CRIDF

# Final Resiliency Screening and Climate Change Risk Assessment Guidelines (PROTOCOL)

**Cross Cutting- Climate Resilience**

**Version: Final**

6 November 2015

**Version #:** Final

**Date:** 6 November 2015

**Lead Author:** Ioannis Chrysostomidis

**QA'd by:** Jeremy Richardson, Ayanda Bam, Caroline Brown

**Disclaimer**

The British Government's Department for International Development (DFID) financed this work as part of the United Kingdom's aid programme. However, the views and recommendations contained in this report are those of the consultant, and DFID is not responsible for, or bound by the recommendations made.

# Contents

# List of Figures



# List of Tables

# List of Acronyms

| Acronym | Long-Form |
|---|---|
| CCRA | Climate change risk assessment |
| CRIDF | Climate Resilient Infrastructure Development Facility |
| CVT | Climate Vulnerability Tool |
| DFID | Department for International Development |
| GCRP | Global Change Research Programme |
| ITCZ | Inter Tropical Convergence Zone |
| LCLIP | Local Climate Impacts Profile |
| NAPA | National Adaptation Plans of Action |
| NGOs | Non-Government Organisations |
| RS | Resilience Screening |
| SADC | Southern Africa Development Community |
| SHE | Stakeholder Engagement |
| SOM | Self-Organising Maps |
| THIRA | Threat and Hazard Identification Risk Assessment |
| WASH | Water Sanitation and Hygiene |

# Introduction

The Climate Resilient Infrastructure Development Facility (CRIDF) is DFID's innovative water infrastructure programme for southern Africa. CRIDF prepares small-scale water infrastructure projects and facilitates access to finance for the implementation of these projects. Activities are selected according to a set of CRIDF principles to ensure that investments align with strategic objectives that have been developed specifically for each SADC river basin.

According to the CRIDF Climate Resilience Strategy, climate resilience should be practically integrated into all CRIDF Projects, at Programme, Project and Activity levels and in order to do so there is a need to develop a more systematic assessment of the risks associated with the CRIDF portfolio of projects.

This protocol provides guidance on the activities to be undertaken and deliverables to be produced in order to assess, document and manage climate risk for CRIDF projects.

The key questions that we aim to answer by following this process are:

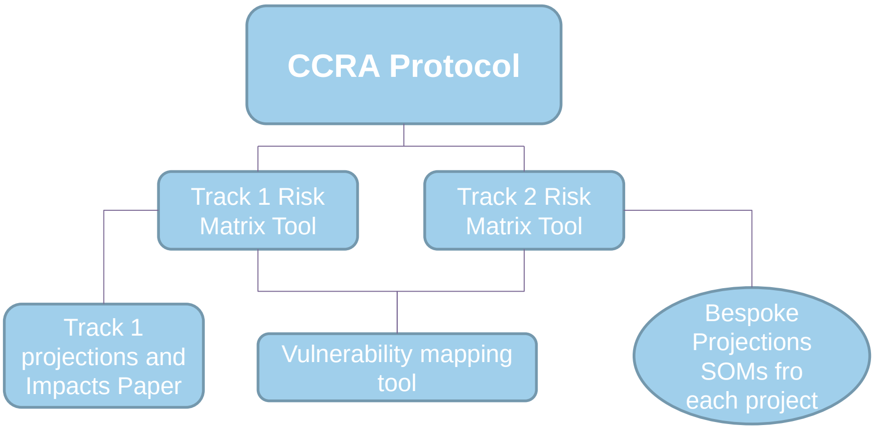
- How and where will climate change impact on new irrigation and WASH infrastructure?
- How can we optimize existing technologies and systems to maximize their resilience to climate change?
- What needs to be done differently, so that the CRIDF projects and the services they provide to the beneficiary communities are better able to cope with the climate changes we can anticipate?
- What do we need to understand better to respond effectively?

The guidelines in this protocol which set out the CCRA process are accompanied by four tools (see figure 1 below to see how it all fits together):

1) The CRIDF **climate vulnerability tool** which provides a high level analysis of the regions vulnerability to climate change through a set of key indicators (see Annex A: CRIDF Climate Vulnerability Tool Risk Indicators for more information). To access the tool: [online: http://geoservergisweb2.hrwallingford.co.uk/CRIDF/CCVmap.htm
2) The **Climate Change Risk Assessment Risk Matrix Tools Track 1 and 2** to support the Project Director & Manager with undertaking Tracks 1 and 2: Climate Change Risk Assessment. They include a comprehensive risk matrix for which this protocol provides guidance on how to complete.
3) **A set of projections and accompanying impact statements** covering the whole of the CRIDF operating environment in Southern Africa. These projections provide a consistent basis for conducting the track 1 CCRA. They will reduce the time required to produce bespoke projections on a project by project basis. They will make use of a new technique call self-organising maps (SOMs) to help manage some of the uncertainty associated with the range of different models available. However, they will be less able to take account of local topographic features which a much more resource intensive statistical downscaling study would entail. This means that a site visit and some interpretation at the local level will be important (see Annex B: Self Organising Maps (SOMs) for more information).

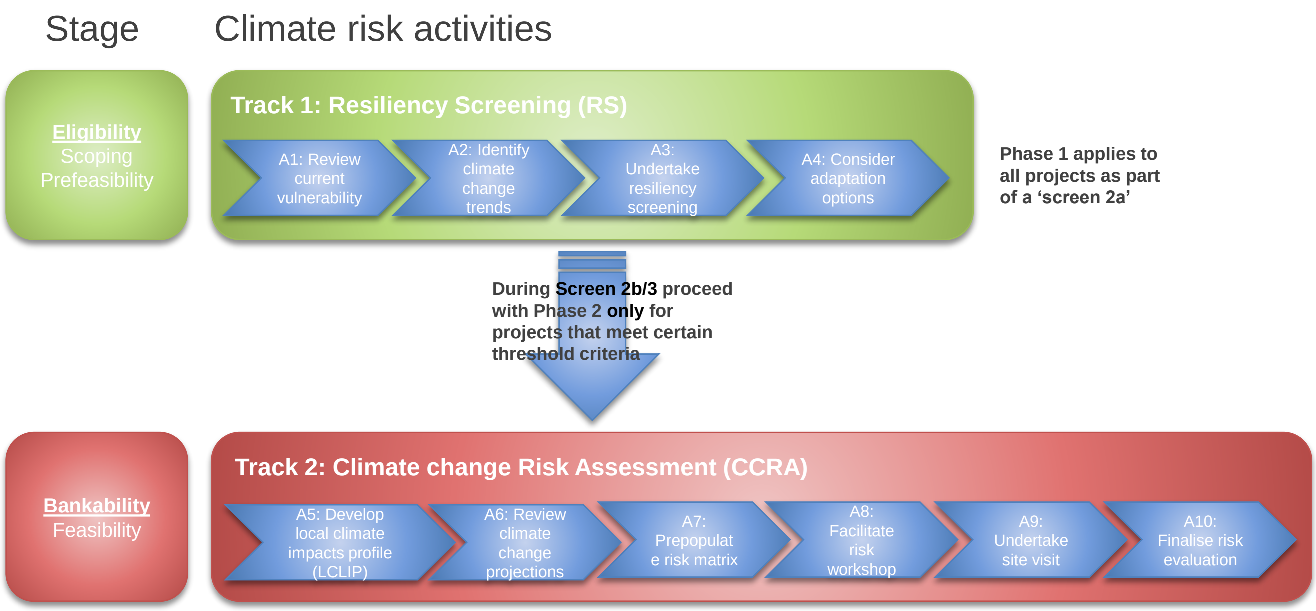
While going through this document, the user should open and familiarise themselves with the above tools as they form a key part of the CCRA process.

Figure 1 **Suite of CRIDF Tools**




An overview of the CCRA approach, which is comprised of two tracks and 10 distinct activities, is presented in Figure 2 below.

Figure 2 **Overview of Climate Risk Activities by Project Stage**

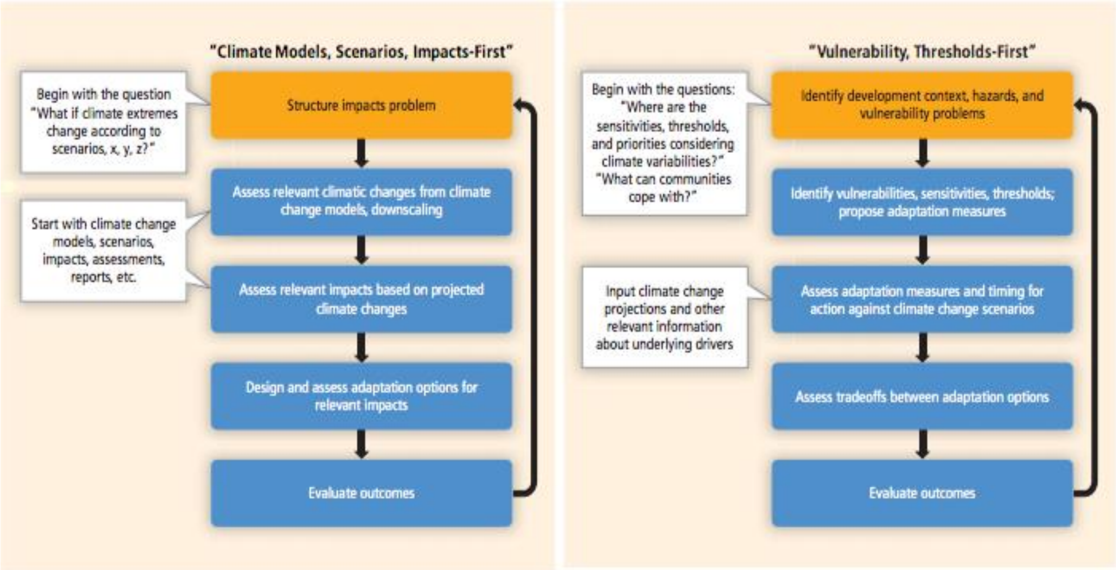



**Track 1: Resiliency Screening** is comprised of activities 1 – 4. These activities form a basic preparatory due diligence and are to be undertaken at concept stage (scoping/pre-feasibility) and most likely undertaken by members of the project team.

**Track 2: Climate Change Risk Assessment** is comprised of activities 5 – 10. It is detailed and intensive, and requires specialised inputs from climate scientists, modellers and climate risk experts, travelling, engagement with stakeholders and on-site presence by a specialist/CCRA Activity Lead. As such, it is only required for projects that meet certain threshold criteria e.g. size, risk, financing, and other strategic considerations.

Figure 3 below describes the different approaches of Tracks 1 and 2 below (IPCC, 2012).[1] The CRIDF track 1 review is more of a 'vulnerabilities-threshold-first' approach which draws on an understanding of the current vulnerabilities of an area and more suitable for small scale projects. Track 2 is more of an 'impacts-first' approach which draws more heavily on future climate change projections as the basis for establishing a risk score.

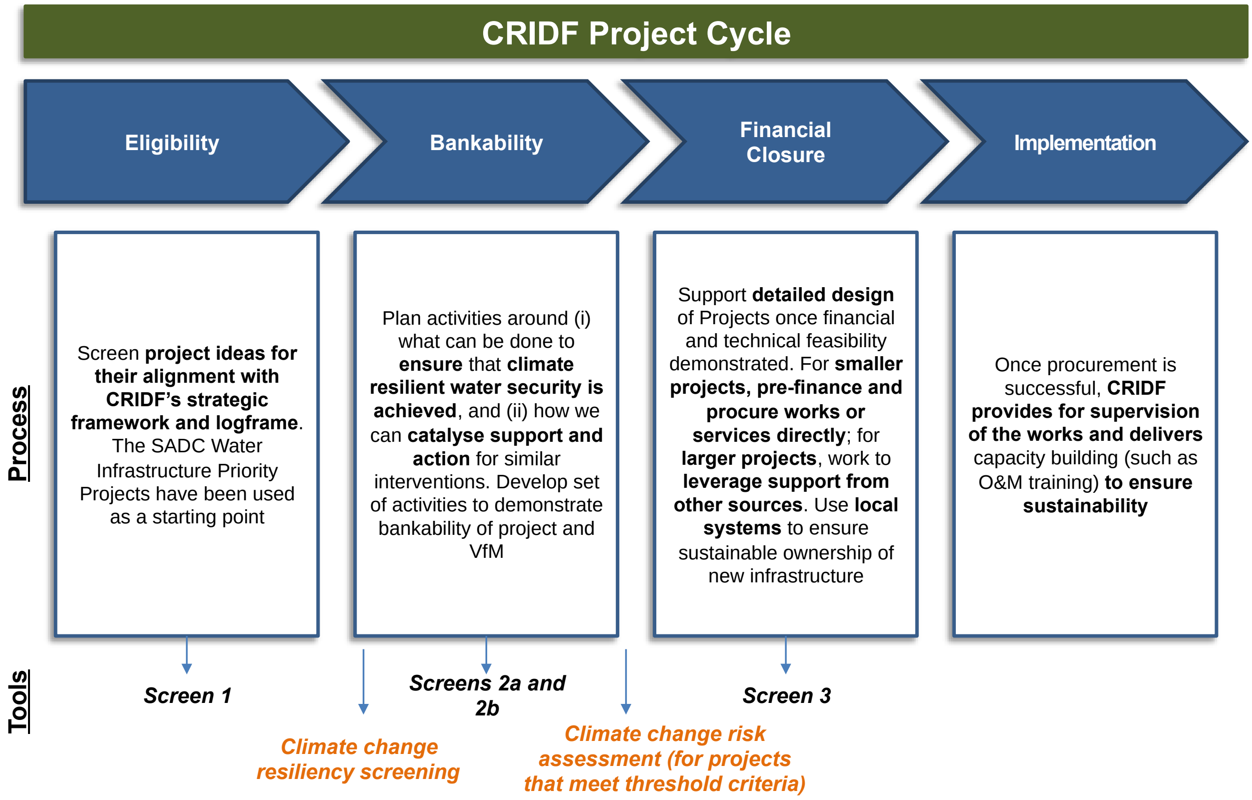
Figure 3 **Different Approaches to Climate Change Risk Assessments**




An overview of the CRIDF project cycle, with the climate risk process input gates, is presented in **Figure 4** below.

