FOCUS-AFRICA

Full-value chain Optimised Climate User-centric Services for Southern Africa

SADC regional climate services gap analysis: in-depth analysis of the SARCOF and SWIOCOF training needs and materials

Deliverable D7.1

Lead Beneficiary: African Centre of Meteorological Applications for Development - ACMAD

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ABOUT FOCUS-AFRICA

FOCUS-Africa – Full-value chain Optimised Climate User-centric Services for Southern Africa – is developing sustainable tailored climate services in the Southern African Development Community (SADC) region for four sectors: agriculture and food security, water, energy and infrastructure.

It will pilot eight case studies in five countries involving a wide range of end-uses to illustrate how the application of new climate forecasts, projections, resources from Copernicus, GFCS and other relevant products can maximise socio-economic benefits in the Southern Africa region and potentially in the whole of Africa.

Led by WMO, it gathers 14 partners across Africa and Europe jointly committed to addressing the recurring sustainability and exploitation challenge of climate services in Africa over a period of 48 months.

For more information visit: www.focus-africaproject.eu

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ACRONYMS

ACMAD	African Centre of Meteorological Application for Development
ANN	Artificial Neural Network
ARG	Automated rain gauge
ASMET	African Satellite Meteorology Education and Training
AWS	Automatic Weather Station
BDMS	Botswana Department of Meteorological Services
C3S	Copernicus Climate Change Service
CFT	Climate Forecasting Tool
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CLICOM	CLImate COMputing project
CLIMSA	Intra-ACP Climate Services and Related Applications
CLIMSOFT	CLIMSOFT Climate Data Management
CPT	Climate Prediction Tool
CSIR	Council for Scientific and Industrial Research
DCCMS	Department of Climate Change and Meteorological Services
DRC	Democratic Republic of Congo
EGOS-IP	Implementation Plan for the Evolution of Global Observing Systems
ENSO	El Niño–Southern Oscillation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FA	FOCUS-Africa
FAO	Food and Agriculture Organization of the United Nations
FOCUS-Africa	Full-value chain Optimised Climate User-centric Services for Southern Africa
GFCS	Global Framework for Climate Services
GPC	Global Producing Centre
HPC/ HPCS	High Performance Computer / High Performance Computer System
ICAO	International Civil Aviation Organization
IDF	Intensity-Duration-Frequency
IOD	Indian Ocean Dipole

IRI	International Research Institute for Climate and Society
MESA	Monitoring of the Environment for Security in Africa
MO	United Kingdom Meteorological Office
MSLP	Mean Sea Level Pressure
NAP	National Adaptation Plan
NCEP	National Centers for Environmental Prediction
NCOF	National Climate Outlook Forum
NDC	Nationally Determined Contribution
NetCDF	Network Common Data Form
NMHS	National Meteorological (and Hydrological) Service
NMME	North American Multimodel Ensemble
NOAA	National Oceanic and Atmospheric Administration
PCA	Principal Component Analysis
PICSA	Participatory Integrated Climate Services for Agriculture
QMS	Quality Management System
RCC	Regional Climate Centre
RCOF	Regional Climate Outlook Forum
RPSS/ CRPSS	Ranked Probability Skill Score / Continuous Ranked Probability Skill Score
RSMC	Regional Specialized Meteorological Centre
SADC	Southern African Development Community
SADC-CSC	Climate Services Centre (of the Southern African Development Community)
SARCOF	Southern Africa Regional Climate Outlook Forum
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SAWIDRA	Satellite and Weather Information for Disaster Resilience in Africa
SAWS	South African Weather Service
SIOD	Southern Indian Ocean Dipole
SPI/SPEI	Standardized Precipitation Index/ Standardized Precipitation and Evaporation Index
SPSS	Statistical Package for the Social Sciences
SST	Sea Surface Temperature
SWAS	South African Weather Services

SWIO	South-West Indian Ocean
SWIOCOF	South West Indian Ocean Climate Outlook Forum
VCI	Vegetation Condition Index
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
WMO	World Meteorological Organization
WP	Work Package

EXECUTIVE SUMMARY

Efforts to provide effective climate services globally will only be successful if capacity is systematically built to enable all countries to manage climate risk effectively. Current capacity development activities to support climate services need to be tailored per region, scaled up and better coordinated. To address the issues of capacity building, the FOCUS-Africa (FA) project is identifying and addressing the current gaps in producing and delivering climate services in the Southern African Development Community (SADC) countries. The project consists of eight work-packages, for which African Centre of Meteorological Application for Development (ACMAD) is leading work package 7 (WP7) to develop capacity for climate services delivery. WP7 has three (3) phases, and this report concentrates on Phase 1, which is to identify training gaps in climate services provision for SADC countries, focusing on the Southern African Regional Climate Outlook Forum (SARCOF) and South West Indian Ocean Climate Outlook Forum (SWIOCOF) training material gap analysis. A comprehensive capacity building initiative is needed to strengthen existing capabilities in the areas of governance, management, human resources development, leadership, partnership creation, science communication, service generation and delivery as well as resource mobilization. For this report, the World Meteorological Organization (WMO) Competency Framework for Climate Services was used as the main means to structure the analysis. The results are hence presented according to the five competency areas as follows: create and manage climate data sets; derive products from climate data sets; create and interpret climate forecasts and models; ensure quality of climate forecasts; and communicate information to users. In order to be able to identify the gaps in climate services, with emphasis on the analysis of limitations in the SARCOF and SWIOCOF training material, ACMAD used a SMART goal worksheet. The analysis began with a review of the WMO Competency Framework in relation to Climate Services. Training materials and documents for literature review were compiled, reviewed and gaps identified according to the competency framework. A climate services questionnaire on *"Checklist for Climate Services Implementation"* was also distributed to 16 SADC member states, of which 14 responded. The questionnaire responses were analyzed to have descriptive statistics on the gaps currently faced in the region in relation to implementing climate services. The results of the survey indicate that there are significant challenges in climate data management and processing, and climate services monitoring and evaluation. The broader assessment identified gaps in capacities and training materials on data rescue, indices generation, statistical and dynamical downscaling, model outputs interpretation and verification, impact-based forecasting, performance assessment, quality assurance and control, driver's detection and analysis, and predictors definition and identification. Based on the identified capacity gaps, the authors of this report compiled a list of recommendations, as well as an action plan for developing training materials and conducting capacity development programmes to be supported by a combination of regional and international organizations, projects and initiatives that are operating in the region.

KEYWORDS

Capacity assessment, capacity development, climate services, competency, gap analysis, training, training needs.

1. Introduction

1. 1. Overview of FOCUS-Africa and Work Package 7

FOCUS-Africa (FA) is developing sustainable tailored climate services in the Southern African Development Community (SADC) region for four sectors: agriculture and food security, water, energy and infrastructure. The project has 8 work packages, one of which is focusing on capacity building (Work Package 7, WP7). The Capacity Building component supports systematic development of the necessary institutional, infrastructural and human resources to provide effective climate services. Many of the foundational capabilities and infrastructure that make up capacity building already exist or are being established but require coordination and strengthening focusing on user needs. The role of this work package is therefore to facilitate and strengthen the current efforts, not to duplicate.

Moreover, FA capacity development work package contributes to strengthening capacity of NMHSs and other climate service providers as well as scientists to generate science-based user and technology driven and innovative climate information. New technology (i.e. Artificial Intelligence, high performance computing), better climate knowledge and understanding of processes and phenomena have emerged over the past several years. However, impacts on the quality of climate information provided and/or applied are lagging due to little investment in training material upgrades and modernization of training delivery mechanisms using new technology.

FA's project strategy to develop better capacity includes:

- Assessment of the capacity development needs;
- Review and upgrading of current training materials;
- Development and testing of materials; and
- Delivering of online training resources.

