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Ministry of Health

Assessment of Health Vulnerability and Adaptation to Climate Change in Botswana

Final Report

World Health Organization

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Acronyms

AdCom	Adaptation Communication
AfDB	African Development Bank
AR6	Sixth Assessment Report
ARI	Average Recurrence Interval
BCWIS	Botswana Core Welfare Indicator Survey
BDS	Botswana Demographic Survey
BMTHS	Botswana Multi-Topic Household Survey
BNTP	Botswana National TB Program
CBA	Cost Benefit Analysis
CBS	Case-Based Surveillance
CCH	Climate Change and Health
COP	Conference of Parties
CSDH	Commission on Social Determinants of Health
DPH	Department of Public Health
DMS	Department of Meteorological Services
DR-NCDs	Diet Related Non-Communicable Diseases
EWS	Early Warning System
IPCC	Intergovernmental Panel on Climate Change
GCM	General Circulation Models
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GoB	Government of Botswana
HNAP	Health National Adaptation Plan
HVI	Health Vulnerability Index
IDSR	Integrated Disease Surveillance and Response
NCDs	Non-communicable diseases
NDMO	National Disaster Management Office
NMP	National Malaria Programme
PHC	Primary Health Care
RCM	Regional Circulation Model
RCP	Representative Concentration Pathway
SANA	Situation Analysis and Needs Assessment
TNC	Third National Communication
TORs	Terms of Reference
V&A	Vulnerability and Assessment
V&I	Vulnerability and Impact
UNFCCC	United Nations Framework Convention on Climate Change
WASH	Water, Sanitation and Hygiene

Table of Contents

Acronyms 3
Executive Summary 7
1.0. Introduction 12
2.0. Objectives 13
2.1. Main Objective 13
3.0. Methods and approaches 13
3.1. Study Sites and Climate 14
4.0. Botswana Economic Status 26
4.1. Population and Health Status 28
4.1.1. Population 28
4.1.2. Population's health Status: 28
4.1.3. Health care system: 30
4.1.4. Healthcare Challenges 32
4.2. Health Sector Investment 33
5.0. Linkages between climate and health 34
5.1. Global Scale 34
5.1.1. Climate Change impacts on Non-Communicable Diseases (NCDs) 35
5.1.2. Climate Change impacts on Communicable Diseases 37
5.1.3. Climate Change impacts on Nutrition 38
5.1.4. Climate change and Zoonotic diseases 38
5.2. Current national impact of climatic variability on health 39
5.2.1. Malaria outbreak 39
5.2.2. Diarrhoea outbreak 41
5.2.3. Current Climate Extremes 43
5.2.4. Incidences of Malnutrition 44
5.2.5. Impact on the Operations of the Health Facilities 46
6.0. Climate outlook for Botswana for 2030 and 2050 47
6.1. Annual maximum temperature 49
6.2. Heatwaves days 50
6.3. Number of days above 35 ºC 52
6.4. SPEI Drought Probability 53
6.5. Extreme rainfall events 55
7.0. Projected impacts of Climate Change on Health 57

7.1. Impacts on non-communicable diseases 57
7.2. Impacts on Climate-sensitive diseases 58
7.3. Impacts on malnutrition 58
7.4. Impacts on Health Infrastructure 59
8.0. Vulnerability Assessment of the Health sector to Climate Change 60
8.1. Exposure 60
8.2. Sensitivity 63
8.3. Adaptive Capacity Factors / Determinants 66
8.4. Health Vulnerability Index 70
9.0. Feasible Health adaptation measures for building climate-resilient health system 76
10.0. Conclusions 82
11.0. Recommendations 82
12.0. Limitations of the study 84
13.0. References 85

List of Tables

Table 1a: Justification for selecting settlements for impact assessment based on highest criteria incidences per district 16
Table 1b: Colour ramp for vulnerability scores 26
Table 1c: Colour ramp for Adaptive Capacity scores 26
Table 2: Proportion of national budget allocation to health and environment ministries 33
Table 3: Heatwaves days per year 52
Table 4: Drought probability for the selected settlements 55
Table 5: Extreme precipitation based on ARI 100 Drought probability for the selected settlements 56
Table 6: Projected Malaria cases for 2030 and 2050 58
Table 7: Projected Diarrhoea cases for 2030 and 2050 58
Table 8: Projected Malnutrition for 2030 and 2050 59
Table 9: Projected health facility closure due to extreme events 60
Table 10: The combined scores for climate variability and extreme events and exposure by district 62
Table 11: The combined scores for natural capital, and vulnerable population attributed to health conditions and sensitivity by district 65
Table 12: The combined scores for health care services, human resources, water and sanitation, social capital, and adaptive capacity by district 69
Table 13: Computed indices for contributing factors and the Health Vulnerability Index (HVI) by district 72
Table 14: Area coverage and population of Botswana by vulnerability classes and district 76

List of Figures

Figure 1a: Botswana Census Districts for Vulnerability Assessment 15
.... 17
Figure 1b: Map of Botswana and Selected settlements for Impact Assessment.......................... 17
Figure 1c: Botswana Annual average rainfall 1981– 2010... 18
Figure 1d: Mean monthly maximum temperature for 30 years 18
Figure 1e: Mean monthly minimum temperature for 30 years 19
Figure 2: Top-down approach for V&A assessment 21
Figure 3: Schematic representation of the impact assessment model.. 22
Figure 4: Climate change impact, vulnerability, and risk interface 23
Figure 5: Estimating the Health Vulnerability Index (HVI).. 24
Figure 6: Botswana's GDP at current prices.. 27
Figure 7: Organisation and management structure for health care service delivery in Botswana 32
Figure 8: Impacts of Climate Change on health 35
Figure 9: Recorded malaria outbreak and annual precipitation for the selected settlements........ 40
Figure 10: Map of Malaria distribution in Botswana.. 41
Figure 11: Recorded Diarrheal cases in major settlements.. 42
Figure 12: Average monthly diarrheal cases at National level 42
Figure 13: Relationship between diarrheal cases, temperature, and rainfall 43
Figure 14: Recorded heatwaves in the country... 44
Figure 15: Food insecurity in the country.. 45
Figure 16: Malnutrition status for children under 5.. 46
Figure 17: Global population projects based on different SSP scenario 48
Figure 18: IPPC Concentration pathways.. 48
Figure 19: Annual maximum temperature under SSP5-8.5 scenarios... 49
Figure 20: Annual Maximum temperature under SSP2-4.5 50
Figure 21: Number of heatwaves days based on SSP5-8.5 scenario 51
Figure 22: Number of heatwaves days based on SSP2-4.5 scenario 51
Figure 23: Number of days above 35 ºC under SSP5-8.5.. 52
Figure 24: Number of days above 35 ºC under SSP2-4.5.. 53
Figure 25: SPEI drought probability under the SSP5-8.5.. 54
Figure 26: SPEI drought probability under the SSP2-4.5.. 54
Figure 27: Extreme precipitation under 24 hrs. ARI 100 years SSP5-8.5 scenario...................... 55
Figure 28: Extreme precipitation under 24 hrs. ARI 100 years SSP5-8.5 scenario...................... 56
Figure 29: Spatial distribution of Exposure Index... 63
Figure 30: Spatial distribution of Sensitivity Index... 66
Figure 31: Spatial distribution of Adaptive Capacity Index 70
Figure 32: Computed indices for the Health Vulnerability Index (HVI) by district 73
Figure 33: Spatial distribution of the Health Vulnerability Index (HVI) by district 74

Executive Summary

Climate change is at an advanced stage in the country as evident from frequent and intense heatwaves, floods, drought and other extreme event. As a cross-cutting phenomenon, climate change affects all key economic sector mainly agriculture, health, energy, water, rangelands and ecosystems and infrastructure. The health sector is one of those sectors that could be vulnerable to climate change due to strong correlation between climate parameters and diseases. Studies reveal that climate variability is already affecting health systems, with future impacts projected to be extensive.

The Government of Botswana developed its National Adaption Plan (NAP) Framework which calls for each sector to develop its sectoral NAP. Prior to the development of the sectoral NAP, the NAP framework recommended undertaking a detailed vulnerability and adaptation (V&A) assessment to inform the NAP.

In line with the NAP framework and the WHO recommendations, a V&A assessment for the health sector is undertaken with the ultimate objective of developing its health NAP.

Undertaking climate change V&A for the Health sector involved multi-methodological approaches. Methods consisting of desk review, consultation with key informants and probabilistic dose-response, application of General Circulation Models (GCM) and computation Health Vulnerability Index (HVI), were employed.

- **Development of climate scenarios**

Based on the developed climate scenarios generated from Shared Socio-economic Pathways (SSPs) 2-4.5 and 5-8.5, it is projected that temperature for the country will warm by as much as 1.5 and 3 ^{o}C by the years 2030 and 2050 respectively. Precipitation is expected to decline marginally for the years 2030 and 2050. Furthermore, it is projected that drought will increase significantly by as much as 78% compared to the baseline of 16% for some of the selected settlements. The projected changes (increases and declines) in climate variables could have significant impacts on the health sector.

- **Assessment of the impact of climate change on the health sector**

Climate change could have an impact on communicable diseases, non-communicable diseases, malnutrition, mortality from heatwaves, and on the operational efficiency of the health sector. These impacts are briefly highlighted below.

Malaria and Climate change

The correlation coefficient for the malaria and precipitation is estimated at 0.60 based on the recorded malaria cases and precipitation. With the projected decline in precipitation by 2030 and

2050, it is estimated that malaria cases in the country could stabilise slightly. It is projected that there could around 650. This analysis assumes that the government initiatives of malaria elimination will still be in place and strengthened. Furthermore, the assessment assumes that the two selected years (2030 and 2050) will be characterised by normal rainfall events. If there is an extreme precipitation, it is expected that the malaria cases could double.

Mortality from Heatwaves

Under the baseline (1960-1990) it was estimated that mortality from heatwaves was around 3 per million per year. With the projected increased frequency and intensity of heatwaves, the assessment estimate that by 2030 and 2050, the country could experience mortality of approximately 90 persons per million per year and 240 persons per million per year respectively. The most vulnerable members of the public are infants (less than <5 years), elderly (>65 years) and people with compromised conditions.

Diarrhoea incidence and Climate change

A correlation coefficient of 64% was established between diarrheal outbreak, temperature and rainfall. Under baseline, recorded Diarrhoea cases are around 3,000 and by 2030 and 2050, they are expected to double to over 6,000. This is mainly attributed to extreme temperature resulting in food spoilage and rainfall events.

Malnutrition and Climate change

Climate change could affect malnutrition through decline in rainfall which could affect agricultural productivity. According to the climate scenarios, there will be marginal changes in precipitation of less than 10%. Therefore, because the government has robust social safety nets in place, climate change could not have major impact on malnutrition if the existing social safety nets are maintained.

Health infrastructure operational efficiency

Health infrastructure constitutes clinics, hospitals, vehicles (ambulances) medicine storage facilities amongst others. The infrastructure is core to the provision of health sector. Climate change could affect the infrastructure operational efficiency through infrastructure damage and the health staff working under unbearable conditions. Based on the extreme event analysis it is projected that by 2030 and 2050, the infrastructure (clinics and hospitals) could be partially closed for over 10 days from infrastructure damage.

- **Vulnerability assessment**

On the basis of the impact assessment, vulnerability assessment was undertaken. The vulnerability index was based on exposure, sensitivity and adaptive capacity. The vulnerability index for the selected settlements ranged from 0.4 to 0.8 with an average of 0.68. Consequently, the health sector is moderately highly vulnerable to the impacts of climate change

- **Adaptation strategies to climate proof the health sector**

Health sector is vulnerable to climate change as evident from the vulnerability index scores. It is therefore necessary to implement robust adaptation measures that will build a climate resilient health sector to the impacts of climate change. Most of the proposed adaptation measures are existing and some of classified as both adaptation and mitigation measures. They are listed as below:

- **Multi-Hazard Early Warning Systems are** critical for hazard monitoring, forecasting and prediction, and preparing the public to respond in order to take timely action to reduce disaster risks in advance of hazardous events. Multi-hazard EWS are appropriate for all the extreme events associated with climate change such as floods, fires, heatwaves, and storms. It is therefore crucial that the health sector in collaboration with Department of Meteorological Services develop an efficient Multi-hazards EWS with the ability to cover the entire country and public. The starting point will be to develop a comprehensive national Multi-hazards EWS strategy for the country to be aligned with the already existing multi-hazard plan.

- **Strengthening National Malaria Programme:** This is an on-going initiative that needs to be maintained and strengthened to reduce the incidence of malaria in the country. Over the years, the government has done a remarkable job in controlling and containing malaria cases in the country.

- **Introduce conducive working hours for vulnerable and exposed employees:** Climate change is projected to result in frequent and intense heatwaves by 2030 and 2050. Certain members of the communities are more vulnerable than others. Construction workers, farm workers are some of the employees who bear the full blunt of heatwaves as they in most cases work directly under the sun. It is therefore essential to establish a legislation stipulating conducive working hours for these group to avoid the impact of heatwaves and extreme temperatures particularly when working outdoors. Consequently, a consultative meeting with the workers union, the affected sectors (agriculture, construction) should be undertaken to determine appropriate working conditions for these groups.

- **Improved Water, Sanitation and Hygiene (WASH) programme:** The link between WASH and climate change is irrefutable. According to WHO improved WASH is central to strengthening the community health resilience to climate change. WASH aids societies to cope with climate extreme events by preventing diseases and ensuring promotion of adequate hydration due to increasing temperatures (WHO, 2022). GoB has done a tremendous job of improving WASH as evident on percentage of the population with access to clean water, sanitation amongst other WASH indicators. For instance, by 2022 it was estimated that the population with access to clean water was 85.4% while the population practicing open defecation was 10% (Statistics Botswana, 2023). It is critical that WASH programmes are maintained as a way of climate proofing the health sector.

- **Promote a healthy lifestyle:** Promoting healthy lifestyles is one of the fundamental adaptation measures which includes a combination of activities that are aimed at improving the health and wellbeing of an individual. Key activities that promote healthy lifestyles include eating healthy, drinking adequate water daily, engaging in physical activities such as walking, exercising, cycling, and running amongst others, and this reduces incidences of NCDs such as diabetes. Consequently, this could reduce the members of community with compromised health issues vulnerable to climate change.

- **Maintenance of Social Protection Programmes:** Climate change could result in food insecurities from extreme heat and droughts and even flooding. These could result in increased malnutrition and even famine by 2050. Maintaining and strengthening the existing social protection programme as an adaptation measure against malnutrition and famine is fundamental. Over the years, GoB has established and maintained a comprehensive social protection programme as social safety net. The programme is aimed at protecting the destitutes and other vulnerable groups from food insecurity and they include food basket, vulnerable group feeding program, and school feeding program (The World Bank, 2022).

- **Heatwave adaptation strategy:** heatwaves are projected to be more frequent and intense. This could increase heatwaves related mortality rates significantly. There is a need to develop a national heatwaves response plan or strategy to heatwave proof the communities.

- **Promote conducive residential and business infrastructure:** Heatwaves and extreme temperature would make residential, civic, and private building to be unbearably hot which could in turn exacerbate the associated impacts. It is thus paramount that houses, offices, schools and shopping malls are designed to protect occupants from excessive temperatures. This will include: Installation of air condition systems at shopping malls, churches, homes and offices and schools; Design building to maximise the use of natural air flow systems for cooling purposes; Ensure that buildings have adequate insulation to retain coldness for a long period of time even when the air conditioning systems have been turned off.

- **Introduce subsidies on solar powered air conditioning systems:** Air conditioning systems is becoming a requirement for the residential dwelling. There is a need to establish healthy houses grant which will cover air conditioning and ventilations systems powered by solar energy. A fund must be established which should be funded through carbon tax.

- **Retrofitting existing health infrastructure:** it is a process that involves updating and modifying existing structures to improve their performance, safety, and energy efficiency. It entails fitting air conditioning, improving the ventilation systems, strengthening the structure of the infrastructure, and fit in features that can withstand impacts associated with hailstorm. Retrofitting is both a climate change adaptation and mitigation measure as it generally results in energy efficiency.

- **Installation of solar rooftops in all the health institutions:** Climate change could result in increased electricity outage from powerline destruction, increased in demand for cooling and aging electrical grid. It is therefore necessary that all the health facilities are installed with solar PV systems as backup systems to guard against prolonged electricity outages. This strategy will act as both mitigation and adaptation and will contribute to the country's attainment of the nationally determined contributions (NDCs) target of reducing the national GHGs emission.

- **Increase the number of healthcare workers in all health facilities:** Heatwaves and other extreme climate events such as floods and storms could result in health workers overworked, fatigue and burnout. It is necessary to adapt to the possible scenario by increasing the number of workers in each health facility to ensure that there are adequate staff workers to reduce work overload and fatigue. This adaptation measure will ensure that each worker is given adequate off days. Consequently, each health facility should have a recommended adequate number of workers.

- **Establish health and climate data management system**: Building a health climate resilient system data for V&I assessment and M&E on the implemented. Effectively, this calls for improved data collection and management to support both V&A and M&E. Critical data include mortalities associated with climate extreme events, climate related hospital admissions, distinction between non-viral and viral diarrhea etc.

1.0. Introduction

The global knowledge based on impacts of climate change on health has expanded over the past few decades, particularly with the publication of reports by the Intergovernmental Panel on Climate Change (IPCC) (Smith et al. 2018). The IPCC paints a pessimistic future regarding climate change if no global immediate climate action is undertaken. For instance, under the worst-case scenario it is projected that global temperature will rise by 2 ^{o}C by 2050. Climate change, as a pervasive phenomenon, is expected to impact nearly all socio-economic sectors (Adom, 2024), with the health sector emerging as one of the most vulnerable. Studies reveal that climate variability is already affecting health systems, with future impacts projected to be extensive. Climate change is anticipated to heighten the prevalence of climate-sensitive diseases while undermining the operational efficiency of healthcare facilities through damage to properties and health workforce availability. These could be through extreme weather events such as flooding, drought, and heatwaves (Watts et al. 2020). Specifically, the weather events result in adverse health outcomes including high morbidity and mortality due to injuries, heatstroke, drowning, waterborne diseases, zoonoses, vector-borne diseases, malnutrition, non-communicable diseases, and mental health issues (WHO, 2024). It is projected that climate change could make changes to geographical diversity, as well as increasing the injuries, morbidity and mortality from climate-sensitive diseases and health outcomes therefore affecting the health care systems' adaptive capacity (WHO, 2021).

The impacts of climate change on the health sector could be more severe and pronounced in countries where health sector is already overwhelmed and lacking. Consequently, developing countries which have weak and overwhelmed health systems could be more vulnerable to the impacts of climate change. This is because majority of developing countries have the least adaptive capacity attributed to limited access resources, (Schleussner et al. 2016). Subsequently, it is crucial that countries undertake impact and vulnerability assessment to inform the development of health adaptation plans that will build climate resilient health sector.

Botswana like other developing economies is highly vulnerable to the impacts of climate change (GoB, 2019). Climate change is at an advanced stage in Botswana (Urich et al. 2022) as evident from frequent and intense drought event, increased number of heatwaves days, hailstorms, and floods amongst other climatic related disasters. As a party to the United Nations Framework Convention on Climate Change (UNFCCC), Botswana is required to develop and submit its National Communication (NC) as per Decision 17/CP.8. The NCs details amongst other climate scenarios and projections, impacts of climate change on various economic sectors and vulnerability assessments. Not only is the GoB undertaking vulnerability and impact assessment to meet the UNFCCC reporting requirements, but the government has recognized the potential impacts of climate change in reversing the development gains made over the years. The country developed its National Adaption Plan (NAP) Framework which calls for each sector to develop its sectoral NAP. Prior to the development of the sectoral NAP, the NAP framework recommended undertaking a detailed vulnerability and adaptation (V&A) assessment to inform the NAP. It is thus against this background that a V&A assessment for the health sector is undertaken with the ultimate objective of developing its health NAP. This is in line with the WHO recommendations that calls for assessment of the health sector and the potential impacts to inform developing climate resilient strategy. This report thus details the assessment of the health sector vulnerability and adaptation to climate change and aims to contribute to the development of the Health National Adaptation Plan (HNAP). The health sector vulnerability and adaptation will form part of the forthcoming Botswana Fourth National Communication (TNC) to the UNFCCC Secretariat.

2.0. Objectives

2.1. Main Objective

The main objective is to undertake climate change V&A assessment of the health sector and identify the feasible adaptation measures to build a climate resilient health sector. Ultimately, the adaptation measures proposed will inform a comprehensive Health National Adaptation Plan (HNAP).

2.2. Specific Objectives

The specific objectives are as follows:

1. Assess the existing and expected impacts of climate change on the [1]health system in Botswana using available data sources.
2. Assess the vulnerability, and adaptation capacities and needs of the health systems and services such as inter-alia, facilities, frontline workers, and vulnerable community segments including their ability to adapt to the impact of climate change with strong focus on children, gender, and equity.

3.0. Methods and approaches

A multi methodological approach was employed to undertake V&A assessment of the health sector to climate change. Methods consisting of desktop review, consultation/interviews with key stakeholders mainly Ministry of Health (MoH), Ministry of Agriculture (MoA), review and application of General Circulation Models (GCM), System Dynamic Model, Probabilistic Dose response modelling, and Health Vulnerability Index (HVI) were employed. The relevant methods are discussed under each thematic area as a way of demonstrating how each specific objective and broad theme were achieved.

[1] **Health system** includes delivery of patience services, healthcare workers, health information systems, financing, and governance.

The assessment of vulnerability and adaptation of the health sector to climate change followed the methodology recommended by the WHO (2021). The WHO recommended methodology is aligned to the IPCC's Sixth Assessment Report (SAR). Consequently, the vulnerability assessment took into consideration the climate-sensitive health aspects, social, economic, and environmental aspects of vulnerability (Frizsche et al. 2014).

The assessment was guided by the six steps recommended by the WHO, and the specific stages of this assessment followed this sequence:

1) Mobilisation and inception stage- at this stage the scope of work was defined. Health risks, outcomes, and geographical region (e.g., district as unit of analysis) were defined, and health priorities identified.

2) Review of relevant policies and the identification of data sources to inform the assessment. The selection of indicators was based on the availability of data.

3) Data collection- primary and secondary data gathering for the vulnerability and adaptation assessment followed which includes data on biological factors, demographic factors, geographical factors, and socio-economic factors, as well as climatological data, among others.

4) Development of climate scenarios and assessing the impact of climate change on the health sector- Development of climate scenarios for the specific settlements in the country was conducted using Global Circulation Models (GCM). Assessing the impacts of climate change involved application of an integrated assessment model based on System dynamic models. The developed model was simulated under climate scenarios to assess the impacts of climate change on the health variables.

5) After computing the Health Vulnerability Index (HVI) based on the three components of vulnerability to climate change (exposure, sensitivity, and adaptive capacity) the resultant HVI scores were mapped using Arc GIS and the analysis followed thereafter.

6) Adaptation assessment, this phase involved identifying feasible adaptation measures to address both current and projected health risks.

3.1. Study Sites and Climate

Study Sites: For the vulnerability assessment all the census districts of Botswana were used as the study area (refer to Figure 1a) because all the districts have different levels of vulnerability.

Therefore, they need to be investigated in order to inform health adaptation action to the impacts of climate change.

Due to the vastness of the country and time constraints the impact assessment of the health sector to climate change was undertaken for selected settlements which were deemed to be representative of the districts. A total of 9 settlements were selected throughout the country to represent their respective districts (Figure 1b). The settlements were selected based primarily on the climate extremes, accessibility, socioeconomics and demographics, and prevalence of climate-sensitive diseases (Table 1a). Map below depicts the settlements that were selected and their respective districts.

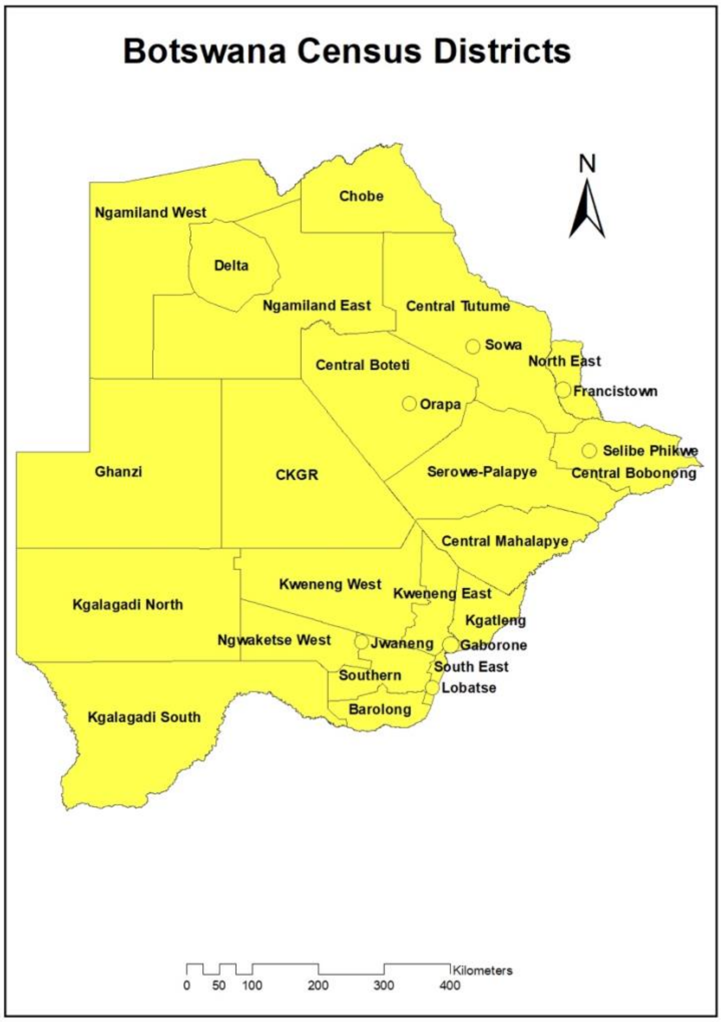

Figure 1a: Botswana Census Districts for Vulnerability Assessment

Note: The map scale cannot clearly show area of cities and towns because of their small land area; hence the use of circles to denote the area under in each settlement.

