Synthesis

Evidence suggests that **climate change is already underway in Botswana**. Rainfall in Botswana has been reducing at the start of the growing season whilst the annual means of the temperatures have been steadily increasing during the last century, especially **for the last 30 years.** This is expected to **increase extreme weather events in the region, heightening the intensity and frequency of droughts and flooding**. With most of the agriculture in the Limpopo River Basin in Botswana being rainfed, increasing variability of precipitation and temperature makes them more vulnerable. This introduces **water stress**, hence **compromising crop yields**. While the yields of most crops including millet and maize are compromised by the changes in temperature, sorghum and the majority of roots may be able to produce high yields under high temperatures due to their resilience to climate variability. Besides increasing temperatures, **precipitation variability poses a significant threat** to agricultural productivity. Water from the Limpopo river's surface and alluvial aquifers could be used to provide smallholder farmers with additional irrigation water, **enabling year-long farming** in Botswana as South Africa does. This will require further investigation to ascertain feasibility.

The ecological vulnerability of agriculture to climate change affects the livelihoods of inhabitants within the Limpopo River Basin. Farmers employ both coping strategies (short-term) and adaptation strategies (long-term) to deal with climate variability. **Short-term coping strategies** are most common and are prompted by key barriers such as lack of access to financial resources and knowledge on how to sustainably adapt in the long-term, thereby increasing adaptive capacity. **Shortage of physical infrastructure** hinders accurate weather data collection and thus, analysis and communication via weather service organisations. This negatively affects farmers' ability to respond to a changing climate in an informed way. This could be tackled by investing in **weather forecasting** stations and the **appropriate weather service organisations** to interpret and communicate the weather data to the farmers. Amongst farmers, **women** are identified as a **more vulnerable group**, due to pressures that are placed on them to fulfil traditional roles and prevailing socio-cultural and socio-economic factors. This **limits their access to resources** such as land, credit, and education enforcing a downward spiral.


Overall, the results indicate that **rain-fed agriculture is highly exposed to climatic changes** and physical factors such as **water flow and crop yield are sensitive to changes** in key variables including temperature and rainfall. This climate variability increases the sensitivity of ecological systems translating into high exposure of smallholder farmers who rely on rain-fed agriculture. **Capital, technology and education** were identified as key contributors to improving adaptive capacity, thereby reducing vulnerability amongst farmers in general but especially amongst female farmers.

# Recommendations

**Localised climate awareness.** Relevant ministries and stakeholders should promote campaigns and workshops for farmers communicated in Setswana, English, and Kalanga (with more languages to be added) to inform the farming community about transitioning to more climate-resilient practices. Inclusivity should be ensured through the involvement of all relevant stakeholders such as men, women, the elderly, and youth in the consultation and implementation processes.

**Investment in climate research and information services.** This includes expanding existing infrastructure (i.e., regional weather stations) and personnel training on the monitoring of monthly rainfall, temperature, and consecutive wet and dry days at regional and national scales and subsequent translation to actionable knowledge accessible by farmers.

**Open-source data portal for farmers.** To be facilitated by the government ensuring that local weather stations gather reliable data to provide farmers with up-to-date information (in English and local languages) to better inform adaptation practices.

**Establishment of Botswana National Strategy for Women and Girls** with action points for each sector, for example, establishing a gender quota in environmental decision-making at all levels beginning with greater (improved) women's representation in farming groups and local committees. The strategy would build on the efforts of the National Gender-Based Violence Strategy 2015-2020 and work in collaboration with UN Women.

**Microfinancing e-platform,** such as the WoFarming described in the full report would provide farmers with support systems, relevant knowledge, and access to funding mechanisms to aid in transforming existing farming practices. The microfinance platform would be initially set up by a small team and would incorporate development partners, County government and civil society in set up.

**While further research is required to extend and verify the findings of this report, the findings show the benefits of using transdisciplinary research methods for assessing climate change vulnerability of systems and the people that rely on these systems. The research framework and methodology used in this challenge can be applied to other countries/contexts with alterations to account for differences in social, economic and environmental (the three pillars of sustainability) structures. The research endeavored to present the complexity of adaptation to climate change while showing opportunities for how these complexities can be teased out to aid the development of solutions which incorporate the three pillars of sustainability ensuring a just transition to a more sustainable and inclusive society when confronted with climate change.**

# Glossary

**Adaptive capacity:** The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2022).

**Climate change:** A term that refers to the transformation of the climate which can be observed by a long-term shift in temperatures and weather patterns (United Nations, n.d.). Climate change translates into extreme weather conditions, flooding, extreme droughts and sea level rise (Clarke et al., 2022).

**Climate variability:** Term that refer to "interannual or interdecadal fluctuations in temperature and precipitation" (Malpeli et al., 2020).

**Coping:** The use of available skills, resources and opportunities to address, manage and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organisations and systems in the short to medium term (IPCC, 2022).

**Ecocentric epistemology:** A new way of experiencing, studying, and evaluating the world around us, as it represents the split of the traditional anthropocentric epistemology. It provides a system to systematically analyse the whole system or ecosystem without centering humans (Borland & Lindgreen, 2013).

**Exposure:** The nature and degree to which a system is exposed to significant climatic variations (IPCC, 2022).

**(Potential) Impacts:** The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability.

**Sensitivity:** The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change (IPCC, 2022).

**Transdisciplinary:** A research approach which aims to produce context-considerate knowledge to solve 'real-world' problems by being solution driven (Odume et al., 2021; Pohl & Hirsch Hadorn, 2008; Wickson et al., 2006) as it integrates disciplinary epistemologies and theories (Nyangau et al., 2018).

**Vulnerability:** The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2022).

**Water scarcity:** Water scarcity occurs in situations where there is insufficient water to fulfil both human needs and support ecosystem services. This can either occur in a basic lack of water (physical water scarcity) or there is a lack of water due to indirect consequences such as insufficient infrastructure or insufficient financial means to ensure ample water resources (economic water scarcity) (Sabater et al., 2019).

**Water stress:** A situation in which there is not enough water of good quality to meet the need of both humans and the ecosystem (European Environment Agency, n.d.)

**Wicked problem:** Complex societal issues that lack clarity in aims and solutions (Rittel & Webber, 1973).

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