This report describes gaps in available training materials with WMO competency requirements for climate services as reference for the needs assessment.

1. 2. Capacity development recommendations from the report of the high-level taskforce for the Global Framework for Climate Services

According to the document from the high-level task force (WMO, 2011), a strategy for building capacity in developing countries will be essential in successful implementation of the Global Framework for Climate Services (GFCS, the Framework). A strong Executive Committee for Capacity Building was proposed for the Framework. A principal near-term strategy for the implementation of the Framework was to design and implement a range of projects that target the needs of developing countries. Specifically, the Taskforce proposed the following capacity building activities, to be implemented as soon as possible:

1. Linking climate service users and providers. The Taskforce proposed inclusion of a User Interface Platform in the Framework to link climate service providers and users with a view of building the capacity of users to make better use of climate services, collecting user requirements, assisting in the monitoring and evaluation of the Framework and promoting a global understanding of the Framework. In FA, this effort involves co-production of climate services with users in all the stages of the development of a climate service, including the design, execution, and evaluation processes. This approach will lead to more efficient and useful climate services. As an example of linking climate services users and providers, Figure 1 shows steps in the coproduction of climate services for the agriculture sector, a process which also links to and mirrors various climate services competency areas.

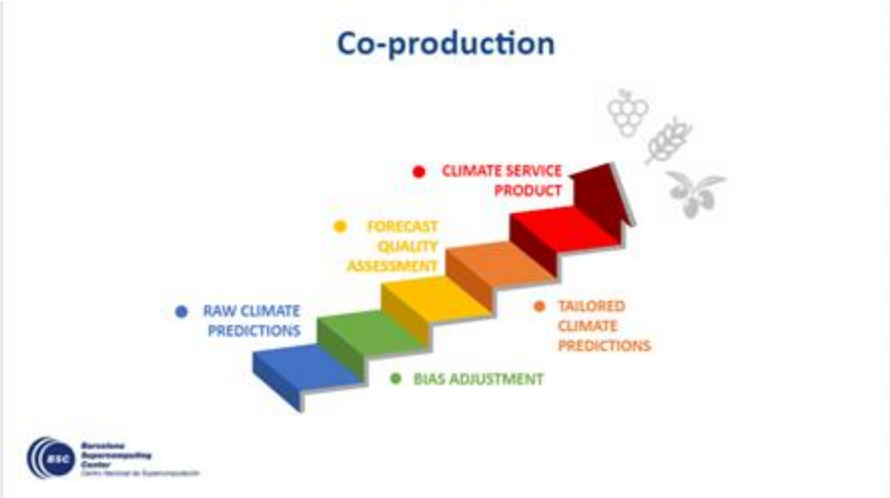

FIGURE 1: DIFFERENT STEPS IN THE CO-PRODUCTION PROCESS OF CLIMATE SERVICES FOR AGRICULTURE

2. *Building national capacity in developing countries.* The Taskforce has found that about 70 countries worldwide do not have the necessary basic capabilities to provide sustainable climate services in support to national adaptation and mitigation actions. It therefore recommended that a high-profile programme of fast-track projects be established to build the necessary capacity of the countries, in accordance with their needs and priorities. The FA project is concerned with identifying training gaps in SADC countries on climate services, with an in-depth analysis of the SARCOF process, in order to close the gap found in the individual SADC countries, and eventually Africa as a whole.

3. *Strengthening regional climate capabilities.* Enhanced regional coordination and technical capabilities will be important to the functioning of the Framework. The Taskforce therefore recommended that a fully effective network of regional centres be established. This will require strengthening existing centres and creating several new centres. The roles and activities of regional climate centres (RCCs) will vary according to each region's specific interests and needs.

4. *Improving climate observations in data sparse areas.* Effective climate services rely on the availability of adequate, high quality climate data. The Taskforce proposed a programme to be put in place to address the gaps in the basic atmospheric global observation systems, the Global Surface Network and the Global Upper Air Network.

This report and the activities under WP7 of FA are aligned with the above recommendations.

2. Methodology

A gap analysis was conducted in order to understand the extent to which SADC NMHS and SADC-CSC follow the WMO guidelines or meet certain competency standards as proposed by WMO. These would involve new technology-based products to assist with early warning and climate services for different sectors in the SADC region and eventually Africa as a whole. In order to identify the gaps in the SADC Climate Services Centre (SADC-CSC) and SARCOF training material, ACMAD used a strategic action plan approach. The action plan included the SMART goal worksheet, to see if the goals set are Specific, Measurable, Attainable, Result oriented and Timely. Specifically, the SMART framework aimed to identify the following:

Task	Identify training gaps in SADC NMHS and the SARCOF Material
Is it Specific?	YES, to identify SADC Climate Service and SARCOF/SWIOCOF training material gaps
Is it Measurable?	YES, through use of a survey on climate services implementation
Is it Attainable?	YES, a dedicated climate expert from SADC Region is responsible for the task.
Is it Relevant?	YES, it will improve enormously on the SARCOF/SWIOCOF process to be able to implement the GFCS to all SADC NMHS through capacity building.
Is it Timely?	YES, Final Gaps Analysis report to be provided by September 2021.
SMART Goal:	SADC climate services gap analysis report: In-depth analysis on the SARCOF and SWIOCOF training material.

The conducting of the analysis and preparation of the report involved the following steps:

1. Collect and compile training materials from SARCOF/SWIOCOF
2. Conduct literature review to familiarize oneself with WMO competencies in relation climate services and identify and analyze gaps in the SARCOF/SWIOCOF training materials
3. Conduct climate services implementation survey among SADC NMHSs
4. Identify required and desired recommendations for SADC NMHS and SARCOF/SWIOCOF climate services capacity development.

A key part of the gap analysis involved an in-depth review of the SARCOF/SWIOCOF training material and WMO publications in relation to climate services capacity building. The review helped to familiarize with WMO recommendations and essential activities and products in line with what is required in terms of providing climate services. The material reviewed are listed in the

References

Literature and training materials used in the various climate outlook forums in the region were reviewed according to two methods:

1. Process based gap analysis: i) verification of forecasts; ii) Climate variability monitoring (past and present); iii) Drivers of climate variability (analysis and predictability); iv) seasonal forecasting methods, tools and products; v) Interpretation of model outputs and other products; vi) consolidation of outputs and generation of consensus; and vii) tailoring and communication for each sector and level of users.
2. Competency based gap analysis: i) Create and manage climate data sets; ii) Derive products from climate data sets; iii) Create and interpret climate forecasts and models; iv) Ensure quality of climate forecasts; and v) Communicate information to users (as described in the WMO Guide to Competency (WMO, 2018a)). This report follows the format according to the competency-based framework.

A climate services questionnaire on “Checklist for Climate Services Implementation” (WMO, 2020a) was also distributed to 16 SADC member states, of which 14 responded. The questionnaire responses were analyzed, in order to quantify the gaps currently faced in the region on implementing climate services. A part of this report focuses on analyzing responses to the questionnaire to identify the gaps in line with the four (4) recommendations of the high-level taskforce of the GFCS.

3. Climate services governance

Before looking at the capacity gaps according to each competency area, it was deemed useful to look at issues around governance of climate services in the NMHSs, based on the climate services competency questionnaire. NMHSs were first asked whether they collaborate with other NMHSs, research institutions, RCCs or any other sectors for their training events and capacity development. The results in Figure 2 show that 64% of the NMHS do collaborate and get assistance on training, but 36% indicated that they do not get assistance especially from Global Producing Centres (GPCs) of WMO, but more so from the Regional Climate Centres (RCC). NMHSs also often invite their stakeholders to participate in relevant training events.