Table 1a: Justification for selecting settlements for impact assessment based on highest criteria incidences per district

No.	Settlements	District	Justification	Source
1.	Gaborone	South East	• Incidences of heat waves • Diarrhea cases • Population density	Statistics Botswana (2020a). Botswana Environment Statistics- Human Settlements Report 2018 Statistics Botswana (2020b). Botswana Environmental Statistics: Natural & Technology Disasters Digest 2019. GoB (2021). Pilot National Multidimensional Poverty Index Report 2021. Statistics Botswana (2022). Botswana Environment Statistics: Climate Change Digest 2021. Statistics Botswana (2024). Population and Housing Census 2022, Population Distribution, Structure and Density in Botswana.
2.	Gweta	Central	• Floods incidences	
3.	Maun	Ngamiland	• Malaria cases • Diarrhea cases • Extreme temperature	
4.	Kasane	Chobe	• Malaria cases • Extreme temperature	
5.	Francistown	North East	• High incidences of hailstorms and thunderstorms proximity to tropical storms from Indian ocean • High Diarrhea cases • Population density	
6.	Tsabong	Kgalagadi	• High incidence of heat waves and cold fronts • Highly water stressed • Aridity which makes it highly vulnerable to agricultural drought	
7.	Ghanzi	Ghanzi	• High percent of under 5 undernourished • Highly vulnerable to agricultural drought (crops)	
8.	Mopipi	Boteti	• Poverty rate • Highly vulnerable to agricultural drought	
9.	Molepolole	Kweneng	• Cases of Malaria (recent years) • Population density	

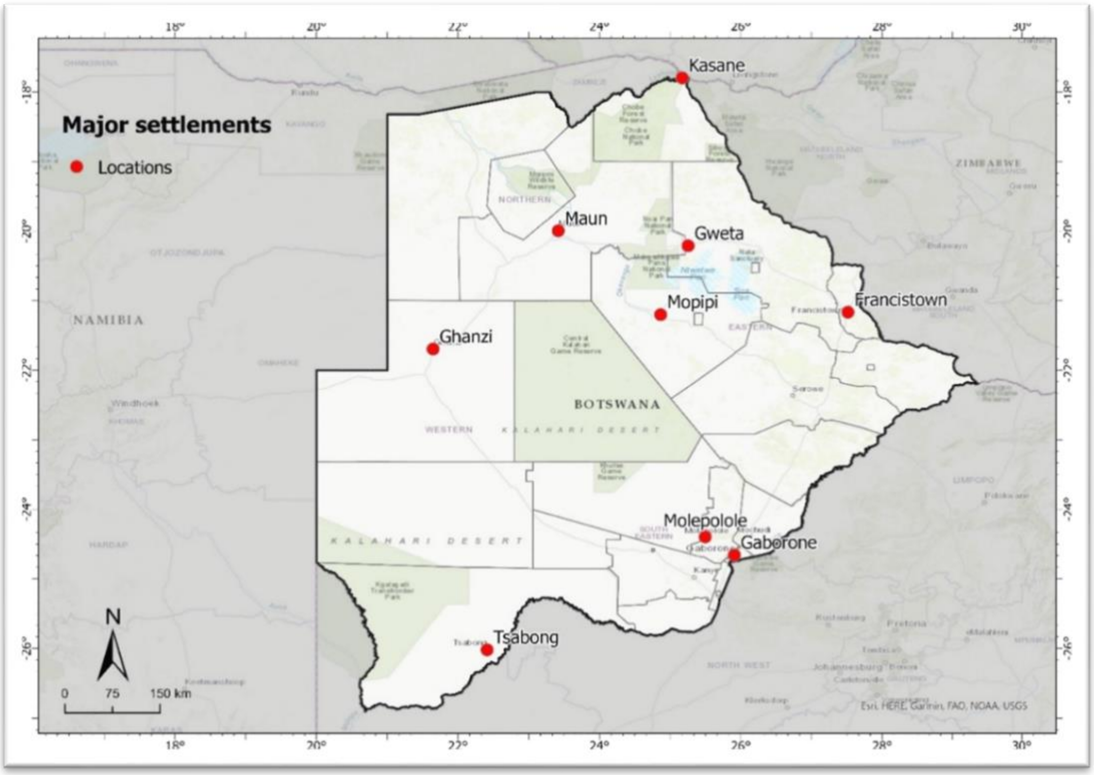

Figure 1b: Map of Botswana and Selected settlements for Impact Assessment

Climate: Botswana is characterized by semi-aridity to aridity climate. This is a result of a combination of high evapotranspiration and high erratic low rainfall. The country is landlocked and has a subtropical desert climate characterized by great differences in day and night temperatures and overall low humidity. The rainy season runs through the summer months of October to March, with little to no rain during winter. Annual rainfall declines from an annual average of 600 mm year^{-1} in the northern part (Chobe district) of the country to approximately less than 250 mm year^{-1} in the south western part of the country, the Kgalagadi district (Figure 1c). Evapotranspiration is estimated at 2,000 mm year^{-1}. In terms of the temperatures, the winter season starts in May to August, with average monthly maximum temperatures ranging from 22˚C to 29˚C, and cool minimum temperatures, ranging between 2.8 ˚C to 10.6˚C (GoB, 2019). On the other hand, mean monthly maximum temperatures in summer months (October to February) range from 31˚C to 34˚C, and mean monthly minimum temperatures are warm and range from 16 ˚C to 20.5 ˚C.

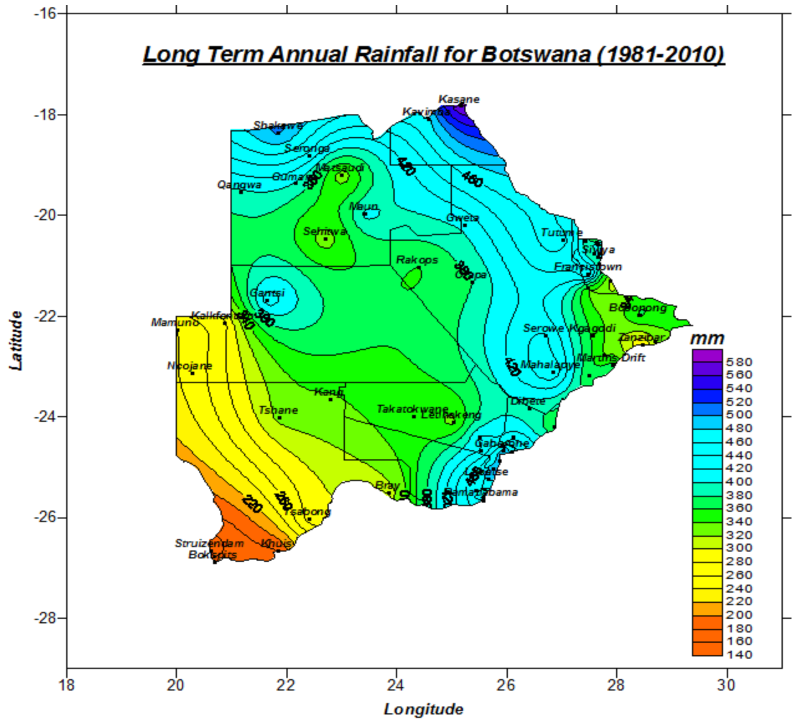

Figure 1c: Botswana Annual average rainfall 1981– 2010
Source: GoB (2019)

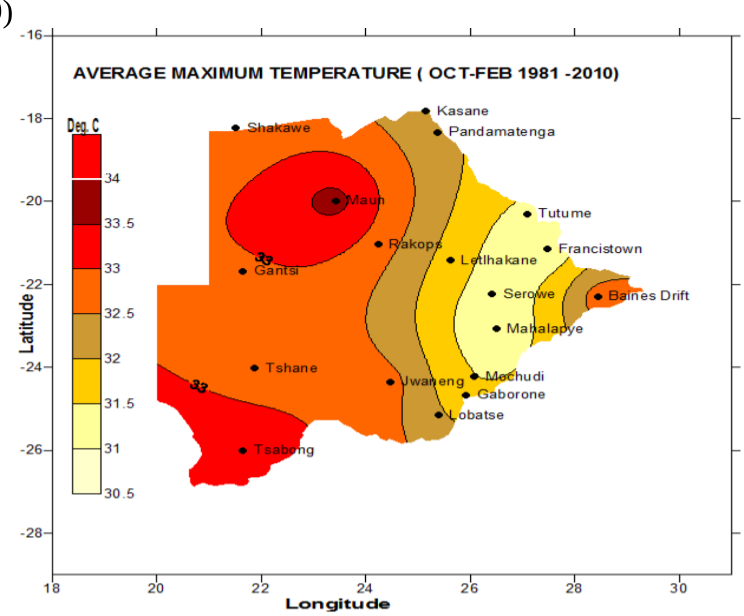

Figure 1d: Mean monthly maximum temperature for 30 years
Source: GoB (2019)

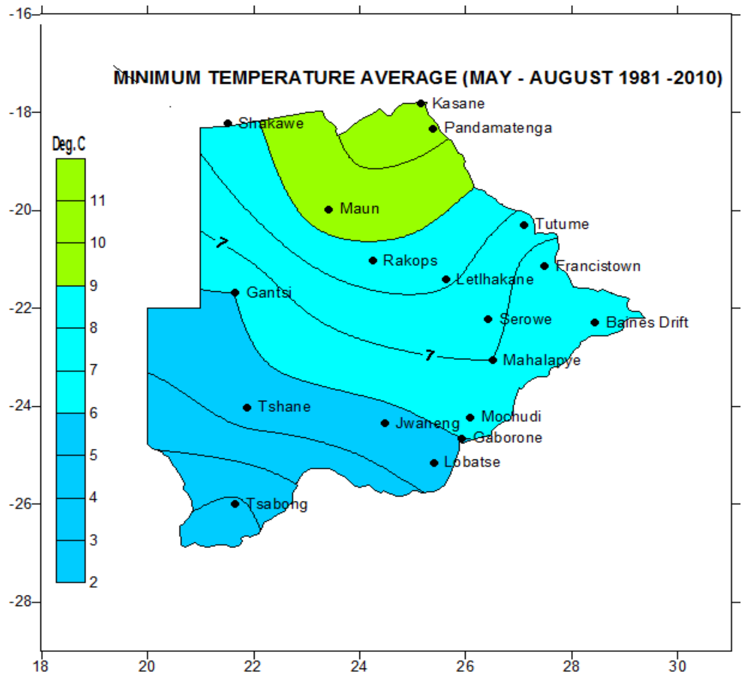

Figure 1e: Mean monthly minimum temperature for 30 years
Source: GoB (2019)

3.2. Development of Climate Scenarios

This is the critical step towards vulnerability and adaptation assessment of the health sector to climate change. Climate scenarios are the core of the climate change Vulnerability and Impact (V&I) assessment. A scenario is defined by IPCC (2007) as a coherent, internally consistent, and plausible description of a possible future state of the world. It is also defined as a plausible description of how the future may develop based on current recognizable signals and trends, and on assumptions about how these will progress in the future. The climate scenarios were developed based on an ensemble of 50 Global Circulation Models (GCM) outputs. Climate scenarios were developed based on the Representative Concentration Pathway (RCPs) 4.5. and 8.5., and the Shared Socio-economic Pathways (SSPs) 2-4.5 and 5-8.5. The scenarios were constructed for the year 2030 and 2050. The parameters of interest were precipitation and temperature specifically:

- Monthly and annual precipitation
- Monthly and annual mean temperature
- Monthly and annual maximum temperature
- Monthly and annual minimum temperature
- Heatwaves days
- Maximum temperature over 35 degrees
- Cooling degree days

- Standardised precipitation evapotranspiration index (SPEI) drought probabilities
- Average recurrence interval (ARI) 100 daily extreme precipitation

The selection of SSPs, particularly SSP5-8.5 is that it has the potential to project the most global warming making the climate change signal most easily identifiable from the background noise of natural climate variability. In research applications, where the objective is to find a correlation between climate change and some other event, SSP5-8.5 is the best pick as the climate signal is strongest under this emissions scenario (Lee et al. 2021). On the other hand, SSPs were used together with RCPs because they have levels of Radiative Forcing that correspond with the RCPs (high or RCP8.5, and medium or RCP4.5).

3.3. Assessment of the impact of climate change on health sector

Following the development of the climate scenario, the impacts of climate change were simulated on the various components of the health sector. Assessing the impacts of climate change involved application of an integrated assessment model based on System Dynamic Models as depicted in Figure 3, specifically using the Probabilistic Dose Response model. The model simulates various aspects of the health sector, particularly climate sensitive diseases: malaria, diarrhea; malnutrition, and mortality from extreme heat, as well as impacts on health infrastructure associated with extreme events over time as perturbed by climate scenarios. All the aspects of the health sector (climate sensitive diseases- malaria, diarrhea, and malnutrition, and extreme events infrastructure damage, etc.) were identified and simulated. The developed model was simulated under climate scenarios to assess the impacts of climate change on the health variables, and it involved the following methods and approaches.

Desk review: the impact of climate change on the health sector is one of the widely researched areas globally. Health issues such as vector-borne diseases (e.g., malaria) and water-borne diseases (diarrhea, cholera, typhoid fever, E.coli and others), heatwaves and related mortality, malnutrition and their linkages to climate change have been extensively researched. Similarly, the country has undertaken a sizable number of studies on vulnerability assessment such as the Third National Communication (TNC). Therefore, the findings from these studies were accessed and used to inform the assessment of this study. Importantly, WHO climate change and health vulnerability and adaptation assessment guidance document and WHO operational framework for building climate-resilient health systems were reviewed to inform the methodology.

Consultation with stakeholders: this is another important method that was used to inform the development of the integrated assessment model to simulate the impact of climate change on the health sector. The consultation sessions were undertaken in the 9 selected locations which are strategically located to represent all the respective districts. The locations include Gaborone, Molepolole, Francistown, Kasane, Maun, Gweta, Mopipi, Ghanzi, and Tsabong. The consultation was undertaken based on the following approaches:

a. Field visits to selected districts agreed with MoH and WHO Botswana Office to understand the context and assess health infrastructure vulnerability to climate change. Both MoH and WHO supported in identifying health facilities and frontline workers (including community health workers) situated in high-risk zones, including those exposed to floods, Malaria, and extreme temperatures. Direct data collection using a standardized questionnaire was used to gather the necessary data for assessing the impact of climate change on health. Furthermore, field visits and consultation covered ongoing programmes and educational initiatives in health facilities to identify practices (both harmful practices and opportunities) including medical waste management by health facilities, water management, handling of hazardous materials, and disposal of equipment.

b. Consultation (face-to-face) with health workers (medical doctors, nurses, environmental health officers, and DHMT coordinators) was undertaken to identify and assess the health impacts and risks emanating or likely to occur from climate change. Furthermore, through these consultations health adaptation measures were identified and prioritized.

Collection of secondary data on climate extreme events and health related mortality: data from the selected district health centers were collected on climate related health incidents.

Dose response modelling approaches: a dose response model is a causal-effect model that is based on empirical evidence to determine the relationship between two variables. Based on the data collected, the relationship between climate extreme events and health incidents were developed and projected based on the developed climate scenario (extreme events).

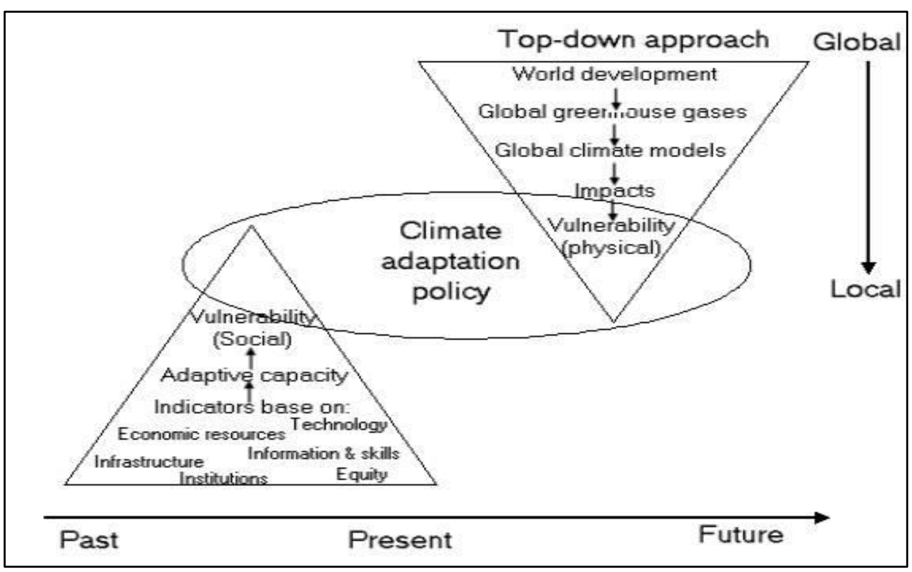

Figure 2: Top-down approach for V&A assessment

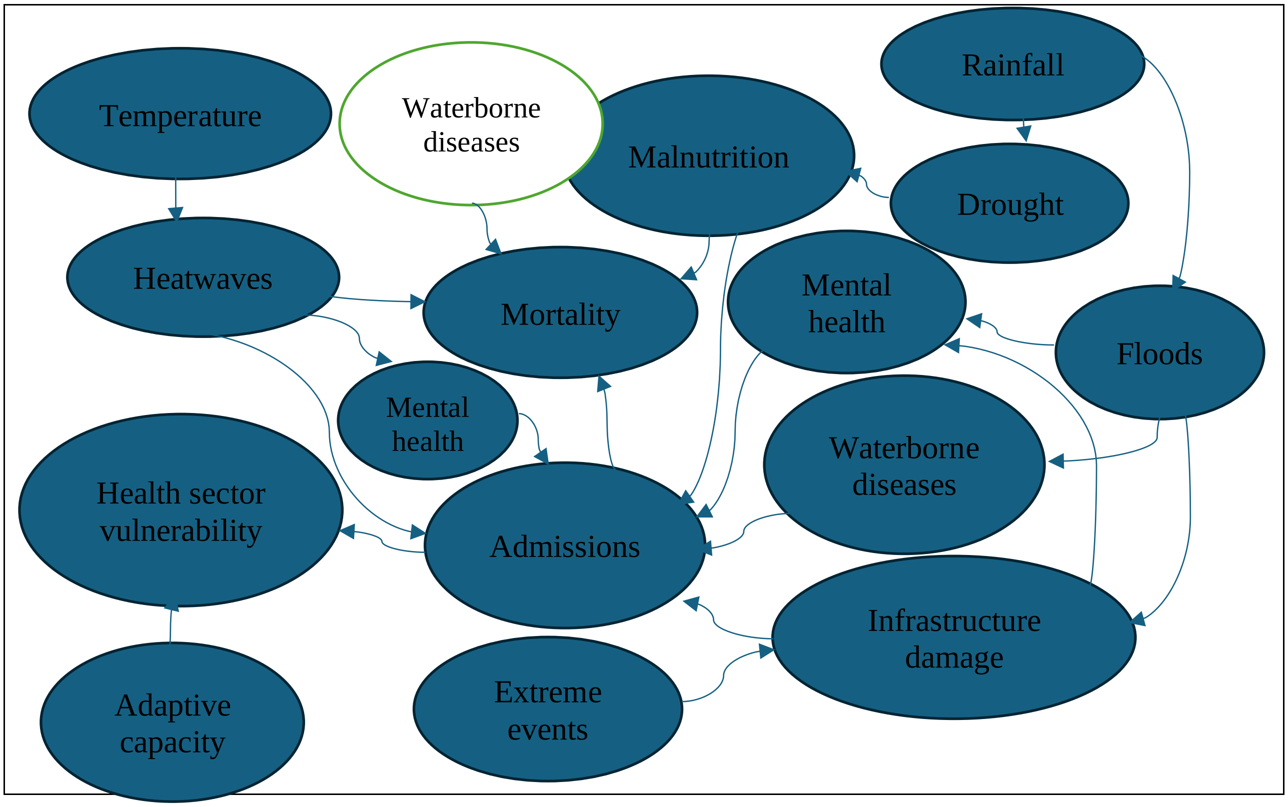

Figure 3: Schematic representation of the impact assessment model

3.4. Health Vulnerability Assessment

Vulnerability assessment involves analysing the extent to which the various aspects of the health sector are exposed to the impacts of climate change. It is a function of adaptive capacity of a unit (systems) and its sensitivity to the impacts (Figure 4).

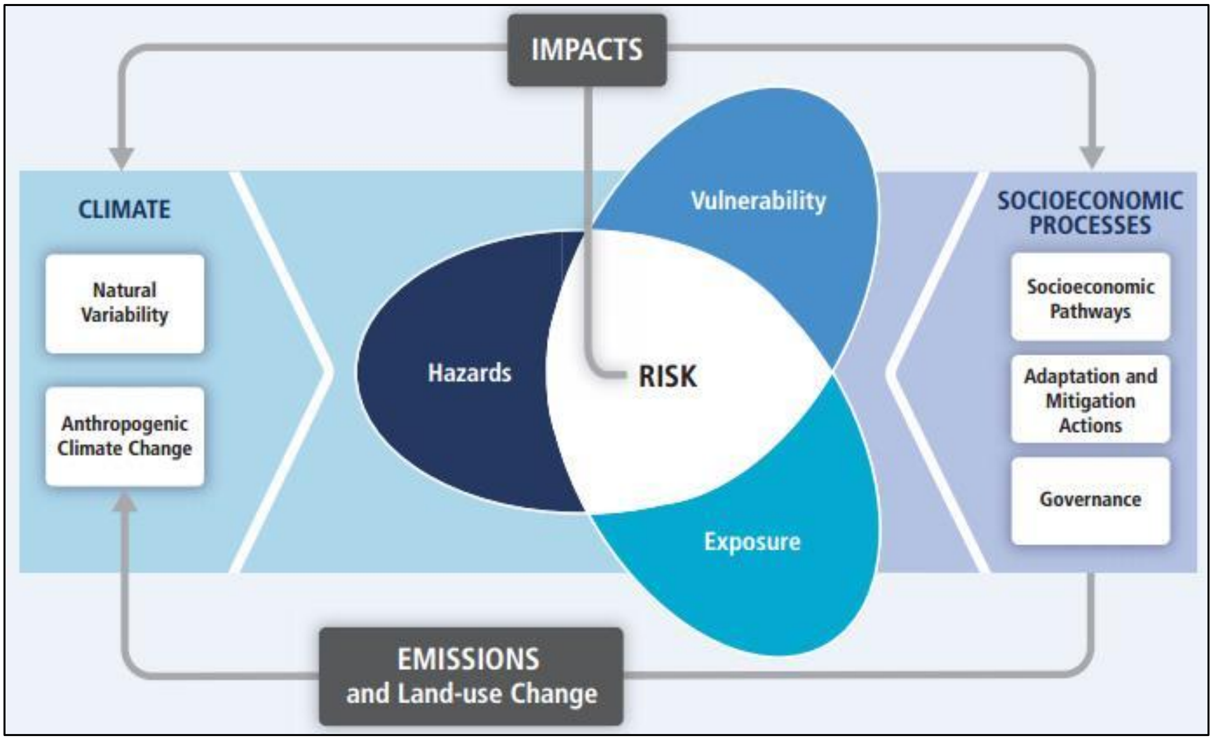

Figure 4: Climate change impact, vulnerability, and risk interface

The assessment of vulnerability involved the following steps:

- Simulate the impact of climate change on the health sector based on the constructed climate scenarios. Systems vulnerability is a function of the extent of the impact on the system.
- Assessing the future adaptive capacity of the health sector: vulnerability is a function of impact and the adaptive capacity of the sector. The adaptive capacity is a function of resources available and strategies in place to adapt to extreme events. The adaptive capacity of the health sector was therefore analysed in consultation with the health practitioners and multi-stakeholders, as well as using secondary data. The designed guiding questionnaire was used in the interviews.

  Assess the overall future vulnerability: this is the final stage of the vulnerability assessment, and it is based on a ratio of impacts and adaptive capacity (Figure 5). The higher the impact and low adaptive capacity the highly vulnerable is the sector to climate change impacts.

