CMF CLIMATE MAINSTREAMING FACILITY

Learning from the CRIDF programme

Resilience, adaptation and the use of climate information

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UKaid from the British people

Paul Watkiss Associates

SOUTH SOUTH NORTH TOWARDS CLIMATE RESILIENCE

Acronyms

AfDB	African Development Bank
ASLF	African Legal Support Facility
CCRA	Climate Change Risk Assessment
CRDP	Climate Resilient Development Pathway(s)
CIVAT	Climate Impacts and Vulnerability Assessment Tool
CRIDF	Climate Resilient Infrastructure Facility
CRVAT	Climate Risk and Vulnerability Assessment Tool
DFID	Department for International Development
ESAWAS	Eastern and Southern Africa Water and Sanitation Regulators Association
EU	European Union
FCDO	Foreign, Commonwealth and Development Office
GCF	Green Climate Fund
GEF	Global Environment Facility
FRM	Flood risk management
KAP	Knowledge, Attitude, Practice
LIMCOM	Limpopo Watercourse Commission
LWSC	Lusaka Water and Sewerage Company
NEPAD	New Partnership for Africa's Development
OKACOM	Permanent Okavango River Basin Water Commission
ORESACOM	Orange-Senqu River Commission
RBO	River Basin Organisation
RVA	Risk and Vulnerability Assessment
SADC	Southern African Development Community
SIWI	Stockholm International Water Institute
SOM	Self-Organising Map
ZAMCOM	Zambezi Watercourse Commission

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Summary

The Climate Resilient Infrastructure Development Facility (CRIDF) is a DFID/FCDO water infrastructure programme for southern Africa, which commenced in 2013 and is currently scheduled to run until 2023. CRIDF works across 12 SADC countries on a variety of projects under the categories of 'livelihood interventions', 'border towns and transport corridors', 'flood forecasting and early warning', 'accessing agriculture value chains', and 'enhanced adaptation through monitoring'. The programme supports pilot/demonstration projects focusing on small-scale water infrastructure with a pro-poor focus, and provides technical assistance for larger projects, working with a range of stakeholders but with a key focus on river basin organisations (RBOs) and transboundary water management.

This report was commissioned by DFID Africa, through the Climate Mainstreaming Facility, to distil learning from CRIDF around resilience and adaptation programming, the use and communication of climate information, and the impact of resilient infrastructure initiatives.

CRIDF's framing of resilience and adaptation

CRIDF's stated aim is to drive transformational change in the way projects across SADC are conceived, planned, financed and implemented, by embedding new approaches in planning processes, based on tools and guidance developed by CRIDF and on enhanced integration of climate information into planning. CRIDF has adopted a pragmatic framing of resilience and adaptation, in which adaptation is viewed in terms of specific measures to address specified climate (change) risks and impacts in the near term, and resilience is viewed in terms of capacity building to enable people and organisations to design and implement their own adaptation responses in the longer term. This is a novel framing that is unusual in setting out a clear relationship between resilience and adaptation, and departs from common practices that conflate these two concepts and frame resilience in terms of preparing for, coping with and recovering from existing, albeit evolving, climate hazards. CRIDF has developed its own definition of resilience, which is tailored to the CRIDF context but is consistent with other definitions, including that of the IPCC (2018).

Learning around resilience, adaptation and development

The work of CRIDF illuminates the often complex and ambiguous relationship between resilience, adaptation and development. In many parts of southern Africa, climate change is challenging the viability of rain-fed agriculture. Infrastructure such as dams and irrigation systems, which otherwise might be viewed as conventional development interventions intended to increase agricultural reliability and productivity, are viewed by CRIDF and its partners as vital for sustaining

agriculture under climate change. In order for this infrastructure to be economically viable, shifts to commercialisation might be necessary to generate income to cover maintenance costs. The installation of this water infrastructure on the grounds of adaptation to climate change thus may ultimately result in the adoption of different agricultural practices, resulting in 'adaptation driving development'. In other contexts, people in peri-urban areas rely for their day-to-day needs on surface water sources that are potentially at risk from climate change, although climate change will interact with changes in the balance between supply and demand driven by demographic and economic changes. In these contexts, the installation of piped water represents a solution from an adaptation perspective, meaning that adaptation provides a motivation for infrastructure interventions that meet what are generally viewed as basic development needs.

These examples of adaptation driving development call into question approaches to adaptation finance based on the concept of additionality, which implicitly assume that adaptation is incremental in nature, involving adjustments to existing systems and models to maintain their functioning and protect them from the impacts of climate change. Additionality is a problematic framing when adaptation involves more systemic, transformational changes, or when the impacts of climate change mean that the provision of basic services becomes imperative. Nonetheless, it is important to ensure that climate finance is directed at genuine climate change challenges, meaning that convincing narratives and evidence linking interventions with climate change impacts, risks and vulnerabilities are vital. These narratives are weak or absent in most of the CRIDF projects reviewed, with links between climate hazards and climate change generally being very tenuous, even where they are highly plausible. Most of these projects take a very general approach to resilience, with only a minority demonstrating targeted adaptation responses in relation to specific, demonstrable climate change impacts. Few projects actively consider longer-term climate change risks and impacts.

While this approach is likely to deliver resilience and adaptation benefits in the near term, a lack of consideration of longer-term sustainability may amplify future risks. A focus on near-term resilience may give the impression that adaptation has been adequately addressed where it has not, and divert attention from longer-term adaptation needs. While CRDIF projects undoubtedly deliver near-term resilience benefits, and notwithstanding the arguments discussed above, the weak treatment of climate change in project documentation gives the impression that many CRIDF projects are essentially conventional water development projects justified by simple climate change narratives. This can be addressed through stronger narratives that make better use of empirical evidence.

Use of climate information

CRIDF has developed a range of tools and guidance to support the integration of climate change resilience into its projects and basin-wide planning, consistent with the wider body of practice on climate change screening and vulnerability and risk assessment, but tailored to the CRIDF context. Different tools and guidance are used for assessing basin-scale investment strategies, undertaking general basin-wide risk assessment, assessing the eligibility of existing projects for CRIDF support on the basis of adaptation needs, assessing localised risks and needs in the scoping of new projects, and guiding detailed risk assessments of small and large projects.

CRIDF has developed climate change scenarios at the regional, basin and sub-basin level to inform basin-wide and transboundary decision-making. These scenarios have been generated using a novel approach based on self-organising maps (SOMs) that use a neural network to identify groups of similar climate projections for different time periods, across different global climate models and representative concentration pathways (RCPs). Three to four scenarios are identified. One of these is based on groupings of projections exhibiting the strongest agreement across models and RCPs, with others represents lower levels of agreement and more extreme but still plausible climate change trajectories.

These scenarios are used to characterise future climate change risks and impacts at the basin scale, and to provide input to hydrological and flood risk models representing smaller scales. Based on these scenarios and information from other sources such as the IPCC, CRIDF has developed a Climate Impacts Table that collates information on climate change impacts and vulnerabilities for five distinct climatic zones across SADC. This table and CRIDF's web-based vulnerability mapping tool represent easily accessible tools for integrating climate information into project development.

CRIDF conducts climate risk and vulnerability assessments (RVAs) at the basin scale and at the local scale for project locations. These RVAs combine information derived from climate scenarios with information on existing hazards, risks and vulnerabilities. This observational information is derived from a variety of sources, including a web-based vulnerability mapping tool and the Climate Impacts Table. Information on observed climate trends, variability, hazards, impacts and vulnerabilities is also gathered from local stakeholders at project locations.

CRIDF's approach to RVA reflects global good practice; for example, in combining assessments of current and future hazards and vulnerabilities. The scenarios approach employed by CRIDF provides information relating to a range of plausible future conditions, although it implicitly frames uncertainty in terms of ranges represented by ensembles of climate projections, rather than in terms of model limitations, with implications for how risk and uncertainty is treated in planning and project design, as discussed below.

While climate projections and scenarios are discussed in documentation for half the projects examined, treatment of uncertainty is extremely limited in both extent and scope. Only three projects appear to consider uncertainty in any meaningful sense, and these frame uncertainty solely in terms of model projections There is some evidence that climate information is informing project design, more often in general terms (e.g. to justify 'low regret' approaches) than in relation to specific infrastructural design parameters. Just under half the projects reviewed appear to intend to use climate information beyond the assessment and design stage, for modelling, forecasting and informing decisions around water management and agricultural planning.

Communication of climate information and technical findings

CRIDF's tools and guidance relating to climate impacts, risks and vulnerabilities, and the requirement to use them to carry out climate risk and vulnerability assessments for CRIDF projects (Figure 1), represent the principle mechanisms via which climate information is integrated into CRIDF projects. Use of these tools and guidance acts to communicate climate information and related CRIDF findings within and beyond CRIDF as a matter of course, as part of the programming and project development process, owing to their being applied at the project level by external CRIDF partners and stakeholders.

Where CRIDF supports pre-existing projects, these are subject to eligibility assessment using the mapping tool, to assess whether there are valid resilience issues that CRIDF can address. Projects are then subject to a 'Track 1' RVA at the pre-feasibility stage, using information from the Climate Impacts Table, information from stakeholders, and information from other readily available sources (Figure 1). At the bankability (effectively feasibility assessment) stage, larger projects are then subject to a more rigorous RVA using bespoke data and information, for example from hydrological models. Smaller projects will be subject to a 'refresh' of the Track 1 RVA based on the more detailed understanding of their design.

Where CRIDF supports the development of new projects, the CRIDF Climate Risk and Vulnerability Assessment Tool (CRVAT) is deployed to perform an RVA of the project location, using structured questions relating to current and future hazards, exposure and vulnerability, answered using stakeholder interviews and specialist climate expertise. These projects should

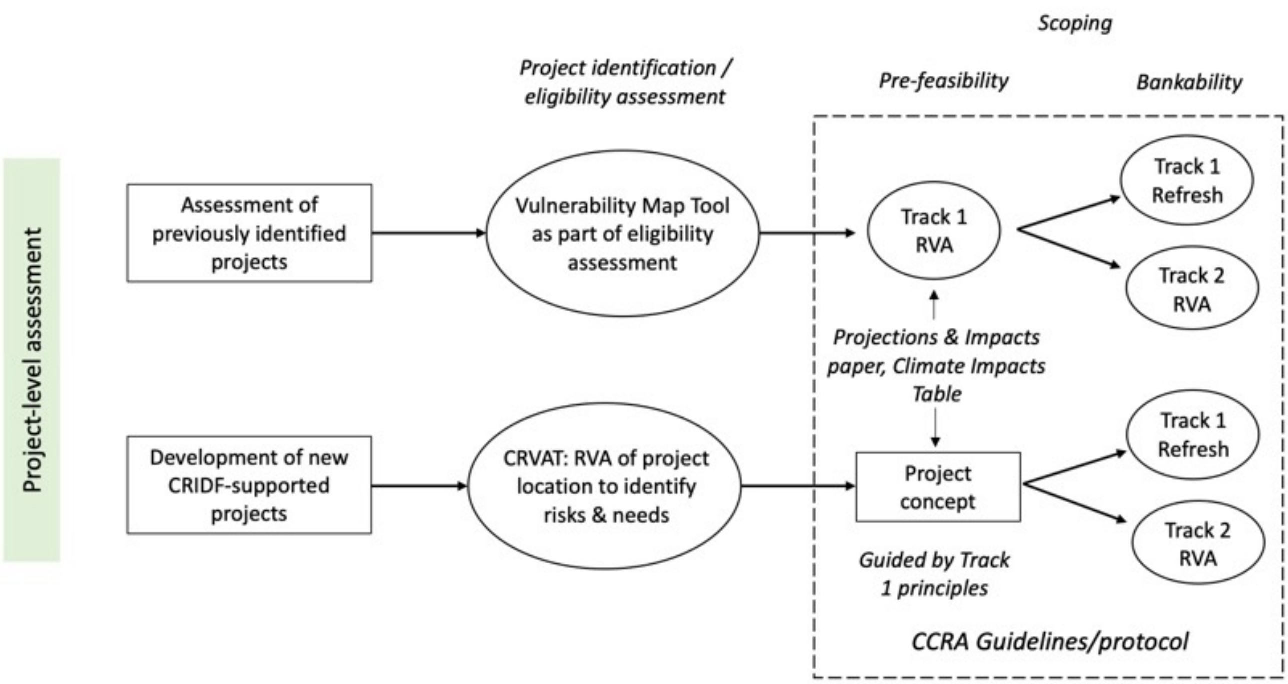

Figure 1: Use of tools and guidance to integrate climate information into project identification and scoping.

be designed to be climate resilient from the outset, with principles of RVA built into their design. However, a Track 1 RVA refresh or a Track 2 RVA may be appropriate, depending on the nature and size of the project (Figure 1).

Communication of technical findings within CRIDF is also facilitated through regular team meetings at the programme and project level, workshops, and interactions between core CRIDF staff and external climate science specialists. The existence of a Climate Change Lead position within CRIDF provides a focus for the collation and dissemination of technical findings related to climate change projections and impacts.

At the more strategic level, climate information and related CRIDF findings are communicated principally through basin-wide studies and scenario reviews/reports and direct engagement with RBOs, for example via workshops. Some basin-wide studies are commissioned by RBOs, and some of the CRIDF tools have been developed and piloted in cooperation with RBOs. These studies and reports are also available via the CRIDF website and associated Resource Centre web portal, from tools, guidance, strategic and project level documentation and other information can also be downloaded.

CRIDF has also engaged in communication of learning at the global level, for example in discussions with the Green Climate Fund relating to the limitations of framings based on the concept of additionality.

While the above mechanisms communicate climate information at a range of scales, particularly at the project level, the internal communication of CRIDF technical findings appears rather piecemeal. Staff numbers, resource constraints and the concentration of knowledge and responsibility for climate change technical information in the single climate change lead role undoubtedly limit the extent to which information and support around technical findings can be delivered throughout the programme and project portfolio.

The communication of climate information is mentioned or discussed explicitly in documentation for only a minority of the projects reviewed, although it is implicit in documentation for others.

Integration of risk into planning and projects

CRIDF uses a ‘decision scaling’ approach to climate risk. Rather than starting with one or more climate projections and employing these in a ‘predict-then-act’ approach, decision scaling starts with an assessment of a system’s vulnerability, and asks under what conditions that system is likely to fail. The potential for these conditions to be met is then examined for a range of plausible climate scenarios.

This approach appears to work best for larger projects, where climate model outputs representing the scenarios can be used as input to hydrological models to examine the sensitivity of phenomena such as flooding to different changes in climate. For smaller projects, where engineers need to make judgments on design parameters, there is often a mismatch between rather general, low-resolution climate information and the need for specific, quantitative, high-resolution information on which to base decisions about infrastructure designs or codes. Insofar as smaller projects use scenarios to inform decision-making, there appears to be a tendency to use the scenario of strongest agreement across models and RCPs as a 'most likely' scenario. There also appears to be a tendency to use information about the impacts of climate change and variability, and resilience narratives, to justify projects that are essentially conventional water infrastructure projects. These may well deliver short- to medium-term resilience benefits, but their role in longer-term, transformational changes in resilience is open to question.

Longer-term risks associated with the sustainability of infrastructure under climate change, for example as a result in changes in hydrological regimes, is assessed for some larger projects. However, long-term risks are not assessed for smaller projects, as they are not necessarily envisaged as permanent. The focus for smaller projects is on their financial viability based on projected returns on investment. While this is a pragmatic approach, greater consideration might be given to the potential downstream impacts of smaller projects via their influence on development trajectories. A significant proportion of the projects reviewed are associated with potential sustainability and maladaptation risks that remain unaddressed. More fundamentally, most projects base assessments of risks and sustainability on implicit assumptions that future conditions will resemble those of today, and do not consider how climate change will alter factors such as abstraction-to-recharge ratios. Where the potential for maladaptation is identified, this need not undermine the case for a project. Rather, it would require the development of strategies to address maladaptation risks; for example, based planning for phased transformational adaptation.

The decision scaling approach used by CRIDF is very similar to Robust Decision Making (RDM). There are inherent tensions in RDM, between the range of plausible future conditions and the ranges represented in climate projections. These can make such approaches problematic in data and resource-scarce contexts, and where decision-makers are not involved in scenario development and the focus is on scenarios as a product rather than on their development as a process. However, decision scaling has the potential to result in more iterative adaptive management approaches, particularly where they are linked with approaches based on adaptation pathways and frameworks for developing transformational adaptation strategies.

Improving the uptake of climate information and decision-making

CRIDF is broadly following international good practice in its development and use of climate information, and CRIDF projects provide multiple examples of instances in which CRIDF support has improved decision-making through the use of climate and related information. However, the use of tools and guidance to support climate-informed decision-making is largely down to external project partners, operating with varying amounts of CRIDF support. This support is often limited and delivered remotely via telephone, owing to issues of staffing and the remoteness of project sites. The process might be improved through more intensive support, although this would have significant resource implications and would need to avoid undermining the extent to which the current approach results in partners 'learning by doing'. Ex-post analyses of how CRIDF tools have been used, the extent to which climate information and CRIDF technical findings have genuinely informed project design, and how decision scaling approaches have been employed in practice, could provide valuable lessons on improving uptake of information, tools and methods.

Decision-making might be improved further through approaches based more explicitly on the co-production of information, coupled with support to local communities to establish low-cost mechanisms for tracking climatic and environmental trends, variations, impacts and vulnerabilities; for example, through phenological approaches that can track the evolution of seasonal changes. Using principles of co-production, CRIDF might also intensify its focus on bridging the gap between climate information and engineering needs and enhancing the decision scaling and related approaches. The latter could involve an emphasis on more cooperative processes of scenario development, rather than on scenarios as products, and the development of longer-term risk assessments and transformational adaptation strategies where potential maladaptation risks are identified. While it might be impractical for CRIDF to implement such changes in its final phase, the programme might support a small number of pilot initiatives. At the very least, this area should be a priority for learning. Flexible, iterative approaches involving co-production are likely to be constrained by the current CRIDF operating model, which is based on highly prescriptive task orders that allow little, if any, flexibility in how projects are implemented,

Evidence of uptake and impact

CRIDF reports on impact in its annual reviews, based on an outcome harvesting approach that examines evidence of impact on knowledge, attitude and practice (KAP). The 2020 Annual Report finds changes in one or more of these three factors in ten out of 17 organisations examined, consisting of 27, 26 and 15 reported instances of positive change in knowledge attitude/thinking and practice respectively.

While it is difficult to quantify wider capacity-building results across the SADC region, CRIDF's approach of developing tools, guidance and climate information with stakeholders including RBOs and other project partners is likely to increase awareness and understanding of climate information and its use among these actors. The application of CRIDF tools and guidance by partner individuals and organisations, including infrastructure sub-contractors and some 100-200 individual experts from the region, can be assumed to be having a similar impact.

Evidence of impact is also apparent in the context of individual projects. For example, the Lower Incomati Flood Risk Management project provides evidence of the establishment of new multi-scale stakeholder networks which have evolved into de facto flood management committees, transformational changes in cooperation and relations between sugar estates and smallholder farmers, and changes in flood risk management regimes encompassing changes in physical infrastructure. These changes have been predicated on the use of climate and related information including scenarios, projections, hydrological modelling and cost-benefit analysis. Other projects, such as the Kufandada and Bindagombe irrigation projects, have been instrumental in leveraging finance and served as models for scaling up.

Conclusions and recommendations

CRIDF has developed a pragmatic framing of resilience and adaptation to support climate resilience infrastructure in the SADC region. The programme has piloted novel approaches to the development and dissemination of climate information and tools and guidance for integrating climate information into decision-making at multiple scales from the basin scale to the local project level. Communication of climate information and project insights has been achieved through the mandated application of these tools and guidance at the project level, and through basin-wide studies and engagement with RBOs at the regional and basin level. The public availability of these tools and methods, along with a wide range of other documentation on the CRIDF website, has delivered a high degree of transparency and potential for uptake of CRIDF processes and learning. CRIDF's approach to climate risk and vulnerability assessment reflects global good practice, blending considerations of current and future hazards, vulnerabilities and risks.

There is significant evidence of impact, at both the project and basin scale, in terms of infrastructure delivered, the establishment of stakeholder networks focused on enhancing resilience to climate variability and change, shifts to more resilient flood management, and climate-informed planning by RBOs.