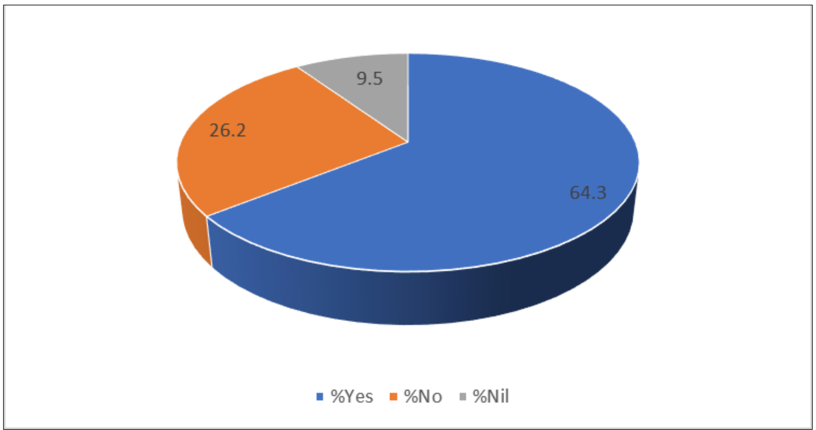

FIGURE 2: CAPACITY DEVELOPMENT IN SADC NMHSS

Eighty-six percent (88.6%) of the members participate in the identification of climate-sensitive national development priorities (Figure 3). Regarding capacity assessment of key stakeholders, including identifying stakeholders to work wort to improve delivery of climate services, 88% have done that. The gap as shown in Figure 4 is on identifying feasible climate services for meeting priority needs and capacity needs/requirements for their development and delivery.

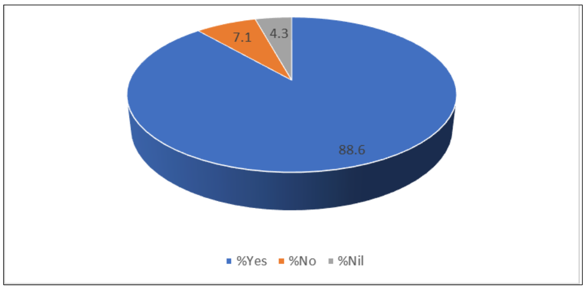

FIGURE 3: CLIMATE SENSITIVE NATIONAL PRIORITIES

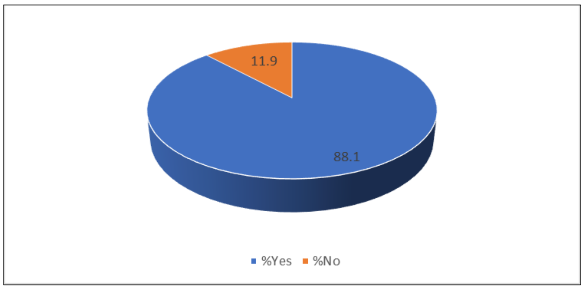

FIGURE 4: CAPACITY ASSESSMENT OF KEY STAKEHOLDERS

Most of the NMHSs (76%), participate in the implementation of national plans/frameworks (e.g., National Adaptation Plans (NAPs) or Nationally Determined Contributions (NDCs)) as shown in Figure 5. Only 67% of the NMHSs undertake resources reviews of relevant ongoing and planned partner projects. There is still a gap of 33% of the NMHSs (Democratic Republic of Congo (DRC), Madagascar, Namibia and South-Africa) not taking advantage of the available projects and programmes (Figure 6).

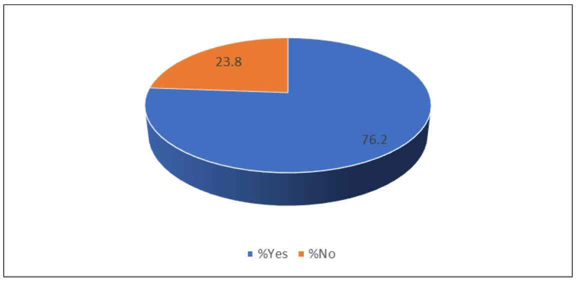

FIGURE 5: IMPLEMENTATION OF NATIONAL PLANS/FRAMEWORKS

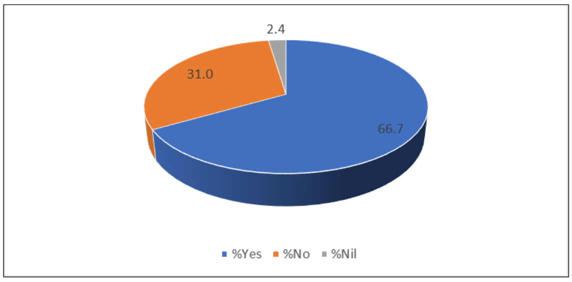

FIGURE 6: UTILISING RESOURCES FROM PARTNER PROJECTS

The results show that most of the SADC NMHSs do participate in identification of climate-sensitive national development priorities, support implementation of climate-relevant national frameworks and engage sectoral stakeholders to improve climate services. However, there is a gap in relation to leveraging resources from partner projects and programmes.

4. Capacity gaps in the SADC region by competency area

4.1 Competency area 1: Climate data management for climate services

While existing capabilities for climate observation provide a reasonable basis for strengthening climate services, commitment to sustaining high quality observations is inadequate and enhancements to existing networks are required, particularly in developing countries. Further effort is also needed by governments and others to overcome the currently significant restrictions concerning sharing of, rescue of and access to climate and other relevant data.

The results of the questionnaire in terms of observing networks, data, data management, monitoring and forecasting (Figure 7) show that 76% of the SADC countries do comply with data service requirements. DRC, Angola and Seychelles were noted to be lagging in this area.

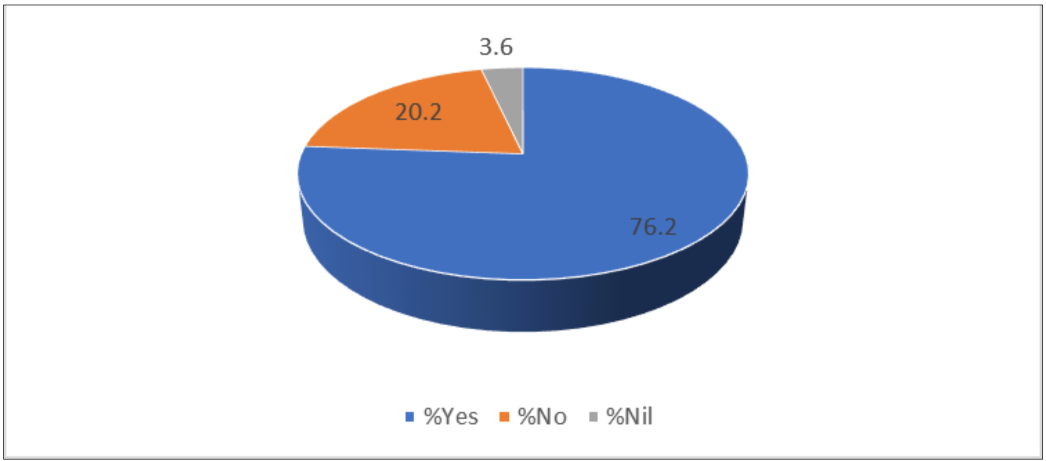

FIGURE 7: OBSERVING NETWORKS, DATA, DATA MANAGEMENT, MONITORING AND FORECASTING SYSTEMS

Most SADC countries have installed AWS through national government funding, through projects like the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) and some with support directly from the SADC-CSC. Some countries like South Africa and Botswana have installed automated rain-gauges (ARG's) too and are still in the process of installing more AWS and ARG's. Figure 8 shows that most NMHS are implementing the basic, essential and full requirements, whereas 50% of the NMHS are still not following the regional WMO Integrated Global Observing System (WIGOS) and Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP).