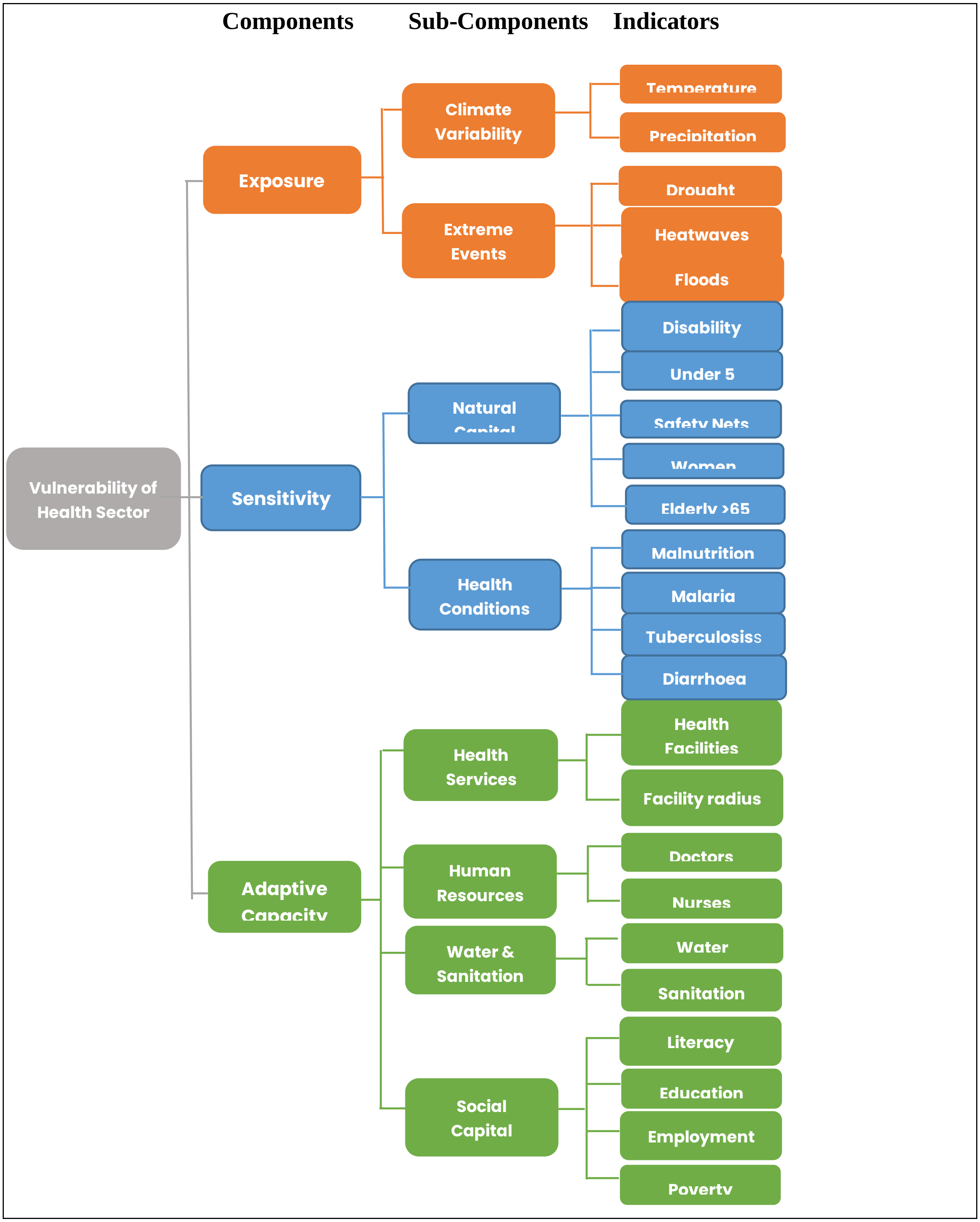

Figure 5: Estimating the Health Vulnerability Index (HVI)

Preceding the computation of the Health Vulnerability Index, all the indicators were normalised. In statistics, normalisation is a process that involves adjusting values to a common scale, or to a standard interval, to make them easier to compare or interpret. Based on the functional relationship between vulnerability and indicators, the following equation was used to normalise the values:

$$X_{ij} = \frac{X_{ij} - minX_{ij}}{MaxX_{ij} - MinX_{ij}}$$

Where X_i represents the value for a given indicator for the i^{th} district, and X_{min} and X_{max} represent the minimum and maximum values of the indicator, respectively. The normalisation ensures that the values are bounded between 0 and 1.

Based on the composite index (Figure 5), as well as Shah et al. (2013); Muleia et al. (2024) the Health Vulnerability Index (HVI) was derived based on the following equation:

$$HVI = (E - AC) \times S$$

E is the exposure index, *S* is the sensitivity index, and *AC* represents the adaptive capacity index. Additive or direct approach was used to define the index, it is known as the weighted sum method (Hahn et al. 2009). The weighted sum model is given as follows:

$$E_j = \sum_{i=1}^{N} w_i Y_{i,j,}$$

Where $Y_{i,j,}$ depicts the normalized indicator at district $,j$ and w_i is the weight assigned to Y_i, in order that $\sum_{i=1}^{N} w_i = 1$ and *N* is the total number of indicators. Equal weights were assigned to the normalised indicators, then the exposure index was computed using the arithmetic mean. In the same way the sensitivity index was computed as the average score of the set of selected indicators. Just like the other two indices, the adaptive capacity also followed the same approach: an average score was computed from equally weighted indicators. Each component included a various number of sub-components and each sub-component contributed equally to its major component. The HVI was calculated for each census districts after deriving the three indices (sensitivity, exposure, and adaptive capacity). The HVI scores, and the scores of the three components of vulnerability range from 0 to 1 and the categorisations are depicted in Tables 1b and 1c below.

Table 1b: Colour ramp for vulnerability scores

Index scores	Level of Vulnerability	Colour code
0.000-0.199	Low	
0.200-0.399	Medium Low	
0.400-0.599	Medium	
0.600-0.799	Medium High	
0.800-1.000	High	

Table 1c: Colour ramp for Adaptive Capacity scores

Index scores	Level of Adaptive Capacity	Colour code
0.000-0.199	Low	
0.200-0.399	Medium Low	
0.400-0.599	Medium	
0.600-0.799	Medium High	
0.800-1.000	High	

4.0. Botswana Economic Status

The economic status of the country determines its adaptive capacity and hence strongly influences its vulnerability to climate change. As countries' GDP determine the level of adaptive capacity, it thus implies that there is an inverse relationship between GDP and vulnerability to climate change. Hence, it is crucial that Botswana socio-economic status is discussed which will be used to assess its health sector vulnerability to climate change.

Botswana is classified as an upper middle-income country with a GDP of approximately US$19.4 billion and a GDP per capita of $7,859 (The World Bank Group, 2024; Statistics Botswana, 2024). The major contributors to the country's GDP in 2023 were Public Administration and Defence (16.6%), Mining and quarry (16.7%), and Wholesale and Retail (11.3%). The three top contributors account for approximately 45% of the country's GDP. Within the mining and quarry sector, diamonds account for approximately 90% mining sector GDP. Figure 6 depicts the country's GDP at current prices.

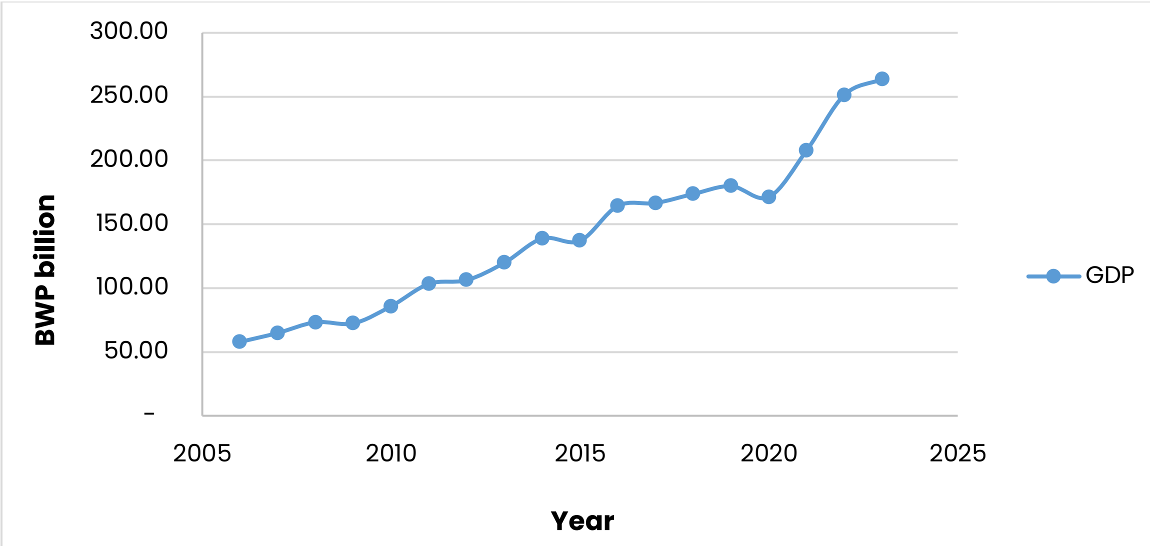

Figure 6: Botswana's GDP at current prices

Source: Statistics Botswana (2024)

Over the years the country has experienced a steady growth with some significant declines in the years 2009, 2015 and 2020. Similarly, in 2023 the economy experienced a decline in the country's GDP of 2.7% (AfDB, 2023). This was due to a decline in the production of water, electricity, and diamond trade due to drought and weak diamond trade demand. According to the AfDB (2023), the 2023/24 fiscal deficit widened by 22.5% of the GDP. This is influenced by lower mineral earnings and higher recurrent spending. The country's heavy reliance on minerals, as well as its large public sector and impact of climate change on the key sectors such as agriculture are aggravating the country's fiscal and external vulnerabilities (World Bank, 2024). With the projected increase in penetration of the lab diamonds, the country could see some significant decline in its GDP in the future. A combination of decline GDP growth and impacts of climate change could worsen the health sector system and expose it to climate change.

In addition to over-reliance on diamonds, Botswana has one of the highest income inequalities in the world. The country has a GINI index of 53.3 and an unemployment rate of 27.6%. (The World Bank Group, 2024). The challenges are a threat to the gains that have led to the attainment of a high middle-income status. Furthermore, despite a relatively high GDP per capita, many families are reliant on subsistence farming and are particularly vulnerable to climate change. The effects will inevitably affect the health of populations and individuals through under-nutrition and exposure to extreme weather conditions among others.

4.1. Population and Health Status

4.1.1. Population

Botswana's population is approximately 2.35 million based on the recent population census of 2022. The annual population growth rate is estimated at 1.4%. The population is projected to be approximately 2.6 million by 2026 (Statistics Botswana, 2015). The country is sparsely populated with a density of 4.1 inhabitants per square kilometre. Life expectancy at birth (years) has improved modestly from 68 years in 2011 to current 70.94 (Statistics Botswana, 2023). Fertility is on the decline, estimated at 2.9 children per woman. Likewise, mortality is also experiencing a decline. This may in part reflect improvement in the health of the population due to government investments and sound health programmes. However, Infant mortality rate increased from 17 in 2011 to 27.9 in 2022 (Statistics Botswana, 2023).

The Pilot National Multidimensional Poverty Index (MPI) indicate that in 2021, about 20.84% of the population in Botswana were classified as multidimensional poor, with average poverty intensity of 51.08% (GoB, 2021). Poverty incidence is significantly high in rural areas relative to urban settlements. The results also show that those in severe multidimensional poverty accounted for 3.9%, while the vulnerable ones were 15.94% of the population. On the other hand, The World Bank estimates the poverty rates for the country as follows:

- International poverty rate ($1.9) at 14.5%
- Lower middle-income poverty rate ($3.2) at 36.5%
- Upper middle-income poverty rate ($5.5) at 59.1%

These figures are concerning as poverty has a significant impact on household adaptive capacity and vulnerability to climate change. One of the factors that have a bearing on poverty in the country is unemployment.

4.1.2. Population’s health Status:

Conducting a comprehensive V&I assessment requires first performing a thorough situational analysis of the current health status of the population. The baseline information is critical as it will inform prevalence of the diseases in the country and hence baseline vulnerability of the population. Secondly, based on the current disease prevalence, a dose response technique can be used to project the possible changes of the current diseases under climatic conditions. Diseases discussed are those likely to worsen due to climate change and those that could weaken the immune system, increasing individual vulnerability to extreme climate events such as heatwaves.

Communicable Diseases

Botswana's national estimated HIV/AIDS prevalence is 20.68% (GoB, 2023) which is considered the highest in the world. Over the years, the country has achieved a remarkable reduction in the HIV/AIDS related deaths by establishing and operationalising a comprehensive and robust HIV programme. The programme involved prevention and treatment, including the widespread access to antiretroviral therapy (ART). The “treat all” policy, provides ART to all Batswana diagnosed with HIV, regardless of the CD4 count. Botswana has also implemented programs aimed at reducing mother-to-child transmission of HIV, resulting in a significant decline in new infections among infants. Despite notable developments, challenges such as adherence to treatment, stigma, and discrimination as well as need for continuous education and public health outreach remain.

Women are disproportionately affected by HIV/AIDS, with more women at higher risk of infection than men. Sex differentials reveal that HIV prevalence among adult females aged 15-64 years was lower in urban areas 23.8 % than in rural areas, 31.3%. Furthermore, HIV prevalence among adult males aged 15-64 years was 13.7% in urban areas and 18.0% in rural areas.

Subsequently, high HIV prevalence in the country and the associated expenditure could increase the country’s health sector vulnerability to climate change in two ways. Firstly, HIV positive results in compromised immune system and would be affected by climate induced events such as heat waves, drought, and associated food insecurity. Secondly, the high costs associated with HIV programs mean that a significant portion of resources is allocated to them, potentially limiting the country's ability to invest in other health adaptation measures needed to address the impacts of climate change. Consequently, climate change would worsen the current resource deficiencies to deal with health challenges.

TB is another communicable disease in the country that is presenting some challenges to the health sector. Botswana is among the Southern African countries with a high burden of TB and remains enlisted in the 2021–2025 high TB/HIV burden countries (Falzon et al. 2015). According to WHO (2021), Botswana has an estimated TB incidence rate of 235/100,000, TB-related death rate of 32/100,000 among the HIV negatives, 50/100,000 among the HIV-positive, and treatment coverage of 39 % in 2021. The overall treatment success rate for the new and relapse cases was 78 %, with 76 % among HIV-coinfected patients (WHO, 2021). Robust support structures and policies, as well as integrated patient-centered treatment and prevention are at the core of the Botswana national tuberculosis control program strategic plan of 2018–2023 (GoB, 2018). The aforesaid strategies were meant to reduce TB incidences to 234 per 100,000 in 2020 and 198 per 100,000 in 2022, and TB/HIV death rates were projected to drop to 32 per 100,000 (GoB, 2018). To date, all these targets have not been accomplished.

Malaria is another significant burden on the country’s healthcare system, and its prevalence could increase with climate change. The disease is endemic in specific regions, particularly the north-western parts of Botswana, including the Okavango, Northwest, and Chobe districts, as well as the Bobirwa area. Despite these challenges, WHO notes that Botswana has made commendable progress, achieving a 93% reduction in malaria cases by 2021. In the Okavango district, 96% of malaria cases were reported within 24 hours in 2021, contributing to a six-fold decrease in cases between 2016/17 and 2022/23. Okavango District is reporting the highest malaria incidence in the country, the total number of cases reduced from 1,193 in 2016/17, to just 198 in 2022/23. Despite the reduction in malaria cases in the Okavango the risk of new infections is probable. This is attributed to the fact that many of the residents of Okavango district build temporary accommodation structures which are not suitable for indoor residual spraying. Furthermore, the climatic conditions and hot temperatures force members of households to spend a lot of evenings and often sleep outside, presenting a risk in continuing malaria transmission. There are reliable information reporting systems that ensure that all malaria cases are tested, treated, and tracked to avoid further transmission such as malaria Case-Based Surveillance (CBS) system introduced in 2012, and the National Malaria Programme (NMP).

Non-Communicable Diseases (NCDs)

NCDs also known as chronic diseases are defined as diseases that are not transmissible directly from one person to another. They tend to be of long duration and are the result of a combination of genetic, physiological, environmental, and behavioural factors.

The main types of NCDs are cardiovascular diseases (heart attacks and stroke), cancers, chronic respiratory diseases (chronic obstructive pulmonary disease and asthma) and diabetes. These diseases are a leading cause of deaths globally, claiming 40.5 million lives annually (71% of all deaths) and accounting for more deaths than HIV, TB and malaria combined (WHO, 2016). NCDs such as stroke, diabetes, heart diseases, chronic lung disease are increasingly prevalent in Botswana. The rising burden of NCDs in the country is of great concern to the GoB and is a threat to the achievement of the Sustainable Development Goals 2016-2030 and Vision 2036 (GoB, 2018). It is estimated that NDCs cause about 46% of all deaths in Botswana (WHO, 2016). The prevention and control of NCDs has been prioritised at the national level as evident from the 11th National Development Plan (2017-2023), and Ministry of Health Strategy 2017-2023. In 2016 GoB developed the country’s first national primary health-care guidelines for NCDs for adults. These guidelines contain standardized algorithms for screening, risk stratification and management of diabetes, hypertension, asthma, and screening for, as well as algorithms for broader management of common clinical complaints and preventive care in adults (WHO, 2019). Climate change could exacerbate the conditions of the people with NCDs through extreme temperatures, winds and associated atmospheric air quality.

4.1.3. Health care system:

The GoB aims to provide quality affordable healthcare to all. The healthcare system offers a combination of public and private services. Botswana health care is decentralised, with the primary health care as the foundation of the system. It has a vast network of health institutions including hospitals, clinics, health posts and mobile clinics. The Ministry of Health (MoH) serves as the principal provider of health care, managing 27 health districts. According to the Botswana MoH Facilities Master Plan of 2021, there are 619 MoH facilities in total as follows:

- 3 national referral hospitals,
- 1 teaching hospital,
- 7 district hospitals,
- 16 primary hospitals,
- 99 clinics with maternity / beds,
- 159 clinics without maternity, and
- 334 health posts.

In addition to a comprehensive network of MoH facilities, there are 931 mobile stops. Moreover, there are non-MoH facilities within the primary healthcare system. There are 77 non-MoH facilities in total, made up of 6 hospitals, 6 clinics with maternity / beds, 51 clinics, and 14 health posts. Botswana's primary health care (PHC) services are integrated into total hospital services and are given in the outpatient sections of all levels of hospitals. These structures provide a comprehensive range of preventative, promotional, and rehabilitative health treatments.

Management of Health Care Service Delivery

The MoH is responsible for overseeing and coordinating health service provision in Botswana. The decentralised District Health Management Teams (DHMT) have been created in all health districts to plan, implement, monitor, and evaluate all the services from the community level up to district hospitals (GoB, 2012). The DHMT are also charged with the responsibility of managing and provision of health care services. The decentralised Hospital Boards for referral hospitals have been established. All the afore-mentioned functions are coordinated at a national level by a main coordinating body known as the National Health Council. To ensure effective collaboration and efficient use of resources, coordination and partnership structures have been established at national, district and community levels. These structures facilitate coordination and collaboration between MoH, other public sector departments, central agencies, development partners, NGOs, and umbrella organisations for the private sector and civil society. The MoH is represented at lower levels by the public sector departments, NGOs, and CBOs (see Figure 7).

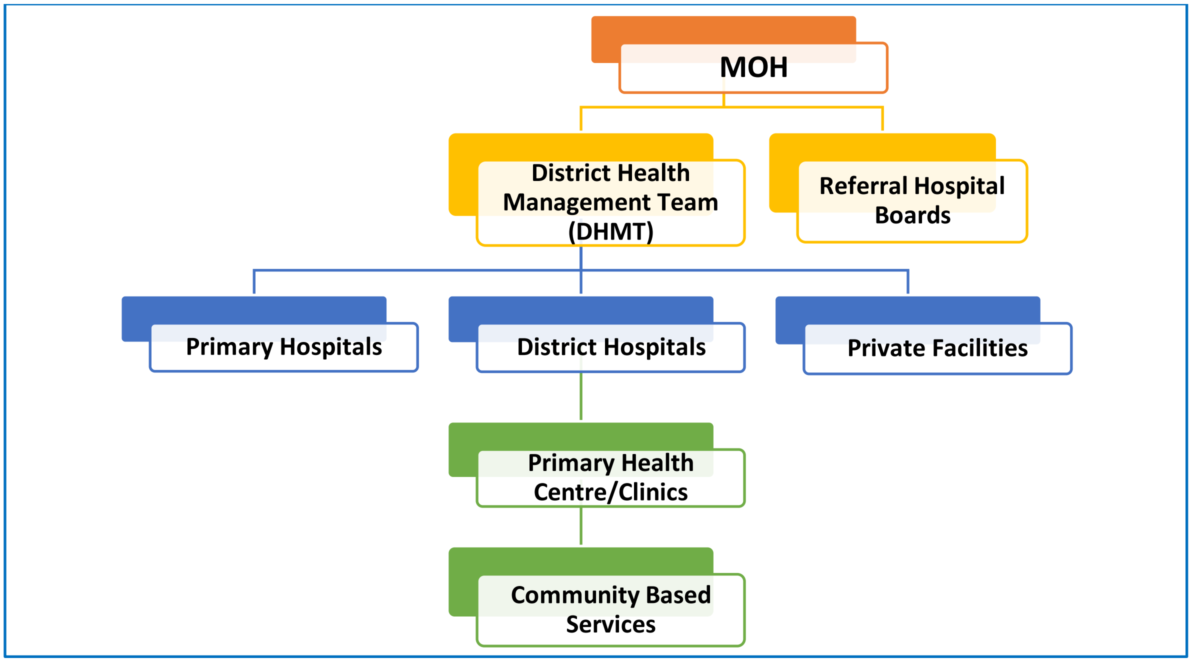

Figure 7: Organisation and management structure for health care service delivery in Botswana
Source: GoB (2012)

Health care providers

Primary healthcare providers play an indispensable role in the healthcare system to prevent and manage common health conditions, hence a reduction in morbidity and mortality. Over the years, the country has experienced an increased number of public sector Nurses and Medical doctors. Currently, there are 906 Medical Doctors and 7,679 Nurses (Statistics Botswana, 2022). Despite the increase in the number of nurses and doctors, nationally and across the districts, there is a higher scarcity of doctors than nurses. Nonetheless, there are some districts that have reached the threshold of 45 Nurses per 10,000 population in 2020 noticeably Chobe, Lobatse, Kgalagadi North, Gantsi, Kgalagadi South, Mabutsane, Selibe Phikwe and Serowe (Statistics Botswana, 2022).

4.1.4. Healthcare Challenges

Despite all the Government's effort to provide health care for all, the healthcare system still faces several challenges. These challenges include.

- **Health Infrastructure**: Firstly, the health infrastructure in the country is inadequate to meet the needs of the population. This is particularly true in the rural settlements where the health infrastructure is limited and cannot cope with the population demand. Consequently, this results in the infrastructure being strained. Secondly, the infrastructures are aged and dilapidated requiring maintenance. Furthermore, some of the infrastructure do not provide a conducive working environment with no air conditioning and health employees work under extreme high ambient temperatures.

- **Resource Allocation**: It is estimated that the current health expenditure is approximately 6.31% of the country's GDP. This budget allocation is inadequate to meet the population health demands are evident for shortage of medicines.
- **Education and Awareness**: Continued efforts are needed in health education and awareness, particularly regarding lifestyle diseases and reproductive health.

However, the GoB actively works with international organizations including the WHO, to address these health challenges and continues to implement programs aimed at improving the overall health status of its population.

4.2. Health Sector Investment

As a signatory to the Libreville Declaration, which seeks to establish linkages, collaboration and coordination between the health and environment sectors in African states, Botswana is currently undertaking an update of the country's Situation Analysis and Needs Assessment (SANA). The SANA was first undertaken and published in 2012 and provided information that is vital for the formulation of joint plans of action. The SANA is expected to lead to joint planning between the Ministries of Health and Ministry of Environment and Tourism (MENT) with joint actions that cover capacity building, resources planning, research, policy, institutions, monitoring and evaluation (M&E) and environmental surveillance among others. Therefore, it is worth noting that the GoB has allocated increasing amounts of the national budget to the MoH and stable proportions to the MENT between the years 2017/18 and 2021/22, as indicated in the table below

Table 2: Proportion of national budget allocation to health and environment ministries

Year	2017/18	2018/19	2019/20	2020/21	2021/22
MoH	10.9%	10.4%	10.6%	11.7%	11.4%
MENT	1.0%	1.0%	1.1%	1.1%	1.0%

Source: Ministry of Finance (Annual Statements of Accounts)

The two ministries in addition to others like Ministry of Agriculture, Ministry of Land and Water Affairs are important for mitigation and adaptation planning for the impacts of climate change on livelihoods and wellbeing.

Botswana is focusing on significant investments in its health sector, particularly in primary health care, which reflects its commitment to enhancing public health services. A proposed budget of BWP9.46 billion for 2024 aims to acquire necessary medical supplies, including vaccines and medicines. The GoB is also exploring opportunities for the private sector to invest in health care.

As one of the national priorities under the financial year 2024/2025 budget, the GoB has prioritized sustaining livelihoods, among others, in its endeavor to transform the economy and ensure the creation of sustainable jobs and eliminate abject poverty. An overall budgetary provision of BWP6.09 billion is proposed for this priority (GoB, 2024). The key initiatives include:

i. Social Protection Programmes will continue to be implemented to eliminate absolute poverty and substantially reduce inequalities as well as improve the quality of life of all Batswana.
ii. Construction, upgrading and maintenance of health facilities as well as improving the rollout and update of healthcare programmes will be undertaken.
iii. The 2019 Informal Sector Strategy will be reviewed during the 2024/2025 financial year with its implementation expected the same year.

The initiatives are critical for increasing the country's health sector resilience to climate change impacts as communities will now live beyond poverty thresholds therefore increasing their adaptive capacity and making them less vulnerable to the impacts of climate change. Similarly, upgraded, and well-maintained health infrastructure will be climate resilient to extreme climate events such as strong winds, storms, hailstorm, and strong winds. Lastly, upgraded infrastructure that has been retrofitted provide a conducive environment even under extreme events such as heatwaves.

