Grantham Research Institute on Climate Change and the Environment

Centre for Climate Change Economics and Policy

Climate information needs in Southern Africa: a review

Daleen Lötter, Claire Davis, Emma Archer, Katharine Vincent, Joanna Pardoe, Mark Tadross, Willem Landman, Sabine Stuart-Hill and Graham Jewitt

June 2018

Centre for Climate Change Economics and Policy Working Paper No. 335
ISSN 2515-5709 (Online)

Grantham Research Institute on Climate Change and the Environment Working Paper No. 300
ISSN 2515-5717 (Online)

NERC SCIENCE OF THE ENVIRONMENT

FUTURE CLIMATE FOR AFRICA

UKaid from the British people

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

The Grantham Foundation for the Protection of the Environment

UNIVERSITY OF LEEDS

LSE The London School of Economics and Political Science

The Centre for Climate Change Economics and Policy (CCCEP) was established by the University of Leeds and the London School of Economics and Political Science in 2008 to advance public and private action on climate change through innovative, rigorous research. The Centre is funded by the UK Economic and Social Research Council. Its second phase started in 2013 and there are five integrated research themes:

1. Understanding green growth and climate-compatible development
2. Advancing climate finance and investment
3. Evaluating the performance of climate policies
4. Managing climate risks and uncertainties and strengthening climate services
5. Enabling rapid transitions in mitigation and adaptation

More information about the Centre for Climate Change Economics and Policy can be found at: www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established by the London School of Economics and Political Science in 2008 to bring together international expertise on economics, finance, geography, the environment, international development and political economy to create a world-leading centre for policy-relevant research and training. The Institute is funded by the Grantham Foundation for the Protection of the Environment and the Global Green Growth Institute. It has six research themes:

1. Sustainable development
2. Finance, investment and insurance
3. Changing behaviours
4. Growth and innovation
5. Policy design and evaluation
6. Governance and legislation

More information about the Grantham Research Institute on Climate Change and the Environment can be found at: www.lse.ac.uk/grantham

The Future Climate for Africa UMFULA project is a four-year research project that aims to improve climate information for decision-making in central and southern Africa. More information about UMFULA can be found at: www.futureclimateafrica.org/umfula/

CLIMATE INFORMATION NEEDS IN SOUTHERN AFRICA: A REVIEW

Daleen Lötter[1], Claire Davis[1], Emma Archer[1 7], Katharine Vincent[2], Joanna Pardoe[3], Mark Tadross[4], Willem Landman[5], Sabine Stuart-Hill[6] and Graham Jewitt[6, 8]

[1] Council for Scientific and Industrial Research, South Africa
[2] Kulima Integrated Development Solutions, South Africa
[3] London School of Economics and Political Science
[4] University of Cape Town
[5] University of Pretoria
[6] Centre for Water Resources Research, University of Kwazulu Natal
[7] Global Change Institute, University of the Witwatersrand
[8] Umgeni Water Chair of Water Resources Management, School of Engineering, University of Kwazulu Natal

Acknowledgements

The authors would like to thank Prof Andy Dougill and Elias Nkiaka from the University of Leeds for reviewing this paper. This work was carried out under the Future Climate for Africa UMFULA project, with financial support from the UK Natural Environment Research Council (grant reference NE/M02007X/1) and the UK Government's Department for International Development. Further thanks are due to the Grantham Foundation for the Protection of the Environment, the ESRC Centre for Climate Change Economics and Policy, and the ACCESS programme for their support of certain of the work presented here, as well as those surveyed and consulted, for their time and efforts.

Table of contents

List of Acronyms

ACPC	African Climate Policy Centre
CCAM	Conformal Cubic Atmospheric Model
CIRDA	Programme on Climate Information for Resilient Development in Africa
CORDEX	Coordinated Regional Downscaling Experiment
CRU	Climatic Research Unit
CSAG	Climate Systems Analysis Group
CSC	Climate Services Centre
CSIR	Council for Scientific and Industrial Research
DRC	Democratic Republic of Congo
EWS	Early Warning System
FEWS-NET	Famine Early Warning Network
GCM	Global Climate Model
GCOS	Global Climate Observation System
GHCN	Global Historical Climate Network
HYCOS	Hydrological Cycle Observation System
NMHS	National Meteorological and Hydrological Services
MONIS	Real Time Extreme Weather and Climate Monitoring System
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction (models)
O&M	Operating and Monitoring
RBO	River Basin Organisation
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RIMES	Regional Integrated Multi-Hazard Early Warning System
RSAP	Regional Strategic Action Plan
SADC	Southern African Development Community
SARCOF	Southern African Regional Climate Outlook Forum
SARFFGS	Southern Africa Regional Flash Floods Guidance System
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SPI	Standardised Precipitation Index
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
TAMHO	Trans-African Hydro-Meteorological Observatory
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Reduction
WHO	World Heath Organisation
WMO	World Meteorological Organisation
WWW	World Weather Watch

1. Introduction

The effects of the extremely low 2015/6 summer rainfall levels seen across the Southern African Development Community (SADC) region have emerged as the most severe since the early 1990s (Archer et al, 2017). The impact of adverse climatic conditions can be exacerbated due to the ineffective use of forecasts, variously relating to the scientific presentation of seasonal forecasts and climate projections, lack of capacity to interpret the findings to suit the needs of different sectors, and challenges in interpreting forecasts in the context of a decision, or combining it with other information sources (Vincent et al, 2016).

Reliable and accessible climate information is a key need when managing current risks and adapting to anticipated future changes. Understanding the information requirements of different sectors is important both to inform evolving themes in climate research, and to produce tailored, useful and useable products in a timely and effective manner. In essence, this requires a move from climate science – which generates observations, forecasts and projections – to climate services – where robust climate information is based on user-identified needs at appropriate timescales (Goddard, 2016), and is presented in a user centric way. The generation of climate services that bridge the gap between climate providers and end users is developing, albeit ad hoc, as part of a number of programmes across southern Africa (see, for example, initiatives under the Global Framework for Climate Services), but still requires substantive and strategic attention.

There are, however, challenges to generating climate services – and these relate both to the supply of climate science and its application in particular environments/decision contexts. Key challenges faced by the climate science community include a lack of adequate climate observation networks across the region, insufficient institutional arrangements and trained manpower, and weak communication and computational capacity (Jones et al, 2014). Applying climate science to decision-making is difficult due to the inherent uncertainty and complexity of the climate as well as a rapidly changing socio-economic environment. There has been evidence of the 'front-end loader' approach to information transfer, where scientists work to improve dissemination of their science. However, this science is not always the information that is required for end-users. For science to remain relevant and for it to be applied, the outcome of climate research needs to both reflect and address the information needs of users. More specifically, needs for climate information differ between sectors depending on the kind of priorities and decisions that need to be made. It is thus critical to understand the information requirements and decision-making context of end-users also in relation to their capacities, may this be financial, training or human resources related. Such an approach facilitates the development of climate information and services that truly are of use to users (Vaughan and Dessai, 2014).

This review has two objectives:

- To review the current availability of climate information in a southern African context; and,
- To assess the climate information requirements of a variety of end users in the southern African region using empirical findings from an innovative regional survey.

The findings are based primarily on a literature review and survey results, combined with experiences of the authors in assessing needs, and producing and translating climate information to users in SADC, as well as past and current consultations.

2. Types of climate information and services available in southern Africa

Weather and climate information (hereafter climate information), including observations, analyses and forecasts at different time scales, is important for assessing the (potential) impacts of climate variability and change; and for planning associated risks and adapting to anticipated future changes in various socio-economic sectors. Weather and climate data are mostly derived and predicted on three different time scales; observational (meteorological monitoring), short-term (daily to seasonal forecasts) and long-term (inter-annual climate variability and climate change projections) (Figure 1). Climate services include the use of historical climate data sets to understand climate variability and trends over time, as well as more complex products such as predictions of weather on monthly, seasonal or decadal timescales. Climate information provides details of parameters that are either of direct relevance to end users – for example accumulated ten day rainfall data – to interpreted products, such as advisories that highlight implications of changes for particular sectors. An agricultural advisory, for example, may provide advice on irrigation scheduling based on how rainfall, temperature and evapotranspiration are likely to affect soil moisture levels.

The formal political mandate for producing and disseminating climate information falls under the remit of the National Meteorological and Hydrological Services (NMHS) of each country. However, there are various other SADC-based institutions that also contribute information on different time scales (Table 1), as well as regional initiatives such as SADC-Hydrological Cycle Observing System (HYCOS), which is highlighted as an outcome of SADC Water's Regional Strategic Action Plan (RSAP) IV. Climate information for SADC is also available from sources based outside of the region, for example the International Research Institute for Climate and Society at Columbia University, NOAA, the Norwegian Meteorological Institute, and the European Centre for Medium-Range Weather Forecasting. The importance of indigenous knowledge as the basis of local level decision-making in many rural communities across southern Africa has also been acknowledged (Ziervogel and Opere, 2010), but has not yet been contextualised into climate services. However further analysis of the role of indigenous and local knowledge in prediction and projection of climate information is beyond the scope of this paper.

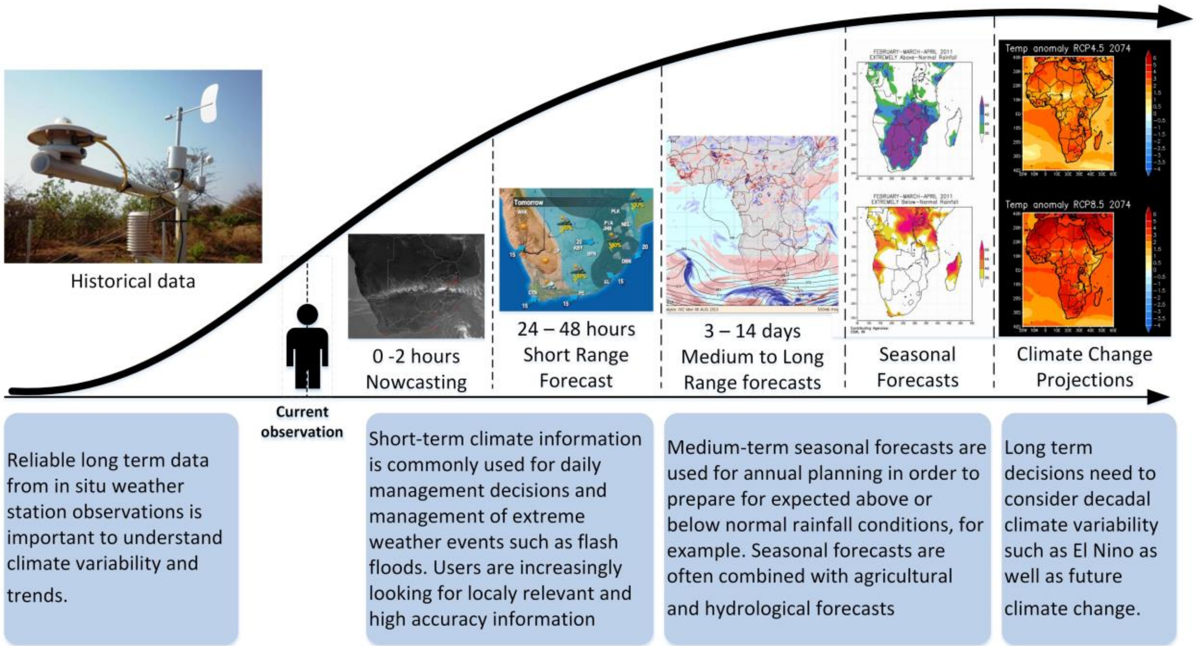

Figure 1: Types of climate information available; short-term weather forecasts (days), medium-term: seasonal climate forecasts (week to months), and long-term: climate variability and change (decades). Source: Davis-Reddy and Vincent 2017; figure reproduced with the authors' permission.

Table 1: Research institutions and organisations involved in development, interpretation and dissemination of climate information in southern Africa. Climate information for SADC is also available from sources based outside of the region, for example the International Research

Institute for Climate and Society at Columbia University, NOAA, the Norwegian Meteorological Institute, and the European Centre for Medium-Range Weather Forecasting.