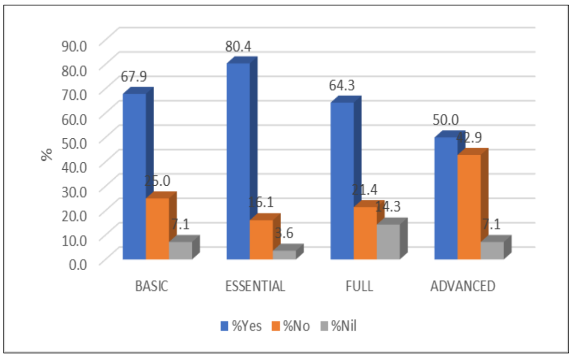

FIGURE 8: OBSERVING NETWORKS

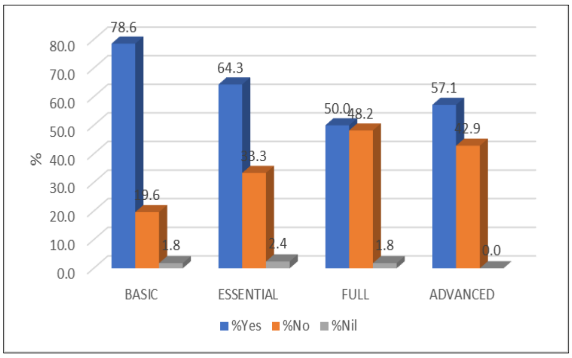

FIGURE 9: DATA AND DATA MANAGEMENT

Most SADC countries use CLIMSOFT as their database for storing climate metadata, and they also use it for quality control for climate data products. Namibia recently, in 2020, migrated from using CLICOM to CLIMSOFT, whereas the SADC regional centre, SADC-CSC, uses CLISYS for climate data management. Some countries perform statistical methods with Excel spreadsheet for quality control, whereas others, but just a few use R-Instat like Lesotho, Zambia, Mozambique and Malawi. Only a handful of experts from Zambia find CLIMPACT to be much easier than R-Instat. The challenge with CLIMSOFT is that it is not easy to identify missing dates, and it tends to create a lot of duplicated data, which is the case with Botswana datasets. Another challenge is that CLIMSOFT was developed by a small team, and there is no support desk, hence the meteorologists have not been fully trained for its use. There is an evident challenge in obtaining good data, as there are always data gaps and duplicates.

It became apparent from the survey (Figure 9) that 13 out of 14 NMHSs did not document and register rescued and non-rescued data in the WMO-GFCS International Data Rescue (I -DARE) portal, showing that not all NMHS have the capabilities for data rescue and archiving. Even though most NMHSs do not make efforts to improve their data availability (for example through research), some of them did undertake specific case studies, although these studies or research have not been adequately documented for future use by young experts. Sometimes experts who receive training do not train other experts.

At present, most NMHSs prepare climate data for analysis using MS Excel, which is a cumbersome process. During SARCOF 24 (2020), SADC-CSC made a presentation (Gamedze, 2020a) on the practice of preparing climate data for seasonal forecasting in Climate Predictability Tool (CPT), INSTAT, SYSTAT, Statistical Package for the Social Sciences (SPSS), however, since it was a virtual meeting, most experts did not fully understand the processes, and they did not become familiar with the packages. Most climate experts are not familiar with using different statistical tools, even Excel is not used to its full capability due to lack of advanced knowledge on its full potential. For example, for fast calculation, macros can be used but most experts do not know how to create macros and only know the basic functions of Excel. Identifying the cause of errors is also a challenge, with most climate experts in the SADC region not conversant with techniques for doing so. There is also no dedicated software for calculating extremes and normals in climate data.

For homogenization techniques (Gamedze, 2020b), SADC-CSC trained climate experts on using Principal Component Analysis (PCA), however this process was not completed, and most experts had requested additional training to be done on PCA. There is also a manual available on homogenous zoning, using the SYSTAT and SPSS and more information in relation to climate metadata and homogenization. But from the survey most SADC NMHS did not fully follow the manual for improving their data management. Most of the SADC countries use filming and digitizing for data rescue and there are storerooms available for archiving files, whereas some of the archiving is done in the databases.

Knowledge on descriptive statistics is very limited when using statistical software. Return periods and extreme values with norms can be analyzed but only by a few officers, using Excel. There is inadequate knowledge on climate systems and their processes. In fact, according to some end-users that reported to WP4, climate change was generally not considered in planning in different sectors and only return periods of runoff, peak discharges and intensity-duration-frequency (IDF) were considered. For example, in infrastructure the associated 100-year design values only considered historical maximum daily rainfall from in-situ rain gauge stations in the region of the railway infrastructure but did not consider future possible climate change scenarios.

4.2 Competency area 2: Climate data processing and derived products

This competency ensures that the climate observations necessary to meet the needs of climate services are generated. The competency area is relevant for decadal, monthly and seasonal timescales of climate monitoring. Even though the required standard from WMO for climate monitoring is the monthly basis[1], there are only a few experts in the SADC region who have the knowledge to retrieve

[1] WMO National Climate Monitoring Products brochure. WMO. (2012). www.metoffice.gov.uk/hadobs/opace2_tt_ncmp/

data from available data sources and conduct analysis. For data archive and retrieval processes, most experts might be retrieving data from available data sources, but they do not know all the available data sources. Only three scripts are used for retrieving monthly data in the NetCDF format for three predictors: Mean Sea Level Pressure (MSLP), Sea Surface Temperature (SST) and pressure at 850hpa (Gamedze, 2020a). The International Research Institute for Climate and Society (IRI) Data Library[2] is the preferred source of predictor data for use in the SADC-CSC CFT for producing monthly and seasonal forecasts. But experts were encouraged to try out different parameters, as predictors, to test the predictive skill over their respective countries. Very few, though, have knowledge on advanced statistical analysis techniques.

For climate monitoring, during the Monitoring of the Environment for Security in Africa (MESA) project, experts from the SADC NMHS were trained on drought monitoring using satellite data and in-situ rainfall data. These experts were the focal points from their countries on drought monitoring, and they were required to train other experts. The data used for such monitoring are observed rainfall, rainfall estimates (RFE) and Normalized Difference Vegetation Index (NDVI). The MESA project also supported development of the Drought Monitoring Software (DMS) which allowed experts to download decadal and monthly RFE and NDVI data. DMS software can be used to produce different products like Vegetation Condition Index (VCI) maps, NDVI Difference maps, and RFE Cumulative and Anomaly maps. It also has the drought monitoring map, which uses the three-month seasonal rainfall outlooks from South African Weather Services (SAWS). With this input, seasonal drought forecast maps for the next three months are produced, and this support early warning and early actions, as they were included in the monthly agro-meteorological bulletins.

A challenge with using the DMS is that the format for the RFE and NDVI has recently changed, and since SADC countries are not involved in the follow up Global Monitoring for Environment and Security (GMES) project, they are unable to retrieve the current RFE and NDVI for monitoring purposes. Some countries have hence adopted the use of the VCI and RFE products from the Food and Agriculture Organization of the United Nations (FAO) website, whereas most of the NMHS are lacking behind in climate monitoring. Figure 10**Error! Reference source not found.** shows that there are NMHS that are not even involved in the basic part of climate monitoring systems. Even though most NMHSs indicated having basic climate monitoring services, it is evident that more than 50% of the NMHS do not implement climate monitoring to its full capacity, with few indicating having essential, full or advanced climate monitoring services. Some NMHS did not answer this question, which could imply that they are not aware of the monitoring part.

