Adapting Together, Thriving Tomorrow

Approach Paper on Climate Change Risk Assessment

Enhancing Multi-Sector Planning and Capacity for Effective Adaptation in Ghana

UN environment programme

GREEN CLIMATE FUND

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Acronyms

AR	Assessment Report of the IPCC (AR5 published 2013-4; AR6 2021-2)
CCAM	Conformal-Cubic Atmospheric Model
CCAU	Climate Change Adaptation Unit
CCKP	Climate Change Knowledge Portal
CCRA	Climate Change Risk Assessment
CERES Crop Environment Resource Synthesis	
CORDEX	Coordinated Regional Downscaling Experiment
CORE	Coordinated Output for Regional Evaluations
CRIDF	Climate Resilient Infrastructure Development Facility
CROPWAT	Crop Water and Irrigation Requirements Program
CSPG	Cross Sectoral Policy Group
CMIP	Climate Model Intercomparison Project; CMIP5 was used extensively in the IPCC AR5 and CMIP6 in the AR6
ENSO	El Niño/Southern Oscillation
EPA	Environmental Protection Agency
GCF	Green Climate Fund
GCM	Global Climate Model
GHG	Greenhouse Gas
GIS	Geographic Information System
I&APs	Interested and Affected Parties
IPCC	Intergovernmental Panel on Climate Change LE Lower Extreme
MENA	Middle East/North Africa
MESTI	Ministry of Environment, Science, Technology and Innovation
MMDAs	Metropolitan, Municipal and District Assemblies
NAP	National Adaptation Plan
NCCSAP	Netherlands Climate Change Studies Assistance Programme
PSC	Project Steering Committee
RCM	Regional Climate Model
RCP	Representative Concentration Pathways

SMILE	Single Model Initial-condition Large Ensemble
SOM	Self-Organising Map, an artificial intelligence technique used to analysis the CMIP ensembles
SoW	Scope of Works
SRES	IPCC Special Report on Emissions Scenarios
SSP	Shared Socioeconomic Pathways
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UE	Upper Extreme
WATBAL	Watershed Response Model for Forest Management
WGI	Working Group I of the IPCC – The Physical Science Basis

1. Introduction

1.1. Background and Context

The Government of Ghana, through the Environmental Protection Agency (EPA), under the auspices of the Ministry of Environment, Science, Technology, and Innovation (MESTI), has successfully obtained a grant from the Green Climate Fund (GCF) for a three-year project to build capacity to advance National Adaptation Plan (NAP) process in Ghana. The United Nations Environment Programme (UNEP) is the Delivery Partner, supporting and overseeing the project implementation.

The project entitled **"Enhancing multi-sector planning and capacity for effective adaptation in Ghana"** is being implemented by a small project team headed by a National Coordinator. The NAP project seeks to support multi-sectoral, medium- to long-term adaptation planning and budgeting in Ghana and promote the integration of climate change adaptation issues into development planning processes and policies. Systems for developing and sharing climate risk and vulnerability information will be reinforced, and sustainable financing mechanisms for climate change adaptation initiatives are set to be developed. This specific study is intended to support multiple objectives of the NAP program.

Central to the preparation of effective climate change risk assessments (CCRAs) is the ability to understand the science behind the projections, manage the inherent uncertainty associated with them, analyse them using a variety of techniques and then communicate the impact risks clearly and concisely in an actionable format for decision makers and wider non-technical stakeholders and users.

This work is intended to support several national initiatives in Ghana, including the updated NAP. However, it must also be able to underpin the climate rationales necessary to secure international climate finance. This requires an understanding of the past and current climate impacts, the potential impact of future climate, with and without climate change and the disaggregation of other changes that are occurring in the area covered by the risk assessment, so that the impact of climate change can be isolated, analysed and presented in the form of a robust and clear climate risk narrative for Ghana.

1.2. Document Purpose

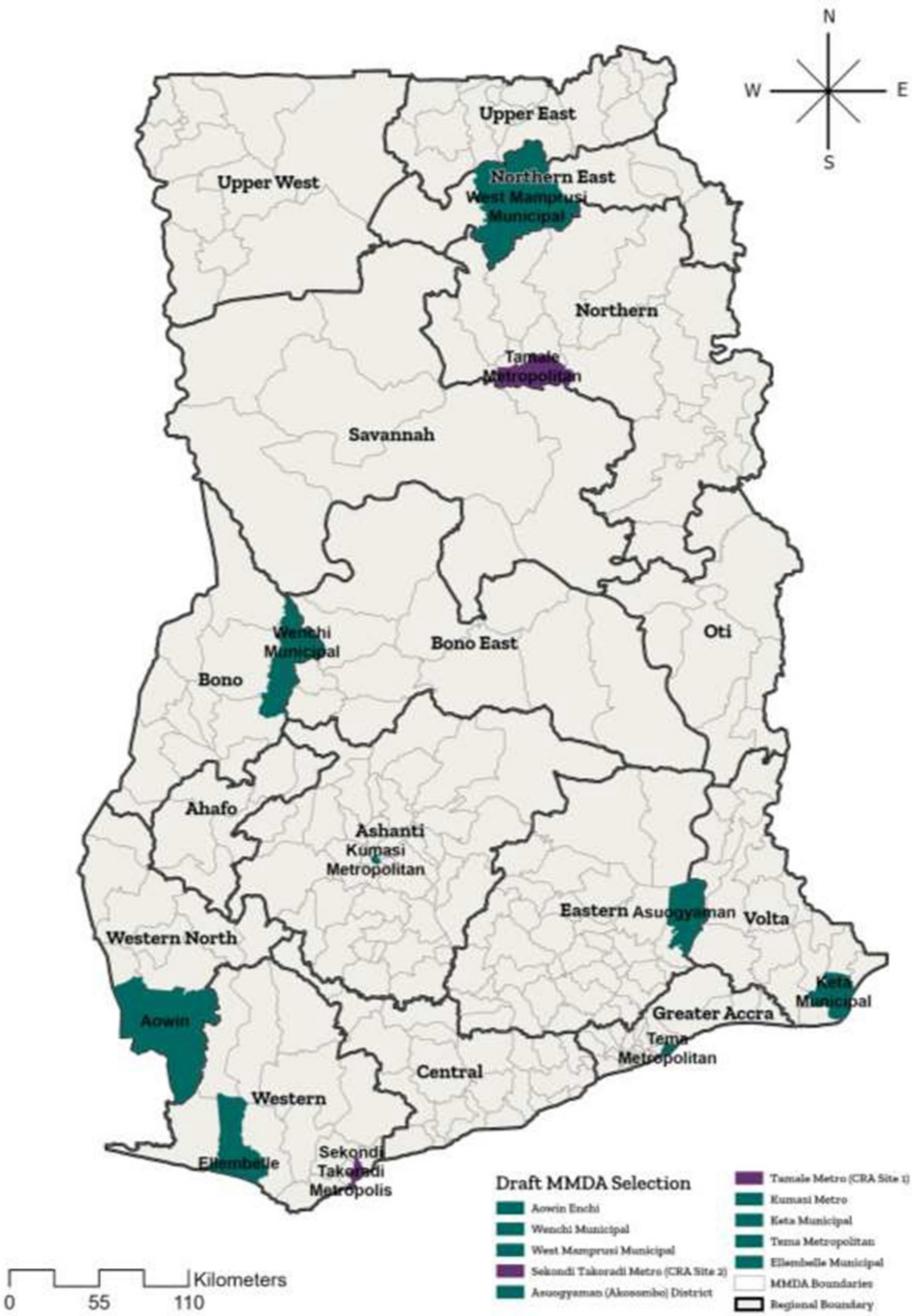
This report is the deliverable from Task 3.3 of the Study and provides an approach that identifies the most cost-effective method of producing climate change risk assessments relevant to the sub-national planning unit and paying attention to the impact chain: first order (biophysical) risks and second order (economic sectors: health, energy, agriculture, water, disaster management, and transport) risks. This Document follows on from a previous Report that determined the most likely future climate scenarios for Ghana based on analysis using Plume Plots and Self Organising Maps (SOMs). The results of this analysis and the resulting national level climate risk maps for Ghana as well as the range of potential impacts of each of ten priority MMDAs are presented in the section describing the assessment of risks

Note that the approach to undertaking a sub-national level climate risk assessment presented here has been developed in consultation with representatives of the Government of Ghana and with technical support from the United Nations Development Program (UNDP). Following the description of the general approach in this Report, the approach will be tested by application in two focus MMDAs.

The location of the ten priority MMDAs for which initial climate risks are identified, and the two focus MMDAs that will be used to test the approach to the sub-national level CCRA are shown in Figure 1.

The implementation of the national level risk assessment and the sub-national level risk assessments will also be supported by additional work to be undertaken to determine future socio-economic development scenarios for Ghana which is necessary to inform the assessment of future climate risks.

Figure 1 | Priority MMDAs for developing downscaled climate scenarios and local risk assessments



2. Understanding Climate Change Risk and Vulnerability

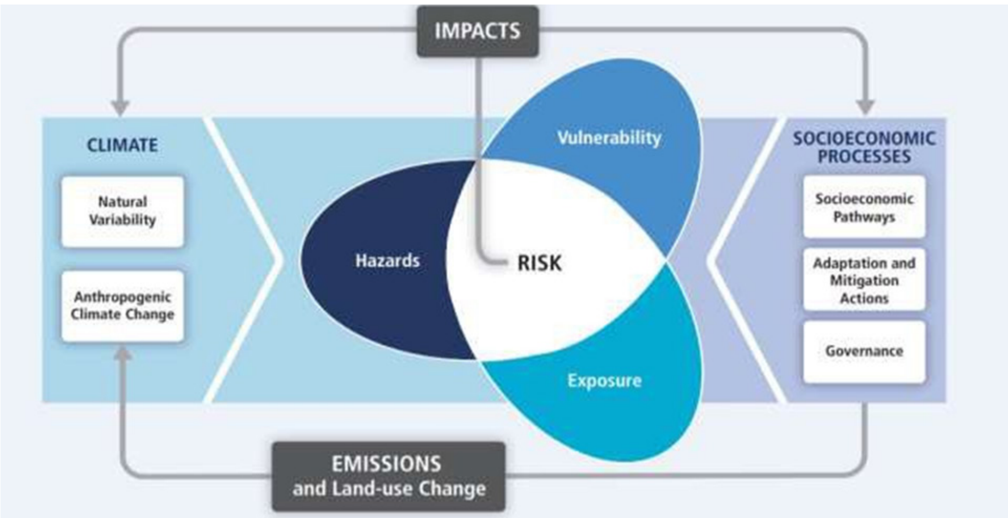
According to the Intergovernmental Panel on Climate Change (IPCC), climate risk results from the interaction of hazard, exposure, and vulnerability. In the IPCC online glossary[1] the revised definition of **Risk** [used in the Special Report on Climate Change and Land and Special Report on the Ocean and Cryosphere in a Changing Climate – SRCCL (09/2019)] is the following, and is shown graphically in Figure 2 (from IPCC, 2014):

Climate Change Risk is defined as the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.

- In the context of climate change impacts, **risks** result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. **Hazards, exposure**, and **vulnerability** may each be subject to uncertainty in terms of **magnitude** and **likelihood of occurrence**, and each may change over time and space due to **socio-economic changes** and **human decision-making**.
- In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals. Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.

Source: IPCC online glossary (https://apps.ipcc.ch/glossary/)

Figure 2 l Risk assessment framework for evaluating climate change risks (IPCC, 2015)



Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability.

Source: IPCC's Fifth Assessment Report (WGII AR5) (Field, et al., 2014)

1 https://apps.ipcc.ch/glossary/

The following definitions of Hazard, Exposure, Sensitivity and Adaptive Capacity are used:

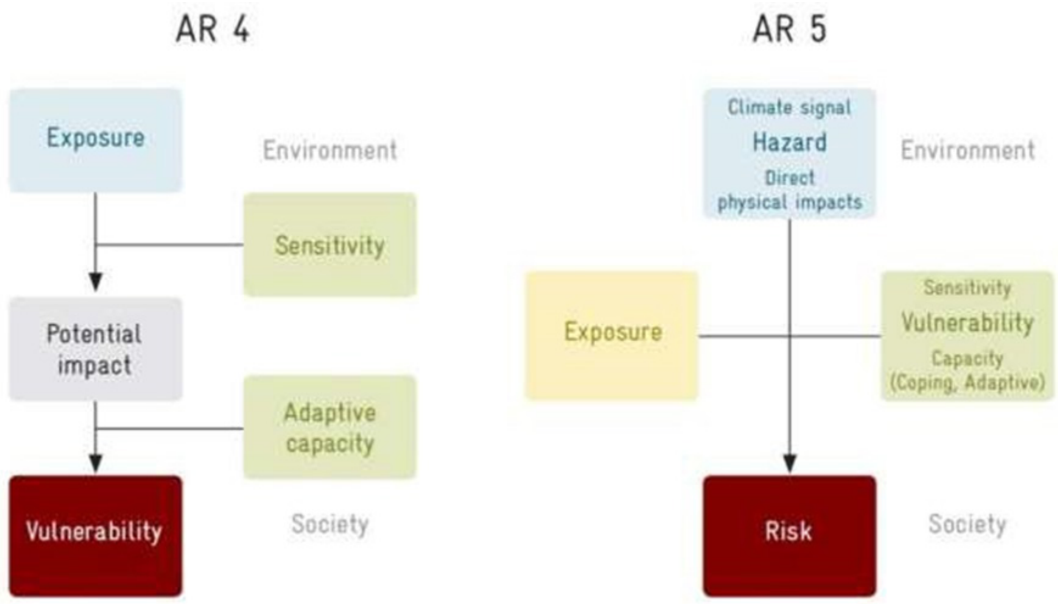
- **Hazard** is the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
- **Exposure** entails the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
- **Vulnerability** deals with the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including **sensitivity** or susceptibility to harm and lack of **capacity to cope and adapt**.
- **Sensitivity** refers to the degree to which a system is affected by, or responsive to a hazard. In other words, sensitivity captures the potential of a system to be impacted by a hazard. Sometimes sensitivity is determined by the criticality of the service that the system provides. For example, a community uses a road located close to the low-lying area of the coast as its main access to a major hospital. In the past, this road has been inundated during a storm event making access to the hospital difficult. Because the hospital provides such an essential service, this community should be considered more sensitive to coastal inundation event.
- **Adaptive Capacity** is the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Source: IPCC online glossary (https://apps.ipcc.ch/glossary/)

In summary, a **climate risk** (e.g. drought damage in agriculture) results from interactions between **climate-related hazards** (e.g. the frequency and intensity of droughts) with **exposure** (e.g. agriculture land) and **vulnerability** (e.g. drought resistance of crops, presence or absence of irrigation) of natural and human systems.

It is important to note the change in the definitions used for determining vulnerability and risk, as discussed above, between the fourth (AR4) and fifth (AR5) assessment reports as shown in Figure 3.