5.0. Linkages between climate and health

5.1. Global Scale

Climate change as a cross-cutting phenomenon has multiple impacts on the health sector with projections of increased mortality from extreme events and impact of the functioning of the health infrastructures/systems. Climate change is associated with rising temperatures (heatwaves), increased frequency of droughts and floods, smoke, and air particulates from increased wild fires (CDC, 2024). These extreme events could result in increases in heat-related deaths and cardiovascular failure, increases in vector-borne diseases (such as malaria), increases in malnutrition, diarrheal diseases, cholera, and mental health issues. Figure 8 below illustrates interactions between changing climate variables, their extreme events, and possible impacts on public health.

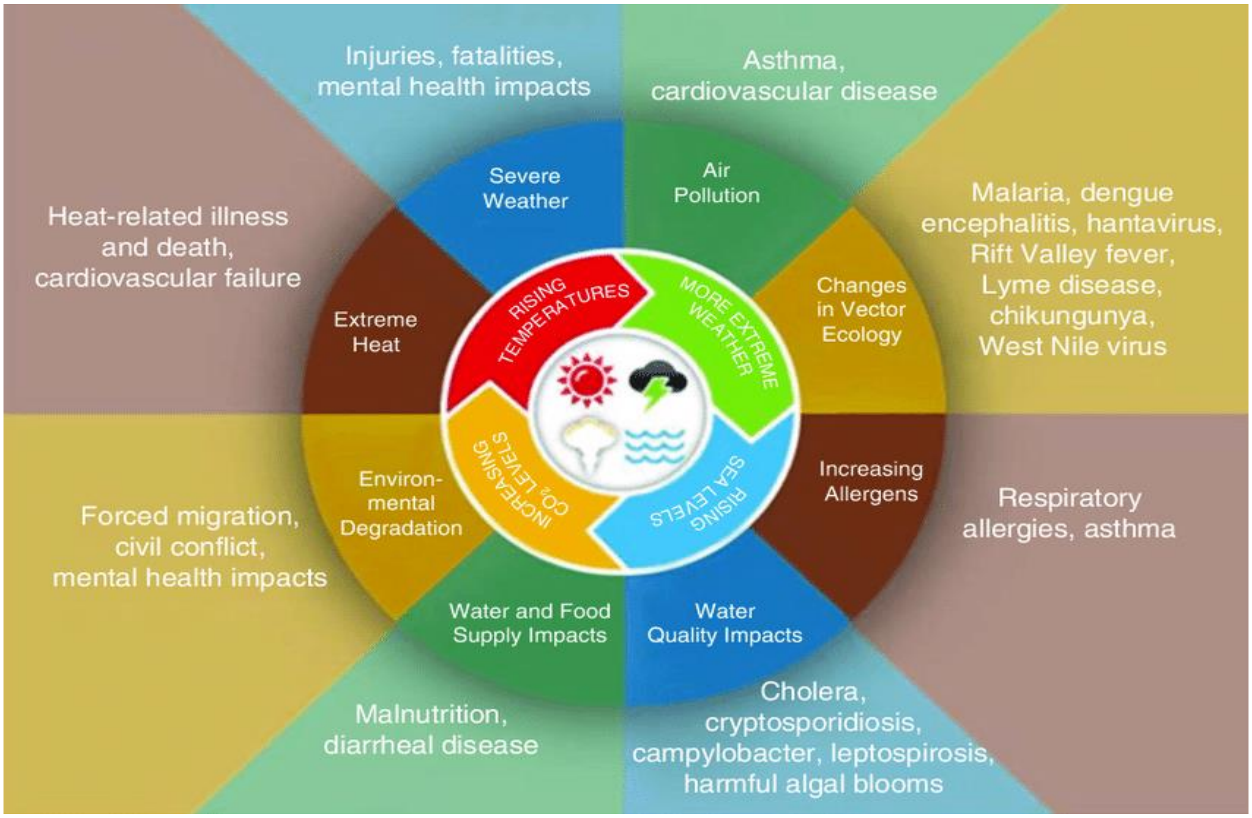

Figure 8: Impacts of Climate Change on health
Source: CDC (2024)

5.1.1. Climate Change impacts on Non-Communicable Diseases (NCDs)

As highlighted in Figure 8 above, climate change will have significant impacts on the public health. One of the parameters that has a strong bearing on the public health is heatwaves. WHO (2024) identifies heatwaves as a primary environmental and occupational health hazard. Apparently, heat stress is the leading cause of weather-related death and compound underlying aliments such as cardiovascular disease, diabetes, mental health, asthma. Furthermore, climate change can increase incidences and transmission of some infectious diseases which are not endemic to the country (WHO, 2024).

According to Epstein & Yanovich (2019); Siiba et al. (2024), heat stress has a potential of causing accelerated blood circulation and heart rate, and high blood pressure levels can result in insufficient cardiac output to fulfill the thermoregulatory needs of the human body. That is, high blood pressure increases the resistance the heart must pump against, which can lead to decreased cardiac output (Oh & Cho, 2020). For example, when the heart cannot generate enough cardiac output, blood flow to vital organs is reduced, and this can lead to symptoms like fatigue, light-headedness, and low urine output (Khan et al. 2020). It is projected that heat-related deaths for the elderly (65+ years) could increase to about 136 deaths per 100,000 by 2080 compared to the estimated baseline of approximately 3 deaths per 100,000 annually between 1961 and 1990. WHO (2024) heat-related statistics indicate that heat-related mortality for people over 65 years of age increased by approximately 85% between 2000–2004 and 2017–2021. With projected increase in global temperature and number of heatwaves, the number of people exposed to extreme heat is projected to grow exponentially globally.

Extreme heat which is projected to increase substantially will also have a direct impact on food security and malnutrition rates globally. In fact, the cumulative impacts of extreme heat and drought are potentially severe to the agricultural sector that there will be pronounced food insecurities globally. Thus, these extreme climate events through reduced and failed food production would contribute to an increase in diet related NCDs (Tapkigen et al., 2023; Popkin et al. 2012). Consequently, climate change could potentially amplify the underlying driver associated with Diet Related-NCDs (DR-NCDs). The DR-NCDs that climate change is likely to influence include cardiovascular diseases, liver cancer and diabetes (Tapkigen et al. 2023). Studies in Cameroon, Kenya and Malawi depicted a positive correlation between climate variables with diabetes, heart disease and obesity (Tapkegen et al. 2023).

Fanzo and Downs (2021) ascertain that "Low-income and middle-income countries in Africa and Southeast Asia will experience the largest reductions in food availability, leading to both decreased deaths attributed to overweight and obesity and increased deaths attributed to underweight. It is estimated that by 2019, every 1 °C temperature increase was associated with a 1.64% global increase in the probability of severe food insecurity (Fanzo and Downs, 2021).

Furthermore, extreme temperatures would adversely impact the functioning of the health infrastructure resulting in disruption from unavailability of the health workforce to work under extreme temperature, to lack of water supply. Effectively, this will compound to the impact of climate change to the health sector.

In a nutshell, climate change would have a significant impact on the NCDs directly through extreme temperature which could result in increase in heat-related deaths (heat strokes) and vascular diseases. Additionally, it will have a major influence on DR-NCDs related deaths through food insecurities.

Botswana is currently undergoing rapid epidemiological transition indicated by a decline in infectious diseases and an increase in NCDs and their associated risk factors (Keetile et al. 2020). In Botswana, NCDs are a major health concern, accounting for 46% of deaths in 2019 (WHO, 2023). STEPS survey conducted in 2014 revealed adult prevalence of 29% for hypertension, 5% for diabetes, 30% for obesity, 18% for tobacco use, and 95% for unhealthy diet (GoB, 2015). These worrisome figures, together with the recognition that the drivers of NCDs are broad, highlight the urgent need for a multi-sectoral and concerted national response.

5.1.2. Climate Change impacts on Communicable Diseases

Climate change is projected to have an influence on the emergence and re-emergence of climate-sensitive communicable diseases (Baharom et al. 2021). Among the communicable diseases, vector-borne and water-borne diseases are projected to be most affected by climate change (Kurane, 2010). Vector-borne diseases such as malaria, water-borne disease such as cholera and leptospirosis are highly correlated to climatic variables (Chadsuthi et al. 2012; Baharom et al. 2023). The risk of vector-borne diseases such as malaria increase if water remains stagnant for some time after flooding (Ascramet al. 2013). Increased risk of diarrheal disease happens during dry seasons or drought, and increased incidence is linked to rising temperatures and variable rainfall patterns (Challa et al. 2022).

Globally malaria-related deaths increased by 10% between the years 2019 and 2020 (WHO, 2022). About three quarters of malaria deaths occur in children aged <5 years, constituting 7.8% of childhood mortality, and over 90% of these malaria-related childhood deaths occur in sub-Saharan Africa (Perin et al. 2024). Baharom et al. (2021) notes that increases in temperature, humidity, and rainfall facilitate the proliferation of mosquito populations at high altitudes, expanding the geographical distribution of malaria to new areas where mosquito populations previously did not exist. Rotavirus is a substantial climate-sensitive disease burden in East Africa with mortality rates ranging from more than 100 per 100,000 children under five years old in Uganda and South Sudan, to 50–100 per 100,000 children under five years old in Djibouti and Somalia (IVAC, 2022). Tate et al. (2019) adds that about 40-45% of childhood deaths from diarrhea can be attributed to rotavirus infections.

According to CDC (2024), water temperatures and rising air and more severe extreme events are expected to increase exposure to waterborne and foodborne diseases, affecting food and water safety. As far as the future disease burden is concerned, it was reported that malaria projection saw a gradually increased trend in South Korea using the RCP4.5 climate change scenario and the CNCM3 climate model, with maximum occurrence shifting from August (during 2010-2011) to July (using simulation data of 2011-2100) (Kwak et al. 2014). The projected changes in transmission pathways for malaria as reported by Vogel et al. (2024), reveals that transmission areas and season are already increasing and shifting e.g., towards highlands, and an increase in suitable areas and transmission months are expected in almost the entire East African region under every emission scenario. In Botswana, the risk of malaria is projected to increase under a high emissions scenario, and this increase will be coupled with a projected rise of about 2 degrees Celsius on average from 1990 to 2100 (WHO, 2015).

In Botswana, the risk of malaria could increase by 2030 and 2050 due to extreme rainfall events and increase in temperature. This projection is consistent with WHO (2015).

5.1.3. Climate Change impacts on Nutrition

Climate change, through higher temperatures, erratic precipitation, and drought, is projected to negatively impact agricultural production resulting in food insecurity (WHO, 2015), which in turn leads to malnutrition (Helmy, 2023). Climate change affects all forms of malnutrition, linking directly or indirectly to all three underlying causes of malnutrition: insufficient household food security, inadequate maternal and childcare, and insufficient health services and an unhealthy environment (World Vision, 2022). Rural communities in Africa are highly dependent on the agriculture sector mainly crop production and livestock rearing. These sub-sectors could be adversely affected by climate change resulting in food insecurity and loss of income. Livestock is a major source of income for most households in rural areas in Africa which is used to procure stable food such as maize, sorghum and rice. Consequently, with the projected decreases in rainfall, heatwaves, increased frequency and intense drought, livestock productivity could be significantly affected and the loss of income to the household could be severe. It is also worth noting that the nutritional quality of crops is also affected by climate change due to increases in ambient carbon dioxide levels (World Vision, 2022).

Thus, the combined impacts of climate change on crop production and loss of income from livestock could worsen malnutrition in the developing countries. In Botswana, smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income and well- being (GoB, 2019). According to the 2023/24 Drought Assessment Report, the total estimated crop production for 2023/24 cropping season stands at 23,748 tons compared to 89,173 tons in 2022/2023 and 123,642 tons in 2021/2022 cropping seasons (GoB, 2024). The report also reveals that the estimated cereal production for 2023/2024 stands at 17,693.14 tons (14,316.32 tons sorghum, 2,938.73 tons maize, and 438.09 tons millet) which is lower than 57,103 tons for 2022/23 (GoB, 2024). The entire country experienced extended dry spell from January through March 2024 which resulted in crops reaching permanent wilting and ultimate crop failure. However, the productivity and quality of different fodder crops that have been produced in Botswana is promising. Fodder production provides an opportunity for reducing supplementation costs and improved soil fertility (legumes), food security and income (Franzel et al. 2014), and only a few farmers are involved in fodder production in Botswana.

5.1.4. Climate change and Zoonotic diseases

Zoonotic diseases are diseases and infections which are naturally transmitted between vertebrate animals and humans, as defined in 1951 by the World Health Organization (WHO) Expert Committee on Zoonoses (Chomel, 2014). For instance, the breakout of Covid-19 is an example of the emergency of zoonotic diseases. One of the mechanisms through which the zoonotic diseases are spread is through increasingly interactions and contact between the animal-human (Magouras et al. 2020). With increasing incidents of droughts, floods, the interaction between animals and human could increase as wildlife come into settlements searching for water. Additionally, species such as bats could increase their occupation of human dwelling places. Disease such as tick fevers and rabies could increase in the country as wildlife come into contact with livestock and with humans. In 2019 there were 26 rabies exposure cases and zero exposure death reported in Botswana, with Serowe recording the highest with 6 cases (GoB, 2019). Ngamiland district recorded 13 cases of rabies from nine stray dogs and four goats in 2020, and these cases were in Maun, Chanoga, Kareng, Tsau, Semboyo, and Gumare (GoB, 2020).

There is evidence to confirm the existence of a national plan on zoonotic disease in Botswana. According to Botswana's Joint External Evaluation (JEE), conducted in December 2017, the Department of Veterinary Services (DVS) has a national animal disease surveillance plan that includes seven zoonotic diseases (WHO, 2017). The seven zoonotic diseases of particular interest are avian influenza, rabies, brucellosis, bovine tuberculosis, cysticercosis, Rift Valley fever, and anthrax.

5.2. Current national impact of climatic variability on health

Current climate variability as evident from extreme events (floods, hailstorms, and heatwaves) have significant impact on the health sector in the country. The health impacts that are linked to climatic variability include:

- Malaria outbreak.
- Diarrhoea outbreak.
- Heat stroke and hypertension.
- Respiratory illness.
- Pneumonia.
- Skin diseases.
- Injuries and health.
- Staff mental wellbeing.
- Food security and malnutrition.
- Destruction and damage to health infrastructure.
- Operational efficiency of health facilities.
- Malnutrition and deficiency in diet.

5.2.1. Malaria outbreak

Malaria in the country is endemic in the North-west, North East, Central Districts (Boteti, Tutume, Bobirwa), Chobe and Okavango districts (Figure 10). Over the years, GoB has successfully reduced Malaria cases. According to the MoH, in 2023, there were 651 reported cases of Malaria, a decrease from 953 cases in 2020. However, noticeable increases in malaria related cases have been observed and are correlated with precipitation in the districts where malaria is endemic. The highest outbreaks were recorded in the years 2008, 2010, 2014 and 2021/22. The correlation coefficient for the malaria and precipitation is estimated at 0.60 based on the recorded malaria cases and precipitation. Figure 9 depicts the trends in precipitation and malaria cases. Thus, current climatic variabilities have a strong impact on malaria cases.

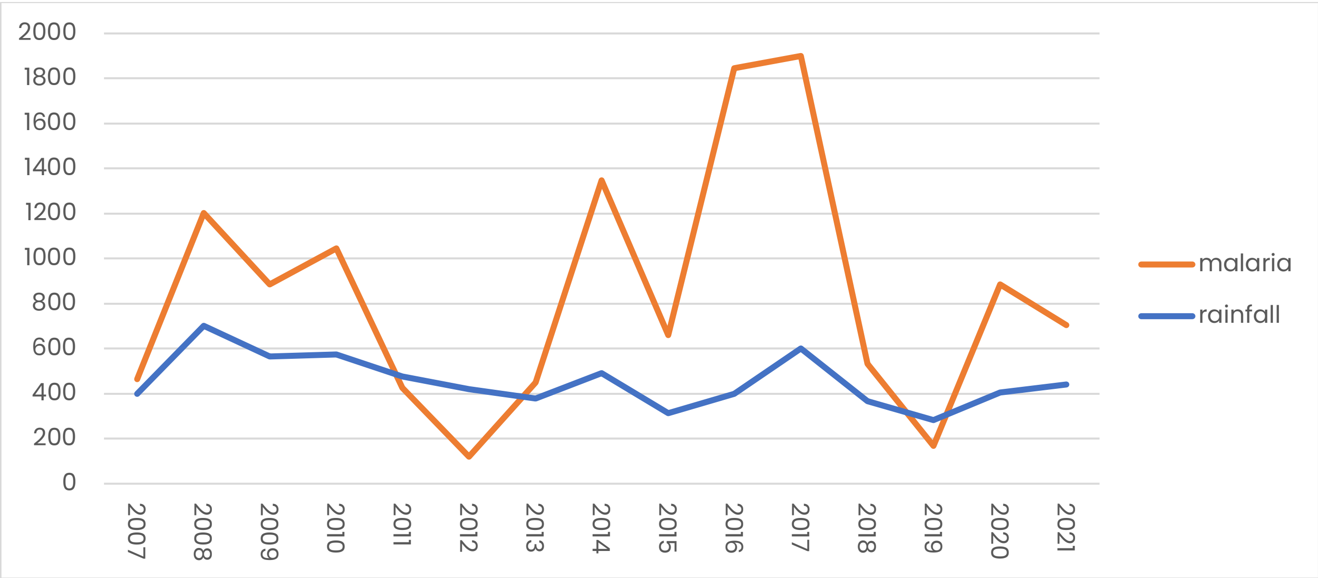

Figure 9: Recorded malaria outbreak and annual precipitation for the selected settlements

The data collected was collaborated with the consultation from the key experts. All the consulted experts noted that there is a strong positive relationship between precipitation and malaria outbreak in areas where malaria is endemic. It was noted that during the above-normal rainy years, hospital admission increases drastically mainly attributed to malaria outbreak.

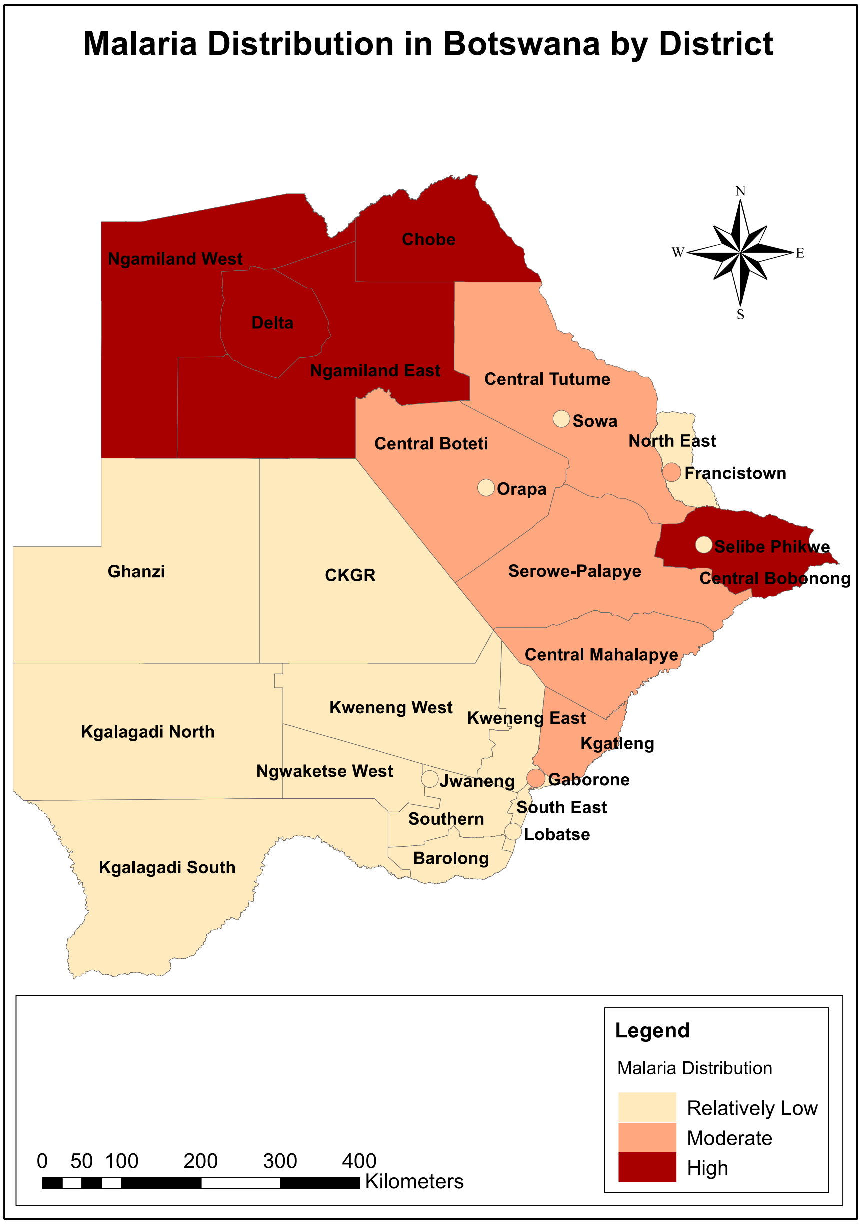

Figure 10: Map of Malaria distribution in Botswana

5.2.2. Diarrhoea outbreak

According to Levy et al (2017) there is a positive relationship between ambient temperature, heavy rainfall and flooding events and diarrheal diseases. All the experts interviewed noted that during rainy months and summer months (high temperatures) they experience high admissions and treatment of diarrheal cases mainly attributed to drinking of untreated pond water. Other stakeholders noted that diarrheal cases are high in summer due to consumption of spoilt food which easily rot in high temperature. The vulnerable age group is children under the age of 5.

An assessment of the recorded diarrheal cases in 28 major settlements in the country from 2017 to 2022 was undertaken. The results were consistent with the health experts that there is a strong positive relationship between temperature and rainfall. Summer and rainy months recorded the highest diarrheal cases compared to dry and cold months as depicted in Figure 11 while Figure 12 shows the average cases over a 5-year period.

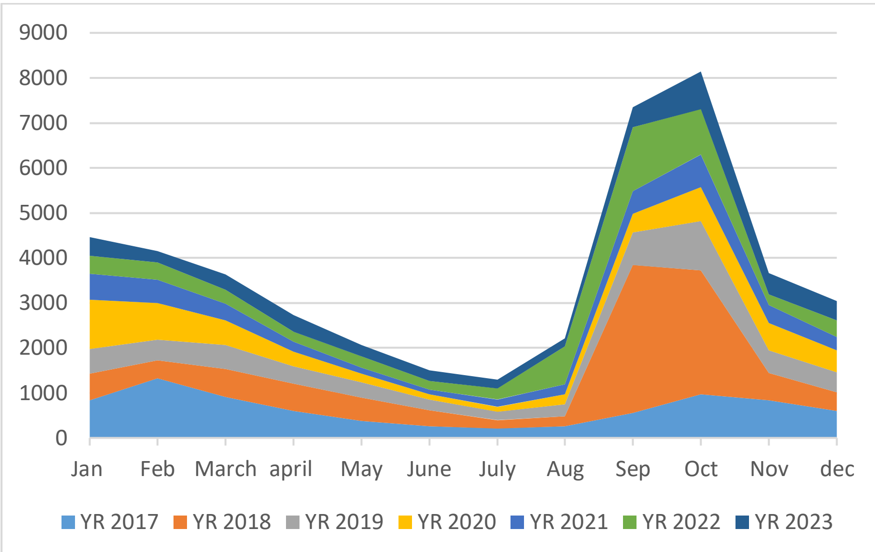

Figure 11: Recorded Diarrheal cases in major settlements

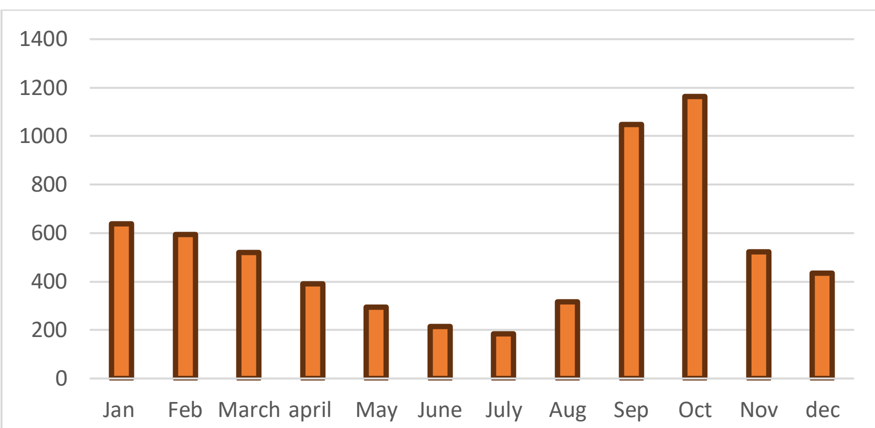

Figure 12: Average monthly diarrheal cases at National level

The diarrheal cases follow monthly changes in temperature and precipitation. However, the months for September and October experience abnormal diarrheal cases outbreak. For the year 2018, the outbreak was due to the rotavirus (WHO, 2018).