	Institution	Type of climate information	Link
Historical climate data	CSAG, University of Cape Town	• Weather station data: temperature and rainfall	http://cip.csag.uct.ac.za/webclient2/app/
	Climatic Research Unit (CRU) Google Earth	• Weather station data: temperature	https://crudata.uea.ac.uk/cru/data/temperature/
Short-term Forecast	National Meteorological and Hydrological Services	• Daily and weekly weather forecasts, early warning information	*Per country department or agency*
	Famine Early Warning Systems Network (FEWS-NET)	• Severe weather warnings related to drought and food security	http://www.fews.net/
	SADC Climate Services Centre (CSC)	• Weather forecasting and early warning	http://www.sadc.int/sadcsecretariat/services-centres/climate-services-centre/
	Regional Integrated Multi-Hazard Early Warning System (RIMES) for Africa and Asia	• Multi-Hazard Early Warning System	http://www.rimes.int/
	UK Met Office	• Daily and weekly weather forecasts	http://www.metoffice.gov.uk/
	CSIR Meraka Institute	• Advanced Fire Information System (AFSIS) • Wide Area Monitoring Information System (WAMIS)	http://afis.meraka.org.za/
	CSIR	• CCAM weather forecasts	http://www.gfcsa.net/csir.html
	CSAG, University of Cape Town	• Weather forecasts	http://www.gfcsa.net/csag.html
	Locust Watch	• Information on the movement of locust swarms and the potential impact on agriculture	http://www.fao.org/ag/locusts/en/info/info/index.html
	Regional Specialized Meteorological Centre (RSMC) La Réunion	• Early warning system for tropical cyclones in south-west Indian Ocean	http://www.meteofrance.re/
Medium-term	National Meteorological and Hydrological Services	• Seasonal Forecasts in collaboration with CSC and SARCOF	*Per country department or agency*
	CSIR	• Seasonal Forecasts	http://www.gfcsa.net/csir.html
	SADC Climate Services Centre (CSC)/SARCOF	• Seasonal Forecasts	http://www.sadc.int/sadcsecretariat/services-centres/climate-services-centre/
Long-term	CSAG, University of Cape Town	• Statistically downscaled climate change projections	http://cip.csag.uct.ac.za/webclient2/app/
	CSIR	• CCAM Dynamically downscaled climate change projections	• ??
	CORDEX	• 50km resolution projections of climate up to the year 2100 for regions across the world	• ??

2.1. Weather forecasting

The World Meteorological Organisation (WMO) distinguishes several types of weather forecasts that are issued with a lead time of less than a month; nowcasting (0-2 hours), very short-range (up to 12 hours), short-range (12-72 hours), medium-range (72-240 hours) and extended-range weather forecasting (10-30 days). Long-range forecasting includes monthly and seasonal forecasts, and is issued with lead-times that typically range from 1 to 6 months.

Forecasting the weather begins by continuously observing the state of the atmosphere, the ocean, and land surface. The main inputs for this are country-based surface observations from weather stations, both automated and manual, which measure amongst others, air temperature, air pressure, wind, and humidity. This data is then assimilated into numerical weather prediction (NWP) models. NWP models are computer-based models of the atmosphere, representing the current atmospheric state on a three-dimensional grid, applying the physical laws and dynamical equations that govern how the atmosphere will change in time at each grid point, and repeating this process to generate a forecast.

2.1.1. Short-term weather forecasts

Across southern Africa, each of the SADC countries have their own National Meteorological and Hydrological Services (NMHS), making use of data provided from meteorological observation networks to deliver climate related services and products to different stakeholders. They are responsible for maintaining observation networks, and providing citizens, communities and business sectors with information, products and services derived from weather variables at a time scale of hours to months. Under the support of WMO, NMHS are required to monitor and forecast extreme weather events such as tornadoes, severe storms and tropical cyclones as well as longer time-range events such as El Niño-Southern Oscillation. This is typically part of mandated disaster management legislation – at both country and regional (SADC) scale. For immediate weather related shocks (cyclones, flash flooding etc), early warnings are usually issued by the NHMS. However, early warnings for longer term hazards, such as riverine flooding, drought and agricultural production, are normally issued by other ministries and institutions, who frequently meet to discuss with NHMS the current situation and expected evolution of weather/climate anomalies which may exacerbate the current situation. At the regional level the SADC Climate Services Centre (CSC) provides and disseminates operational services for monitoring and predicting extreme weather events. The Real Time Extreme Weather and Climate Monitoring System (MONIS) is the primary tool used to gather and visualize meteorological data for analysis and early warning (OCHA, n.d [1]).

2.1.2. Seasonal forecasts

The real-time operational issuance of seasonal rainfall and temperature forecasts for southern Africa has been undertaken for more than two decades - developed to improve the ability of users to cope with fluctuations in rainfall and temperatures on a seasonal time scale. Forecasts are usually issued for a period of three to six months, and are updated throughout the season. Seasonal forecasts typically apply probabilities to three equi-probable categories of above-, near- and below-normal rainfall totals and temperatures means. However, seasonal forecasts work on seasonal total quantities of rainfall, but not the distribution of rainfall within that period or the initiation of the rainy season (Landman et al, 2011). Notwithstanding, predicting seasonal characteristics, such as the number of days during which certain predetermined rainfall thresholds are expected to be exceeded, has skill (Phakula et al, 2018).

The SADC Climate Services Centre (CSC) provides monitoring of seasonal characteristics such as onset of rainy season, monthly rainfall predictions for 3 months ahead, flood potential prediction and drought potential analysis. The CSC hosts the Southern Africa Regional Climate Outlook Forums (SARCOF), which is a regional climate outlook prediction and application process adopted by the fourteen countries comprising the SADC Member States (Patt et al, 2007). The aim is to develop a region-wide consensus on climate outlooks for the upcoming (summer rainfall) season, which NMHS then contextualise to their national contexts and disseminate. SARCOF forecasts are issued in August/September for the October-November-December and January-February-March season. Updates are then issued during the season. Other regular monitoring tools such as the Standardised Precipitation Index (SPI) have also been successfully used as an indicator of drought conditions in South Africa (McKee et al, 1993).

---

[1] Notes - http://www.sadc.int/sadc-secretariat/services-centres/regional-climate-data-processing-centre/

Seasonal forecasts, if carefully targeted, may be a useful tool for reducing the risks related to seasonal climate extremes such as floods and droughts (Ropelewsky & Halpert 1989; Mason 1998). SADC CSC further issues agrometeorological updates which summarise observations from the season to date, provide an overview of crop conditions, report on any disease outbreaks and provide a brief overview of anticipated weather conditions. However, these bulletins are more retrospective-looking status updates than forward-looking interpreted climate information providing advice for agricultural practice. Other key users of the seasonal forecast include the humanitarian and disaster management sector, where forecasts are used to help prepare and plan for contingency and humanitarian responses.

2.2. Climate change projections

Climate change projections provide estimates of expected future changes, based on the average of simulated weather over longer time periods. The projections typically extend from the middle to the end of the 21st century, and are derived from atmospheric and coupled atmosphere-ocean General Circulation Models (GCMs). Run under different scenarios of greenhouse gas emissions (the Special Report on Economic Scenarios, or SRES), or different concentrations of greenhouse gases in the atmosphere (the Representative Concentration Pathways, RCPs), they simulate changes in atmospheric circulation, clouds, temperature, rainfall, and other parameters such as sea ice and glacier cover.

The resolution of Global Climate Models is typically low. There are two methods for downscaling these projections to regional scale: statistical downscaling and Regional Climate Models (RCM). The two largest climate change modelling centres within SADC are both in South Africa - the Climate Systems Analysis Group (CSAG) at the University of Cape Town, and the Climate Studies, Modelling and Environmental Health research group at the Council for Scientific and Industrial Research (CSIR) are respective experts in generating regional projections. CSAG produces regional climate change information using a statistical downscaling procedure, whilst CSIR uses a regional climate model – the Cubic Conformal Atmsopheric Model (CCAM) to simulate both present-day and future climate over southern Africa and its surrounding oceans. Both institutions are working together with non-southern

Africa based partners (under the Co-ordinated Regional Downscaling Experiment[2]) to evaluate and improve regional climate downscaling models and techniques to provide better climate change projections over southern Africa.

2.3. Improving the quality and skill of climate information

Southern Africa experiences a highly variable climate due to the complex topography of the region and its position between the Atlantic and Indian Oceans. High climate variability is also linked to the El Niño-Southern Oscillation (ENSO), which is the dominant mode of interannual variability over eastern and southern Africa (Landman et al, 2011; Nicholson and Entekhapi, 1986; Nicholson and Selato, 2000). El Niño is a recurring natural climate phenomenon, and the occurrence of extreme El Niño events may double in the future as a result of greenhouse gas warming (Cai et al, 2014). This is important for southern Africa since El Niño events typically – although not always – bring lower than average rainfall to the region (Nicholson and Kim, 1997) and can be associated with drought (Hoell et al, 2015). In southern Africa, seasonal forecast skill is strongly dependent on the existence of active El Niño or La Niña events (Landman and Beraki, 2012).

Determining future climate in southern Africa is complicated due to the operation of a variety of different factors. The aforementioned limitations of the ability of climate models to accurately represent southern African climate make seasonal forecasting more challenging over the region, even though significant progress has been made in the development of seasonal forecasting system in South Africa (Landman, 2014). For example, weather forecasts for the next day may be predicted correctly nine out of ten consecutive days, but for seasonal timescales, even during the mid-summer season of highest predictability, forecasts are typically correct only about three out of five summer seasons (Landman et al, 2011). According to Kusunose and Mahmood (2016), seasonal forecasting has therefore often not achieved the desired precision and accuracy, especially for enterprises such as agriculture, where relatively small changes in predicted weather events can cause losses in crop and livestock production.

---

[2] Coordinated Regional Climate Downscaling Experiment (CORDEX) of the World Climate Research Program (WCRP), uses the latest generation of regional climate models (RCMs) to provide 50km resolution projections of climate up to the year 2100 for regions across the world.

3. Climate information infrastructure and communication needs

Challenges to the generation and communication of effective climate information follow from inadequate data availability and poor capacity to compile, analyse and interpret data. These challenges are compounded by poor budgetary allocations and limited human capacity.

3.1. Meteorological observation networks in SADC

An important thread that runs throughout the literature on climate information needs is the prerequisite for good meteorological observation networks to provide data. Long-term, reliable historical climate data provides the basis for understanding trends, deriving climate statistics of interest, and placing current observations into a historical context. Quality controlled historic data are the basis for downscaling and calibrating forecast products, calibration of satellite data and assessing the performance of forecasting systems (GCOS, 2006). Adequate climate observing systems are essential for effective climate risk management across different sectors.

The weather and climate monitoring systems in SADC currently do not meet the requirements of weather and climate monitoring as recommended by the World Meteorological Organisation through the World Weather Watch (WWW) and Global Climate Observation Systems (GCOS). The WMO's Annual Global Monitoring Report noted that 26 per cent of Global Surface Networks and 20 per cent of the Global Upper Air Network stations within southern Africa are non-operational, and most of the remaining stations are poorly performing. According to SADC's Regional Infrastructure Development Master Plan for the Meteorology Sector (SADC, 2012), most countries in SADC lack an adequate observation network of both surface and upper air stations as well as remote sensing such as radar networks. The density and coverage of existing climate observations over most of Southern Africa is typically very sparse (Figure 2). Many stations are also inoperative due to lack of equipment and consumables (GCOS, 2006).

There is thus an urgent need to strengthen the meteorological observation network across southern Africa. In the SADC Meteorology Sector Plan of the Regional Infrastructure Master Development Plan, a comprehensive strategy is outlined, whereby a number of projects and interventions have been proposed to strengthen the Meteorological Observation Network in the SADC Region by 2027. These include the Trans-African Hydro-Meteorological Observatory (TAHMO), which seeks to install 20,000 automatic weather stations across sub-Saharan Africa and the United Nations Development Programme, through its Programme on Climate Information for Resilient Development in Africa (CIRDA) which is working in 11 African countries, including Tanzania, Malawi and Zambia in SADC. Further efforts to adapt existing networks to cope with expected increases in climate hazards due to climate change are being funded through international climate finance sources. This includes, for example, the Green Climate Fund support for a project in Malawi, Climate Investment Funds support to Mozambique and Zambia through the Pilot Program for Climate Resilience, as well as other planned Africa-wide investments in hydro-meteorological infrastructure. However, these investments can only proceed if governments are willing to cover the costs of operating and maintaining (O&M) existing and planned investments. The sustainability of these networks is a key consideration and reason for supporting the introduction of low-cost (capital and O&M) alternatives such as TAHMO and use of satellite-derived data where possible.