Figure 3 | Change in the conceptual approach to climate change risk and vulnerability assessments



Source: (Zebisch, et al., 2021)

3. Overview of the Approach

A Climate Change Risk and Vulnerability Assessment (CCRVA) follows a general risk assessment process as shown in Figure 4. The process consists of the following phases and main steps:

Phase 1: Risk Identification

1. Establish the context
2. Identify critical climate related risks
3. Analyse risks (past, current, and future)

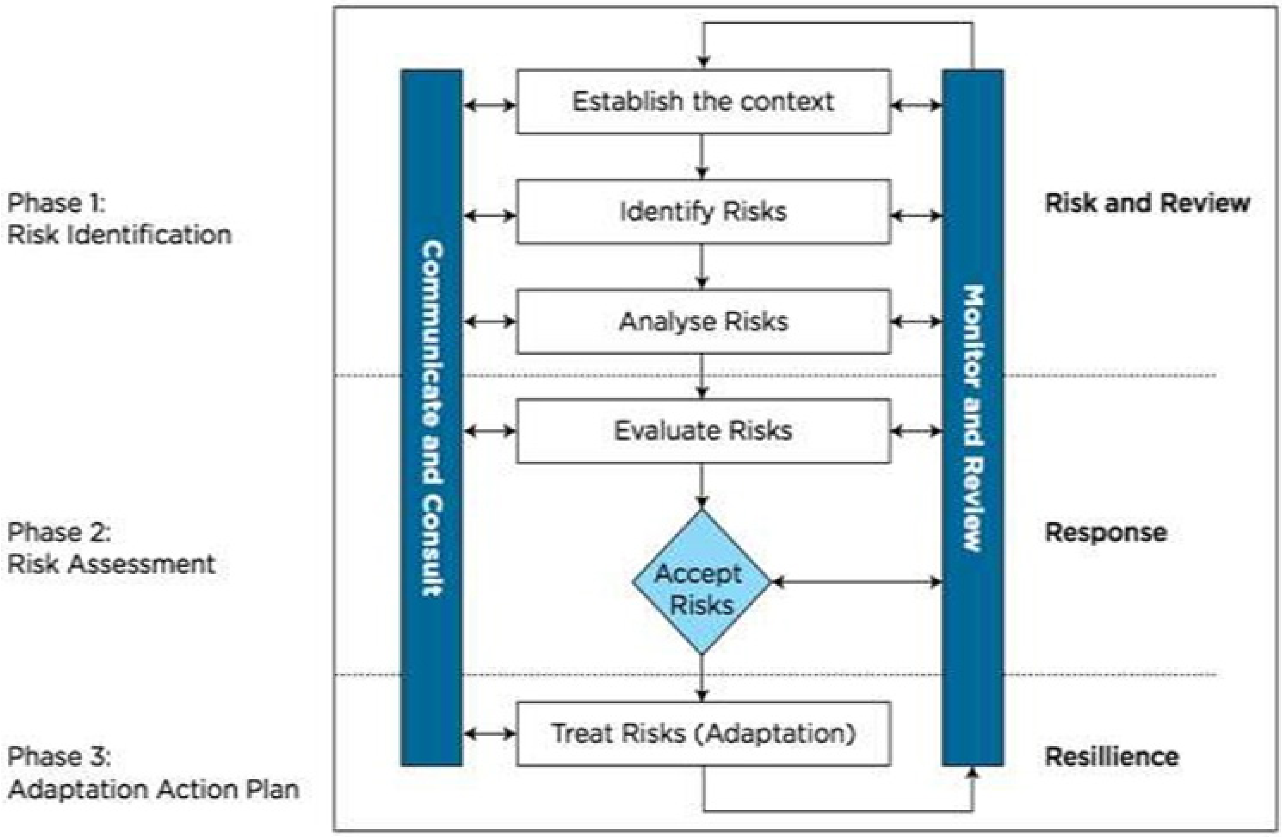
Phase 2: Risk Assessment

4. Evaluate Risks
5. Accept or Reject Risks

Phase 3: Adaptation Action Plan

6. Treat Risks (Adaptation)

Figure 4 I General overview of the risk assessment process



The steps covered under this assignment relate to Phase 1 (Risk Identification) and Phase 2 (Risk Assessment). The results of the risk assessment can then be used to inform adaptation planning.

3.1. Step 1: Establish the Context

Prior to undertaken a climate change risk assessment (CCRA), it is necessary to do the following:

a. Determine the spatial resolution and focus of the CCRA

b. Determine the level of the risk assessment dependent on the purpose and available resources,

c. Outline the process to be followed and review the availability of data,

d. Identify the key stakeholders to help in undertaking the risk assessment and for implementation,

3.1.1. Defining the Spatial Resolution and Focus

A risk and vulnerability assessment can be undertaken at multiple spatial levels and with different intended objectives (see box below). In general, these can be summarised as follows and including examples for where these different levels of risk and vulnerability assessment are applied in Ghana:

- National level CCRVA
    - Summary by MMDA (4th National Communication) – identify priority MMDAs for adaptation.
    - Summary by Sector (Infrastructure, Agriculture, Energy, etc) – identify hot hotspot risk areas and potential for national or sector level adaptation strategies and plans/interventions.
- District/MMDA/City Level CCRVA
    - **Summary by sector/risk domain (semi-qualitative risk and vulnerability assessment)**
    - Summary by ward (top-down indicator based spatial risk and vulnerability assessment)
- Community/Local Level CCRVA
    - Assessment of individual/vulnerability communities and/or groups (qualitative assessment)
- Individual Asset/Project Based CCRVA
    - E.g., Lake Volta Hydropower plant, ports, major roads, etc.

National Level Climate Change Risk and Vulnerability Assessment

As part of the Fourth National Communication (FNC) and national level climate vulnerability assessment was undertaken to determine the overall climate vulnerability for each of the 216 MMDAs.

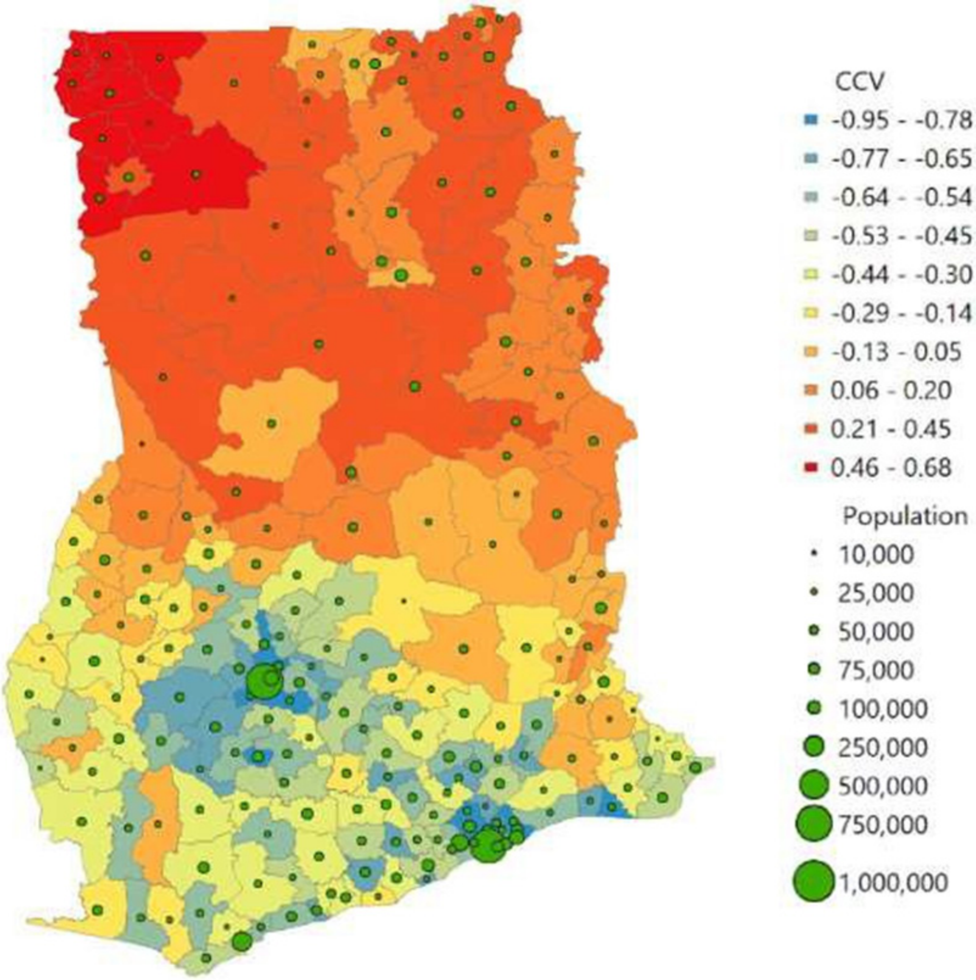
The national level vulnerability assessment undertaken for the FNC was based on the original AR4 definition of climate change vulnerability (CCV) as (Exposure x Sensitivity) – Adaptive Capacity. Data was collected at the MMDA level for a range of representative variables and used to determine a CCV score for each MMDA based on the relative ranking for each of the representative variables.

For this analysis exposure to climate change risk was determined based on the relative change in temperature and precipitation derived from an ensemble of 10 general circulation models downscaled using five regional climate models and for four sub-parameters including percentage change by: i) 2060 under RCP2.6; ii) 2060 under RCP 8.5; iii) 2080 under RCP 2.6; and iv) 2080 under RCP 8.5. Sensitivity was determine based on the population employed in the agriculture sector, and adaptive capacity was based on the results from the

District League Table which incorporates measures of education, sanitation, rural water availability, health, security, and governance effectiveness to assess development across Ghana's 2016 districts and several other development related variables.

The final derived CCV for each district as well as the total population is shown in Figure 5.

Figure 5 | Climate change vulnerability scores for Ghana's 216 districts (Fourth National Communication)



National Flood and Drought Risk Maps (Fourth National Communication)

As part of the Fourth National Communication (FNC), national level flood hazard and drought risk maps were also produced for current and future conditions (2050). The flood hazard map was based on the Height Above Nearest Drainage (HAND) method, while the drought hazard maps were produced based on the 14-year average of the cumulative rainfall deficit (i.e. evaporation minus rainfall) under current and future climate conditions. The resulting current and future drought hazard maps for Ghana (Figure 7) reflected the number of days a deficit threshold of 600mm is exceeded.

The future flood hazard map was based on the IPCC's A1B and A2 emissions scenario, which represent a high level of global greenhouse gas emissions and so are comparable with the more recent RCP8.5 and SSP5 global emission scenarios. The results of the analysis (Figure 6), showed that the areas that are likely to experience flood would remain relatively unchanged (i.e. the exposure) even with higher emission scenarios, but that the frequency and magnitude of these events (i.e. the hazard) might change which would impact on the overall likelihood and associated flood risk, but that this was dependent on the level of interventions such as flood protection works and early warning systems as well as the specific vulnerability and adaptive capacity of the assets and communities.

Figure 6 | Flood hazard maps showing the distribution of the likelihood of an area to experience a flood under current conditions (left) and future (2050) conditions (Fourth National Communication).

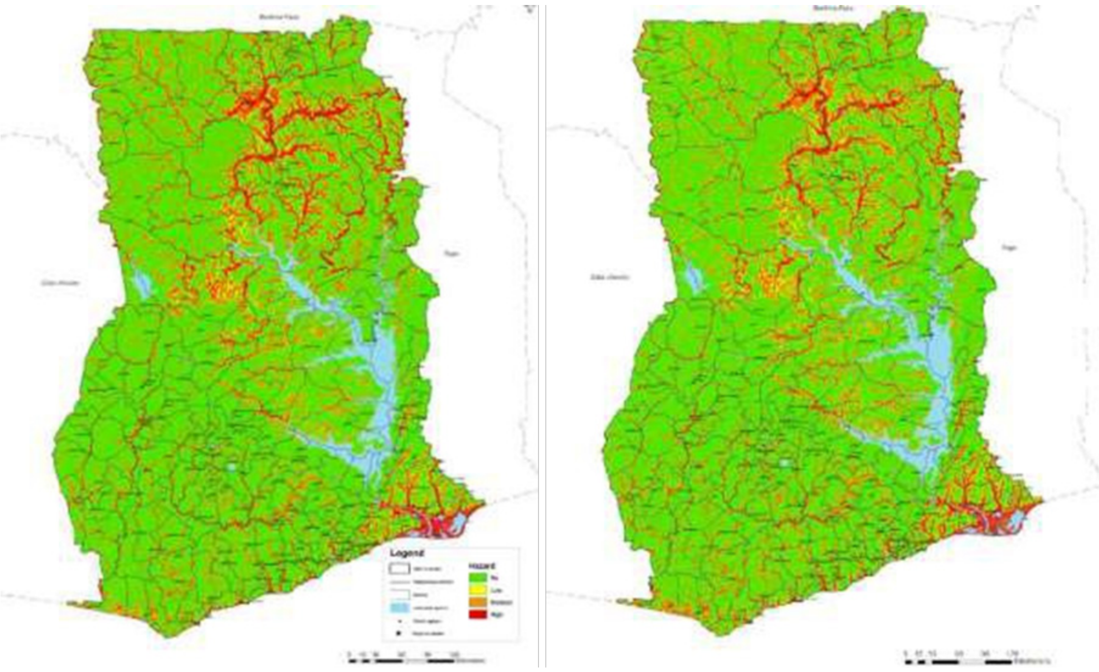
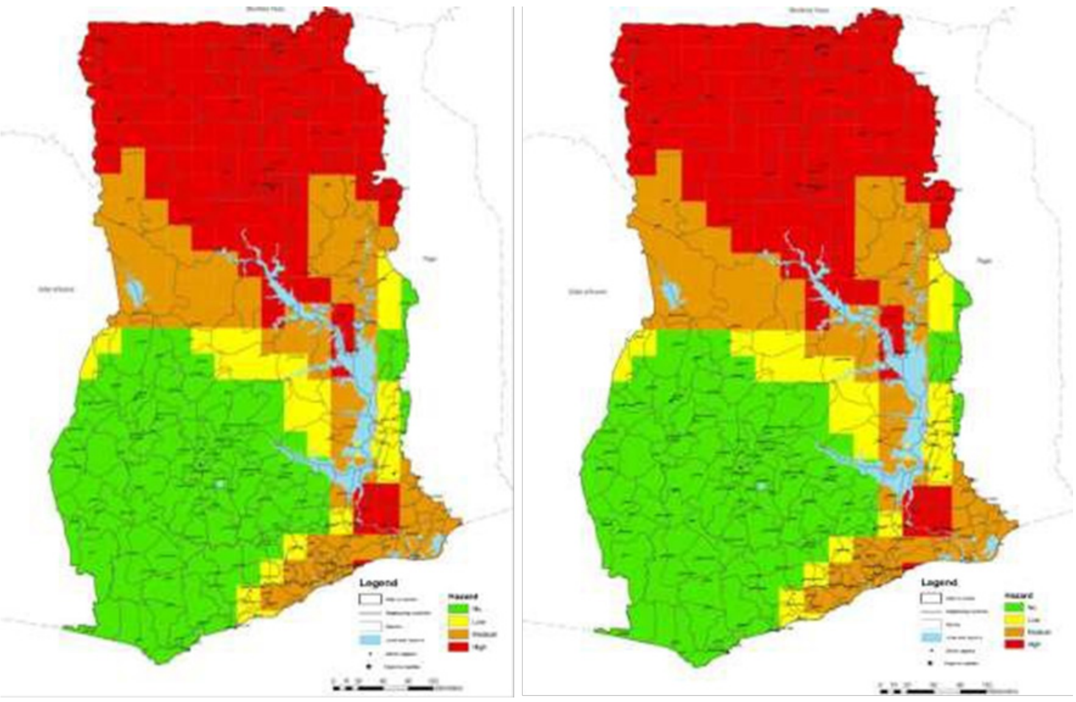


Figure 7 | Current and Future Drought Hazard Maps for Ghana (Fourth National Communication)



National Sector Level Climate Risk and Vulnerability Assessments

Sector specific climate risk and vulnerability assessments have been undertaken relatively recently for both Infrastructure (Adshead, et al., 2022) and Agriculture (Choudhary, Christienson, D'Alessandro, & Josserand,

2016) sectors in Ghana. These reports present a summary of the overall climate change related risks for each of these two sectors and recommendations for adaptation that can be used to inform a National Adaptation Plan (NAP). The outcomes from these national studies are also necessary to support the local level risk assessments at the MMDA level.

Selected outcomes from the national sector level climate change risk and vulnerability assessment for Ghana include the expected change in crop suitability for staple crops such as groundnuts, sorghum, maize and cassava and different future climate change scenarios (Figure 8) and an assessment of the climate change risk associated with increased flooding of roads across Ghana (Figure 9).

Figure 8 | Modelled change in crop suitability for groundnut, sorghum, maize, and cassava by 2050.