Nonetheless, the extent to which CRIDF tools and guidance have been robustly adopted and have genuinely informed project design and implementation appears to vary across projects. One the one hand, use of CRIDF tools and guidance by external partners and stakeholders represents a process of 'learning by doing' that should enhance the capacity of individual experts and organisations, including private contractors, in the region. On the other, the limited and largely remote support offered by CRIDF for the application of these tools and methods – a function of resource and staff constraints – has likely been an impediment to the effective and meaningful integration of climate information into decision-making, at least in some contexts. This is evident in the emphasis on climate information and resilience narratives in project rationales, but their often much lower visibility in project design. Narratives linking climate hazards with climate change at the project level are often weak, and assessments of risks and sustainability often ignore how climate change may impact key variables such as water demand and abstraction-to-recharge ratios. A focus on near-term resilience may risk longer-term maladaptation by failing to consider, and diverting attention away from, longer-term adaptation needs.

CRIDF's decision scaling approach rightly seeks to move beyond the 'predict-then-act' approaches that have been widespread in climate change planning, and represents a novel approach to the use of climate projections to develop scenarios representing a broad range of plausible future conditions. In practice, particularly for smaller projects, there appears to be a tendency to treat scenarios of most agreement (across projections and greenhouse gas concentration pathways) as 'most likely' scenarios and use these for planning in a way that reflects the predict-then-act approach. Where multiple scenarios are employed, there is a risk that their use as 'products', rather than the co-development of scenarios as a process, may result in their being treated as representing all possible futures, with risks associated with 'unknown unknowns' being ignored. This could be addressed by blending the decision scaling approach with other related approaches based on Climate Risk Informed Decision Analysis (CRIDA) and decision trees.

The integration of climate change risks into decision-making might be enhanced through a greater focus on co-production, with CRIDF or successor bodies playing the role of knowledge broker. Co-production approaches and the incorporation of frameworks such as CRIDA could also help to identify and address risks of maladaptation, supported by local monitoring of climate trends, hazards and impacts. However, CRIDF's current rigid, task order driven approach to implementation may inhibit more flexible approaches to co-production and learning.

CRIDF has an opportunity to capture and communicate critical lessons and secure its legacy in its final two to three years of operation, and lay the foundation for subsequent work in the SADC region and beyond; for example, through the planned legal entity that will provide similar services to CRIDF. This should be a priority for the programme.

A number of specific recommendations, which are widely applicable across FCDO's climate change programming, are listed in the box below. These recommendations are presented in more detail in the main report.

Recommendations applicable across FCDO's climate change programming

1. Strengthen narratives around climate change impacts, vulnerabilities, risk and resilience at the project level and ensure that these go beyond project justification to frame and inform project design more explicitly.
2. Extend CRIDF's role as a knowledge broker to enhance the co-production of new knowledge at the local level.
3. Support the establishment of community mechanisms to monitor climate trends, variability, impacts and vulnerabilities, to enhance local capacity to track and respond to climate change risks.
4. Pay closer attention to the downstream effects of smaller/short-term projects and their potential to result in longer-term maladaptation, and develop strategies to address any such risks through transformational adaptation based on principles of co-production and informed by community monitoring.
5. Use principles of co-production to address the gap between climate information and engineering design needs for smaller projects.
6. Promote the decision scaling approach as an alternative to the 'predict-then-act' approach, but also consider extending this with adaptation pathways for larger projects following recent international best practice.
7. Review how external stakeholders responsible for project implementation have been supported, and evaluate the use of information ex post in practice (in contrast to guidance) for a range of projects; identify lessons about how this support might be improved in programmes.
8. Distil and communicate lessons around the relationship between resilience, adaptation and development, and implications for current climate financing models, particularly those based on the concept of additionality.
9. Consolidate and communicate lessons around good practice in the use of climate information and adaptation decision-making, based on CRIDF experience.
10. Consolidate learning and ensure curation and communication of information, learning, tools and guidance so they remain accessible beyond the close of the programme, regardless of the outcome related to the planned legal entity to replace CRIDF.

1. Background

This report is the result of an assignment undertaken by Nick Brooks on behalf of Garama 3C Ltd, commissioned by SouthSouthNorth (SSN) in response to a Request for Service (RfS) to the Climate Mainstreaming Facility (CMF) from the DFID/FCDO Africa Regional Office, via the DFID/FCDO Facility Executive Committee (FEC). SSN hosts the CMF under the Future Climate for Africa (FCFA) initiative. Fifteen days was allocated for this assignment initially, with an extension of four days for finalisation of outputs based on FCDO feedback. The work was conducted over late 2020 and early 2021.

The purpose of the assignment was to review the work of the UK Aid-funded Climate Resilient Infrastructure Facility (CRIDF), across its portfolio. The assignment is not an evaluation of the CRIDF programme, but an assessment of how CRIDF approaches climate change resilience and adaptation, integrates climate change into the planning and design of projects, and uses climate information to promote resilience and support adaptation to climate change. The objective is to deliver learning around the issues of resilience, adaptation and climate information that is useful to CRIDF staff and to FCDO more widely, and that might assist future programming, planning and project design.

The review is based on CRIDF reports issued as part of infrastructure pipeline development, basin-wide strategy plans, CRIDF tools, and interviews with key CRIDF personnel.

This report constitutes the principal output of the assignment, and is accompanied by a non-technical report to inform capacity development in DFID/FCDO offices, and a guidance note on the review of third party service providers outlining what is expected when a third party provides climate information.

1.1. The CRIDF programme

CRIDF is the United Kingdom's water infrastructure programme for southern Africa. The programme commenced in 2013, with Phase I running until 2017. Initially scheduled to run until 2020, Phase II of the programme has been extended until 2023. CRIDF activities span a wide range of projects focused on water infrastructure at a range of scales, across 12 SADC countries that share water resources.

CRIDF works on a wide range of projects involving the installation of small-scale water infrastructure, hydrological monitoring, flood management, technical support for strategic planning and the development of larger-scale infrastructure, and other interventions to address the needs of the poor. CRIDF classifies its projects into the following five types:*

* http://cridf.net/types-of-projects-cridf-works-with/

1. **Livelihoods interventions**, focused on small-scale infrastructure such as weirs, solar pumps and low-cost storage, linked with irrigation systems to provide a more reliable water supply in the face of increasing climate variability, enabling farmers to grow crops away from river banks and thus avoid erosion, and to expand production;
2. **Border towns and transport corridors**, focusing on improving water and sanitation infrastructure to reliably meet the needs of permanent and transient populations while improving health and environmental outcomes;
3. **Flood forecasting and early flood warning**, to enable communities and business to prepare for and manage floods more effectively;
4. **Accessing agriculture value chains**, via the improvement of accessible water resources for communities and crops to improve production, linking communities with markets, and reducing competition between agricultural water use, environmental water demands and human-wildlife conflict; and
5. **Enhanced adaptation through monitoring**, focusing on designing and equipping monitoring stations in key locations to improve information values chains to support better water resources management, flood early warning, and drought mitigation planning.

CRIDF has a strong focus on pilot/demonstration projects involving the construction of small-scale water infrastructure, principally irrigation, dams and water supply, to support local livelihoods in remote areas. These projects are designed with a pro-poor focus and an emphasis on gender and inclusion, and typically have budgets of less than £1 million. These are generally proof-of-concept projects intended as demonstrations of interventions that are required at scale in a given area. They typically address the water-energy-food nexus, focusing on water supplies underpinned by solar and wind power. Collectively, these projects are intended to address the regionally prevalent issue of rural poverty, which affects some 40-60% of the SADC population. However, as they are focused on local contexts, they are diverse in nature.

Technical support for larger initiatives includes pre-feasibility studies, the development of financial models, and other aspects of project preparation, as well as assistance with procurement and the mobilisation of finance. Examples of these projects include large dams and basin-wide climate resilient infrastructure planning, including hydrometeorological monitoring, flood warning systems, and water supplies linked to border crossings.[*] Via its support for these, CRIDF deals with all aspects of water infrastructure.

The generation, curation and management of climate data and information is central to CRIDF's activities, and data is seen as essential to transboundary cooperation on water resources issues; for example, through the sharing of data and information between countries to foster confidence. In addition, CRIDF has supported the collation of previously fragmented data from computer and paper records, to extend datasets from the middle of the 20th century as far back as 1923.[†]

* Twelve projects were reviewed as part of this assignment (Annex 4), and are referred to throughout the report.

† Based on an interview with LM (Interview 2, Annex 1)

2. Approach and Methodology

The learning assignment consisted of the following steps:

Scoping phase

1. Identification of a set of eight broad research questions based on the eight key tasks outlined in the ToR (Table 1);
2. Initial review of strategic, programme-level documents provided by CRIDF, in the context of the research questions;
3. Initial interviews with CRDIF programme manager, climate change lead and chief engineer, based on research questions;
4. Collation of learning from initial programme-level document review and interviews, including identification of subsidiary questions;
5. Agreement of structure of final report and work plan with FCDO.

Assessment phase

6. Identification of a list of CRIDF projects based on CRIDF databases, and development of a 'longlist' of projects for possible review;
7. Selection of a sample of projects for detailed review (see below for methodology);
8. Detailed review of project documentation in relation to the eight research questions;
9. Further interviews with CRIDF personnel;
10. Development of final report and other deliverables based on above review and interviews;
11. Delivery of draft final report to DFID and virtual presentation of results to DFID;
12. Revision of report based on feedback from DFID.

A list of CRIDF staff consulted and summary details of interviews is provided in Annex 1.

Table 1: Summary of tasks outlined in ToR and associated research questions.

Tasks outlined in ToR	Research questions
1. Identify what CRIDF considers to be robust, climate resilient development, to establish a standard of success.	What does CRIDF consider to be robust climate resilient development?
2. Review the technical approach to downscaling climate model outputs, including trade-offs and options for other appropriate methods based on capacity and data availability.	How is climate data used by CRIDF?
3. Review how technical findings are communicated internally for planning and design, including communicating uncertainty, appropriate reference materials and caveats.	How are technical findings communicated internally?
4. Review how the technical findings are communicated externally to stakeholders for planning and design, with a focus on accessibility for different audiences.	How are technical findings communicated externally?
5. Review CRIDF's recommendations and conclusions for integrating climate change risk and uncertainty into projects, focusing on accuracy and applicability of recommendations with respect to technical limitations and target audience.	How does CRIDF integrate climate change risk and uncertainty into projects?
6. Identify and provide high-level recommendations on potential tools, models, and processes for scaling up/improving the communication and uptake of climate information and enhancing climate resilient decisions (evidence of uptake, change, impact narratives, knowledge brokering).	How can uptake of climate information and decision-making be improved?
7. Report on whether there is evidence of uptake and impact of communicated climate information with a sufficient standard to lead to engagement between DFID and CRIDF for further collaboration and aligning of goals and interests.	What is the evidence of uptake and impact of climate information?
8. Develop a guidance note for DFID on the review of third party providers of climate information – what is appropriate, robust and ethical? Outline appropriate standards and practices, limitations, caveats and trusted sources of information and data.	What is 'best practice' with regard to providing and using climate information?

2.1. Document review

Initial document review focused on strategic CRIDF documents relating to the programme's framing of resilience and adaptation, climate information and engagement. An initial set of such documents was provided by the CRIDF management team, and further relevant documentation was identified via the CRIDF Resource Centre web portal (http://cridf.net/RC/). These documents were reviewed with reference to the eight research questions (Table 1). A list of strategic, programme-level documents consulted is provided in Annex 2.

The review of strategic documents was followed by a review of project documentation. A list of around 80 CRIDF projects and programmes was compiled by interrogating the Resource Centre web portal and the CRIDF SharePoint database.* Details of each project were entered into a spreadsheet, including geographical and thematic focus (Annex 3). Each project was assigned a code indicating the type and extent of documentation available (Table 2). A longlist of 52 projects was identified for which significant documentation was available (codes 4, 3, 2.5 and 2 in Table 2). A subset of 12 projects was selected from this longlist for review, spanning a range of geographies and project types. The purpose of this review was to assess how projects are framed in relation to climate change, how they use and communicate climate information, how they address uncertainty and longer-term risks, and the extent to which they explicitly address climate change risks and impacts. This was achieved by assessing each project against 21 criteria addressing climate change framing, climate information and uncertainty, and the nature of project activities, listed in Table 3.

Table 2: Codes assigned to projects indicating level and type of documentation available.

Code	Documentation indicated
0	No documentation accessible (includes documentation only available to CRIDF staff on SP, and documentation not readable with standard software).
1	General info only – short briefings, articles, ToR, non-CRIDF docs incl. proposal to CRIDF, etc; i.e. no detailed project documents.
2	Detailed project documents from stages prior to design – detailed concept note, pre-feasibility, scoping study.
2.5	As above plus dedicated engagement documentation.
3	Detailed project documents from design stage onwards.
4	Proposal to GCF.

* The number of projects is approximate, as some projects are components of larger CRIDF programmes, some projects may be named differently in the different databases, and distinct but sometimes related projects in the same location (e.g. funded in different phases of CRIDF) may have similar names, resulting in their being treated as a single project.

Table 3: Criteria against which projects were assessed in review.

Climate change framing	
1.	Describes vulnerabilities to and impacts of existing hazards.
2.	Provides evidence of existing maladaptation.
3.	Claims hazards have worsened owing to climate change.
4.	Provides supporting evidence for (3).
5.	Discusses future climate change impacts and implications.
6.	Provides supporting evidence for (5).
Use of climate information and treatment of uncertainty	
7.	Provides quantitative observational data to support climate change claims.
8.	Discusses climate projections and scenarios.
9.	SOMs discussed in project documentation.
10.	Uncertainty in climate projections discussed in project documentation.
11.	Decision scaling discussed or evident in project documentation.
12.	Evidence that climate information has informed project design.
13.	Project will involve use of climate information beyond design and CCRA.
14.	Communication of climate information to stakeholders and beneficiaries discussed.
15.	Long-term sustainability and maladaptation risks discussed/addressed.
Nature of project activities	
16.	Measures focused on delivering reliable water supply where none exists, or on increasing productivity via irrigation and commercialisation (regular development).
17.	General resilience-building measures to address climate variability (resilience).
18.	Targeted measures to address specific actual or expected climate change impacts, beyond general resilience to drought and variability (incremental adaptation).
19.	Replacement of climatically unviable systems and practices with alternatives suitable for new climatic conditions, beyond transition to irrigated commercial agriculture (transformational adaptation).
20.	Implementation of new crops and agricultural systems with alternatives to pay for irrigation and generate income (transformational change).
21.	Changes in institutions and governance for new NRM/WRM (transformational change).

The full list of projects, the longlist and the projects selected for review are provided in Annex 3. This also includes a tabulated summary of the project reviews. Full project reviews in light of the 21 criteria in Table 3 are included as Annex 4, along with a short narrative summary for each project. Raw notes from the project reviews are included as Annex 5, which also lists the documents reviewed for each project.

Based on these reviews, individual projects are referred to throughout this report where relevant. A synthesis of the reviews is included in relation to climate change framing and relevance, use of climate information, longer-term climate risks and transformational change at the end of the relevant sections of the report.

It is appreciated that the extent to which the above questions are relevant to an individual project will vary, depending on the nature of the project. For example, a project supporting the development of large-scale, long-lived water infrastructure will need to consider the implications of climate change for future extremes of flow, while a small-scale project intended to deliver immediate development benefits may not (although see 3.5.3 below).

In addition, the amount and type of documentation available varied across the projects reviewed; for example, because of the different stages of the projects. For projects with more limited documentation, the absence of discussion of certain issues may be due to information or documentation gaps or the early stage of a project represented by the available documents. These considerations, coupled with the remote, desk-based nature of the review, mean that assessment of projects against the criteria in Table 3 is likely to be conservative, and may underestimate the extent to which projects address certain issues, for example around climate information, risk assessment and communication.

The projects reviewed also spanned a significant time period, over which CRIDF approaches have evolved. This is evident in the more comprehensive treatment of climate risks and information in some later project documents (see Annexes 3-5). Therefore, the review of projects was not an exercise in scoring, grading or assessing the quality of individual projects. Rather, the aim was to generate learning around CRIDF approaches and how these relate to the wider framing of resilience and adaptation and their relationship to development at large. Based on this learning, the report seeks to identify questions, issues and knowledge gaps that require further attention and clarity in order to inform future programming.

3. Addressing the research questions

3.1. What does CRIDF consider to be robust climate resilient development?

3.1.1. CRIDF's framing and definition of resilience, adaptation and vulnerability

CRIDF's Final Resilience Strategy (2017: 8) sets out definitions of resilience, adaptation and vulnerability. The definition of vulnerability used in the strategy is that of the IPCC AR5 (2014). However, CRIDF has developed its own framings and definitions of adaptation and resilience.

CRIDF frames adaptation as measures to reduce vulnerability over the short to medium term, based on the understanding and prediction of specific climatic changes. Resilience is viewed in terms of the ability of people and organisations to respond to longer-term risks based on their access to tools and mechanisms to reduce vulnerability in the longer term. The CRIDF's Final Resilience Strategy cites the WRI vulnerability-impact spectrum (McGray et al. 2007), recognising the importance of a mix of general measures to build resilience and reduce vulnerability, and targeted adaptation measures to address specific climate change risks and impacts.

CRIDF's paper on climate projections and impacts for southern Africa (CRIDF, 2016) states that there is 'high confidence that managing risk and developing adaptive capacities for ensuring food security, managing health vulnerabilities and governance systems will be insufficient to deal with the predicted impacts of climate change in the short (2025) and medium (2055) term'. This appears to recognise that general measures to reduce vulnerability and build resilience will be insufficient to address the impacts of climate change if they are not complemented with more targeted adaptation actions to address the specific impacts of climate change on these timescales.

The CRIDF framing of resilience and adaptation thus is a pragmatic one in which adaptation involves measures to address/mitigate specific climate change impacts, and resilience building involves measures to enhance adaptive capacity. The aim of this capacity building is to enable people and organisations to develop and implement their own adaptation measures in a more autonomous manner, to address future climate change risks and impacts that currently may not be well understood. Examples of measures to address specific climate change risks in the context of CRIDF would include irrigation and water storage to address increases in drought frequency (most CRIDF projects), severity and duration, and flood early warning systems to address increases in flood risk result from climate change (e.g. Lower Incomati Flood Risk Management project[*]). Examples of measures to enhance adaptive capacity would include the development of climate change scenarios and their dissemination, along with other CRIDF assessment tools, to river basin organisations to inform basin-wide planning (see 3.2 and 3.4.1 below).

This framing clearly articulates the relationship between, and complementarity of, resilience and adaptation from a CRIDF perspective, and also provides a practical means of bridging the near term and longer term.

Conceptualisation of resilience has evolved with the programme, to address practical issues of what constitutes a reasonable standard of resilience in relation to water resources. The Resilience Strategy also includes a CRIDF-specific definition of resilience as:

> *"… improving the capacity of the poorest and most climate vulnerable social, economic and environmental systems in transboundary river basins to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation."* (CRIDF 2017a: 9).

This definition allows for resilience to accommodate adaptation, learning and transformation, in line with the most recent IPCC (2018: 557) definition.

3.1.1.1. Incremental versus transformational adaptation

Adaptation may be incremental or transformational in nature. Incremental adaptation seeks to maintain 'the essence and integrity of a system of process at a given scale' (IPCC 2018: 542), to 'avoid disruption of systems at their current locations' (Kates et al. 2012: 7156). Incremental adaptation involves 'adjustments made to manage proximate climate risks and impacts while retaining the function and resilience of existing structures and policy objectives' (Chung Tiam Fook, 2015: 2).

In contrast, transformational adaptation 'changes the fundamental attributes of a system in response to climate and its effects' (IPCC 2018: 542). Transformational adaptation 'on the ground' will be necessary where climatic and environmental thresholds are reached beyond which existing systems and practices are no longer viable. Where this occurs, systems and practices will need to be radically restructured, replaced with alternatives that are viable under the new conditions, or simply abandoned. Transformational adaptation might also be viewed as desirable where climate change results in changes in the relative risk, reliability, difficulty, productivity or cost effectiveness of different options. Where this happens, systems and practices that previously were not considered practical or desirable may become more attractive than current systems or practices. For example, the additional investment required by certain agricultural practices may become worthwhile where existing low-input agriculture fails more frequently due to climate change.

Both transformational and incremental adaptation on the ground may require transformational

* Project index no. 20 in Annexes 3 and 4.

changes in decision-making processes, policies, institutional arrangements, financial flows and indeed thinking, in order to ensure that climate change risks and impacts are adequately addressed. Such transformational changes may be required for transformational adaptation to occur, but they do not guarantee successful adaptation on the ground. Transformational change and transformational adaptation are closely related, but are not necessarily the same thing.

CRIDF aims to drive transformational change by embedding new approaches in longer-term planning processes (CRIDF 2017b). To a large extent this involves the 'indigenisation' of CRIDF tools and methods for risk and vulnerability assessment and adaptation planning in relevant institutional contexts. 'The second phase [of CRIDF] seeks to recognise much more explicitly that the technical interventions undertaken by CRIDF seek to bring about transformational change in the way that projects across SADC are conceived, planned, financed and implemented' (CRIDF 2017b: 5). Such transformational change arguably is necessary if planning is to support either transformational or incremental adaptation as defined above.