[2] https://iridl.ldeo.columbia.edu/index.html?Set-Language=en

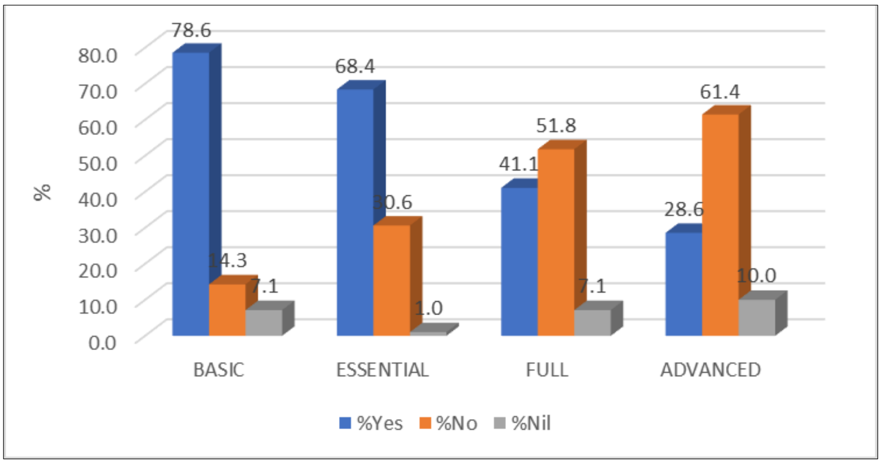

FIGURE 10: CLIMATE MONITORING IN THE SADC REGION

Regarding the drought forecast map, SAWS stopped making them available due to a change in the format of the seasonal rainfall outlooks. Experts recommended to SADC-CSC to produce the seasonal forecast in ASCII format so to continue the use of the DMS software, but this has not yet occurred. The DMS was used to produce the decile index maps using RFE but now those maps are not produced due to the change in format of the input data. NMHS, though, still produce decile index graphs and Standardized Precipitation Index (SPI) for drought monitoring purposes using in-situ rainfall data. Since the RFE and NDVI data sources keep changing their formats, and there was no support for continuous update of the DMS software, all SADC members stopped using the DMS. Some countries like Zambia, Malawi and Tanzania are using the Climate Data Tool (CDT) which only uses RFE to produce RFE related products like deciles, SPI and Standardized Precipitation and Evaporation Index (SPEI). Botswana uses VCI and RFE products from the FAO website, and for the anomalies it uses in-situ rainfall data. Surfer and QGIS mapping tools are used for plotting and analyzing rainfall and temperature data, to produce maps. Regarding the computation of indices, the most common index used is SPI, VCI and Decile, whereas very few use SPEI, which could be considered as the gap in most of the SADC countries. Most experts can do basic statistical analysis but there is still a gap in using advanced statistical analysis techniques like R and R-Instat. Most member states use Surfer as a mapping tool for their analysis, very few use QGIS for geo-statistical analysis and maps. Hence most experts have little to no knowledge in using QGIS.

EUMETSAT is working with regional meteorological centres such as SADC-CSC, to enhance capacity development. Currently EUMETSAT leads the African Satellite Meteorology Education and Training (ASMET) consisting in a project that produces training materials to capacity build forecasters to better use satellite images and products to improve their forecasts by integrating the information in their forecast process. It is structured as a course with different modules taught by EUMETSAT in selected countries selected as a representation of a language and cultural region of the continent. In the SADC region, South Africa is included in the programme with expectation that capacity built in this country will be cascaded to others in the region. Under the Intra-ACP Climate Services and Related Applications (CLIMSA) project which also targets the SADC region, JRC is developing a 'climate station' tool to allow access data from Copernicus C3S, EUMETSAT e-station and others. Linking with and building on this work will enhance sustainability of capacity building actions.

4.3 Competency area 3: Climate model outputs and forecasts interpretation

Figure 11 shows that about 90% of the SADC NMHS do implement the basic requirements for climate forecasting systems. All SADC NMHSs do participate in the SARCOF process and communicate the seasonal forecast during their National Climate Outlook Forum (NCOF). DRC is the only country that does not implement the NCOF process. Most of the NMHS do not register their forecasting products in WIS, only Zimbabwe and Mauritius indicated that they do that. About 29% to 40% of the SADC NMHSs have not implemented some of the essential and full parts of climate forecasting, and only 43% of the NMHS have advanced systems, though not all the requirements are met.

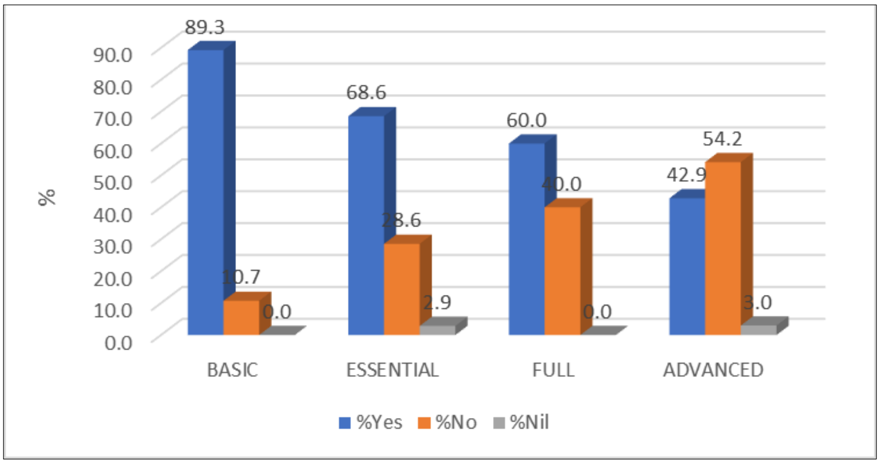

FIGURE 11: FORECASTING SYSTEMS IMPLEMENTED IN SADC NMHSS

The following part provides a more detailed description on the gaps for three key aspects under this competency area, namely, verification, seasonal and sub seasonal forecasting.

Verification

SADC-CSC trained few experts on the use of a verification template[3], which includes probability of detection, bias skill scores, hits and false alarms. The methodology uses observed data, which is transformed in the tercile scale, using the long term mean and the standard deviation based on the long-term average. The verification of the October-November-December 2017 and January-February-March 2018 season provides a good example of the verification method used[4]. There was also an evaluation of the SARCOF rainfall outlooks from 2001 to 2012 done by FEWSNET (Magadzire, 2012) to determine the performance of the forecast with the observations. The evaluation showed that the SARCOF forecasts over those twelve years on average performed very well. SADC-CSC had an improved version of the verification of the SARCOF 22 rainfall outlook, which used Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) version 2 and included the half hit and half

[3] The Verification Template is in Excel and uses mean and standard deviation formulas to verify forecast performance per station.

[4] Verification of the OND 2017 and JFM 2018 rainfall season over Southern Africa, SADC Climate Services Centre (CSC). ftp://cscftp.sadc.int/documents/SARCOF22/day%201/SADC-CSC%20VERIFICATION_2017_2018%20season.pdf

miss approach for the first time. The methodology[5] used however, was not shared with the climate experts and no manual on the process was produced.

During SARCOF 24 in August 2020, ACMAD introduced and trained SADC-CSC officers on the ranked probability skill score (RPSS) method, but the knowledge was not cascaded down to the NMHS climate experts in the region. At that same SARCOF, SADC-CSC used an improved method of verification, whereby the climate drivers were considered. This method was not shared with the regional experts and was only shown in the presentation[6]. It can be concluded that there is limited exposure of the experts to verification methods and tools. The methodology for intercomparison and comparison of operational global or regional forecasts with observations and the user-relevant verification schemes are hereby identified as regional capacity gaps to be addressed using WMO guidelines and manuals for available best practices.