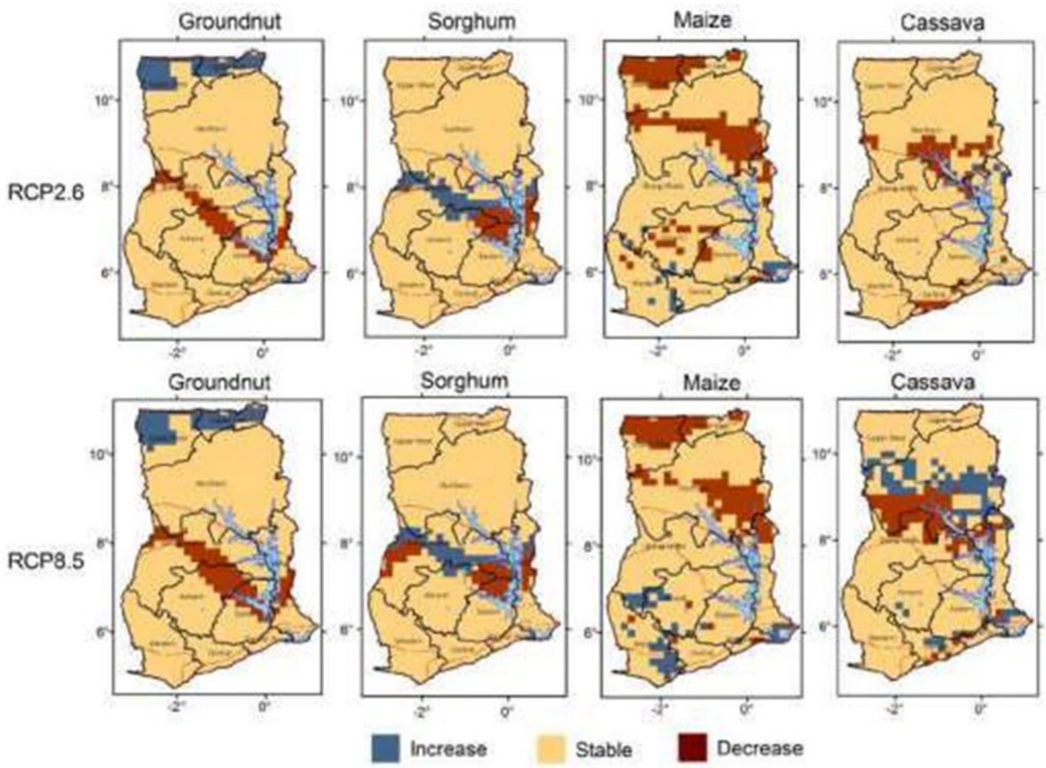
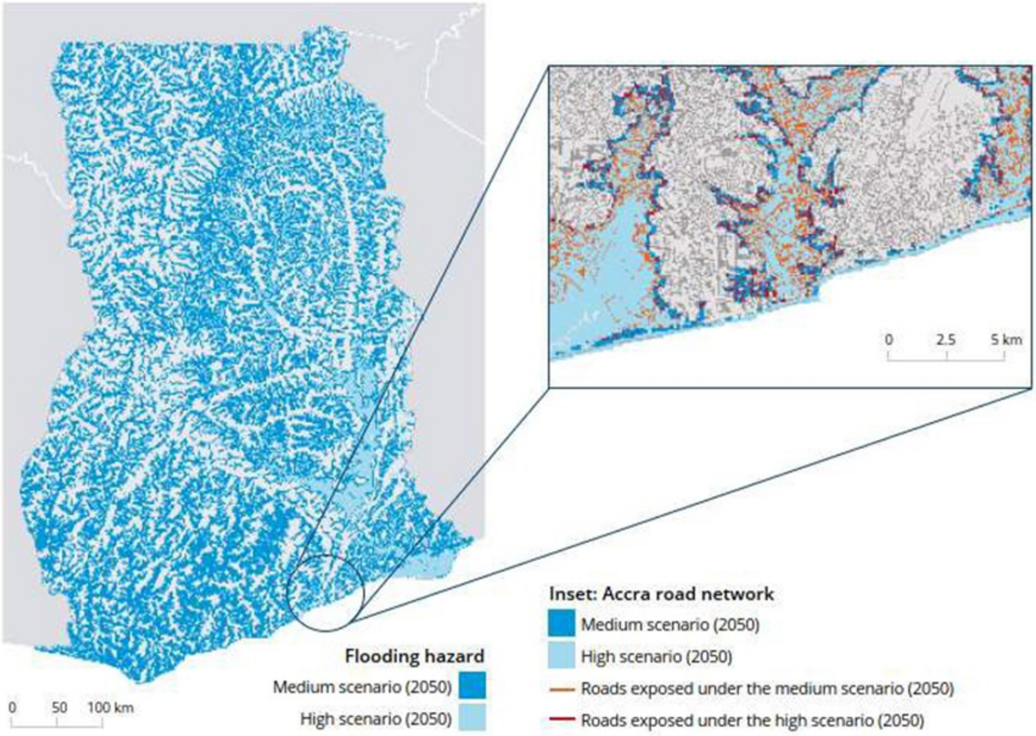


Figure 9 | Flood hazard mapping of Ghana's road network for medium and high climate change scenarios.



Local/District/City Level Climate Change Risk and Vulnerability Assessments

Local or District or City level climate change risk and vulnerability assessments can either focus on specific sectors or risk domains and evaluate these at the level of the district or MMDA, based on the specific nature of this risk domains in each MMDA, or they can consist of a finer resolution climate risk and vulnerability hazard mapping to assist in identifying the most vulnerable or high risk areas within a district that can become the focus of investments in reducing climate change related risks.

- Sector or Risk Domain focused CCRVAs (semi-quantitative)
- Spatially based indicator mapping approach (quantified)

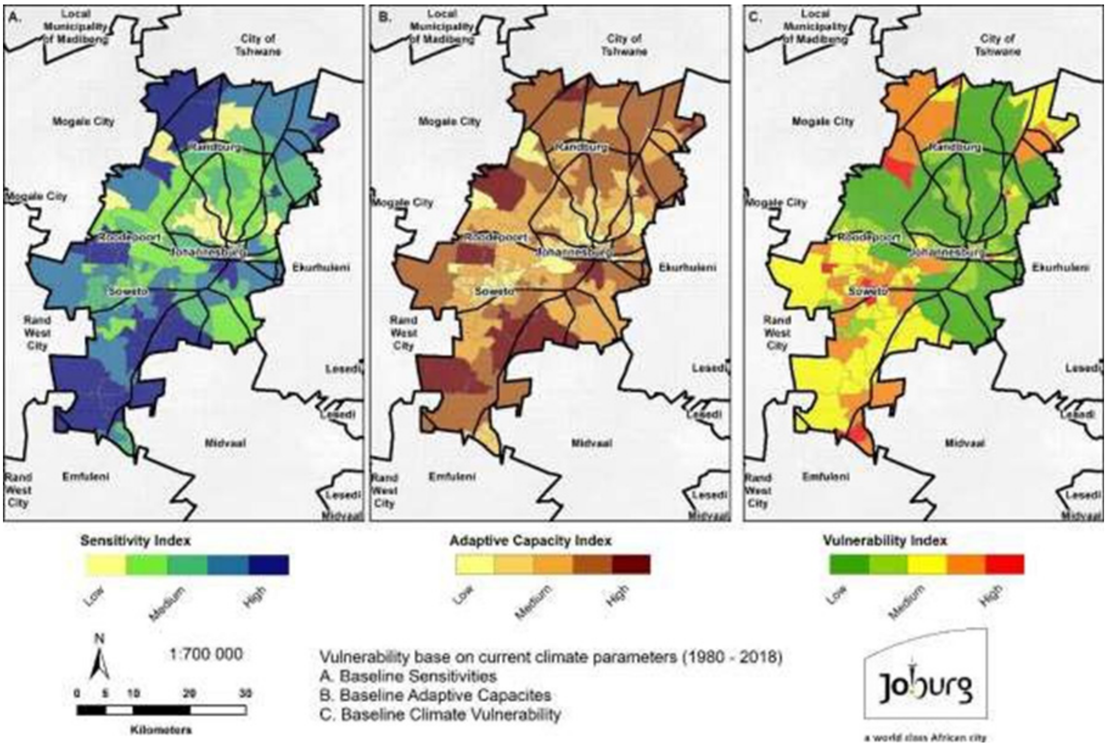
For this study, the approach used will be based on the identified critical first and second order risk domains and determines the overall climate change risk at the MMDA level, rather than the finer scale mapping of climate change risk and vulnerability within an individual MMDA.

For a sector or risk domain focused CCRVA, the basic approach is to identify the relevant key risk domains and then to determine the relevant climate hazards and indicators for exposure and sensitivity as well as potential for adaptive capacity relevant to that specific risk domain, or sub-sector.

These are then used to determine the likelihood and consequence of the specific impact which are then combined using a risk matrix to determine the priority risks and vulnerable sectors.

An example of a climate risk and vulnerability mapping undertaken at city scale is shown in Figure 10.

Figure 10 | Example of climate risk and vulnerability mapping at city level (source: City of Johannesburg)



Community Based CCRVAs

In terms of potential interventions, or for identified high risk communities, it may be necessary to undertake a more detailed community level CCRVAs. This would typically be a bottom-up approach with extensive stakeholder engagements to identify the specific level of sensitivity and exposure to climate related risks. An example of the final risk identification matrix is shown in Table 1, below.

Again, this level of detailed engagement is beyond the scope of the current approach, although some aspects of this will be incorporated into engaging with stakeholders from the priority risk sectors.

Table 1 I Example matrix of climate change vulnerability (Exposure x Sensitivity) for a target community.

Sensitivity[2] of natural and human systems	Exposure[1] to climate threats (hazards): Drought	Flood	Sea level rise	More Intense Rain Events	More Variable Rainfall	Increasing temperature and heat waves	Change in seawater temperature, pH and oxygenation	Calema (giant waves)
Natural systems and ecosystem services								
1. Coastal and marine resources and ecosystems								
1.1. Coastline	(1.2)	(2.3)	(3.4)	(3.3)	(1.2)	(1.2)	(1.1)	(5.5)
1.2. Marine currents (marine temperature and circulation)	(1.2)	(2.2)	(4.3)	(2.2)	(2.2)	(1.2)	(2.3)	(4.5)
1.3. Marine biodiversity and fish fauna	(1.2)	(3.3)	(4.3)	(2.2)	(2.1)	(1.2)	(4.2)	(4.3)
1.4. mangrove ecosystems	(3.4)	(3.3)	(5.4)	(3.3)	(4.2)	(2.3)	(4.3)	(4.4)
1.5. Estuarine ecosystems and other marine wetlands	(2.3)	(3.2)	(4.5)	(3.2)	(2.2)	(3.3)	(2.2)	(4.3)
2. Terrestrial resources and ecosystems								
2.1. Vegetation, terrestrial flora and forests	(1.3)	(2.2)	(2.1)	(2.2)	(3.2)	(2.2)	(1.2)	(1.1)
2.2. Surface water resources	(1.3)	(3.3)	(3.2)	(2.2)	(2.3)	(2.2)	(1.2)	(1.1)
2.3. Watersheds	(1.3)	(4.4)	(3.2)	(3.1)	(2.3)	(2.2)	(1.2)	(1.1)
2.4. Pedological resources	(2.3)	(3.3)	(3.1)	(2.1)	(2.2)	(3.3)	(1.2)	(1.1)
2.5. Land fauna	(1.3)	(3.3)	(2.1)	(3.2)	(3.1)	(3.3)	(1.2)	(1.1)
Human systems and livelihoods								
3. Socio-economic sectors and livelihoods								
3.1. Agriculture	(1.3)	(4.5)	(2.3)	(3.3)	(4.4)	(2.4)	(2.2)	(1.1)
3.2. Fishing and aquaculture	(1.2)	(3.3)	(3.2)	(2.2)	(2.2)	(2.2)	(3.3)	(4.5)
3.3. Oil explorations	(1.3)	(2.2)	(3.3)	(3.4)	(2.2)	(2.2)	(2.2)	(3.4)
3.4. Mining industry and exploration	(1.1)	(2.2)	(2.2)	(3.4)	(2.2)	(2.2)	(2.2)	(3.3)
3.5. Transport (roads and bridges)	(1.2)	(5.5)	(3.3)	(3.5)	(2.2)	(2.2)	(2.2)	(2.2)
3.6. Transport (ports)	(1.2)	(4.4)	(3.4)	(2.4)	(1.2)	(1.1)	(2.2)	(5.5)
3.7. Transport (airport)	(1.2)	(3.3)	(2.2)	(2.2)	(1.1)	(1.1)	(1.1)	(2.2)
3.8. Housing/building infrastructure	(1.3)	(3.5)	(2.2)	(2.4)	(1.1)	(2.2)	(1.1)	(2.4)
3.9. Trade and services	(1.2)	(4.4)	(2.2)	(2.4)	(2.2)	(2.2)	(2.2)	(2.2)
3.10. Tourism	(1.3)	(3.3)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(2.3)
3.11. Water and sanitation	(1.3)	(3.4)	(2.3)	(2.2)	(2.4)	(2.3)	(1.1)	(2.2)
3.12. Energy	(1.2)	(2.3)	(2.2)	(2.2)	(1.1)	(2.2)	(2.2)	(2.2)
3.13. Public health and safety	(1.2)	(4.5)	(3.3)	(4.4)	(3.5)	(2.2)	(2.2)	(4.3)
3.14. Forestry/Forest exploration	(1.3)	(2.3)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(1.1)
3.15. Urbanization & urban areas	(1.2)	(4.4)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)	(2.2)
4. Human systems and issues of inequality and/or potential conflict								
4.1. Internal migrations	(2.3)	(3.3)	(1.4)	(2.3)	(2.3)	(1.2)	(1.2)	(2.4)
4.2. Inequalities and gender issues	(2.2)	(2.2)	(2.3)	(2.2)	(2.2)	(1.2)	(1.2)	(2.3)
4.3. Indigenous and/or marginalized groups	1.1	(1.1)	(2.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)

1 Exposure: 1 – Very low; 2 – Low; 3 – Average; 4 – High, 5 – Very high

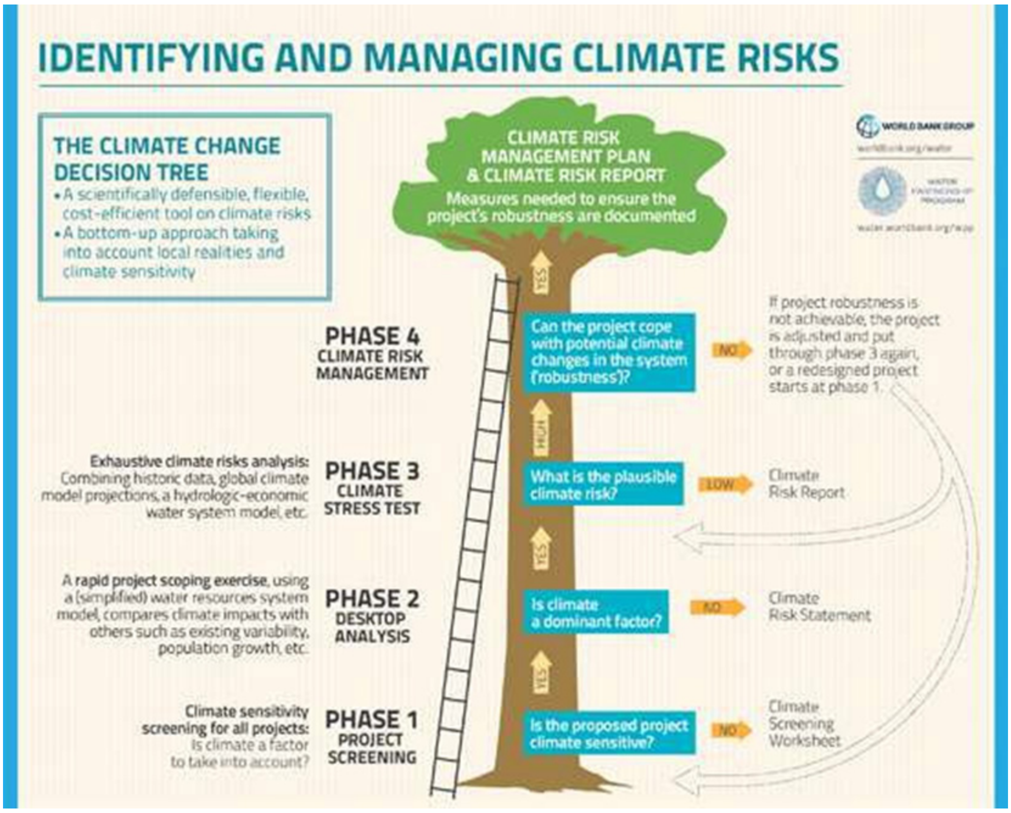
2 Sensitivity: 1 – Negligible; 2 – Low; 3 – Moderate; 4 – High, 5 – Catastrophic

Asset/Project Based CCRVAs

Several tools and approaches are available for undertaking climate change risk and vulnerability assessments for individual assets. These would include for individual buildings, roads or bridges, current and proposed dams and hydropower schemes, water supply systems or planned irrigation schemes. Increasingly asset based CCRVAs are adopting a bottom-up approach such as outlines in the World Bank Decision Tree Framework (Figure 11), that focus on developing a better understanding of the underlying risks and vulnerabilities of the system rather than a top-down approach where selected climate scenarios are applied to model a range of potential impacts. The bottom-up approach has the advantage in that it can account for the uncertainties associated with individual climate models and supports an approach to decision making under uncertainty.