Figure 4 **Overview of CRIDF Project Cycle and Input Gates for Climate Change Process**

[1] IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press




## Track 1 Overview

The initial Resiliency Screening track kicks-off when Screen 2a is undertaken for a CRIDF project (see figure 4 above). Screen 2a is undertaken at the end of eligibility and start of bankability in CRIDF's project cycle. It aims to ensure that climate resilience is addressed early on in the project. It is intended that the track 1 CCRA make use of project site visits to gather additional climate related information from project stakeholders, including beneficiaries, and do walk-over surveys to complement, in particular, stages A1 and A3.

At this point, the Project Director/Engineering Lead will seek to establish a high level understanding of the climate risks in the area. CRIDF uses its own Climate Vulnerability Tool (CVT) to help do this but this can also be done or augmented by research on local risks and information from local stakeholders (A1). Subsequently the Project Director/Engineering Lead will identify, at a high-level, climate change trends in the broader area by using results provided by a dedicated CRIDF projections paper as well as self-organising maps (to help manage some of the uncertainty associated with climate projections) and other climate trend sources as necessary (A2). The CRIDF project activities will then be evaluated at a high level for their resiliency to climate change in light of the baseline risk and future climate change information. The Project Director/Engineering Lead will also identify a number of specific climate impacts (A3) for different types of projects (i.e. irrigation, water supply, sanitation, hygiene, small scale hydro and dams) and take into account a list of resiliency considerations (see Annex D) whilst scoping and designing the project (A4). The above process applies to all projects at concept stage. If certain threshold criteria are met then the Project Director/Engineering Lead should proceed with Track 2: Climate Change Risk Assessment during the bankability/feasibility stage.

## Track 2 Overview

The CCRA specialist will kick off track 2 by undertaking an in-depth review of the project context and the historic impacts and vulnerabilities of the area and develop a Local Climate Impacts Profile (A5). Climate projections for risk parameters of interest are also to be developed (A6). This can be done by reviewing localised downscaled projections and studies where available and/or by using specialist support from climate modellers and scientists as necessary. Then a CCRA specialist will proceed with a more detailed risk assessment that involves developing a series of hazard and impact scenarios and evaluating associated climate risks to the project during a risk workshop (A7). Results to be confirmed and/or further amended by undertaking a site visit (A8). Subsequent to the site visit the CCRA specialist will finalise the risk evaluation and overall outputs (A9). The above process is described in further detail for each activity in the remainder of this document. The characteristics of each track are summarised in **Table 1**.

Table 1 **Summary Overview of CCRA Tracks**

| | Track 1 | Track 2 |
|---|---|---|
| **Scope** | CRIDF project portfolio (i.e. the infrastructure itself) | CRIDF project portfolio, local communities, area, region |
| **Type** | High-level screening | Detailed assessment |
| **Objective** | Climate proofing is incorporated early on in project scoping to enable changes in project content | Impacts of projects are systematically documented, benefits are reported clearly and enable changes in project design and climate finance from other donors/sources |
| **Timing** | Scoping/prefeasibility | Feasibility/detailed design |
| **Location** | Desk-based | Desk-based and site visit |
| **Effort** | 3 – 4 days (CRIDF) | 20 – 35 days (Specialists) |
| **Lead** | CRIDF Project Director/Activity Lead supported by CRIDF Manager | Climate change specialist/CCRA Lead |
| **Specialist support** | Not needed | Yes climate change risk specialist and possibly climate scientist |
| **Projections** | Vulnerabilities-led but makes use of CRIDF's own high level projections for the whole of Southern Africa | Impact-led thus may require more detailed projections from a downscaling study and its own SOM analysis |

# Track 1: Resiliency Screening

The first track of this process is a high-level risk screening exercise, a climate resilience 'health-check' to ensure that major risks have been taken into account in the project design and no/low regrets adaptation measures have been considered by project engineers. It aims to support the Project Directors & Managers and CRIDF engineers in addressing issues associated with climate proofing projects and ensuring resiliency considerations are adequately addressed in the project concept and early design. For projects that meet the criteria in Table 2 below a more detailed risk assessment is required.

Table 2 **Criteria and Thresholds for Undertaking Track 2**

| Criterion | Threshold |
|---|---|
| **Size** | If CapEx costs exceed approx. GBP5,000,000, consult with the CRIDF Climate Lead (Jeremy Richardson) as to whether a Track 2 is required. |
| **Risk** | High risk (resulting from a Track 1 risk assessment) |
| **Financing considerations** | Seeking external sources of finance particularly climate finance |
| **Strategic considerations** | Flagship projects serving as pilots for programmes of activities or leading to transformational adaptation |

Under Track 1, the Project Director/Engineering Lead, supported by the CRIDF Manager[2], would review the types of impacts or risks that can be expected for climate vulnerability and future trends identified in the project area depending on the type of project that is to be implemented. A spread sheet tool, including the matrices that accompany this part of the protocol (Risk Matrix Tool Track 1), sets out the constituent steps of the track 1 process, which are as follows:

- Step 1: Run the CRIDF climate vulnerability tool to ascertain the current level of vulnerability to climate and water in the area. This is best used as some additional context to scoring the risk in the CCRA matrix reproduced below. E.g. if a number of the vulnerability indicators score highly in the area of the project (i.e. very vulnerable) that should be considered in determine the risk scoring for the track 1 CCRA. At this stage it is important for the Project Team to define, differentiate and document the *inherent* and *additional* climate resilient elements of the proposed Project:
    - *Inherent* climate resilience refers to how the Project would support the livelihoods of communities who would otherwise be unable to subsist, as a result of *current* climate change impacts. The Vulnerability Mapping helps demonstrate this inherent resilience and the CCRA should document this

[2] A project manager

  - The *additional* climate resilience of the Project refers to how elements of the Project would support the livelihoods of communities who would likely be unable to subsist in the future as a result of *projected* climate change impacts which tend to be more easily identified as the CCRA progresses below.
- Step 2: Make a list of the components of the proposed project (e.g. irrigation pipe work, river off-take infrastructure, bore holes, weir or dam, water supply and sanitation infrastructure, training and capacity building etc.)
- Step 3: As part of a feasibility site visit, engage with project stakeholders to confirm the vulnerability and better understand the weather and climate related problems in the area (i.e. predictability of rain fall, drought, flooding, ground water changes, water course siltation/pollution, vegetation loss soil erosion etc.). A very useful approach is to ask how these things have changed in the last 10 or 20 years – i.e. is soil loss and/or revegetation getting worse or better; is crop failure due to rain failure more or less common today than in the past? See Annex C for more suggestions of questions to ask.
- Step 4: A walkover survey of your site is important. Basic, key considerations are:
  - Is the project and or community that is prone to flooding located near a river which may flood or dry up, or in a steep-sided un-vegetated valley or a flat plain – i.e. prone to soil erosion
  - Is the project and or community area vegetated (Steep un-vegetated slopes are more prone to soil erosion and rapid run off (potential for flooding) than flat vegetated areas)
  - Are the soils sandy or clay (clay soils are less prone to erosion but restrict ground water recharge).
  - How has the community reacted previously during severe flood or drought? What measures were put in place, if any?
  - Is there plenty of available agricultural land and how productive is it.
  - Are there existing flood defences of rain water harvesting infrastructure
- Step 5: Identify the projected climate trends in the future. This can be done in two ways
  - Use CRIDF's regional projections and impact paper[3] to understand what how the future climate change might impact your project. The Table (see Annex G) provides information on projected climate change trends and the potential sector impacts for 5 climatic zones in Southern Africa. Climate change trends include: precipitation variability, temperature variability and extreme events. The Agricultural and Health sectors were included in the Table as they were viewed as most relevant to CRIDF due to the nature of our projects – that is, livelihoods and irrigation, and water supply, respectively. See map (Figure 5) below.
    - Region 1, Summer ITCZ region. Angola, Zambia, Malawi, central and NE Zimbabwe - This is a temperate/tropical region with dry winters (subtropical high pressure cells) and rainy summers (tropical lows driven by seasonal migration of the ITCZ).
    - Region 2, Summer Indian Ocean cyclone/monsoon zone. Mozambique, Tanzania - Tropical/seasonal monsoon climate characterized by incoming cyclones from the Indian Ocean.

[3] Southern African Projections and Impacts Guidance Paper [online:www.cridf.com/]

- Region 3, Arid descending arm of Hadley cell. Namibia, Botswana, SW Zimbabwe, S Mozambique - This region has a negative hydrological balance, low and variable precipitation and seasonally high temperatures.
- Region 4, Temperate cyclonic zone. E South Africa, Swaziland, Lesotho - This region has a wet summer regime with thunderstorms and subtropical cyclones.
- Region 5, Semi-arid/winter rainfall zone. W South Africa - This region is characterized by a steppe climate inland with winter rainfall and fog at the coast.

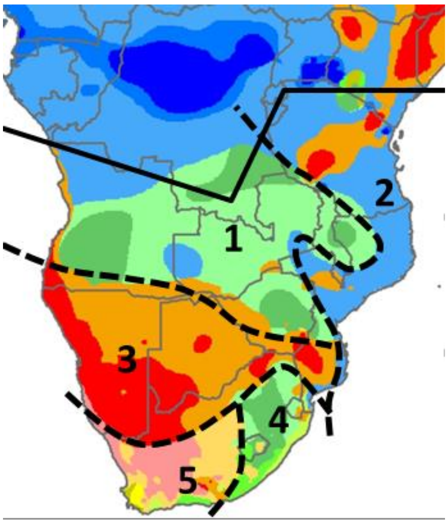



Figure 5 **Climatic Zones in SADC**

- The relevant climatic zone to your project needs to be identified. If the project is near a climate zone boundary you may need to consider a potential shift in the boundary which may impact your project. This should be discussed with a readily available specialist[4] prior to proceeding with the assessment.
- Read the introductory text to the table and cut and paste the relevant table row into your own document for analysis as part of your climate change evidence base for your project
- Look at the regional projections and set of Codex maps to see if they provide any additional information to the impact table and augment your climate change evidence
- The Impact table and the projections provide an up to date and consistent approach to climate change projections for CRIDF, as well as additional interpretation from climate scientists.
- If an impact/occurrence is noted during the site mission or expressed by local stakeholders, but does not fit within the Impacts table template – internet/desktop research should be conducted. For example, if your project falls within significantly different sub-climatic zone within one of the 5 climate zones (see North of Climatic Zone 2) then you may need to also consider information

[4] In CRIDF the PMU Climate Resilience Lead (Jez Richardson)

from other (relevant) climatic zones. Advice on this should be sought from a specialist[5] to ensure the appropriate emissions scenario is selected.

- Step 6: Combine the projections and your notes from the site survey, and your list of project components and summary of community vulnerabilities from the project documents into your evidence base for the project CCRA
- Step 7: Organise a project stakeholder meeting with Project engineers, Project Director and CRIDF Manager and other subject matter experts (e.g. livelihoods, transboundary water, and gender experts etc.). For Projects with an irrigation/livelihoods component, it is critical that the Project Agronomist also be engaged – as he/she will need to take into consideration and expand upon the high level Agricultural Impacts outlined in the Impacts Table (Annex G). This should help inform the development of their designs and proposed cropping schedules, and any agricultural extension support recommendations. Similarly, for water supply projects the Sociologist and WASH Engineer must be engaged to ensure that the high level Health Impacts outlined in the Table are considered and expanded upon as part of their design recommendations, as well as any accompanying WASH support programmes.
  The purpose of this meeting is to agree and list the key risks associated with future climate change (using the projections and scenarios as appropriate) and the proposed mitigation actions in terms of project design. See tables 5 and 6 below as well as figure 6 to understand the scoring criteria.
- Step 8: Fill in the risk and resilience benefits matrices (see figure 6 and 7 below) during the workshop based on the presentation of the evidence you have collated to the meeting and the resulting discussion. as well as ensure you agree recommended project design changes to address those risks as part of the scoping or pre-feasibility report that is being prepared, as appropriate.
- Step 9: Write up the results of the CCRA in the project document including the complete matrix and mitigation recommendations. Key information in the write up includes:
  - Summary of climate changes and impact expected in the project area.
  - Key potential  vulnerabilities of the project and the beneficiaries (site survey)
  - The risk table with the different project components and the key risks identified and scored
  - A discussion of the recommended mitigation measures

See **Figure 6** below for the structure of the risk matrix

Figure 6 **Track 1 Risk Matrix**

| | Hazard | | | | | Comment on Proposed Mitigation |
|---|---|---|---|---|---|---|
| **Project component** | **Flood** | **Drought** | **Fire** | **High Winds / Cyclones** | **Sea level rise** | |
| **Irrigation pipe work** | High | Low | Medium | No risk - N/A | No risk - N/A | |
| **River off-take infrastructure** | High | Low | Low | No risk - N/A | No risk - N/A | |
| **Boreholes** | Medium | Low | Low | No risk - N/A | No risk - N/A | |

[5] Ibid

| | | | | | | |
|---|---|---|---|---|---|---|
| **Weir or dam** | Medium | Low | Low | No risk - N/A | No risk - N/A | |
| **Power generators** | High | Low | Medium | No risk - N/A | No risk - N/A | |
| **Roads** | High | Low | Low | No risk - N/A | No risk - N/A | |
| **VIP Latrines** | High | Low | Low | No risk - N/A | No risk - N/A | |
| **Training & capacity building** | Low | Low | Low | No risk - N/A | No risk - N/A | |
| **...** | Low | Low | Low | No risk - N/A | No risk - N/A | |

Figure 7 **Track 1 Resilience Benefits Matrix**

| Project component | Livelihoods | Safety | Health & nutrition | Governance | Gender | Education | Environment |
|---|---|---|---|---|---|---|---|
| **Provision of water supply** | No significant benefits | No significant benefits | High: Water supply will improve access to water and hygiene | No significant benefits | High: Water supply will provide more time for women currently fetching water. | High: Less absenteism due to fetching water or disease | Medium: Project is establishing a 'green zone' around the abstraction points that can result in revegetation and improved habitats |

# Track 2: Climate Change Risk Assessment (CCRA)

This track is required for projects that meet certain threshold criteria in terms of overall size, level of risk, financing or other strategic considerations. These thresholds are presented in the following table.