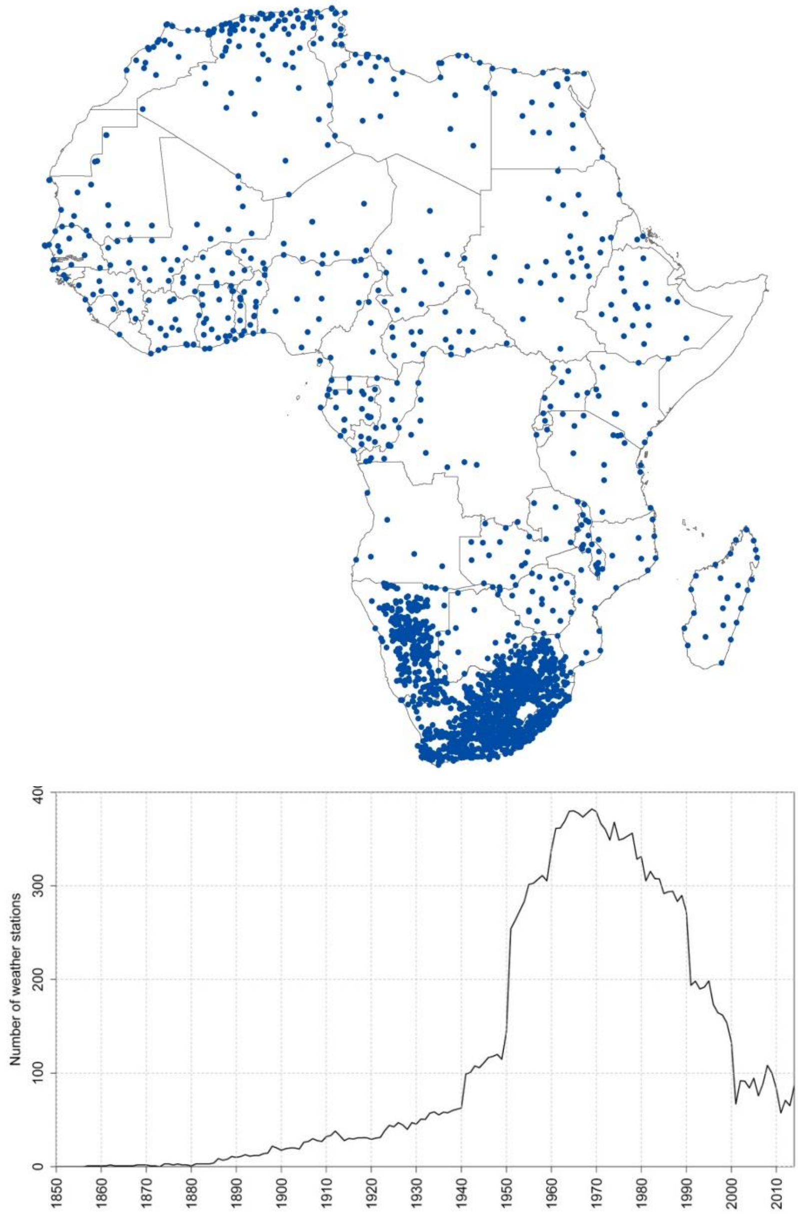

Figure 2: Location of NOAA's Global Historical Climate Network (GHCN) weather stations, as used by CRU, across Africa (top) and the number of weather stations collecting daily temperature records across southern Africa from 1850 to 2014 used in the gridded CRUTEM4 product. Source: Davis-Reddy and Vincent 2017.

3.2. Interpretation and communication of climate information

In addition to gaps in observational data, there are also deficiencies in the analysis of meteorological data and its translation into products. Such gaps include a lack of modern telecommunications infrastructure for efficient exchange of data and products, as well as inadequate and uncoordinated data management systems and real-time data processing facilities, including forecasting and dissemination systems. Even where these systems are in place, there are further challenges associated with technical capacity, availability of professional staff and applications software (ACPC, 2011). Technical improvements and modernization of infrastructure will be unsuccessful unless there are qualified and experienced meteorologists to use the tools to generate timely warnings and improved forecasts. Building such capacity requires sustained efforts (Hewitson, 2015). In addition, coordination is essential. Further, various programmes use different software and have different approaches (e.g. TAHMO, SASSCAL and SADC-HYCOS, and NMHS) that exacerbate the issue.

Even if the climate information is accurate, scientists tend to rely on scientific language and visuals to convey the message, which is frequently insufficient to inform decisions and practical applications (Wilke and Morton, 2015). The effective uptake of climate information and services amongst the end user community in Africa is mainly dependent on relevance, accessibility and familiarity of the products to the users (Ziervogel et al, 2008). There typically remains a gap between what is currently provided by the scientific community and what is needed as a result of a lack of knowledge and understanding of user needs (Tall et al, 2014; Blench, 1999).

User needs assessments have taken place in various contexts around different timespans of weather and climate information needs - what is evident here is an emerging common set of findings when assessing the uptake of climate information into national planning and decision-making (refer to Figure 3 for some examples) (e.g. Vincent et al, 2017; Jones et al, 2015; Steynor et al, 2016; Koelle et al, 2014). Barriers to uptake often include scale, accessibility and credibility, policy planning cycles and timing (Vincent et al, 2017). These barriers interact in a number of ways that restrict the flow of climate information, and in order to overcome them it is important to understand the inter-relationships and driving mechanisms.

Figure 4 shows the relationships between barriers, which restrict the flow of climate information. Reliable climate data (R1) is driven by government and/or regional support and funding (R2) the presence of capability building and skilled technical staff to produce and disseminate climate information to users (B1). Accessible climate information needs to be driven by user needs and effectively targeted scientific outputs as well as the ability of the users to interpret and apply climate information (R3)(ACPC, 2011). Improving climate services will only be successful if there are increased interaction with users and better communication of the science (Davis 2012, Vincent et al, 2015).

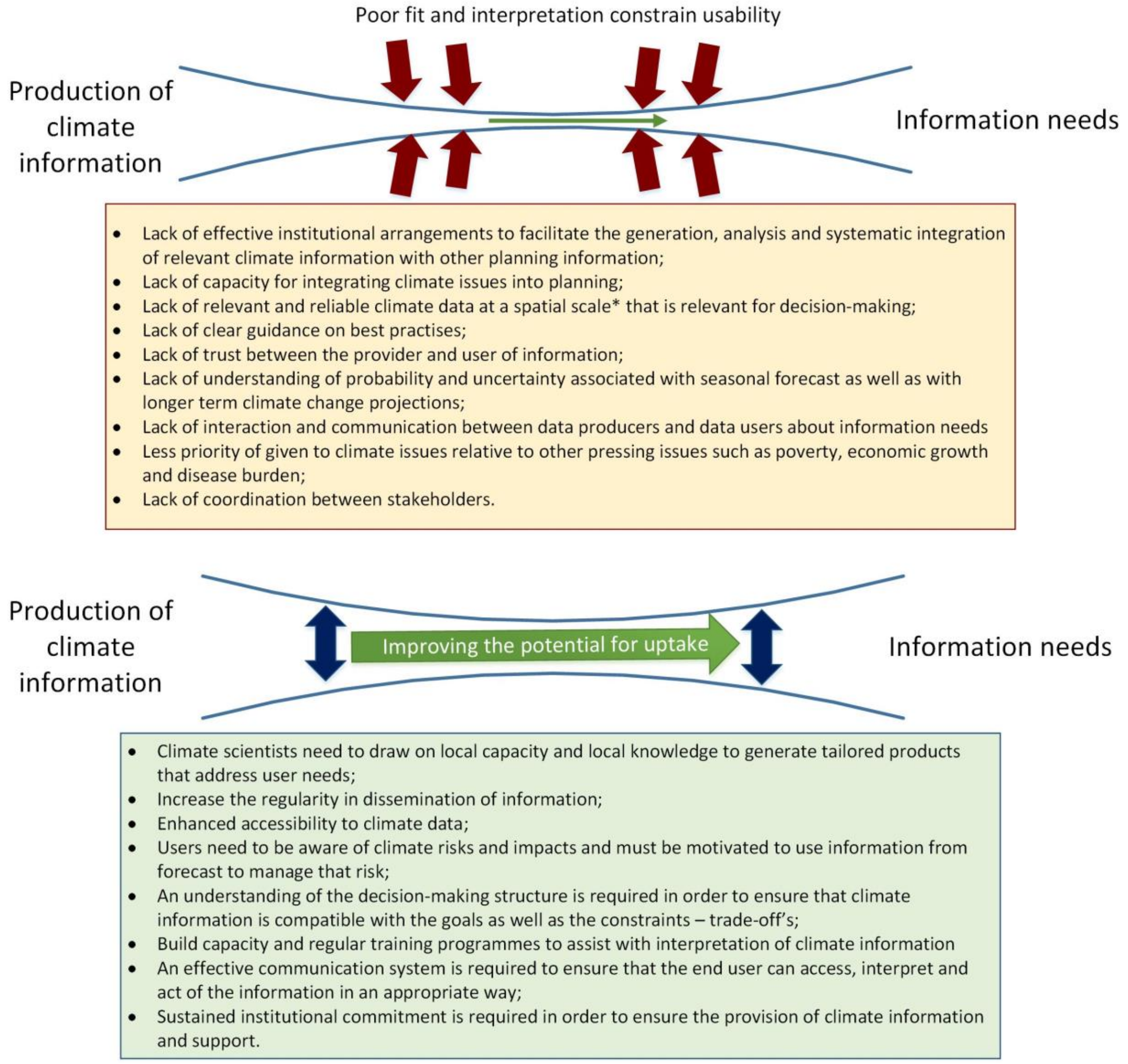

Figure 3: Conceptual model of flow of climate information from producers and users with (a) outlining primary barriers to uptake of climate information and (b) potential actions required to overcome these barriers. Illustration adapted from Lemos et al., (2012).

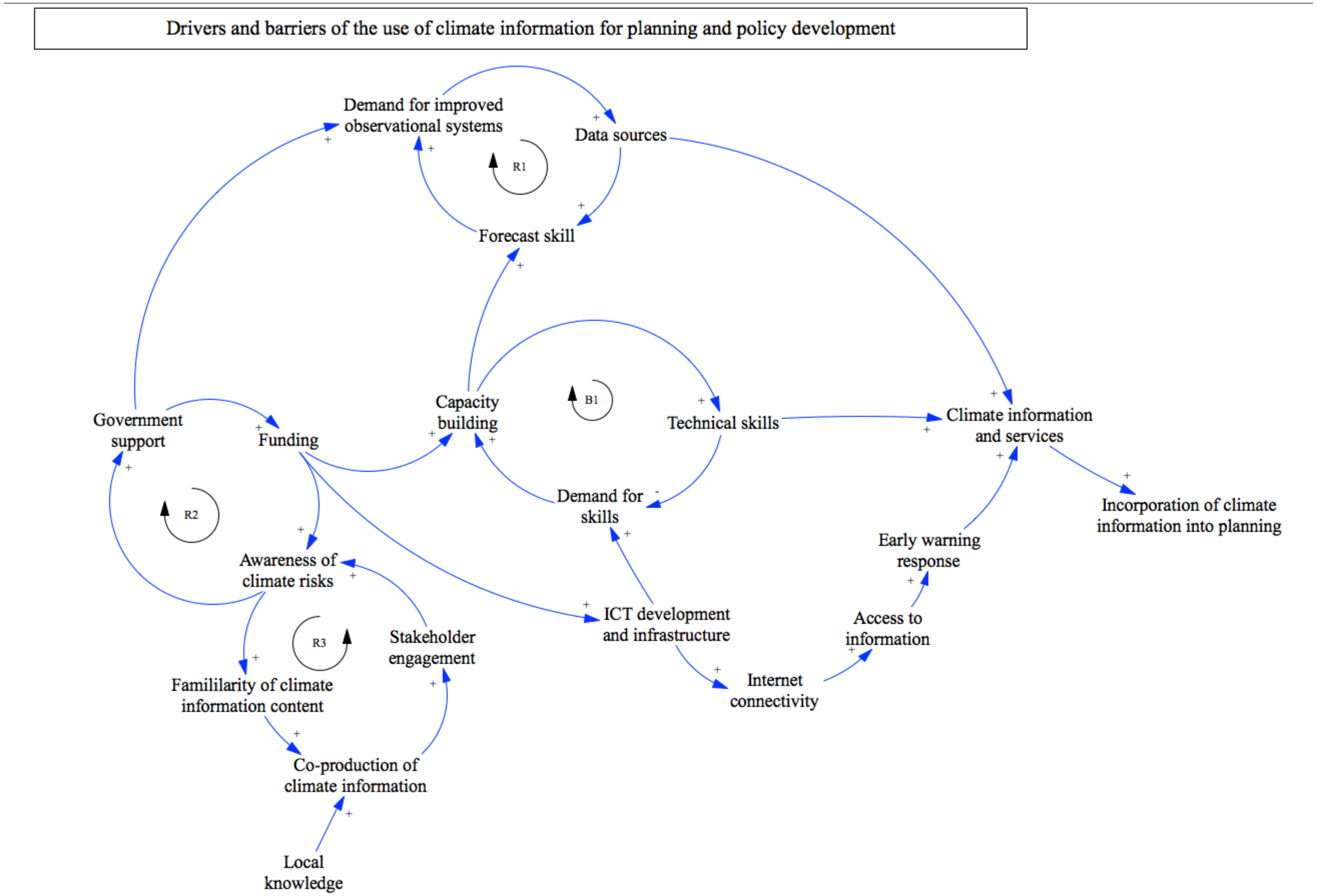

Figure 4: Casual loop diagram illustrating the drivers and barries of the use of climate information for planning and policy development where R1 refers to need for reliable climate data; R2 the need for government support and funding; R3 the importance of stakeholder enegagement and the co-production of climate information with end users; and B1 the need for skilled techical staff to produce and disseminate climate information to end users.

4. Use and barriers to use of climate information in southern Africa

This section presents findings from user needs assessments in southern Africa as part of a USAID funded project - climate information needs assessments were conducted through an online questionnaire (refer to Appendix A), and in country interviews in Mozambique, Namibia, Zambia and Zimbabwe, supported by literature for the other SADC member states. The purpose of the assessment was to understand the existing uptake of climate information in decision-making structures and the various barriers to uptake.

4.1. Questionnaire results

The questionnaire was designed and distributed to stakeholders operating in southern Africa. Stakeholders were identified though a stakeholder mapping exercise (refer to Appendix A), which gathered data on individuals and organisations actively involved in the climate change sector and decision-making processes, as well as users or potential users of climate information in southern Africa. The purpose of this exercise was to:

- Establish the current impacts of climate which are of concern and the possible responses to minimise these impacts;
- Determine what climate information might be relevant to their needs;
- Understand constraints to using climate information;
  Determine the format in which stakeholders would like the results to be represented (for example raw data, interactive website and/or maps).