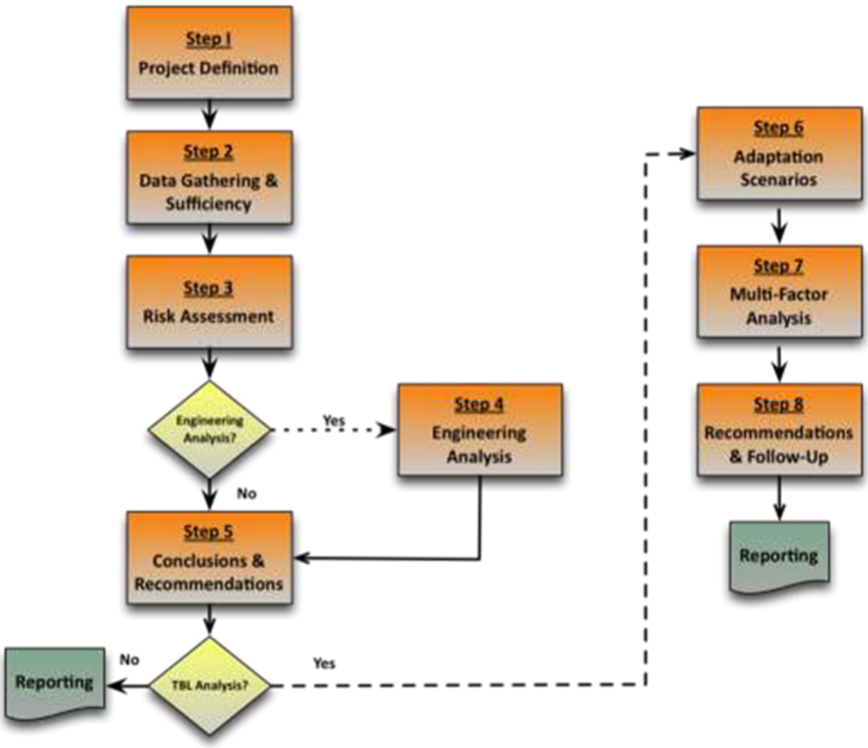
Another example of an existing framework for undertaking a climate change risk and vulnerability assessment for a specific asset (e.g. a dam) is the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol developed by Engineers in Canada in collaboration with Natural Resources Canada (NRCan). THE PIEVC is a structured, rigorous qualitative process for assessing the vulnerabilities and risks of individual infrastructures or infrastructure systems to current and future extreme weather events and climatic change using the five steps laid out in the Protocol (Figure 12)

Figure 11: Overview of the World Bank Decision Tree Framework



Source: (Ray & Brown, 2015)

Figure 12: The PIEVC protocol process (Source: Natural Resources Canada)

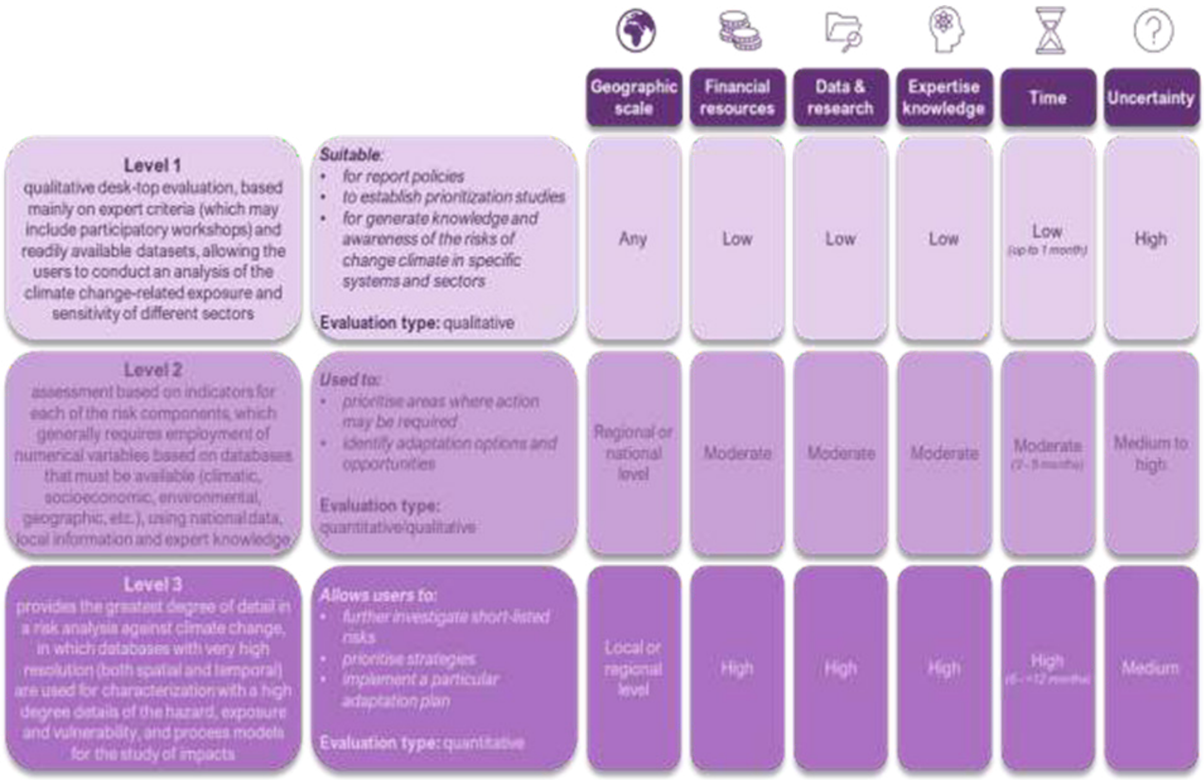


3.1.2. Determining the Level of the Risk Assessment

Climate Change Risk Assessments (CCRAs) generally take either an "impacts driven" or "vulnerability driven" approach. In the assessing the priority risk domains for the specified ecosystem types, both the impacts and the general vulnerability of the country will need to be understood in order inform a detailed risk assessment process. The methodology outlined below demonstrates the methodological approach to develop context specific risk assessments, at sub-national (i.e., MMDA) scale, with the objective of producing outputs which can help to inform the national adaptation plan (NAP) for Ghana.

Based on the degree of detail in a risk analysis against climate change, three levels of risk analysis displayed in Figure 13 should be considered. The recommended level of analysis for the sub-national risk assessments for individual MMDAs in Ghana is aligned with that of a **Level 2 risk assessment.**

Figure 13 I Risk assessment levels of analysis



Source: Adapted from CoastAdapt[2]

The level of detail of the analysis required to support the CCRA at the sub-national level, i.e. MMDA, will be determined by the assessment of current vulnerability, on the available information and on information from previous studies that, particularly involving an assessment of climate related risks.

In Ghana (and other countries in Africa) the availability of hydrological and meteorological information is a major challenge in terms of the validation of any climate or hydrological model and a major challenge in terms of picking up trends and making an early assessment of climate change shifts or even in terms of more short-term early warning systems for floods and droughts. In some ways this is being addressed through more remote sensing information, but there is not a long track record of information. Understanding the non-climate related risks that contribute to the vulnerability will be critical and particularly in terms of identifying what are the most significant climate change risks and making recommendations for

2 https://coastadapt.com.au/how-to-pages/how-to-conduct-a-climate-change-risk-assessment

adaptation. An understanding of the likely future socio-economic development scenarios affecting the induvial MMDAs is also critical in terms of identifying future risks.

3.1.3. Outline the Basic Process to be Followed

Climate risks, according to the IPCC, are potential adverse consequences for human or ecological systems caused by climate extremes and climate change. A climate risk (e.g. drought damage in agriculture) results from interactions between climate-related hazards (e.g. the frequency and intensity of droughts) with exposure (e.g. agriculture land) and vulnerability (e.g. drought resistance of crops, presence or absence of irrigation) of natural and human systems.

Due to the complex nature of climate related risks with its interplay of hazard, exposure and vulnerability factors and the high uncertainty in data and process understanding, climate risks generally cannot be measured in a deterministic way. Instead, a risk assessment is in most cases a synthetic assessment based on a pool of information that consists of facts (e.g. climate observations, past events), simulations (e.g. climate projections, hydrological models), but also semi-quantitative or qualitative surveys, expert knowledge and narratives.

The methods adopted for risk assessments are often a combination of top-down assessments, which are usually based on quantitative data (e.g. census data, downscaled climate models) and bottom-up methods, which usually employ local knowledge in identifying risks qualitatively. Indicator-based risk assessments use sets of indicators that can be both quantitative and qualitative and can be assessed both through modelling and/or stakeholder consultation.

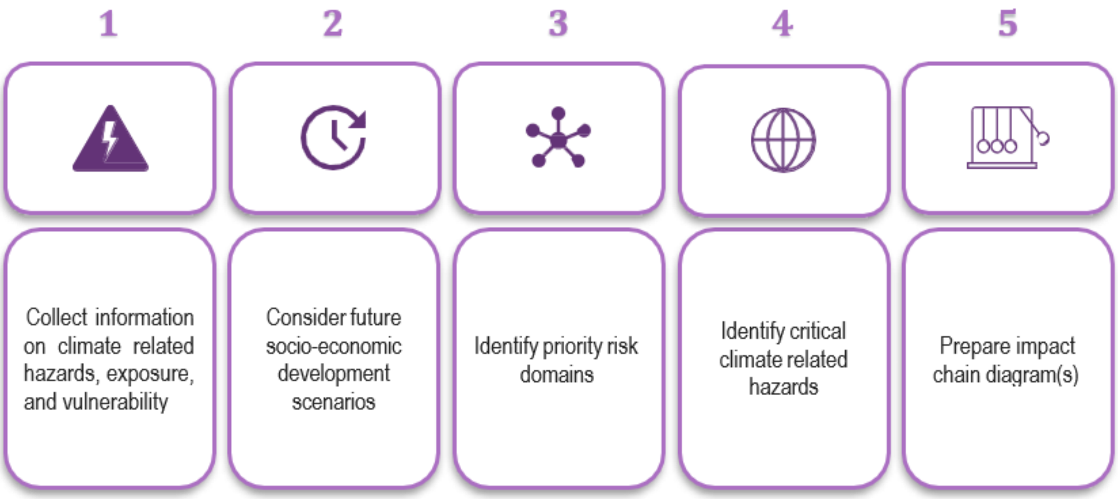
3.1.4. Identify Key Stakeholders and Vulnerable Communities

Climate change risk assessment should be a participatory process, sensitive to issues of gender, youth and the possible presence of vulnerable groups (indigenous peoples, for example). To this end, the involvement and commitment in the assessment process of all interested and affected parties (I&APs), including members of local communities, should be integrated throughout the risk assessment process and phases. The level of engagement will vary depending on the aims and objectives of the study, the relevant scope and the process to be followed.

3.2. Step 2: Identify Relevant Climate Change Related Risks

The objective of Step 2 in the risk assessment process is to identify the critical climate related risks by way of developing a better understanding of the local conditions and key economic sectors and a first order assessment of the most critical climate related hazards. The main tasks to be undertaken in Step 2 of the Risk Assessment Process are listed in Figure 14. This information is then used to develop impact chains which can then be used to identify specific indicators for analysis under Step 3.

Figure 14 | Main tasks to identify climate change related risks



3.2.1. Collect information on Climate Related Hazards, Exposure and Vulnerability

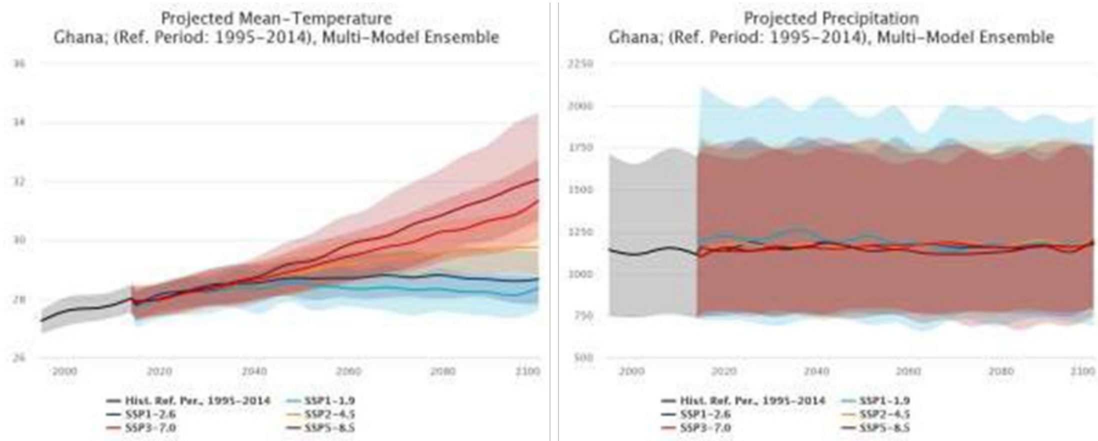
In order to identify the priority risk domain and the relevant climate hazards it is necessary to develop a better understanding of the context and status quo assessment of the focus area for the risk assessment (i.e. the MMDA). This would include a high-level summary of physical and socio-economic factors including location, current climate, population statistics, key economic sectors, development plans and objectives, etc. These are summarised in a short summary of the MMDA.

The **status quo** assessment should provide the following information:

Review of the climate change policies and institutional development environment, to understand the national government strategies and policies context

- Information on past and current climate related impacts and risks. Learning from the past and present situation is crucial for identifying obvious or hidden vulnerabilities of the system. This includes data on past events and their impacts as well as trends.
- Current climate situation and future trend projections of various climate variables and hazards (e.g. average temperature, heat days, intensive rainfall events, snow cover), based on a range of different climate scenarios. Examples of this are the plots in Figure 15.
- Data and information on exposure and vulnerability. This includes data on current socio-economic conditions such as on population density or age structure but might also include qualitative information such as on institutional capacity to cope with a specific risk.

Figure 15 | Mean temperature and precipitation scenarios for Ghana



Source: Climate Change Knowledge Portal (World Bank Group, 2021)

3.2.2. Consider Future Socio-Economic Development Scenarios

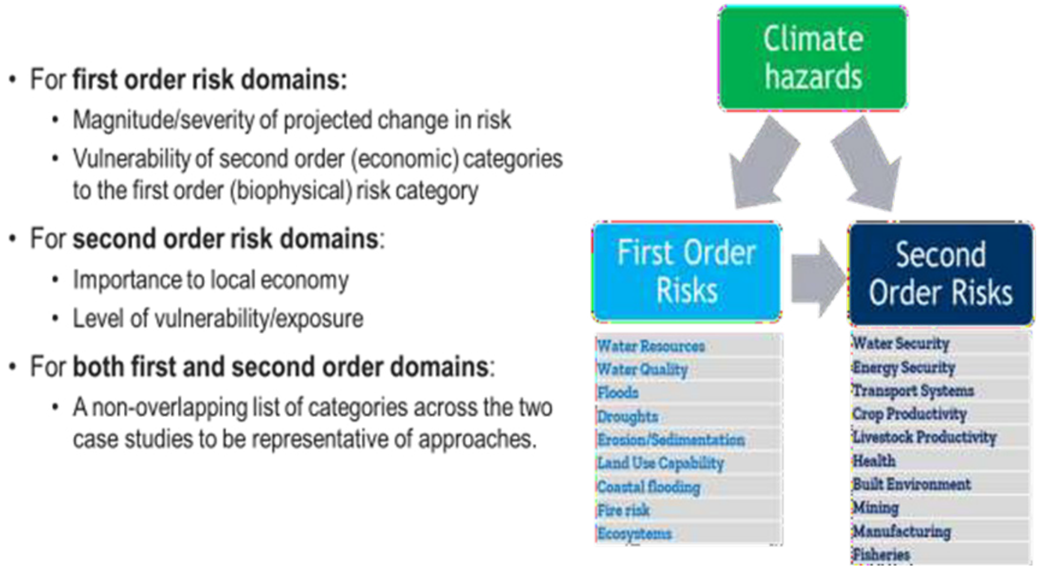
For some categories of climate risks, such as water related risks or risks related to agriculture, simulation or scenarios on future risk approaches exist. Future water availability or expected yield can be simulated with models considering different climate scenarios. However, such simulations are mostly limited to physical impacts of a hazard and do not fully consider vulnerability factors. They should therefore be interpreted as proxies of what could happen and should be complemented by further expert knowledge. Future socio-economic development and other non-climatic factors and trends such as demographic change, investments in critical infrastructure, use of resources or market trends, have a significant influence on a vulnerability to climate change. While it is often difficult to get any information about potential future socio-economic development, such trends are often as important for determining risk as climate change itself. For example, the future risk of heat related health problems is most likely not only increasing because the frequency and intensity of heatwaves is increased, but also because the population in cities is increasing and the population is aging. Similarly with more people living in cities there is increasing pressure of housing including in flood prone areas.

3.2.3. Identify Priority Risk Domains

To determine the specific priority risk domains considered for each of the MMDAs, it is necessary to consider the location and the specific economic activities in each area that would determine which would be the most appropriate risk domains to address as part of the CCRVA.

The criteria in selecting first and second order risk domains is shown in Figure 16.