3.1.1.2. Linking resilience, adaptation and development

Even where we are not dealing with transformational adaptation, the boundary between adaptation and development is often unclear. For example, a review of 54 initiatives under the DFID Strategic Adaptation and Climate Resilience in Kenya Plus (StARCK+) programme concluded that only around a third could be said to be directly addressing specific climate change risks and impacts (Brooks, 2017). The remainder consisted of familiar development activities that would be desirable even in the absence of climate change. Most of these initiatives focused on capacity building, improving agricultural productivity or addressing the 'adaptation deficit' associated with existing climate variability, with little or no explicit attention paid to how climatic conditions might change. However, up to two thirds of the initiatives exhibited the potential to deliver indirect or ancillary resilience and adaptation benefits, and to help people cope better with changed climatic conditions. While resilience and adaptation are necessary to secure development as the climate changes, well-planned and implemented 'regular' development can also enhance resilience and support adaptation. However, poorly designed or implemented development and adaptation interventions can also drive maladaptation and increase climate change risks (Eriksen et al. 2021).

The CRIDF portfolio casts further light on the complex relationship between adaptation, resilience and development (see Box 1). For example, one interviewee described how 'regular' development has delivered adaptation benefits in Livingstone, Zimbabwe (Annex 1, Interview 1). Here, the availability of piped water is a clear development issue. However, some people in informal settlements rely on surface water which will become less reliably available as a result of climate change. The provision of piped water – a basic development goal – reduces the vulnerability of these people to dry periods where surface water is not available, and thus delivers resilience and adaptation benefits.

While many CRIDF projects involve interventions that reflect standard development practices associated with the installation of basic infrastructure, one interviewee argued that climate change makes such interventions mandatory (Annex 1, Interview 2). This is because climate change is already resulting in an unacceptable frequency of agricultural failures, making rain-red

BOX 1: Adaptation, resilience and development

Many measures that carry the adaptation and resilience labels would be desirable even in the absence of climate change. These include measures to improve the management of, for example, agricultural systems and water resources, and measures to enhance resilience to familiar hazards associated with historical climate variability (addressing the 'adaptation deficit'). Both of these categories of measures might simply be viewed as good development, regardless of climate change considerations.

In contrast, 'genuine' adaptation can be viewed as consisting of actions that would not be required in the absence of climate change, involving necessary responses to persistent changes in climatic and environmental conditions, including changes in climate variability.

Resilience to climate change therefore encompasses adaptation to changing climatic and environmental conditions, as well as changes in non-climatic factors that themselves might be influenced by climate change (e.g. global commodity prices and value chains). Development will only be sustained in the face of climate change if it integrates resilience and adaptation. In other words, resilience and adaptation should not necessarily be seen as ends in themselves, but rather as the means to sustaining and enhancing development performance and human wellbeing in the face of climate change.

This has implications for resilience and adaptation monitoring, evaluation and learning (MEL), and for how we assess the success of resilience and adaptation actions. One approach is to track resilience at the outcome level in terms of the factors that enable people and systems to anticipate, absorb and adapt to evolving hazards (e.g. climate trends, variations and extremes) in specific contexts (Bahadur et al. 2015; HMG 2018), and to complement this with assessments of how development results and human wellbeing are affected by individual climate (change) hazards when they occur, or over extended periods of time during which societies will be exposed to multiple such hazards. Assessments of development performance and human wellbeing in the face of climate hazards are the ultimate means by which we can determine whether adaptation has been effective, and whether societies are resilient. To do this, development and wellbeing measures need to be interpreted in the context of climate information, to measure results at the impact level (Brooks 2014; Brooks & Fisher 2014; Barrett et al. 2019).

agriculture unviable in much of the SADC region. Irrigation is thus essential if agriculture is to be sustained in many areas.

Where adaptation is pursued through the implementation of irrigation systems, these systems need to be financially sustainable. Depending on what crops are already grown, this might be achieved through higher yields resulting from an increased, and more stable, supply of water. For example, this model is proposed in the documentation for the Sioma Irrigation Scheme.* In other contexts, the need to pay for the installation and maintenance of irrigation infrastructure may necessitate a switch to higher-value crops that can generate the necessary income (CR). In both cases, the need to generate income acts as a trigger for agricultural commercialisation and the linking of growers with supply chains. In these contexts, climate change is driving development 'beyond subsistence,' based on the need for adaptation and the means to pay for it.

Transitions from subsistence to commercial agriculture are a mainstay of economic development policies and programmes, and are central to historical development models based on ideas of modernisation. They can both reduce and increase vulnerability and inequality, depending on how they are designed and implemented; commercialisation does not necessarily constitute adaptation (Eriksen et al. 2021). In the CRIDF context, shifts from subsistence to commercialisation are viewed as constituting transformational adaptation on the following grounds:†

1. climate change makes irrigation mandatory;
2. commercialisation is necessary to generate income to pay for the installation and maintenance of irrigation systems;
3. commercialisation often involves new livelihood models and cropping systems that replace previous subsistence systems that are now unviable.

In these cases, incremental adaptation to preserve existing production systems and livelihood models (through irrigation to address water deficits) is impractical not because 'hard' adaptation limits, based on physical viability, have been reached; rather, such an approach is economically unviable. Transformational adaptation – in this case a transition to a different type of production system – thus can be driven by a combination of climatic and economic factors.

3.1.1.3. Additionality

Most current adaptation is incremental in nature, and this is reflected in the concept of 'additionality', whereby climate finance covers the costs of additional measures/expenses that are required to 'climate-proof' a development initiative, over and above what would be required in the absence of climate change. Additionality is based on a 'development first' approach, in which development priorities and interventions are decided upon first, with climate change adaptation approached as an 'add-on'. This approach assumes (explicitly or implicitly) that current or desired development models and outputs can be preserved and protected from climate change, given the availability of sufficient finance and technical expertise. While approaches

* Sioma Irrigation Scheme: Feasibility Report, Mar. 2016 (Project no. 65 in Annex 3).

† Based on Interview 1, Annex 1.

based on the concept of additionality may be compatible with incremental adaptation, they are much less suited to transformational adaptation, which by definition involves systemic changes in which separating the 'development' and 'adaptation' components is much more problematic, and arguably nonsensical.

More fundamentally, initiatives that might resemble conventional development interventions may be driven by an adaptation imperative, as illustrated by the above examples of the installation of water infrastructure in areas where people rely on surface water that is increasingly unreliable as a result of climate change, and of irrigation infrastructure where climate change means existing rain-fed agricultural systems are likely to be unviable. Nonetheless, where initiatives are based on climate finance, climate change narratives need to be convincing and backed up with evidence based on climate information (quantitative or qualitative), in order to ensure that climate finance is directed to addressing genuine climate change challenges, as intended.

3.1.2. Implications of CRIDF framing for the use of climate information

As discussed above, CRIDF views adaptation in terms of measures to address specific, identifiable risks in the short to medium term, and resilience in terms of measures to ensure the longer-term sustainability of adaptation in the face of currently uncertain risks and impacts. Based on this framing, adaptation will be informed by climate information relating to specific risks and impacts, including observed, emerging and anticipated risks and impacts. Therefore, to a significant extent, resilience will depend on the ability of the public and decision-makers to access, interpret and act on climate information that will evolve over time, relating to currently uncertain future risks and impacts. Enhancing this ability therefore will be a critical aspect of resilience building, and of creating enabling environments for adaptation.

To a large extent, the question of what constitutes a reasonable standard of resilience in the water sector relates to the conditions under which water systems (and linked systems such as agriculture) fail, and how likely these conditions are to occur in the future under climate change. Most CRIDF projects are in the central zone of Southern Africa where, according to one interviewee, the main impact of climate change to date has been increased climatic variability (Annex 1, Interview 1). This can manifest as more frequent and severe rainfall deficits resulting in increasing crop failures, for example from approximately once every decade to once every two years on average, as has occurred in southern Zimbabwe, according to another interviewee (Annex 1, Interview 1).

A key function of climate information will be to help decision-makers identity where and when critical thresholds in climate-related variables will be reached, beyond which current or planned systems fail. This failure may be due to absolute limits on the ability of systems to adapt, or to the necessary adaptations that would allow these systems to persist being economically impractical. These thresholds might be pushed back through incremental adaptation to prolong the life of existing systems (e.g. irrigation). Where this is not possible, transformational adaptation involving the radical restructuring, replacement or abandonment of existing systems will be necessary. CRIDF's focus on identifying the circumstances under which water and related systems are likely to fail lends itself to analysis of when and where transformational adaptation might be necessary, informed, on the one hand, by climate information relating to the likelihood of these circumstances being realised, and on the other by assessments of the potential for incremental adaptation to address climate change impacts. Frameworks for such analysis already exist (e.g. Rippke et al. 2016) and are discussed in more detail below.

More fundamentally, climate information is important for identifying genuine climate change challenges that can be addressed using climate finance.

3.1.3. Resilience and adaptation narratives in CRIDF projects

The narrative of transformation in which climate change makes irrigation necessary, and commercialisation is required to make irrigations systems financially viable and sustainable, is reflected in some of the project documentation reviewed for this assignment (Annexes 3, 4 and 5). However, the strength of the narrative linking project activities to climate change risks and resilience varies across projects in the documentation examined.

Climate hazards and their impacts are mentioned frequently in the 12 sets of project documents reviewed. Nine projects combine discussion of existing climate hazards with claims that these have worsened because of climate change, and discussion of future climate change impacts. Of the remainder, the available Kateshi Dam (project 59) documentation does not discuss climate variability or change at all. Bindagombe Climate Resilience (project 39) focuses on existing hazards and claims these have worsened owing to climate change, but does not consider how these may continue to evolve. Makonde Water Supply (project 43) is unusual in emphasising future rather than current climate risks, with the latter being characterised as low.

3.1.3.1. Framing of observed climate change impacts

Claims that hazards have already been exacerbated by climate change are often very general in nature. Discussions about observed climate change trends and impacts are grounded in supporting evidence for just four projects. However, this evidence supports specific claims about climate hazards and impacts in the project area in at most three cases.

The Makonde risk assessment provides observational data and graphics for Tanzania as a whole.* However, this documentation does not claim that climate hazards have worsened in the project area.

The Bindagombe documentation cites reports from local stakeholders and provides rainfall records that support claims of rainfall declines. However, the rainfall time series presented is somewhat inconclusive as it covers just 20 years and exhibits high variability.

The Southern Zimbabwe Livelihoods documentation (project 99) provides citations to back up statements about observed changes.

* Makonde Plateau Water Supply Scheme Climate Change Risk Assessment (C1 FP07-008 OVI 1 Annex 3), Nov. 2015

The Livingstone Water Supply and Sanitation Concept Note (project 58) mentions increased variability in Zambezi water levels, an overall decline in Zambezi flows, a contraction of the rainfall seasons (starting later and ending earlier), and increased drought frequency. This document presents rainfall time series that indicate a decline in two out of three rainfall zones. However, this data covers only the period 1970-2000, and says nothing about seasonal rainfall distribution or river flow. This reflects a wider problem, namely that available climate data might be of limited relevance to assessments of the hazards that are most relevant to project beneficiaries. Rather than total annual rainfall or average temperature, relevant hazards are likely to relate to changes in rainfall onset and termination dates, duration of growing seasons, prevalence of dry periods within growing seasons, and extremes of rainfall and temperature .

Other projects cite decreasing rainfall trends, worsening droughts, declining water security, increased flood risk and shorter rainfall seasons/longer dry seasons. These phenomena are frequently attributed to climate change without further elaboration. The Sioma Irrigation documentation (project 65) Feasibility Report focuses on risks associated with high seasonal variability, emphasising that the area is prone to 'droughts which are attributed to climate change', without presenting any evidence or elaborating on the claim that drought behaviour has changed.[*] The Concept Note for the Buzi River Basin Climate Change Fund (project 23) states, 'Rising temperatures and rainfall variability have caused recurrent droughts and extreme flood events in Mozambique and Zimbabwe' but again provides no evidence to support the claim that these are worsening as a result of climate change.[†] The Mayana Community Climate Vulnerability Reduction Project (index no. 27) climate change risk assessment simply states that the area is 'increasingly prone to droughts'.[‡]

Multiple documents relating to the Kufandada Irrigation Scheme mention a lengthening of the dry season, a decline in the predictability of rainfall, and more frequent and severe droughts. The Kufandada Feasibility Assessment[§] mentions 'increasingly low rainfall' (p. 73) and 'rainfall data from a nearby rainfall station [that] shows decreasing rainfall trends after 1999/2000' (p.11). These statements are not corroborated by the timeseries of annual rainfall presented in the same document. While this indicates a decline from 1973 to 1991, this is followed by an increase to 2003, after which rainfall varies around the mean with no clear trend (p. 76). It is difficult to conclude that there has been a long-term decline in rainfall resulting from climate change based on this record, which may simply demonstrate decadal variability that is not unusual in the longer historical context. Annual rainfall data may mask seasonal trends, or trends in the temporal distribution of rainfall within seasons. Reported declines in rainfall may be referring to specific seasons, but it is not clear whether this is the case.

The above claims about observed changes in climate and their impacts are certainly highly plausible, and are generally consistent with regional trends and expectations (Nhamo et al. 2019; Nhemachena et al. 2020). However, the general and anecdotal nature of these claims can leave the reader wondering whether they truly reflect local realities, or simply a widely accepted and useful narrative for explaining phenomena such as crop failures and floods, and for justifying

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* CCAP Sioma Irrigation Scheme: Feasibility Report, Mar. 2016, p.13 (document Extlib-16).

† Buzi River Basin Climate Resilience Fund – concept note for GCF, 2015.

‡ Mayana Community Climate Vulnerability Reduction Project (Qw10) Track 1 CCRA, no date.

§ Kufandada Irrigation Scheme – Feasibility Assessment: Deliverables, Dec. 2013.

interventions funded via climate finance. Greater use of empirical evidence, more robust stakeholder-informed narratives, and better linking of hazards to climate change in key project documents would engender greater confidence in claims around climate change impacts.

3.1.3.2. Climate change impacts or historical maladaptation?

In many project documents, climate change narratives sit alongside discussion of other factors that can be described in terms of maladaptation – the inadvertent exacerbation of vulnerability and risk by development practices that fail to consider climate variability and/or change. Seven of the 12 projects reviewed describe development trajectories and practices that might be described in terms of maladaptation (Annexes 3 and 4).

For example, the Lower Incomati Flood Risk Management project (index no. 20) focuses on better flood risk management through the reversal of historical maladaptation (see 3.7.5). There is a suggestion that 'the frequency of flooding events may be increasing in relation to climate change'.[*] However, this claim is unsupported, and modelling for this project also identifies prior flood management practices by sugar estates as a cause of increased flooding in adjacent areas.[†]

A shortage of agricultural inputs is identified, along with inadequate rainfall, as a cause of crop failure in the Kufandada area.[‡] In the documentation for the Bindagombe Irrigation Scheme, it is stated that 'rain-fed agriculture has generally failed due to occurrence of droughts in the past seasons, lack of resources to buy and apply fertilizers, general poor soil practices, unsuitable crop choices and failure to adapt to climate change induced droughts'.[§]

These statements conflate drought and inadequate rainfall with climate change without offering any evidence that conditions have changed. They paint a picture of poorly resourced agricultural systems that are not well suited to local climatic and environmental conditions, perhaps even in the absence of climate change impacts. They beg the question of how significant a factor climate change is in the failure of these systems, and the extent to which addressing such failures is a question of adapting to climate change versus addressing historical maladaptation and adaptation deficits.

Addressing historical maladaptation and adaptation deficits is legitimate in itself. However, such an approach may be insufficient to address climate change impacts in the foreseeable future. There are risks in framing interventions as addressing climate change impacts when they are, in reality, addressing historical adaptation deficits and maladaptation. Measures to address existing adaptation deficits may be inadequate for addressing the impacts of climate change in foreseeable future. Where they are framed as adaptation to climate change they may lead people to believe that the adaptation problem has been solved where it has not. Clarity in terms

* Inception Report on the Real Time Flood Forecasting System including Climate Change Scenarios, Sep.2016, p. 8.

† Pathways to Impact. Coordinating to halt the damage of floods in the Lower Incomati Basin – 4-page briefing, Nov. 2018.

‡ Kufandada Irrigation Scheme Feasibility Assessment, Dec. 2013.

§ Bindagombe Irrigation Scheme: Detailed Design Report, Mar. 2015, p. 71.

of whether a project is addressing actual or anticipated changes in hazards associated with climate change, and poor management of historical or existing climate variability or of basic development needs is thus paramount. Of course, these issues are not mutually exclusive and a project may address all of them. However, clarity in terms of precisely what problem(s) are being addressed, and what problems are not, provides transparency regarding a project's scope and limits, and what further interventions might be necessary.

3.1.3.3. Development, resilience or adaptation?

As discussed above, CRIDF views irrigation as adaptation in the SADC context, based on evidence of increased climate variability and reduced rainfall reliability across the region. However, this narrative remains relatively undeveloped in most project contexts, where the emphasis is on irrigation to support agricultural intensification and expansion rather than to address demonstrated climate change threats.

Five projects identify actions that go beyond irrigation for general agricultural intensification and expansion in a context of climatic deterioration, and that might be viewed as demonstrable climate change adaptation measures. The Buzi River Basin Climate Change Fund Concept Note mentions irrigation to support maize and bananas, which are already grown, as well as short-season varieties of maize. This is compatible with incremental adaptation to sustain existing systems and practices in the face of increased climate risks.* The Southern Zimbabwe Livelihoods project document outlines specific measures targeted at adapting to three categories of climate change hazard, namely higher temperatures, increased rainfall variability, and increased risk of extremes. The Makonde water supply design documents indicate a number of measure to anticipate future climate change risks, including monitoring to track how climate change is affecting performance and sustainability. Adaptation is implicit in the Livingstone water supply project, given the discussion around failure of surface water sources under climate change, necessitating piped water to secure supply in this context.

As discussed above, the Livingstone example arguably could be viewed as an example of transformational adaptation, in which existing systems or practices threatened by climate change (in this case reliance on surface water sources) are replaced by alternatives that are viable under changed conditions (piped water from a reliable source). The Southern Zimbabwe Livelihoods and Buzi River Basin documentation propose a shifts to less water-intensive and more drought-tolerant crops and cropping systems in response to specific changes in rainfall amounts and distributions. They thus make a more direct appeal to transformational adaptation than projects that frame irrigation-led agricultural innovation in terms of productivity and general resilience. The Makonde water supply project is in many regards a conventional development project with resilience benefits. However, it anticipates future climate risks and employs a phased approach in which existing sources are rehabilitated in the near term pending a shift to a single water source. This phased approach reflects models of transformational adaptation in which general resilience and incremental adaptation measures are used to 'buy time' as more qualitative transformational shifts are developed and piloted (e.g. Rippke et al. 2016, Box 2).

* Buzi River Basin Climate Resilience Fund – Concept Note for GCF, 2015.

Of the other projects reviewed, the Kateshi Dam project is framed as a conventional development intervention, with no discussion of resilience. Other projects are framed as improving resilience to climate variability or change. However, in many cases resilience considerations are restricted to narratives justifying a project. Where climate change impacts are discussed, they often appear not to be considered at the project design stage, with design parameters based on current conditions.

For example, the Metuchira and Gorongosa Dam and water supply project (index no. 22) aims to reduce existing variability in water supply, with improvements to water security, irrigation and livelihoods, and reduced community vulnerability to droughts and floods. Climate change is expected to increase the unpredictability of water supply, and exacerbate water shortages and the impact of poor land use practices on water security. The project is framed as one that will build resilience to climate change by addressing vulnerability to existing climate hazards and risks, and is described as a 'routine engineering project' in the CRIDF screening documents.

Such projects have the potential to deliver significant development and resilience benefits in the near term, and may contribute to adaptation. However, there may be questions about their adequacy in the face of longer-term climate change risks and impacts. For example, will proposed irrigation-based agricultural systems be sustainable in the face of future changes to hydrological regimes, water availability and temperature extremes?

Even where projects may not sustainable in the longer term they may still be worth pursuing as part of a strategy of phased transformational adaptation. As mentioned above, this may involve a period focusing on the reversal of maladaptation and incremental adaptation to worsening climate risks, during which longer-term responses involving shifts to new systems and practices are developed. These can then be implemented if and when risks of current system failure reach an agreed level. However, such risks need to be identified and addressed in order to avoid projects resulting in maladaptation. This might take the form of increased settlement in areas where future risks will be unacceptably high, and high reliance on economic activities and production systems that are sustainable today but are at risk of collapse under future climatic conditions.