The majority of questionnaires were completed by stakeholders operative in South Africa (n=10). Other represented countries include Botswana, Lesotho, Malawi, Mauritius, Namibia, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. National government and research sectors were equally represented, accounting for 60% of the stakeholders surveyed. The research sector was further divided into the areas of interest, of which water resources, conservation and agriculture were equally represented. The other sectors represented included local government, Non-Governmental Organisations, private sector, and academic institutions (3%). The NGO sector was represented by stakeholders operative in both tourism and conservation.

More than half of the stakeholders utilised climate and/or weather information, and the majority of stakeholders felt that there was a need to use such information. The type of climate information that was most widely used was own weather records, daily/weekly forecasts as well as long-term (3 month predictions) (Figure 5). This information was utilised for short-term planning, management and research purposes. Poor internet connectivity, spatial accuracy of prediction models and the inability to know where to find the data were highlighted as key barriers to utilising climate change information. Furthermore, concerns were raised about lack of understanding and uncertain predictions from climate change models.

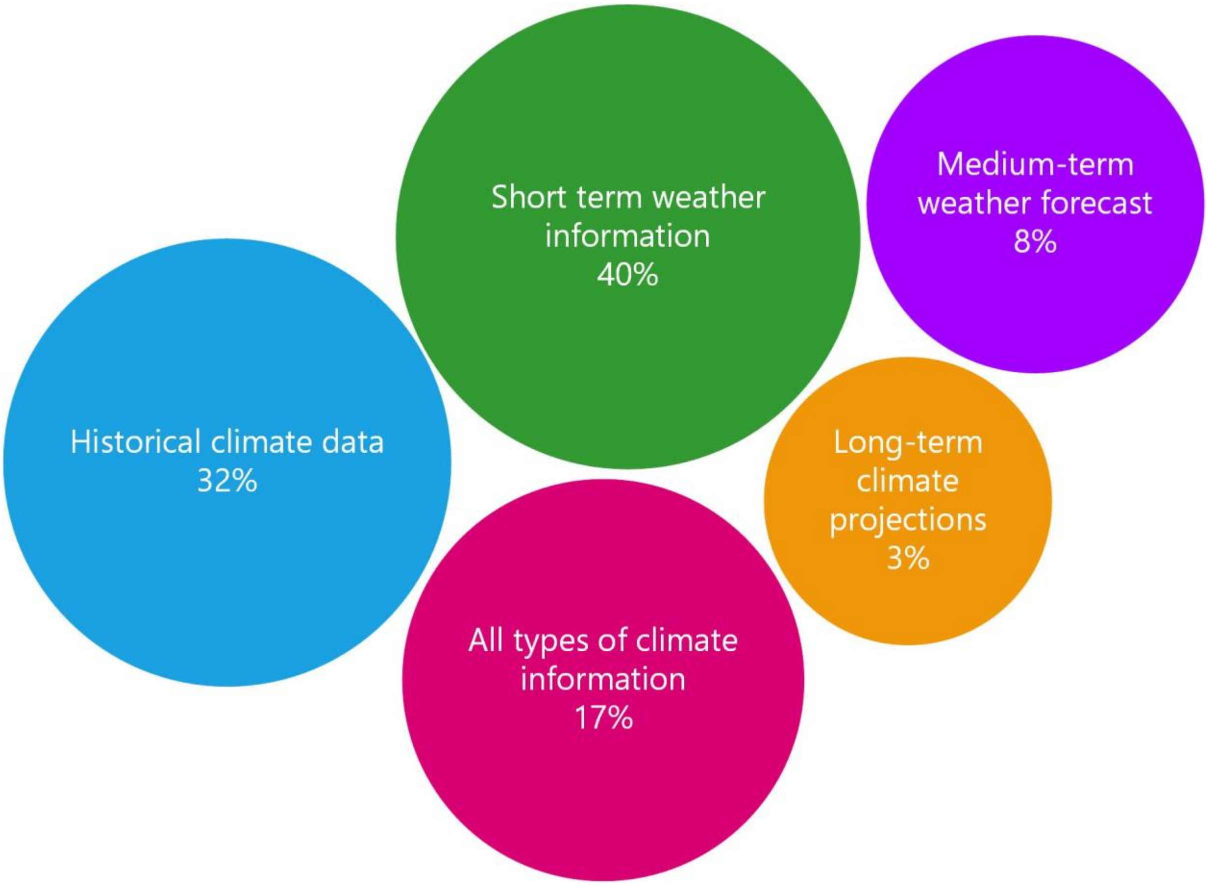

Figure 5: The types of climate information that stakeholders utilise (Davis 2012)

4.2. Interview Results

Table 2 shows the use and barriers to use of climate information cited by representatives from different SADC countries.

Table 2: Key climate information needs identified per country in SADC

Country	Climate information needs	Barriers to uptake of climate information into planning
Mozambique	• Given Mozambique's 2,700 km stretch of coastline, there is a great need for mapping and predicting risks associated with sea level rise (USAID, 2013). • Early warning and flood prediction in coastal zones as well as rivers in the central region (CSAG, 2014; USAID, 2013). • Climate info regarding vector- and water-borne diseases (USAID, 2013). • Climate info regarding future impacts in urban areas (CSAG, 2014). • Better understanding of regional atmospheric circulation (Indian Ocean dynamics and the El Niño Southern Oscillation (ENSO)) to improve seasonal forecasts (McSweeney et al., 2010; USAID, 2013).	
Namibia	• Information on seasonal fluctuation, and extreme events such as floods, drought especially in rural/remote areas (UNDPCC, 2010). Agricultural specific predictions (agriculture weather forecast). • Presenting information in different indigenous languages of Namibia (UNDPCC, 2010). • Improved data and data management for effective flood forecasting in the northern part of Namibia. • Improved early warning of extreme events (UNDPCC, 2010). • Need for services and infrastructure to support the production and distribution (channelizing) of modelled information and to support the execution of the information.	
Botswana	• Climate information relevant to livestock production such as drought and heat stress indicators (Thornton et al., 2015). • Climate change relevant information on conditions favourable for malaria	

	outbreaks outside endemic areas (towards the south of the country). Omari, 2010. • Updated and fine scale climate change information for input into surface water runoff and groundwater recharge modelling (Post et al., 2012). •	
Zambia	• Inadequate weather and climate information infrastructure, which limits data collection, analysis and provision of meteorological services (it is important to note that improved observation per se does not alone result in better forecasts) (Helmschrot *et al*., 2016; Venäläinen et al., 2015) • No long-term sustainability of observational infrastructure and technically skilled human resources (Venäläinen et al., 2015). • Forecast products are too technical and produced in a foreign language.	• Limited knowledge and capacity to effectively forecast future climate events as a result of an acute shortage of technology and skilled human resources; • Weak institutional coordination between institutions leading to limited packaging, translating and disseminating of climate information and warnings; (Helmschrot *et al*., 2016)
Zimbabwe	• Improve national monitoring system and network (see comment in section for Zambia above) • Strengthening systematic observations (Helmschrot *et al*., 2016) • Seasonal forecasts: knowledge on seasonal forecast is limited • Modelling of time scales other than conventional time frames (e.g. between seasonal forecasts and multi-decadal climate change) (source: SARUA-Vol2No12-Zimbabwe-Country-Report)	• Better accessibility of climate data to researchers • Capacity gaps - Shortage of climate modelling experts • Packaging of climate change information in formats that are appropriate to different stakeholder groups such as policy makers, industry and commerce, extension workers, NGOs, donors and farmers; • Communication: Interpretation of seasonal forecasts to lay people i.e. language used in forecasts (Helmschrot *et al*., 2016)
Tanzania	• Serious constraints to systematic monitoring of climate as a result of inadequate meteorological data and infrastructure. • More timely and focused dissemination of weather forecasts to farmers (rainfed) by improving data	• Invest in efforts to develop and test appropriate climate change terminology in Swahili and other languages.

	collection, knowledge integration and information dissemination (Tumbo et al., 2010). • Updated sea-level rise and extreme water levels information (Kebede and Nicholls, 2011).	
Democratic Republic of Congo	• Need to rebuild the climate station network (weather stations have been damaged during conflict or have ceased to function) (Mason *et al.*, 2015) • Gather and restore what historical data is available. • Climate info regarding vector- and water-borne diseases (USAID, 2012). • Mapping and predicting risks associated with sea level rise (USAID, 2012).	• Invest in capacity building to ensure that the technical skills required to generate, understand and use climate data are in place
Angola	• Critical lack of meteorological data and infrastructure as a result of long periods of conflict. • Lack of systematic and extensive data collection. • Serious need for translating climate change information into risks for food security, health and coastal zones. • Food security – Urgent need for climate change impacts on Angolan production systems. More fine-scaled climate change data and information on extreme events to use as input in crop models (Pereira, 2017). • Health – Information needs on future prevalence of malaria in the Angolan highlands, infectious diseases associated with flooding. • Need for more robust climate data to improve flood monitoring in coastal zones and low lying areas. –(30 percent of Angola's population lives within 100 km of the coast (Cain, 2017). • Improved, more fine-scaled climate modelling to provide climate information for impact studies, especially in areas characterized by a	• Climate information, training, and analysis in Portuguese. • Financial, technical and capacity support for improved monitoring and recording of observational climate data and projections of future climate change and impacts.

	diverse and heterogeneous land surface. • Strongly analytic, risk-based vulnerability assessments that identify geographic regions and economic sectors which are particularly threatened, in order to inform the development of adaptation policies and measures (USAID, 2012).	
Malawi	• Financial constraints towards maintenance of climate data systems and lack of funding to provide standard infrastructure. • Recovery of important long-term historical weather data from old computers (also require conversion to digital format). • Inadequate availability of climate-risk information (i.e. climate change data applied and translated into risk and vulnerability for specific sectors) (Venäläinen et al., 2015).	• Inadequate human resources for effective climate data capture and management (Venäläinen et al., 2015). • Better communication and packaging of climate change information in formats that are appropriate to different stakeholder groups. • Need to improve individual and institutional capacity for analysis of data, hazard mapping, modelling and the use of scenario-based tools for long-term planning (Venäläinen et al., 2015).

4.3. Case study on the usability of seasonal forecasts-lessons from SARCOF

As mentioned earlier, seasonal forecasts have been issued by national and regional metrological offices in southern Africa since the 1990's, but the extent of uptake is limited, partly since the nature of seasonal forecasts means that they are not appropriate for all users. Seasonal forecasts lack spatial details and often have inappropriate temporal resolution (3 month average) and are difficult to interpret. For example, most of the seasonal rainfall forecasts are typically presented in rainfall categories representing probabilities for the highest, middle and lowest third of seasonal values to occur. Even when seasonal predictions are understood properly, it may not be obvious how to use them, since the uncertainty in the predictions is very high and the predicted variable may not be immediately relevant to an impact or decision. This notion does not imply that seasonal forecasts cannot be useful. These problems simply emphasise the need for the development of tools that can translate such information to quantities directly relevant to end-users, and thus for better communication between modelling centres and end-users.

In order to understand the requirements of users, an open interactive session was held during SARCOF-15 in Namibia. A number of key challenges and requirements were raised, namely:

- Users requested that seasonal forecast information be made more specific to both locations and time-scales for events;
- Interpretation of forecast categories (above normal/normal/below normal) is challenging and users recommended that probability values for rainfall to exceed specific amounts would be of more value;
- Need to publish regular monthly rainfall totals with updated forecast in order to assess how the forecast is performing. This would assist with decision-making and preparedness;
- A revised 5 scale of very wet/wet/normal/dry/very dry was proposed as an alternative to standard 3 scale system of above normal/normal/below normal. This would account for more of the extremes which are being experienced;
- Probability-based forecasts need to be converted into risk based assessments for users;
- Timing of rainfall and dry spells as well the distribution of rain during the rainfall season are important sources of information required by the users;
- Requests to include estimates of tropical activity;
- Interpretation of rainy season information is required to ensure appropriate application across various sectors and decision-making processes.

5. Sectoral climate information uses, barriers and needs

Once climate information is derived from observational records, the usefulness thereof, on either short or long-term timescales, is tested when it is being applied in different socio-economic sectors. Different types of forecasting information and products are used in different ways within each sector, depending on the kinds of priorities and decisions that need to be made. Frameworks within which forecasts can be brought into sectoral decision-making processes can and should recognise that current conditions (and associated risks) affect the way a forecast is interpreted and even the skill and accuracy required for forecasts to be informative. This is an area of research that has, to date, received limited attention.

5.1. Agriculture and food production

In southern Africa, agriculture and food production will arguably be the most vulnerable sector to climate variability and change, due to the high dependence on agriculture for livelihoods and economic growth. The high level of vulnerability of farming is largely attributed to reliance on rain-fed agriculture accounts (Niang et al, 2014). In systems reliant on rainfall as the sole source of moisture for crop or pasture growth, rainfall variability both within and between seasons imposes significant uncertainty on production. Hence, seasonal rainfall forecast products with lead times of two to four months are particularly suited for rain-fed farming systems (Klopper et al, 2006). They can enable farmers and other stakeholders to adjust medium-term strategies in the context of the approaching season to make tactical decisions on timing of planting, weeding, crop varieties (Roudier et al, 2014) and farm more effectively in context of the variable weather (Cooper et al, 2008).