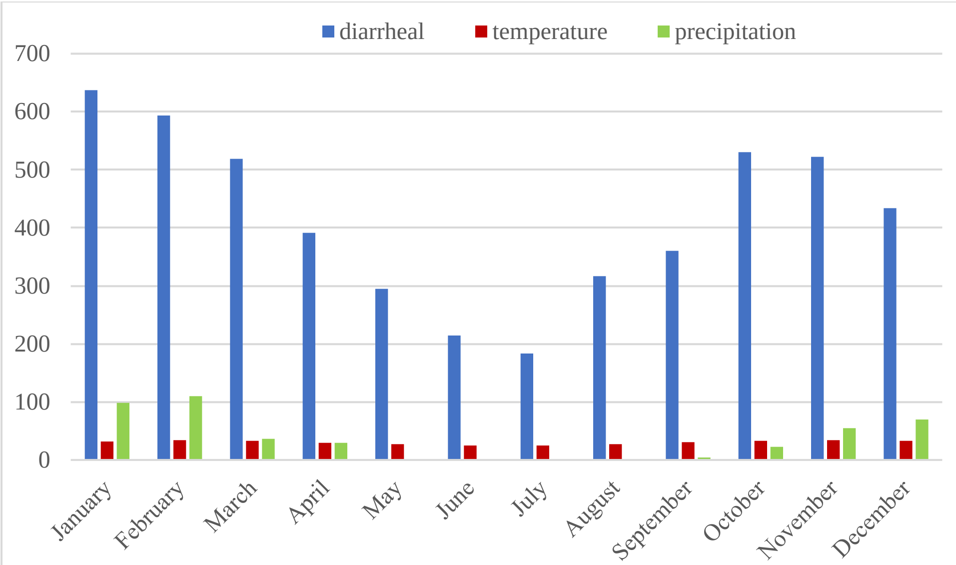

Figure 13: Relationship between diarrheal cases, temperature, and rainfall

A correlation analysis revealed that seasonal changes account for 64% of the diarrheal cases in the country which is logical given that diarrheal outbreak is also caused by viral outbreaks as was the case in 2018.

5.2.3. Current Climate Extremes

One of the current climate extremes in the country that is having an impact on health sector is hailstorms and flooding. These extreme events have impacts on human mortality and injury through drowning, hit by hailstorms and flying objects. The death toll attributed to floods was 1 in 2017 and 4 in 2019 (Statistics Botswana, 2020). There were no records of deaths and injuries from hailstorms and strong winds over the years. These impacts were identified during the stakeholder's consultation. Consulted members highlighted that drowning after heavy rainfall is common amongst the youth and teenagers.

Botswana is currently experiencing increased number of heatwaves annually. Figure 14 depicts recorded heatwaves days since 2015 to date. Heatwaves are defined as excessive temperature above 37 ^{o}C. Heatwaves have significant health impacts on Batswana. Since 2017 the country has experienced significant increase in number of days with extremely high temperatures of over 38 ^{o}C. Consultation with the experts revealed that heatwaves have various health impacts mainly heat exhaustion, heat stroke, cardiovascular and hypertension complications amongst others. It was noted that the most vulnerable members of the community are the infants and elderly (>65). Furthermore, it was highlighted that between 1979 and 2022, the death rate from heatwave/heat stroke was 2 per million. Other studies indicated that prior to 1990, the country recorded about 3 heat death per year (African press, 2024). Currently, there are no records on the impact of heatwaves on people with cardiovascular conditions and hypertension in the country.

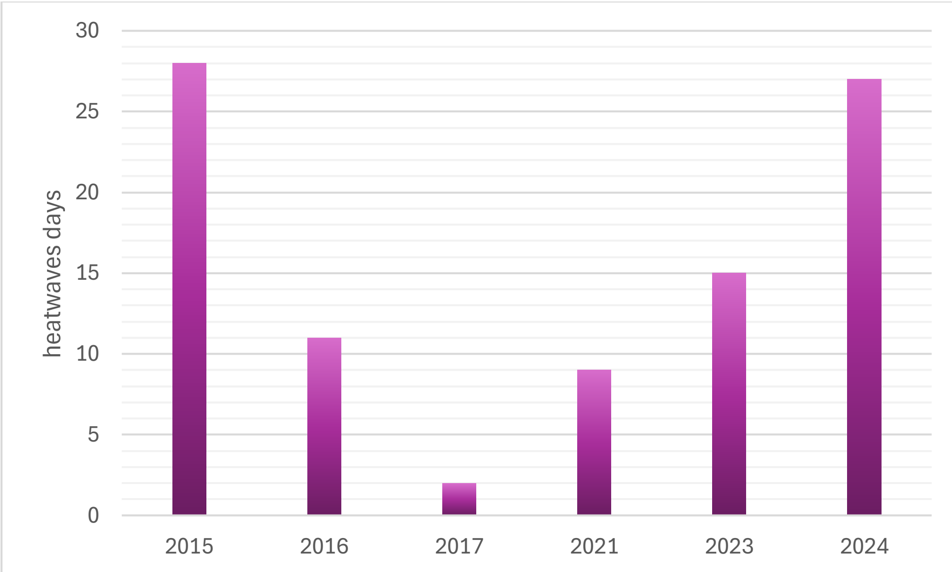

Figure 14: Recorded heatwaves in the country

Other impacts of extreme temperature on health include persistent headaches and nose bleeding. However, there are no hospital records to undertake a dose response to ascertain the impacts of current climate variability on the headaches and nose bleeding.

Similarly, extreme cold temperatures were highlighted to contribute to various diseases. Consulted experts noted that cold temperatures are associated with influenza, common colds and outbreak of rotavirus which causes diarrheal outbreak. Similarly, the cold months results in outbreak of respiratory diseases and pneumonia affecting the infants and children under 5 years.

5.2.4. Incidences of Malnutrition

The combined effects of heatwaves and droughts will be devastating on crop yields and correspondingly food security. According to the survey by Statistics Botswana, food insecurity in the country is high (Figure 15).

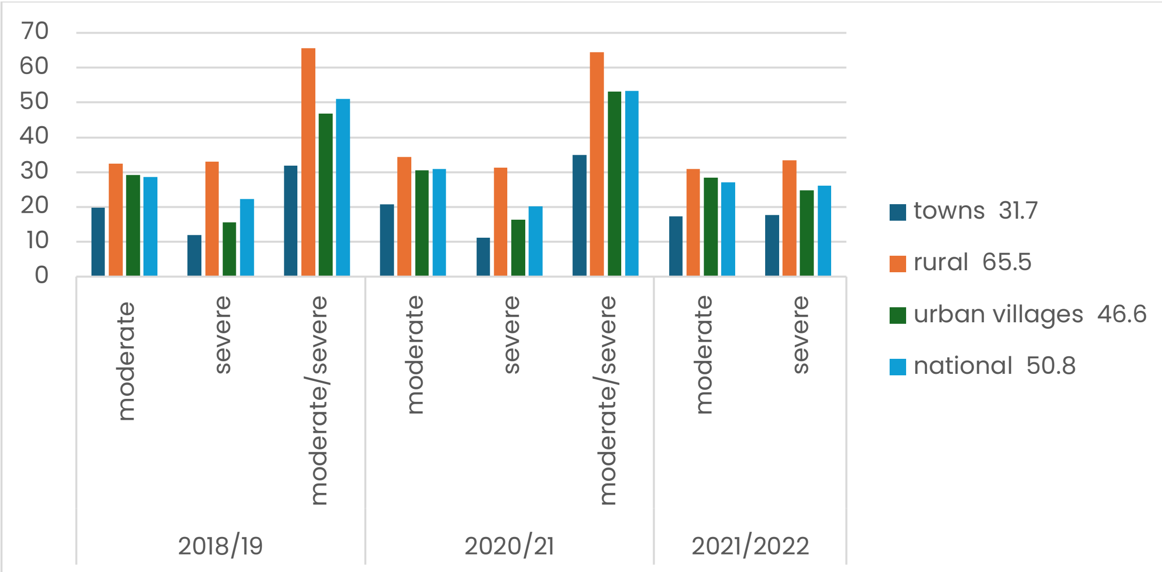

Figure 15: Food insecurity in the country

Through reduced yield and crops failure, current climate variabilities could be contributing to incidences of malnutrition in the country. According to UNICEF (2017) Botswana has high malnutrition rates, despite being an Upper Middle- Income country. In 2008, it was estimated that stunting in children under age 5 was 31.4%, the prevalence of underweight children and wasting in children under 5 was 11.2% and 7.2%, respectively, indicating high degrees of vulnerability for the country and specifically its poor and rural populations (WHO, 2015).

There is an obvious link between food insecurity, hunger, and malnutrition. An assessment was made to determine the current linkages between malnutrition measured by stunting, underweight, waste, and overweight at the national level, food production and precipitation. Figure 16 depicts malnutrition records in the country as measured by stunting, underweight, wasting, and overweight in children. The results indicate that even though droughts and heatwaves have been observed to intensify and to be frequent, malnutrition is on the decline. This is primarily due to the comprehensive social protection programs in the country. The country has established and operationalised a social assistance program which is designed to assist households and individuals cope with chronic poverty and food insecurities. The assistance programs include destitute persons (food basket), orphans care, community home based care, vulnerable group feeding program, disability allowance, Ipelegeng, old-age pension and school feeding program (The World Bank, 2022). Therefore, these social protection programs buffer the current impacts of drought and heatwaves on food security and malnutrition in the country hence a decline in malnutrition rates. Figure 16 shows a declining trend in malnutrition in Botswana. Statistics Botswana (2023), reports that 21.3 percent of children in 2017 were too short for their age (stunted), a decrease from 28.0 percent in 2009/10; prevalence of underweight decreased from 13.7 percent in 2009/10 to 7.5 percent in 2017; wasting decreased from 11.6 percent in 2009 to 4.0 percent in 2017; overweight prevalence of children under five years showed a decrease from 6.9 percent in 2009 to 3.5 percent in 2017.

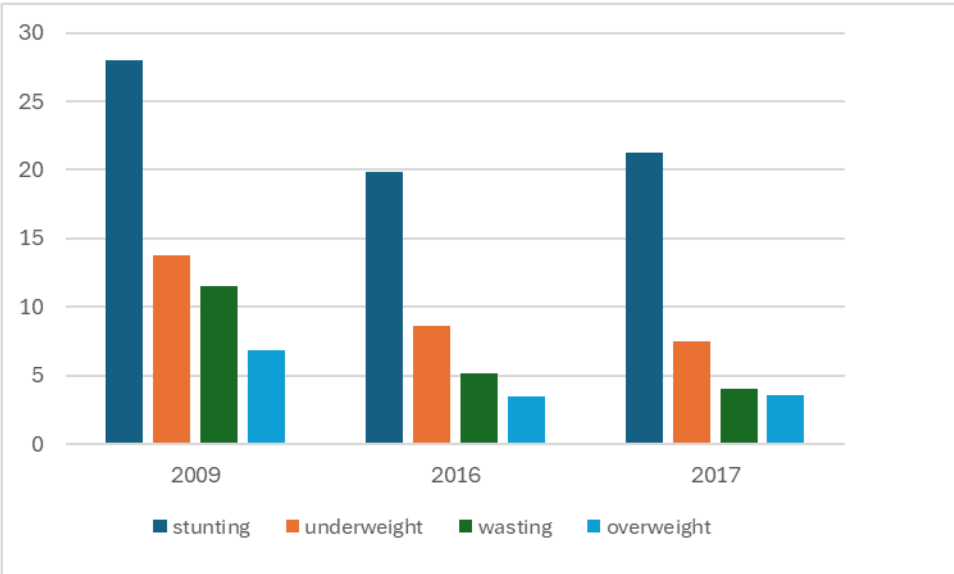

Figure 16: Malnutrition status for children under 5

Source: BCWIS 2009; BMTHS 2016; BDS 2017

However, drought and heatwaves are having an influence on malnutrition in the country. This was also verified by the experts during the consultation meetings.

5.2.5. Impact on the Operations of the Health Facilities

In addition to the impacts on the general population, current climate related events such as heatwaves, storms, hailstorms, strong winds and floods have a direct impact on the operations of the health facilities. Three impacts have been identified in consultation with the experts in various health facilities. Firstly, the current extremes result in physical damage to the health assets. These include buildings and vehicles mainly ambulances. Consultation revealed that health facility roofs, windows and ceiling have over the year been destroyed by storms, hailstorms, and strong winds. The recent case was Thamaga hospital which was destroyed by hailstorms in 2020. Approximately 13 health vehicles including an ambulance were destroyed by the hailstorm. Similarly, other health facilities throughout the country have been destroyed by the extreme climate events.

The second impacts of climate extreme is impairing the operational efficiency of the health facilities. Destroyed health facilities operate at a minimum rate sometimes they are closed for a long period for repairs. These affect the service delivery resulting in increased mortality and morbidity of the patients. Furthermore, the events cause injury and in some instance death to the patients admitted in the affected hospitals (Bergmüller et al. 2018). Another impact of heatwave is on the potency of the medicine. Medicines that are exposed to extreme temperature loss their potency and this is common where the health facilities loss power from malfunction of the equipment due to overheating.

Another impact is on the operational efficiency through the health workers. Consultation revealed that the health workers in many health facilities are working in poor environment with no working air conditioning systems. During the hot months they work in unbearably hot environments. The health workforce is thus frequently heat exhausted, and experience physical and mental stress during extreme heat waves. It was also noted that when there is a climatic extreme event resulting in high admissions (malaria, diarrheal outbreak), health workers also experience physical and mental stress from work overload. These results in high incidents of health staff morbidity and shortage of staff. Consequently, this affects operational efficiency of the health facilities in the country.

Currently, there is no database on the impact of climate extreme on physical asserts to undertake a comprehensive analysis of the current impacts. However, there are sparsely recorded cases of the impacts of climate events on health infrastructure.

6.0. Climate outlook for Botswana for 2030 and 2050

To undertake a comprehensive V&A assessment of the impacts of climate change on the health sector, it is necessary to construct climate scenarios for climate variables that have a direct and indirect impact on the health sector. Climate scenarios define the future climate outlook of a region (from few km^2 to regional level). Consequently, climate scenarios for the selected 9 settlements in the country were constructed which were used to model the impacts of climate change on health. Climate scenarios were constructed for the years 2030 and 2050 using the Shared Socio-economic Pathways (SSPs) 4-4.5 and SSP 5-8.5. Figure 15 below depicts the SSPs population growths that were used to project the Greenhouse gases (GHGs). On the other hand, the 4.5 and the 8.5 are the Representative Concentration Pathways (RCPs) which define the GHG concentration in CO_2 equivalency ppm (Figure 18).

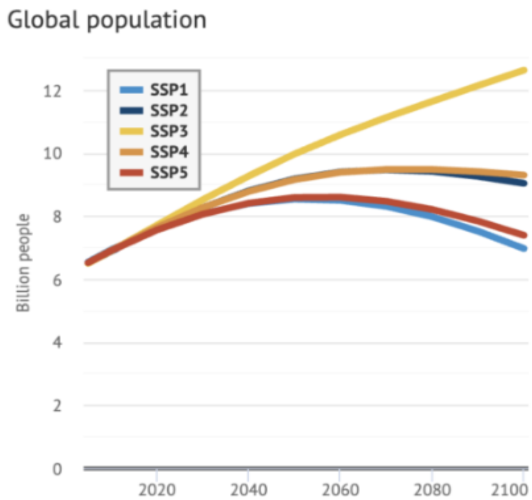

Figure 17: Global population projects based on different SSP scenario

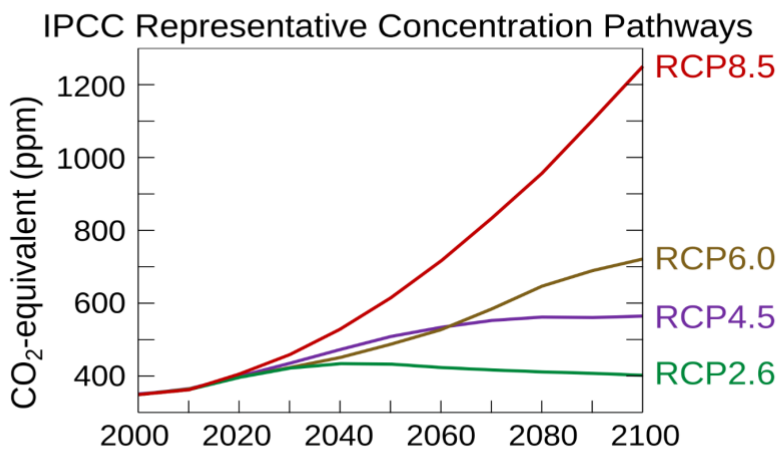

Figure 18: IPPC Concentration pathways

Based on the SSP 2-4.5 and SSP 5-8.5, the climate scenarios for temperature and precipitation were generated. The scenarios were constructed for the following variables:

1. Monthly and annual precipitation
2. Monthly and annual mean temperature
3. Monthly and annual maximum temperature
4. Monthly and annual minimum temperature
5. Heatwaves days
6. Maximum temperature over 35 degrees
7. Cooling degree days
8. Standardized precipitation evapotranspiration index (SPEI) drought probabilities
9. Average recurrence interval (ARI) 100 daily extreme precipitation

Scenarios were constructed for a total of 9 parameters for 9 settlements. Consequently, this resulted in over 81 figures and tables generated from the analysis. The data was used to model/simulate the impact of climate change at settlements levels. Due to the amount of data and figures generated, this section provides an overview of the climate outlook at the national level and summary in tabular format for the settlements. However, it must be emphasized that for each settlement, the downscaled climate scenarios were used to model/simulate the impacts of climate change at the settlement level.

6.1. Annual maximum temperature

Annual maximum temperature for the country is expected to increase for the years 2030 and 2050 relative to the baseline based on SSP -8.5. by 2030 the central district around the Bobirwa will significantly warmer while by 2050 most of the country will experience a significantly high temperature in the 36 ºC region. However, there will be pockets areas in the country that will warm slightly relative to baseline years.

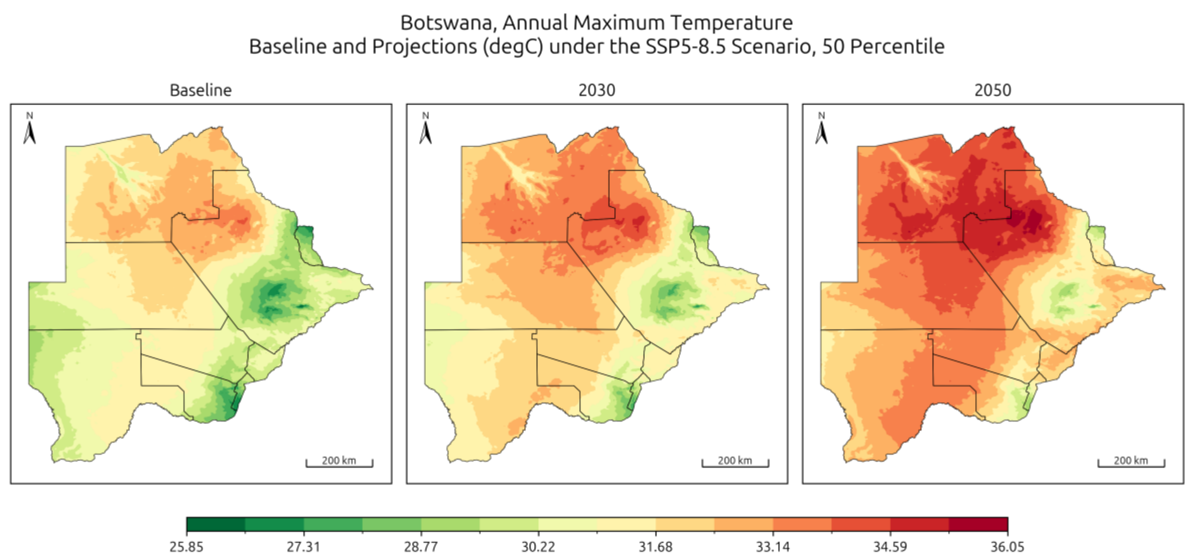

Figure 19: Annual maximum temperature under SSP5-8.5 scenarios

Under the SSP2-4.5, by 2030, the country will experience moderate increase in annual maximum temperatures relative to SSP 5-8.5 whilst for the year 2050, Central, North West, Ghanzi and Kgalagadi district will warm significantly as per Figure 20.

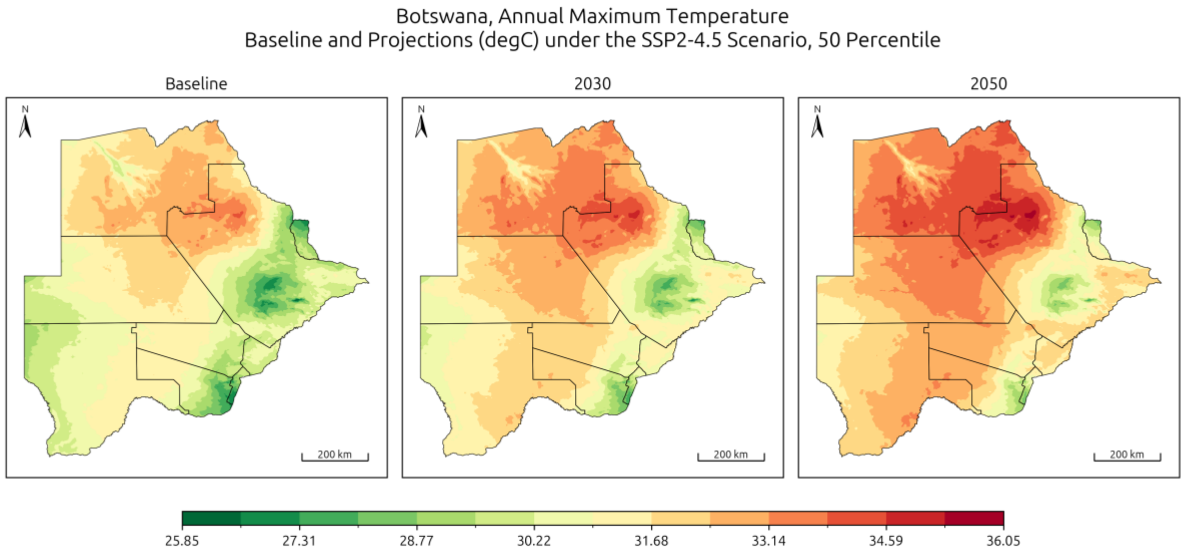

Figure 20: Annual Maximum temperature under SSP2-4.5

6.2. Heatwaves days

Heatwaves is another climatic induced phenomenon that will have a significant impact on the public health mainly the vulnerable population such infants, people with compromised health status and the elderly. It is measured by the number of days when temperatures are abnormally high, specifically where the daily maximum temperature is at least 5 ^{o}C higher than the average maximum temperature (IPCC, 2022). For this study the relative temperature threshold of above 35 ^{o}C, lasting for two days or more are regarded as heat wave days. Similarly, the heatwaves days were projected for 2030 and 2050 using the SSP5-8.5 and SSP2-4.5 respectively. As depicted in Figure 21, by 2030, the number of days in a year will increase to an average of 10 and by 2050 to an average of 17.5 and 30 some regions in the country. Consequently, some districts will have a whole month of heatwaves in a year.

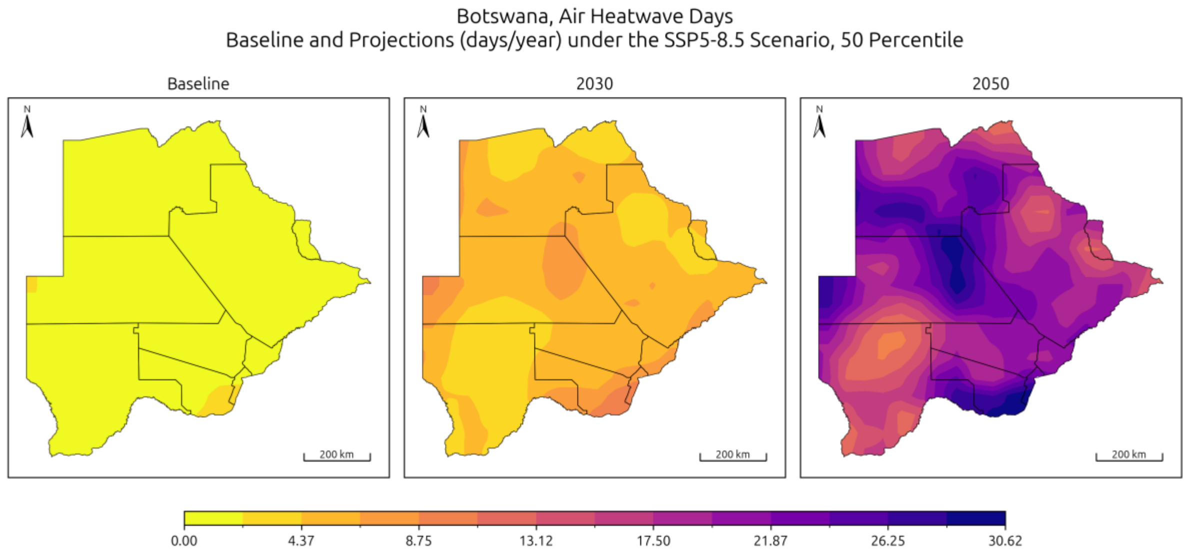

Figure 21: Number of heatwaves days based on SSP5-8.5 scenario

The SSP 2-4.5 scenario on the other hand project a slightly optimistic picture by 2030 and 2050 respectively. The baseline number of heatwaves is similar for both SSP2 and SSP5. By 2030, the number of days would increase to between 6 and 8 for the different districts in the country. However, by 2050, it is projected that some districts will have a substantial increase in the number of heatwaves days up to 20 days. This will have significant implications for the heat stroke incidences and the associated mortality for the vulnerable populations.