These longer-term maladaptation risks, and their relevance to CRIDF projects, are addressed in more detail under 3.5.4 below.

3.1.4. CRIDF framing of resilience and adaptation: Summary

CRIDF has developed a novel but pragmatic framing of resilience and its relationship to adaptation, which reflects and informs its programming approach. In this framework, adaptation is viewed in terms of measures to address specific hazards and impacts in the shorter term, while resilience is viewed in terms of the capacities of people and institutions to develop their own responses to currently uncertain risks in the longer term. This deviates from much current practice, which tends to conflate resilience and adaptation and focuses on resilience to existing hazards and risks, implicitly or explicitly assuming that this will increase resilience to climate change. The CRIDF framing thus brings some clarity to the often confused landscape of resilience and adaptation practice. In addition, CRIDF has developed a definition of resilience that is specific to its needs but consistent with other definitions, including that of the IPCC (2018).

CRIDF supports water infrastructure projects that deliver basic services such as domestic potable water and irrigation, on the grounds that climate change makes these services more critical, given reduced reliability of rainfall and surface water supplies. In this sense, CRIDF views adaptation as driving development through necessity. In addition, the need to pay for infrastructure may mean the adoption of new practices; for example, shifts from subsistence to commercial agriculture to pay for irrigation systems. This further drives development in certain directions. These observations challenge models of adaptation and resilience finance based on the concept of additionality. They both inform and complicate the debate around the relationship between resilience, adaptation and development, and underline the need for strong narratives to justify support for such initiatives using dedicated climate finance.

A sample of 12 CRIDF projects reveals frequent references to climate hazards, climate change impacts, and resilience. However, links between climate hazards and climate change tend to be very tenuous, even where they are plausible. Most of the projects reviewed take a very general approach to resilience, assuming that this will be delivered through measures to address current adaptation and development deficits and current climate hazards. Only a minority of projects include targeted measures that may be framed as incremental or transformational adaptation to specific climate change risks and impacts.

The danger is not that the activities supported by projects may be unnecessary. Indeed, there is an urgent need for an expansion of basic services and general measures to enhance resilience to a range of existing threats (including climate change) in the SADC region. The risk is that projects may focus on delivering near-term benefits without adequately considering or addressing longer-term risks and sustainability. Where such projects carry the adaptation label, they may give the impression that adaptation has been adequately addressed where it has not, and divert attention from longer-term adaptation needs. Perhaps more seriously, a focus on near-term resilience and productivity may lock people into potentially unsustainable or maladaptive development pathways that increase future risks (see 3.5.4).

The above issues may be addressed through more robust narratives linking interventions to current and potential future risks, supported by a more convincing mixture of quantitative and qualitative evidence. Projects should be clearer as to what risks they are addressing, over what timescales. There should be more transparency around the likely limits and adequacy of these interventions in the context of potential future climatic and environmental changes.

The negative impacts of climate change in southern Africa, and on agriculture in particular, are expected to increase with time as warming intensifies (Serdeczny et al. 2017; Nhamo et al. 2019; Nhemachena et al. 2020). Narratives that link agricultural failures and phenomena such as flooding with climate change may be questionable in some instances today, but are likely to be increasingly pertinent as climate change accelerates in the coming years and decades. Furthermore, where there is an urgent need for resilience to address current climate hazards that may or may not have been exacerbated by climate change, there is likely to be a need for further resilience and adaptation in the future. Nonetheless, without strong climate and resilience narratives based on evidence, programmes such as CRIDF are vulnerable to the charge that they are simply using the language of climate change, resilience and adaptation to attract climate finance for conventional development projects, without genuinely contributing to climate change resilience or adaptation. While resilient development under current conditions may also deliver longer-term adaptation benefits, it may also increase risks where it does not consider longer-term sustainability under future climatic and environmental conditions (Eriksen et al. 2021).

3.2. How is climate information used in CRIDF?

CRIDF uses different types of climate information in different contexts, and at different scales. Qualitative information relating to the types of climate change impacts anticipated in specific geographical contexts is used universally across the CRIDF programme to characterise potential climate change risks relevant to individual projects. Quantitative climate data derived from global and regional climate models is used to develop scenarios for strategic, basin-wide planning, in certain project contexts, and to inform general risk and vulnerability assessments at different stages of the project cycle.

CRIDF has developed a range of tools and guidance to support the integration of climate change resilience into its projects and basin-wide planning, the most important of which are listed in Table 4. These tools and guidance, which are part of a much wide body of tools and guidance relating to a range of issues, are consistent with the wider body of guidance on climate change screening, risk and vulnerability assessment (Jurilevich et al. 2016; De Sherbinin et al. 2019). The CRDP guidance document describes a review of vulnerability assessment processes and approaches, and provides a list of literature reviewed in this context (CRIDF 2017c: 12-13 and 54-57).

The CRIDF tools and guidance listed in Table 4 have been designed to support climate vulnerability and risk assessments, to ensure that appropriate climate information is used in these assessments and to inform planning and project design. Different tools and related guidance are used in different contexts; for example, at the basin versus project scale, and for the screening of existing projects versus the development of new projects, as described in detail below.

To a large extent, assessments of climate change risks and vulnerabilities are predicated on the use of quantitative information in the form of climate change scenarios, which are derived from ensembles of climate projections. These projections are the outputs of future climate simulations generated by multiple climate models, based on a variety of socio-economic scenarios and emissions pathways. A discussion of CRIDF's approach to the use of climate projections, below, is followed by a discussion of how CRIDF develops scenarios using self-organising maps (SOMs). This is followed by a summary of how climate information is collated and packaged for general use across CRIDF, and a detailed discussion of how specific tools and guidance are used to facilitate the integration of climate information into planning and project design.

Table 4. CRIDF tools and guidance for integrating climate resilience through the use of climate information.

Tool	Description	Use
CRIDF Climate Vulnerability Tool Web Map, developed in 2014	Online map-based tool displaying layered information on physical water risks, population resilience, risks to people and climate change pressures. http://geoservergisweb2.hrwallingford.co.uk/CRIDF/CCVmap.html	Project identification: eligibility screening (existing projects), identification of resilience issues (new projects).
Climate Impact Vulnerability Assessment Tool (CIVAT)	Spreadsheet tool for scoring environmental, economic and social impacts of investment strategies on a 7-point scale from strong negative to strong positive, for different climate scenarios. Used as part of Multi Sector Investment Opportunities Analysis (MSIOA) to identify risks and impacts associated with different investment scenarios under different climate scenarios.	Assessing risks associated with existing basin-wide investment strategies.
Climate Resilient Development Pathways: Final CRDP Guidance, Mar. 2017	Guidance to be used in conjunction with the CIVAT. CDRP process seeks to enable decision-makers to incorporate climate change impacts into planning using quantitative and qualitative methods and information. Piloted with OKACOM.	Assessing risks associated with existing basin-wide investment strategies. (support to CIVAT)
Final Resiliency Screening and Climate Change Risk Assessment Guidelines (PROTOCOL), 6th Nov. 2015	Guidance on assessing, documenting and managing climate risk for CRIDF projects, including on conducting Track 1 and Track 2 risk and vulnerability assessments for small and large projects respectively. Includes Climate Impacts Table for 5 SADC climate zones as Annex G.	Supporting Track 1 & 2 risk and vulnerability assessments (RVAs) for projects.
Southern Africa Projections and Impacts Guidance Paper, 11th Feb. 2016	Information on climate projections and impacts across five SADC climate zones. Includes Climate Impacts Table. Used for Track 1 risk and vulnerability assessments, which are based on existing information.	Pre-feasibility: Track 1 RVAs (existing projects), project concept (new projects).
Climate Risk and Vulnerability Assessment Tool (CRVAT), Jul. 2018	Spreadsheet with questions relating to hazard, exposure, sensitivity and adaptive capacity for assessing risk and vulnerability of communities and associated water infrastructure. Used to assess risks, vulnerabilities and needs at a given location for project identification.	Project identification, to support RVA of project location.

Climate Risk and Vulnerability Assessment Tool: Communities and Water Infrastructure Projects (Guidance Document), Jun. 2018	Guidance to accompany CRVAT.	Project identification, to support RVA of project location.

charge that they are simply using the language of climate change, resilience and adaptation to attract climate finance for conventional development projects, without genuinely contributing to climate change resilience or adaptation. While resilient development under current conditions may also deliver longer-term adaptation benefits, it may also increase risks where it does not consider longer-term sustainability under future climatic and environmental conditions (Eriksen et al. 2021).

3.2.1. Climate projections

CRIDF uses projections from global and regional climate models (GCMs and RCMs) to develop scenarios for the SADC region and SADC sub-regions including individual river basins. GCM data are obtained from the CMIP5 datasets developed for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2013). RCM data is obtained from the Coordinated Regional Downscaling Experiment (CORDEX) datasets. The CORDEX models are regional models that use data from global climate models as input, which produce higher-resolution temporal and spatial data at the regional scale through a process of dynamical downscaling.

The climate projection data used by CRIDF are generated by models run with a variety of Representative Concentration Pathways (RCPs). RCPs are denoted by numbers representing the additional 'climate forcing' resulting from cumulative greenhouse gas emissions by 2100, expressed in Watts per metre squared. For example, RCP2.6 is a pathway resulting in an additional forcing of 2.6 Wm2 by the end of the century. Model outputs represent changes in climatic variables resulting from greenhouse gas emissions trajectories that are compatible with a specific end-of-century forcing associated with a given RCP. Any given forcing in 2100 can result from a variety of emissions trajectories; for example, representing strong mitigation of emissions prior to 2050, or weak early mitigation followed by rapid emissions reductions from mid-century.

The CRIDF projections and impacts paper (Table 3) emphasise RCP4.5 and RCP8.5. RCP8.5 represents the best fit with historical emissions (Schwalm et al. 2020) but is regarded by some researchers as an unrealistic or at least a worst-case scenario because it assumes a significant expansion in coal use, and appears pessimistic in relation to current energy trends, climate policies and pledges (Ritchie & Dowlatabadi 2017a, b; Hausfather & Peters, 2020). RCP4.5 represents stronger emissions reductions than under current policy regimes, but is associated with a very low probability of limiting global warming below the Paris temperature threshold of

1.5°–2°C). The paper acknowledges that future emissions will most likely fall between these two pathways.

CRIDF also uses projections from RCP2.6 and RCP6.0 (Annex 1, Interview 5). The former is likely* to limit warming below the 2°C Paris temperature threshold (but depends on significant future negative emissions), while the latter is associated with a warming of around 3°C by 2100 (Van Vuuren and Carter 2014), similar to that projected under current policies.† In practice, the GCM data is as useful as the RCM data for the purposes of scenario development (Annex 1, Interview 5). In addition, the RCM data represents only a subset of potentially available projections; to develop a full ensemble of RCM data, each RCM would need to be run with outputs from each GCM, which would require a prohibitive number of simulations.

GCM and RCM projections encompass a range of variables, including annual and seasonal average temperatures, precipitation totals, and evaporation. Interannual variability is addressed by assessing projected changes in the probability of events such as successive years in which annual average temperatures are more than two standard deviations above the historical mean, or years/seasons in which precipitation is in the lowest or highest 10% of historical values. In this way, potential changes in the return periods of such extremes under different plausible scenarios can be assessed. Variables relating to climate extremes from the IPCC (Hartmann et al. 2013: 221) have been examined, although these can be complex for stakeholders to understand, and simpler measures such as the likelihood of multiple years of drought may be more effective from a communications perspective (Annex 1, Interview 6).

3.2.2. Self-organising maps and scenario development

CRIDF uses self-organising maps (SOMs) as a tool for developing climate scenarios representing a range of plausible future conditions, from multiple climate projections. SOMs use artificial intelligence to place projections into similar groups, based on sets of climate variables. Projections in a given group will share similar characteristics. For example, one group may cluster around strong positive increases in temperature coupled with strong negative declines in rainfall. Another group may consist of projections with similar changes in temperature, but considerably smaller declines in rainfall, or increases in rainfall.

The CRIDF approach is to generate four SOMs for each RCP, based on the CMIP5 projections of temperature and precipitation for different time periods (typically centred on the 2030s, 2050s and 2080s). These SOMs facilitate the identification of climate change pathways that have the highest support among the full CMIP5 ensemble, based on the nature of the groupings and the number of projections in each group.

In practice, broadly similar results are obtained from RCP2.6, RCP4.5 and RCP6, with a 'step change' over southern Africa (and most likely for other regions) between the projections representing these RCPs and those representing RCP8.5 (Annex 1, Interview 5). This is reflected in the clear separation of the clustered projections for RCP8.5 from those for the other RCPs in the SOMs (Figure 1).

* At least a 66% chance, following the IPCC (2018) terminology.

† Based on 2100 warming projections from Climate Action Tracker.

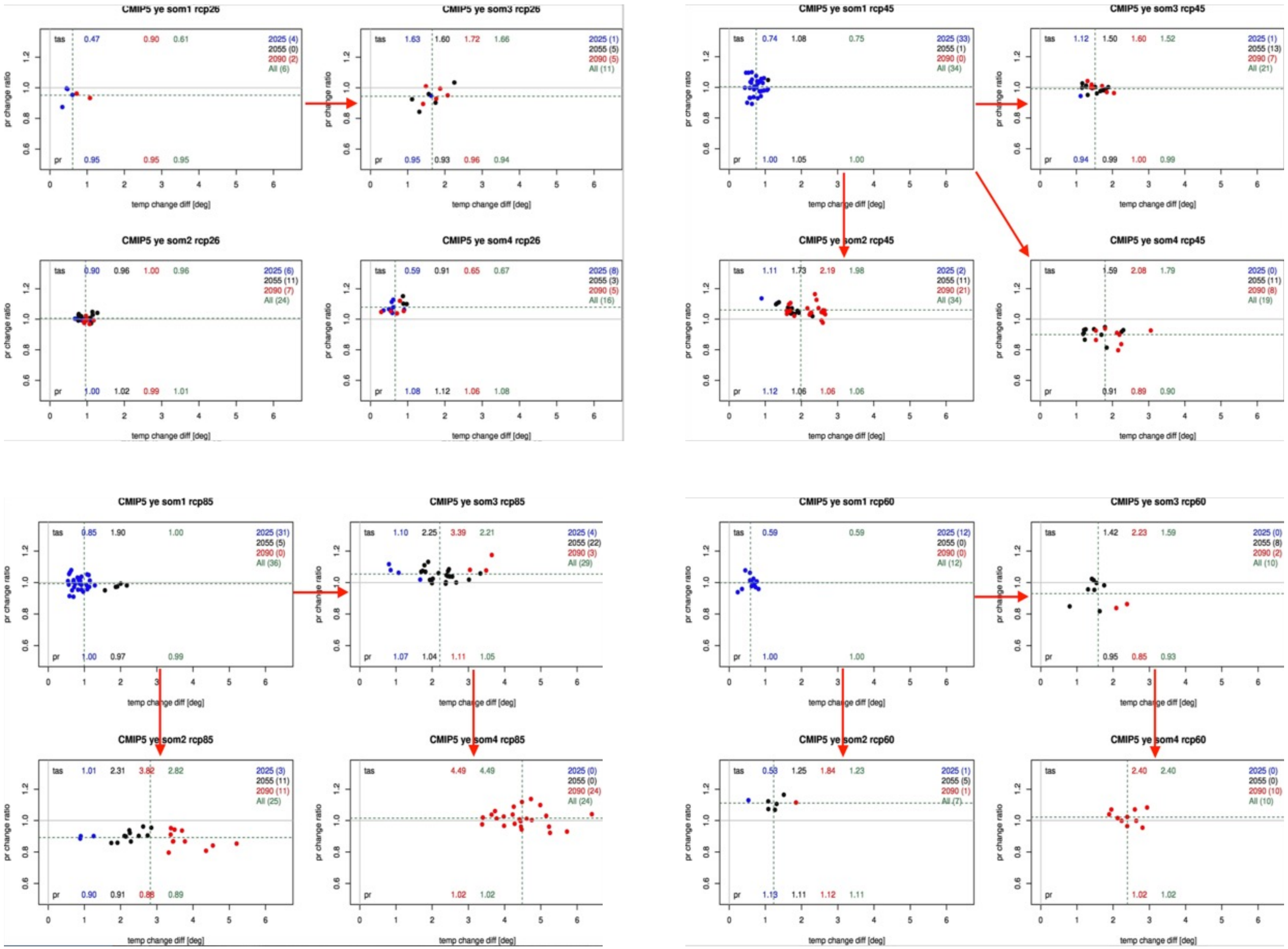

Figure 2: Self-organising maps (SOMs) from the Swaziland CCRA Final Report (CRIDF 2017d). Each panel shows a set of four SOMs for annual precipitation change ratio plotted against annual temperature change for a particular RCP. SOMs 1–3 are broadly comparable across RCP2.6, RCP4.5 and RCP6.0 (clockwise from top left), with much greater divergence in the RCP8.5 SOMs (bottom right). Different colours represent projections for different time periods.

Scenarios are developed by identifying appropriate sequences of groups through all three time periods as represented on the maps. Projections from all three periods are included in the calculations from which the SOMs are generated. As CRIDF's focus is on water, and there is greater variation in rainfall than temperature across projections, rainfall has been prioritised in scenario development. The number of scenarios developed depends on the SOMs. For example, if two maps suggest future increases in rainfall and two suggest decreases, they are likely to be combined to form two scenarios. However, more scenarios may be suggested, for example if the SOMs indicate multiple groups of projections with decreased rainfall distinguished by the magnitude of the decrease, or differences in the change in an accompanying variable. An approximate estimate of the likelihood of each scenario can be determined by the proportion of projections in the clusters used to create that scenario. This is consistent with ensemble theory, but subject to the caveat that it does not account for all uncertainties. The range of climatic conditions represented in an ensemble of projections is determined by how physical processes in the climate system are represented in the models, and the assumptions built into the socio-economic scenarios and pathways used to drive the models. The former may omit or poorly represent certain processes, while the latter will not encompass all possible development trajectories. Ensembles of climate projections therefore provide only a lower bound on uncertainty, defined by the range of conditions simulated by the climate models used to generate them. The range of possible changes in the actual climate system is likely to be greater than that represented in ensembles of projections (see 3.5 and 3.6. for further discussion).

Typically, three scenarios are developed for use in the CRIDF context. These are described in terms of **'most agreement'**, **'second most agreement'**, and **'less agreement'**. The scenario in which there is most agreement across projections reflects the climate pathway that is best supported by the SOMs, i.e. a trajectory through the parts of the SOMs where there is the greatest degree of clustering of the projections. The scenario of 'second most agreement' represents an alternative climate pathway that is also well supported by the SOMs, but for which there is a lower degree of clustering of the scenarios. These scenarios typically reflect the clustering of the projections representing RCPs 2.6, 4.5 and 6.

The scenario with less agreement reflects a pathway through clusters of projections that typically lie outside the main or most dense clusters. These projections might represent larger or more 'extreme' changes than those in the main clusters used for the other scenarios. Such projections may be taken from the RCP8.5 SOMs. However, they might simply be outliers from these clusters based on other RCPs, and will not necessarily represent larger projected changes in climatic variables.

Scenarios are selected using a degree of expert judgment, which may conclude that certain pathways are more plausible than others. For example, the 'less agreement' scenario may not represent the most extreme projections, particularly if these are associated with models that are viewed as producing anomalous results that are not thought to be particularly realistic. The aim is to use scenarios that represent a reasonable and meaningful range of possible futures that can be used as a basis for 'sensitivity testing' development strategies and interventions. This approach examines how a strategy would perform under different scenarios (rather than developing a strategy to fit with a 'most likely' scenario).

CRIDF has developed scenarios using the above methodology for annual and seasonal values of temperature and precipitation, and also for temperature and precipitation minus evaporation.

In order to address uncertainty in climate sensitivity as represented in the models used to generate the projections, scenarios are based on changes in temperature and precipitation in the projections relative to a historical reference period (the 'delta-change' approach), rather than projected absolute values of these parameters. Scenarios have been developed for the SADC region as a whole, at the basin and sub-basin scale. Because climate models are limited in their ability to represent changes at higher spatial resolutions, scenarios covering larger areas will be based on data that is more statistically stable. However, scenarios covering smaller areas are needed to account for variations in geography and climate across the region, and across individual basins, to constrain a scenario within a specific rainfall regime. The result is that scenarios are usually developed for scales well below basin size, except for relatively small basins.