Table 3 **Criteria and Thresholds for Undertaking Track 2**

| Criterion | Threshold |
|---|---|
| **Size** | GBP£5,000,000 Construction |
| **Risk** | High risk area |
| **Financing considerations** | Seeking external sources of finance particularly climate finance |
| **Strategic considerations** | Flagship projects serving as pilots for programmes of activities or leading to transformational adaptation |

The Project Director/Engineering Lead should proceed with Track 2 for projects that meet or exceed the above criteria. This detailed assessment kicks in at the Bankability / Financial Closure stages. The remainder of this section explains in detail how to undertake a climate change risk assessment. This should be read in conjunction with the Spread sheet risk matrix tool that accompanies the track 2 process (Risk Matrix Tool Track 2).

## Activity 5: Develop Local Climate Impacts Profile (LCLIP)

Under this activity, the CCRA specialist should seek to understand the existing local context and collect information that can help with characterising the baseline risk situation in the area for climate parameters of interest. Historic information on past weather events, their impacts, and the institutional responses are very important to a LCLIP Such information is important in helping to understand risks associated with current climatic conditions and to provide a reference point from which future climate changes can be evaluated in the following activity.

The information that will support the development of a preliminary climate baseline for the project and the nearby area will come mainly through desk-based research. The desk-based research involves the development of a high level LCLIP in order to identify historic weather data and incidences. Local communities may already be experiencing a changing climate, which can affect their quality of life and livelihoods. A number of social challenges can arise from climate or weather-related issues. For example, water scarcity, due to declining levels of precipitation, can threaten the livelihoods of communities that depend on agriculture. Information on social issues that may be caused by or relate to climate and weather can be gathered by undertaking a desk based LCLIP review, and by talking to local stakeholders during the site visit activity.[6]

The CCRA specialist should capture information that might typically be found on the Internet, in newspaper and in other reports and secondary sources. The CCRA specialist should also review weather-related news stories and build up information on the weather reported, (type, details and impact) but more importantly, on the consequences – what happened as a result – how local communities and businesses were influenced and how the different departments and services reacted. This is the details which not being documented at the moment and will assist in portraying how the project and the locals currently handle the impacts of weather circumstances. In the CCRA Risk Matrix Tool Track 2 under tab 'LCLIP' a basic template to collect such information is provided. Information on historical temperature and rainfall anomalies in the area of interest should also be collected, where available. A list of indicative information sources can be found in Annex E: Climate Change Information Sources

Consideration can also be given to existing risk, techno-economic, social and other climate related studies where those are available and include:

- Existing reports on historical or projected impacts in area/country of interest by organisations such as the World Bank, IIED, the UK Met Office, NGOs and others.
- Existing project cost-benefit analysis studies that can provide further information on climate related benefits of projects to local communities
- Surface and ground water hydrology studies that look at how changing precipitation and evaporation might affect stream flow and ground water recharge at the area.
- Biodiversity studies that look at how local ecology and agricultural practices might change with changing temperature and precipitation patterns and how this might impact on local livelihoods.
- Flood risk assessments, including research on the frequency and severity of historical flooding in the area, the influence of topography on flood prone areas, and the projected trends for flood events in light of predicted climate change
- Information on any climate adaptation plans that might already be in place at local, regional, state or national levels. This should help to align the CCRA as well as the project's/local communities' adaptation options with such plans.
- CRIDF climate vulnerability mapping tool

At the end of this activity the CCRA specialist will be able to identify hazards and have collected a body of information / evidence that can support determinations of the level of baseline risk for the CRIDF project and local community in subsequent activities. It may also reveal a change in climate trends in recent years, which can help with interpretation of the projections in Activity 6.

The outputs from Activity 1 will provide a description of climate and weather characteristics and risks for a project and the local community. A summary of these details should be included in the CCRA report for the project and reviewed by theme, (e.g. rainfall, temperature, flooding, drought, groundwater resources and other climatological

[6]: A template for undertaking a LCLIP is provided in the CCRA tool and further guidance can be found at the UKCIP website at www.ukcip.org.uk/wizard/current-climate-vulnerability/lclip/

and weather characteristics in the area etc.). See examples of already completed CCRAs for guidance (e.g. the Kufandada and Bindagombe CCRA case studies on the CRIDF website[7] show how outputs from this activity can be taken into account and incorporated into a CCRA report).

### Activity 5 Output

- Description of climate and weather characteristics and risks for the project and the local community using LCLIP tab in CCRA Risk Matrix Tool Track 2.

## Activity 6: Review Climate Change Projections

Having constructed the climate baseline for a site, projections of the estimated change in the regional or local climate should be collected for parameters of interest. For example, if the main risk identified is drought then information should be collected to help determine future climate change for parameters such as rainfall patterns and inter-annual/inter-seasonal variability, and also surface flows and groundwater drought projections where available.

A number of sources can be used for this Activity, as outlined in Annex E: Climate Change Information Sources It should be noted that there is uncertainty in climate change projections for all climate variables. This is particularly the case where there is an argument between various climate models and scenarios (each using its own data and making specific assumptions on the behaviour of climate variables and systems) on the direction of change for a particular climate variable. For example, some models might project future increases in winter precipitation in a region, whereas others might project decreases for the same region. When interpreting the climate change projections, information and findings on the level of certainty behind particular projections (or lack thereof) should be documented in the outputs of the analysis so that the climate change risk can be interpreted appropriately.

The CCRA Specialist should go through the following sources of information presented in Table 3 to identify suitable climate change projections for the area. In the first instance, the CCRA specialist should review climate change information from the IPCC website and any national / regional climate change studies that exist for the area, where available. For example, an extensive and recent study from the World Bank has assessed in detail the impacts due to climate change using downscaled models in the Save Basin. Should such information not exist or it proves insufficient for the purposes of the assessment the CCRA specialist can consider specialised inputs from climate scientists and modellers as needed. Such specialised input support includes, for example, local models that downscale global or regional climate modelling to a more local level, or commission a set of SOMs for the particular sub basin (to complement CRIDF's Southern Africa ones set out in its projections and impacts paper), which can help with uncertainty with regards to various climate change scenarios.

Table 4 **List of Information Source Categories**

[7] Or contact CRIDF on via the website [online: www.cridf.com/] for a suitable example.

| Information/Data Sources | Comments |
|---|---|
| **IPCC Assessment Reports** | The Intergovernmental Panel on Climate Change (IPCC) Assessment Reports provide a detailed summary of scientific, technical and socio-economic information on the potential effects of climate change. A detailed list of indicative information sources and links can be found in Annex E. |
| **National / regional climate change studies** | National and/or regional climate change studies are useful in summarising climate projections at a national scale. Amongst others, the UK Met Office has published a number of country-level climate change reports, and the United States Global Change Research Program (GCRP) regional climate change impact studies provide useful information on climate variability and change at a national / regional level. Many local governments and academic institutions have conducted country-level modelling and such organisations can be approached to determine whether national/regional studies have been undertake which will provide more detailed and accurate information than global studies. |
| **Climate change models** | Climate change projections are based on the output of global or regional climate models. These models can be used to obtain climate change projections and data for a particular area. A more textured understanding of projected changes can also be achieved through 'downscaling' with modelling at regional, provincial or catchment levels. More detailed outputs on climate change models can be conducted by specialist consultancies, local academic institutions, or meteorological organisations with access to models with global reach. |

A detailed list of indicative information sources can be found in Annex E.

The following factors should be considered when determining the accuracy, reliability, and relevance of data and information used to summarise the climate projections for an area:

- **Sources of climate change data and information:** As far as possible robust, peer reviewed, widely recognised sources should be used. Such sources include the Intergovernmental Panel on Climate Change (IPCC), and any robust national climate studies as discussed in Annex E. If publically available data is insufficient to determine, at a high level, the direction of change, external support could be sought in the form of specialised climate modelling experts and academic institutions. Reasons to do so include:
    - Studies are old and based on out-of-date data, or there is no data at all
    - There is a lack of sufficient representation of climate models
- **Climate change time horizons under consideration:** Climate change projections are typically determined for future scenarios in the middle to end of the 21st century. It is recommended that the climate change horizon selected is in line with the project lifetime. Information availability is an issue and projections may only be

available for a single horizon. It is recommended that the most extreme projections are used in order to ensure future changes are adequately considered.

### Activity 6 Outputs

- Detailed climate change projections, downscaled and localised where possible for the project and area

The climate specialist and the project lead should compile a summary of the information found on baseline and projected climate in the CCRA Risk Matrix Tool Track 2.

## Activity 7: Pre-populate CCRA Risk Matrix

Information collected on the climate baseline (A5) and future climate projections (A6) for an area should be interpreted prior to the workshop and transformed into hazard and impact scenarios. Pre-populating the high-level risk assessment in the CCRA Risk Matrix Tool Track 2 involves undertaking the following four steps, which are presented in **Figure 8** below and in more detail in the remainder of this section.

Figure 8 **Key Steps for Activity 7**


### 1. Identify hazards and impact scenarios

The first step in this Activity would be to determine the climate baseline risk for the site area by using expert judgement and information collected in previous Activities. As a starting point, the CCRA specialist should consider the threats and hazards that have historically affected the area. Historical risk information collected in Activity 5 should provide the CCRA specialist with a list of identified hazards. For each hazard identified, specify the potential impacts and any related indirect consequences. For the applicable hazards (provided in the drop-down menu in the tool), the CCRA specialist should develop impact scenarios on the project by considering the question 'How could this event cause additional cost, disruption, or damages to the local community or the project itself at any point over its lifecycle?'. Climate events and hazards should be listed in the tool along with a defined description of an impact scenario i.e. what the manifestation of this hazard would mean for the area. For example, heavy rainfall of 300mm over 24 hours causes 80% of local community housing to flood and damages the project infrastructure or results in crop losses of 50% etc.

Example scenarios that were developed from a CRIDF case study (Bindagombe) are presented in **Figure 9** below.

Figure 9 **Example of Impact Scenarios for Bindagombe Case Study**

| Issue number | Hazard | Element at risk | Impact scenario |
|---|---|---|---|
| 1 | Changes in rainfall patterns | Livelihoods (Crops and Live Stock) | Volatile rainfall patterns and drought cause very poor average crop yields at location (0.2-0.3 t/hectare) and in worst crop failure years there is reduction of yields to 0.1t./ha. - complete failure |
| 2 | Pluvial/Fluvial flooding | Project infrastructure | Heavy flooding causes damages to irrigation infrastructure (pump, storage reservoir or mains) and renders the system unused for one growing season until repair |
| 3 | Drought | Livelihoods (Crops and Live Stock) | Frequent drought incidences (1 every 3 years) cause crop failure and lead to increased deforestation in the area, soil erosion and flood risk |

This exercise should cover not only direct and physical impacts to local communities but also indirect knock-on impacts when material to the long-term sustainability of the project. For example, one of the Makonde case study's[8] impact scenarios identified was related to the local communities' ability to pay for projects services, due to climate change knock-on effects to local livelihoods. More information is presented in Box 1 below.

[8] A CRIDF project

### Makonde project example of indirect impact scenarios

In Makonde the livelihoods of local population are heavily dependent on agriculture activities that include primarily cultivation of cashew nuts that constitutes the main source of income for the majority of the locals and to a lesser extent cassava and mango. Although the cashew tree can withstand high temperatures, a monthly mean of 25 °C is regarded as optimal. Projected temperature increases in the area along with increased rainfall variability and unseasonal rains could impact crop quality and quantity. This in turn could have a knock-on-effect on the local population's willingness to pay for water jeopardising the commercial viability of the project. In addition to this the overall risk is exacerbated by the fact that there are cost-free water supply alternatives in the area. More info in 'Makonde CCRA'

#### 2. Score baseline risk

Once a detailed description of the impact scenario has been defined the CCRA specialist should proceed to characterise the likelihood and consequences of its manifestation with the aim to determine baseline risk (i.e. existing risk) for each parameter of interest.

Likelihood is the chance of something happening, whether defined, measured, or estimated objectively or subjectively. The question that needs to be answered is "How often is this hazard likely to manifest now?" (Likelihood can be scored subjectively based on information collected in the previous Activity. Some generic guidance on how the CCRA specialist could approach the likelihood scoring exercise along with some examples is provided in Table 5 below.

Table 5 **Likelihood Ratings**

| Likelihood | Example |
|---|---|
| **Rare** | The location or nearby areas have rarely experienced related events in the past (less than one event every 50 years) and/or CRIDF CVT indicators rank the risk for the area as low for the hazard in question |
| **Unlikely** | The location or nearby areas have sporadically experienced related events in the past (1 every 20-50 years) and/or CRIDF CVT indicators rank the risk for the area as low for the hazard in question |

| | |
|---|---|
| **Possible** | The location or nearby areas have experienced related events in the past (1 every 10-20 years) and/or CRIDF CVT indicators rank the risk for the area as medium or high for the hazard in question |
| **Likely** | The location or nearby areas have regularly experienced related events (1 every 5-10 years) and/or CRIDF CVT indicators rank the risk for the area as medium or high for the hazard in question. |
| **Almost certain** | The manifestation of the hazard is a common (1 every 1-5 years) and well known occurrence in the area and CRIDF CVT indicators confirm this for the hazard in question |

Take into account that over-reliance on past averages or patterns may create an not accurate sense of likelihood. For instance, many serious natural hazards (such as floods) happen in such low frequency (1/100 year event) that relying only on historical records alone may be misleading. For scoring purposes the CCRA specialist should also consider the threats and hazards that similar, nearby areas have experienced or are prepared to respond to.