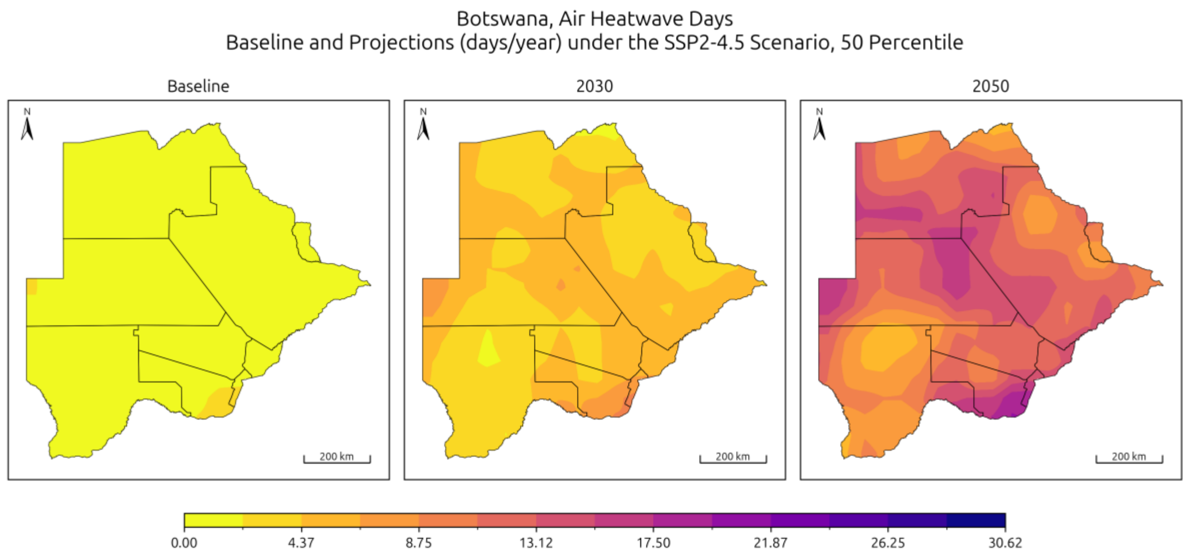

Figure 221: Number of heatwaves days based on SSP2-4.5 scenario

Table 3 below provides baseline and the projected number of days for 2030 and 2050 under different GHG concentration scenarios.

Table 3: Heatwaves days per year

Settlement	Baseline	Year 2030 SSP2-4.5	Year 2030 SSP-5-8.5	Year 2050 SSP2-4.5	Year 2050 SSP5-8.5
Gaborone	1.5	5.5	6.73	13.47	22.73
Gweta	0.8	2.73	3.57	9.97	16.07
Maun	0.97	2.93	3.80	11.17	20.53
Kasane	0.27	1.7	1.9	5.13	10.80
Francistown	0.43	2.57	3.10	6.87	12.70
Tsabong	0.57	1.57	2.03	7.07	12
Ghanzi	0.97	3.4	4.4	9.83	15.07
Mopipi	0.6	4.13	4.7	12.17	21.83
Molepolole	1.03	3.67	4.8	11.30	20.10

6.3. Number of days above 35 °C

The number of days above 35 °C are also projected to increase markedly by 2030 and 2050 respectively due to the radiative forcing of GHGs. Under the baseline, the number of days which have temperature above 35 °C are ranges between 7.5 and 88. Based on SSP5-8.5, by 2030, it projected that the days above 35 °C will be between 20 and 128 days whilst by 2050, the days with temperature above 35 °C will be around 148 per year (Figure 23).

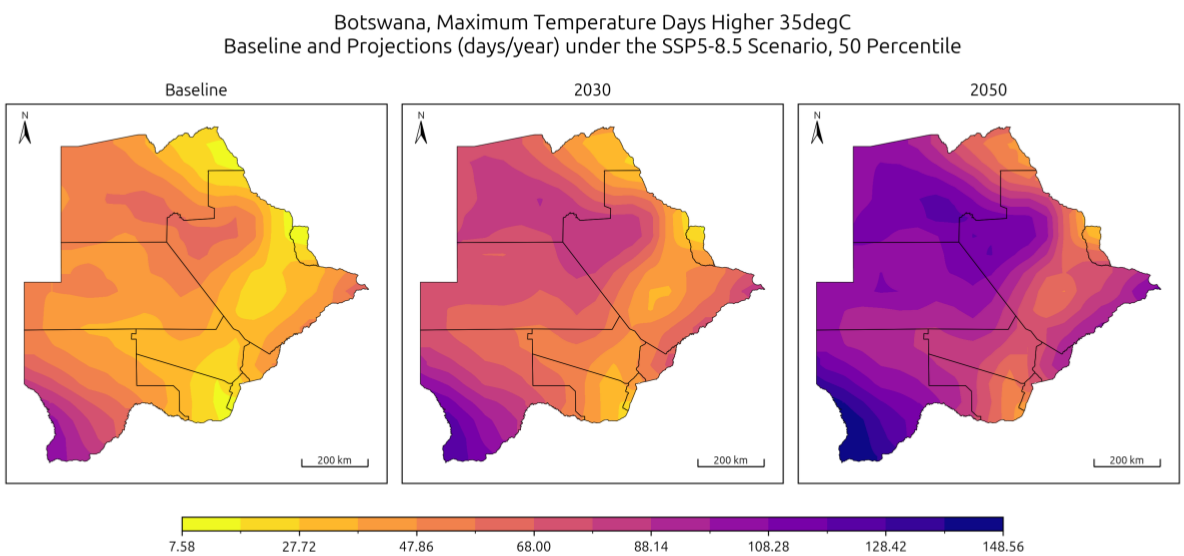

Figure 23: Number of days above 35 °C under SSP5-8.5

The situation is slightly optimistic under SSP2-4.5 scenario as depicted in Figure 24. Whilst the number of days with temperature above 35 °C are the same for 2030 and 2050, it is limited to certain districts and not covering the entire country.

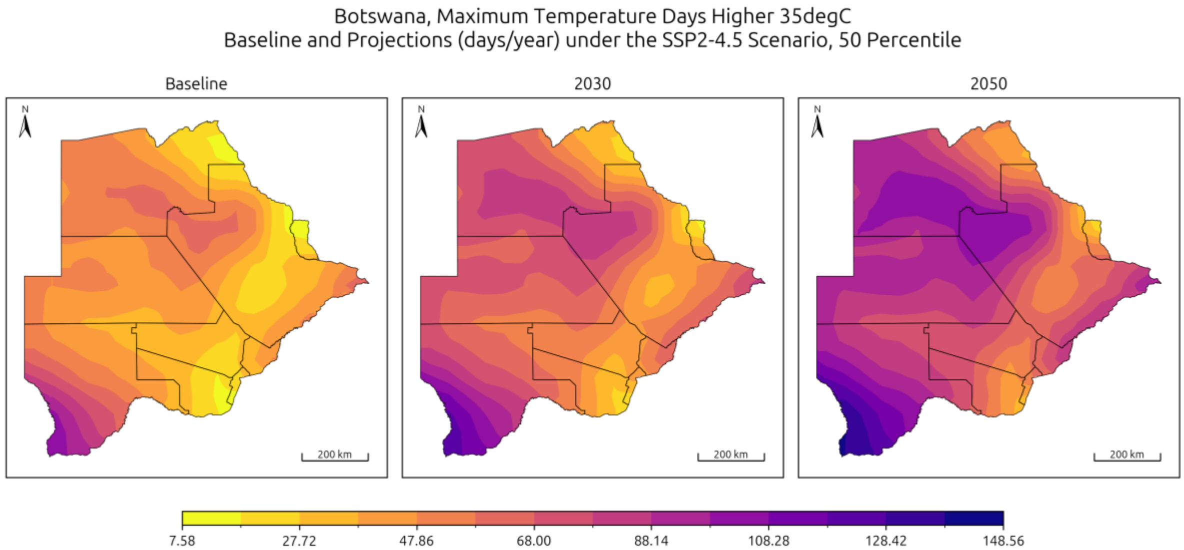

Figure 24: Number of days above 35 ^{o}C under SSP2-4.5

6.4. SPEI Drought Probability

According to WHO, drought will have impacts on the health sector through food insecurity and malnutrition. Therefore, drought scenarios were constructed and will be used to model food insecurity and malnutrition. Drought affects water availability resulting in lack of water and sanitation, and disruption of local health services due to lack of water supplies. The drought probability was modelled/projected for the years 2030 and 2050 using the SPP2-4.5 and SPP5-8.5 scenarios. Under the baseline period, probability of drought is estimated at 18%. Based on SSP5-8.5, some districts will have a drought probability of 37% and other 78% by 2030. By 2050, it is projected that the probability will increase to 96% (Figure 25). The same scenario is projected under SSP2-4.5 with the different degree of spatial coverage (Figure 26). Consequently, climate change will drastically alter the drought episodes frequency in the country, and this will have major impacts on food security, country's GDP particularly the manufacturing, livestock, and water sector GDP. These impacts will have an effect on sanitation resulting in increased incidences of water-borne diseases, food security and the ability of the government to provide social safety needs such as distribution of food to those living under poverty.

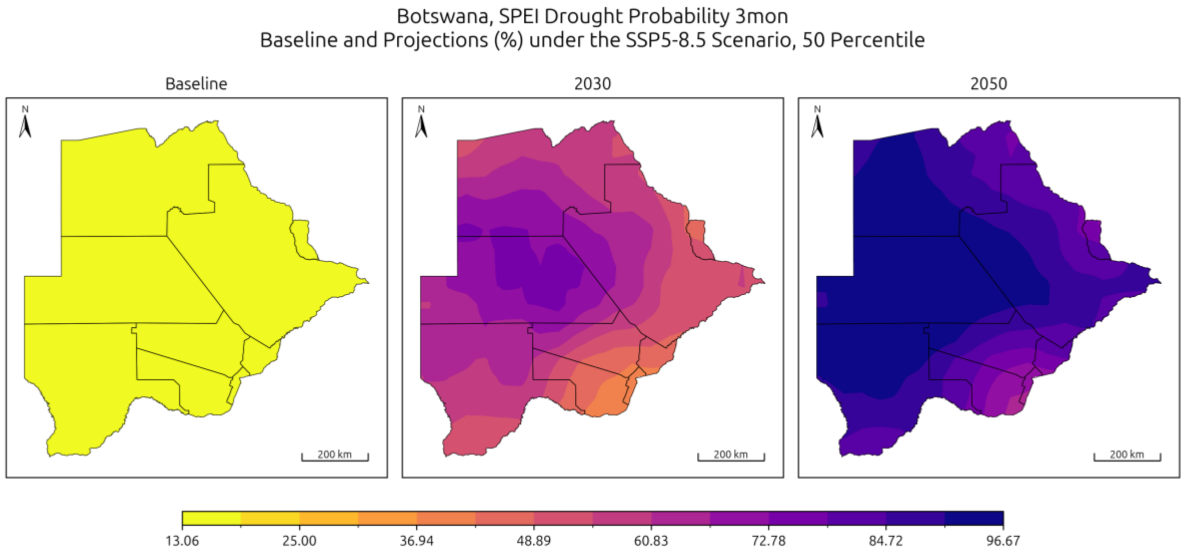

Figure 25: SPEI drought probability under the SSP5-8.5

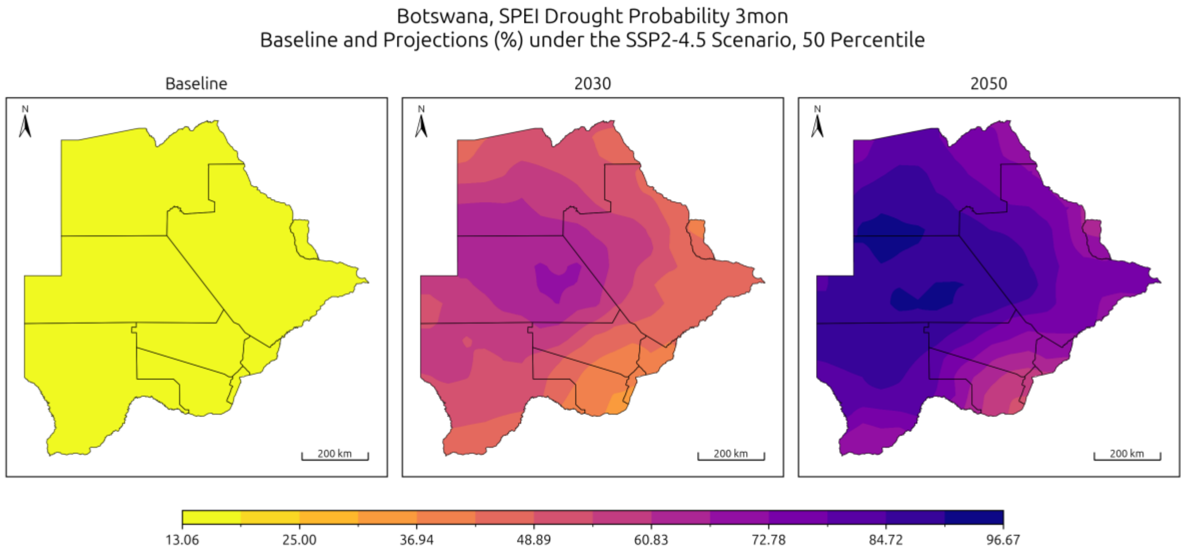

Figure 26: SPEI drought probability under the SSP2-4.5

Table 4 below provides a summary of the weighted mean probability of drought for the selected settlements. Areas such as Maun, Ghanzi, and Mopipi are projected to have frequent drought episodes. In general, all the settlements will experience more frequent drought events from an average of 15% to 30%.

Table 4: Drought probability for the selected settlements

Settlement	Baseline	Year 2030 SSP2-4.5	Year 2030 SSP-5-8.5	Year 2050 SSP2-4.5	Year 2050 SSP5-8.5
Gaborone	14.45	23.05	25.83	42.77	53.33
Gweta	16.11	38.05	44.72	63.61	70.28
Maun	13.33	44.7	54.17	70.83	79.45
Kasane	16.39	33.62	39.99	56.39	63.61
Francistown	16.11	28.89	34.72	54.45	63.33
Tsabong	15	31.11	36.11	55.55	68.90
Ghanzi	15.84	48.06	52.80	70.27	73.61
Mopipi	15.84	48.33	52.22	73.33	78.05
Molepolole	13.05	28.05	33.33	51.95	59.72

6.5. Extreme rainfall events

Extreme rainfall events result in flooding which affect public health in various ways. Extreme rainfall events were modelled based on a 24-hour rainfall ARI. Figures 27 and 28 depict the extreme precipitation based on ARI 100 years under the SSP5-8.5 scenario and SSP2-4.5 scenarios respectively. Under the two scenarios, extreme rainfall events are projected to rise marginally as evident from Table 6.3. Currently, the highest extreme precipitation recorded in 24 hours for the country is 81.99 mm in Ghanzi and the lowest recorded extreme precipitation is 39.99 in Mopipi. The constructed extreme precipitation scenario project that by 2030, extreme 24-hour precipitation will increase by minimum of 4% and maximum of 6.93% (Table 5) and by 2050 it could increase by a range of between 9.5% and 16.9%.

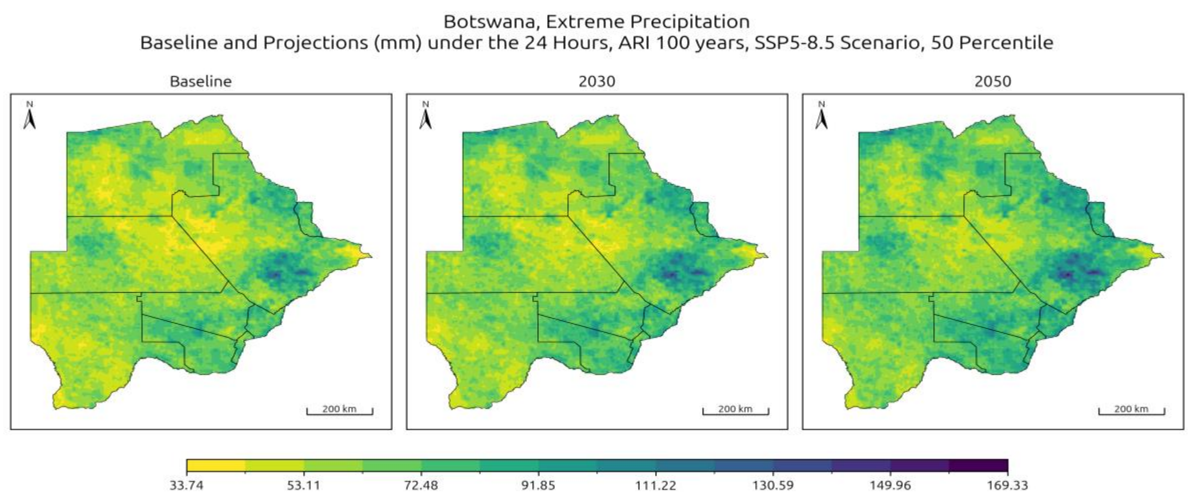

Figure 27: Extreme precipitation under 24 hrs. ARI 100 years SSP5-8.5 scenario

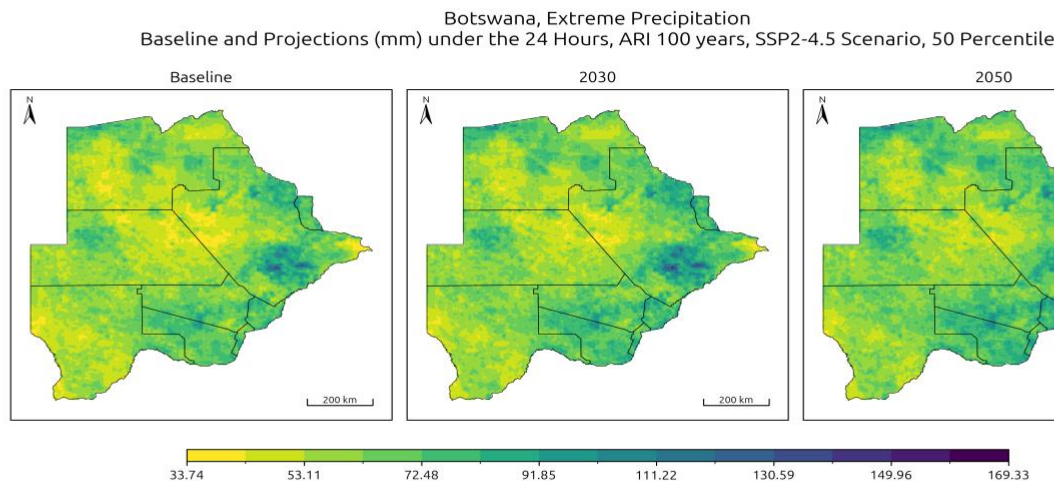

Figure 28: Extreme precipitation under 24 hrs. ARI 100 years SSP5-8.5 scenario

Table 5: Extreme precipitation based on ARI 100 Drought probability for the selected settlements

Settlement	Baseline mm	Year 2030 SSP2-4.5 (%)	Year 2030 SSP-5-8.5 (%)	Year 2050 SSP2-4.5 (%)	Year 2050 SSP5-8.5 (%)
Gaborone	66.29	6.93	6.77	11.00	14.39
Gweta	56.22	6.18	7.06	11.46	15.00
Maun	57.69	5.37	6.13	9.97	13.03
Kasane	61.34	6.71	7.67	12.46	16.30
Francistown	80.27	6.83	7.81	12.68	16.59
Tsabong	51.04	4.09	4.67	7.59	9.93
Ghanzi	81.99	5.11	5.89	9.50	12.42
Mopipi	39.29	6.51	7.44	12.10	15.82
Molepolole	47.75	5.79	6.69	10.75	14.06

Botswana is at an advanced stage of climate change as evident from frequent occurrence of heatwaves, droughts, floods, hailstorm, amongst others. Climate scenarios were generated using SPPs2-4.5 and SPPs5-8.5 for the years 2030 and 2050. The projected scenario reveals that the country will warm up rapidly relative to the global average temperatures. The constructed scenario further reveals that the country could experience high frequency and intensity of drought, heatwaves, and number of days above 35 ^{o}C. The increase and decrease in rainfall could have a significant impact on the health sector. Consequently, the constructed climate scenarios will be used to perturb the health sector and assess the impacts on various public health variables such as incidents of climate-related diseases, mortality, admissions at the health care centers and functionality of the health care facilities.

7.0. Projected impacts of Climate Change on Health

Assessing the impacts of climate change on various health parameters (disease outbreak, mortality, injury, and the operational efficiency of the health systems) is crucial as it generally informs the sector's vulnerability. It is on the basis of the V&A assessment that the health sector adaptation plan is developed. Projecting climate change's impacts on health require baseline data to establish mathematical functional relationship between climate variable and health parameters. Based on the baseline mathematical/statistical functional relationship a dose response model is developed and used to project the impacts of climate change on health. However, the country has limited data conduct such analysis. Nevertheless, an attempt is made to project the impacts of climate change based on constructed climate scenarios. The results are discussed under each section.

Assessing the health impacts of climate change is essential to identify vulnerabilities and inform adaptation strategies. Key areas include disease outbreaks, mortality, injuries, and the operational efficiency of health systems. This section highlights projected impacts based on climate scenarios (SSP2-4.5 and SSP5-8.5), focusing on non-communicable diseases, waterborne diseases, malnutrition, and health infrastructure.

7.1. Impacts on non-communicable diseases

By 2030, the country will experience an increase in temperature of approximately 1.5 and 2.0 ^{o}C based on the SSP 2-4.5 and SSP 5-8.5 and by 2030, it is projected that average maximum average temperature will increase by 2 ^{o}C and 3 ^{o}C based on the SSP 2 4.5 and SSP 5-8.5. Similarly, heat waves are projected to increase significantly from a baseline (1960-1990) of 0.78 days per year to an average of 10 to 16 days by 2050 based on the SSP2-45 and SSP5-8.5. These heatwaves could ultimately increase mortality rates. Under the baseline climatic conditions, it was estimated that mortality rate is 3 per million. Using the dose responsible based on probabilistic model, it is projected that by 2030 and 2050 the country could experience mortality of approximately 90 persons and 240 persons per year respectively. As per the baseline studies, the most vulnerable age groups will be infants (less than <5 years) and elderly (>65 years). In addition, people who have already compromised conditions are highly vulnerable to heatwaves events. Therefore, infants, elderly and people with compromised conditions will be affected by heatwaves.

Similarly, it is projected that increase in heatwaves could result in an increase in cardiovascular (e.g., heart attacks and stroke) and exacerbate chronic respiratory diseases, such as chronic obstructive pulmonary diseases (COPD) and asthma, particularly among vulnerable populations. Unfortunately, there is no baseline data to model the current and future impacts of climate change on these ailments.

7.2. Impacts on Climate-sensitive diseases

Malaria is directly influenced by rainfall as evident from this analysis that the correlation coefficient between Malaria and Climate is 0.60. According to the climate scenario generated, it is projected that annually precipitation by 2030 and 2050 will decline by a range of 1% to 3%. Given the projected changes in rainfall and assuming a normal rainfall year, Table 6 depicts the projected malaria cases for 2030 and 2050 respectively. This projection does not take into account the impact of climate change in influencing malaria to new areas as insinuated by some studies. Thus, malaria cases are projected could stabilise due to the decline in rainfall. However, it is important to note that the malaria cases could be higher than the projected because of heatwaves. According to the consultation with health workers, during heatwaves people sleep outside the houses and huts as one of the adaptation measures against heat and exposing themselves to Malaria. Obviously, this could negate the government efforts of malaria elimination of spraying and distribution of treated nets.

Table 6: Projected Malaria cases for 2030 and 2050

Baseline	**Scenarios**	**2030**	**2050**
651	SSP 2-4.5	640	638
	SSP 5-8.5	625	621

From the data collected on Diarrhoea and correlated with temperature and rainfall, it was found that there is a strong a correlation coefficient of 0.87 when the viral diarrhea cases are excluded. SPP2-4.5 and SSP5-8.5 project an increase in temperature by between 0.8 ºC and 2 ºC for the years 2030 and 2050. These changes will drive diarrhea cases from an average of recorded cases of 3,000 to approximately 6, 000 per annum taking into account population. Therefore, it is projected that diarrhea cases could increase by 2.0 times based on the baseline cases. These increases are primarily attributed to rising temperatures and their potential impact on food quality, which may lead to an increase in diarrhea cases.

Table 7: Projected Diarrhoea cases for 2030 and 2050

Scenarios		**SSP2-4.5**		**SSP5-8.5**	
Year	**Baseline**	**2030**	**2050**	**2030**	**2050**
Diarrhea	3,102	6,116	6,118	6,113	6,106

7.3. Impacts on malnutrition

Climate change is projected to result in a decline in malnutrition, accompanied by minimal reductions in annual precipitation by 2030 and 2050, as shown in Table 8 below.