Seasonal forecast products are therefore advocated as a key adaptation strategy for farmers to reduce production risks posed by climate variability. However, a range of sources have also cited some challenges associated with seasonal forecast usefulness in the agricultural sector, including a number cited in this report. District Commissioners in Tanzania, for example have highlighted that they currently receive seasonal forecasts which they would like to integrate into their seasonal district plans - however, these forecasts are currently received after the district plans have been developed and approved (FCFA, 2016). Timely dissemination of seasonal forecasts for District planning may, therefore, be earlier than the lead time required for farmers. Other challenges in the southern African context include inappropriate spatial and temporal scale at which forecasts are issued, lack of supporting information to interpret implications of forecasts, and not receiving forecasts at all (Vincent et al, 2016).

Farmers in Sub-Saharan Africa will increasingly face risks associated with variable rainfall in terms of start and end of season, and amount and distribution of rainfall within growing seasons. In a recent study to address climate services needs of decision makers in Sub-Saharan Africa, the need for information on characteristics of rainfall other than monthly totals, such as when the rains might start, the likely duration of the wet season and the potential for dry spells within this came to the fore (Vincent et al, 2015). These needs were based on what decision makers thought they would ideally need to aid them in their planning, regardless of the scientific feasibility. The study further emphasized the need for sub-annual information on the occurrence of extreme events – especially floods and droughts, strong winds and hail, as well as insight into the location of these extremes. Improved spatial accuracy is also a significant need, since the regionally aggregated nature of forecasts are often not sufficient if the forecast is to be used on a local scale, for example at the village level. One possible solution to inappropriate temporal and spatial scales of forecasts, as an example, is to directly model crop yields trough building statistical links between climate model output and historical crop yield values (Malherbe et al, 2014).

Apart from the need for seasonal forecasting products with more climate variables at a finer resolution, there is also the need for longer term climate information. Climate change information is usually disseminated on fixed timescales such as early, mid and late-century projections. In Malawi for example, information on a 1–5 year timescale would enable departments to better support their three-year planning horizons (Vincent et al., 2015), while in Mozambique there is a strong need for more decision relevant climate information on the 5 to 40 year time frame (CSAG et al, 2014). Available climate information in Mozambique is largely restricted to historical data, and short-term forecasts informing disaster early warning, which makes it difficult to plan for long-term adaptation.

Although the potential benefits of seasonal forecast information in farming related decision-making processes are widely acknowledged, Tarakidzwa (2007) states that problems of effective dissemination and interpretation of seasonal forecasts still exist in many rural areas in Africa. There is a significant challenge in spreading the information to farmers and in supporting them to apply it in their particular situations. Such challenges are starting to be addressed by initiatives which focus on not just providing locally appropriate climate information, but engaging and training farmers to better understand and use the information in their farming decisions throughout the year. When forecasts are combined with agricultural advisories that elaborate on what actions farmers can take based on the information provided (i.e. when to plant, what crops might be most suitable for the projected rainfall, level of fertilizer input, etc.), the value of forecasts is markedly enhanced for farmers. In Malawi and Tanzania, for example, the Climate Services Adaptation Programme in Africa (a UN-led initiative spearheaded by the WMO) has launched pilot trainings where farmers receive climate data together with participatory tools to help them evaluate their options and make on-farm decisions. However, participatory training was found to be very time-consuming and it required a lot of resources. This means that relatively few farmers can benefit directly and it may be difficult to scale-up these initiatives.

Continued work is required in engaging farmers on interpreting seasonal climate forecasts. One approach is to supplement meteorological forecasts with farmers' indigenous knowledge of local weather indicators in predicting the seasonal climate. Understanding how local communities perceive and predict climate variability is essential to communicating scientific weather forecasts (Okonya and Kroschel (2013). Another option for disseminating forecasts is to disseminate forecasts through agricultural extension officers. Extension officers can be trained to interpret the forecasts, combining their local knowledge to provide farmers with a more tailored message and advice on cropping in line with their interpretation of the forecasts. Extension officers have often developed strong relationships with farmers in their local communities, which results in farmers trusting their advice more than they might a standard advisories coming from the national meteorological services.

5.2. Water resource management

Surface water is fundamental for many sectors in southern Africa, including agriculture, power generation and fisheries. Consequently, there is a strong link between economic performance and rainfall, as well as runoff. Already unreliable in much of the SADC region, access to water is predicted to become more challenging, with deteriorating water quality and the continued onset of climate change. In South Africa, it is anticipated that there will be a 17% gap between water supply and demand by 2030 (WWF-SA, 2017). In the future, competition amongst different sectors for limited water supplies might also constrain development efforts in many countries.

Within the SADC region, as mentioned earlier, there is significant spatial and temporal variability in rainfall (Nicholson, et al, 2017) and the availability of water resources (Malzbender and Earle, 2007). The rainfall-runoff ratio is generally low, with high evaporation rates resulting in approximately 80% of the continents rainfall being returned to the atmosphere (UNEP/GRID-Arendal, 2015). With few exceptions, utilisation of water resources requires investment in storage infrastructure combined with well-informed catchment management in order to ensure yield. Approximately, 70% of the catchment areas cross national boundaries, and least 15 of the major river basins are shared by more than one country, giving rise to efforts to manage these holistically through River Basin Organisations (RBO) (SADC, 2016).

At present, agriculture is by far the largest consumer of water in the region, using between 70 and 80 percent of available resources (SADC, 2016). However, it is estimated that only 7% of available irrigable land is being irrigated, compared to 20% in Africa as a whole (SADC, 2012). The Democratic Republic of the Congo holds the largest share of freshwater resources in SADC. Notably, the Congo River being the world's second largest in terms of flow, has very high hydropower potential that could contribute significantly to the needs of the continent. Both Rwanda and Tanzania's major rivers have also proven potential to support hydropower generation. In recent years, there has been considerable effort and focus on groundwater resources. In many places, groundwater can provide a reliable store of water for domestic and agricultural use. Efforts to map and exploit groundwater resources at national level are mirrored at the SADC level through efforts such as the SADC Ground Water Management Institute.

In Southern Africa, climate change is expected to significantly impact the availability and demand for water resources. The challenges thereof have become an important focus in long-term water resource management planning studies, especially when examining options for providing new water-related services and infrastructure. Appropriate climate information for effective decision making in the water sector is therefore crucial. Resource managers need to plan for infrastructure development, such as dams, reservoirs, irrigation schemes and hydropower generation. At present, many decisions and current planning (e.g. irrigation projects) are often based on relatively simple extrapolation of past annual averages or forward projection of information for the same times of the year, instead of being based on forecasts and linked model output. Such linear modelling is potentially problematic, as it assumes that the future will mirror the past, which may not be the case under projected climate change (Vincent et al, 2015).

Precipitation is the major driving variable in hydrological modelling, but also the most difficult variable to simulate in climate change scenarios (Wilby and Fowler, 2010). Even a limited climate model bias can substantially affect hydrological response. This translates into uncertainty of the usefulness of products for sector decision-making. Hence, in water resources planning at the regional to local scale, there is a huge need for downscaled data at finer space and time resolutions that can be used with confidence to translate physical variables into assumed variability in future water supplies, demands, and/or operational constraints (Fung et al, 2010).

On a shorter time scale there is a need to improve and apply seasonal forecasts for understanding effects of climate variation on flows and water demand. Although seasonal forecasts are known to be used in the agricultural sector, they have tended to have less application in the water management sector (Ziervogel et al, 2010). Seasonal climate forecasts could potentially benefit the water sector in making tactical decisions about water allocation and demand management. Dam planners and operators need to consider a multitude of factors and conflicting objectives, making day-to-day decision making problematic (McCartney, 2017). Developing a formal mechanism for comparing yield curves, current observations and seasonal forecasts could allow seasonal forecasts to be integrated into existing decision frameworks. Seasonal climate and streamflow forecasts can also provide vital information for government to prepare for extreme drought and other crises. In fact, in a recent study on the predictability of seasonal inflows into Lake Kariba it was shown that the onset of inflows into the lake as well as the inflow during the main inflow season is possible with several months lead time (Muchuru et al, 2014).

Ziervogel et a,. (2010) explored reasons for water resource managers not making use of seasonal climate forecasts in their planning. The study drew on experiences of water resource managers in the Cape Metropolitan area in the Western Cape region of South Africa. Results indicated that managers would rather use short-term (daily to fortnightly) forecasts as opposed to seasonal forecasts since the latter were seen as less skilful, and thus less useful, than short-term forecasts. Water resource managers did, however, acknowledge that seasonal forecasts could be useful to inform planning in terms of, for example, whether to apply water restrictions, prepare for emergencies, and whether to make an environmental flood release. However, managers suggested that uptake and use of forecasts would be enhanced if climatologists could improve forecast skills, provide better context of drivers behind the seasonal forecasts, and provide reference to normal (or mean) values. In addition to current available information, managers indicated that data on historical as well as predicted rainfall intensity, change in temperatures and wind conditions could be useful in planning irrigation schedules, flood prediction, water transfer planning and design of stormwater infrastructure.

Once again, good observational records of rainfall and streamflow underpin the ability to do hydrological modelling and planning of water supplies, as well as the distribution thereof. These climate and hydrologic data provide the foundation upon which operational water management strategies can be developed. Rainfall is one of the key driving variables of any hydrological model, yet over most of southern Africa as mentioned earlier, there is a very poor spatial distribution of rainfall measuring stations (Wheater, 2007; see also Figure 2), and the network is declining (Nicholson et al, 2017). This situation is exacerbated by frequent missing data, closure of stations or the complete collapse of hydrological monitoring during periods of social and political upheaval and a lack of coordination of data gathering efforts. The prospects for improving the network of ground-based measurements would seem to be poor and therefore the future probably lies in the use of satellite and radar measurements, despite efforts such as SASSCAL and TAHMO.

Hydro-meteorological extremes underpin many disasters in southern Africa, and are projected to increase in occurrence as well as intensity under climate change. Flow forecasting is a key component of hydro-meteorological monitoring and is led by the 3rd phase of the SADC-HYCOS (Hydrological Cycle Observing System) under the banner of the WMO. This seeks to integrate SADC-HYCOS into Regional Disaster Risk Reduction and Flood Risk Management, to integrate SADC-HYCOS with the Southern Africa Regional Flash Floods Guidance System (SARFFGS), and to disintegrate SADC-HYCOS into RBOs (WHYCOS, 2017). This will hopefully lead to increased preparedness and awareness across the continent in the near future.

5.3. Human health

According to the World Health Organisation (WHO), climatic variations and greater extremes of temperature and heavy rainfall can have significant implications for human health. Human health is affected directly by climatic conditions such as heat waves (Koppe et al, 2004), but also indirectly by modifying the transmission dynamics of some infectious diseases, such as those transmitted by insects or water (Wu et al, 2016). Flooding can increase the risk for water-borne diseases, such as typhoid fever, cholera, leptospirosis and hepatitis, if the floodwaters become contaminated with human or animal waste. The risk for vector-borne diseases, such as malaria, dengue fever, yellow fever, and West Nile Fever has been correlated with an increase in extreme temperature, flooding and humidity (Silal 2012, Craig et al, 2004, Briët et al, 2008, Earnest et al, 2012). The availability of skilful climate information on decadal timescales would therefore also contribute to setting up early warning systems for other diseases as well.

Research on predicting the outbreak of climate sensitive diseases in Southern Africa has focussed mainly on malaria (e.g. Silal 2012). By incorporating seasonal climate forecasts and weather monitoring alongside, epidemiological, social and environmental factors, it is possible to indicate changes in malaria risk several months ahead of a potential epidemic. Malaria Early Warning Systems are also advocated by the World Health Organization as a means of improving the opportunity for preparedness and timely response in Africa. There have been numerous publications on using seasonal forecasting for malaria research in Africa, and some attempts to transform these research projects into operational tools (Thomson et al, 2005; Kazembe et al, 2007; Craig et al, 2007; Tompkins and Di Giuseppe, 2015; MacLeod et al, 2015). Currently, the only operational malaria early warning system that includes data for southern Africa is run by the International Research Institute for Climate and Society (IRI).

Certain challenges are evident with regard to the usefulness of the timescale and climate variables provided by seasonal forecasts for development of health applications. Seasonal forecasts normally provide generalised forecasts of rainfall and temperature based on probabilities; hence they are often difficult to use within the context of specific health early warning systems. Forecasts therefore need to be tailored to specific disease control problems. It is also necessary to address uncertainty in forecasts when setting thresholds for early warning systems (Vera et al, 2010).

5.4. Disaster risk management

As mentioned earlier, Southern Africa faces high levels of exposure to drought, floods, heatwaves and cyclones, and will likely suffer from increases in the frequency and magnitude of some of these events (Wilkinson et al, 2015). In south eastern Africa, devastating floods can have serious consequences through damage to infrastructure, leaving people homeless, killing livestock, destroying crops and causing outbreaks of diseases. During the summer season of 2014/2015, for example, heavy seasonal rainfall affected 135,000 people in Malawi, Mozambique, Madagascar and Zimbabwe. Accurate flood forecasts could have reduced the impact of the floods by helping authorities to evacuate people in advance of flash floods and moving livestock to higher areas. Early warning of extreme events such as floods and droughts is crucial for developing and implementing various flood preparedness and response strategies. Multiple studies and analyses propose that prevention, alert with Early Warning Systems (EWS) and risk information are key elements for managing of disaster risk and among the best options to mitigate the impacts and costs of such events (e.g. Archer et al, 2017).