Subsequently, the CCRA specialist should proceed with scoring the consequences associated with the impact scenario both for the community and the project itself. A range of inputs, including historical records in impacts from previous similar incidences, and expert judgment should be used to score consequences according to the following categories.

Key things to consider when scoring for consequences include:

- Size of geographic area affected
- Likely magnitude of losses/damages
- Disruption to infrastructure and downtime of local community and project activities
- Population density and likely number of affected households, fatalities, injuries, illnesses, and capacity to adapt
- Taking all the above into consideration in light of the resiliency of local populations. Low resiliency of local population means more severe consequences for any given impact. The CRIDF CVT includes two indicators that can shed some light on overall resiliency of the local community.

Some generic guidance on how the CCRA specialist could approach the consequence scoring exercise along with some examples is provided in **Table 6** below.

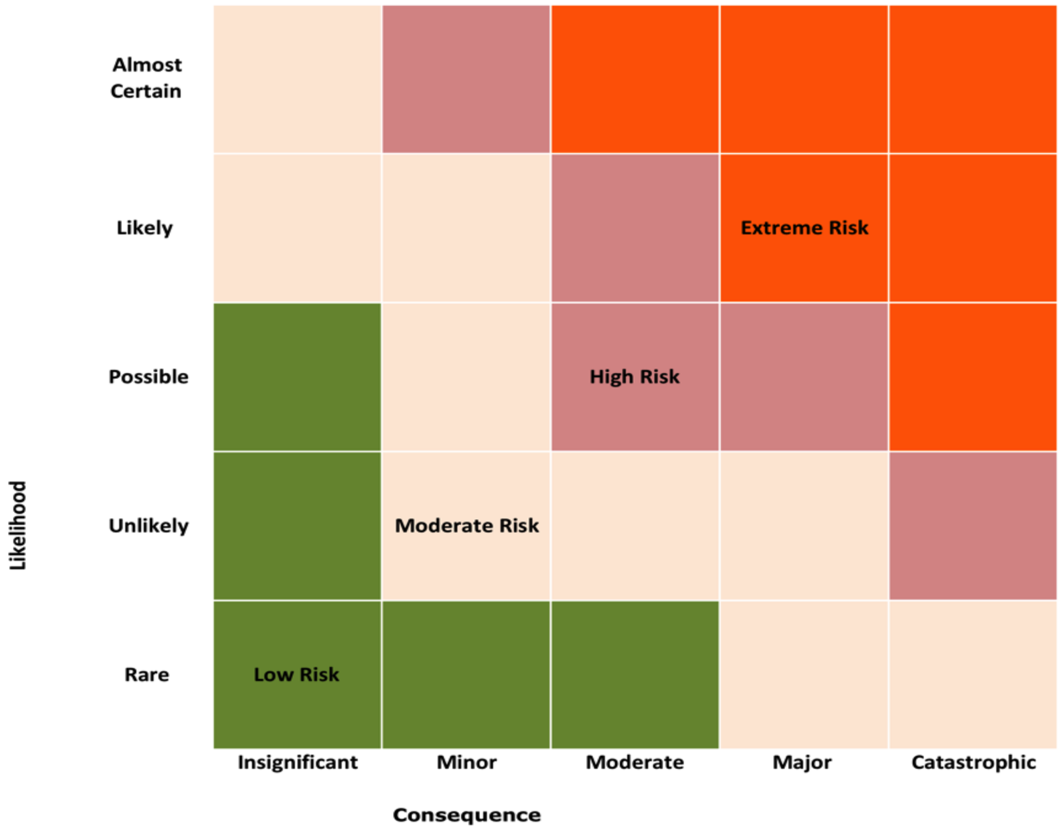
Table 6 **Consequence Ratings**

| Consequence | Example |
|---|---|

| | |
|---|---|
| **Insignificant** | Temperature extremes could marginally affect the expected lifetime of installed equipment. Here consequences are minimal in themselves therefore consequence is rated as insignificant. |
| **Minor** | Strong winds or floods result in minor structural damages to WASH infrastructure. This could result in some minor disruption of services but coupled with a relatively more resilient population (CRIDF CVT Tool indicator), the consequence is rated as minor. |
| **Moderate** | Strong winds or floods create moderate damage to infrastructure. Increased incidence of dengue, carrion's disease, diarrhoea, bartonellosis, malaria or other vector-borne diseases impact the health of the local community and put a strain on WASH infrastructure and agricultural activities. A moderate drought may lead to some loss of income but may not require external aid. |
| **Major** | Severe drought impacts CRIDF small scale hydro-power project, reduces hydro-power capacity causing 'black-outs' to local community and failure of irrigation and water supply pumps. This is a major impact to a hypothetical, very resilient local community that has other irrigation alternatives in place and can withstand seasonal shocks of this sort, and consequence is rated as major. |
| **Catastrophic** | Heavy flooding leads to overflow of water storage facilities, breakage of water pipelines and disruption of water supply to irrigated areas and local community for a month. This is a potential moderate/major impact, however local community is least resilient and most reliant on the facilities for subsistence farming and meeting their basic needs. Therefore consequence is rated as catastrophic. |

The main output from this step is a high level characterisation of risk by qualitatively scoring the severity of the consequence and its likelihood (using the columns provided in the Risk Matrix Tool Track 2). The tool also includes a risk matrix, presented in Figure 10 that can be used to prioritise risks.

Figure 10 **Risk Matrix**




An example of baseline risk scoring for a CRIDF case study is presented in **Figure 11** below.

Figure 11 **Baseline Risk Scoring for Bindagombe Case Study**

| Impact scenario | Likelihood | Consequence | Risk | Assumptions and rationale for score |
|---|---|---|---|---|
| | Present | | | |
| Volatile rainfall patterns and drought cause very poor average crop yields at location (0.2-0.3 t/hectare) and in worst crop failure years there is reduction of yields to 0.1t./ha. - complete failure | Likely | Major | Extreme | Previous use was under rain-fed agriculture which was becoming increasingly difficult to sustain due to frequent drought and volatile rainfall patterns. Farmers indicated that agricultural production was characterized by volatile changes due to drought. Current yield levels are poor and the risk of crop failure is high at one out of three years. Yield values used in impact scenario are based on info collected from site visits and interviews with farmers and other local stakeholders |
| Heavy flooding causes damages to irrigation infrastructure (pump, storage reservoir or mains) and renders the system unused for one growing season until repair | Possible | Minor | Moderate | The area has experienced extreme weather and flooding events in the past but the equipment is far away from the river so no/minor consequences are expected |
| Frequent drought incidences (1 every 3 years) cause crop failure and lead to increased deforestation in the area, soil erosion and flood risk | Likely | Major | Extreme | There is an increased problem of erosion in Bindagombe. According to local farmers and villagers it is primarily due to deforestation. Drought and crop failure has indirectly driven local deforestation since it drives local people to cut trees downs and sell them as wood fire. |

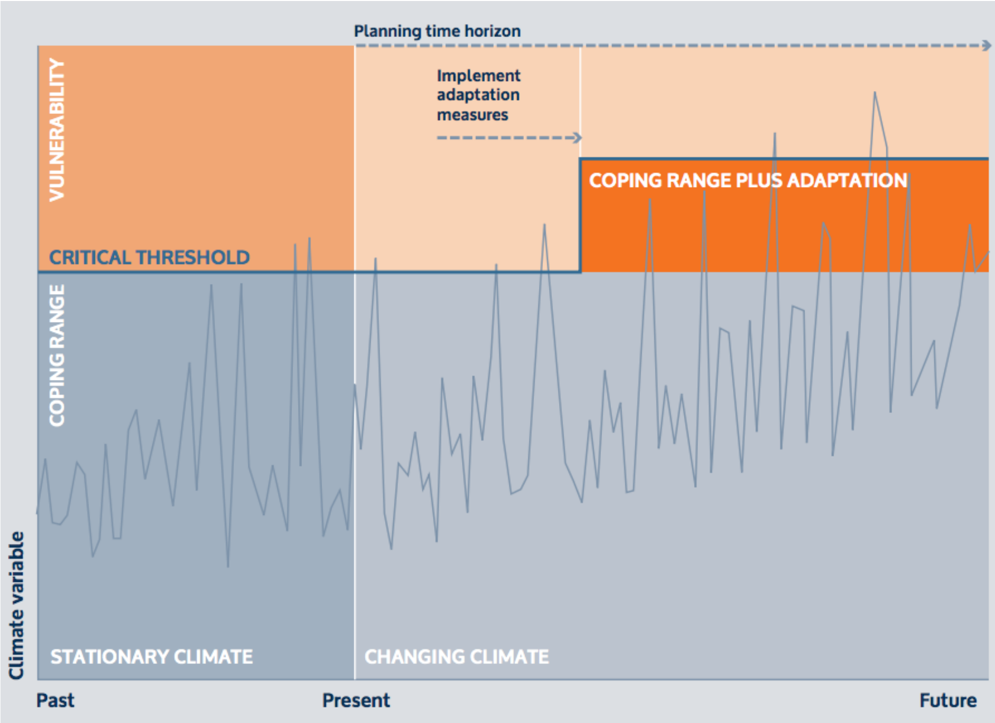
## 3. Understand future risk

Each risk identified and scored in step 2 should then be considered again in this step, but this time in the context of future climate change projections collected in Activity 6. Given the information available on climate projections, the CCRA specialist supported by climate specialists/modellers/scientists should make a judgement on whether the severity or likelihood of the impact and consequence of each risk will change (increase or decrease) in the future, and if so how.

Consideration should be given to risks arising not only from changes in the frequency and severity of extreme events but also to gradual climate changes that might cause a change in overall conditions and increase vulnerability.

Vulnerability could increase as the climate hazard under question rises over time and exceeds the critical coping threshold as illustrated in **Figure 12** below. Thresholds may be natural (such as the water level at which a river bursts its banks, or a temperature threshold above which irrigation equipment cannot operate effectively or crops cannot grow fully), or they may be socially constructed, based on risk attitude (e.g. the 1 in 200 year return period standard for coastal floods).

Figure 12 **Climate Variability and Coping Ranges**[9]




Some example interpretations of climate change projections are provided below:

- Projected increases in precipitation intensity and winter rainfall could mean that in future there is increased flood risk in localised sites in the region that are vulnerable to flooding (for example, sites located at the base of a hill, near to a body of water, or in a relatively flat area with poor drainage capacities).
- Projected increases in average and maximum temperatures could mean that there is increased risk of heat wave events during the hot summer months, wildfires and drought.
- Projected intensification of tropical storm and cyclone events for a site area located in a tropical cyclone zone could mean that there is increased risk of damage and disruption from storm events and flooding in the future

An example of future risk scoring for the Bindagombe case study is presented in **Figure 13** below.

[9] Willows, R.I. and Connell, R.K. (eds). 2003. Climate adaptation: Risk, uncertainty and decision making. UKCIP Technical report, UKCIP, Oxford

Figure 13 **Future Risk Scoring for Bindagombe Case Study**

| Impact scenario | Likelihood | Consequence | Risk | Assumptions and rationale for score |
|---|---|---|---|---|
| | | | L x C | |
| | Future | | | |
| Volatile rainfall patterns and drought cause very poor average crop yields at location (0.2-0.3 t/hectare) and in worst crop failure years there is reduction of yields to 0.1t./ha. - complete failure | Almost certain | Major | Extreme | Two studies were able to predict intra-annual changes in precipitation. They found that there would be increased variability in precipitation. |
| Heavy flooding causes damages to irrigation infrastructure (pump, storage reservoir or mains) and renders the system unused for one growing season until repair | Likely | Minor | Moderate | Climate trends show rainfall increases in most months followed by decreases in the second part of the season for the area and increased variability. i.e. more intense rainfall events |
| Frequent drought incidences (1 every 3 years) cause crop failure and lead to increased deforestation in the area, soil erosion and flood risk | Almost certain | Major | Extreme | Increased drought and rainfall variability is projected for the area. |

## 4. Identify adaptation measures

**Figure 12** demonstrates how adaptation aims to reduce vulnerability e.g. by increasing the critical threshold i.e. building resiliency and countering the increased risk that the un-adapted threshold will be exceeded due to climate change.

The main aim of this step is to identify, at a high level, possible adaptation to manage risks that have been deemed high or extreme to the project or local community in previous steps to lower the level of risk to a manageable level. For each of these, the CCRA specialist should liaise with the Project Engineer and local communities to detail an appropriate adaptation measure. Adaptation measures should address the risk today (based on baseline) but CCRA specialist and project engineers should also be mindful of possible future climate change. As such, adaptation measures should be 'future-proof' to cater for future climate change (including both changes in the severity and/or frequency of weather events, and long-term increases or decreases in climate variables) and result in reduction in risk for the project and the services and adaptation benefits it provides. Once adaptation measures have been identified, engineers should be able to amend the Project design to ensure that it is climate resilient or, if no risks are identified and project is deemed already resilient, engineers to provide a statement to that effect.

An example of identification of adaptation options for high and extreme risks and scoring of residual risk for the Bindagombe case study is presented in Figure 14.