Table 8: Projected Malnutrition for 2030 and 2050

Scenarios	**SSP2-4.5**		**SSP5-8.5**	
Baseline	2030	2050	2030	250
406	400	394	399	391

The projected precipitation declines are not likely going to have an impact on crop yield as they are marginal. However, it will be through the impacts of climate change on rainfall variability in terms of rainfall spacing that will have major impact on crop yield. According to the GoB (2019), climate change could result in an increase in some crops such as cowpea yield of approximately 55% for Maun while Maize around Gaborone is projected to increase by a range of between 8% and 21%. Other regions such as Francistown are expected to have a decline of 15 and 37% for maize. These projections are not in line with the projected insignificant declines in precipitation and no explanation is given on the increase.

Climate change will influence crop production through drought, and it is projected that the probability of drought will increase. The probability of a Drought year is projected to increase from 20% to 35% and 67% by 2030 and 2050. However, given the current social safety programme, it is projected that climate change will not have a significant impact on malnutrition rates as household will be supported. Unless the government programmes are stopped, then climate change through drought episodes will have a significant impact on malnutrition.

7.4. Impacts on Health Infrastructure

Climate change could impact the health infrastructure (hospitals, clinics, mobile clinics) through extreme events mainly floods, storms, strong winds and hailstorms. The impact could be through be through blown-up roofs and wall collapse, resulting in unbearable working conditions for the workforce. Similarly, hailstorms can damage and destroy rooftops, windows, and doors. Furthermore, extreme temperatures could affect the potency of medicine particularly when they coincide with electricity outrage.

Ultimately, the combined impacts of climate change on the health workforce, destruction on infrastructure and reduced potency of medicine could result in poor operation efficiency of the health sector. The operational efficiency is measured by the number of days when the health infrastructure is closed for repairs, or lack of health workforce amongst others. Estimating the operational efficiency was based on the probability of extreme event occurrence (strong winds, hailstorm, flood, and extreme temperature) and the number of days a facility is likely going to be closed for repair once an event occurs. Based on the developed scenarios, the probability of occurrence, impact likelihood and number of facility closure were estimated.

It is projected that climate change is expected to increase the frequency and severity of extreme weather events. For instance, increased temperature is likely going to increase hailstorm intensity and frequency due to low-level moisture and an increase in convective instability leading to the formation of larger and violent hailstorms. Based on climate scenario extreme event analysis, extreme events such as hailstorms, floods, and strong winds could cause physical damage to health facilities. This may result in the temporary closure of specific facility sections or wings. Table 9 outlines the projected closures of health facility sections due to the impacts of climate change by 2030 and 2050.

Table 9: Projected health facility closure due to extreme events

Scenarios	**SSP2-4.5**	**SSP5-8.5**	**SSP2-4.5**	**SSP5-8.5**
Year	2030	2030	2050	2050
Projected closure days	7.345	8.81375	7.71375	9.605

8.0. Vulnerability Assessment of the Health sector to Climate Change

Vulnerability assessment is one of the first steps in adaptation planning and it involves the assessment of various components that contribute to climate change vulnerability. IPCC (2001) defines vulnerability as the degree to which a system is unable to cope with or is susceptible to the adverse effects of climate change. A vulnerability assessment is a key aspect of linking climate change impact assessments to current development planning (IPCC, 2001), and it helps to communicate the extent of the problem and the potential impacts of climate change. It also helps in identifying the most feasible adaptation measures. The results of this vulnerability assessment do not only feed into international reporting obligations, e.g., national communications to the UNFCCC, but it also helps in understanding the current vulnerability of the health sector and helps evaluate the capacity of the health sector to adapt to the impacts of climate change.

The analysis of the HVI took into consideration the three components of vulnerability as defined in the IPCC assessment reports, and they include exposure, sensitivity, and adaptive capacity.

8.1. Exposure

The exposure component involves two exposure sub-components: climate variability, and extreme events. Climate variability is made up of average temperature variation, and average rainfall variation, while Extreme events is constituted by floods incidences, days of heat waves and drought occurrences/declarations.

It is evident from Table 10 that the combined climate variability sub-component scores range from 0.236 – 0.898 and the combined extreme events scores range from 0.000 – 0.963. The highest variation in climate is evident in the northwest, west, and northeast parts of the country, while the highest incidences of extreme events are evident in the northeast, west, and central parts of the country. Table 10 further shows that the overall exposure scores range from 0.160 – 0.923. The results reveal that the North East district (0.923) is highly exposed. The following districts exhibit medium high exposure, Ghanzi, Ngamiland West Central Serowe Palapye, and Central Tutume districts with scores of 0.705, 0.666, 0.660, and 0.620 respectively. The districts which are moderately exposed include Kgatleng, South East, Francistown, Central Mahalapye, Central Boteti, Kgalagadi North, Kgalagadi South, Central Bobonong, and Ngamiland East, in that order. The moderate to medium high exposure are mainly driven by a combination of high variation in climate variability component and high scores of extreme events component. Chobe is the only district with low exposure, with a score 0.160.

Table 10: The combined scores for climate variability and extreme events and exposure by district

District	Climate Variability	Extreme Events	Exposure
Gaborone	0.538	0.000	0.269
Francistown	0.884	0.013	0.449
Lobatse	0.538	0.000	0.269
Selibe Phikwe	0.727	0.013	0.370
Orapa	0.778	0.000	0.389
Jwaneng	0.681	0.000	0.340
Sowa Town	0.751	0.013	0.382
Southern	0.587	0.136	0.362
Barolong	0.587	0.000	0.294
Ngwaketse West	0.681	0.000	0.340
South East	0.601	0.248	0.424
Kweneng East	0.236	0.370	0.303
Kweneng West	0.236	0.330	0.283
Kgatleng	0.538	0.274	0.406
Central Serowe Palapye	0.690	0.631	0.660
Central Mahalapye	0.690	0.288	0.489
Central Bobonong	0.690	0.407	0.548
Central Boteti	0.690	0.301	0.495
Central Tutume	0.793	0.447	0.620
North East	0.884	0.963	0.923
Ngamiland East	0.898	0.288	0.593
Ngamiland West	0.898	0.433	0.666
Chobe	0.320	0.000	0.160
Ghanzi	0.843	0.568	0.705
Kgalagadi South	0.765	0.281	0.523
Kgalagadi North	0.765	0.248	0.506
Average	0.665	0.240	0.453
Max	0.898	0.963	0.923
Min	0.236	0.000	0.160

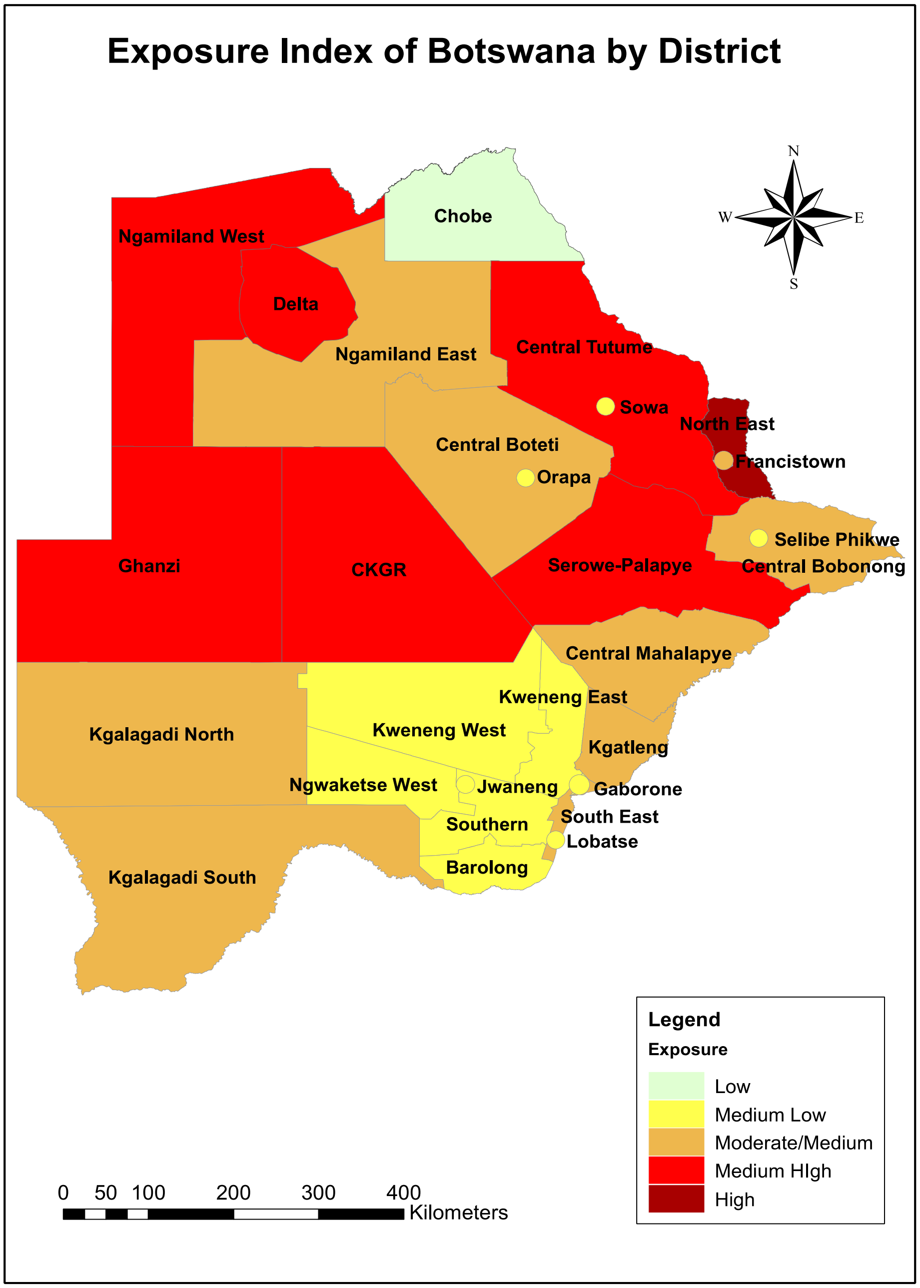

Figure 29: Spatial distribution of Exposure Index

8.2. Sensitivity

Sensitivity shows the degree to which a system can be affected by climate variability. The sensitivity component involves two sensitivity sub-components: natural capital (demography and vulnerable population), and vulnerable population attributed to health conditions. Natural capital (demography and vulnerable population) is made up of women, elderly, under five, population density, population under social safety nets, and disabled, while vulnerable population attributed to health conditions is constituted by cases of TB, malaria, diarrhea, and undernourished.

Table 11 shows the combined scores for natural capital (demography and vulnerable population), vulnerable population due to health conditions, and sensitivity by district. It is evident from the table that the combined natural capital sub-component scores range from 0.126-0.573 and the combined vulnerable population attributed to health conditions scores range from 0.000 – 0.450. Table 11 further reveals that the combined natural capital sub-component is moderate in the central and southern part of the country, while the vulnerable population due to health conditions sub-component is generally at the lowest across the country. The overall Sensitivity scores range from 0.063 – 0.470. The results show that sensitivity is moderate in Central Serowe Palapye, Gaborone, Kweneng East, Ngamiland West, and Central Mahalapye in that order, with sensitivity scores ranging between 0.419 and 0.470. The moderate sensitivity is mainly driven by a combination of moderate natural capital component scores and moderate vulnerable population attributed to health conditions sub-component. The districts with low sensitivity include Sowa Town, Orapa, Chobe, and Jwaneng, with 0.063, 0.167, 0.169, and 0.171 in that ascending order.

Table 11: The combined scores for natural capital, and vulnerable population attributed to health conditions and sensitivity by district

District	Natural Capital	Vulnerable Population Attributed to Health Conditions	Sensitivity
Gaborone	0.512	0.420	0.466
Francistown	0.379	0.223	0.301
Lobatse	0.361	0.121	0.241
Selibe Phikwe	0.343	0.115	0.229
Orapa	0.335	0.000	0.167
Jwaneng	0.258	0.083	0.171
Sowa Town	0.126	0.000	0.063
Southern	0.416	0.182	0.299
Barolong	0.493	0.102	0.298
Ngwaketse West	0.408	0.031	0.220
South East	0.366	0.163	0.264
Kweneng East	0.480	0.421	0.451
Kweneng West	0.486	0.093	0.289
Kgatleng	0.397	0.186	0.291
Central Serowe Palapye	0.491	0.450	0.470
Central Mahalapye	0.573	0.266	0.419
Central Bobonong	0.498	0.228	0.363
Central Boteti	0.380	0.345	0.363
Central Tutume	0.522	0.163	0.342
North East	0.455	0.133	0.294
Ngamiland East	0.355	0.225	0.290
Ngamiland West	0.475	0.376	0.425
Chobe	0.269	0.068	0.169
Ghanzi	0.329	0.160	0.244
Kgalagadi South	0.393	0.129	0.261
Kgalagadi North	0.374	0.299	0.337
Average	0.403	0.192	0.297
Max	0.573	0.450	0.470
Min	0.126	0.000	0.063

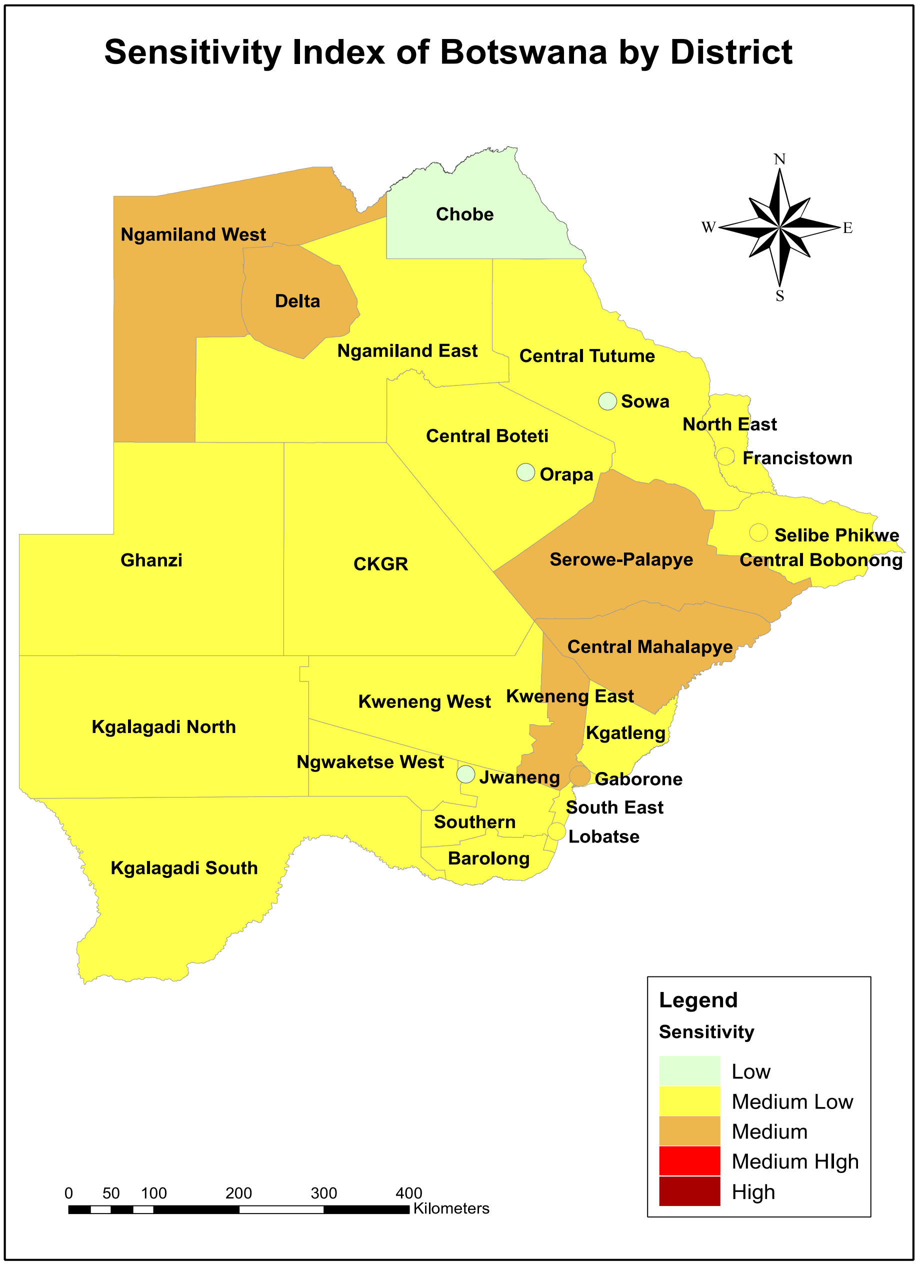

Figure 30: Spatial distribution of Sensitivity Index

8.3. Adaptive Capacity Factors / Determinants

Adaptive capacity is defined as the ability of a system/unit to respond to the threats and opportunities emanating from climate change. For the health sector, adaptive capacity is determined by various socio-economic factors such as infrastructure integrity, finance, social programmes, and economic opportunities. Adaptive capacity scores were calculated based on the following sub-components / factors: health care services, human resources, water and sanitation, and social capital. The health care services sub-component is made of number and type of health facilities, and coverage radius of a health facility. Health human resources sub-component is made up of ratio of nurses and doctors per inhabitants, other health professionals, and administrative and specialised secretaries. Medical doctors include generalists and specialist medical practitioners, while nurses include nursing and midwifery personnel. The water and sanitation sub-component is made of access to safe drinking water and access to improved sanitation facilities. Social capital, also known as social determinants of health, is constituted by the following variables which were aggregated by sex: poverty, employment, and education.

Health care services

The combined health care services component scores show that majority of the districts have high capacity, and the sub-component scores range from 0.218 (Kgalagadi South) to 0.930 (Chobe). A total of 12 districts (46.2%) have high capacity, while moderate capacity is constituted by a total of 8 districts (30.8%). Low adaptive capacity is exhibited in Kgalagadi South and Kgatleng.

Health human resources

In terms of the combined human resources all the districts have scores ranging from 0.008 (Ngwaketse West) to 0.986 (Gaborone). Even though there is generally low capacity in terms of human resources, Gaborone, and Francistown have highest scores compared to other districts, with the combined human resources sub-component scores of 0.986, and 0.767 respectively. This is mainly driven by high scores of numbers of nurses, doctors, other professionals, and administrative and specialised secretaries.

Water and sanitation

Water and sanitation are some of the important factors constituting the Water Sanitation and Hygiene (WASH) practices in a location. They show a level of capacity to cope with the impacts of climate change. The results show that, all the districts exhibit high water and sanitation sub-component scores. Additionally, it can be noted that Kweneng East, Ngamiland east, Francistown, Gaborone, Central Mahalapye, Lobatse, Central Serowe Palapye, Selebi Phikwe, Orapa, Central Boteti, Ghanzi, Kgalagadi North, and Central Bobonong have the highest capacity with scores ranging between 0.999 to 0.908. This attributed to high access to sources of safe drinking water and improved sanitation facilities.

Social capital

Social capital sub-component is made of some of the social determinants, and they include the following variables: employment, poverty, and education. The social capital sub-component ranges from 0.315 (Lobatse) to 0.053 (Central Serowe Palapye). Majority of cities and towns have slightly higher scores of social capital sub-component compared to other districts. For example, the highest scores are recorded in Lobatse with 0.315, followed by Francistown, Orapa, and Selibe Phikwe, with scores of 0.308, 0.281, and 0.280, respectively. The low social capital sub-component is mainly driven by a combination of low literacy, high unemployment, and high multi-dimensional poverty.

Generally, the results reveal that the highest overall adaptive capacity scores were recorded in Gaborone with 0.773, followed by Francistown with 0.747. This is influenced by a combination of high scores of health care services, human resources, and water and sanitation sub-components. Majority of the districts have moderate adaptive capacity with scores ranging between 0.403 and 0.571. Low adaptive capacity was recorded in Kweneng West, Central Boteti, Ngwaketse West, South East, and Ngamiland West with 0.312, 0.343, 0.349, 0.393, and 0.394 respectively. This is attributed to a combination of low scores health care services, human resources, and social capital sub-components. (Table 12)

Table 12: The combined scores for health care services, human resources, water and sanitation, social capital, and adaptive capacity by district

District	Health Care Services	Health Human Resources	Water & Sanitation	Social Capital	Adaptive Capacity Index Scores
Gaborone	0.900	0.986	0.996	0.225	0.866
Francistown	0.900	0.767	0.996	0.281	0.756
Lobatse	0.600	0.244	0.990	0.315	0.555
Selibe Phikwe	0.582	0.119	0.992	0.262	0.501
Orapa	0.509	0.021	0.999	0.280	0.470
Jwaneng	0.445	0.013	0.995	0.259	0.439
Sowa Town	0.500	0.018	0.998	0.257	0.465
Southern	0.791	0.145	0.879	0.084	0.487
Barolong	0.800	0.068	0.908	0.182	0.494
Ngwaketse West	0.490	0.008	0.777	0.124	0.353
South East	0.380	0.037	0.979	0.170	0.399
Kweneng East	0.589	0.243	0.947	0.063	0.457
Kweneng West	0.379	0.027	0.757	0.072	0.292
Kgatleng	0.703	0.110	0.951	0.194	0.500
Central Serowe Palapye	0.872	0.332	0.893	0.053	0.535
Central Mahalapye	0.930	0.213	0.883	0.083	0.533
Central Bobonong	0.493	0.141	0.816	0.248	0.414
Central Boteti	0.218	0.099	0.858	0.156	0.352
Central Tutume	0.679	0.129	0.862	0.095	0.436
North East	0.791	0.049	0.939	0.249	0.508
Ngamiland East	0.681	0.163	0.824	0.140	0.455
Ngamiland West	0.722	0.087	0.661	0.064	0.392
Chobe	0.380	0.070	0.954	0.308	0.423
Ghanzi	0.550	0.146	0.812	0.074	0.398
Kgalagadi South	0.682	0.057	0.870	0.257	0.472
Kgalagadi North	0.467	0.045	0.884	0.203	0.402
Average	0.617	0.167	0.901	0.181	0.475
Max	0.930	0.986	0.999	0.315	0.866
Min	0.218	0.008	0.661	0.053	0.292

Figure 31: Spatial distribution of Adaptive Capacity Index

8.4. Health Vulnerability Index

Table 13 and Figures 32 and 33 depict districts' overall health vulnerability index scores. The overall health vulnerability index was computed by combining all the three components of exposure, sensitivity, and adaptive capacity. The results show that the higher the exposure scores relative to adaptive capacity scores results in high vulnerability, and this is in line with studies done elsewhere (e.g., Belay et al. 2014; FMoH, 2015). Conversely, low scores of exposure relative to adaptive capacity yields low vulnerability scores. According to IPCC, sensitivity is a multiplier, if sensitivity is high in a location which exposure exceeds adaptive capacity this will result in high scores of vulnerability. On the other hand, if sensitivity is low in a location which exposure is less than adaptive capacity this yield low scores of vulnerability. The health vulnerability index scores lie between 0 and 1.

Table 13 reveals that the computed HVI scores ranged from 0.417 (Gaborone district- moderate vulnerability) to 0.817 (North East, high vulnerability). The table depicts that only Gaborone (0.417) has moderate vulnerability. This is driven by a combination of low exposure, moderate sensitivity, and high adaptive capacity. Majority of the districts exhibited medium high vulnerability with scores ranging between 0.603 in Francistown and 0.770 in Ghanzi. This is attributed to a combination of moderate exposure, low sensitivity, and moderate adaptive capacity. Only two districts exhibit high vulnerability, North East (0.817) and Ngamiland West (0.812).

It is worth noting the districts with high vulnerability experience deficit in adaptive capacity and high exposure compared to other districts. On the other hand, the districts with moderate vulnerability exhibit adaptive capacity exceeding exposure.