Figure 16 I Criteria in selecting first and second order risk domains



The provisional list of first and second order risk domains that could be considered for the selected MMDA should be developed and presented to the key stakeholders to determine the relative importance to the MMDA with accompanying justifications. It should be noted that there are clearly interconnectivities between the first and second order risk domains that require refinement of the final priority risk domains. For example, in order to investigate the potential impact on water security (i.e. water supply and sanitation) as a second order risk domain, it will also be necessary to consider the impact on water resources as a first order risk domain. Similarly, to investigate the possible impact on transport systems and the built environment it may be necessary to analyse river flooding as well as coastal flooding and sea level rise in the coastal zones. For agriculture it will also be important to consider water resource availability. In addition, it will be important to distinguish between agricultural impacts on crops and livestock as they have different climate dependences. In both cases they are impacted by primary climate variables such as precipitation and temperature, but these impact differently on crop production potential, and extreme heat which affects livestock productivity.

A preliminary list of first and second order risk domains considered relevant for Tamale Metropolitan and Sekondi-Takoradi MMDAs (presented in table below) was developed and presented to the key stakeholders to determine the relative importance to each MMDA.

Summary of considerations for identifying critical first and second order risk domains for Tamale and Sekondi-Takoradi

MMDA	Second order risk domains	First order risk domains
Tamale	Tamale city and the region around it, are recognised as the "breadbasket" of Ghana; the potential climate change impacts on **agriculture** and **livestock farming** will be a very important consideration in this region.	Important first order risks that support agriculture and water security are **water resources**, **droughts**, and **natural ecosystems**, particularly in terms of the potential for ecosystem-based adaptation. Hence these are proposed as the key first order risk domains for Tamale City.
	Water security, in terms of reliability of supply, is a significant challenge for all cities in Ghana and is particularly sensitive to the impacts of climate change. This is likely to be of much greater concern in the dry land ecosystem region and so this is an important second order risk for Tamale.	
	The potential impact of heat on **human health** is another important second order risk domain. ThinkHazard classifies the extreme heat hazard in Tamale City as High	
Sekondi-Takoradi	An important economic sector is the **fisheries industry**, and this has already been highlighted as an area of concern due to possible climate change risks. A component of this is also the potential impact on **transport systems** (i.e. roads and ports), mainly due to sea-level rise, as well as the overall impact on the **built environment**, particularly for cities like Accra.	Critical first order risk domains that support fisheries, transport and the built environment include **coastal flooding** and **river flooding**, and in particularly areas where they overlap. **Upland and coastal ecosystems** are important in terms of ecosystem-based adaptation**.**
		It has been noted that there are several important **cultural sites** located on the coast near to Sekondi-Takoradi that could be impacted by **sea level rise** and increased **coastal flooding.**

3.2.4. Initial Assessment of Critical Climate Related Hazards

The preliminary critical climate related risks can be assessed using a tool like the **ThinkHazard! Tool.**[3]

This web-based tool uses open-source code and provides an overview of the hazards, for a given location, that should be considered in project design and implementation to promote resilience to climate disasters. This tool highlights the likelihood of different natural hazards affecting project areas (very low, low, medium, and high), provides guidance on how to reduce the impact of these hazards and where to find more information. The information about climate indicators is obtained from the Climate Change Knowledge Portal (CCKP) published by World Bank Group and from additional studies. Hazard data may be available with global, regional, or national coverage, depending on the scope of the generating

3 https://thinkhazard.org/en/

project, or intended primary use of the data. The results of this initial screening tool, however do need to be considered in context and also with information provided based on the current situation. For example the initial screening results for Tamale and Sekondi showed urban flooding to be of low risk, and yet there is increasing evidence that this is a major area of risk.

MMDA	Hazard										
	River flood	Urban Flood	Flood	Earthquake	Landslide	Tsunami	Volcano	Cyclones	Water Scarcity	Extreme Heat	Wildfire
Tamale	Medium	Very Low	N/A	Very Low	Very low	N/A	N/A	N/A	Low	High	High
Sekondi Takoradi	Low	Low	Medium	Very low	Very low	Low	N/A	N/A	Medium	Medium	Medium

Source: ThinkHazard! (Global Facility for Disaster Reduction and Recovery (GFDRR) , 2022)

These results show that the critical climate related risks for Tamale or Extreme Heat (high) and Wildfire (high) and River Flooding (medium), while the critical climate related hazards for Sekondi-Takoradi are Coastal Flooding, Water Scarcity, Extreme Heat and Wildfire (all at medium level risk). It is interesting to note that urban flooding was not consider high risk and yet, there is increasing evidence that an increase in urban flooding is a major are of concern for both these locations. This is likely because Thinkhazard is based mainly on the result of the climate models, i.e. based on the relative change in critical climate variables and does not necessarily take into considerations the underlying vulnerability of each location.

This shows why the results of these global tools need to be considered carefully and within context.

3.2.5. Prepare Impact Chain Diagram(s)

An impact chain diagram (or risk flow diagram) is an analytical tool that helps to better understand, systematize, and prioritize the factors that drive risk in a system. They are generally represented as a schematic that allows the key components of the conceptual framework presented in the previous section to be identified. This means that, for each impact that causes a risk, the components of the danger that cause it, the exposure that may be affected, and the vulnerability that relates the level of damage on the exposure to the magnitude of the risk are identified and represented. impact.

An example of a generic climate hazard impact chain is shown in Figure 17. This includes a summary of all the relevant climate hazards and the likely first and second order risk domains. Some of the main causal links are shown in the generic impact chain diagram, however this will need to be adapted for use in each specific MMDA based on the identified priority hazards and risk domains.

At the time of identifying the impact chain diagrams and their development, the particularities of each of the target MMDA must be considered, especially regarding to:

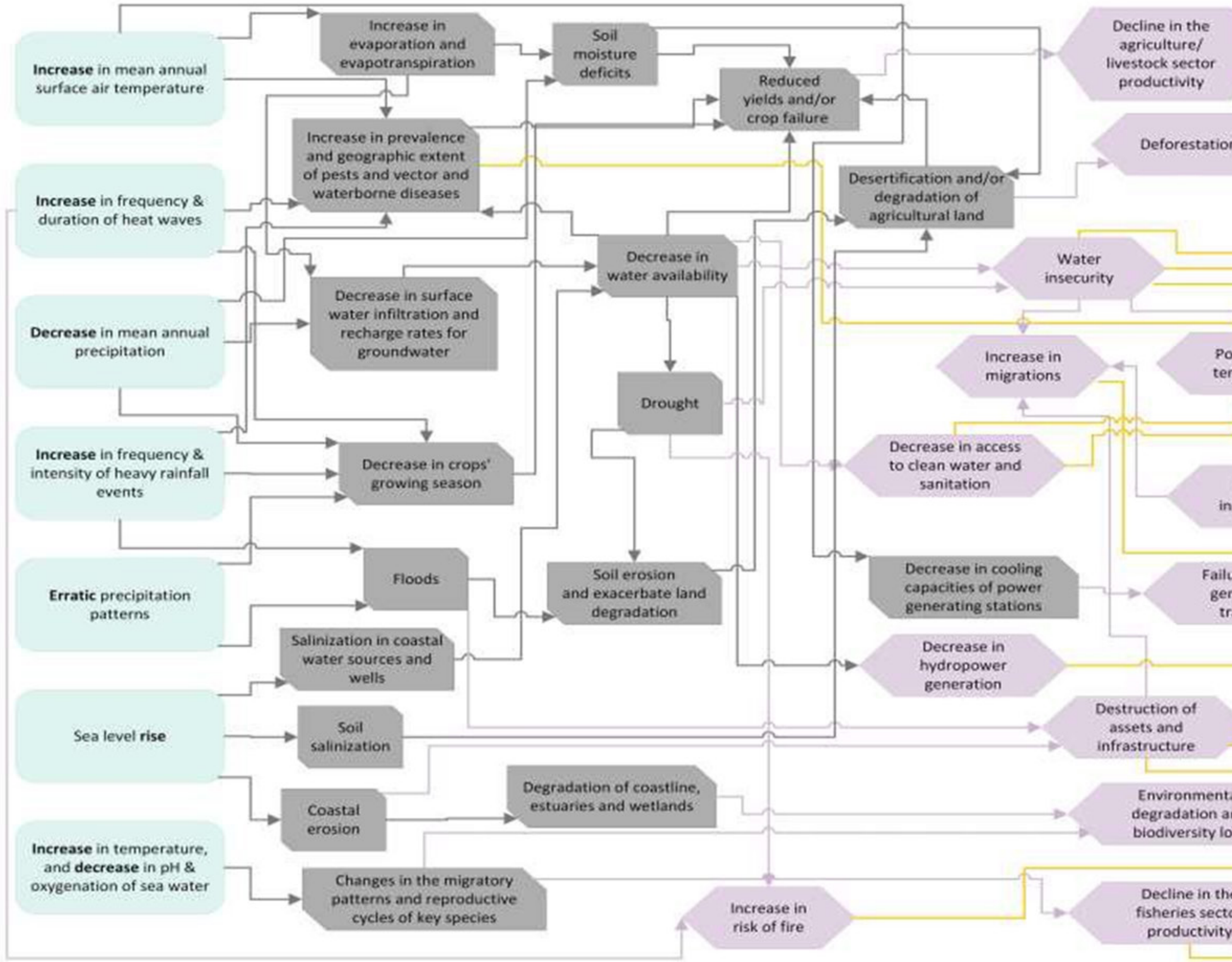
- the impacts that can affect each MMDA,
- consider the exposed elements that should be included in the risk analysis,

- analyse the vulnerabilities,
- determine data needs,
- and consider how limitations in the existence of data may affect subsequent analyses.

Following the development of the Impact Chains it will be necessary to identify specific indicators that can be used to quantify the various relationships that characterise the likely change, sensitivity, and adaptive capacity for each of the priority risk domains as part of the overall risk assessment process.

Where possible the impact chains should also identify the primary climate driver as this will assist in determining the relevant indicators to determine the expected change due to climate change.

Figure 17 I Impact chain diagram for selected climate hazards and risk domains relevant for use at the MMDA level in Ghana



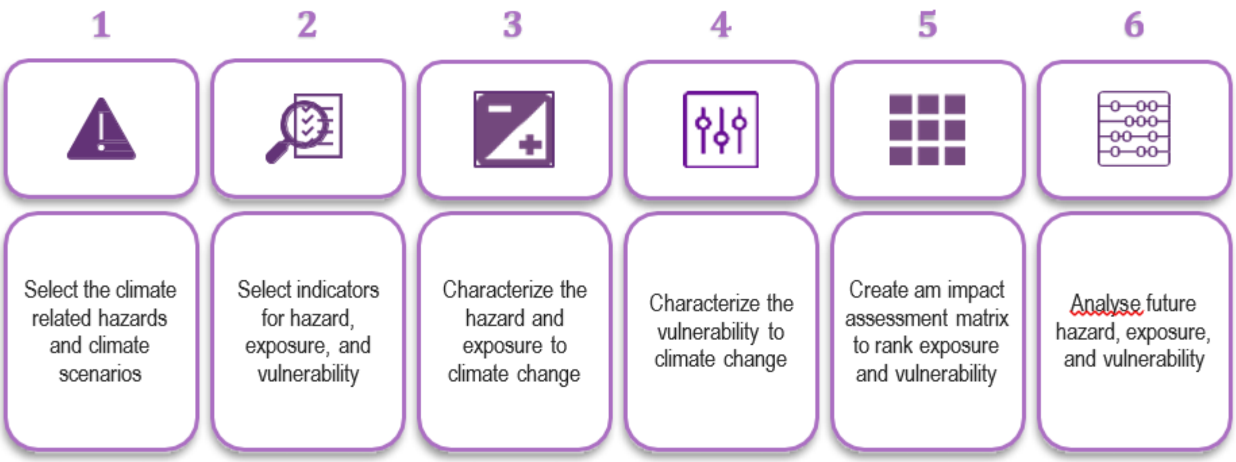
3.3. Step 3: Analyse Past, Current and Future Risks

The potential to undertake quantified climate change risk assessment and impact modelling for the priority first and second order risk domains will be determined based on the availability of data and the level of detail required to inform the risk assessment process. Where possible information from previous risk assessments will be used for example in determining current and future climate risk associated with urban and coastal flooding as well as changes in crop productivity across all regions of Ghana which have already been studied. In the case of information being available from these previous studies then these results will be interpreted in the context of the updated future climate change scenarios identified in the previous tasks. If existing studies cannot be found, and there is sufficient data available then, some preliminary impact modelling will be undertaken to inform the final climate risk and vulnerability assessments for each of the two priority MMDAs and risk domains.

The type of impacts modelling that might be considered is simple hydrological modelling of water resources availability, flood risk mapping based on readily available data, and the mapping of possible inundation areas due to projected sea level rise using a simple "bathtub" model and available data.

The process to analyse and evaluate climate change risks for an MMDA is shown in Figure 18.

Figure 18 I Methodological approach and workflow steps to analyse risks



Source: Adapted from CoastAdapt[4]

3.3.1. Select the Climate Related Hazards and Climate Scenarios

The most visible impacts of climate change are increasing variability in rainfall leading to more extreme events - floods and droughts, as well as increasing temperatures with respective impacts on evapotranspiration and respective agricultural impacts as well as freshwater availability changes in space and time in many regions. There are however a very large number of derived climate related hazard variables/indicators that can be considered relevant to different sectors and climate related risks. It is therefore necessary to consider the most relevant climate related hazard for each risk domain and to specify the specific climate related variable that will be considered. This can then be used to determine the relevant climate information and scenarios to be used in the risk assessment.

The expected change in key variables such as precipitation and temperature under the different climate scenarios are assessed using Plume Plots and SOMs analysis for the four regions in Ghana.

4 https://coastadapt.com.au/how-to-pages/how-to-conduct-a-climate-change-risk-assessment

As described in the Downscaled Scenarios Report, the most readily available source of downscaled climate information is the CORDEX data set. The selected CORDEX variables are given in Table 2.

Table 2 I Recommended CORDEX variables to be used to support sub-national risk assessments.

Output variable name	Long_name
tas	Near-surface air temperature
tasmax	Daily Maximum Near-Surface air Temperature
tasmin	Daily Minimum Near-Surface air Temperature
hurs	Near-surface relative humidity
pr	Precipitation
sfcwind	Near-surface wind speed
sfcwindWindmax	Daily maximum near-surface wind Speed
evspsbl	Evaporation
evspsblpot	Potential Evapotranspiration
mrros	Surface Runoff
prhmax	Daily maximum Hourly Precipitation

These have been downloaded for Ghana for each of the 16 identified climate scenarios that are considered to cover the range of possible futures under the relevant global emission pathways. These downscaled climate data can then be used to determine the relevant hazards score for the MMDA.

A selection of derived climate variables that could be used to characterise the climate related hazard for different sectors such as water resources, agriculture and ecosystems are shown in Table 3.

Table 3 I Climate variables used to characterise the climate related hazard for different sectors

Climate variable / hazard	Climate index
Temperature	Extreme heat: average monthly mean daily maximum temperature > 38°C
High temperatures	Maximum value of daily maximum temperature

High temperatures	Number of days when Tmax >= 35 °C
Precipitation	Number of very heavy rain days: Annual count of days when R ≥ 20mm
Precipitation	Days with rainfall >95th percentile
Precipitation	Maximum precipitation intensity (yearly maximum) (mm/h)
Precipitation	Number of heavy rain days: Annual count of days when R ≥ 10mm
Drought / low precipitation	Extreme drought potential (seasonal): Seasonal (3-month) SPI < -1.59
Drought / low precipitation	3-month standardized precipitation index
Drought / low precipitation	High drought potential (seasonal): Seasonal (3-month) SPI between -0.8 and -1.59
Winds	Maximum value of daily maximum wind gust (m/s)

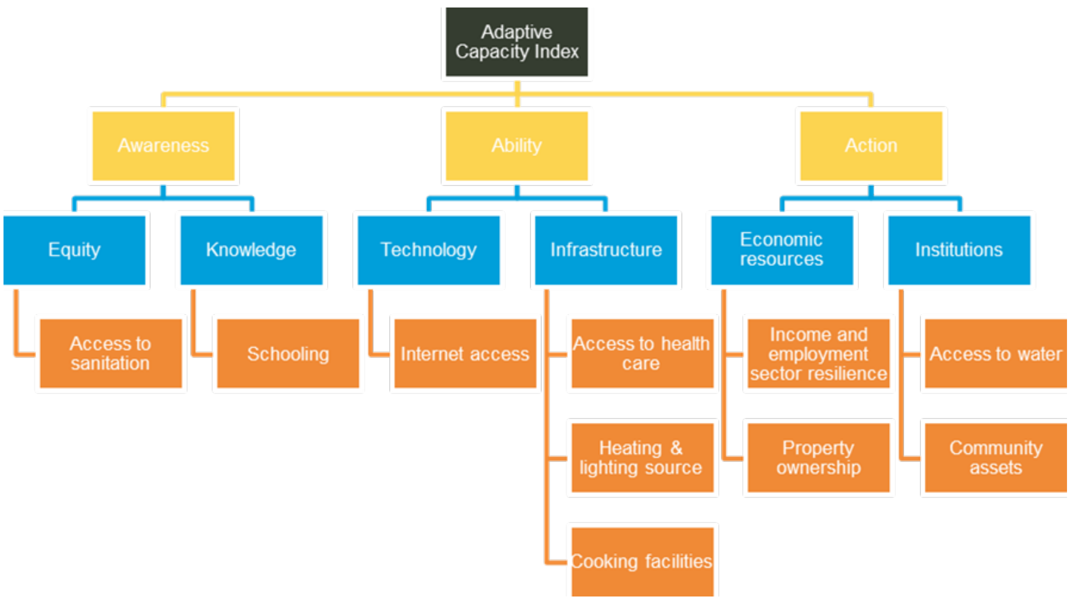
3.3.2. Select Indicators for Hazard, Exposure and Vulnerability

For the risk analysis of climate change in the selected MMDAs, it will be necessary to have indicators to characterize climate threats **(hazard)**, which can be obtained from observational data or models depending on the requirements. For **exposure**, the indicators that characterize the biophysical or socioeconomic aspects of the area at risk will be highly dependent on the availability of national, regional, or local statistical databases, or on the characterization of land uses based on historical data.