Figure 14 **Future Risk Scoring for Bindagombe Case Study with identification of adaptation options**

| Impact Scenario | Adaptation Measure | Likelihood | Consequence | Risk | Assumptions and rationale for score |
|---|---|---|---|---|---|
| | | | | L x C | |
| | Description | Estimated future residual risk (post adaptation) | | | |
| Volatile rainfall patterns and drought cause very poor average crop yields at location (0.2-0.3t/hectare) and in worst crop failure years there is reduction of yields to 0.1t./ha. - complete failure | Irrigation project will allow farming to not be dependent on rainfall reducing the exposure to the hazard. Yields are expected to increase from 0.1-0.7t/ha. to 2-3t./ha. The project will help towards a stable, competitive, market oriented and profitable production, with profound impacts on both food self-sufficiency and income generation for local community | Likely | Minor | Moderate | By reducing exposure to drought risk and volatile rainfall patterns it is expected that yield levels would increase to x tonnes/hectare after the implementation of the project and contribute to market participation by enabling farmers to venture into stable, competitive, market oriented and profitable production, with profound impacts on both food self-sufficiency and income generation. |
| Heavy flooding causes damages to irrigation infrastructure (pump, storage reservoir or mains) and renders the system unused for one growing season until repair | No adaptation measures warranted | Likely | Minor | Moderate | |
| Frequent drought incidences (1 every 3 years) cause crop failure and lead to increased deforestation in the area, soil erosion and flood risk | The Bindagombe irrigation scheme | Almost certain | Minor | High | By providing a secure source of income for the local community, the Bindagombe irrigation scheme has clear benefits of reducing flood risk and deforestation. |

This is a preliminary desk-based exercise and the results from this Activity will be reviewed and validated with Project Engineers, local stakeholders and communities in the following activities 8 and 9. For example, the Project Engineers can help determine whether the design specifications for the project are adequate to deal with future changes in risk e.g. in relation to the quantity of rainfall and flood levels, drought etc. The CCRA specialist will consult the Project Engineers to ensure that this aspect of the CCRA adequately reflects potential future climate change in the area in terms of its inherent resiliency and its continued ability to provide the services in the community both temporarily and in the longer term.

### Activity 7 Outputs

The following outputs should be generated at end of this Activity:

- Summary of the baseline and future climate risk along with future climate projections for the area, in terms of likely climate change impacts for area and project
- Population of CCRA matrix of major climate risks associated with the project and local community;
- The CCRA Risk Matrix Tool Track 2 should be used to document the above process.

The CCRA specialist should compile a summary of the information found on baseline and projected climate in the CCRA tool.

## Activity 8: Facilitate Risk Workshop

The objective of Activity 8 is to consult with subject matter experts and engineers and gain further information with the aim to confirm the outputs and to develop the draft risk matrix. The CCRA Risk Matrix Tool Track 2 should be completed by the CCRA specialist in collaboration with the Project Engineer and other Project Team members as required (e.g. Project Director, CRIDF/project Manager, Task lead, Risk, Climate, Water Specialists etc.). Outputs from previous activities – particularly Activity 7 – should facilitate this exercise.

During this Activity the CCRA specialist should hold a workshop with engineers and subject matter experts and present the preliminary desk-based results. In the risk workshop, a Threat and Hazard Identification Risk Assessment (THIRA) process should be undertaken which, combined with the climate projections, should confirm the high-level risk score for the site both for the baseline and the future.

There are four key activities that the CCRA specialist should facilitate in the workshop presented in **Figure 15** and in more detail in the remainder of this section.

Figure 15 **Workshop Activities**


1. **Discuss context:** Provide and discuss the project and area context, historical data and other information collected in Activities 1 and 2. Based on a draft results and information collected in previous activities and a combination of experience, forecasting, subject matter expertise, and other available resources, finalise list of the threats and hazards of primary concern to the community and the project.
2. **Confirm hazards and impact scenarios:** Describe the threats and hazards of concern, thinking through in detail the causal chain of how a threat may affect the community and the project and refine existing or develop further impact scenarios using the expertise in the room.
3. **Score probability and likelihood:** Jointly, the group should assess each hazard in context to develop a specific risk score for each repeating step 3 from Activity 3 but in a group process.
4. **Identify adaptation options.** For each 'high' and 'extreme' risk, the group should think through possible adaptation options considering existing capacity, preparedness activities etc. The CCRA specialist should liaise with the Project Engineer and local communities to detail an appropriate adaptation measure. Adaptation measures should address the risk today (based on baseline) but CCRA specialist and project engineers should also be mindful of possible future climate change. As such, adaptation measures should be 'future-proof' to cater for future climate change (including both changes in the severity and/or frequency of weather events, and long-term increases or decreases in climate variables). In this way, projects can be designed to be resilient to future climate change.

Following outcomes from the above process, Project Engineers are expected to amend the project design to ensure that it is climate resilient or, if no risks are identified and project is deemed already resilient engineers, to provide a statement to that effect. Annex F provides a high level generic overview of the key climate events and potential risks as well as an indication of the types of adaptation measures that could be implemented.

This assessment should be done in accordance with the CCRA Risk Matrix Tool Track 2 accompanying this protocol (see [online: www.cridf.com/]). The CCRA Risk Matrix Tool Track 2 draws together all the aspects requiring consideration into a single tool to support the CCRA process. The population of the tool relies on subject matter experts' and engineers' inputs, and on information gathered during Activities 5, 6, and 7.

### Activity 8 Outputs

The expected outputs from Activity 8 are:

- The preparation, attendance, facilitation of the risk workshop by CCRA specialist
- The completed CCRA Risk Matrix Tool Track 2, containing details of identified weather and climate risks for the project and local community;
- A summary of the 'high' and 'extreme' risks, together with the potential consequences for the project and local community and adaptation measures for each.

## Activity 9: Undertake Site Visit

For this activity the Lead will carry out a site visit at the project under investigation in order to:

- Develop a more detailed understanding of the local area conditions
- Discuss with stakeholders how climate and weather have affected them in the past
- Understand resiliency characteristics of the project and local community
- Discuss how benefits that the project will bring to the local communities can help with climate resiliency

**Prior to the site visit:**

- The CCRA specialist should set some high-level goals, identify stakeholders and plan the site visit with help from the CRIDF Project Director / CRIDF Manager / Task Lead.
- It is important from the outset to have an understanding of what data needs and gaps exist that can be covered during the stakeholder engagement process.
- The CCRA specialist can use the stakeholder engagement (SHE) questionnaire template presented in Annex C as a basis to develop a custom one for the site visit depending on outstanding data gaps from previous activities and workshop risk results requiring 'on-the-ground' validation.
- The CCRA specialist, working with the CRIDF Project Director / Task Lead should then proceed to identify stakeholders. In this process the targets should be considered carefully, and as a wide range of stakeholders to be engaged with as possible.

**During the site visit:**

- A high level review of the local topography, environmental, demography, socio economic, and institutional conditions to be undertaken using a set of generic questions as a basis towards gathering information on climate vulnerabilities, hazards, and exposure, capacity to adapt and determine climate change risk that people and infrastructure face.

- Local data, where available and feasible, will be collected to help further refine the baseline (LCLIP) and local capacity to adapt. The aim is to collect as much useful data as possible given the constraints of the pilot location.
- The stakeholder engagement should involve a systematic check of each issue with relevant stakeholders with the aim to make any final changes to the risk scores that have come out from the previous Activity and identify any further adaptation options.
- The above are to be done through interviews with stakeholders, including resident groups, community-based organizations, economic and recreational sectors, local authorities, regional authorities and public agencies, and review of documents where available. Workshops with stakeholders where possible can be held to explore further perspectives on climate risk.
- In stakeholder workshop or meetings the projected changes to communities should be presented and they should be asked to evaluate the implications of what this might mean to the local population over a given timeframe. By sharing previous experiences and anecdotal evidence, stakeholders can indirectly confirm how the project will benefit the local community. The CCRA Risk Matrix Tool Track 2 would already be populated with risk scores from the previous Activity that can be further confirmed or amended as needed at this stage.

**After the site visit:**

- Following completion of the site visit the CCRA specialist should consolidate findings from the engagement process and incorporate them into the final CCRA report and risk matrix along with the final results.

### Activity 9 Outputs

The key output from Activity 9 are:

- The CCRA specialist planning and undertaking the site visit including the facilitation of the stakeholder workshop/meetings and write-up

## Activity 10: Finalise Risk Evaluation

Taking into account outcomes from the site visit the CCRA specialist should liaise with Project Managers, Directors, and Engineers and finalise the risk evaluation of the project and the local community. This involves preparing a CCRA for the project and finalising the risk matrix results in the CCRA Risk Matrix Tool Track 2. Risk evaluation should take into account widely accepted adaptation indicators to ensure consistency with practices undertaken by other donors and agencies.

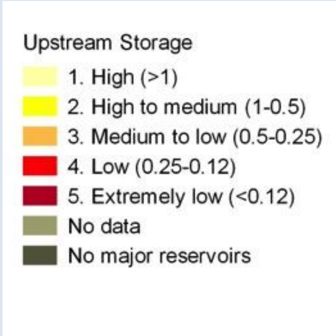
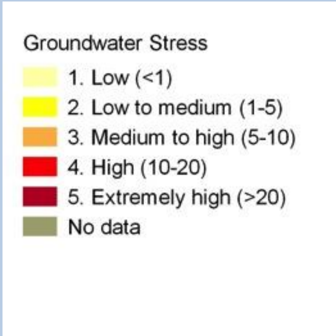
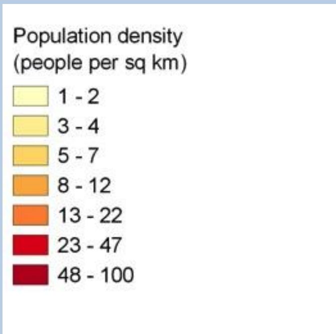
### Activity 10 Outputs

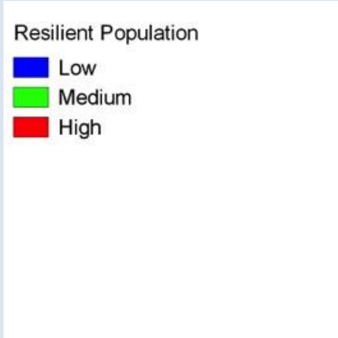
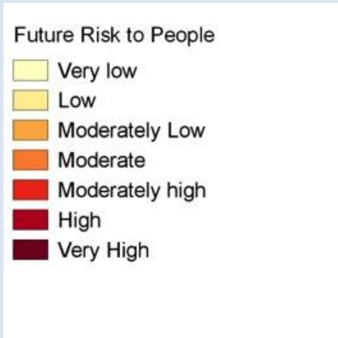
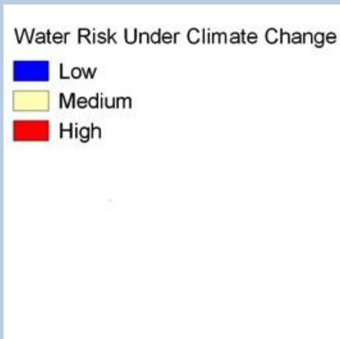
The output from Activity 10 are:

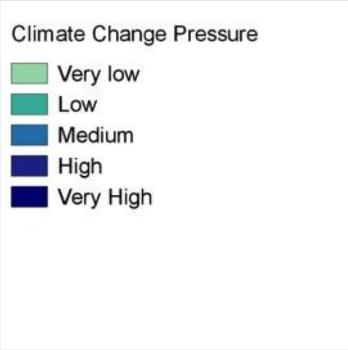
- A finalised CCRA Risk Matrix Tool Track 2 and CCRA report, containing details of all identified weather and climate risks for the project and local community

# Annex A: CRIDF Climate Vulnerability Tool Risk Indicators

| Risk indicator | Comments | |
|---|---|---|
| **Baseline Water Stress** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow. Higher values indicate more competition among users. It provides an overview of the water stress situation at a country or area in cases where the dataset underpinning the stress level has enough granularity. | Baseline Water Stress<br>1. Low (<10%)<br>2. Low to medium (10-20%)<br>3. Medium to high (20-40%)<br>4. High (40-80%)<br>5. Extremely high (>80%)<br>Arid & low water use<br>No data |
| **Inter-annual variability** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures the variation in water supply between years. This indicator is useful for understanding risks particularly to agriculture. High inter-annual variability creates difficulties in managing water resources in low water availability periods and can create stresses to ecosystems. | Interannual Variability<br>1. Low (<0.25)<br>2. Low to medium (0.25-0.5)<br>3. Medium to high (0.5-0.75)<br>4. High (0.75-1.0)<br>5. Extremely high (>1.0)<br>No data |
| **Seasonal variability** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures variation in water supply between months of the year. The higher this indicator the less reliable water supply can be expected during any given a year. High seasonal variability can have negative implications for steady water supply for households and year round agriculture particularly when rain-fed. This indicator can be helpful to characterise drought risks for rain-fed agriculture. | Seasonal Variability<br>1. Low (<0.33)<br>2. Low to medium (0.33-0.66)<br>3. Medium to high (0.66-1.0)<br>4. High (1.0-1.33)<br>5. Extremely high (>1.33)<br>No data |
| **Drought severity** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures drought severity calculated as the average length of droughts times the dryness of the droughts. It includes data from 1901 to 2008. This indicator can be taken into account to characterise drought risk in an area. | Drought Severity<br>1. Low (<20)<br>2. Low to medium (20-30)<br>3. Medium to high (30-40)<br>4. High (40-50)<br>5. Extremely high (>50)<br>No data |

| | | |
|---|---|---|
| **Upstream storage** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures the water storage capacity available upstream of a location relative to the total water supply at that location. Higher values indicate areas more capable of buffering variations in water supply (i.e. droughts and floods) because they have more water storage capacity upstream. |  |
| **Groundwater stress** | This indicator is based on WRI's Aqueduct 2.0 dataset and measures the ratio of groundwater withdrawal relative to its recharge rate over a given aquifer. Higher values indicate areas where unsustainable groundwater consumption could affect groundwater availability and groundwater-dependent ecosystems. This indicator can be taken into account to characterise water availability risk at an area that is mainly dependent for groundwater for its water supply needs. |  |
| **Household and community resilience** | This indicator is based on the Climate security vulnerability model by the Robert S. Strauss Centre and combines data on physical, socio-economic, demographic, and political insecurities to provide an indication on household and community vulnerability to climate change. It can be taken into account when characterising impacts to local communities. The lower the resiliency the higher the consequence can be expected for any given impact. Most resilient communities can withstand a 20% crop loss however this can be catastrophic for the least resilient |  |
| **Population density** | This Population density index is based on the Climate security vulnerability model by the Robert S. Strauss Centre. This indicator can be taken into account when trying to understand H&S impacts to local communities from extreme weather events. |  |

| | | |
|---|---|---|
| **Resilient population** | HR Wallingford has developed this indicator by combining population density, the CCAPS governance layer and the CCAPS household and community resilience layer. It can be taken into account when characterising impacts to local communities. The lower the resiliency the higher the consequence can be expected for any given impact. Highly resilient communities can withstand a 20% crop loss however this can be catastrophic for the least resilient |  |
| **Baseline risks to people** | HR Wallingford has developed this indicator by combining the resilient population layer and the AQUEDUCT physical water quantity risk. |  |
| **Future risks to people** | HR Wallingford has developed this indicator by combining the baseline risks to people layer, the climate change pressure layer and the physical water risk layer. |  |
| **Water risk under climate change** | HR Wallingford has developed this indicator by combining the climate change pressure layer and the physical water risk layer. |  |

| | | |
|---|---|---|
| **Climate change pressure** | HR Wallingford has developed this indicator by using the average rainfall and temperatures from 2006 to 2026 of the low emissions scenario (RCP 2.6) and compared this to the average rainfall and temperatures from 2080 to 2100 of the high emission scenario (RCP 8.5). To calculate a climate change pressure indicator the change in temperature was subtracted from the change in rainfall, multiplied by two. These values have been rescaled linearly to a scoring system of 1 to 5. |  |

# Annex B: Self Organising Maps (SOMs)

A problem with climate change projections for a region is that there are a large number of climate models each (correctly) producing different projections. Scientists have tried to answer the question: What is the best approach to managing this and the most likely future climate for a region? One way of answering this, frequently taken in National Adaptation Plans of Action (NAPAs), is to use a subset of models, but then the choice of which models to use is generally a subjective one. Another option is to use the ensemble of all available models and to produce an ensemble mean, and perhaps a range of likely outcomes as presented by the IPCC. There are, however, technical limitations to this approach.