In order for EWS to be effective, they should address four key elements as defined by the United Nations International Strategy for Disaster Risk Reduction (UNISDR): (i) risk identification, (ii) monitoring and warning system, (iii) warning dissemination, and (iv) response actions (Seng & Stanley, 2012). EWS have evolved considerably over the last two decades and there are a number of systems in operation, covering the majority of natural hazards in southern Africa (refer Table 1).

Recently, some countries, notably Malawi, Tanzania and Mozambique, have been developing some level of early warning for certain sectors. In Malawi, for example, a UNDP project was launched to invest in the use of climate information for planning agricultural and on-farm activities, providing warnings of severe weather for fishers on Lake Malawi, improving flood forecasting and monitoring, and fostering information exchanges through mobile platforms (UNDP, 2013).

By contrast, the United Nations Framework Convention on Climate Change (UNFCCC) has identified the Democratic Republic of the Congo and Zambia as countries having a low capacity to provide early warning. In the DRC, there is no operational early warning system and an overall lack of reliable or sometimes any information on weather, climate and hydrology that would improve the performance of weather dependent sectors (CREWS, 2015). In cases where early warning information is robust and reliable, there are often challenges associated with the communication and dissemination of the information particularly to rural communities, as mentioned earlier.

5.5. Energy

Climate has significant influence on energy production in southern Africa, particularly hydropower (Table 4). Periods of high rainfall have negative implications for hydro-electric power generation, as flooding results in increased sediments reducing the catchment capacity (Mulumba et al, 2012). In dry years, low water flows and sedimentation of rivers occur in areas where hydropower plants are located. The resultant black-outs in all these cases leads to an unreliable electricity supply, For example, in 2000, Tanzania reported that drought conditions resulted in reduced hydro-electric generating capacity, which led to the country experiencing power interruptions (Blacksher et al, 2011).

Table 4: Electricity generation capacity (MW) of southern African countries in the 2014/2015 year derived from hydropower and wind (source: SAPP, 2015).

Country	Technology	
	Hydro-electric (MW)	Wind (MW)
Mozambique	2573	0
Democratic Republic of Congo	2442	0
Zambia	2156	0
South Africa	2000	2492
Angola	1528	0
Zimbabwe	750	0
Tanzania	717	0
Malawi	351	0
Namibia	348	0
Madagascar[1]	105	0
Lesotho	74	0
Swaziland	61	0
Mauritius[2]	56	0
Botswana	0	0
Total	13161	2492

[1]Electricity generation capacity for the year 2007; [2]Electricity generation capacity for the year 2013

Hydropower installations in Tanzania mostly rely on daily and weekly forecasts for day-to-day operation. However, seasonal forecasts could be better utilised to manage periods of droughts and reduce the risk of blackouts. In addition, long-term climate projections would be useful to help with planning and design of new installations which continue to be planned in Tanzania, particularly in the Rufiji Basin (Noel, 2010; Jones and Walmsley, 2014). Key informants have highlighted the value of information on climate trends over the next 50 to 100 years as being particularly helpful for designing new installations in light of potential climate change. Informants further emphasised that it is not clear to them whether recent variations in weather patterns are anomalies or part of longer term trends of climate change. They felt that in addition to helping with the design of new hydropower plants, longer term climate information could be helpful for operational management as well, incentivising plans for managing dry or wet years on a more regular basis. In this respect, information on rainfall was felt to be most useful, particularly information on seasonal variability.

6. Conclusion and recommendations

This report has identified the challenges facing users of current weather and climate information products, and highlighted the importance of creating user-tailored climate services in order for successful integrating of climate issues into planning and policy development. User needs assessments, feedbacks and the co-production of climate information are critical factors in providing increasing useful and accessible products for the management of climate risks and informing climate change adaptation. Addressing the apparent disconnect between data producers and data users will be crucial for advancing the use of climate information across sectors in southern Africa. Climate service centres/partnerships are advocated as the primary mechanism through which this gap can be addressed. Climate services should consist of the following:

- Consolidation of knowledge about past, present and future state of the climate system;
- Engagement with users of climate information and the development of partnerships to facilitate the co-production of knowledge;
- Identification of climate information needs within specific sectors;
- Risk assessments that highlight sector and regions that are particularly vulnerable to climate variability and change;
- Development and delivery of a range of products driven by the user needs;
- Developing communication strategies to ensure a continuous two-way learning process that will enhance monitoring, data processing and its presentation;
- Continuous efforts, such as training programmes, for building capacities for the effective uptake and use of climate information.

As projects and programmes move forward, taking time and space to be reflective, and to learn about what is effective in climate services is essential. At times, such reflection might require revisiting some of our assumptions as to how climate services might function.

7. References

ACPC (2011) 'Climate science, information, and services in Africa: Status, gaps and policy implications.' Working Paper 1. United Nations Economic Commission for Africa, African Climate Policy Centre (ACPC).

African Climate Policy Centre (ACPC), 2013, United Nations Economic Commission for Africa, Working Paper 1, CLIMATE SCIENCE, INFORMATION, AND SERVICES IN AFRICA: STATUS, GAPS AND POLICY IMPLICATIONS.

Archer van Garderen, E.R., 2013. *Are we disabling climate science in southern Africa?: A brief consideration of the draft South African Weather Service Amendment Bill*. CSIR.

Archer, E.R.M., Landman, W.A., Tadross, M.A., Malherbe, J., Weepener, H., Maluleke, P. and Marumbwa, F.M., 2017. Understanding the evolution of the 2014–2016 summer rainfall seasons in southern Africa: Key lessons. *Climate Risk Management*, *16*, pp.22-28.

Asrar, G.R., Ryabinin, V. & Detemmerman, V. 2012, "Climate science and services: Providing climate information for adaptation, sustainable development and risk management", *Current Opinion in Environmental Sustainability,* vol. 4, no. 1, pp. 88-100.

Blench, R., 1999, Seasonal Climatic Forecasting: Who can use it and how should it be disseminated? *Natural Resources Perspectives*, 47, Overseas Development Institute

Blacksher, B., Crocker, T., Drucker, E. and Filoon, J. (2011) 'Hydropower Vulnerability and Climate Change', Middlebury College Environmental Studies Senior Seminar, p. 82.Briët OJT, Vounatsou P, Gunawardena DM, Galappaththy GNL, Amerasinghe PH. 2008, "Temporal correlation between malaria and rainfall in Sri Lanka", *Malar J,* 7:77. doi:10.1186/1475-2875-7-77.

Cai, W., McPhaden, M.J., England, M.H., Wang, G., Guilyardi, E., Jin, F-F., Collins, M. and Wu, L., 2014, Increasing frequency of extreme El Niño events due to greenhouse warming, *Nature Climate Change*, 4, DOI 10.1038/NCLIMATE210

Cain, A. (2017) Water resource management under a changing climate in Angola's coastal settlements. IIED working paper, IIED, London.

Cooper, P., Dimes, J., Rao, K., Shapiro, B., Shiferaw, B. & Twomlow, S. 2008, "Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change?", *Agriculture, Ecosystems & Environment*, vol. 126, no. 1, pp. 24-35.

Craig MH, Kleinschmidt I, Nawn JB, Le Sueur D, Sharp BL: Exploring 30 years of malaria cse data in KwaZulu-Natal, South Africa: part I. The impact of climatic factors. Trop Med Int Health 2004, 9:1247-1257.

Craig MH, Sharp BL, Mabaso ML, et al. Developing a spatial-statistical model and map of historical malaria prevalence in Botswana using a staged variable selection procedure. Int J Health Geogr. 2007;6:44–58.

CREWS, 2015. Building Seamless Multi-Hazard Early Warning System and Risk Information Capacities with Strengthened International Cooperation. CLIMATE RISK & EARLY WARNING SYSTEMS. Available from: http://newsroom.unfccc.int/media/454810/crews-presentation.pdf/ [6 October 2016].

CSAG, START, SEI and University of Ghana. 2014, Report from the future climate for Africa pilot country case study project. Climate and Development Knowledge Network.

Davis, C. 2012. SADC capacity building in relation to the Risk and Vulnerability Atlas. Unpublished Report. CSIR, Pretoria.

Davis-Reddy, C.L. and Vincent, K. 2017. Climate Risk and Vulnerability: A Handbook for Southern Africa. 2nd edition. CSIR, Pretoria.

Earnest A, Tan SB, Wilder-Smith A. 2012, "Meteorological factors and El Niño Southern Oscillation are independently associated with dengue infections." *Epidemiol Infect*, 140: 1244-1251. 10.1017/S095026881100183X.

FCFA, 2016. Tanzania country fact sheet. Weather and climate information for decision making. Available from http://2016report.futureclimateafrica.org/wp-content/uploads/2016/10/CDKNJ4897_FCFA_Print_WEB_14.pdf [20 July 2017].

Fung, F., Lopez, A. and New, M. (2010) Introduction, in Modelling the Impact of Climate Change on Water Resources (eds F. Fung, A. Lopez and M. New), John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781444324921.ch1

GCOS. 2006. CLIMATE INFORMATION FOR DEVELOPMENT NEEDS: AN ACTION PLAN FOR AFRICA. REPORT AND IMPLEMENTATION STRATEGY. GCOS 108. (WMO/TD No. 1358)

Goddard, L., 2016, From Science to service. Science 353 (6306), 1366-1367 (September 22, 2016). doi: 10.1126/science.aag3087

Hales S, de Wet N, Maindonald J, Woodward. 2002, "A: Potential effect of population and climate changes on global distribution of dengue fever: an empirical model." *Lancet*, 360: 830-834. 10.1016/S0140-6736(02)09964-6.

Helmschrot, J., Muche, G., Hillmann, T., Josenhans, K., Butale, M., Nascimento, D., Kruger, S., Strohbach, B., Wassenaar, T., Ribeiro, C., Clercq, W. De and Kenabatho, P. (2016) 'SASSCAL WeatherNet to support regional weather monitoring and climate - related research in Southern Africa.', in. Victoria Falls, Zimbabwe: Southern Africa Regional Climate Services Workshop.

Hewitson, B., 2015. To build capacity, build confidence *Nature Geoscience* **8**, 497–499. doi:10.1038/ngeo2465

Hoell, A., Funk, C., Magadzire, T., Zinke, J., and Husak, G., 2015, El Niño–Southern Oscillation diversity and Southern Africa teleconnections during Austral Summer, *Climate Dynamics*, 45(5), 1583-1599. DOI 10.1017/S0014479710000876

Jones, L. and Walmsley, N. 2014. Future Climate for Africa - Scoping papers Examining the utility and use of long-term climate information for hydropower schemes in sub-Saharan Africa. Available at: https://cdkn.org/wp-content/uploads/2014/05/hydropower.pdf.twe5r4e45j45245i.

Jones, L., Carabine, E., Hickman, A., Langston, L., 2014. Exploring the Role of Climate Science in Supporting Long Term Adaptation and Decision Making in Sub Saharan Africa. CDKN Working Paper.

Jones, Lindsey, Dougill, Andrew, Jones, Richard G., Steynor, Anna, Watkiss, Paul, Kane, Cheikh, Koelle, Bettina, Moufouma-Okia, Wilfran, Padgham, Jon, Ranger, Nicola, Roux, Jean-Pierre, Suarez, Pablo, Tanner, Thomas and Katharine Vincent, 2015, Ensuring climate information guides long-term development, *Nature Climate Change* 5, 812–814 doi:10.1038/nclimate2701

Kazembe LN. 2007, "Spatial modelling and risk factors of malaria incidence in northern Malawi". *Act Trop*, 102:126–37.

Kebede, A.S. and Nicholls, R.J., 2011. *Population and assets exposure to coastal flooding in Dar es Salaam (Tanzania): vulnerability to climate extremes*. Global Climate Adaptation Partnership (GCAP).University of Southampton, School of Civil Engineering and the Environment, Tyndall Centre for Climate Change Research. Southampton, United Kingdom.

Klopper, E., Vogel, C.H. & Landman, W.A. 2006, "Seasonal climate forecasts–potential agricultural-risk management tools?", *Climatic Change*, vol. 76, no. 1-2, pp. 73-90.

Koelle, B., Bachofen, C., Suarez, P., Jones, R., Coughlan, E. & Mudenda, W. 2014, Future Climate For Africa Pilot Phase: Zambia Technical Report, Red Cross/Red Crescent Climate Centre.

Kusunose, Y. and Mahmood, R. (2016) 'Imperfect forecasts and decision making in agriculture', Agricultural Systems, 146, pp. 103–110. doi: https://doi.org/10.1016/j.agsy.2016.04.006.

Koppe, C., G. Jendritzky, R. S. Kovats, and B. Menne, 2004: Heatwaves: Risks and Responses. World Health Organization, 125 pp. [Available online at www.euro.who.int/__data/assets/pdf_file/0008/96965/E82629.pdf.