Likewise, there must be indicators to characterize the **sensitivity** and the **adaptive capacity** in order to assess the **vulnerability** of the exposed communities and assets and the risks or consequences.

The **sensitivity** of different risk domains will depend on the degree to which a system is affected by individual climate hazards and potential impacts Finally, it will be necessary to have indicators that adequately characterize the **adaptive capacity** of the system. Determining adaptive capacity is quite subjective and indicators are considered as representative of adaptive capacity of the system, even if they are not directly related to the hazard. Examples of indicators for adaptive capacity are shown in Figure 19. These can then be used to compliment a bottom-up approach to assessing adaptive capacity based on feedback received by key stakeholders as discussed later in Section 3.3.4.

Figure 19 I Example of indicators, determinants and components used to assess adaptive capacity



Source: Adapted from (Araya-Muñoz, Metzger, Stuart, Wilson, & Alvarez, 2016)

When preparing a list of potential indicators for adaptive capacity, it is necessary to associate each indicator with a set of metadata that will facilitate the analysis of the factors described above and, especially, their suitability and replicability. This metadata should include the following:

- Description: a brief description of the indicator.
- Risk component represented by the indicator: (threat, exposure, impacts, vulnerability, risk/consequences, adaptive capacity).
- Rationale: a brief explanation that justifies the selection of the indicator.
- Spatial coverage: the spatial coverage required for the indicator data.
- Unit of Measure: The unit of measure or spatial resolution required.
- Temporary coverage: the temporary coverage required.
- Monitoring: the period necessary to update the values of the indicators.
- Trend: An explanation of whether a high or low score for the indicator decreases or increases risk.
- Data source: existing and potential data sources, where possible.

A high-level summary of the climate hazards and potential impacts for different economic sectors are given in Table 4. The climate risks posed by extreme weather events adversely impact health and damage infrastructure and private property, reducing wealth and decreasing productivity.

Table 4 I Climate hazards and potential impact for Climate Sensitive Sectors

Sectors	Climate Hazards	Possible Impacts
Agriculture	Precipitation Temperature Droughts Floods Fire Storms Sea Level	Decreased crop yield and potential crop failures Increased exposure to pests and diseases Increased irrigation demand and costs Commodity price volatility Disruptions to farmers and labor force loss in livestock production
Mining & Quarrying	Precipitation Temperature Floods Fire Droughts Storms	Constrained exploration, processing, refining, and site rehabilitation Damage to infrastructure and facilities Higher operating and decommissioning costs Altered access to mining deposits and coastal facilities Disruptions in daily operational mining activities Risks to worker health and safety Water conflicts with communities

Manufacturing	Floods Droughts Storms	Availability, quality, and cost of raw materials Disruptions for operations and workers at manufacturing facilities Disruptions in supply chain and distribution network, including transport, warehouses, Shifting consumer preferences (e.g., less reliable seasonal cycles and temperatures) Reduced output due to an inadequate quantity and quality of water for hydroelectric plants or to cool nuclear and fossil fuel plants Damage to infrastructure and facilities Changing seasonal power demand and increased peak demand during extreme heat or other conditions
Electricity, Gas & Water	Floods Droughts Storms Sea level	Increased electricity losses in transmission and distribution systems due to heat load and reduce efficiency of power plants due to higher temperatures.
Construction	Temperature Floods Storms	Operational interruptions delays on project delivery, Damage at the construction site and increased costs Damage to infrastructure and facilities Rising risks to employee safety and health
Extractive Oil & Gas	Floods Droughts Storms Sea level	Altered access to fossil fuel reserves Constrained production of water-intensive oil and gas resources, conflicts with communities and other users due to limited water resources
Transport, Storage & Communication	Precipitation Temperature Floods Sea Level High Wind	Increased maintenance costs for due to impact on road pavements. Damage to transport infrastructure due to flooding and extreme events Operational disruptions (airports, roads, bridges, ports, etc) Increased wind speeds delays at ports and harbours

3.3.3. Characterize Hazard and Exposure to Climate Change

3.3.3.1 Determining Climate Related Hazard Values

The level of hazard is determined either directly from individual climate change parameters such a temperature and precipitation, or from derived variables such as changes in drought frequency, extreme rainfall events, mean annual runoff, impact on water supply, heat stress, or crop productivity.

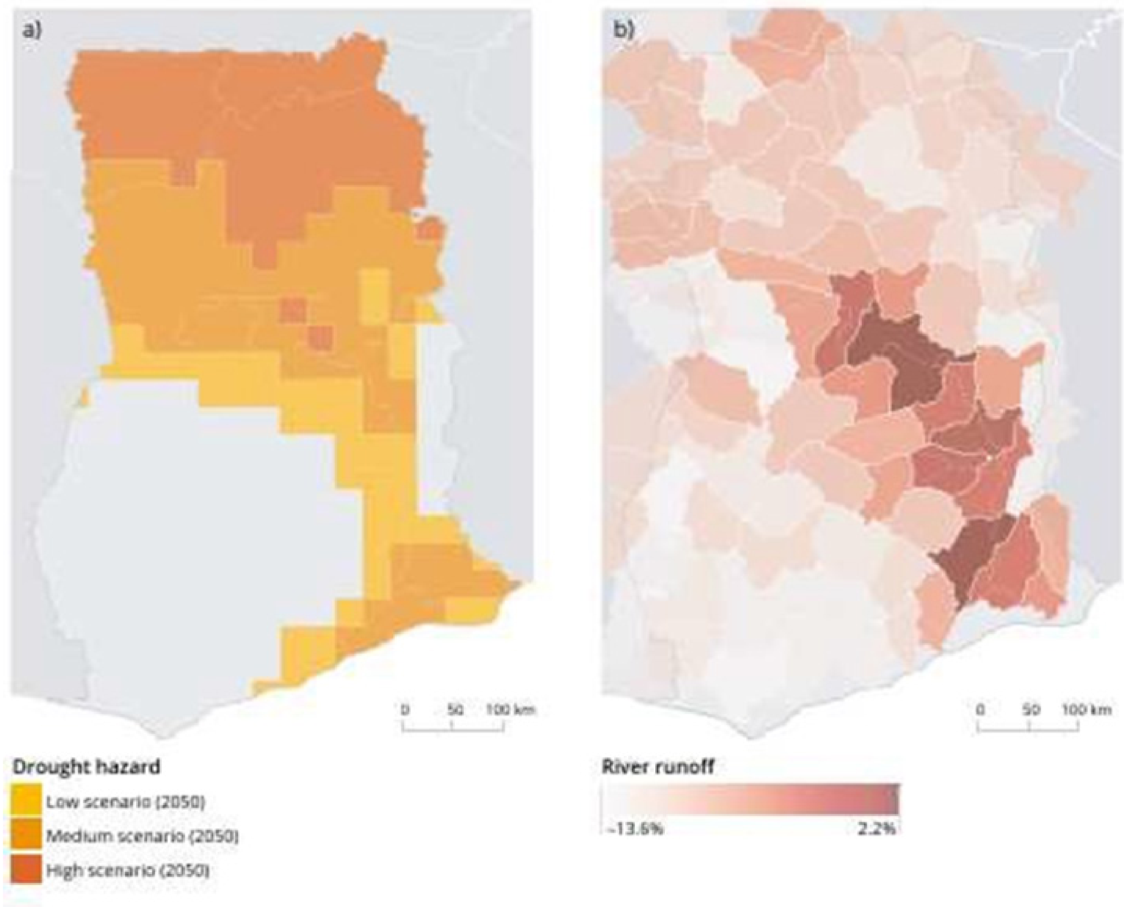
The severity of potential impact is then characterised in terms of thresholds such as in Table 5.

Table 5 I Climate hazard thresholds to characterise the severity of potential impacts

Climate Hazard	Climate change parameter used	VL	L	M	H
Temperatures	Change in Mean Temperatures	TBD	TBD	TBD	TBD
Precipitation	Change in Mean Annual Rainfall	TBD	TBD	TBD	TBD
Droughts	Change in SPEI	TBD	TBD	TBD	TBD
Floods	Change in extreme rainfall	TBD	TBD	TBD	TBD
Wildfires	Change in extreme temperatures	TBD	TBD	TBD	TBD
Winds/Storms	Change in maximum daily wind speed	TBD	TBD	TBD	TBD
Water Availability	Change in mean annual runoff	TBD	TBD	TBD	TBD
Agriculture	Change in crop suitability	TBD	TBD	TBD	TBD
Livestock	Change in heat index (HI)/max temperature	TBD	TBD	TBD	TBD
Human Health	Change in heat index (HI)/max temperature	TBD	TBD	TBD	TBD

Some of the values for the above variables can be derived directly from climate risk maps (for example changes in mean annual temperature or precipitation) or from derived hazard maps such as are shown below in terms of drought hazard and water resource availability (Figure 20) and crop suitability for primary crops grown in Ghana under different climate change scenarios (Figure 21).

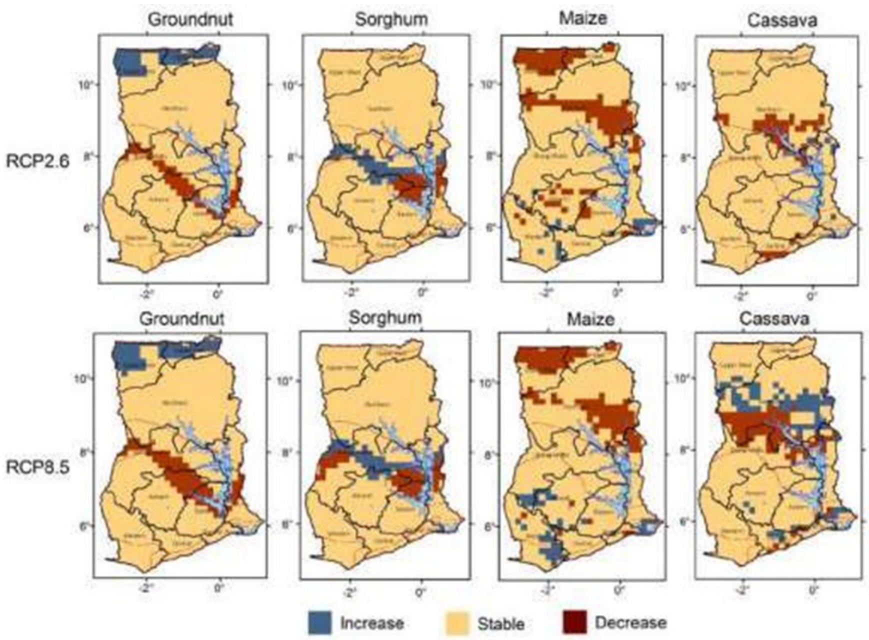
Figure 20 I Comparison of drought hazard (left) and changes in surface water runoff (right) for Ghana



This information can be used to determine the current and future hazard for different MMDAs

Source: Ghana: Roadmap for resilient infrastructure in a changing climate (Adshead, et al., 2022)

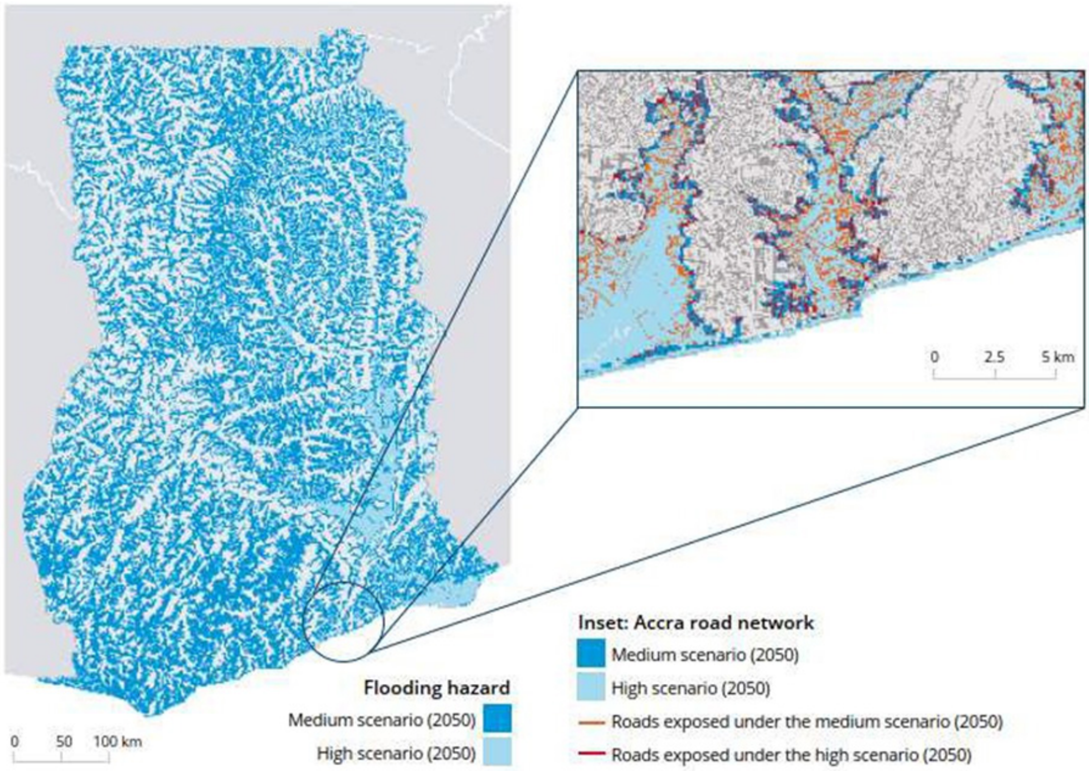
Figure 21 I Modelled change in crop suitability for selected crops in Ghana



3.3.3.2 Determining the Level of Exposure

The exposure critical hazards such as increasing flood risk can be supported by hazard mapping. Several hazard mapping studies have already been undertaken in Ghana, particular with regards to flood hazard mapping. These maps can be used to determine the exposure for people or infrastructure. An example taken from the climate risk and vulnerability assessment for infrastructure is shown below and can be used to identify say the number of people or building or other critical infrastructure (such as roads in this case) that are located in high-risk flood areas under different climate scenarios. The results of this analysis showed that the people or assets exposure to flood risk does not necessarily significantly increase with different climate scenarios, but the frequency and magnitude of these might change which is driven primarily by changes in extreme rainfall events.

Figure 22 I Example of flood hazard mapping using the existing NDMO flood hazard layers



Source: Ghana: Roadmap for resilient infrastructure in a changing climate (Adshead, et al., 2022)

Table 6 presents a series of indicators chosen to assess the exposure of natural and human systems to climate change in Ghana, which can serve as an example for different risk domains in the MMDA:

Table 6 I Example of exposure indicators that can be selected for different risk domains

Exposure (E)	
E1	Number of people/buildings located in a flood risk area
E2	Number of people exposed to drought risk
E3	Number of people exposed to fire risk
E4	Number of people dependent on local surface water supply

E5	Number of people dependent on local groundwater supply
E6	Number of people dependent on regional water supply scheme
E7	

Exposure (E)	
E…	…

Exposure is analysed by evaluating the history of past and recent weather events in the areas under study. If there is not enough secondary data to establish the exposure, it is necessary to prioritize interaction with local communities through interviews and meetings with focus groups and observation of the site during field visits. Table 7 presents an indicative list of questions that can be asked of various entities including local populations, civil society organizations and local authorities, to assess their exposure to climate change. This information is used to complement the quantitative indicators such as the estimate of the number of people or buildings located in flood prone areas.