Given that climate projections for a location from a set of models tend to be non-Gaussian (i.e. not normally distributed), especially for rainfall, the ensemble mean may not provide an optimal value for planning adaptation. To overcome this, our partner climate modellers have used, successfully, a technique called Self-Organising Maps (SOM), similar to cluster analysis in multivariate statistics, with which we attempt to identify the main directions of climate change suggested by all models. This technique normally produces at least two scenarios; the approach does not address all issues regarding identification of future climate changes but is significantly more informative than selecting either a subset of models or the ensemble mean.

In previous work we have taken the process forward first by identifying adaptation strategies available to a particular community without consideration of any climate change scenarios, and then subsequently by assessing these strategies in terms of the two or more scenarios produced by the SOM technique. In this project we will use these techniques to produce an assessment of the likely climate change in selected regions of interest and to produce a solid base with which to understand climate variability, adaptation options, and decision-making.

### Outputs

We have the capacity, through our climate modellers, to look at the range of IPCC CMIP3 (AR4), CMIP5 (AR5) models and CORDEX downscaled outputs to understand the variability in projections for temperature, rainfall and seasonality for regions of interest in southern Africa. Any or all of these model data sets might be used; it should *not* be expected that they will offer identical scenarios.

Using this approach the SOMs deliverables will be:

1. a series of mapped climate projections for the Southern Africa region of interest (see below for more info on how this will be done)[10]

[10] CMIP3 (AR4) - this is the full global atmosphere-ocean model set used in the production of the 2007 IPCC AR4
CMIP5(AR5) - the 2013/4 AR5 uses an expanded number of different model data sets compared to AR4; the one we will use is the data set used for the main results in the AR5, and is equivalent to that in CMIP3 but includes newer model versions and several more models
CORDEX is a set of projections from Regional Climate Models (RCMs). RCMs work over a limited domain (there is one that covers just Africa) on rather higher resolutions than the global models, both spatially and temporally. So they provide information over, say, Africa on substantially improved space and time scales than the global models. That sounds attractive but there are a number of technical issues with this approach - hopefully by the time of the AR6 these will have been resolved.

2. an SOM analysis for the Southern Africa region and one other smaller sub region for comparison (probably covering the tree Zimbabwe project sites which are about to go to procurement: QW02 – Bindagombe; QW06 Kufandada, and possibly QW08 – Ntalale)
3. a summary of observed and predicted regional climate trends and an assessment of climate vulnerabilities for crucial locations.

### Technical Account

The standard approach to developing the climate component of climate change scenarios is to examine differences between projections produced by climate models for a future period paired with those by the same models based on simulations of historical periods with known greenhouse gas concentrations, an approach that eliminates to an extent any biases inherent in simulations from any particular model. In order to incorporate all uncertainties involved in producing climate projections the theoretical optimal approach is to employ projections from as large a number of credible models as possible, an ensemble, an approach used by, for example, the IPCC. Because each model, quite correctly, produces unique projections there is a practical issue of interpretation of the spectrum of projections produced. Typically within IPCC assessment reports 'preferred' values of future, say, temperatures are produced somewhat subjectively but informed by the ensemble mean; in addition the IPCC also produces indications of ranges across the ensemble as guidance on uncertainties. Users tend to prefer single value projections for decision making, akin to deterministic predictions, rather than attempting to interpret the broader range of projections encompassed by the full ensemble. In many documents produced by developing countries under the auspices of the UNFCCC, such as National Communications and National Adaptation Plans of Action, the process towards determinism is taken a step further by identifying, normally by quasi-subjective means, a preferred single model, or perhaps just two or three models, from which to build scenarios.

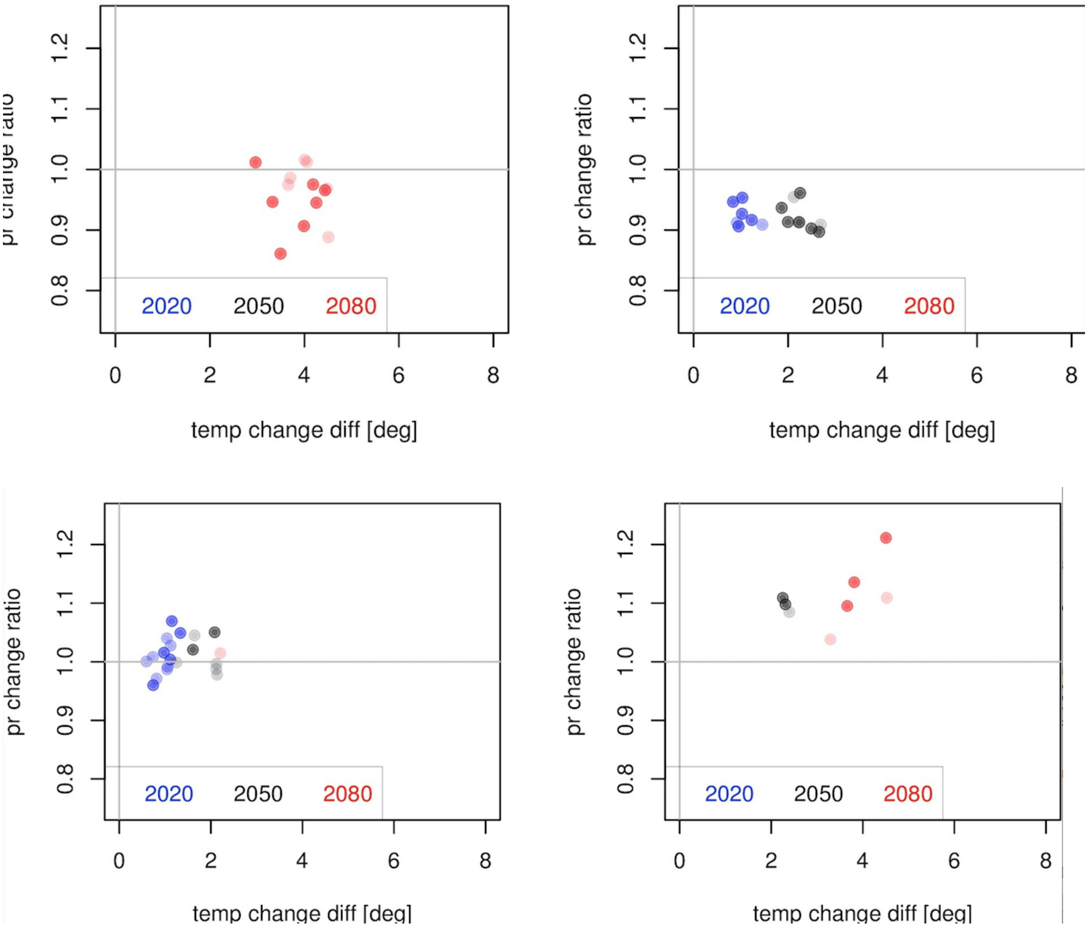
The approach taken here is an attempt to address the question of identifying multiple reasonable scenarios for a location sidestepping the restrictive needs to use the full ensemble mean or a subset of models. Essentially the question is one of identifying the main signals present within the full ensemble using the approach of Self-Organising Maps (SOMs) is used, a non-linear and highly flexible approach akin to a neural network.

With any SOMs analysis an *a priori* decision is required on the number of maps to produce. Experience with the technique suggests that, given ensembles with sizes as employed by the IPCC, a target of four maps is reasonable, which typically produce two scenarios. In principle the number of four could be changed to reduce or increase the number of scenarios but, again from experience, such changes add only limited information. Note that this approach implicitly assumes that the ensemble distribution is correct in all senses and ignores the possibilities of outlying solutions.

An example of a SOMs analysis pairing mean temperature and rainfall changes for an ensemble is illustrated in the attached Figure. Rainfall as a ratio of change is on the y axis and temperature change in °C on the x axis.

Given all of the issues and uncertainties that are involved in producing climate change projections we always advise at this time using either the CMIP3 or CMIP5 sets - with the knowledge that results from these two sets will not be identical. We do not recommend use of CORDEX on its own, but if that is required then we recommend using both CMIP5 and CORDEX, and again results are not likely to be identical. We recommend CMIP5 + CORDEX because the RCMs run inside projections produced by global models, and the models used to run the RCMs are included in CMIP5.

There is no specific order in which the SOMs methodology presents the maps, and so interpretation of sequences is required; this interpretation is given numbering the charts clockwise from top left. Interpretation may depend to an extent upon the observer, but in general different assessors are likely to produce equivalent interpretations. In this specific case two reasonable scenarios appear to be present; in the first, which starts on chart 2 followed by chart 1, there is a decrease in rainfall, while in the second, chart 4 followed by chart 3, rainfall increases. There are marginally more models included in the former, reduced rainfall, sequence suggesting, assuming that the ensemble is formed correctly, that this is the more likely of the two.




Normally SOMs are run for averaged changes over periods of typically 30 years for the combined changes in temperature and rainfall. Thus, to oversimplify, a result might say that by 20xx there will be changes of +2degC and +10% rainfall. In principle we can apply the technique to any pairs of data that are present in the data sets, but the T and R analysis usually covers the priority questions. We add to those basic analyses details, extracted from the model projections that cover further aspects, such as heat waves, drought, flooding, etc. We interpret these independently from the SOMs to attach them to the scenarios produced from the SOMs work.

# Annex C: Stakeholder engagement questionnaire templates

The following questionnaire templates are provided to enable the CCRA specialist to collect information during interactions with engineers and local community members whilst undertaking site visits. The purpose is to obtain complementary qualitative (and quantitative where available) information on climate related aspects and its effects in the area and projects.

Table 7 **Indicative List of Impacts Related Questions**

| No. | Question |
|---|---|
| 1 | Ask for experiences of climate related events in the area and cases of vulnerability? |
| 2 | Are the locals aware of any changes in weather patterns over the years? (e.g. less/more overall rainfall, frequent droughts/floods, higher temperatures, vegetation changes, late/early start of rainfall season, uneven rainfall distribution etc.) |
| 3 | What have been the impacts to people, the area and local livelihoods from these changes? (e.g. changes in seasons/vegetation types, new strains of pests and diseases, increasing water scarcity) |
| 4 | Show climate trends and ask what they think the expected impact to livelihoods and productivity to be? Also how could they additionally mitigate (or maximise benefit if positive) some of these impacts? |
| 5 | Have the project components been sited at the best possible locations (e.g. boreholes in areas prone to flooding, close to latrines etc.) |

Table 8 **Indicative List of Resilience Related Questions**

| No. | Question |
|---|---|
| 1 | Do members of the community have access to a range of communication systems that allow information to flow during an emergency? Is there a risk that community could be isolated during an emergency event? |
| 2 | What is the level of relationship and communication between local governing body and population? E.g. passive, consultation, engagement, collaboration, active participation? With the larger region? E.g. No or limited/informal networks with other towns/region, some representation at regional meetings, regular planning and activities with other towns/ region |

| | |
|---|---|
| 3 | What is the degree of connectedness society across community and gender groups? (E.g. ethnicities/sub-cultures/age/gender groups) and what proportion of local population is engaged with social activities and organisations (e.g., clubs, service groups, sport teams, churches, library)? |
| 4 | What proportion of the population has the capacity to independently move to safety? (e.g., non-institutionalised, mobile with own vehicle, adult) |
| 5 | To what extent and level are households within the community engaged in planning for response and recovery from climate related events e.g. droughts, floods, cyclones etc.? |
| 6 | Is there a local infrastructure emergency protection plan and if so how comprehensive is it? (e.g. irrigation, water supply, sewerage, power system) |
| 7 | "Does the local population have skills useful in response/ recovery (e.g., first aid, food storage, safe food handling) can be mobilised if needed? Are available medical and public health services included in emergency planning? |