Table 13: Computed indices for contributing factors and the Health Vulnerability Index (HVI) by district

District	Exposure	Sensitivity	Adaptive Capacity	Health Vulnerability Index	Health Vulnerability Index (Normalised)
Gaborone	0.269	0.466	0.866	-0.278	0.417
Francistown	0.449	0.301	0.756	-0.093	0.603
Lobatse	0.269	0.241	0.555	-0.069	0.626
Selibe Phikwe	0.370	0.229	0.501	-0.030	0.665
Orapa	0.389	0.167	0.470	-0.014	0.682
Jwaneng	0.340	0.171	0.439	-0.017	0.678
Sowa Town	0.382	0.063	0.465	-0.005	0.690
Southern	0.362	0.299	0.487	-0.047	0.648
Barolong	0.294	0.298	0.494	-0.069	0.626
Ngwaketse West	0.340	0.220	0.353	-0.003	0.692
South East	0.424	0.264	0.399	0.007	0.702
Kweneng East	0.303	0.451	0.457	-0.069	0.626
Kweneng West	0.283	0.289	0.292	-0.003	0.693
Kgatleng	0.406	0.291	0.500	-0.028	0.668
Central Serowe Palapye	0.660	0.470	0.535	0.059	0.754
Central Mahalapye	0.489	0.419	0.533	-0.018	0.677
Central Bobonong	0.548	0.363	0.414	0.049	0.744
Central Boteti	0.495	0.363	0.352	0.052	0.747
Central Tutume	0.620	0.342	0.436	0.063	0.758
North East	0.923	0.294	0.508	0.122	0.817
Ngamiland East	0.593	0.290	0.455	0.040	0.735
Ngamiland West	0.666	0.425	0.392	0.116	0.812
Chobe	0.160	0.169	0.423	-0.045	0.651
Ghanzi	0.705	0.244	0.398	0.075	0.770
Kgalagadi South	0.523	0.261	0.472	0.013	0.708
Kgalagadi North	0.506	0.337	0.402	0.035	0.730
Average	0.453	0.297	0.475	-0.006	0.689
Max	0.923	0.470	0.866	0.122	0.817
Min	0.160	0.063	0.292	-0.278	0.417

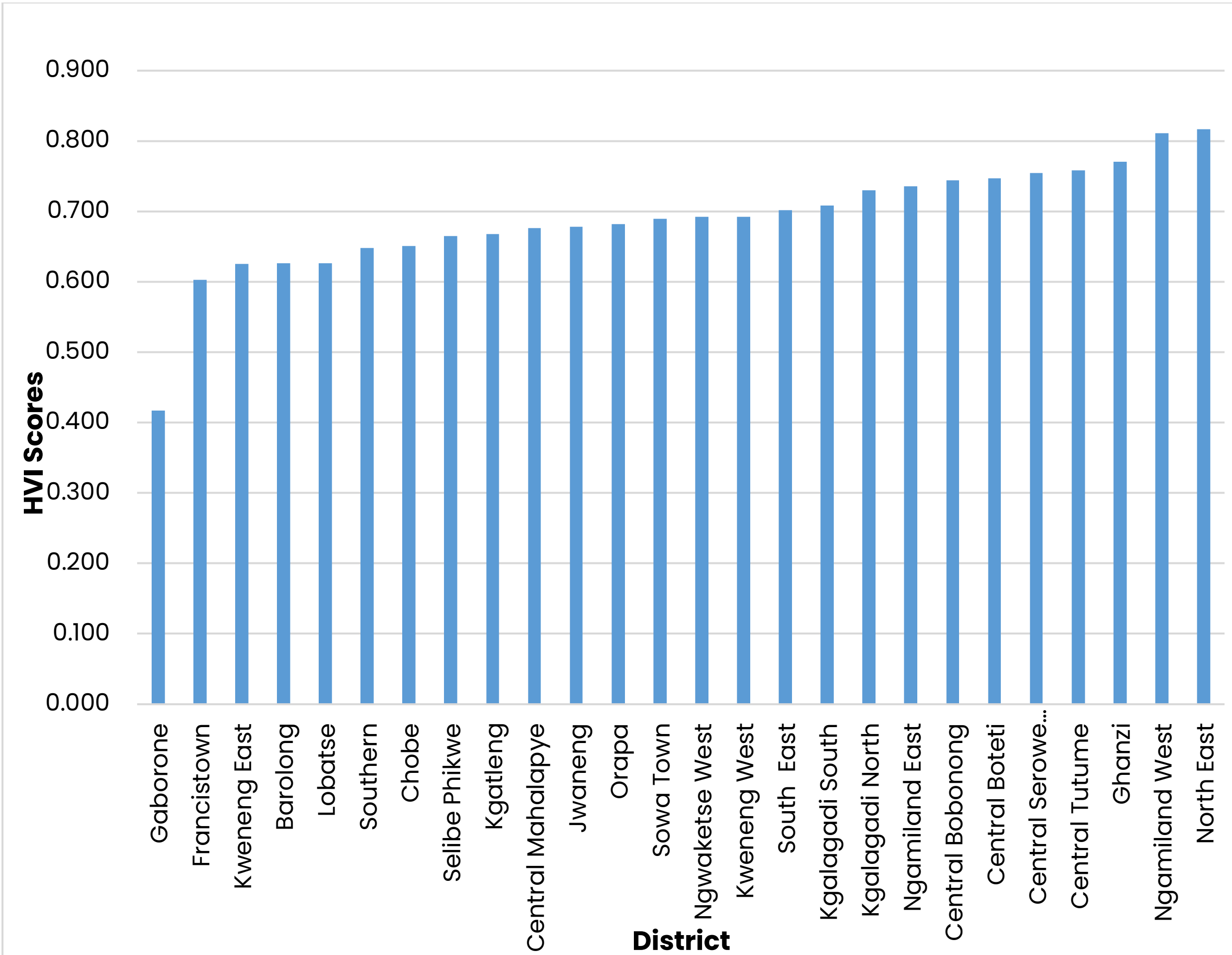

Figure 32: Computed indices for the Health Vulnerability Index (HVI) by district

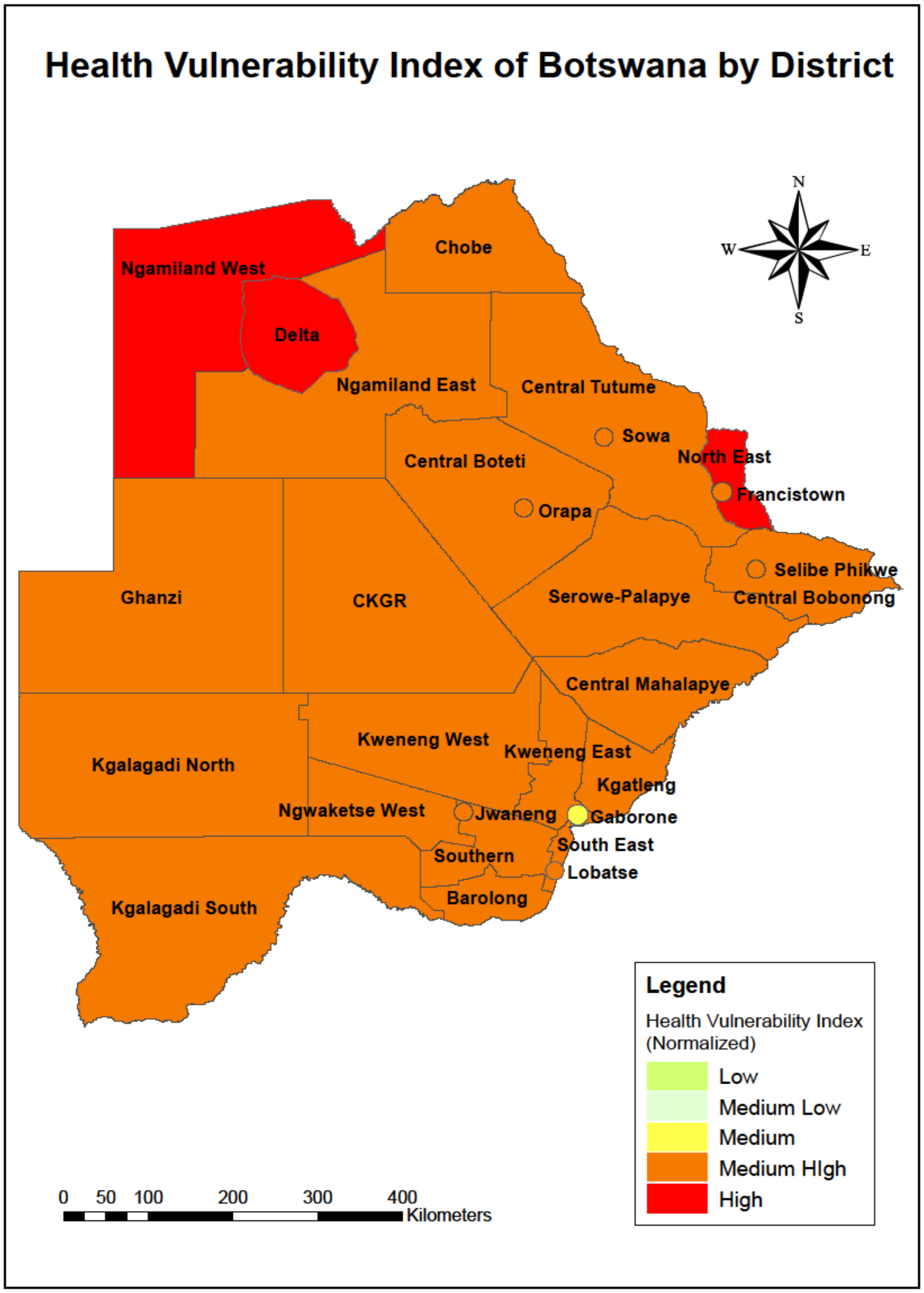

Figure 33: Spatial distribution of the Health Vulnerability Index (HVI) by district

In geographical context, the HVI scores concludes that about 0.029% of the total land area (Gaborone) is moderately vulnerable or has medium vulnerability to climate change relative to other districts. About 4.787% of the land area (Ngamiland West, 3.907% and North East, 0.880%) is highly vulnerable relative to other districts. The rest of 95.184% of the land area of the total area is categorized as having relative medium high vulnerability (Table 14). This includes the land area under the districts not mentioned above. It is worth noting that there are minute differences between districts scores that have been classified similarly under medium high vulnerability.

Regarding population, Table 14 reveals that about 10.439% of the population reside in a land area with relative medium vulnerability (Gaborone). About 6.204% of the population reside in a land area with relatively high vulnerability (Ngamiland West, 3.265% and North East, 2.939%) while, the rest of population (83.357%) reside in the land area that has medium high vulnerability.

Table 14: Area coverage and population of Botswana by vulnerability classes and district

Vulnerability Class	HVI Scores	District	Average Coverage		Population	
			Km^2	Percent	Count	Percent
Medium	0.417	Gaborone	169	0.029	246,325	10.439
Medium High	0.603	Francistown	79	0.014	103,417	4.383
	0.626	Kweneng East	7,901	1.358	330,220	13.995
	0.626	Lobatse	42	0.007	29,772	1.262
	0.626	Barolong	7,118	1.224	58,885	2.496
	0.648	Chobe	20,800	3.576	28,743	1.218
	0.651	Southern	14,235	2.447	139,383	5.907
	0.665	Selibe Phikwe	50	0.009	42,488	1.801
	0.668	Kgatleng	7960	1.368	121,882	5.165
	0.677	Central Mahalapye	16,876	2.901	131,977	5.593
	0.678	Jwaneng	100	0.017	18,784	0.796
	0.682	Orapa	17	0.003	8,648	0.367
	0.690	Sowa Town	159	0.027	2,914	0.123
	0.692	Ngwaketse West	16,655	2.863	23,660	1.003
	0.693	Kweneng West	24,841	4.270	57,763	2.448
	0.702	South East	1,800	0.309	111,440	4.723
	0.708	Kgalagadi South	32,800	5.638	35,347	1.498
	0.730	Ngamiland East	86,400	14.852	121,398	5.145
	0.735	Kgalagadi North	72,400	12.446	23,510	0.996
	0.744	Central Serowe Palapye	31,381	5.394	202,740	8.592
	0.747	Central Bobonong	14,242	2.448	77,504	3.285
	0.754	Central Boteti	33,806	5.811	74,553	3.160
	0.758	Central Tutume	46,140	7.932	165,311	7.006
	0.770	Ghanzi	117,910	20.269	56,555	2.397
High	0.812	Ngamiland West	22,730	3.907	77,038	3.265
	0.817	North East	5,120	0.880	69,352	2.939
	Total		581,731	100.000	2,359,609	100.000

9.0. Feasible Health adaptation measures for building climate-resilient health system

The country's health sector is vulnerable to the impacts of climate change. These impacts are projected to emanate from extreme events mainly heatwaves, hailstorm, floods, and drought. These events could have significant impacts on occurrence of NCDs, communicable diseases, heat mortalities, drowning and injury.

Similarly, through the rise in temperature and other extreme events, climate change could have a significant impact on the operational efficiency of the health facilities (clinics and hospitals). The impacts will be through health workforce, particularly those working in offices and facilities that do not have efficient air conditioning and hence constantly fatigued. The impact will be shortage of staff and hence affects operational efficiency. In addition, through floods, hailstorm and strong winds, the operational efficiency could be affected through health facilities partially or total closure for repairs following destruction of roofs, windows and ceilings and other components of the hospital facilities. Furthermore, destruction on electricity infrastructures (powerlines, power outrages) could affect the medicine potency. It is therefore necessary to implement and operationalise comprehensive and robust climate adaptation measures to build the resilience of the health sector in the country.

A climate resistant health system is one that can anticipate, respond to, cope with, recover from and adapt to climate-related shocks and stress while operating at an optimal level under changing climates. Consequently, the need for a climate-resilient health sector is inevitable. It is therefore necessary to implement and operationalise comprehensive and robust climate adaptation measures to build the resilience of the health sector in the country; the adaptation measures recommended for implementation are provided below.

1. **Multi-Hazard Early Warning Systems**

An early warning system (EWS) is defined as "an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events (UN, 2016)." An effective early warning systems is characterised by the following:

a) Multi-Hazard: they are designed to detect different hazards that may occur alone, or simultaneously such as fires, floods, heatwaves, storms, and strong winds amongst others.
b) End-to-end: the system covers the entire range, from hazard detection to action, which includes providing understandable and actionable warning messages. It is crucial that the EWS relay the information to the communities to prepare and enable them to take appropriate and timely action to reduce the impact associated with the extreme event
c) People-centered: this means designing the systems with people in mind, to empower them to act on time and in an appropriate manner to reduce potential harm (UNDRR, 2023).

Multi-hazard EWS are necessary as they increase the communities and public health sector preparedness and enable them to take appropriate timely action to avert the associated impacts. Multi-hazard EWS are appropriate for all the extreme events associated with climate change such as floods, fires, heatwaves, and storms. Studies have shown that advancement in early warning systems which results to preparedness have significant lessened impacts of climate related extreme event. It is therefore crucial that the health sector in collaboration with Department of Meteorological Services develop an efficient Multi-hazards EWS with the ability to cover the entire country and public. The starting point will be to develop a comprehensive national Multi-hazards EWS strategy for the country to be aligned with the already existing multi-hazard plan.

2. **Strengthening National Malaria Programme**

The programme was established in the 1950s. GoB realigned the National Malaria Programme (NMP) in 2010 with the aim of eliminating malaria by 2030 as per the Global Technical Strategy for Malaria 2016–2030 targets. The programme constitutes key vector control interventions being: indoor residual spraying for households in areas and distribution of long-lasting insecticidal nets to the general public where malaria is endemic. Over the years the NMP has yielded some significant positive results, Malaria incidence rates remains below 1 per 1000 population with no significant change over 2019-2023. However, elimination of Malaria by 2020 proved to be illusive and the gaps identified to achieve the target include low targeted coverage of IRS and insecticide treated nets, funding gap, shortage of resources including HR and transport, case management and overall coordination issues. However, it is essential that this programme as a climate change adaptation strategy is continued and strengthened by closing the identified gaps. Furthermore, a holistic approach on the management of mosquito breeding sites be mainstreamed into the integrated vector management strategy. In addition, there is a need to link the NMP to the Multi-hazard EWS to ensure effectiveness and efficiency.

3. **Introduce conducive working hours for vulnerable and exposed employees**

Climate change is projected to results in frequent and intense heatwaves by 2030 and 2050. Currently, the country is experiencing increased number of days with extreme temperatures. Even though the public is exposed to these heatwaves, certain section of the communities is relatively more exposed than others. Construction workers, farm workers are some of the employees who bear the full blunt of heatwaves as they in most cases work directly under the sun. It is therefore essential to establish a legislation stipulating conducive working hours for these group to avoid the impact of heatwaves and extreme temperatures particularly when working outdoors. Consequently, a consultative meeting with the workers union, the affected sectors (agriculture, construction) should be undertaken to determine appropriate working conditions for these groups.

4. **Improved Water, Sanitation and Hygiene (WASH) programme**

The link between WASH and climate change is irrefutable. According to WHO improved WASH is central to strengthening the community health resilience to climate change. WASH aids societies to cope with climate extreme events by preventing diseases and ensuring promotion of adequate hydration due to increasing temperatures (WHO, 2022). GoB has done a tremendous job of improving WASH as evident on percentage of the population with access to clean water, sanitation amongst other WASH indicators. For instance, by 2022 it was estimated that the population with access to clean water was 85.4% while the population practicing open defecation was 10%

(Statistics Botswana, 2023). According to WHO (2021), due to improvements in WASH in the country, WASH mortality is estimated at 11.8 deaths per 100,000 population. It is, therefore, critical that the WASH programme is maintained and improved in the country to build a resilient population to climate related health impacts. There are various ways to maintain and improve the WASH programme in the country. The following strategic activities are recommended for improving WASH in the country:

- Allocation of reasonable and adequate budget for water sectors to ensure improved water access and quality.
- Allocation of adequate budget for provision of appropriate sanitation facilities.
- Implementation of waste management policy, and Waste and Waste Water Master Plan.
- Prioritisation of WASH as a national priority area and mainstream WASH within climate change and health policy and implementation processes.
- Integrating WASH within Integrated Water Resources Management (IWRM). This can be done through the involvement of the health sector in planning and implementation of IWRM at transboundary and national levels.
- Mainstream WASH in education curriculum.

5. Promote a healthy lifestyle

Promoting healthy lifestyles is one of the fundamental adaptation measures which includes a combination of activities that are aimed at improving the health and wellbeing of an individual. Key activities that promote healthy lifestyles include eating healthy, drinking adequate water daily, engaging in physical activities such as walking, exercising, cycling, and running amongst others, and this reduces incidences of NCDs such as diabetes. A study found that every 66-gram increase in daily fruit and vegetable intake was associated with a 25 percent lower risk of developing type 2 diabetes. Moreover, eating 90 grams (or three 30-gram servings) of whole grains daily reduced the risk of cardiovascular disease by 22 percent, coronary heart disease by 19 percent, and cancer by 15 percent (Tighe et al. 2010). The following strategic activities should be undertaken to increase the uptake of this adaptation measure:

- Promote physical education in primary and secondary schools' curriculum.
- Promote and mainstream health lifestyles at the workplace.
- Introduce a tax on food items that are deemed not healthy to discourage their consumption.
- Promote walking and cycling through construction of walk path and cycling.

6. Maintenance of Social Protection Programmes

Climate change could result in food insecurities from extreme heat and droughts and even flooding. These could result in increased malnutrition and even famine by 2050. Maintaining and strengthening the existing social protection programme as an adaptation measure against malnutrition and famine is fundamental. Over the years, GoB has established and maintained a comprehensive social protection programme as social safety net. The programme is aimed at protecting the destitutes and other vulnerable groups from food insecurity and they include food basket, vulnerable group feeding program, and school feeding program (The World Bank, 2022). Climate change could result in food insecurities from extreme heat and droughts and even flooding. Some of the strategic activities for maintaining and enhancing social protection programme include:

- Ensure that government maintains adequate budget to strengthen social protection programme.
- Enhance economic growth and development to create employment opportunities for the citizens.

7. Heatwave adaptation strategy

Of all the extreme events, heatwaves are projected to be more frequent and intense. This could increase heatwaves related mortality rates significantly. There is a need to develop a national heatwaves response plan or strategy to heatwave proof the communities. The plan/strategy should constitute the following critical aspects:

- Heatwave forecasting and monitoring.
- Impact of heatwaves to communities.
- Education and awareness.
- Response program to heatwaves.
- Adaptation strategies such as public cooling centers.

8. Promote conducive residential and business infrastructure

Heatwaves and extreme temperature would make residential, civic, and private building to be unbearably hot which could in turn exacerbate the associated impacts. It is thus paramount that houses, offices, schools and shopping malls are designed to protect occupants from excessive temperatures. This will include:

- Installation of air condition systems at shopping malls, churches, homes and offices and schools.
- Design building to maximise the use of natural air flow systems for cooling purposes.
- Ensure that buildings have adequate insulation to retain coldness for a long period of time even when the air conditioning systems have been turned off.

9. Introduce subsidies on solar powered air conditioning systems

Air conditioning systems is becoming a requirement for the residential dwelling. However, in many instances, households cannot afford it. There is a need to set healthy houses grant which will cover air conditioning and ventilations systems powered by solar energy. A fund must be established which should be funded through carbon tax.

10. Retrofitting existing health infrastructure

Retrofitting is a process that involves updating and modifying existing structures to improve their performance, safety, and energy efficiency. It entails fitting air conditioning, improving the ventilation systems, strengthening the structure of the infrastructure, and fit in features that can withstand impacts associated with hailstorm. Retrofitting is both a climate change adaptation and mitigation measure as it generally results in energy efficiency. Therefore, in addition to creating a conducive work environment and enhancing operational efficiency, retrofitting results in lower energy consumption and water saving. Ultimately, it is necessary to develop a national building retrofitting plan for all the health sector infrastructure and its implementation strategy to ensure that all the health infrastructure are retrofitted.

Furthermore, it is necessary to mainstream climate change into infrastructure planning, design, and development processes to ensure that all future health infrastructure is constructed to enhance the climate resilience of both health facilities and associated dwellings.

11. Installation of solar rooftops in all the health institutions

Climate change could result in increased electricity outrage from powerline destruction, increased in demand for cooling and aging electrical grid. Consequently, the electricity outages threaten public health (Do et al. 2023). As indicated one of the major impacts of electricity outages is medicine that require refrigeration losing their potency. It is therefore necessary that all the health facilities are installed with solar PV systems as backup systems to guard against prolonged electricity outages. This strategy will act as both mitigation and adaptation and will contribute to the country's attainment of the nationally determined contributions (NDCs) target of reducing the national GHGs emission. It is critical to note that this adaptation measure (Solar PV systems) is emphasised in the NDCs and aligns with the National Energy Policy objective of increasing the share of renewable energy in the energy mix.

12. Increase the number of healthcare workers in all health facilities

Heatwaves and other extreme climate events such as floods and storms could result in health workers overworked, fatigue and burnout. It is necessary to adapt to the possible scenario by increasing the number of workers in each health facility to ensure that there are adequate staff workers to reduce work overload and fatigue. This adaptation measure will ensure that each worker is given adequate off days. Consequently, each health facility should have a recommended adequate number of workers.

13. Establish health and climate data management system

Building a health climate resilient system is a continuous process that require V&A assessment. Furthermore, there is a need to undertake M&E on the implemented adaptation measures to assess the effectiveness. Effectively, this calls for improved data collection and management to support both V&A and M&E. Critical data include mortalities associated with climate extreme events, climate related hospital admissions, distinction between non-viral and viral diarrhea etc. At the moment, there is lack of data on health-related climate anomalies. There is thus a need to improve the data collection, processing, storage, and management on this sphere/thematic area.

10.0. Conclusions

It is evident that climate change is impacting the health sector through extreme events such as drought, floods, heatwaves, hailstorms, strong winds. Furthermore, the health sector is vulnerable to climate change impacts. High vulnerability is due to a combination of factors mainly moderate exposure, moderate to high sensitivity, and low adaptive capacity. Cities and towns have medium vulnerability, while majority districts have medium high vulnerability. Only two districts exhibit high vulnerability, Ngamiland West and North East districts. The combined impacts of climate change on health workforce, destruction of infrastructure and reduced potency of medicine could result in reduced operational efficiency of the health sector. SPP2-4.5 and SSP5-8.5 project an increase in temperature by between 0.8 ^{o}C and 2 ^{o}C for the years 2030 and 2050. These changes will drive diarrhea cases from an average of recorded cases of 3,000 to approximately 6, 000 per annum taking into account population.

11.0. Recommendations

For Botswana to improve the health response and ensure climate resilient health care system in tackling the impacts of climate change, the study recommends the implementation of the following:

- Develop the Health National Adaptation Plan (HNAP) as per the National Adaptation Plan Framework of 2020.
- Engage the community during the development of the HNAP. This can help address climate change and health by raising awareness, empowering residents, and encouraging sustainable practices.

- Strengthen the health climate data to ensure monitoring and evaluation of the effectiveness of the HNAP.

- Build a strong Monitoring and Evaluation (M&E) framework for the HNAP.

- There is need to set healthy houses grant which will cover air conditioning and ventilations systems powered by solar energy. A fund must be established which should be funded through carbon tax.

- Strengthen cross-sectoral partnerships with other ongoing adaptation programmes in the country to avoid duplication of efforts. By so doing co-benefits from on-going adaptation programmes in other sectors can be identified and taken advantage of, particularly those that receive complementing funding, and technical assistance from development partners.

- Conduct interdisciplinary, collaborative, and participatory research on the interconnections between climate change and mental health to strengthen the evidence base and facilitate the design of effective interventions.

- Furthermore, there is need to understand the extent to which current public health and health care policies and programmes are effective and reasons limiting effectiveness in an endeavor to find out what modifications are needed to address the risks of climate change.

- There is need to develop a national heatwaves response plan or strategy to heatwave proof the communities in an endeavour reduce heat-related mortality.

- There is a need to develop a communication and stakeholder engagement strategy. This will enhance stakeholder participation and by-in.

- In an attempt to building a climate-resilient healthcare system in Botswana there is need to formulate and implement strategies under the following themes:

    a. ***Governance and leadership***: Developing a Health National Adaptation Plan (HNAP); Using climate vulnerability indices for health planning; Enhancing inter-sectoral and international collaboration; Increasing awareness of healthcare leaders of the changing hazards.
    b. ***Financing***: Providing adequate funding for MoH; Increasing research funding; Improving access to long-term international financing.
    c. ***Health workforce***: Using a sustainable and trained workforce; Improving training provisions to raise awareness among professionals; Recruiting and training of healthcare workers in biostatistics, epidemiology, and climate change.
    d. ***Health information systems***: Forecasting climate impacts and assessing the vulnerabilities and capacities of the health system; Enhancing surveillance targeting climate-sensitive diseases and their risk sources; Research in climate change's impact on health and improve adaptive capacities of health services.

12.0. Limitations of the study

- Currently, there is no database on the impact of climate extreme on physical asserts to undertake a comprehensive analysis of the current impacts. However, there are sparsely recorded cases of the impacts of climate events on health infrastructure.

- Lack of baseline data on cardiovascular (such as heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes, and mental health has made it impossible to model the current and future impacts of climate change on these ailments.

- The adaptation measures presented in this study are broad to undertake CBA. Secondly, these adaptation measures are already being implemented therefore it is not possible to do CBA.

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