Changes in parameters such as annual and seasonal temperature and precipitation, based on the above scenarios, are used as input to system models that are relevant to specific projects. These are most frequently hydrological models which are used to assess potential future changes in water availability and stream flow for the design of water infrastructure such as dams and extraction and distribution systems. For example, sets of scenarios have been developed for dams in Malawi and Swaziland, and water extraction in Livingstone, Zimbabwe. Scenarios have also been developed for more general and wide-ranging assessments of potential climate change impacts in the Zambezi, Limpopo and Senqu-Orange basins (Annex 1, interviews 5 and 6).

The projections and impacts paper emphasises the limitations of climate projections, particularly for representing possible changes in the timing and variability of rainfall, and stresses the importance of complementing projections with discussions of trends with local stakeholders. In addition, CRIDF examines interannual variability to assess the likelihood of events such as multi-year droughts, informed by experiences such as the recent drought that affected Cape Town (Annex 1, interview 6).

3.2.3. Collation of climate information for use in planning and project design

CRIDF developed the Southern Africa Projections and Impacts Guidance Paper to support climate risk and vulnerability assessments for smaller projects, for which it is assumed no additional climate change analysis or modelling will be carried out. This paper is a key tool for informing risk assessments, and synthesises information on observed and projected changes, mostly from the IPCC Fifth Assessment Report (AR5) and CRIDF's own modelling based on the ensembles of projections used by the IPCC. It therefore reflects the state-of-the-art in knowledge from the time of AR5 (2013-14), updated with subsequent CRIDF modelling.

The Projections and Impacts paper describes CRIDF's approach to the use of climate projections and the development of scenarios, and describes climate scenarios for southern Africa. It defines and describes five climatic zones for the SADC region, and summarises the anticipated impacts of climate change in each region in a Climate Impacts Table. This table is also reproduced in the Final Resiliency Screening and Climate Change Risk Assessment Guidelines (PROTOCOL) document, as Annex G.

The Climate Impacts Table describes changes in precipitation, temperature and extreme events, and anticipated impacts on agriculture and health, for the short term (2016-2035) and medium term (2046-2065), for the five climatic zones, using a mixture of qualitative and quantitative information. This information has been derived from the IPCC (2013) AR5 reports and projections generated using global and regional climate models, as described above. The guidance recommends that information from the Impacts Table is combined with information from site missions and discussions with stakeholders, to determine whether anticipated impacts, particularly for the short term, are consistent with observations and experience at any given project location.

While the projects and impacts paper has been designed to support project-level climate risk and vulnerability assessment, it is useful in other contexts such as basin-level or sub-basin level assessments.

3.2.4. Use of climate information for basin-wide planning

CRIDF supports RBOs and other stakeholders to conduct climate impact and vulnerability assessments of existing development strategies, as well as more general assessments of the implications of climate change at the basin scale.

Where the focus is on an existing basin-wide development strategy, CRIDF supports a Multi Sector Investment Opportunities Analysis (MSIOA), following the Climate Resilient Development Pathways (CRDP) approach. The MSIOA approach was originally developed for the Okavango Basin in a partnership between OKACOM and the World Bank, supported by CRIDF (CRIDF 2017b: 31, World Bank 2019). It has since been adopted by CRIDF to inform other strategic planning (Annex 1, Interview 6). Such planning involves applying the Climate Impacts and Vulnerability Assessment Tool (CIVAT) to examine the environmental, economic and social impacts of different investment scenarios under different climate change scenarios. For each investment scenario, impacts are assessed in the absence of climate change, and for a low and high probability climate change scenario. These scenarios are derived from the SOMs based on the method described above.

Where a basin-wide assessment of climate change impacts, risks and vulnerabilities is required in the absence of a specific strategy, a more open-ended risk and vulnerability assessment is undertaken. This takes the form of a documentary review informed by climate change projections and scenarios, and general information from sources such as IPCC reports. General information on anticipated climate change impacts in different SADC sub-regions, informed by IPCC data, CRIDF analysis of climate projections, and CRIDF scenarios, is included in the Southern Africa Projections and Impacts Guidance Paper (Table 3). An example of a more open-ended basin-level assessment is the 2020 CRIDF Limpopo River Basin Review.

3.2.5. Use of climate information at the project level – existing projects

CRIDF supports projects that have already been identified by its regional partners, and is also involved in the development of new projects from the outset. Climate information is used in different ways for these two tracks of project development, as represented in Figure 3.

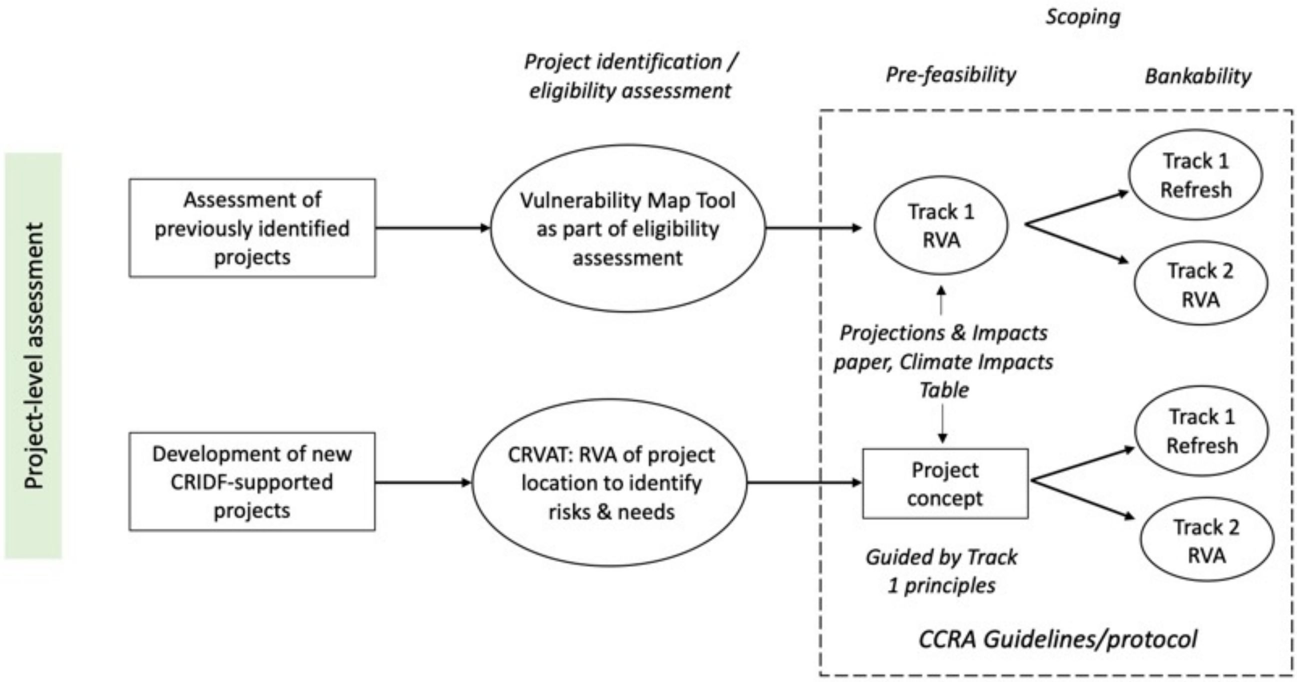

Figure 3: Use of tools and guidance to integrate climate information into project identification and scoping.

3.2.5.1. Assessing eligibility of existing projects

Projects from existing project lists developed by external partners are first subject to eligibility assessment, in order to determine whether they are appropriate for CRIDF support. This eligibility assessment is based on the CRIDF Climate Vulnerability Tool Web Map (Table 5). This tool is based on a map that displays layered information on physical water risks, population resilience, risks to people and climate change pressures (Table 4), enabling these factors to be assessed for any project location. The tool thus embodies a variety of climate, hydrological and other information in a form that is easily accessible and usable for CRIDF staff, partners and other parties, provided they are supported to become familiar with the different layers and their interpretation.

The Web Map is used to conduct a high-level assessment of a project, to determine whether it is associated with climate risks and resilience issues that can be addressed through CRIDF support. This assessment informs the completion of an eligibility screening tool (the Stage 1 Assessment Tool), which provides a summary of the proposed project and assesses the project against a number of criteria, including climate resilience. The project is scored against this criterion based on the extent to which climate resilience is a key objective, the extent to which the project will be 'climate proofed', and the extent to which the project will build resilience for those most vulnerable to climate change. The extent to which this criterion is met depends on the nature of the project activities, but also on the nature of the climate risks and vulnerabilities in the project location as indicated by the Web Map tool.

Table 5. Information layers in the CRIDF Climate Vulnerability Tool Web Map.

Variable	Details
Physical water risks	
Baseline water stress	Low to extremely high (five categories plus arid and low water use, no data), based on ratio of withdrawals to available blue water, expressed in %.
Interannual variability	Low to extremely high (five categories plus no data), based on ratio of standard deviation of annual blue water to total blue water.
Seasonal variability	Low to extremely high (five categories plus no data), based on ratio of standard deviation of monthly blue water to mean of monthly total blue water.
Floods per 100 years	Low, medium, high (unquantified).
Drought severity	Low to extremely high (five categories plus no data), based on average length of droughts x dryness for 1901-2008.
Upstream storage	High to extremely low (five categories plus no data, no major reservoirs), based on ratio of upstream storage capacity to mean total blue water 1950-2008.
Groundwater stress	Low to extremely high (five categories plus no data), based on ratio of groundwater footprint (function of abstraction, recharge rate and contribution to environmental stream flow) to aquifer area.
Population resilience	
Household and community resilience	Least to most resilient (six categories), no explanation given.
Population density	People per sq. km. (seven quantified categories/ranges).
Risks to people and climate change pressures	
Resilient population	Low, medium high, based on combination of population density, governance layer and household and community resilience layer from CCAPS Climate Security Vulnerability Model.
Baseline risk to people	Very low to very high (five categories), based on resilient population layer and AQUEDUCT physical water quantity risk.

Climate change pressures	Very low to very high (five categories), based on where climate change impact is expected to be greatest on people and environment, informed by data from Hadley Centre HadGEM2 model.
Water risk under climate change	Low, medium high, based on combination of climate change pressure layer and physical water risk layer.
Future risk to people	Very low to very high (seven categories), based on combination of baseline risks to people layer, climate change pressure layer and physical water risk layer.

3.2.5.2. Risk and vulnerability assessment for existing projects

If a project passes the eligibility screening stage, it is subject to a climate risk and vulnerability assessment (RVA). For smaller projects with a budget of under £1 million, a 'Track 1' RVA is carried out. This is based on existing information relating to climate projections and impacts, as described in the projections and impacts paper and the Climate Impacts Table included at the end of this paper. For larger projects, a 'Track 2' RVA is conducted. This is likely to involve the commissioning of new studies, which may include the development of new climate scenarios, or the modelling of hydrological and other systems with data from climate projections and scenarios as input.

In practice, an initial Track 1 RVA is likely to be carried out as part of a pre-feasibility study that establishes the scope and likely budget of the project. If the pre-feasibility study indicates a large project, a Track 2 RVA will then be carried out at the subsequent stage, which involves a bankability assessment to determine if the project is viable (essentially a form of feasibility study). If the pre-feasibility study indicates a small project, the Track 1 RVA is likely to be 'refreshed' as part of the bankability assessment.

Both Track 1 and Track 2 RVAs are supported by the 2015 *Final Resiliency Screening and Climate Change Risk Assessment Guidelines* (PROTOCOL) (Table 3). An example of a Track 1 RVA is the CCRA carried out in Swaziland for the proposed Nondvo Dam (CRIDF 2017d). This identifies potential impacts and risks associated with four scenarios. The likely performance of different dam design options under each scenario is examined in order to identify an option that works best across all four scenarios. SOMs are presented for different combinations of RCPs (RCP2.6, RCP,4.5, RCP6.0 and RCP8.5) and seasons (October-December, January-March and annual). In each case, four SOMs are presented for a given pairing of an RCP and a season. For each such pairing, a number of scenarios are constructed based on the SOMs. Tables of projected changes in key variables are then presented for each scenario, for three time periods.

Information from the Track 1 or Track 2 RVA (as appropriate) is used as input in the Stage 2 Assessment Tool, in which climate resilience is one of 11 categories against which a project is assessed to determine its feasibility or bankability.

3.2.6. Identification of new projects

CRIDF participates in the development of new projects, for example where a general basin-level assessment indicates hotspots of vulnerability to climate change impacts. In these contexts, the CRIDF Climate Risk and Vulnerability Assessment Tool (CRVAT) is used to conduct an RVA for a particular location, to identify risks, vulnerabilities and needs, and thus to determine what type of project(s) are appropriate at that location.

The completion of the CRVAT requires a combination of stakeholder information and information based on climate projections. The CRVAT includes questions relating to current and future hazards, exposure, sensitivity and adaptive capacity. Questions relating to hazards are grouped around temperature, rainfall, droughts, floods and other factors. Questions relating to exposure are grouped under the categories of livelihoods, health and safety, services, water supply, and infrastructure. Questions relating to sensitivity and adaptive capacity are under categories labelled as human, institutions, infrastructure, natural resources, and financial resources. Answers to questions relating to current conditions are informed by feedback from stakeholders. Questions relating to future hazards are answered by a Project Assessor or technical expert based on desk research, and are heavily informed by the climate projections and impacts paper, and in particular by the information contained in the Climate Impacts Table. Questions relating to future exposure, sensitivity and adaptive capacity are answered by the Project Assessor based on the confirmed project pipeline or commitments.

Based on the assessment captured in the CRVAT, CRIDF and its partners will develop the project concept. In practice, projects developed with CRIDF support from the outset should be framed and informed by an understanding of relevant climate change hazards, impacts, vulnerabilities and risks, based on RVAs and CCRAs of the project area. They are conceived precisely to build resilience and deliver adaptation in this context, meaning that a subsequent project-focused RVA to identify and address climate resilience and adaptation issues should be redundant. Nonetheless, a Track 1 or Track 2 RVA, as conducted for pre-existing projects originating with RBOs, is a means of subjecting a new project to what is essentially a quality assurance process, to ensure it conforms to CRIDF criteria.

3.2.7. Use of climate information in projects reviewed

The Nondvo Dam CCRA discussed above provides a good example of climate information driving the selection of project design options. The review of 12 other CRIDF projects examined how the use of climate information is reflected in project documentation, and the extent to which there is evidence of climate information influencing project design.

As discussed above, claims about the observed impacts of climate change were backed up with quantitative climate information in documentation for only a minority of the projects reviewed. These include the Makonde water supply project, which was one of two projects used as a pilot for testing the CCRA process (CRIDF 2017d). Discussion of climate projections and scenarios was evident in documentation for six of the projects reviewed. However, SOMs are discussed in relation only to the Livingstone water supply project, in the CCRA section of the feasibility/

bankability study.*

Discussion of uncertainty was identified in the documentation for only three projects: Lower Incomati FRM, and the Makonde and Livingstone water supply projects. For the Incomati FRM project such discussion is largely implicit and limited to the use of multiple scenarios. In the Makonde case, ranges of uncertainty are defined based on projections, and uncertainty on how climate change should be addressed is cited as justification for a low-regrets approach. The Livingstone concept note includes explicit discussion of SOMs and individual scenarios and discusses two 'most likely' and one 'worst case' scenarios.† Water availability is discussed for three time periods for these scenarios, and the note refers to climate 'predictions'. This framing is somewhat problematic, given that the purpose of projections is to characterise plausible future conditions rather than predict what is likely to happen.

Documentation for five projects, including two of the three discussed immediately above and the Kufandada, Mayana and southern Zimbabwe livelihoods projects, suggests that climate information has influenced or will influence project design, or the design of project components, to at least some extent. One of the intentions of the Livingstone project is to mainstream the use of climate information into subsequent water management.

Modelling of flood risk based on historical data informed the design of the Lower Incomati FRM project, and it is indicated that subsequent modelling will examine the implications of climate change for flood risk.

Climate information informs the Makonde water supply design and the selection of no-regrets options, but also suggests potentially significant longer-term risks (see 3.5.4).

For Kufandada, hydroclimatic variables are considered, but there is no indication that the impact of climate change on these variables has been factored in.

Physical project components for the Mayana initiative have been screened for climate risks, using information on past droughts and climate projections to examine low flows and how these might interact with peak demand. However, it is not clear precisely how these considerations influenced project design.

Assessments of future water demand and availability for the southern Zimbabwe livelihoods project will be informed by climate projections. The project concept note also proposes a decentralised approach incorporating context-specific CVRAs, and capacity building to support the use of forecasts in agricultural decision-making.

With the exception of Kufandada, documentation for the above projects indicates that they will involve the use of climate information beyond the design and CCRA stages. The Incomati FRM project is predicated on the continued use of climate and weather information to understand and manage flood risk. The Mayana project suggests exploring options for seasonal forecasting, although this does not appear to be confirmed in the documentation reviewed. The southern Zimbabwe livelihoods project seeks to improve hydrometeorological observing and forecasting

* Livingstone (Zambia) Border Town Water Supply and Sanitation Bankability (Feasibility), Aug. 2019.

† Livingstone Water Supply Project, Concept Note for GCF (revised), 2019, p.6.

systems, and enhance access to climate information for agricultural planning; improved access to climate information is one of the project's core outputs. In the Makonde project, post-implementation use of climate information appears to be limited to monitoring of drought and the impacts of the project on downstream water bodies. The Livingstone water supply project seeks to mainstream considerations of climate variability and change into the decision-making of water management bodies, implying the subsequent use of climate information.

3.2.8. Use of climate information: Summary

CRIDF has developed a suite of practical tools and guidance to facilitate the integration of climate information in basin-wide planning and project identification and design, focusing on climate risk and vulnerability assessment at different scales. These tools and guidance, and the processes they describe, are consistent with the wider body of tools and guidance on RVA. They follow global good practice in RVA, for example by combining assessments of current and future hazards and vulnerabilities, and blending scientific information with information from local stakeholders. The vulnerability mapping tool and the Climate Impacts Table are particularly helpful as sources of readily accessible climate information.

The scenarios approach employed by CRIDF is novel and practical, and ensures that planning is, at least in principle, informed by scenarios representing a broad range of possible future conditions that are not tied to a single model or set of assumptions about emissions pathways. The use of changes in key climate variables, rather than absolute values, represents a practical approach to addressing model biases. However, the approach implicitly frames uncertainty in terms of ranges represented by ensembles of climate projections, and does not address model limitations and 'unknown unknowns'. This has implications for how risk and uncertainty is treated in planning and project design, as discussed in more detail below.

While climate projections and scenarios are discussed in documentation for half the projects examined, treatment of uncertainty is extremely limited in both extent and scope. Only three projects appear to consider uncertainty in any meaningful sense, and these frame uncertainty solely in terms of model projections There is some evidence that climate information is informing project design, more often in general terms (e.g. to justify 'low regrets' approaches) than in relation to specific infrastructural design parameters. Just under half the projects reviewed appear to intend to use climate information beyond the assessment and design stage, for modelling, forecasting and informing decisions around water management and agricultural planning.

3.3. How are technical findings communicated internally?

Internal communication of CRIDF findings, including findings relating to climate change impacts, vulnerabilities and risks, is achieved through a combination of meetings, workshops, presentations, face-to-face interactions, and the use of specific tools and guidance as part of the programming and project development process.

Technical information relating to climate change projections and scenarios is generated through work with external consultants, working closely with CRIDF staff, including the climate change lead. This and other information is communicated at a high level within CRIDF through regular meetings between the climate change lead, the team leader and the workstream leader, to discuss progress and next steps across all CRIDF initiatives. The existence of a climate change lead position within CRIDF provides a focus for the collation and dissemination of climate and related information within the programme.

At the project level, regular team meetings are held at different stages in the project development cycle, and a **climate specialist** is embedded in the design team to ensure that relevant climate information and related findings are communicated to the project team.

A key vehicle for the internal communication of CRIDF technical findings relating to climate information and its use is the body of tools and associated guidance on climate impact, risk and vulnerability assessment listed in Table 3 and discussed in detail above. These are part of a much larger body of tools and guidance that frame and guide planning, programming, and project identification, scoping, design, implementation and MEL.

Through the use of these tools and guidance documents, information and findings around climate change impacts, vulnerabilities and risks is thus routinely embedded in CRIDF programming and the CRIDF project development cycle.

At the strategic level, use of the CIVAT to assess different investment scenarios, supported by the CRDP guidance, is predicated on information relating to different climate change scenarios. The application of CIVAT thus represents a mechanism for the communication of climate scenario information at the strategic, basin-wide level.