Table 7 I Indicative list of exposure-related questions

No.	Questions
1	What are the climatic events experienced in the region in recent years (floods, droughts, heat waves, etc.)
2	What is the frequency and intensity of these weather events over the years?
3	What is the trend of events happening (increase/decrease) over the years?
4	What are the changes in weather patterns over the years? (*eg* , less/more rainfall in general, frequent droughts/floods, higher temperature, changes in vegetation, late/early onset of the rainy season, uneven distribution of rainfall, etc.)
5	What were the impacts of these changes on the local people, area and livelihoods? (*eg* , changes in seasons/vegetation types, new strains of pests and diseases, water shortages)
6	What are the climate trends and their future impacts on natural systems and livelihoods and productivity in the region? Also, how would you mitigate (or maximize benefit, if positive) some of these impacts?
7	Are there any infrastructures/assets are in the selected areas? (villages/cities, housing, roads, power stations, agricultural warehouses, agricultural processing stations, factories, water/sewage treatment, etc.) How many?
8	How many people live in the selected areas?
9	How many people work in the selected areas?
...	...

After identifying the main climate threats present in the areas under study, the exposure classification criteria are as follows:

Table 8 I Criteria for assessing exposure

Exposure	Description
Very low	In the past, the study area, or areas nearby, have rarely experienced extreme weather events (less than one event every 50 years).
Low	Exposure is almost unlikely. In the past, the study area, or areas nearby, have sporadically experienced extreme weather events (1 every 20-50 years).
Average	Exposure is possible to occur. In the past, the study area, or areas nearby, have experienced extreme weather events (1 every 10-20 years).

High	Exposure is likely to occur. The study area, or areas nearby, have regularly experienced extreme weather events (1 every 5-10 years).
Very high	The exposure is almost certain. Hazard manifestation is common (1 every 1-5 years).

3.3.4. Characterize the Vulnerability to Climate Change

Vulnerability is determined as a function of sensitivity and adaptive capacity.

VULNERABILITY = SENSITIVITY − ADAPTIVE CAPACITY

3.3.4.1 Determining Sensitivity

Sensitivity determines the degree to which a system can be harmed by its exposure to climate risks. Sensitivity is normally informed by natural and/or physical attributes of the system, including relief, the ability of different soil types to resist erosion, etc.; but it also refers to human systems, e.g., population pressure. As most systems have been adapted to the current climate (e.g., construction of dams and dykes, irrigation systems), sensitivity already includes historical and recent adaptation. Social factors such as population density should only be considered sensitivity if they directly contribute to a specific climate (change) impact. Table 9 presents a series of sensitivity indicators that were chosen to assess the sensitivity of natural and human systems to climate change at the MMDA level in Ghana.

Table 9 I Examples of sensitivity indicators

Indicators of Sensitivity (S)	
S1	Sedimentation of water bodies
S2	Change in the coastline (due to erosion and sedimentation)
S3	State of water resources
S4	Demographic and community factors
S5	Means of production and livelihood of communities (economic activities)
S6	Income level and poverty indices
S7	Typology of building material for houses, or other infrastructure
S8	Typology of water supply systems
S9	Typology of wastewater treatment and sanitation systems
…	

Table 10 presents an indicative list of questions that can be asked of various entities including local populations, civil society organizations, local authorities to assess their sensitivity to climate change.

Table 10 I Indicative list of questions related to sensitivity

No.	Questions
1	What are the trends and projections for population growth, by sex and age structure, and how has each group been affected by climate events?

2	What are the main economic activities in the community (subsistence agriculture, fisheries, commercial agriculture, tourism, industry, etc.) and how has each sector of activity been affected by climate events?
3	What are the roles of women in the economic activity of the local community? (agriculture, fetching water, etc.) and how do weather events make it difficult to carry out these tasks?
4	What type of infrastructures/assets are in risk areas? (villages/cities, housing, roads, power stations, agricultural warehouses, agricultural processing stations, factories, water/sewage treatment, etc.)
5	Has there been any change in the structure of the vegetation cover in recent years (trees cut for firewood? fire damage? salinity damage? flood washout? etc.)?
6	What is the primary source of water (drinking water and irrigation) - has there been any change in its availability (eg, drought of wells) or quality (eg, increased salinity)?
7	What is the crop's dependence on rainwater and what irrigation systems are there?
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After identifying the natural and human systems at risk in the area under study, the criteria for classifying their sensitivity to the risks present, using the classification scale indicated in Table 11, are as follows:

Table 11 | Criteria for assessing sensitivity

Sensitivity	Description
Very Low	Extreme weather events and climate change related hazards may marginally affect the study area and there are no assets critically affected.
Low	Extreme weather events (strong winds, floods, extreme temperatures, droughts, sea level rise, coastal erosion etc.) relatively more resistant population, the consequence is classified as minor.
Moderate	Extreme weather events cause moderate damage to local goods and services (eg increased incidences of dengue, diarrhoea, malaria or other vector -borne diseases affect the health of the local community and put greater pressure on sanitation and agricultural goods; or a moderate drought may lead to some loss of household income, but may not require external assistance).
High	Extreme weather events affect assets, reducing the capacity of local services to respond, causing damage to local communities (eg floods that lead to the interruption of water supply affecting communities and irrigation pump failures, reducing the productivity of agricultural productions, can have a major impact on a weak local community that has no other alternatives and cannot withstand seasonal shocks of this type).
Very High	Extreme weather events lead to the failure or destruction of local goods and services, communities have to be relocated for at least several months, etc. This is a very high potential impact that could seriously affect local communities and the consequence is considered to be catastrophic.

3.3.4.2 Determining Adaptive Capacity

Adaptability is the system's ability to accommodate potential impacts resulting from climate change. The IPCC describes 'adaptive capacity' as the ability of a system, institution, human being or other organisms to adjust to potential impacts resulting from climate change, taking advantage of opportunities or responding to the resulting consequences (IPCC, 2014).

In this way, adaptive capacity integrates the combination of different factors that determine the ability of a system to define and implement adaptation measures, both for current impacts and for those resulting from climate change. These factors include resources and capacities of a socio-economic, structural, institutional, and technological nature (Fritzsche, et al., 2014).

Table 12 presents a set of possible indicators that could be used to assess the adaptive capacities of ecosystems and communities in Ghana, as an example: These would be assessed based on engagements with the relevant risk domains and could be complemented with quantitative indicators based on census information or data already captured for each MMDA as part of the Fourth National Communication (FNC). The FNC considered several variables for determining adaptive capacity at the MMDA level, but the primary variable being the District League Table score shown in the table below.

Adaptive capacity	District League Table score[150]	The DLT incorporates measures of education, sanitation, rural water availability, health, security, and governance effectiveness to assess development across Ghana's 216 districts. These factors are considered good indicators of the capacity of private citizens and local governments to adapt to a changing climate[151].	Lower score = lower adaptive capacity ranking

Table 12 I Example of adaptive capacity indicators

Indicators of Adaptive capacity (AC)	
AC1	Awareness / conceptual perception of climate change and its effects
AC2	Awareness / experiential perception of climate change and its effects
AC3	Adaptability of individuals (including traditional and local practices that can be used to reduce vulnerability, as well as measures that have been implemented and that can be improved)
AC4	Adaptability of communities (existence of legal, institutional and operational framework at the local level; existence of basic energy services, water supply to communities, etc.)
AC5	Access to resilient infrastructure (built and natural/ecosystem services) that support means of production and livelihoods
AC6	State/Administration support in case of emergency or disaster
AC7	Response capacity of key entities to the consequences of climate change (existence of technical capacity, existence of a disaster risk reduction plan, etc.)
AC8	Response capacity of civil society organizations, including Non-Governmental Organizations (NGOs), religious groups, etc. (organizational structure, experiences, available resources, history of interventions in communities, etc.)
AC9	Access to new climate-resilient technologies
AC10	Adoption of new climate-resilient technologies
AC11	Adoption of new climate-resilient practices
AC12	Existence of insurance products and services, in view of climate risks
AC13	Existence of alternative sources of income
AC14	Access to microcredit and private financing
AC...	

A series of questions should be asked of all affected parties including local populations, public authorities and civil society organizations in order to assess their resilience and adaptability in the face of extreme weather events. Table 13 presents an indicative list of questions that can be used to interview local communities to assess their resilience and capacity to adapt to climate change.

Table 13 I Indicative list of questions related to resilience and adaptive capacity

No.	Questions
1	Do community members have access to a variety of communication systems that allow information to flow during an emergency? Is there a risk of the community becoming isolated during an extreme weather event?

2	What is the level of relationship and communication between the local government agency and the population? e.g., passive, consultation, commitment, collaboration, active participation? With the regional or supra -regional entity (e.g., Province)? E.g., none or limited/informal networking with other cities/regions, some representation at regional meetings, regular planning and activities with other cities/regions
3	What is the degree of societal linkage between communities and the most vulnerable groups (e.g., ethnicities / subcultures / age groups / gender/sex)? And what proportion of the local population is involved in social activities and organizations (e.g., clubs, service groups, sports teams, churches, library)?
4	What proportion of the population is able to independently move to a safe place? (e.g., non-institutionalised, mobility with own vehicle, adult)
5	To what extent and level are community households involved in response and recovery planning after catastrophic weather events, e.g., droughts, floods, cyclones etc.?
6	Is there a protection and infrastructure plan to deal with a local emergency and, if so, how comprehensive is it? (e.g., irrigation, water supply, sanitation, electricity system)
7	Do local people have in-house response/recovery capacity (e.g., first aid, food storage) in good time and can they be mobilized if necessary? Are available medical and public health services included in the emergency plan?
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indicative criteria for rating the dimensions of adaptive capacity and the indicators used, using a rating scale opposite to that used for determining the level of sensitivity to the impcats of climate change (i.e. a very high adaptive capacity indicates a lower level of vulnerability, and a very low adaptive capacity indicates a lower level of vulnerability). highest vulnerability), are shown in Figure 14, below:

Table 14 I Criteria for assessing the adaptive capacity

Adaptive capacity	Description
Very high	Existence of good knowledge, institutions that function perfectly and sufficient means and technologies to avoid or reduce the exposure and/or sensitivity of the identified climate risks. Local communities have a good understanding of climate change and its effects/impacts and adopt initiatives to increase their resilience in the short, medium and long term. Existence of action strategies for climate change at the study area level.
High	Existence of alternative resources and capacities to diversify the local economy. Local populations have access to resilient infrastructure (built and natural/ecosystem services) that support means of production and livelihoods. Existence of technical capacity, strategies, a risk and disaster prevention plan, an action plan for climate change, etc.
Average	Existence of a national/regional action plan for climate change etc., but no local climate action plan, including the participation of local communities. There is a moderate capacity to reduce sensitivity to identified climate risks and some adaptation measures are implemented at the community level to mitigate risks in the short and medium term. Existence of basic energy services, water supply to communities, etc. to address the potential impacts resulting from climate change.
Low	Lack of a legal, institutional and operational framework at the local level to mitigate climate risks and their effects on local ecosystems and livelihoods. Restricted access to resilient infrastructure (built and natural/ecosystem services) that support means of production and livelihood against the effects of variability and climate change.

Very Low	Lack of basic energy services, water supply to communities, etc. to address the potential impacts of climate change. Lack of knowledge and perception about the phenomenon of climate change and its effects on natural ecosystems and local livelihoods. Very limited and vulnerable means of survival and no alternative means.

There is no single approach to adaptive capacity, as its components are highly dependent on the system in question. There are numerous attempts to structure the “ingredients” of adaptive capacity and to introduce standard indicators into the assessment. The main dimensions that can be found in the literature include knowledge, technology, institutions and the economy (Table 15), and the relevance of these dimensions varies from case to case and from one system to another.

Table 15 I The dimensions of adaptive capacity

No.	Dimensions of adaptive capacity	Description	Criteria
1	Knowledge	It refers to general levels of education and awareness on issues related to climate change and its impacts, as well as the dissemination of information on climate and weather conditions.	C1, C2, C3
2	Technology	It includes the availability and access to technological adaptation options and the technological stage of development of a system. Although it does not include pre-existing measures such as dams and irrigation schemes (which are already considered under system sensitivity), it can incorporate new technological solutions or the improvement of existing ones.	C5, C9, C10, C11
3	Institutions	It covers a variety of governance, institutional and legal issues, including the capacity and efficiency of key institutions, enforcement of environmental laws, transparency of procedures and decision-making. This dimension may also include accountability and participatory practices to ensure the sustainable management of natural, financial and human resources.	C4, C6, C7, C8
4	Economy	It includes the resilience of livelihoods, the diversification of the local economy, the employment/unemployment rate (in rural or urban areas), a country's dependence on food and energy imports, etc. At a micro level, it can also include household income, expenditure on food, housing and dependency rates.	C5, C12, C13, C14

3.3.4.3 Impact assessment matrix to rank sensitivity and adaptive capacity

Once the sensitivity and the adaptive capacity of communities are assessed, the matrix below can be used to assess the vulnerability of natural and human systems present in the study area.

Table 16 I Vulnerability Matrix (Sensitivity / Adaptive capacity)

Vulnerability	Sensitivity [from reduced impact (1) to extreme impact (5)]				
	(1.5)	(2.5)	(3.5)	(4.5)	(5.5)
	(1.4)	(2.4)	(3.4)	(4.4)	(5.4)
	(1.3)	(2.3)	(3.3)	(4.3)	(5.3)
Adaptative capacity [from very high (5) to very low (1)]	(1.2)	(2.2)	(3.2)	(4.2)	(5.2)
	(1.1)	(2.1)	(3.1)	(4.1)	(5.1)

The colour of each cell in the matrix corresponds to the intersection between the **S**ensitivity, on a scale of one (very low) to five (very high), and the **A**daptive **C**apacity (**S, AC**), on a scale of five (very high) to one (very low) of the system in question.

3.3.5. Create an Assessment Matrix to Rank Hazard, Exposure and Vulnerability

Finally, the final risk calculation involves obtaining risk indicators that reflect the situation of the different components that comprise it: hazard-impacts, exposure, and vulnerability.

The combined hazard, exposure and vulnerability determine the risk of climate change. *Eg*, flooding due to heavy rain events (hazard x exposure) in combination with houses built in steep slopes and soils with high susceptibility to erosion (vulnerability) will result in gullies and landslides (potential risk). Climate change impacts can form a chain of impacts, from the most direct (eg, erosion) to indirect impacts (eg, reduction or loss of income) that extends from the biophysical to the social sphere.

In many developing countries such as Ghana, direct dependence on natural resources means that the link between the biophysical impacts of climate change and human activities and their well-being is particularly strong. Interviews with local, communal, municipal and provincial authorities and populations will make it possible to establish the chains of impacts relevant to the study communities.

The assessment of potential risk that climate change will have on natural and human systems is done through the matrix of exposure and vulnerability. This potential risk assessment matrix makes it possible to rank exposure and vulnerability to climate change. The final risk assessment matrix helps to identify the priorities and systems and sectors at risk (Fall, Correa, & Sarr, 2011).

Table 17 presents the matrix used to rank the potential risks of the hazards associated with climate change on natural and human systems, based on exposure to identified climate hazards and the vulnerability of key natural systems, socio-economic sectors and local livelihoods.

Table 17 | Classification matrix of potential risks [(Hazard x Exposure) x Vulnerability]

Risk	Hazard x Exposure [from reduced impact (1) to extreme impact (5)]				
	(1.1)	(2.1)	(3.1)	(4.1)	(5.1)
	(1.2)	(2.2)	(3.2)	(4.2)	(5.2)
	(1.3)	(2.3)	(3.3)	(4.3)	(5.3)
Vulnerability [from reduced (1) to very high (5)]	(1.4)	(2.4)	(3.4)	(4.4)	(5.4)
	(1.5)	(2.5)	(3.5)	(4.5)	(5.5)

The colour of each cell corresponds to the intersection between the **E**xposure to the **H**azards and the **V**ulnerability (**HE,V)** of the system on a scale of risk from one (very low) to five (very high).

3.3.6. Analyse future hazard, exposure, and vulnerability

Based on future projections and their impacts, and following the same methodology for assessing current vulnerabilities, future vulnerabilities to climate change can also be assessed. The assessment of future vulnerability must integrate, in addition to future climate trends, trends in ecological and human systems changes, including demographic trends and socio-economic projections.