Table 9 **Indicative List of Questions for Discussion with Engineers for Irrigation and WASH projects**

| No. | Question |
|---|---|
| 1 | Has a basin-wide, integrated water resource management-based perspective taken on project's water availability assessment? |
| 2 | Does it take into account future changes to climate and water availability/flows? |
| 3 | Does the project involve new or untested technologies? |
| 4 | Does the project make use of groundwater resources and if so has their potential been assessed? |
| 5 | Is the project site / irrigated area / infrastructure prone to flooding? |
| 6 | Have soil quality considerations taken into account? |
| 7 | Is the storage capacity enhanced in all practical ways? |
| 8 | If in coastal zone, has the design considered salinity control and drainage as well as water supplies? |
| 9 | Are there facilities for flow control to allow for a functional water allocation within the irrigated area? |
| 10 | Would there be adequate flow capacity of regulators and other structures (such as bridges) in order to prevent scour? |

| | |
|---|---|
| 11 | Have the latrines been sited in sufficient distance from boreholes and other groundwater sources? |
| 12 | Are borehole/well heads properly designed to prevent erosion damage that may increase infiltration? |

# Annex D: Resiliency considerations

This Annex presents parts of the following reports:

World Health Organization, (2009) Summary and policy implications Vision 2030: the resilience of water supply and sanitation in the face of climate change

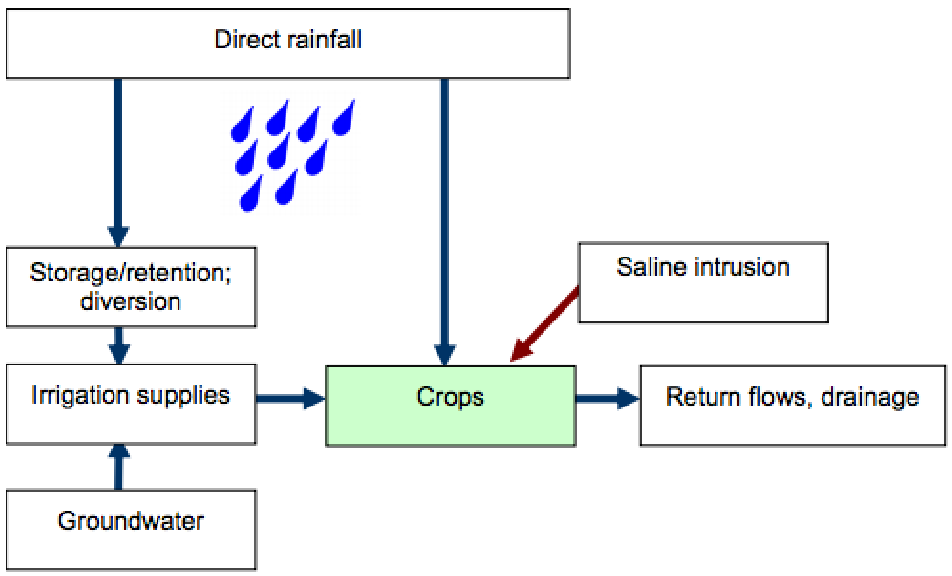
WHO, UNICEF (2008). Joint Monitoring Programme: progress on drinking-water and sanitation – special focus on sanitation. Geneva, World Health Organization

Cambodia Climate Change Alliance, UNEP-DHI Centre for Water and Environment, (2013) Climate-resilient irrigation Guidance paper

## Climate risk and resilience considerations in irrigation systems

Irrigation involves supply of water to the fields, by gravity or pumping. The water can be diverted from a river or canal, or drawn from a lake or a reservoir, or from the ground; or it can simply be retained at the place where the crop will be cultivated. An overview of a typical irrigation system is presented in Figure 16 below.

Figure 16 **Overview of an irrigation system**




Source: Climate-Resilient Irrigation Guidance Paper, Cambodia Climate Change Alliance Program, March 2013

A good irrigation scheme is characterized by the predictable availability of adequate water at the place and the time when the crops need it. Climate change is likely to mainly affect the hydraulic feasibility but also the design and the operation of irrigation systems. To ensure that the project is resilient the following considerations should be taken into account:

- Is the hydraulically resilient for example in terms of raw water availability and flows?
- Is it designed to take into account climate change for example in terms of storage capacity, conveyance capacities and control structures?
- Have operational considerations with respect to resiliency taken into account for example in terms of water allocation within the scheme?

**Some examples of responses include:**

- Institutional capacity-building covering climate-related concerns and management options related to operation
- Additional storage capacity
- Additional stormwater drainage capacity, and improved operation and maintenance of drainage facilities, supported by public awareness
- Flood risk mapping
- Drought preparedness, including contingency planning
- Improved monitoring, providing data and information for operation

The Climate-Resilient Irrigation Guidance Paper developed by the Cambodia Climate Change Alliance Program provides detailed guidance on various resiliency aspects with respect to hydraulic, design and operational considerations. [11]

## Climate risk and resilience considerations in Water Supply and Hygiene Systems (WASH)

### Drinking water systems

Direct management of drinking-water supplies by households and communities is common in small communities worldwide. Inadequate operation and maintenance cause frequent failures and contamination. Climate change impacts will adversely affect this already substandard situation by increasing the range and severity of challenges to system management.

There are a wide range of potential climate change impacts on water supply technologies, including flood damage to infrastructure, increased contamination, deteriorating water quality, increased treatment requirements and reduced availability. The technologies considered "improved" under the WHO-UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP) were categorized with respect to their resilience to climate change.

Shallow groundwater systems, roof rainwater harvesting and some surface waters could be vulnerable to extended dry periods. It is less likely that impacts will be felt in the medium term in deep or old aquifers that have long recharge times.

[11] http://www.unepdhi.org/-/media/microsite_unepdhi/publications/documents/unep_dhi/carp-resilient%20irrigation-final%20ud.pdf

Table 10 **Resilience of water technology to climate change: applicability by 2030**

| Resiliency category | Technologies |
|---|---|
| Potentially resilient to all expected climate changes | • Utility piped water supply<br>• Tubewells |
| Potentially resilient to most of expected climate changes | • Protected springs<br>• Small piped systems |
| Potentially resilient to only restricted number of climate changes | • Dug wells<br>• Rainwater harvesting |
| Technologies Categorized by JMP as “not improved drinking-water sources” | • Unprotected dug wells<br>• Unprotected springs<br>• Carts with small tank or drum<br>• Surface water (rivers, dams, lakes, ponds, streams, canals, irrigation channels)<br>• Bottled water |

Source: Summary and policy implications Vision 2030: the resilience of water supply and sanitation in the face of climate change, World Health Organization, 2009

Piped distribution networks are typically vulnerable to contamination and will be at increased risk where more frequent flooding occurs. In drying environments, piped water supplies may become more intermittent unless resource management measures conserve drinking-water sources. Tubewells are the most resilient of these technologies; protected springs and small piped supplies have resilience to some climate changes; and dug wells and rainwater harvesting are resilient only to a few climate changes. Existing climate variability already represents a significant problem.[12]

### Sanitation Systems

The effects of climate impacts on sanitation may be direct – where water is an essential part of the technology process (e.g. sewerage) – or indirect – where the capacity of the environment to absorb or reduce the adverse effects of wastes is changed. Sanitation technologies considered “improved” under the JMP were categorized on the basis of their resilience to climate change.

[12] Summary and policy implications Vision 2030 : the resilience of water supply and sanitation in the face of climate change, World Health Organization, 2009

Table 11 **Resilience of sanitation technology to climate change: applicability by 2020**

| Resiliency category | Technologies |
|---|---|
| Potentially resilient to all expected climate changes | • Pit latrines<br>• Low-flush septic systems |
| Potentially resilient to most of expected climate changes | • High-volume septic systems<br>• Conventional and modified sewerage |
| Technologies categorized by JMP as “not improved sanitation” | • Latrines without a slab or platform<br>• Hanging latrines |

*Source: Summary and policy implications Vision 2030: the resilience of water supply and sanitation in the face of climate change, World Health Organization, 2009*

Where precipitation levels decline, sewerage systems may become more difficult to operate and maintain. This will be a particular problem for conventional sewerage with its relatively high water requirements. Further problems may also arise from the reduced capacity of water resources to absorb and dilute pollution, which will increase the performance requirements, and hence the cost and potentially the carbon footprint, of wastewater treatment. Sewers are also at risk from flooding damage. Where sewers also carry storm water, increased flooding will result in widespread contamination, overwhelm treatment facilities and increase public health risks. Pit latrines as a group of technologies are resilient, because different designs allow adaptation to changing climate. Individual facilities may, however, not be resilient. Where groundwater levels rise, pollution from pit latrines may become more difficult to control.

# Annex E: Climate Change Information Sources

| Relevant country(s) | Source | Link | Description |
| --- | --- | --- | --- |
| 52 developing countries | UNDP Country Profiles | http://country-profiles.geog.ox.ac.uk | Includes climate data and climate change projection report for each country |
| African countries | CSAG Climate Information Portal | http://cip.csag.uct.ac.za/webclient2/app/ | Observed climate data and future climate projections related to temperature and rainfall for a number of weather stations across Africa |
| SADC countries | Climate Risk and Vulnerability: A Handbook for Southern Africa | http://www.rvatlas.org/sadc/download/sadc_handbook.pdf | Current weather conditions and future projections and impacts for Southern Africa |
| Selected countries around the world | UK Met Office | http://www.metoffice.gov.uk/climate-guide/science/uk/obs-projections-impacts | The UK Met Office has published a number of country-level climate change reports. |
| Selected national/regional studies | United States Global Change Research Program (GCRP) | http://www.globalchange.gov/ | The United States Global Change Research Program (GCRP) has issued a series of regional climate change impact studies that provide useful information on climate variability and change at a national / regional level. |

| | | | |
|---|---|---|---|
| Selected countries around the world | Tiempo.net | http://www.tutiempo.net/en/Climate/africa.htm | Climate data for specific cities/towns in selected countries for specific years. Information available for free. |
| All countries | UNFCCC: National Communications (NCs) and National Adaptation Programmes of Action (NAPAs) | http://unfccc.int/national_reports/items/1408.php | NCs and NAPAs contain country-specific information on climate change risks and changes projected for each country. |
| All countries/regions | IPCC Assessment Reports | http://www.ipcc.ch/ | The IPCC Assessment Reports provide provides knowledge on the scientific, technical and socio-economic aspects of climate change. |
| All countries/regions | IPCC Observational Data | http://www.ipcc-data.org/cgi-bin/ddc_nav/dataset=cru21 | IPCC database allowing one to view climate data for specific coordinates for a specified timeframe (between 1901 and 1990). |
| Global | UNEP - GRID | http://preview.grid.unep.ch/ | The Global Risk Data Platform shares spatial data information on global risk from natural hazards. Users can visualise, download or extract data on past hazardous events, human & economical hazard exposure and risk from natural hazards. |
| South Africa | South African Risk and Vulnerability Atlas (SARVA) | http://www.sarva.org.za/ | Current weather conditions and future projections and impacts for South Africa |

| | | | |
|---|---|---|---|
| Global | AIACC Regional Studies | http://www.start.org/Projects/AIACC_Project/aiacc_studies/aiacc_studies.html | A global initiative to advance scientific understanding around climate change and its impacts. To achieve this, AIACC provides funding, training, and mentoring to scientists within developing country to undertake multi-sector, multi-country research of priority to developing countries. Currently comprises 24 regional studies involving 46 countries. |
| Global | World Bank Climate Change Knowledge Portal | http://sdwebx.worldbank.org/climateportal/index.cfm | The Portal provides a web-based platform to assist in capacity building and knowledge development. The portal's aim is to help provide development practitioners with a resource to explore, evaluate, synthesise, and learn about climate related vulnerabilities and risks at multiple levels of details. Baseline and future climate information is available at the country level as well as at a regional level. |

# Annex F: Generic Overview of Key Climate Events and Potential Risks for CRIDF Portfolio of Projects

| Climate variable/event | Potential impact on CRIDF portfolio and associated activities |
|---|---|
| Changes in rainfall patterns | Volatile rainfall patterns and drought cause reduction of/poor average crop yields, particularly in rain-fed agriculture. Subsistence agriculture becomes increasingly difficult to sustain. |
| Heavy rain | Increased rainfall causes groundwater levels to rise leading to inundation of the pit latrines from below. This may result in contamination of groundwater and soil, potentially reaching drinking-water sources. |
| | Increased rainfall can overwhelm reservoirs or dams, especially if the flow volumes exceed the dam design criteria, which are based on past rainfall and flow regimes. |
| | High intensity rainfall and heavy erosion may adversely affect the water storage capacity of irrigation systems where no dams or reservoirs are available and result in loss of field water due to lateral seepage. |
| | Decreasing rainfall causes lower and decreasing average yields of key crops because of the regular impacts of climate extremes, continued soil degradation, and increasing water scarcity. Food insecurity can be increased due to lower crop yields as well as higher food prices. |
| | An increase in episodes of high rainfall will reduce the infiltration of rainwater (i.e. reduced groundwater recharge). This may be coupled with increased abstraction of water, blockage of streams and capture and recycling of rainfall to have negative impact on groundwater levels downstream impacting agriculture and community activities. |
| Drought | Drought may threaten the security of water supply and/or result in reduced abstraction levels from neighbouring rivers leading to reduced production. |
| | For areas dependent on hydro-power, drought will reduce hydro-power capacity and thus energy supply. |
| | In drought-prone areas where water availability is increasingly strained, drought may threaten the livelihoods of subsistence farmers and/or pastoralists and result in rural incomes reduction. |

| | |
|---|---|
| | More frequent and prolonged drought periods and/or times of low river flows cause crop failure or reduction of yields due to low nutrient content and inadequate soil moisture. |
| | Recurrent drought causes a shortage of water supply and in combination with lack of sanitation facilities it results in more incidents of diseases in local populations. |
| | Falling groundwater tables and reduced surface water flows can lead to wells drying up, extending distances that must be travelled to collect water, and increasing water source pollution. |
| Cyclones/high winds/storm events | Destruction or damage of crucial infrastructure, such as irrigation systems (pipelines), water supply and storage systems (i.e. reservoirs, pumps, drinking water pipelines etc.), sewage lines, access roads and farms. |
| | More frequent and intense storm events contribute to higher inter-annual variation of yields that may result in rising malnutrition due lower crop yields, particularly in rural areas. |
| | Loss of crops and livestock. |
| Pluvial/fluvial flooding | Heavy flooding can cause damages to irrigation infrastructure such as pipelines, storage reservoirs, pumps etc. |
| | Farms in the riparian zone result in crop losses due to severe floods. |
| | Flooding increases the strain on sewerage infrastructure as infiltration of floodwater into sewer may lead to plug flow of pollutants and re-suspension causing overloading of treatment works, pollution of water resources downstream, and ingress of silt. |
| | Flooding causes damage to VIP latrines. Inundation of domestic and public toilets also distributes human excreta and poses health risk to the community. |
| | Water treatment plants and/or pumping stations located in low-lying areas are vulnerable to flooding as they may be put out of action. |
| | Increased flooding in areas where untreated waste has been dumped carries the risk of groundwater contamination and the spread of infection. |

| | |
|---|---|
| | Extra water flow rates and the force of the water after heavy rain are quite likely to damage infrastructure /water intakes such as drains, culverts, and water supply pipelines. |
| | Floods can also overwhelm reservoirs or dams, especially if the flow volumes exceed the design criteria. |
| | Flooding causes drinking-water infrastructure, such as wells, to flood increasing the risk of groundwater contamination that may cause diseases such as diarrhoea, dysentery, cholera and typhoid. |
| Sea level rise/saline intrusion | In coastal areas or in areas in proximity to coasts, water resources are often limited and the water demand very high. Saline intrusion due to sea level rise is expected to aggravate the stress on water resources. |