The Climate Projections and Impacts Paper, and the associated Climate Impacts Table, provide a mechanism for the communication of findings about climate change impacts, vulnerabilities and risks across the five SADC climatic zones. These information sources are the foundation for more general risk and vulnerability assessments at the basin level, and also at the more local level for Track 1 RVAs of small projects. Any such assessments will be informed by the information embedded in these tools. Track 2 RVAs will build on this information with supplementary information and findings from bespoke scenario development and impact assessment, for example using hydrological models. Track 1 and 2 RVAs are guided by the *Final Resiliency Screening and Climate Change Risk Assessment Guidelines* (PROTOCOL) document, which provides a framework for assessment that indicates what information, tools and methods should be used. Finally, the CRVAT and its accompanying guidance forms the basis for assessments of risks, vulnerabilities and needs at potential project locations.

The above tools and guidance thus constitute a de facto system for the communication of climate information and findings about climate change impacts, risks and vulnerabilities throughout the CRIDF programme, from the strategic the project level. The requirement to generate, collate and consider climate information, and to incorporate this information in specific CRIDF processes, using mandated sources and tools, means that the communication of climate information and related findings is inherent in CRIDF activities.

Nonetheless, this approach is somewhat piecemeal, and formal mechanisms for ensuring that key technical findings and approaches are fully communicated and understood by CRIDF personnel appear to be lacking. Use of regular programming and project management processes to communicate technical information, approaches and findings might be complemented by more proactive, centrally organised activities to frame and reinforce technical approaches and communicate and consolidate learning. Interviews with CRIDF staff suggested that the project-driven nature of the programme means that operations are somewhat siloed, and climate information and technical information are not always shared routinely and effectively across the programme.

3.4. How are technical findings communicated externally?

3.4.1. Communication at the basin level

CRIDF communicates climate information in different ways in different contexts and at different scales. Climate information in the form of climate projections and scenarios is used to inform discussions with stakeholders at the transboundary basin scale. These stakeholders include governments, river basin organisations (RBOs) and other regional bodies. Such information is used to inform strategic planning at the basin level. This information is disseminated principally through a combination of publications and workshops, the latter of which provide an opportunity for CRIDF staff and external consultants to present findings to representatives of RBOs and other partner organisations.

CRIDF has undertaken a number of basin-wide studies addressing climate change projections, scenarios, impacts, vulnerabilities and risks in the SADC region, some of which are the results of direct requests to CRIDF by RBOs. The basin-wide studies conducted by CRIDF to date are:

- Cubango-Okavango River Basin Homogenous Units: Livelihoods Vulnerability Hotspot Mapping, Jul. 2018
- OKACOM Livelihood Vulnerability Hotspot Mapping: Methodology
- Zambezi River Basin Livelihood Response Programme: Consolidated Report on the Revised Hotspot Narratives & Initial Project Repositories, Sep. 2018 (at request of Zambezi River Basin Commission (ZAMCOM))
- Climate Change Scenarios for the Limpopo River Basin, Consolidated Report, Jan. 2019
- Climate Change Scenarios for the Orange Senqu River Basin: Consolidated Report, Jan. 2019
- Update on the Save Basin Self-Organising Maps Analysis: Final Report, Feb. 2019
- Self-Organising Maps Results for the Upper Komati Domain, Apr. 2019
- Komati River Basin Climate Scenarios Review, 2020
- Limpopo River Basin Risk Climate Scenarios Review, 2020
- Orange-Senqu River Basin Climate Scenarios Review, 2020

The above documents present climate and related information, including information on climate projections, scenarios, impacts and vulnerabilities, at the basin scale, targeted at RBOs and other basin-level stakeholders.

CRIDF tools have also been developed in partnership with external stakeholders. For example, the CRDP methodology and associated CIVAT tool were developed in collaboration with OKACOM (CRIDF 2017b). The CRVAT tool was developed in collaboration with stakeholders during the Lower Incomati FRM project.* The communication of information and findings with external stakeholders is an integral part of such development processes.

3.4.2. Communication at the sub-basin/project level

At the project scale, climate and related information is disseminated through a 'learning by doing' approach, in which CRIDF provides varying levels of support to partners involved in project design and implementation. Implementing partners use the CRIDF tools and guidance listed in Table 3 to carry out climate vulnerability and risk assessments. One interviewee emphasised the Vulnerability Tool Web Map as a means of immediately identifying key issues to be addressed at a specific location (Annex 1, Interview 4). The outputs of this tool thus represent a foundation from which to engage authorities and beneficiaries in discussions of vulnerabilities, risks and potential responses. For example, is planned infrastructure at risk from climate (change) hazards and impacts?

CRIDF also commissions studies for specific projects. These often involve hydrological modelling, which is a key vehicle for the generation of project-level data that is then used by CRIDF partners and stakeholders at the local level. An example is the Lower Incomati Flood Risk Management Project, in which CRIDF supported hydrological modelling, the results of which were instrumental in determining the nature and design of flood management responses.

Project CCRAs are also undertaken by CRIDF partners and stakeholders, using the relevant CRIDF tools. CRIDF does not provide formal training in the use of these tools and associated information, but works with partners to apply the tools, with the level of support varying depending on available financial resources, staff availability, and logistical issues such as remoteness of project sites and ease of communication with partners and stakeholders. The quality of these CCRAs varies according to the capacity of the relevant stakeholders, their level of engagement, and the degree of CRIDF support. Nonetheless, the process of undertaking CCRAs represents an avenue via which CRIDF findings and climate information are communicated to partners and stakeholders involved in project scoping and design. This is typically achieved through design workshops which are often managed remotely by telephone, and which are part of a structured stakeholder engagement process. While it is acknowledged that face-to-face meetings would be preferable, this is often not possible owing to issues of remoteness and accessibility, given the ratio of projects to CRIDF staff. The concentration of responsibility for management and communication of climate information and related technical findings in a single climate change lead role undoubtedly impacts CRIDF's ability to engage with stakeholders on these technical issues.

* Interview with JR, 21 October 2020.

3.4.3. Wider external communication

CRIDF has a well-established website (cridf.net) which provides links to a wealth of resources and documentation. The CRIBMAP tab links to a map of the major river basins in southern Africa. Clicking on a basin reveals a set of links to general information about the basin, a list of CRIDF-supported projects, environmental and socio-economic information, high-level information on agriculture and basin threats (including climate change), and a set of references from which the above information has been derived.

The Resources tab links to the CRIDF Resource Centre portal, which allows users to search for documentation by basin, date, CRIDF phase, production source, and type of resource. This allows anyone to download CRIDF tools and guidance, project documentation, briefings, newsletters and other documents. Links are also provided to relevant datasets, videos and other online resources. Search results are presented with a summary of each document or resource including information on source and year of publication.

The website provides a high degree of transparency regarding CRIDF activities and findings, with a wide variety of information being publicly accessible. It results in tools and guidance being accessible, with the potential for their adoption by other projects, programmes and organisations. Reports describing climate projections and scenarios, and making recommendations on their use, means that CRIDF-generated climate information is in the public domain, with the potential to inform climate action throughout the SADC region and beyond (e.g. through the adoption of CRIDF approaches in other regions).

3.4.4. Communication of lessons to international bodies

Learning around the relationship between adaptation and development is relevant to the way international climate finance is spent. CRIDF provides examples of contexts in which conventional development actions such as the installation of irrigation systems, piped water and water storage are imperative as a result of climate change. The programme also illustrates how adaptation can require, and drive, certain development trajectories, for example to generate income to pay for the maintenance of water infrastructure. This learning challenges models of climate finance based on the concept of additionality, as discussed above. These findings, and their implications for additionality as a framework for selecting adaptation and resilience initiatives for funding, have been communicated by CRIDF to the Green Climate Fund (GCF). This type of communication of lessons from individual programmes to global and international actors is critical for informing the international discourses and practices that frame and determine how resilience and adaptation is funded and implemented.

3.4.5. Communication as a goal of CRIDF projects

Only three of the 12 projects reviewed provide indications that their activities will address the communication of climate information. The communication of flood warnings is central to the Incomati FRM project and is mentioned frequently in project documentation, but details on how information is/will be communicated are lacking. The Buzi River Basin Fund concept note proposes an 'effective and well-resourced knowledge management and communications component will build awareness of climate threats and risk reduction processes as well as generate analysis and surveys that will increase the uptake of climate information by policy makers and key decision makers.'* The southern Zimbabwe livelihoods concept note proposes communication and knowledge platforms and emphasises the need for climate information to be actionable. Other projects (e.g. Makonde, Mayana and Livingstone) propose to use and/or enhance access to climate information, but explicit discussion of the communication of this information is absent from the documentation examined.

3.4.6. External communication: Summary

Communication of CRIDF-generated climate information, approaches and findings is achieved via multiple mechanisms, including direct interaction with partners, the production of studies, including basin-wide assessments for RBOs, the CRIDF website, and discussions with international bodies. Arguably the most important mechanism for the communication of climate information and technical approaches is the embedding of climate resilience screening and climate change RVAs in the project development cycle, via a suite of dedicated tools and guidance.

The extent to which CRIDF's RVA tools and guidance result in the effective communication of climate information and technical findings undoubtedly varies across project contexts, depending on the level of support provided and the capacity of implementing partners, and is limited by staffing and resource constraints, and the need to rely to a large extent on remote support via telephone.

The communication of climate information is mentioned or discussed explicitly in documentation for only a minority of the projects reviewed, although it is implicit in documentation for others.

3.5. How does CRIDF integrate climate change risk and uncertainty into projects?

CRIDF uses multiple strategies and techniques to address climate change risk and uncertainty at the project level, from both climate science and engineering perspectives, as discussed in turn below.

3.5.1. Climate science approaches to risk and uncertainty

CRIDF refers to its planning approach as one of 'decision scaling'. This deviates from a 'predict-then-act' approach that starts with climate projections and uses these to identify likely future

* Buzi River Basin Climate Resilience Fund – Concept Note for GCF, 2015, p.8

conditions under which infrastructure and other systems must operate. Instead, decision scaling starts with an assessment of an existing or planned system's vulnerability, examining under what conditions the system (e.g. an irrigation system or dam) is likely to fail (Brown et al. 2019). Climate projections and scenarios are then employed to assess how likely it is that these conditions will occur in the future. This approach closely resembles the robust decision-making (RDM) approach, which 'seeks to find decision strategies that perform well across a wide range of possible future scenarios' (Daron, 2015:467).

The scenarios used for basin-scale RVAs and to guide project design are based on projections that fall within the 95% probability range based on the ensemble of available projections (i.e. after excluding the 5% of projections representing the most extreme changes). However, the probabilities of specific changes in temperature, precipitation and other climate variables represented by the scenarios themselves are not quantified. On the one hand this is intended to discourage preferential planning for the 'most likely' scenario. On the other, it reflects a recognition that any such probabilities necessarily would be based on the range and distribution of simulated changes in climate variables across the available climate projections. The use of such probabilities would implicitly assume that the range of possible future changes was perfectly represented by the available climate projections, ignoring uncertainties associated with the representation of physical processes in climate models (model parametrisation) and the characterisation of socio-economic and technological trajectories.

Risk and vulnerability assessments are not limited to consideration of climate model outputs. For example, climate projection data may be used as input to hydrological models, to examine potential changes in flow regimes under a range of possible future conditions. Resilience and adaptation is then based on designing systems that are robust under a range of hydrological conditions compatible with the climate scenarios.

Rather than planning on the basis of probability, the CRIDF approach is to pursue planning that is robust under a range of possible futures represented by multiple scenarios that are not tied to a single model, projection, concentration pathway or socio-economic scenario. Given the similarities in projections across RCPs 2.6-6, the scenario of most agreement tends to be used as a 'recommended' scenario for planning based on a broad consensus across climate models, socio-economic scenarios and emissions concentration pathways. However, while project planners may use the central/recommended scenario as a guide to 'likely' future changes, projects are, in principle, designed to be robust under all the scenarios used, including those representing more extreme projections.

Decision-making is not based solely on climate projections, but also on observations and feedback from local stakeholders regarding climate trends and variability, and their impacts. Projections are compared with observed changes where possible, to check whether they are consistent with reality. Such consistency will increase confidence in the projections, whereas observed changes that are inconsistent with projections are likely to result in projections being treated more cautiously.

The term 'decision scaling' does not appear to be mentioned in any of the documentation examined during the review of the 12 sample projects. Arguably, the decision scaling approach is reflected in the 'low regrets' approach explicitly advocated in the Makonde water supply project, and justified as the most appropriate approach based on the climate scenarios examined. However, based on the documentation examined, it is difficult to see how this differs in practice from more conventional 'low regrets' approaches to resilience, justified on the basis of uncertainty regarding future climate change. A similar approach is evident in the Buzi River Basin Fund concept note, which describes community-managed water infrastructure that 'avoids the lock-in of long-lived, climate vulnerable infrastructure.'*

3.5.2. Engineering approaches to risk and uncertainty

At the project level, the decision scaling approach and the use of climate information need to be integrated with established engineering approaches to managing risk. Typically, these are based on historical data and planning on the basis of past extremes. This in turn depends on the availability of historical data, of which there is a paucity in the SADC region. Engineering approaches include the use of 'factors of safety', essentially the widening of a system's coping range beyond the range of extreme values (e.g. of river flow) suggested by the historical record, to accommodate future extremes of a higher magnitude than those experienced or recorded historically. A factor of safety will be larger where historical data is scarce or covers a short period, in order to allow for higher-magnitude extremes that might not be represented in the historical record. Where historical records cover longer periods, they are more likely to capture rare, long-return period extremes, and factors of safety will be smaller. Climate change demands larger factors of safety, and these can be established by using output from climate projections as input to other models, for example hydrological models, that are relevant at the project level. This approach is alluded to in the documentation for the Lower Incomati FRM project.

In practice, there are a number of challenges involved in integrating the climate science and engineering approaches to risk and uncertainty. Interviews with key CRIDF staff (Annex 1, Interviews 2, 4 and 6) indicate that engineers do not always find the climate science led approach to be practical, or compatible with established engineering approaches. Engineers are used to working with clearly defined construction codes relating to the required tolerances of infrastructure, and it is often challenging to translate climate scenarios into these engineering codes. For example, engineers may expect quantitative information relating to the return periods of floods and droughts. While climate science can provide information on the likely direction of change for these hazards, it struggles to quantify how their behaviour will or may change. While CRIDF is using climate projections to address how interannual variability may evolve, these projections are very limited in their ability to represent climate variability on the shorter timescales that may be just as important for agriculture, livelihoods and water infrastructure. For example, CRIDF engineers cite the need for irrigation during the rainy season as dry periods within the growing season – which are not captured in the climate projection data – become increasingly prevalent and problematic.

There is thus a mismatch between the rather general, low spatial and temporal resolution results from climate models and the very codified nature of engineering – between what climate science can provide and what engineers want. To a large extent this is an issue of the scale, resolution

* Buzi River Basin Climate Resilience Fund – Concept Note for GCF, 2015, p. 8.

and nature of the variables used to construct climate scenarios.

CRIDF is working to address this gap. For example, hydrological modelling provides a way of deriving local-scale, quantitative data that is relevant to engineering design from climate scenarios. This approach has been used in a number of CRIDF projects, such as the Lower Incomati FRM project. However, this is not practical for many smaller projects. In practice, engineers often make a judgment about what seems most likely, and base infrastructure design on this judgment, incorporating factors of safety. Engineering decisions are based largely on hydrological modelling and the identification and extrapolation of existing trends. A pragmatic approach is taken in which 'over-engineering' from the outside is avoided, on the grounds that this may represent a waste of investment. Instead, the preferred approach is to 'leave the door open' for additional infrastructure or modifications to deal with future changes, underpinned by monitoring to identify where and when such modifications might be necessary. An example is the selection of a lower-cost but less efficient irrigation system from a set of possible options, on the grounds that this might be replaced with a more efficient system in the future if changes in water availability and evapotranspiration alter the effectiveness, sustainability or benefit-to-cost ratio of the existing system (Annex 1, Interview 2).

Economic feasibility is another factor that may mitigate against the full implementation of the decision scaling approach in engineering contexts. Many smaller projects are already on the borderline of economic viability. While they might generate enough income for operation and maintenance, they may not generate sufficient income to repay significant loans. Consequently, they might be unviable under climate change owing to the higher costs involved with larger factors of safety (Annex 1, Interview 2).

This can result in smaller projects considering and addressing the potential impacts of climate change to a more limited extent than would otherwise be desirable. Such projects may still deliver resilience benefits in the near term, for example in the form of greater and more reliable water supply, or improved flood management. From an economic and financial perspective, these projects are considered viable if they deliver sufficient returns to cover input and management costs, and these returns may be realised relatively quickly. The timescales over which such projects will be assessed in terms of viability and resilience benefits therefore may be relatively short.

3.5.3. Sustainability and longer-term climate risks

CRIDF programming has a strong focus on ensuring that agriculture and human settlement can be sustained, expanded and intensified through the installation of water infrastructure in areas facing increasing water stress because of higher temperatures coupled with reduced and/or less reliable rainfall. This raises the question of whether water resources in these areas will remain at the levels required to sustain these systems indefinitely. If they do not, it is possible that adaptation interventions are entrenching and intensifying systems and activities that are unsustainable in the longer term, increasing the risk that these systems will suffer catastrophic collapse in the future. Such interventions would be maladaptive.

CRIDF examines issues of longer-term sustainability for some larger projects, including some dam projects such as the Lombo Dam in Swaziland (Annex 1, Interview 1). However, the extent to which issues of longer-term sustainability are addressed depends on the design life of the infrastructure in question. CRIDF does not formally assess the long-term sustainability of smaller-scale interventions such as irrigation systems, on the grounds that they are not necessarily envisaged as permanent, and will generate sufficient economic returns to make themselves financially viable in years rather than decades. This largely economic framing, coupled with a limited consideration of future climate risks, may mean that risks are underestimated or missed. It also neglects the potential for such infrastructure to influence development trajectories that may be maladaptive in the long term, consolidating patterns of settlement, economic activity and agricultural production in locations that ultimately may be unviable under future climatic conditions.

3.5.4. Longer-term sustainability and maladaptation risks in CRIDF projects

Risks to and from projects are considered in some of the documentation reviewed as part of this study. For example, the Mayana Community Vulnerability Reduction CCRA examines risks to project physical components from climate hazards. It also addresses how extreme low flows might pose a risk to water supply, and this appears to incorporate considerations of climate change impacts on flows. These are included in the project risk matrix. Risk matrices for other projects include comparable risks.

Potential risks around longer-term sustainability and maladaptation can be inferred from the documentation for a number of projects. However, of the 12 projects reviewed, only the Makonde water supply project appears explicitly to consider these risks in any detail.

The Makonde technical and design reports estimate that the project will increase abstraction from the source aquifer to 10% of recharge, with this rising to 13.5% by 2030 owing to increased demand. This compares with a limit for sustainable abstraction of 40%, which would nonetheless have adverse impacts on ecosystems and other water bodies. Worst case climate rainfall projections indicate a maximum abstraction-to-recharge ratio of 33%, approaching but still significantly below the maximum allowable ratio for sustainability. Sustainability risks will be tracked through the project's monitoring component.

Despite the above considerations of sustainability, the Makonde project still raises some concerns. A worst-case scenario of a 29% reduction in annual rainfall is used to stress-test the project in terms of the sustainability of abstraction-to-recharge ratios. However, the impacts of temperature changes on recharge rates have not been considered owing to a lack of information on the effects of temperature on groundwater, although the importance of temperature for yield-to-recharge ratios is noted. Temperature can have a large impact on evaporation, surface runoff and groundwater recharge. For example, in other contexts, a 1°C increase in temperature has been associated with a 6% increase in evapotranspiration (Abu-Taleb & Maher, 2000) and approximately a 10% decrease in runoff (Agoumie, 2003). It is not clear if the projected increase in abstraction based on increased demand accounts for increased irrigation needs associated with temperature increases. For Egypt, a warming of 1°C has been estimated to increase irrigation demand by 2.3%. It is possible that, once these additional temperature-related factors are taken into account, abstraction would exceed sustainable limits in the worst case scenario. Where empirical relationships between temperature and abstraction/recharge ratios have not been established, it would still be possible to explore the potential impacts of climate change through sensitivity studies using plausible relationships based on insights from other contexts.

In other project documentation, discussion of longer-term sustainability and maladaptation appears to be absent altogether, and in some cases assessment of risks and sustainability appear to omit any consideration of climate change.