There are two possible options, depending on the data and resources available for assessing vulnerability to future climate change:

- **Option 1:** Prepare a matrix of potential impacts of future climate risks (following the same process as the elaboration of the matrix of impacts of current risks). In that case, a new matrix of impacts is made considering the projected climate risks (which may be different from the current risks), considering the livelihoods that will be more vulnerable in the future (which may be different from the current ones). Once the new matrix is prepared, apply the same methodology to assess vulnerability to future climate change. A choice must also be made between considering the current adaptive capacity of institutions and individuals, to assess future vulnerabilities, or considering capacity projections (increased or reduced capacity in the future). If the latter is chosen, the reasons for the selection of projected capacity reduction or improvement must be justified; and
- **Option 2:** make a qualitative analysis of future vulnerabilities, without elaborating a new impact matrix. This option may be the simplest if there is not enough data to establish an impact matrix for future/ projected risks or if future climate risks are not very different from current risks (*e.g.* projected climate events are the same as current ones), but with more/less frequency and/or intensity).

3.4. Step 4: Evaluate the Potential Risks

There are different approaches to get from the information pool from Step 3 to a risk assessment for each specific risk (Step 4). Most important is to understand that each risk assessment is value-based, meaning that there is no “objective risk”. Risk is always assessed against agreed values or objectives.

Therefore, a risk is mostly expressed in a qualitative scale such as “low, medium, high”. There is even no standard definition of what a “high” risk means. The “value-setting” should be part of the risk assessment and should be agreed upon by the stakeholders. A “high” risk could for instance be defined by a high expected damage related to the risk in the sense of economic, ecologic, functional, human health related or cultural damage.

In more data-driven, top-down and spatially explicit approaches an established method is to base the whole risk assessment on indicators. Indicators are then defined for single factors and components, which are then aggregated to composite indicators. This approach is on the one hand useful for large scale assessments with many sub-units (for instance municipalities within a district), is transparent and replicable. On the other hand, many subjective decisions on how to transform data and information into indicators and how to aggregate indicators must be taken.

For more bottom-up local risk assessments it is often more suitable to follow a participatory assessment approach based on the data and information pool from Step III. The assessment can still follow the logic of the IPCC and the impact chains by assessing hazard, vulnerability, and exposure components separately. The final assessment procedure can be a consensus-based approach or a voting approach. Often, the discussion on the importance of single elements and specific vulnerabilities in a consensus-based approach opens the discussion towards adaptation options.

The result in both cases (top-down indicator based vs. bottom-up consensus bases) are:

- a narrative description for each specific risk, including the processes and factors which lead to this risk, a description about the past and current situation, a perspective on potential future development of the single factors and the specific risk.
- a specific evaluation for each risk (e.g. low, medium, high) for each selected time period (e.g. present situation, mid of the century, end of the century). In case of an indicator-based assessments, results could also be illustrated as risk maps. But even in a bottom-up approach, maps are useful to illustrate spatially explicit information for certain aspects of specific risks or the underlying components and factors.
- a description about uncertainties in the assessment and the confidence level of the results

Whether a top-down or bottom-up approach is followed, or some combination, it is important that the emerging critical risks are discussed with key stakeholders, to determine if these are indeed relevant and to start to have stakeholder engagement about potential opportunities for addressing these risks.

3.5. Step 5: Treat the Risks

3.5.1. Identify risk reduction or adaptation solutions

One of the purposes of assessing the risk and vulnerability to climate change is to produce scientific data to inform policies, strategies, programs and spatial planning plans at the national, provincial, municipal, local or sectoral level, which integrate evidence of sensitivity of natural and human resources to promote sustainable development. The intention is the to identify was to address the risk.

Adaptation options and strategies aim to break the chains of climate change impacts, reduce exposure and sensitivity, and improve communities' adaptive capacity. Therefore, in the process of choosing adaptation measures, the most effective measure that presents the least risk is usually preferred. Adaptation measures can be ranked as no-risk, low-risk, win-win, flexible/adaptive management, and high-risk (van Garderen, 2013). Each of these groups has advantages and disadvantages that must be carefully considered, as can be seen in Table 18.

Table 18 | Examples of adaptation measures according to the risks of the options

Risk classification	Description	Examples of options
Without risk	Options that will produce benefits with or without climate change.	Culture consociation Mixed farming and livestock systems Conservation and sustainable use of natural resources (eg soil conservation)
Low risk	Options that will produce a large amount of benefit at very low risk	Seasonal weather and climate forecast Rural extension services aimed at implementing new crops and water-saving technologies Promotion of diversification of community sources of income
High risk	Options that are mostly irreversible and therefore have high costs if the measure proves to be unnecessary or is not operational	Water catchment network and infrastructure Resettlement/relocation of communities
With mutual gains	When an option improves adaptive capacity and contributes to other outcomes	Actions that contribute to increasing biodiversity Reduction of global exposure to risk
Flexible / adaptive management	Based on incremental adaptation and, in this way, reducing the risks associated with potential errors in the implementation of options	Diversification of business activity Reduction of pressure on areas and systems at risk Creating a flexible long-term sustainability plan

Source: (UKCIP, 2011)

It is important to note that the differentiation of measures that are no-risk, low-risk and high-risk is not constant and varies over time and space. A certain measure may be high risk in one part of the world, but low risk in another. Furthermore, over time, a high degree of risk can become a low degree of risk or vice versa (World Bank, 2009).

Adaptation options can be categorized in many different ways. A common way of categorizing adaptation options is illustrated in **Error! Reference source not found.** (UKCIP, 2011). According to the Guidelines for the preparation, implementation and monitoring of the climate change adaptation plan for the Municipalities (Adapting to Climate Change in Time Project partners, 2020), this planning implies:

- Have options for **building Adaptative Capacity** that involve building institutional capacity to respond effectively to climate change. These options include: i) obtaining the information (e.g. research, data collection and monitoring, awareness raising); ii) establish social support structures (e.g. organizational development, partnership work, institutions), and iii) produce support strategies that allow strengthening governance capacity (regulations, legislation and guidance), necessary as a basis for carrying out adaptation actions. These measures are essential for carrying out reactive adaptation actions; and

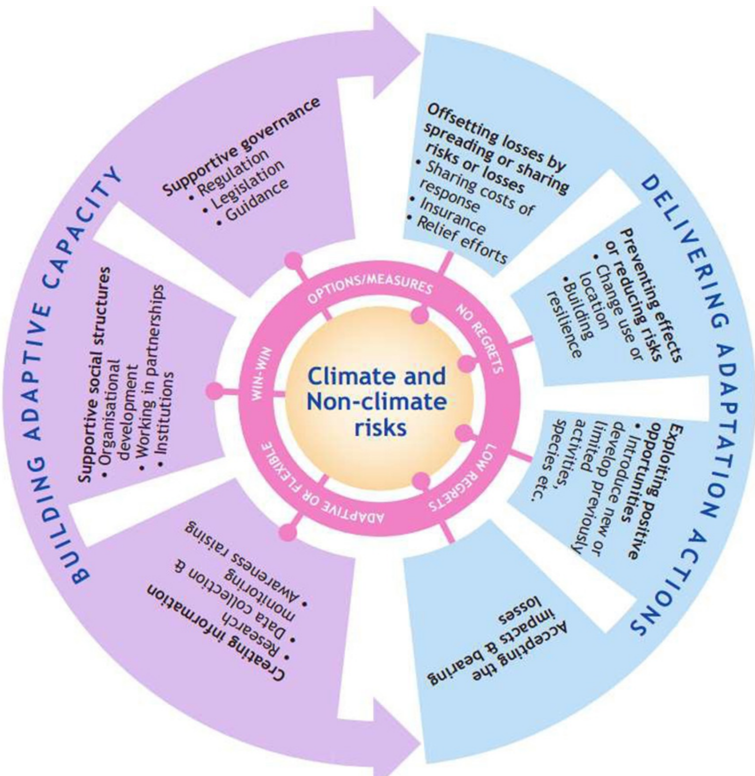
- Taking **Adaptation Actions,** which includes practical actions to reduce vulnerability to climate risks, or to exploit positive opportunities, can range from simple low-tech solutions to large-scale technological interventions. These options include: i) accepting the impacts, and bearing the losses resulting from those risks (e.g. managing the retreat from sea level rise); ii). offset losses by sharing or propagating risks or losses (e.g. through insurance); iii) avoid or reduce exposure to climate risks (e.g. building new flood defences, or changing location or activity); and iv). explore new and improved opportunities (e.g. engage in a new activity, or change practices to take advantage of changing weather conditions).

Possible criteria for ranking and prioritizing the measures to be proposed:

- Economic and financial costs;
- Contribution to social equity;
- Cost-Effectiveness Analysis in reducing vulnerability and increasing resilience;
- Cost-Benefit Analysis, increasing benefits, reducing costs and estimating the costs of the adaptation option compared to the cost of inaction;
- Integration with broader social objectives and activities;
- Consistency and respect for social norms and traditions;
- Legitimacy and social acceptance;
- Sustainability (environmental, institutional);
- Flexibility (can respond to feedback and learning);
- Availability of resources (e.g. information, finance, leadership, management, technology, etc.); and
- Coherence and synergy with other objectives (e.g. mitigation).

Source: Adapted from (Noble, et al., 2014)

Figure 23: Figure 22 | Framework for identifying adaptation options



In practice, adaptation planning will often involve a mix of response strategies: some building climate resilience (e.g., improved design specifications), others 'living with the risks' (e.g., increased preparedness and contingency planning) and others accepting losses (for example, accepting occasional losses or reductions in quality). The mix of these options will be case-specific, as it will depend on aspects such as risk aversion, as well as the values and capacity of the affected community/organization. The optimal selection of options may also include the adoption of measures that also allow for the exploitation of opportunities (e.g., relocating existing activities deemed no longer viable in their current location and introducing new replacement activities in that original location).

All potential adaptation options can be summarized in categories of interventions, namely: ecosystem-based adaptation (EBA) and community-based adaptation (CBA), including sharing knowledge and awareness to support identification, prioritization, implementation and scaling up. good adaptation practices in the country, regulatory measures such as the promotion of legislation and supporting policies and interventions to strengthen institutional frameworks. To these mentioned options can be added solutions for the development of resilient and sustainable physical infrastructures.

To choose and recommend priority adaptation measures to policy makers and I&APs , all identified adaptation options should be analysed using a multi-criteria approach, considering the feasibility of the adaptation option in the local context (political, legal, institutional); the alignment of the option with national, provincial, municipal and local development plans and strategies; the technical and financial resources available, or that may be mobilized, for the implementation of the option; and the potential contribution of the option to reducing the identified vulnerability.

Adaptation planning must identify and agree on a set of criteria that will be used to assess and select the identified adaptation options against agreed objectives, considering their alignment with local strategic policies, as well as other criteria, including its cost-benefit, its cost-efficiency, the time scale of action of the measure (short, medium or long term), etc. Frameworks for implementing adaptation options should be aligned with the Sustainable Development Goals and use a landscape-based approach. The landscape approach it encompasses a series of structures to integrate various competing land use and occupation policies and practices, through the implementation of adaptive and integrated management systems (Reed, Deakin, & Sunderland, 2015). It is a multifaceted, long-term and collaborative process that aims to bring together various stakeholders from various sectors to obtain solutions that act at various scales. The process is designed to facilitate negotiation between stakeholders in order to account for trade-offs and maximize synergies, with the overall objective of maximizing gains and minimizing losses for all stakeholders (Sayer & et al, 2013).

The ALivE tool proposes a solid framework for stakeholders in the EbA planning process, including community members, local authorities, NGOs and policy makers, project managers and practitioners. With a step-by-step approach to identifying EbA options, taking into account local ecosystems, livelihoods and climate change (UNEP, IEMP & IISD, 2018), it provides a user-friendly process to determine whether EbA options are viable and likely to be effective, helping users to identify elements for a monitoring and evaluation framework during the planning phase, emphasizing the need for adaptive management. Adaptation measures can also be presented in a synthetic way according to each identified climate risk, as in the example in Table 19. Another source of potential adaptation options that can be considered is from the weADAPT, which includes a collection of possible options.

Table 19 | Example of a summary presentation of measures by climate risk

Climate threats (risks)	Influence factors[1]	Impacts on physical and biological resources	severity level[2]	Livelihoods most affected	Impacts on livelihoods	Options / Adaptation Measures
Floods	Intense precipitation (storm) Groundwater level rise Inadequate waste disposal	Stagnant water and waterborne diseases Destruction of infrastructure (roads, markets, houses, etc.)	5	Agriculture fishing Tourism	Small agricultural plots flooded Difficulties in transporting crops from production to market	Build retention dikes ensure drainage Look for alternative livelihoods
Droughts	Low precipitation Reduced groundwater levels	Crop yield impacts Reduction in hydropower generation Low environmental flows	5	Agriculture Water supply Electricity supply	Agricultural yields decline; crop loss Unmet urban and rural water demand Unmet electricity demands	Drought tolerant crops Irrigation systems Conjunctive use Reservoir construction - Improved catchment management
[…]	-	-		-	-	-

1– The influencing factors are those that contribute to an increase in sensitivity and, consequently, in the potential impacts associated with climatic events. For example, inadequate waste disposal can contribute to increasing the sensitivity of communities to floods and climate-influenced diseases.

2– On a scale of 1 (very low) to 5 (extreme).

Source: (Fall, Correa, & Sarr, 2011)(Adapted)

4. Indicative Climate Change Risk Assessment (CCRA) report structure (Table of Contents)

The suggested structure for the final CCRA reports for each MMDA, sector or region is as follows:

Executive summary

1. Introduction

1.1. Scope and objectives of the report

1.2. Overview of the District (socioeconomic data environmental status etc.)

1.3. Key Stakeholders

2. Climate Change Risk Assessment Methodology

3. Current Climate Change Related Risks (Hazards, Exposure and Vulnerability)

3.1. Climate Risk Scenarios

3.2. Temperature and Precipitation Trends

3.2.1. Observed Temperature Changes

3.2.2. Observed Precipitation Changes

3.2.3. History of Recent Weather Events and Impacts Observed in the District

3.3. Summary of Current Vulnerability to Climate Change and Impact Storylines 3.3.1.Urban and Land Use Planning

3.3.2. Infrastructure

3.3.2.1. Transport

3.3.2.2. Energy, Electrical and Telecommunications

3.3.2.3. Water and Sanitation

3.3.2.4. Stormwater 3.3.3.Health

3.3.4. Natural Environment

3.3.4.1. Biodiversity

3.3.4.2. Water Resources

An effective approach uses a mix of adaptation strategies:

- Dealing with risks associated with current climate variability and extremes;
- Gradually introduce adaptation measures – which makes sense today, but is designed to allow for incremental adjustments in the future;
- Increase the flexibility or resilience of investments that are difficult to invest;
- Introduce adaptation measures coinciding with planned maintenance and/or rehabilitation programmes.

3.3.4.3. Air Quality 3.3.5.Disaster Risk Reduction

3.3.6.Finance and Economy (Assessment of current vulnerability to climate change by sector)
3.3.7.Livelihoods and Community

3.3.7.1. Housing and Living Environment

3.3.7.2. Employment

3.3.7.3. Food Security

3.3.7.4. Water Supply

3.3.7.5. Poverty

3.3.7.6. Migration

3.3.7.7. Vulnerable Groups

3.4. Priority Risk Domains

3.5. Impact Chain Diagram (Matrix of current impacts of climate change and discussion of impacts by sector)

3.6. Capacity to Adapt to the Main Risks Arising from Current Climate Change

3.7. Impact Storylines and Dependencies

4. Future Climate Change Related Risks (Hazards, Exposure and Vulnerability)

4.1. Projection of Future Climate Change and its Potential Impacts

4.1.1. Projected Climate Variables (temperature, precipitation, etc)

4.1.2. Potential Impacts (droughts, flooding, crop productivity, heat index, etc)

4.2. Socio-economic Scenarios (The impact storylines, and the socio-economic scenarios will help identify secondary impacts and the impact pathways and well as dependencies and determine significance)

4.3. Assessment of Future Climate Change Risks

4.3.1. Matrix of exposure to future climate change potential impacts (soil erosion, forest fries and productivity, livestock foraging, crop productivity) and vulnerability, using results of modeling, stakeholder engagement, literature review, GIS analysis

4.3.2. Discussion on implications compared to current vulnerability

5. Recommended Adaptation Options and Conclusions

5.1. Recommended adaptation options by sector

5.1.1. Strategic and policy options

5.2. Conclusions

References

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