Seasonal Forecasting

The IRI Data Library, Climate Prediction Center (CPC), National Oceanic and Atmospheric Administration (NOAA), and United Kingdom Meteorological Office (MO), are the principle climate predictor's datasets, which is provided at monthly time scales and in Network Common Data Form (NetCDF) format. During previous SARCOFs, SYSTAT[7] was used for statistical forecasting, but the method was improved with the development of the Climate Forecasting Tool (CFT)[8] by SADC-CSC during the Satellite and Weather Information for Disaster Resilience in Africa (SAWIDRA) project. This tool was released during SARCOF 23 in August 2019. Initially, it used Linear Regression (LR), but subsequently in the following SARCOF 24 it was updated with Artificial Neural Networks (ANN), which uses Multilayer Perceptron (MLP) regression. The CFT can be fed by only NetCDF data format. There is a manual[9] available with steps to follow in order to run the CFT using both linear regression, which is a programmed simplified version of the SYSTAT process, and the MLP Regression using Artificial Neural Networks (ANN). This software is available on the SADC-CSC ftp site[10], where all current SADC-CSC tools and materials can be found.

During previous SARCOFs, only the SST predictor was used together with related climate drivers for that year, however, for the past two years more variables like MSLP, temperature at 2m, wind speed and direction at different levels, among others, were introduced and are currently being used during SARCOF and NCOF's. In SWIOCOF, the seasonal forecast uses the number of cyclones, precipitation, the accumulated cyclone energy, number of cyclone days during the season as predictands. SSTs and 850 hPa zonal winds are the predictors in the statistical tools. Dynamical approach is also considered based on global operational forecasts products available at ACMAD and Regional Specialized Meteorological Centre (RSMC) La Reunion. The SWIOCOF put emphasis on statistical-dynamical

[5] Verification of SARCOF 22 Forecasts, Southern African Regional Climate Information Services for Disaster Resilience Development (SARCIS-DR) Project, 28 – 30 August 2019, INAMET, Luanda, Angola.

[6] Arlindo Meque Climate Modelling Expert, *Review of the 2019/2020 rainfall season*, SADC-CSC, August 2020. ftp://cscftp.sadc.int/cem24/Day1/presentations/CEM24_2019_2020_seasonal_performance_SADC.pdf

[7] Mduduzi Sunshine, SADC-*CSC manual on the development of statistical seasonal forecasting models,* pre-SARCOF climate expert meeting manual Version 1, SADC-CSC, 2013.

[8] Thembani Moitlhobogi, *Introduction to the SADC Climate Forecasting Tool (CFT),* Southern African Regional Climate Information Services for Disaster Resilience Development (SARCIS-DR) Project, SADC-CSC, Climate Experts Meeting 10 –26 August 2020. ftp://cscftp.sadc.int/cem24/Day3/Intro%20to%20CFT.pdf

[9] Thembani Moitlhobogi, *Statistical Forecasting using the SADC Climate Forecasting Tool (CFT),* Southern African Regional Climate Information Services for Disaster Resilience Development (SARCIS-DR) Project, SADC-CSC, Climate Experts Meeting 10 –26 August 2020. ftp://cscftp.sadc.int/cem24/Day3/Forecasting%20using%20CFT.pdf

[10] ftp://cscftp.sadc.int/

approach because of its improved forecasting skills. Experimenting this approach in collaboration with SARCOF is recommended.

The second tool used at SARCOF's is the CPT, which has been around since the beginning of the SARCOF process. During SARCOF 24, more training was done on the tool, focusing on enabling experts to conduct station forecasts, and use more predictors from the CPC data set. Seasonal North American Multimodel Ensemble (NMME) hindcast and forecast were also introduced and used for the first time with a different format of predictors also being introduced to the experts. Since the climate expert meeting was virtual, several experts did not learn well the process. Lack of physical interaction with the trainers prevented an in-depth understanding of the process, moreover some experts had connection challenges due to unstable internet signal. Most sessions are recorded, or the presentations made available on the SADC-CSC ftp site[11], however the physical interaction with the trainers cannot be reproduced.

Usually after SARCOF, experts present their results to their relevant NMHS, including the skills of the different models and predictors used. An example to look at it the Botswana Met Service (BDMS) climate expert presentation[12]. After the outlook has been adopted by the NMHS, it is presented to the Minister and, if there is any pressing issue like anticipation of an extreme drought (as it happened in 2015), it will often be presented at cabinet level, with a presentation adapted to the non-expert audience. Subsequently, the outlook is released during NCOF's, where all media platforms are invited in order to disseminate the information and alert to the relevant sectors or communities.

During the SARCOF process, before the seasonal forecast is released, there is a presentation on the "Current Status of the Global Climate System" which is usually presented by a climate expert seconded to SADC-CSC. Mostly the key drivers examined are the current SST's, the current and forecasted El Nino Southern Oscillation (ENSO) conditions, the Indian Ocean Dipole (IOD), the Southern Indian Ocean Dipole (SIOD), and conditions over the South-West Indian Ocean (SWIO). These are then combined with the global model rainfall outlooks from sources such as IRI, National Centers for Environmental Prediction (NCEP) and the South African Weather Service (SAWS). Professionals from other partners like the Famine Early warning Systems Network (FEWSNET) and from different climate sensitive sectors also make presentations from research that they have done, or on the impacts of the previous rainfall season. Research done on "*Historical climate impacts of the El Nino Southern Oscillation in southern Africa*" by FEWSNET (Magadzire, 2018), looking at the 2015/16 drought year and its impacts on the socio-economy of SADC countries, concluded that the following are needed for enhancing the climate services value-chain:

- Comprehensive analysis of climate data
- Accessible publications on ENSO climate effects and impacts
- Regular forecast updates
- User-tailored forecasts
- Greater interaction between users and producers of climate forecasts.

These aspects are basically what the GFCS promotes for climate services to be improved.

[11] ftp://cscftp.sadc.int/

[12] Esther Verena Jansen, *Botswana Climate Outlook for 2020/21 Rainfall Season,* Botswana Department of Meteorological Services, August 2020. Can be accessed at: ftp://cscftp.sadc.int/

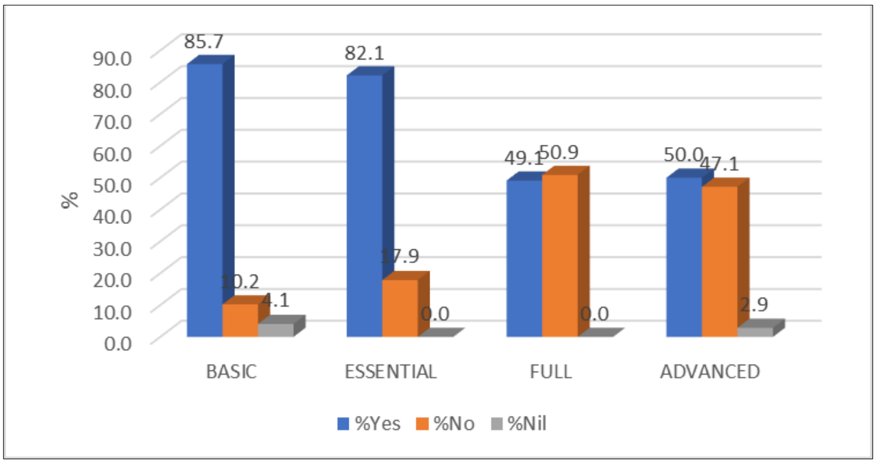

FIGURE 12: DECISION SUPPORT PRODUCT AND SERVICES, ESTABLISHED OR STRENGTHENED

SADC-CSC has also trained SADC NMHSs on the regional model, which is a model for running future Climate Scenarios. The SADC-CSC has also provided all its member states with High Performance Computer Systems (HPCS), but climate change projections in most NMHS is not implemented yet. For sub-seasonal forecasting, huge gaps exist among the NMHS in the region. The provision and application of services is mostly implemented (above 80%) in the Basic and Essential requirements of WMO, but still 20% of NMHS are lagging. Figure 12 shows that only about 50% of the NMHS have implemented the Full and Advanced services.