Landman, W.A. (2014). How the International Research Institute for Climate and Society has contributed towards seasonal climate forecast modelling and operations in South Africa. Earth Perspectives, 1:22, DOI: 10.1186/2194-6434-1-22.

Landman, W.A., DeWitt, D. Lee, D.-E., Beraki, A. and Lötter, D. (2012). Seasonal rainfall prediction skill over South Africa: 1- vs. 2-tiered forecasting systems. Weather and Forecasting, 27, 489-501. DOI: 10.1175/WAF-D-11-00078.1.

Landman, W.A. and Beraki, A., 2012, Multi-model forecast skill for midsummer rainfall over southern Africa, *International Journal of Climatology*, 32, 303-314, DOI: 10.1002/joc.2273

Landman, W., Tadross, M., Engelbrecht, F., Archer van Garderen, E. & Joubert, A. 2011, "Seasonal forecasts: communicating current climate variability in southern Africa", in David, C (ed) Climate Risk and Vulnerability: A Handbook for Southern Africa. Council for Scientific and Industrial Research, Pretoria, South Africa, 92p.

Landman, W.A. (2014). How the International Research Institute for Climate and Society has contributed towards seasonal climate forecast modelling and operations in South Africa. Earth Perspectives, 1:22, DOI: 10.1186/2194-6434-1-22.

Lazenby, M., Landman, W.A., Garland, R. and DeWitt, D. (2014). Seasonal temperature prediction skill over southern Africa and human health. Meteorological Applications, 21, 963-974. DOI: 10.1002/met.1449.

Lemos, M.C., Kirchhoff, C.J., Ramprasad, V., 2012. Narrowing the climate information usability gap. Nature Climate Change 2, 789-794.

MacLeod DA, Jones A, Di Giuseppe F, Caminade C, Morse AP, 2015. Demonstration of successful malaria forecasts for Botswana using an operational seasonal climate model. Environ Res Lett 10:044005.

Malherbe, J., Landman, W.A., Olivier, C., Sakuma, H. and Luo, J.-J. (2014). Seasonal forecasts of the SINTEX-F coupled model applied to maize yield and streamflow estimates over north-eastern South Africa. Meteorological Applications, 21, 733-742, DOI: 10.1002/met.1402.

Malzbender, D., & Earle, A., (2007). Water resources of the SADC: Demands, dependencies and governance responses. African Centre for Water Research.

Mason, S. 1998, "Seasonal forecasting of South African rainfall using a non–linear discriminant analysis model", *International Journal of Climatology*, vol. 18, no. 2, pp. 147-164.

Mason, S., Kruczkiewicz, A., Ceccato, P. and Crawford, A. (2015) Using climate cata and information in fragile data poor states. The International Institute for Sustainable Development, Geneva, Switzerland. doi: 10.13140/RG.2.1.4599.7922

McCartney, M. P. 2007. Decision support systems for large dam planning and operation in Africa. Colombo, Sri Lanka: International Water Management Institute. 47 p. (IWMI Working Paper 119)

McKee, T.B., Doesken, N.J. & Kleist, J. 1993, "The relationship of drought frequency and duration to time scales", *Proceedings of the 8th Conference on Applied Climatology* American Meteorological Society, Boston, pp. 179.

McSweeney, C., M. New, G. Lizcano, and X. Lu, 2010. The UNDP Climate Change Country Profiles: improving the accessibility of observed and projected climate information for studies of climate change in developing countries: Mozambique Country Profile. Bulletin of the American Meteorological Society, 91 157–166.

Muchuru, S., Landman, W.A. and DeWitt, D. (2016). Prediction of inflows into Lake Kariba using a combination of physical and empirical models. International Journal of Climatology, 36, 2570–2581, DOI: 10.1002/joc.4513.

Mulumba, J.P.M., Afullo, T.J.O. and Ijumba, N. (2012). Climate Change and Hydropower Challenges in Southern Africa. Rwanda Journal, Mathematical Sciences, Engineering and Technology, 27 (Vol C), 32-43.

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham and P. Urquhart (2014). Africa. In Climate Change 2014: Impacts, Adaptation and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds)]. Cambridge University Press, Cambridge, UK and NY, USA, pp. 1199-1265. Available online at *http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap22_FINAL.pdf*.

Nicholson, S.E. and Entekhabi, D., 1986. The quasi-periodic behavior of rainfall variability in Africa and its relationship to the Southern Oscillation. *Archives for meteorology, geophysics, and bioclimatology, Series A*, *34*(3-4), pp.311-348.

Nicholson, S.E., Funk, C. and Fink, A.C., 2017. Rainfall over the African continent from the 19th through the 21st century, Global and Planetary Change, Volume 165, 2018, Pages 114-127. https://doi.org/10.1016/j.gloplacha.2017.12.014.

Nicholson, S. and Kim, J., 1997, The relationship of the El Niño Southern Oscillation to African rainfall, *International Journal of Climatology*, 17, 117-135

Nicholson, S.E. and Selato, J.C., 2000. The influence of La Nina on African rainfall. *International Journal of Climatology*, *20*(14), pp.1761-1776.

Noel, S. (2010) 'The Economics of Climate Change in Tanzania Water resources.', Stockholm Environment Institute – Africa Centre., p. 29.

OCHA, n.d. Disaster Response and preparedness in southern Africa: A Guide to International Tools and Services Available to Governments.

Okonya, J. S., & Kroschel, J. (2013). Indigenous knowledge of seasonal weather forecasting: a case study in six regions of Uganda. Agricultural Sciences, 04(12), 641–648. doi:10.4236/as.2013.412086.

Patt, A., Ogallo, L. and Hellmuth, M., 2007, Learning from 10 years of Climate Outlook Forums in Africa, *Science*, 318, 49-50.

Phakula, S., Landman, W.A. and Beraki, A. (2018). Forecasting seasonal rainfall characteristics and onset months over South Africa. International Journal of Climatology, DOI: 10.1002/joc.5417.

Post DA, Vaze J, Teng J, Crosbie R, Marvanek S, Wang B, Mpelasoka F and Renzullo L. 2012. Impacts of climate change on water availability in Botswana. CSIRO: Water for a Healthy Country National Research Flagship.

Ropelewsky, C. & Halpert, M. 1989, "Precipitation patterns associated with the high index phase of the Southern Oscillation", *J.Climate,* vol. 2, pp. 268-284.

Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumaré, M., Batté, L. & Sultan, B. 2014, "The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal", *Climate Risk Management,* vol. 2, pp. 42-55.

SADC. 2012. Regional Infrastructure Development Master Plan - Meteorology Sector Plan. pp. 90.

SADC. 2016, Regional Strategic Action Plan on Integrated Water Resources Development and Management Phase IV, RSAP IV, Gaborone, Botswana, 2016

Seng, C. & Stanley, D. 2012, "A Conceptual Framework for Early Warning System Governance: Towards Effective and Sustainable Resilience", *IDRiM Journal,* vol. 2, no. 1.

Silal, SP. 2012, "Modeling the relationship between precipitation and malaria incidence in Mpumalanga, South Africa". *Malaria Journal*, 11(Suppl 1):P127.

Southern African Power Pool (SAPP), 2015. Southern Africa Power Pool 2015 Annual Report, Retrieved from http://www.sapp.co.zw/docs/SAPP%20Annual%20Report-2015.pdf. Accessed 4 August 2016.

Steynor, A., Padgham, J., Jack, C., Hewitson, B., Lennard, C. 2016. Co-exploratory climate risk workshops: Experiences from urban Africa, Climate Risk Management 13.

Tall, A., Hansen, J., Jay, A., Campbell, B., Kinyangi, J., Aggarwal, P.K. and Zougmore, R., 2014, Scaling up climate services for farmers: Mission Possible. Learning from good practice in Africa and South Asia, CCAFS Report No. 13. Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Tarakidzwa, I., 2007. Use and dissemination of seasonal climate forecasts in agricultural production in Africa, in Use of Seasonal forecasts and climate prediction in operational agriculture, WMO/TD No. 1344, pg29-40.

Thomson MC, Mason SJ, Phindela T, et al. 2005, "Use of rainfall and sea surface temperature monitoring for malaria early warning in Botswana.", *Am J Trop Med Hyg*, 2005;73:214–21.

Thornton PK, Boone RB, J Ramirez-Villegas 2015. Climate change impacts on livestock. CCAFS Working Paper no. 120. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

AM Tompkins, F Di Giuseppe, 2015. Potential predictability of malaria using ECMWF monthly and seasonal climate forecasts in Africa. J Appl Meteor Clim 54:521-40.

Tumbo, S.D., Mbilinyi, B.P., Rwehumbiza, F.B., Mutabazi, K.K. 2010. Economics of climate change for agriculture sector in Tanzania. Soil-water management research group, Sokoine University of Agriculture, Morogoro, Tanzania. UNDP, 2013. "Strengthening Climate Information and Early Warning Systems in Malawi." Available from: http://adaptation-undp.org/resources/project-brief-fact-sheet/project-brief-malawi-oct-2013/. [6 September 2016].

UNEP/GRID-Arendal, 'World's surface water: precipitation, evaporation and runoff', *UNEP/GRID-Arendal Maps and Graphics Library*, 2002, https://www.grida.no/resources/5827 [Accessed 25 April 2018]

UNDPCC, 2010. Case study: Improved weather forecasting and decision-making tools for farmers. http://www.undpcc.org/docs/Investment%20and%20Financial%20flows/I&FF%20reports%20and%20suppl%20information/Namibia/2nd%20Draft%20Case%20study_%20on_%20improved%20weather%20forecasting%20and%20decision%2007-05-2010.doc

USAID, 2012. "Climate Change Adaptation in Angola Fact Sheet." Available from https://www.climatelinks.org/sites/default/files/asset/document/malawi_adaptation_fact_sheet_jan2012.pdf. [2 June 2017].

USAID, 2013. "Mozambique Climate Vulnerability Profile." Available from https://www.climatelinks.org/resources/mozambique-climate-vulnerability-profile [13 April 2017].

USAID, 2012. Climate Change Adaptation in Mozambique: Fact Sheet. Internal resource.

USAID (2012) Democratic Republic of the Congo: Vulnerability Profile. Available at: https://www.climatelinks.org/sites/default/files/asset/document/drc_climate_vulnerability_profile_jan2013.pdf.

Vaughan, C. and Dessai, S., 2014, Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework, *WIREs Climate Change*, 5(5), 587-603, DOI 10.1002/wcc.290

Vera C, Barange M, Dube O P, Goddard L, Griggs D, Kobysheva N, 2010, Needs Assessment for Climate Information on Decadal Timescales and Longer, Procedia Environmental Sciences. 1(0):275-286

Venäläinen, A., Pilli-Sihvola, K., Tuomenvirta, H., Ruuhela, R., Kululanga, E., Mtilatila, L., Kanyanga, J. and Nkomoki, J., 2016. Analysis of the meteorological capacity for early warnings in Malawi and Zambia. *Climate and Development*, *8*(2), pp.190-196.

Vincent, K., Cull, T., Archer van Garderen, E., Conway, D., Dalin, C., Deryng, D., Dorling, S., Fallon, A. and Landman, W., 2016. Improving effective use of seasonal forecasts in South Africa. IFPRI Project Note 01, April 2016, 4p.

Vincent, K., Dougill, A.J., Dixon, J.L., Stringer, L.C. & Cull, T. 2017, "Identifying climate services needs for national planning: insights from Malawi", *Climate Policy, 17(2)*, pp. 189-202.

Wheater HS (2007) Modelling hydrological processes in arid and semi-arid areas: an introduction to the workshop. In: Wheater HS, Sorooshian S, Sharma KD (eds) Hydrological modelling in arid and semi-arid areas. Cambridge University Press, UK

Wu, X., Lu, Y., Zhou, S., Chen, L. and Xu, B. (2016) 'Impact of climate change on human infectious diseases: Empirical evidence and human adaptation', Environment International, 86, pp. 14–23. doi: https://doi.org/10.1016/j.envint.2015.09.007.

Wilby, R. L. and Fowler, H. J. (2010) Regional climate downscaling, in Modelling the Impact of Climate Change on Water Resources (eds F. Fung, A. Lopez and M. New), John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781444324921.ch3

Wilkinson, E., Budimir, M., Ahmed, A. K. and Ouma, G. (2015) Climate Information and Services in BRACED Countries. Resilience Intel No. 1. Available at: http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10128.pdf.

Wilke, A. K., & Morton, L. W. (2015). Climatologists' patterns of conveying climate science to the agricultural community. Agriculture and Human Values, 32, 99-110.

World Hydrological Cycle Observing System (WHYCOS) 2017. http://www.whycos.org/whycos/projects/under-implementation/sadc-hycos-phase-iii

WWF-SA 2017, Scenarios for the Future of Water in South Africa, WWF South Africa, 23p. http://awsassets.wwf.org.za/downloads/wwf_scenarios_for_the_future_of_water_in_south_africa_v7_6_pf.pdf

Ziervogel G, Cartwright A, Tas A, Adejuwon J, Zermoglio F, Shale M, Snith B. (2008). Climate change and adaptation in African agriculture. Prepared for Rockefeller Foundation by Stockholm Environment Institute.