For example, the Bindagombe risk matrix cites a medium probability of 'continued reduction in inflows into Bindagombe resulting in more frequent shortage of water'.* However, the potential for such shortages to become sufficiently frequent and/or severe to threaten the viability of the intensive commercial farming the project is intended to support is not discussed, even to eliminate this possibility. It is mentioned that declining rainfall has affected dam yields, but potential future impacts of climate change on dam yields are not discussed, at least in the available documentation. The lifespan of the benefits from this project are estimated at 20 years. However, there does not appear to be any explicit consideration or quantitative assessment of how climate change might influence irrigation demand and water supply over this lifetime. Assuming the project is sustainable over this period, it is likely to result in high economic and food security dependence on water-intensive commercial agriculture that may be vulnerable to subsequent climate change impacts. If climate change ultimately results in the collapse of intensive agriculture on which populations have become dependent as a result of this project, if could be deemed maladaptive in the longer term, despite its nearer-term benefits.

The risk matrix in the Sioma feasibiity report assesses drought risks to the project as low with no structural impacts and states that 'unless [there is] extreme drought water supply [is] assured.'† However, there is no discussion of what is meant by 'extreme drought', how likely such an event might be, or how climate change might influence this likelihood. The discussion of crop water requirements in the same document does not consider climate change implications, suggesting that project design is based on the implicit assumption that current conditions will pertain into the future. This apparent implicit assumption of climatic stationarity could result in the implementation of a project that is not sustainable in the face of climate change, or that is maladaptive. In addition, this project proposes a hydropower component without considering any climate change risks to hydropower potential.

While the likelihood of maladaptation seems low for the Livingstone water and sanitation project, the affordability of water from a new supply managed by commercial bodies is not addressed in the concept note. This raises the possibility that the project could increase inequality in water access and the vulnerability of the poorest if they lose access to current sources but cannot afford water from new infrastructure (see Eriksen et al. 2021).

The Kufandada irrigation project provides a further example of potential sustainability and maladaptation risks, and is explored in detail in Box 2.

* Bindagombe Irrigation Scheme: Economic & Financial Analysis, Jun. 2014, p. 26.

† CCAP Sioma Irrigation Scheme: Feasibility Report, Mar. 2016, p.91 (document Extlib-16)

BOX 2: Case study

Kufandada irrigation

Documentation for the Kufandada Irrigation Scheme in Zimbabwe identifies longer dry seasons, increasingly erratic rainfall and frequent droughts as factors in recent reductions in agricultural yields and crop failures. Floods and storms have also had adverse impacts in the project location. However, many other factors, including a lack of agricultural inputs, deterioration of existing water sources, and land and ecological degradation are also cited. The project is based on the construction of weirs to act as abstraction points to provide water for irrigation and other uses, to support a shift to a more intensive commercial agriculture model. This is coupled with measures to reduce river bank erosion and support ecological restoration, and other measures to improve water and sanitation. Future climate change impacts are discussed, including a further shortening of the rainy season and a significant decline in reservoir yields.

The Kufandanda Feasibility Study identifies a risk of 'drying up of river downstream since more irrigation water required during drought times', with associated loss of aquatic flora and fauna, and states that 'flow downstream is already very low' (CRIDF 2013: 78). Erosion immediately downstream of the existing Kufandada Dam caused by surges during heavy rainfall is also highlighted. However, the risk register in this report does not include risks of amplified impacts on river flows downstream of the weirs, or risks of severe erosion or infrastructure failure, owing to unanticipated low or high rainfall extremes associated with climate change.

The Kufandada Detailed Design Report (CRIDF 2015b) indicates the construction of a weir 40 metres in length and 3.5 metres high, stability tested against 'a maximum flood surcharge 2.5m above the crest'. However, there is no discussion as to whether or how these calculations accommodate potential increases in river flow or flood behaviour above historical values as a result of climate change. Similarly, while the CRIDF (2015a) CCRA Guidelines highlight this project as an example of a CCRA, there is no discussion in the feasibility study or design report of how potential changes in rainfall, evaporation and flow have been considered in the design of the weir, in relation to its performance and potential downstream impacts on river flow and ecosystems.

This project raises some key questions in the context of medium- to long-term changes in climate, including (i) whether there are risks that abstraction may fail in the event of protracted dry periods, (ii) the potential for such extremes to halt flow downstream of the weir with significant ecological impacts, and (iii) whether measures to address erosion will be adequate in the event of unprecedented high rainfall and flow extremes. The project is predicated on an assumption of increased reliance on intensive irrigated agriculture and enhanced access to local markets, in the context of urbanisation and population growth in the wider area. Failure of the irrigation system under future extreme climatic conditions, coupled with an increase in water stress, therefore may jeopardise not just the livelihoods of those who depend directly on it, but also food security and economic development in the wider vicinity of the project site.

The Kufandada project has been used as a model for scaling up, via a successful application to the GCF for a programme of some 50 small projects based loosely on this model. Should this model fail as a result of a failure to consider its sustainability under future climatic conditions, this could be viewed as constituting systemic maladaptation. This is not to suggest that such risks have been demonstrated, rather that there is nothing in the documentation reviewed to indicate that they have been considered and addressed.

The identification of long-term sustainability and maladaptation risks does not necessarily mean that a project should be abandoned and the implementation of water or other infrastructure avoided. To do so would be to deny adaptation and development benefits to vulnerable populations in urgent need of infrastructure and basic services now, based on uncertain knowledge about the future. Rather, the possibility of future maladaptation should be acknowledged, assessed as far as possible, and addressed through longer-term strategies based on adaptive management. Where potential maladaptation risks are identified, it will be important to monitor climate change trends and impacts to determine at what point current systems are likely to fail. Near-term incremental adaptation responses that are unsustainable in the longer term can then give way to more transformational adaptation responses as part of a phased adaptation strategy (Box 3).

BOX 3: A framework for transformational adaptation

Rippke et al. (2016) present a broad framework for transformational adaptation in the agricultural sector in Sub-Saharan Africa, based on the frequency with which a crop's 'viability threshold' is crossed. This model involves three overlapping phases of (i) incremental adaptation, involving crop and management improvement, (ii) preparation, involving the establishment of enabling environments and the piloting of transformational adaptation measures, and (iii) transformation, involving more systematic crop substitution and/or moves into alternative livelihoods. The preparatory phase would be triggered once crop failures occur more than one year in four on average, if this frequency is projected to increase. Climate information would be important for linking crop failures with observed climate change and variability, and estimating how, and how rapidly, failures linked to climate change and variability are likely to evolve in future. Climate information for monitoring and anticipating change is thus critical for guiding adaptation and thus building resilience. Critically, such information would need to be grounded in local monitoring and driven by the needs and desires of the affected communities, informed by both local and externally generated climate information.

3.5.5. CRIDF's approach to decision-making: Summary

The CRIDF decision scaling approach seeks to deliver resilience and adaptation decision-making that is robust under a range of plausible climate change scenarios. Robust decision-making (RDM), to which it bears a close resemblance, has been criticised for internal inconsistencies related to tension between the goal of decision-making that is robust under all possible futures, and the use of scenarios based on models that may not represent the full range of plausible future changes (Daron, 2015). This tension is particularly problematic when scenarios are used as 'products' by decision-makers who have not been involved in their development, and therefore are not familiar with model and scenario limitations. This may be more likely in developing country contexts where resources (e.g. for engagement) are scarce. In addition, in such resource constrained contexts, decisions that are seen as optimal under 'likely' future conditions may be viewed as preferable to more costly alternatives that are robust under a wider range of future scenarios (Daron, 2015).

This preference for 'optimal' rather than 'robust' decision-making is evident in the engineering approaches of at least some CRIDF projects, particularly smaller projects where RVAs are limited to 'off the shelf' information on future climate risks. In practice it appears that the integration of climate change risks in these projects remains limited, with a focus on delivering short-term benefits in the context of current hazards and risks. In these contexts, climate change impacts and resilience narratives are deployed as justifications for projects whose design and implementation then proceed along the lines of conventional water infrastructure projects.

In many of the projects reviewed, climate change impacts appear to be partly or wholly absent from assessments of risks and sustainability. In at least some cases this is due to an acknowledged absence of appropriate data. This is evident in the Makonde water supply project, that explicitly addresses long-term sustainability under worst case rainfall scenarios, but does not address the impacts of increased temperature owing to a lack of information on the relation between temperature and abstraction-to-recharge ratios. Other projects fail to address the implications of climate change for sustainability altogether.

A significant proportion of the projects reviewed are associated with potential sustainability and maladaptation risks that remain unaddressed. Acknowledging the existence of such risks does not necessarily undermine the rationale of a project. Rather, such acknowledgement opens the door to the development of phased, flexible approaches in which approaches based on conventional development measures and incremental adaptation ultimately give way to transformational adaptation if and when these conventional/incremental measures become unviable. Failure to recognise potential limits to current resilience and adaptation approaches may result in the lock-in of practices that are unsustainable under climate change, increasing the risk that agricultural systems will collapse in the longer term under climate change pressures.

3.6. How can uptake of climate information and decision-making be improved?

The CRIDF programme appears to have achieved some considerable success in improving the extent and quality of climate-informed decision-making, through close engagement with partners, particularly RBOs, and the generation and dissemination of relevant climate information, supported by the development of appropriate tools and guidance that follow international good practice. CRIDF projects provide multiple examples of decision-making that has been improved through the use of climate information, including primary data resulting from vulnerability mapping and hydrological modelling, for example as discussed above in the context of the Lower Incomati Flood Risk Management project. However, the review of CRIDF projects provides numerous examples where the use of climate information to inform decision-making could be improved.

3.6.1. Intensification of support to implementing partners

Interviews with CRIDF staff indicate that implementation of the tools and guidance through which projects incorporate climate information into decision-making is largely a matter for project partners. While CRIDF provides support, the extent of this support is limited, and support is often provided remotely via telephone conversations. Consequently, the quality of integration of climate information into decision-making can be highly variable. It was observed that this situation might be improved through more face-to-face engagement and more intensive support from CRIDF, perhaps with some formal training.

Currently, financial resources, staffing levels and the remoteness of many project sites mitigate against these measures. It must also be stressed that CRIDF views the integration of climate information and the use of tools and guidance by partners as key to building regional capacity through a process of 'learning by doing'. Any additional support, for example based on greater involvement of CRIDF specialists in project development and implementation, should complement and strengthen this model, not undermine or replace it.

It seems unlikely that CRIDF can intensify its support to implementing partners at this stage of the programme, given staff and resourcing levels. However, lessons might be drawn from a review of CRIDF support to implementing partners with a focus on what sort, and level, of support might improve the uptake and use of climate information in decision-making.

3.6.2. Extending co-production

CRIDF engagement with stakeholders at the basin and local level offers potential for the co-production of knowledge (Box 4), although the extent to which CRIDF can be said to be involved in the 'iterative interactional' production of knowledge with stakeholders varies across contexts and cannot be assessed fully within the scope of this desk-based study (Vincent et al. 2020: 2). At the basin level, climate information may be characterised as flowing predominantly from CRIDF to stakeholders, via climate scenarios and basin-wide assessments. RBOs exhibit agency in this process at least insofar as they actively submit requests for such information. At the project level, the flow of information appears to be largely from stakeholders to CRIDF via the mechanism of vulnerability and risk assessments. The flow of climate information in the other direction appears to be focused on project scoping and design, and on specific functions such as flood warnings.

CRIDF projects support climate and environmental monitoring, largely in the form of the installation and improvement of gauging stations. CRIDF does not appear to be involved in supporting community monitoring of climate trends, variability, hazards and impacts. Given CRIDF's primary purpose of supporting infrastructure, rather than, for example, climate information services, this is understandable. However, there are potential opportunities here to engage and support communities in long-term monitoring. Such monitoring can provide highly localised data that can help address gaps in the observational record and complement conventional scientific information. It may also enhance local communities' awareness and capacity to track and respond to evolving climate hazards and risks, for example based on scenario planning informed by the extrapolation of local trends.

Processes of co-production might be pursued that bring together local stakeholders, external experts and other actors, with CRIDF or equivalent entities acting as knowledge brokers, to combine locally generated information with more conventional 'externally generated' climate information. This could help to drive more cooperative processes of scenario development involving stakeholders and beneficiaries, rather than the current focus on scenarios as products (Daron 2015). Supported by local monitoring, such an approach would be especially useful where potential maladaptation risks are identified, highlighting a possible need to develop and pilot phased transformational adaptation strategies as climatic and impacts thresholds or limits are approached (Rippke et al. 2016, Box 3).

BOX 4: Co-production of climate information

Co-production of climate services and information refers to 'the deliberate, collaborative product-development work between climate scientists, or producers of climate data, and practitioners, or users who require climate information' (Bremer et al. 2019:42). A common goal of co-production is to enhance the utility and useability of climate information and services 'by better aligning information supply with demand,' although co-production may also seek to preserve and empower traditional climate knowledge systems and complement conventional scientific knowledge with other forms of knowledge (Hansen et al. 2019: 9).

Vincent et al. (2020) highlight methods and approaches for co-production, including transdisciplinarity, action research, and the use of boundary agents, knowledge brokers and embedded researchers. Daniels et al. (2020: 1) advocate an approach that emphasises the process of knowledge generation with the aim of bringing about long-term benefits, based on different actors working together 'to purposefully design transdisciplinary knowledge integration processes'.

3.6.3. Bridging the gap between climate science and engineering design

As discussed above, engineers often find climate information to be of limited use in infrastructure design, owing to a lack of appropriate metrics and a lack of clarity about how to translate it into design parameters. A greater focus on how to bridge this gap, and how to apply the decision scaling approach, is likely to improve both uptake of climate information and its effective use in decision-making. This is likely to involve closer cooperation between climate scientists and engineers at the local level, which will require additional resources and co-production approaches. CRIDF might seek to pilot such initiatives over the next two to three years and distil the learning around this issue.

The decision scaling approach might also be strengthened and extended by combining it with longer-term risk assessments and transformational adaptation strategies as described above (Bhave et al. 2016). The gap between climate information and engineering needs might be addressed by blending the existing decision scaling approach with related frameworks such as the World Bank's Decision Tree Framework (Ray & Brown, 2015), and UNESCO's Climate Risk Informed Decision Analysis (CRIDA) which specifically seeks to incorporate 'unknown unknowns' into planning, with a particular focus on the water sector (Mendoza et al. 2019). These might offer more formal frameworks for addressing issues such as factors of safety in engineering design in the context of climate change.

3.6.4. Improving uptake: Summary

CRIDF supports its project partners in the use of CRIDF tools and methods, but this support is often limited and delivered remotely via telephone, because of issues of staffing and the remoteness of project sites. This process might be improved through more intensive support, although this would have significant resource implications and would need to avoid undermining the extent to which the current approach results in partners 'learning by doing'. Ex-post analyses of how CRIDF tools have been used, the extent to which climate information and CRIDF technical findings have genuinely informed project design, and how decision scaling approaches have been employed in practice, could provide valuable lessons on improving uptake of information, tools and methods.

Decision-making might be improved further through approaches based more explicitly on the co-production of information, coupled with support to local communities to establish low-cost mechanisms for tracking climatic and environmental trends, variations, impacts and vulnerabilities, for example through phenological approaches that can track the evolution of seasonal changes. Using principles of co-production, CRIDF might also intensify its focus on bridging the gap between climate information and engineering needs and enhancing the decision scaling approach. The latter could involve an emphasis on more cooperative processes of scenario development, rather than on scenarios as products, and the development of longer-term risk assessments and transformational adaptation strategies where potential maladaptation risks are identified.

The flexible, iterative approach required for effective co-production may be hampered by how the CRIDF operates. An external decision was made that CRIDF projects would be based on task orders. These involve a very rigid, prescribed work plan for a project or workstream, from which CRIDF staff are unable to deviate. For example, if someone is not named on a task order they cannot work on a project or workstream, meaning that it is difficult or impossible to bring in additional expertise to address issues that might be raised during a project (Annex 1, Interview 8). This appears to be antithetical to iterative, adaptive management.

3.7. What is the evidence of uptake and impact of climate information, and CRIDF impact more generally?

3.7.1. CRIDF's approach to assessing impact

Assessment of CRIDF's impacts was discussed with the programme's evidence and learning lead and manager (Annex 1, Interview 7), who indicated a shift between the first and second phases of CRIDF to a more process-focused approach and an emphasis on assessing how CRIDF is changing institutional mindsets and approaches. This is pursued through a model based on the assumption that changes in knowledge result in changes in attitude, which in turn result in changes in practice. This 'KAP' methodology is applied to assess changes in institutional thinking, with a baseline report against which future changes can be assessed being completed in 2019 (CRIDF 2020a). Results are examined using outcome harvesting (OH), an approach that identifies outcomes of interest and then asks how an initiative contributed to these, rather than starting with activities under the initiative and looking for resulting outcomes from those activities. CRIDF is using OH to address the question 'To what extent has your organisation strengthened institutional capacity regarding (i) climate resilience, (ii) gender, (iii) pro-poor and (iv) transboundary water?' (CRIDF 2020a: 2), collecting information from 17 organisations through document review and/or KIIs.

3.7.2. Institutional impact at the level of RBOs

CRIDF's own findings indicate a change in knowledge, attitude or practice in relation to climate resilience in 10 out of 17 organisations that it examined using OH. This is based on 27 reports of knowledge change at the institutional level across LIMCOM, OKACOM and ORESACOM, all of which were judged as positive (CRIDF, 2020a). Twenty six instances of (mostly positive, with a minority of neutral or unknown) changes in attitude or thinking around climate change are reported, based on 22 formal reports of institutional change across ESAWAS, LIMCOM and OKACOM. Fifteen positive formal institutional changes in practice/behaviour are identified across five organisations – ESAWAS, LIMCOM, Lusaka Water & Sewerage Company (LWSC), NWASCO and WASAMA.

Changes in KAP are recorded by CRIDF across more organisations in relation to climate resilience (ten organisations) than in relation to gender and transboundary water infrastructure (four and five organisations respectively). However, the number of such changes recorded in relation and transboundary issues is greater (41 and 68 respectively), indicating that these changes are highly concentrated in a small number of organisations. This raises the question of why some organisations have changed more than others, and how the greater extent of change in relation to gender and transboundary issues might be replicated for climate resilience in these organisations. Ninety changes are recorded across 14 organisations in relation to pro-poor KAP (CRIDF, 2020a).

3.7.3. Capacity building impact

CRIDF provides tools, frameworks and guidance for integrating resilience and adaptation into decision-making, and these are applied both within CRIDF and by external partners/stakeholders. A key goal of CRIDF is to 'indigenise' these mechanisms among partner organisations to ensure that such integration is sustainable beyond the programme's lifetime (CRIDF, 2017b). A step-change in the use of climate information and related tools, frameworks and guidance, to inform regional and basin-scale planning so that it builds resilience and supports adaptation, is key to CRIDF's mission to deliver improved access to climate resilient infrastructure, as articulated in the CRIDF theory of change.

As already noted in this report, some of the CRIDF tools and guidance have been developed in collaboration with partners, including RBOs. In addition, CRIDF's work builds on and extends previous work by RBOs on climate change risks, impacts, vulnerabilities, resilience and adaptation. This is evident in the form of studies and reports published by RBOs and regional organisations including SADC, for example the 2011 SADC strategy paper on climate adaptation in the water sector.*

The latest annual review (CRIDF 2020b) cites evidence of uptake of CRIDF tools and techniques by a variety of organisations and in a number of geographical contexts. This includes use of the vulnerability hotspots assessment tool and datasets in the Cubango-Okavango Basin to prepare the Okavango Resilience Fund proposal. The same tool and datasets have been used in related programming by the EC, GEF and USAID, and also by ZAMCOM. The CRVAT has been used by Mozambique's National Institute of Irrigation. In total, CRIDF has developed ten tools and six datasets, most of which are directly concerned with climate information and its application, which have been shared with over 100 institutions (Table 6).

Table 6. Tools and datasets developed by CRIDF and shared with institutions.

Tools	Datasets
1. Gender Toolkit (GESI),	1. Cubango–Okavango Vulnerability and Hotspot Assessment Dataset
2. Climate Risk and Vulnerability Assessment Tool (updated)	2. Zambezi River Basin Vulnerability and Hotspot Assessment Dataset
3. Institutional Assessment and Development Guideline Tool	3. Limpopo River Basin Climate Scenarios
4. Transboundary Vulnerability and Hotspots Analysis Methodology	4. Orange–Senqu River Basin Climate Scenarios
5. Concept Note Guide: Useful Steps & Tools for Livelihood Portfolios & Projects	5. Save River Basin Climate Change Scenarios
6. Southern Africa Climate Change Projection and Impacts Guidance Tool	6. Komati Basin Climate Change Scenarios
7. Environmental Assessment Guidelines	
8. Eligibility Screening Tool	
9. Climate Change Maturity Matrix (initially produced for ESAWAS)	
10. ESAWAS Non-Revenue Water Management Guidelines	

* SADC 2011. Climate Change Adaptation in SADC: A strategy for the water sector.