The main gap identified under seasonal forecasting is the limited use of GCM data sources in the region. There is not good knowledge on how to retrieve data from the different data sources and there is little training done on applications like CPT, and on the documentation, communication and interpretation of the skills of the model outputs. Intra seasonal drivers of seasonal climate (e.g. tropical/equatorial waves) are not considered in seasonal forecasting approach in SARCOF/SWIOCOF resulting in poor forecast in years when intra seasonal drivers dominate the seasonal climate variability. The gaps in seasonal forecasting methodology which need to be addressed include the integration of sub seasonal waves driving seasonal climate variability, documentation of understanding and predictability of drivers in addition to quantitative skill assessments, new bespoke products, interpretation of model outputs, and atmosphere-ocean coupling in models leading to misses of rapid intraseasonal to interannual variability of seasonal precipitation.

Sub-seasonal forecasting

SADC-CSC and its member states have not implemented sub-seasonal forecasting. Research has been done with a few pilot projects, but they never came to a stage of being implemented. Most NMHS do not have established Climate Watch offices, hence they do not conduct climate monitoring programs and do not disseminate climate early warnings, on a regular basis. In addition, 50% of the member states surveyed have not established help desks.

Under FA WP4, analysis of the CMIP5 and CMIP6 climate change simulations over southern Africa is being conducted. This is been done through a range of diagnostics, like bias and trend analysis. More specifically, the WP has studied when the climate change signal breaks out from natural variability bands, to be able to discern its impact on present and future climate. Besides this, an 8km downscaled dataset from CMIP over East Africa has been developed. This downscaled dataset can be the basis for a range of applications, hydrological modelling being one possible application in FA. Apart from this, WP4 has also been working on the verification of raw seasonal forecasting models output over the southern Africa domain. The models studied are the ones available in the Climate Data Store from the Copernicus Climate Change Service (C3S). The aim of this analysis has been to identify the variables, regions and forecast horizons where the model outperforms the basic climatology approach. A range of deterministic (i.e. correlation and bias) and probabilistic metrics (RPSS and CRPSS) has been included in order to offer a thorough picture of different aspects of model's performance in the area of study. The results so far (temperature and precipitation on seasonal forecasts assessments in all SADC countries), show that there is predictability in some seasons and most of the areas, especially for temperature, but also for precipitation. There is also an investigation being carried about alternative indicators as potential predictors of crop yield anomalies being developed.

4.4 Competency area 4: Climate services quality assurance

Climate information and services are defined and routinely updated, while guidelines and quality management procedures for climate information are created and routinely maintained by WMO (for example, WMO No. 1221 on Guidelines on Quality Management in Climate Services (WMO, 2018b)). Monitoring processes of climate services are well documented and used in quality control activities. Quality Management Systems (QMS) for climate services are meant to be implemented in climate data, climate monitoring, climate prediction and climate service delivery. Currently most if not all the NMHS are not implementing QMS for climate services. QMS is only being implemented for aeronautical services and only in a few countries like Botswana, South-Africa and Tanzania. Some countries are still in the process of implementing the QMS for aviation as required by the International Civil Aviation Organization (ICAO).

Evaluation of services, as well as needs assessments, is mostly done through oral interviews with stakeholders. Climate services competency assessments are not regularly done, hence there is no documentation on related Competency procedures. Training approaches for competency development in climatology is missing and climate systems and processes knowledge for prediction is not assessed. There are no harmonized processes and products for integrated climate variability monitoring in the SADC region, as well as no staff performance assessment and operational procedure on how to address different user needs.

The evaluation of seasonal forecast quality through the forecast quality assessment should also be considered. This involves setting up a quality assessment framework to provide end-users with the tools to understand which approaches could better fit their interests. Showing the skill score of a forecast to the user increases the reliability and usefulness of the forecast. Such skill score will vary depending on the season, the variable being evaluated, the region as well as the lead time.

The climate services monitoring and evaluation survey component (Figure 13**Error! Reference source not found.**), shows that only 43% of SADC member states identified climate sensitive user sector outcomes and associated variables i.e., disaster losses, crop yields and hydropower, whereas only 39% established ongoing monitoring systems for documenting user outcomes by establishing baselines of sectoral outcomes for continuous evaluation of climate services.

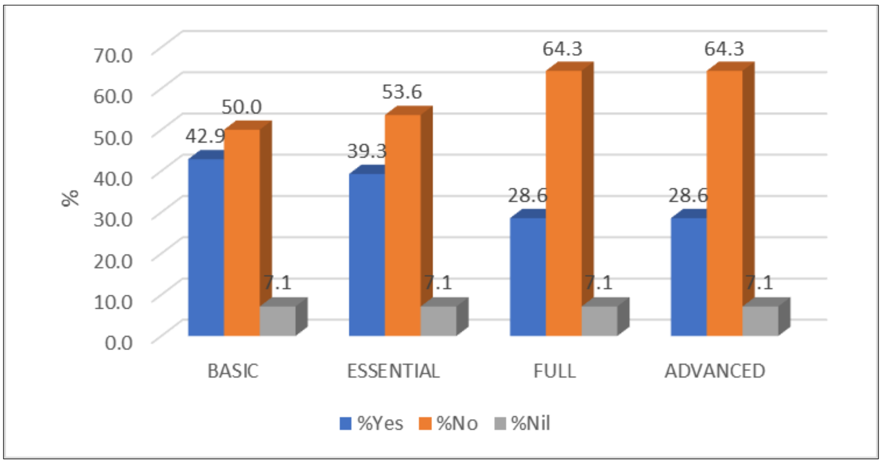

FIGURE 13: CLIMATE SERVICES MONITORING AND EVALUATION

Socio-economic analysis of the costs and benefits of climate services conducted in collaboration with users and decision makers is only implemented by 28% of the member states, with limited use for policy and planning. This shows a huge gap in climate services QMS implementation.

4.5 Competency area 5: Climate services communication to users

To be useful, climate information must be tailored to meet the needs of users. Existing climate services are not well focused on user needs and the level and structure of interaction between providers and users of climate services is inadequate. Users need access to expert advice and support to help them select and properly apply climate information. Climate services often do not reach “the last mile”, to the people who need them most, particularly at the community level in developing and least developed countries. Developing an effective communication platform through bridging the gaps between local service providers and their organizational policy perspective is another complex transdisciplinary challenge for the co-production of information services involving climate scientists, stakeholders, and end-users. The User Interface Platform will thus provide a means for users, user representatives, climate researchers and climate service providers to interact by maximizing the usefulness of climate services and helping develop new and improved applications of climate information. Effective climate services will depend on maximizing the potential of existing knowledge, new research developments and strong support from and strengthened collaboration between all relevant research communities. Understanding of the climate system is advancing quickly but is not being effectively translated into services that can inform decision making. Further effort is required to improve our ability to predict climate and help users incorporate its inherent uncertainty into their decision-making.