# Annex G – Impacts Table

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| 1 | Precipitation variability | Continuing trend of seasonal and interannual variability in precipitation. A transition zone between areas where the annual rainfall is more likely to increase (to the north) and more likely to decrease (to the south). Any changes are most likely (but not definitively) in the range −10% to +10%. The possibility of increased rainfall rises with higher emissions. | Continuing trend of seasonal and interannual variability in precipitation, decreased winter rainfall and increased aridity, in combination with wind gustiness, drying out of seasonal wetlands/pans and ephemeral rivers. Variability in particular at boundary with southernmost extent of intertropical convergence zone (ITCZ). A transition zone between areas where the annual rainfall is more likely to increase (to the north) and more likely to decrease (to the south). Any changes are most likely (but not definitively) in the range −10% to +10%. The possibility of decreased rainfall is higher than around 2025. Water supply is challenged by increased temperatures (and associated evaporation), and more erratic rainfall patterns, leading to vulnerability of perennial river systems and decreased level of the groundwater table. |
| | Temperature variability | Continuing trend of increased mean annual air temperature (MAAT). Likely increase of MAAT by 0.5ºC to 1.5°C, but lower/higher values cannot be | Continuing trend of increased MAAT, aridity trend will reinforce decreased humidity especially under more erratic seasonal precipitation regimes; increased heatwaves; increased thunderstorm activity, heatwaves. Likely increase of MAAT by 0.5ºC |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | | excluded; some increase in length of warm spells and reduced frequency of cold periods. | to 3.0°C, but lower/higher values not excluded; almost certain increase in length of warm spells and reduced frequency of cold periods. |
| | Extreme events | More erratic precipitation and temperature regimes, resulting in some likely increase in extreme flood/drought events. | More erratic precipitation and temperature regimes, resulting in an increased likelihood of extreme flood/drought events, both in severity and duration. This will have a multiplier effect in increasing vulnerabilities to other risk events and thus result in wider likely impacts. |
| | Agriculture | Food insecurity arising from political instability across the region and challenges to both food production and supply, climatic instability<br>Subsist | Increased overall drying trend and decreased winter rains result in decreased food production in total and land surface degradation and soil erosion due to increased aridity and soil moisture loss. Deforestation and loss of biodiversity an increasing issue. Aridification and spread of sand dunes in Sahelian areas. Rain-fed agriculture will be likely less reliable in many areas and irrigated agriculture will become more significant, but this poses problems for famers' access to technology, investment and training (including provision of GM seeds). |
| | Health | Pockets of different disease types as a result of site-specific water/air/pollution, amplified by incorrect | Widespread health effects due to food/water insecurity, availability of potable water, water contamination by runoff, and low water |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | | water, agricultural and land management practices, and mining wastes. Low nutrition/health in some areas due to food insecurity. | quality due to biological diseases, pollution/sewage runoff into rivers, wastewater and groundwater contamination due to poor sanitation in informal settlements and due to industries such as mining. |
| 2 | Precipitation variability | Continuing trend of seasonal and interannual variability in precipitation related to strength of ITCZ and frequency/magnitude of incoming cyclones from Indian Ocean. For planning purposes it might be best to work on decreased annual rainfall, with any decrease most likely not exceeding 10%; however increases of up to, perhaps, 10% are possible. Limited dependency on emissions. | Continuing trend of seasonal summer and interannual variability in precipitation. Variability in particular at boundary with southernmost extent of ITCZ. Variations in strength of cyclones also associated with storm surges, coastal flooding, and wind damage. For planning purposes it might be best to work on decreased annual rainfall, with any decrease most likely not exceeding 10%, although decreases of perhaps 20% are possible in parts; however increases of up to, perhaps, 10% are also possible. The likelihood of decreased rainfall rises with greater emissions. Possibility of higher rainfall, and stronger winds and storm surges with Indian Ocean tropical cyclones. Likely greater seasonal water availability but issues of water quality. |
| | Temperature variability | Continuing trend of increased MAAT. Likely increase of MAAT by 0.5$^{o}$C to 1.5°C, but lower/higher values | Continuing trend of increased MAAT, increased thunderstorm activity, higher sea surface temperatures (SST) driving strong cyclone events, drying out of coastal wetlands. Likely increase of |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | | cannot be excluded; some increase in length of warm spells and reduced frequency of cold periods. | MAAT by 0.5ºC to 3.0°C, but lower/higher values cannot be excluded; almost certain increase in length of warm spells and reduced frequency of cold periods. |
| | Extreme events | More erratic precipitation regimes and increased subtropical cyclones, resulting in some likely increase in extreme flood events. | More erratic precipitation regimes, resulting in an increased likelihood of extreme flood events, both in severity and duration. This will have a multiplier effect in increasing vulnerabilities to other risk events and thus result in wider likely impacts, in particular in agriculture and health. |
| | Agriculture | Food insecurity arising from climatic instability with soil erosion. | Food insecurity arising from climatic instability, deforestation, increased intensity rain events driving higher soil erosion and soil fertility loss, higher sediment and nutrient runoff posing problems for eutrophication, water quality, precipitation hazards impacting on food production especially in rainfed agricultural areas. |
| | Health | Health effects mainly as a result of short term problems with food production due to climatic variability. | Health and nutrition effects, mainly as a result of longer term decreases in food production due to land surface erosion, effects on water quality due to soil erosion and floodwater contamination by sediments and organics; waterborne and biological diseases, including pests and diseases on agricultural crops. Flood events |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | | | result in low water quality with implications for sanitation and water-borne diseases. |
| 3 | Precipitation variability | Continuing aridity of desert and semiarid environments. For planning purposes it is best to work on decreased annual rainfall, especially to the west, with any decrease perhaps reaching 20% in parts; increases are unlikely in the west but may reach 10% in the east. | Continuing aridity of desert and semiarid environments; increased wind erosion, migration of sand dunes, decreased air quality and pollution, health effects, due to land surface aridity; episodic thunderstorms may result in soil erosion, flooding, especially in coastal areas; increased borehole extraction will result in decreased groundwater table, some ephemeral rivers will become permanently dry, perennial rivers may become ephemeral. Groundwater recharge will be reduced under all scenarios. For planning purposes it is best to work on decreased annual rainfall, especially to the west, with any decrease perhaps reaching 20%, or even 30%, in parts; increases are unlikely in the west but may reach 10% in the east. Water supply will decrease under all future scenarios. |
| | Temperature variability | Continuing trend of increased MAAT. Likely increase of MAAT by 0.5ºC to 2.0°C, but lower/higher values cannot be excluded; some increase in length of warm/drought spells and reduced frequency of cold periods. | Continuing trend of increased MAAT, heatwaves inland, increased thunderstorm activity. Likely increase of MAAT by 0.5ºC to 4.0°C, but lower/higher values cannot be excluded; almost certain increase in length and severity of warm/drought spells and reduced frequency of cold periods. |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | Extreme events | Increased frequency of drought and heatwave events. | Increased frequency and magnitude of drought events and soil moisture anomalies, which will have significant impacts on agricultural systems and sustainability. |
| | Agriculture | Food insecurity arising from climatic instability | Increased aridity may result in increased food insecurity, spread of invasive plant and insect species, locusts?, loss of rainfed agriculture and subsistence agricultural systems become less viable, decreased food production in some areas |
| | Health | Health effects mainly as a result of short term problems with food production due to climatic variability | Health and nutrition effects, mainly as a result of longer term decreases in food production due to increased aridity, deflation of dry soils from the land surface, episodic soil erosion; food and water insecurity will increase, may be health impacts of increased pests and diseases; health impacts due to decreased water and air quality. Decreased surface water availability results in increased health and sanitation risk. |
| 4 | Precipitation variability | Continuing trend of seasonal and interannual variability in precipitation related to frequency/magnitude of incoming cyclones from Indian Ocean. For planning purposes it is best to work on decreased annual rainfall, especially to the west, | Continuing trend of seasonal summer and interannual variability in precipitation, variations in strength of cyclones also associated with storm surges, coastal flooding, wind damage, heavy rainfall inland resulting in river flood events. For planning purposes it is best to work on decreased annual rainfall, especially to the west, with any |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | | with any decrease perhaps reaching 10%, any increases are more likely east of the Escarpment. | decrease perhaps reaching 10%; any increases are more likely east of the Escarpment. Possibility of higher rainfall, and stronger winds and storm surges with Indian Ocean tropical cyclones. Water supply is maintained despite increased variability, but issues of decreased water quality during flood events. |
| | Temperature variability | Continuing trend of increased MAAT. Likely increase of MAAT by 0.5ºC to 1.5°C, but lower/higher values cannot be excluded; some increase in length of warm spells and reduced frequency of cold periods. | Continuing trend of increased MAAT, increased thunderstorm activity, higher SST driving strong cyclone events, drying out of coastal wetlands that are important biodiversity hotspots. Likely increase of MAAT by 0.5ºC to 3.0°C, but lower/higher values cannot be excluded; almost certain increase in length of warm spells and reduced frequency of cold periods. |
| | Extreme events | Increased frequency of flood/wind events as a result of likely increased frequency of subtropical cyclones. | Increased frequency and/or magnitude of flood and wind events from the Indian Ocean. |
| | Agriculture | Food insecurity arising from climatic instability, deforestation and land degradation. | Food insecurity arising from climatic instability, increased intensity rain events driving higher soil erosion and soil fertility loss, higher sediment and nutrient runoff posing problems for eutrophication, water quality, precipitation hazards impacting on food production |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | By 2025 | By 2055 |
| | | | especially in rainfed agricultural areas, increased coastal flooding due to sea level rise. |
| | Health | Health effects mainly as a result of short term problems with food production due to climatic variability. | Health and nutrition effects, mainly as a result of longer term decreases in food production due to land surface erosion, effects on water quality due to soil erosion and floodwater contamination by sediments and organics; waterborne and biological diseases, including pests and diseases on agricultural crops, salinization of low lying areas, impacts on sanitation through wastewater and sewage contamination of surface water, especially during floods. |
| 5 | Precipitation variability | Likely increases in rainfall variability and some evidence for increased annual rainfall totals. For planning purposes it is best to work on decreased annual rainfall, especially to the west, with decreases up to 10% but perhaps reaching 20% in parts; any increases are most likely only in the far east of the region; some evidence for larger decreases with highest emissions. | Increasing variability in rainfall patterns, with variation in strength of winter cyclones from the Atlantic; resulting in coastal flooding and over mountains; aridity in northern and inland locations, decreased groundwater table in areas of increased aridity, variations in river discharge with associated changes in water quality during low flow stages and with increase water temperatures; increased land surface instability, soil erosion and deflation. Water supply and variability is driven by winter cyclone strength. Similar to the situation around 2025 but with greater chances of decreases to 20%, perhaps even towards 30%, along the west coast. There is some possibility |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | By 2025 | By 2055 |
| | | | that storm tracks affecting the south-west Cape region may move further south, consistent with reduced overall rainfall. |
| | Temperature variability | Continuing trend of increased MAAT. Likely increase of MAAT of 0.5ºC to 1.5°C, but lower/higher values cannot be excluded; perhaps 0.5°C less warming over coastal regions; some increase in length of warm spells and reduced frequency of cold periods. | Continuing trend of increased MAAT, heatwaves inland with increased aridity, increased thunderstorm activity. Likely increase of MAAT of 0.5ºC to 3.0°C, but lower/higher values cannot be excluded; perhaps 0.5°C less warming over coastal regions; almost certain increase in length of warm spells and reduced frequency of cold periods. |
| | Extreme events | Increased variability of winter storm events from the Atlantic. | Increased frequency and/or magnitude of winter storms especially along the coast, flood events and thunderstorms inland especially over the Great Escarpment. |
| | Agriculture | Food insecurity and land surface degradation arising from climatic instability. | Increased aridity may result in increased food insecurity in inland locations, spread of invasive plant and insect species especially affecting the fynbos biome, loss of rainfed agriculture and subsistence agricultural systems become less viable, decreased food production in some areas with less surface water availability and increased cost of extracting water by groundwater pumping. |

| Region | Climate Change trend/ Sector Impacts | Impacts | |
|---|---|---|---|
| | | **By 2025** | **By 2055** |
| | Health | Health effects mainly as a result of short term problems with food production due to climatic variability. | Health and nutrition effects, mainly as a result of longer term decreases in food production due to increased rainfall variability, deflation of dry soils in northern parts of the area, episodic soil erosion and impacts on water quality; may be health impacts of increased pests and diseases. Implications for sanitation where flood events result in water contamination. |

CRIDF