Ziervogel, G. & Calder, R. 2003, "Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts in Lesotho", *Area*, vol. 35, no. 4, pp. 403-417.

Ziervogel, G., Johnston, P., Matthew, M. et al. Climatic Change (2010) 103: 537. doi:10.1007/s10584-009-9771-3

Ziervogel, G. and Opere, A. (eds) 2010. Integrating meteorological and indigenous knowledge-based seasonal climate forecasts for the agricultural sector Lessons from participatory action research in sub-Saharan Africa. CCAA Learning Paper, 19p.

Appendix

SADC Risk and Vulnerability Atlas

Stakeholder Survey

CSIR
our future through science

science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

The information you provide us will be kept confidential. The information gathered from these questions will be used to help us understand what the general perceptions about climate change are, and how we can best provide information that will improve societies chances of preparing for and adapting to the impacts of climate change.

1. Stakeholder information

What best describes the sector you represent

☐ Regional (SADC) Institution ☐ National Government ☐ Local Government ☐NGO ☐ Research

☐ Water related ☐ Agriculture ☐ Conservation ☐ Health ☐Tourism

☐ Mining ☐ Education ☐Other

Name and Surname:	
Country:	
Organisation:	
Position:	
Key responsibilities:	
Telephone (office):	
Telephone (fax):	
Email:	
Address:	

Page **1** of **3**

2. Climate change planning

		Yes/No	
1	Do you understand what climate change is?	☐ Yes ☐ No	
2	Have you identified areas where climate change will affect you and/or your organisation	☐ Yes ☐ No	
3	Has your organisation thought about incorporating climate change impacts into their future management actions	☐ Yes ☐ No	
4	Detail the impacts of concern (such as heat stress) and how your organization has considered theses concerns into planning	*Concerns:*	*Responses:*

3. Current climate information usage and requirements

	Criteria	Yes/No
1	Do you use long-term climate and/or weather information?	☐ Yes (go to question 3 of this section) ☐ No (go to question 2 of this section)
2	Do you see a need for using this type of information	☐Yes ☐ No (if no go to next section)
3	What type of climatic information do you use	☐ Own weather recordings ☐ Daily/weekly forecasts ☐ Long-term (3 month) predictions ☐ Historical rainfall/temperature records ☐ Download climate records for other sources ☐ GIS generated maps ☐ Other: (Specify below)
4	Where do you obtain your long term weather information from?	
5	What do you use this information for	☐ Own interest ☐ Short term planning ☐ Management ☐ Research ☐Consulting ☐Other: (Specify below)

4. Accessibility of information

	Criteria	Yes/No
1	What barriers do you experience from using publically accessible information e.g. climate information, environmental information, statistical data (e.g. population/ tourism stats)	☐ None ☐ Don't understand the available information ☐ Don't have access to a PC ☐ Limited computer literacy ☐ Don't know where to find such information ☐ Poor internet connectivity ☐ Other: (Specify below)

2	How would you like to access climate change and risk information	☐Presentation ☐ Book ☐ Available online (internet) ☐ Raw data (GIS) ☐ Other: (Specify below)
3	What type of information will be most useful to you	☐ Image of predicted results (map) ☐ Report ☐ Graphs ☐ Interactive website ☐ Shapefiles (GIS required) ☐ GIS generated maps ☐ Other: (Specify below)
4	If you find this information useful would you pass it onto others	☐Yes ☐No

5. General

Please respond to the following statements, by ticking the appropriate box	**Scale of Importance**				
	Not at all	**Not very**	**No Opinion**	**Quite**	**Very**
We will begin to feel the effects of climate change within the next 10 years	☐	☐	☐	☐	☐
Climate change is a factor that my organization considers important to be aware of.	☐	☐	☐	☐	☐
Climate change impacts will be financially negative for our organisation	☐	☐	☐	☐	☐
If you or your organisation we made aware of climate change impacts specific to your area would you you use this information in future planning?	☐	☐	☐	☐	☐
Do you think future climate change scenarios (specific to your region) will be of interest to the general public?	☐	☐	☐	☐	☐

Thank you for taking the time to fill out this survey

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
Angola	The Ministry of Urban Development and Environment (MINUA)	No NAPA or NatComm yet (being formulated, expected 2011)	National Service of Civil Protection		Ministry of Agriculture
Botswana	National Focal Point: Department of Meteorological Services, Ministry of Environment, Wildlife and Tourism	National Communication (2001): http://unfccc.int/resource/docs/natc/botnc1.pdf There is no dedicated policy to respond to climate change in Botswana But see: National Development Plan 10 (http://www.finance.gov.bw/index.php?option=com_content1&parent_id=334&id=338)	National Disaster Management Office in the Office of the President (http://www.gov.bw/en/Ministries--Authorities/Ministries/State-President/Office-of-the-President/Divisions/National-Disaster-Management-Office1/)	National Policy on Disaster Management (1996) The Constitution Of Botswana -Emergency Powers Act (Cap 22.04)	Ministry of Finance and Development Planning
DRC	Ministry of Environment	NAPA (French): http://unfccc.int/resource/docs/napa/cod01.pdf Mining Code (2002) • Environmental Attenuation and Rehabilitation Plan Rehabilitation Plan • Environmental Management Plan National Programme for the Reduction of Emissions related to Deforestation and Forest Degradation Promulgation of the Environment Act (National Climate Change Committee)	Ministry of the Interior		Ministry of Agriculture
Lesotho	Ministry of Natural Resources, Lesotho Meteorological Services	No co-ordinated national policy for climate change	Prime Minister's Office (Disaster Management Authority)	National Disaster Management Policy, 2010 (Final Draft)	Ministry of Agriculture and Food Security

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
	http://www.lesotho.gov.ls/natural/	Key Reference is the First National Communication to the UNFCC (2000) (http://unfccc.int/resource/docs/natc/lesnc1.pdf)			Poverty Reduction Strategy(http://www.finance.gov.ls/development/PRSP_Printable_Version_07-07-05.pdf)
Madagascar	Ministry of Environment and Forests Ministry of Agriculture and Farming	First (2004) and Second (2010) National Communications NAPA (2006)	National Office of Risk and Disaster Management, Ministry of the Interior and Administrative Reform		
Malawi	Ministry of Mines, Natural Resources and Environmental Affairs, Department of Environmental Affairs (http://www.malawi.gov.mw/Mines/EnviromentalAffairs/Home%20%20EnvtAffairs.htm)	Key documents: • The National Environmental Policy (NEP) • Vision 2020 (2000), • Malawi Poverty Reduction Strategy (MPRS 2002), • Malawi Economic Growth Strategy (MEGS, 2003) • National Environmental Action Plan (NEAP, 1994) • National Strategy for Sustainable Development of 2004 Policy: • The Environmental Management Act (EMA) of 1996	Department of Poverty and Disaster Management Affairs (http://www.malawi.gov.mw/Povelty/Home%20Povelty.htm)	Policy: The Disaster Preparedness and Relief Act of 1991 Draft Disaster Risk Reduction policy (2010)	Ministry of Agriculture and Food Security (http://www.malawi.gov.mw/Agriculture/Home%20%20Agriculture.htm) Ministry of Development Planning and Cooperation
Mauritius	Ministry of Environment & National Development Unit Office of the Prime Minister, Mauritius Meteorological Services	First National Communication (1999): http://unfccc.int/resource/docs/natc/maunc1/index.html The Environment Protection Act 2002 Environment Protection (Amendment) Act 2008	National Disaster Management Centre (NDMC) within the Prime Minister's Office	Particular focus on cycles	Minister of Agro Industry, Food Production and Security

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
	National Climate Committee (NCC)	The Public Procurement Act (recently promulgated promotes green procurement)			
Mozambique	Ministry for the Co-Ordination of Environmental Affairs (MICOA) National Directorate of Environmental Management (DNGA)	First National Communication (2003) NAPA (2008) Currently drafting a climate change law. Developing a climate change strategy as part of INGC phase 2	National Institute of Disaster Management (INGC)	Master plan for disaster prevention and mitigation (2006)	The National Agricultural Support Programme (PROAGRI, 1998) - Ministry of Agriculture and Rural Development - impact in food security and poverty reduction Food and Nutritional Security Technical Secretariat (SETSAN)
Namibia	**Directorate of Environmental Affairs**	Namibia has no policy on climate change (being drafted under the Second National Communication – also being drafted) In conjunction, a national climate change strategy and action plan is also being prepared as a necessary tool to facilitate climate change adaptation and mitigation to reduce its impacts on socio-economic development of the country Vision 2030 National Poverty Reduction Action Plan (NPRAP) (2000) National Development Plan 3 Environmental Management Act (2007)	Office of the Prime Minister	National Policy on Disaster Risk (2008) - Draft Bill Disaster Risk Management (2010) - 2011 Act	National Agricultural Policy (stipulates potential strategies to improve food security, expand income through export of products and to create employment

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
		Pollution Control and Waste Management Bill The Water Resources Management Act, Act 24 of 2004 (WRMA) Namibia Forest Act and Policy White Paper on Energy Policy of 1998 National Drought policy (deals with national emergency and long term drought management policy and strategy to combat land degradation)			
Seychelles	Ministry of the Environment	First Nat Comm 2000 Environment Management Plan 2000-2010	Department of Risk and Disaster Management, President's Office	National Disaster Management Policy (2011)	
South Africa	The Department of Environmental Affairs Climate Change web pages: http://www.environment.gov.za/ClimateChange2005/home.htm	First Nat Comm (2000) The Inter-Ministerial Committee on Climate Change Projects: • BASIC project (Brazil, Africa South, India and China) - capacity-building project funded by the EU Key Publications • Country studies (http://www.environment.gov.za/ClimateChange2005/Country_Studies.htm) • 2nd Nat Comm (draft) • CC Response Strategy (draft Green Paper 2010)	Inter-Ministerial Committee (IMC) on Disaster Management established in January 2011 Chaired by the Minister of Cooperative Governance and Traditional Affairs (CoGTA) and includes the Ministers of Social Development, Defence, Police, Water and Environmental Affairs, State Security, Agriculture, Forestry and Fisheries, Human Settlements and Basic Education	Disaster Management Act, 2002 (Act No. 57 of 2002) National Disaster Management Framework of 2005 National Disaster Management Guidelines (under review in 2010) National and provincial Disaster Management Centres and Joint Operations Centres set up to coordinate response	Ministry of Agriculture Integrated Food Security Strategy For South Africa (2002) **Integrated Food Security and Nutrition Programme (IFSNP)**

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
		• Renewable Energy (http://www.environment.gov.za/ClimateChange2005/RenewableEnergy%20wp%202002.pdf)			
Swaziland	Ministry of Tourism & Environmental Affairs - National Climate Change Coordination Office	First NatComm 2002 National Development Strategy (NDS, 25-year vision Swaziland Environment Action Plan (SEAP) Policies: http://www.ecs.co.sz/env_policies.htm	National Disaster Task Force (NDTF) reporting to the office of the deputy prime minister (National Disaster Management Agency)	National Disaster Management Act, 2006 National Disaster Management Policy (NDMP) – policy review during 2009 and final draft in 2010	Ministry of Agriculture and Co-Operatives
Tanzania	Vice President's Office, Department of the Environment	National Environmental Policy (1997) Environmental Management Act (2004) National Strategy for Growth and Reduction of Poverty – NSGRP NAPA (2007) Strategy for Urgent Actions to combat degradation of Land and Water Catchments Tanzania Development Vision 2025	Disaster Management Department in the Prime Minister's Office	Disaster Relief Coordination Act, No. 9 of 1990 Tanzania Disaster Relief Committee (TANDREC) was created to coordinate between national departments and down to local level. National Disaster Management Policy 2004	Famine and Livestock Early Warning System
Zambia	Ministry of Tourism Environment and Natural Resources	First NatComm 2004 NAPA 2007	Disaster Management and Mitigation Unit (DMMU)	Disaster Management Act no 13 of 2010	Ministry of Agriculture Food Reserve Agency (Food Reserve Act of April 1995)
Zimbabwe	Ministry of Environment and Tourism	First Nat Comm 1998 Policy: National Environmental Policy addresses climate change issues including environmental education	Department of Civil Protection reporting to the Ministry of Local Government, Public Works and National Housing Zimbabwe National Water Authority (ZINWA) and The	Civil Protection Act (1998) under review – to be renamed The Emergency Preparedness and Disaster Management Act Meteorological Services Bill (2003) – incl. resp. for	Ministry of Lands, Agriculture and Rural Resettlement Ministry of Labour & Social Services (ZVAC)

Member State	Lead ministry for climate change	Climate change policies/strategies/ frameworks	Lead ministry for disaster management	Disaster management policies/strategies/ frameworks	Lead ministry for early warning
		(http://unfccc.int/resource/ccsites/zimbab/legislat/policy.htm) Legislation: Natural Resources Act (1941), Forest Act (1949), Harzoudous Substances and Articles Act (1977), Atmospheric Pollution Prevention Act (1971) Water Act (1976) and Communal Land Act (1982) (http://unfccc.int/resource/ccsites/zimbab/legislat/legislat.htm)	Meteorological Department form the early warning unit.	advance warnings of severe weather	