The CRIDF head of programme emphasised that CRIDF does not seek to build capacity principally through conventional training (Annex 1, Interview 1). Rather, the programme works with local and regional experts to apply tools and processes aimed at improving planning and delivering climate resilient infrastructure on the ground. CR estimated the number of experts with whom CRIDF has worked to be in the low hundreds, and highlighted that most of the construction associated with CRIDF projects is by private subcontractors working with multi-disciplinary teams. This informant estimated that 80-90% of the people involved in delivering these projects are from the region.

Reinforcing this view, the latest annual review (CRIDF, 2020b) indicates that 347 individuals from institutions in the region have been trained in the use of CRIDF tools. Of those receiving training, 55% were men and 45% women. In 2019-20, CRIDF provided tools and datasets to 104 institutions, the vast majority of which were also provided with related training.

It is therefore reasonable to conclude that CRIDF has contributed to regional capacity to deliver resilient planning and infrastructure by building the capacity of individual experts and local entities through a combination of training and a 'learning by doing' approach, focused on the use of CRIDF tools which are freely available to partners and other stakeholders in the region.

3.7.4. Impact as measured through finance

Through its technical support to specific organisations and projects, CRIDF aims to mobilise finance for transboundary water infrastructure in the SADC region, from sources external to the CRIDF programme. Annual reviews (based on quarterly programme communications) include information on finance mobilised against planned milestones, broken down into public versus private finance, and legally versus formally mobilised finance. The 2020 annual review indicates the mobilisation of £61.626 million and £875,000 of public and private finance respectively, the majority of which (89% and 83% respectively) is formal rather than legal (CRIDF, 2020b). Approximately 91% of the public finance reported here is for the Songwe hydropower project, with most of this (£54.65 million) being in the formal commitment from the African Development Bank (AfDB), and the remainder (£1.32 million) in the form of legally committed funding from the African Legal Support Facility (ASLF). Most of the remainder of this funding is in the form of legally committed finance from the GEF, with other finance supporting infrastructure project preparation (NEPAD), the Lesotho-Botswana Water Transfer Projects (SIWI), and gauging stations in Angola (EU via OKACOM). In addition to figures on mobilised finance, the review identified five innovative financing mechanisms based on new types of funds and novel partnerships.

CRIDF has provided support for the preparation of a number of proposals for funding to the GCF, including a successful proposal for just under USD 50 million for *Building Climate Resilience of Vulnerable Agricultural Livelihoods in Southern Zimbabwe*, based in part on the models piloted under CRIDF's Kufandada and Bindagombe irrigation projects. This example demonstrates the impact of these CRIDF pilot projects in terms of leveraging finance, scaling up (to 137 wards across 15 districts), and the delivery of infrastructure to support climate resilience.

3.7.5. Impact at the project level

Individual CRIDF projects provide evidence of impact, most obviously in the form of water infrastructure installed and the consequent improvements in access to water for domestic, agricultural and other uses. However, other impacts are apparent, including in the way climate-related risks are managed, and in the ways in which multiple stakeholder groups cooperate to manage risks and resources.

For example, the Lower Incomati Flood Risk Management (FRM) project provides a convincing example of transformational change in both thinking and approaches to flood management. CRIDF was approached by Ilovo Sugar, who requested support in addressing an increased frequency of flooding in recent decades, with impacts on the Ilovo Sugar estate and local farmers. A study based on hydrological modelling of the Lower Incomati River Basin, combined with vulnerability assessment and mapping, concluded that the strategy of building dikes to protect sugar estates from flooding had increased flood risk for adjacent smallholders.

This insight, along with the establishment of a stakeholder steering committee facilitated by CRIDF, resulted in a shift from flood avoidance to flood management, based on a combination of better infrastructural interventions, improved early warning, and greater cooperation of sugar estates with smallholders. The last of these was supported by a cost-benefit analysis demonstrating the economic benefits to sugar estates of investing in FRM infrastructure to protect smallholders and outgrowers.

The steering committee established with CRIDF facilitation grew to include national-level institutions, becoming a de facto flood management committee. CRIDF intervention in this context thus appears to have left a lasting legacy of improved infrastructure, reduced flood risk, better and more profitable relations between stakeholders, and new institutional structures to manage climate-related risks.

3.7.6. Evidence of uptake and impact: Summary

CRIDF's own outcome harvesting activities indicate significant positive changes across multiple institutions. While it is difficult to quantify wider capacity building results across the SADC region, CRIDF's approach of developing tools, guidance and climate information with stakeholders including RBOs and other project partners is likely to increase awareness and understanding of climate information and its use among these actors. The application of CRIDF tools and guidance by partner individuals and organisations, including infrastructure subcontractors and some 100-200 individual experts from the region, can be assumed to be having a similar impact.

There is evidence of impact for individual CRIDF projects, for example transformational changes in stakeholder cooperation and institutions, as well as in flood management approaches and methods, for the Lower Incomati FRM project. In addition to their direct impact on beneficiaries, CRIDF projects have acted as demonstrations for larger initiatives and helped secure financing for such initiatives, as in the case of the successful GCF proposal for the Zimbabwe livelihoods initiative.

3.8. CRIDF and good practice in the provision and use of climate information

Good practice in the provision and use of climate information is addressed in an accompanying guidance note addressing the provision of climate information by third parties, based on a rapid literature review. Here, we briefly discuss practice within CRIDF around the provision and use of climate information.

CRIDF has worked hard to develop a framework of practice for the effective and appropriate use of climate information. The programme has developed and curated a body of relevant climate information for the SADC region, as well as specific tools and guidance to ensure that this information is readily accessible in formats that can be understood and used by CRIDF programme and project staff and partners.

CRIDF uses a combination of quantitative and qualitative information, with careful thought given to what type of information is appropriate in any given context. Recognising the limits of climate projections, and the different types of uncertainty inherent in projection data, the programme uses a combination of general, qualitative guidance and expertly developed scenarios to inform planning, programming and project development.

Qualitative information is deployed at the project level for small projects, based on the expected behaviour of climate hazards; for example, increased precipitation variability associated with longer dry periods and a higher likelihood of protracted droughts.

Quantitative information is used to assess the impacts of different basin-wide development strategies under different plausible climate scenarios, and to inform the design of larger projects, for example involving costly, long-lived infrastructure. Scenarios represent a range of plausible future conditions within which development interventions should be viable. Projections typically are compared with observed climate trends to identify discrepancies between projections and observations.

CRIDF's decision-scaling approach represents a shift away from the top-down, technocratic 'predict-then-act', impacts-led approach, in which planning is based on adaptation to a 'most likely' future climate scenario. Instead, CRIDF seeks to identify conditions under which existing or planned systems may fail, and uses climate scenarios to assess the likelihood of these conditions. This approach avoids tying development to a single assumed climate trajectory, which is important for iterative planning in the light of new information, and more generally for facilitating consideration of uncertainty and a view of adaptation as an ongoing process.

Discussions with CRIDF staff suggest that, in practice, there is a tendency for engineering staff at the project level to use the scenario of 'most agreement' in a way that resembles the 'predict-then-act' approach, as discussed above. As discussed above, this might be addressed through additional attention to the way in which climate projections and scenarios are translated into engineering codes and specifications.

Stakeholders are engaged early in the CRIDF project development process, and this engagement includes the gathering of information relating to hazards, risks and vulnerabilities. This focus on stakeholder-generated information constitutes a degree of co-production of climate information, although this is often focused on baseline information used for project identification, scoping and design. In some instances co-production and co-design goes further, for example in the case of projects incorporating flood early warning systems. As discussed above, more continuous engagement of local stakeholders and beneficiaries in the gathering of data on climate variability and hazards, and associated vulnerabilities and impacts, could be beneficial in extending the co-production approach.

At the programme scale, CRIDF follows good practice in the gathering, generation, interpretation and use of climate information. The extent to which this is reflected on the ground at the project scale is difficult to assess without further stakeholder engagement. However, from this review it seems likely that this varies across projects according to context, the nature of projects, and the capacities of the CRIDF partners implementing the projects. The review of 12 CRIDF projects highlights some examples of good practice but many instances where the availability and/or utility of climate information is limited, and where climate information has failed to inform project design. This is probably due, at least in part, to a lack of relevant climate information. However, there are examples where this lack could have been addressed through sensitivity studies using plausible changes in key climate variables (e.g. Makonde water supply, as discussed above).

As noted above, the more detailed RVAs applied to larger projects mean that good practice around planning under uncertainty, using scenarios representing a range of possible future, is more likely to be followed in these contexts, where there is more at stake owing to the cost and longevity of the infrastructure supported by CRIDF.

4. Conclusions and Recommendations

CRIDF has developed a pragmatic framing of resilience and adaptation to support climate resilient water infrastructure in the SADC region. It has raised important questions about the relationship between resilience, adaptation and development, and the implications of this relationship for the way climate finance is allocated. CRIDF has developed strong narratives around climate resilience, although in some of the project-level documentation these could be made more convincing with a greater reliance on climate information, including empirical data. In some instances it seems that climate and resilience narratives are used principally to justify project investments, and lost when it comes to project design. There is some tension between a CRIDF identity as a conventional water infrastructure programme that seeks to integrate climate resilience, and an identity as a programme whose principle goal is to address climate change risks. However, where climate change justifications may be weak today, they are likely to be stronger in the future, meaning that CRIDF-supported interventions are likely to deliver resilience benefits, provided climate risks, including longer-term sustainability and maladaptation risks, are addressed. Consideration of these risks is generally lacking in the project documentation reviewed here.

The CRIDF programme has piloted novel approaches to the development and dissemination of climate information and tools and guidance for integrating climate information into decision making at multiple scales, from the basin scale to the local project level. Communication of climate information and project insights has been achieved through the mandated application of these tools and guidance at the project level, and through basin-wide studies and engagement with RBOs at the regional and basin level. The public availability of these tools and methods, along with a wide range of other documentation, via the CRIDF website, has delivered a high degree of transparency and potential for uptake of CRIDF processes and learning. CRIDF's approach to climate risk and vulnerability assessment reflects global good practice, blending considerations of current and future hazards, vulnerabilities and risks.

There is significant evidence of impact, at both the project and basin scale, in terms of infrastructure delivered, the establishment of stakeholder networks focused on enhancing resilience to climate variability and change, shifts to more resilient flood management, more climate-informed planning by RBOs, and the leveraging of finance for scaling up models piloted in CRIDF projects.

Nonetheless, the extent to which CRIDF tools and guidance have been robustly adopted and genuinely informed project design and implementation appears to vary across projects. One the one hand, use of CRIDF tools and guidance by external partners and stakeholders represents a process of 'learning by doing' that should enhance the capacity of individual experts and organisations, including private contractors, in the region. On the other, the limited and largely remote support offered by CRIDF for the application of these tools and methods – a function of resource and staff constraints – has probably been an impediment to the effective and meaningful integration of climate information into decision-making, at least in some contexts. This is evident in the emphasis on climate information and resilience narratives in project rationales, but their often much lower visibility in project design.

CRIDF's decision scaling approach rightly seeks to move beyond the 'predict-then-act' approaches that have been widespread in climate change planning, and represents a novel approach to the use of climate projections to develop scenarios representing a broad range of plausible future conditions. In practice, particularly for smaller projects, there appears to be a tendency to treat scenarios of most agreement (across projections and greenhouse gas concentration pathways) as 'most likely' scenarios and use these for planning in a way that reflects the predict-then-act approach. Where multiple scenarios are employed, there is a risk that their use as 'products', rather than the co-development of scenarios as a process, may result in their being treated as representing all possible futures. This results in risks associated with 'unknown unknowns' being ignored. This could be addressed by blending the decision scaling approach with other related approaches, such as the Climate Risk Informed Decision Analysis (CRIDA) approach developed by UNESCO (Mendoza et al. 2019) and the Decision Tree Framework developed by the World Bank (Ray & Brown 2015).

The integration of climate change risks into decision-making might be enhanced through a greater focus on co-production, with CRIDF or successor bodies playing the role of knowledge broker. Co-production approaches and the incorporation of frameworks such as CRIDA could also help to identify and address risks of maladaptation, supported by local monitoring of climate trends, hazards and impacts.

CRIDF has an opportunity to capture and communicate critical lessons and secure its legacy in its final two to three years of operation, and lay the foundation for subsequent work in the SADC region and beyond. This is the focus of Outcome 1 of the CRIDF programme, which seeks to establish a regional legal entity to provide similar services to those provided by CRIDF (CRIDF, 2020b). Securing its legacy and ensuring the sustainability and accessibility of learning, particularly around climate change and resilience, should be a priority for the CRIDF. Mechanisms for achieving this might be explored outside the context of the legal entity, given the likely risks and uncertainties inherent in this outcome.

In addition, CRIDF might use its final phase to address certain challenges and enhance and/or pilot certain activities, again ensuring that learning is captured and communicated. With this in mind, and based on the findings of this review, it is recommended that CRIDF undertake or at least consider the following activities, to the extent that they are practical and useful. These **recommendations** are more generally applicable to FCDO climate change programming.

1. Strengthen narratives around climate change impacts, vulnerabilities, risk and resilience at the project level, with a more comprehensive an explicit evidence base incorporating quantitative and qualitative climate information. Ensure that these narratives go beyond project justification to interrogate and frame project design.
2. Extend CRIDF's role as a knowledge broker to enhance and/or pilot more co-production of new knowledge. This should include locally generated knowledge, and its integration into planning, particularly at the project level. Currently, it appears that information exchange is heavily skewed towards the gathering of data from local stakeholders as part of vulnerability assessments. RBOs represent a potential institutional home for such knowledge brokering activities.

3. Support the establishment of community monitoring mechanisms to track climate trends, variability, impacts and vulnerabilities. This might involve the installation of small-scale infrastructure such as meteorological stations coupled with training, or be as simple as establishing a process via which communities report climate-relevant information that does not require specialist equipment. This information might relate to maximum and minimum river flows, rainfall onset and variation, duration of dry periods, and biological indicators based on plant and animal behaviour in response to seasonal changes. This would help to raise awareness and build local capacity for tracking changes and associated adaptation planning.
4. Pay closer attention to issues of longer-term sustainability and potential maladaptation in relation to the downstream impacts of smaller projects. Assess risks that these interventions will entrench patterns of water use, agricultural practices or even patterns of settlement that may not be viable under future climatic conditions. If such risks are identified, they can form a basis for the development of draft long-term strategies for transformational adaptation, based on principles of co-production and informed by community monitoring of climate and related trends.
5. Address the mismatch between scientific information and engineering needs and practices. Use principles of co-production to try and bridge the gap between climate information and design needs, particularly for smaller projects where design is not informed by dedicated (e.g. hydrological) modelling. Pilot initiatives in the final phase of CRIDF to generate and capture learning on bridging this gap and improving the use of decision-scaling and related approaches.
6. Pursue communication avenues to raise awareness of the decision scaling approach and how this differs from, and is preferable to, 'predict-then-act' approaches that are still widespread in some contexts. This approach could be strengthened and extended by blending it with related frameworks such as Climate Risk Informed Decision Analysis (CRIDA) and the Decision Tree Framework, and linking with longer-term risk assessments and phased strategies for transformational adaptation.
7. Review how external stakeholders responsible for project implementation have been supported, and carry out ex-post evaluations of the use of information in practice (as compared to guidance) for a range of projects; identify lessons about how this support might be improved, for example in the context of future programmes.
8. Distil and widely communicate lessons around the relationship between resilience, adaptation and development, and implications for current climate financing models, particularly those based on the concept of additionality.
9. Consolidate and communicate lessons around good practice in the use of climate information and adaptation decision-making, based on CRIDF experience.
10. Consolidate learning and ensure curation and communication of information, learning, tools and guidance so they remain accessible beyond the close of the programme, regardless of the success of the outcome related to the establishment of a legal entity to provide similar services to CRIDF.

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Appendices

Appendix 1: CRIDF Staff Consulted

A small number of key CRIDF staff and consultants were interviewed for this assignment, over seven separate interviews, as detailed below.

Interview no.	Date of interview	Interviewees	Subject of Interview
1	27.07.2020	Charles Reeve (CR) – Head of Programme Jeremy Richardson (JR) – Climate Change Lead	Overview of CRIDF programme and its activities, use of climate information, initial scoping in relation to research questions
2	28.07.2020	Leonard Mangara (LM) – Chief Engineer Charles Reeve (CR) – Head of Programme	Use of climate information in project engineering contexts
3	30.09.2020	Andrew Takawira (AT) – Head of Stakeholder Engagement	Communication of climate information and findings, stakeholder engagement processes and mechanisms
4	13.10.2020	Stuart Steath (SS) – Infrastructure Projects Lead Tsungai Mavambe (TM) – Infrastructure Projects – PM Support Leonard Mangara (LM) – Chief Engineer	Engineering and infrastructure approaches from project perspective
5	14.10.2020	Mike Harrison (MH) – External Climate Change Consultant	Generation of climate information with a focus on projections, scenarios and use of self-organising maps
6	21.10.2020	Jeremy Richardson (JR) – Climate Change Lead	Further discussion on use of climate information based on learning to date
7	31.10.2020	Gordon Freer (GF) – Evidence and Learning Lead Gerry McDonald (GM) – Evidence and Learning Manager	Monitoring, evaluation and learning and measurement of impact
8	11.11.2020	Sharmala Naidoo (SM) – Lead, Mobilising Finance Team	Finance, framing, programme management mechanisms

Appendix 2: Programme-level documents consulted

List of strategic, programme-level documents consulted. Project-level documentation consulted is listed in Annex 4.

- CRIDF, 2020. CRIDF Outcomes Harvesting Interim Report (draft).
- CRIDF, 2020. Final TWM Annual Review.
- CRIDF2 logframe v12 Update, April 2020.
- CRIDF 2020. Revised Theory of Change Jan 2020
- CRIDF, 2019. Basin-wide Livelihood Vulnerability Hotspot Mapping Methodology: Building Inclusive River Basin Resilience.
- CRIDF 2019. GESI Toolkit for Project Preparation, April 2019.
- CRIDF 2018. Climate Risk and Vulnerability Assessment Tool, Jul. 2018
- CRIDF 2018. Climate Risk and Vulnerability Assessment Tool: Communities and Water Infrastructure Projects, Jun. 2018.
- CRIDF 2018. Climate Risk and Vulnerability Assessment Tool: Communities and Water Infrastructure Projects Guidance, Jun. 2018.
- CRIDF, 2017. Stakeholder Engagement and Influencing Strategy. Final Draft for Review by DFID, 22 September 2017.
- CRIDF 2017. Environmental Assessment Guidance, 22 September 2017.
- CRIDF 2101. Mobilising Finance Strategy, 22 September 2017
- CRIDF, 2017. Climate Resilient Development Pathways: Final CRDP Guidance (Guidance Paper), March 2017.
- CRIDF, 2017. OVI7: Final CCRA Report (Nondvo Dam). Climate Finance, FP29. Version 1.0. CRIDF, March 2017.
- CRIDF, 2017. Resilience Strategy for Climate Resilient Infrastructure Development Facility – Phase Two, September 2017.
- CRIDF 2016. CRIDF Procurement Policy, 16 February 2016, version 1.3.1.
- CRIDF, 2016. Southern Africa Projections and Impacts (Guidance Paper). CRIDF, 11 February 2016.
- CRIDF, 2015. Final Resiliency Screening and Climate Change Risk Assessment Guidelines (PROTOCOL), 6th Nov. 2015.
- CRIDF 2015. Cost-Benefit Analysis – CRIDF Guidance & Template, August 2015.
- CRIDF Climate Vulnerability Tool Web Map, developed in 2014.
- CRIDF 2014. Generic Scope of Works for: Eligibility & Scoping, 01/12/14.
- CRIDF 2014. Generic Scope of Works for: Procurement & Implementation Monitoring, 01/12/14.

- CRIDF 2014. CRIDF Procurement Guidelines, 12 December 2014.
- CRIDF CIVAT Tool (Okavango Basin version).
- CRIDF Climate Resilient Engineering Design Considerations (checklist/menu).
- Tools for integrating climate resilience into infrastructure planning: Case study.
- SOMS explanation (from Mike Harrison).
- Climate Change Risk Assessment Risk Matrix Tools Track 1 and 2.
- Stage 1 Assessment Tool, undated: document Extlib58.
- Stage 2 Assessment Tool, undated: document Extlib59.

Appendix 3: List of CRIDF projects examined and reviewed

See separate spreadsheet.

Annex 4: Summaries of project reviews

See separate Word document.

Annex 5: Notes from project reviews

See separate Word document.

Annex 6: Notes from interviews with CRIDF staff

See separate .zip document.