In the SADC region, monthly agro-meteorological and drought monitoring bulletins are produced by NMHSs, but they do not reach all relevant users. SADC-CSC provides information on the institutional website, while some SADC countries also have their own websites. However, most of the SADC NMHSs are still in the process of developing an effective and user-friendly online platform. Seasonal Outlook Statements are communicated using emails, webpages, and various media platforms (radio, newspaper, TV, social media etc.). The *Statement of seasonal rainfall and temperature outlook for October to December (OND) 2020 and January to March (JFM) 2021 by Botswana Department of*

Meteorological Services (BDMS)[13] can be taken as an example. SADC-CSC also prepares an early warning bulletin for climate sensitive sectors, which is loaded on the SADC-CSC website, an example of which can be seen for the 2018/19 rainfall season[14]. Hence, 82% of member states indicated having the Basic and Essential aspects of communicating climate services to users, as shown in Figure 14.

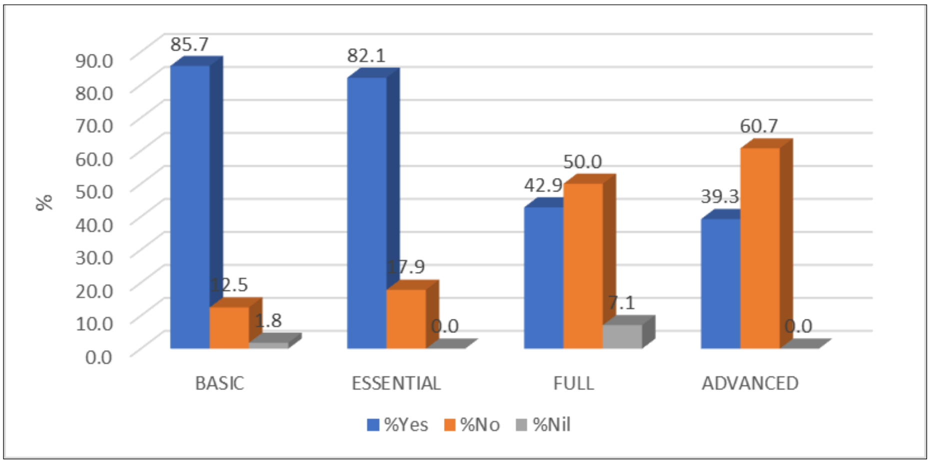

FIGURE 14: USER INTERFACE WITH PROMINENT SECTORIAL USER GROUPS

Most countries undertake questionnaires to get feedback from their climate users, but lack of survey material and related training hamper this. Little is done on the criteria of evaluation of best practices of using climate information in economic sectors. Most countries do comply with the WMO Information System (WIS), however some experts may need to be trained on the WIS.

From research being conducted under other FA work packages and case studies, most users, especially farmers, do not understand the climate information they receive, so they rely on local knowledge and practices. For that reason, understanding farmer needs and capacity, decision-making processes, local institutions, and policy are also fundamental challenges for the co-production of climatic information services. This is also very important to consider when planning capacity building and organizing trainings, especially related to planning (Kumar, 2021). One of the main challenges of seasonal forecasts is how to communicate uncertainty. For the end-users this concept means imperfect information, but the meaning will also be different for scientists and users. It is therefore required, not only a communication adapted to the needs and knowledge of the users, but an effort in capacity development in order to maximize the usefulness and efficiency of the forecasts. Another key concept to communicate is reliability. A forecast is reliable if it gives you the correct forecast at least 70% of the times. For a user 'reliable' means it can be trusted when the weather behaves in the way it is forecasted to. The challenge is then how to build trust between users and producers. In all this process it should be noted that the users of climate information include decision makers, who rely on quality forecasts to be delivered. Currently probabilities are used for seasonal and other forecasts, and these

[13] Statement seasonal rainfall and temperature outlook for October to December (OND) 2020 and January to March (JFM) 2021 by Botswana Department of Meteorological Services (BDMS) 2nd September 2020. https://hydrocon.org/wp-content/uploads/2019/10/Seasonal-Rainfall-Outlook-Statement-2019-2020.pdf

[14] *Early Warning Bulletin on the 2018/19 Southern Africa Rainfall Season*, SADC Climate Services Centre (CSC), August 2018. https://www.sadc.int/documents-publications/show/6345

also need to be adapted and explained according to the nature of the user. This leads to another important aspect, this being the visualization of the forecast, which should also be tailored to the needs and capacities of different users, for example, range from showing percentages as probabilities of a forecast, to a more semantic explanation.

Apart from the sector breakout groups during the SARCOF and the production of the Early Warning Advisory Bulletin, little is done in relation to tailoring climate information to specific user needs by co-designing and co-developing products with users. From the survey component on climate services communication, most SADC members (more than 50%) are lagging in terms of GFCS full implementation. Less than 43% of NMHSs work with sector-based research teams to develop application models (e.g. to combine climate and agriculture information and produce food security knowledge products). In this case there is research done by universities in the SADC region, for example by the University of Botswana, University of Zimbabwe and University of Cape Town, on predictors that could be used for sub-seasonal and seasonal forecasting, onsets, cessation and climate change projections. The challenge here is that the publications are available but the interaction between the NMHS and the research institutions is minimal and insufficient to demonstrate the value of research findings and operationalize and institutionalize delivery of bespoke services. The interaction between researchers and NMHSs are limited to meteorological data for scientific analysis, however, in most cases the researchers do not share their findings with the NMHS, NMHS in order to improve and innovate in the provision of climate services. Hence, less than 39% of NMHSs indicated that they jointly (with sector-based research teams) develop software and product tailored to sector-specific climate products.

There is need to examine the performances of operational model outputs, communicate findings on drivers and uncertainties in forecasting tools, and enhance interaction with users at the SARCOF (e.g. through focus group discussions and sector specific meetings). Formal agreements between climate services providers, intermediaries and users can be developed and regularly updated for sustainable climate services communication business models. Applications tools are often essential to process climate products and provide application relevant variables (e.g. water levels above a threshold for floods or below a threshold for drought impacts).

The FA team is fully aware of the existing 'gap' between end users' needs and science capability, particularly with respect to uncertainty, communication and packaging of climate information (Hewitt et al., 2020). To help bridge this gap, FA will, among other aspects 1) improve the communication and packaging of its climate information via a formalized 'knowledge broker'; 2) conduct research into natural variability and baseline risk to provide a realistic background on which predictions / projections and associated uncertainties are assessed; and 3) develop further tools and methods that deal explicitly with end user needs and the practical limitations end users face (e.g. time, funding, human resources, policy) when attempting to make robust decisions under climate change-related uncertainty.

5. Challenges faced in the SARCOF and recommendations

Based on the gap analysis the following key challenges and recommendations are provided specifically for the SARCOF process.

1. **Duration of the SARCOF training** - SARCOF is only two weeks and there is not enough time for adequate training. If SADC-CSC, ACMAD and partners could send out material in advance like the manuals and WMO material that needs to be read, this would allow the experts time to review the new material and understand the new developments before SARCOF. Longer term and continued training of new and existing NMHS staff is required, while regular awareness raising, and capacity building workshops are also needed for users and SARCOF stakeholders.
2. **Human resources** - At national levels, NMHS experts are also involved with other duties and do not often have enough time for continuous climate monitoring and prediction activities. NMHS should be encouraged to have offices and teams dedicated to climate monitoring, forecasting and verification with experts mostly dedicated to these duties.
3. **Use of impact-based forecasting methods** - SARCOF is still lagging in the use of impact-based forecasts. The only time it was done with the different climate sensitive stakeholders was during SARCOF 23 where different sectors were grouped with experts to discuss and note the impacts per sector. The recommendation here is that application models should be developed based on the impact based. For example, an expert from the water sector in Mozambique developed a model that uses probabilistic forecasts for the water levels in rivers during the rainy seasons, thresholds were identified for occurrence of floods. SADC needs to move towards impact-based forecasts, the way the outlooks are currently given with qualitative information on seasonal rainfall and probabilistic messages are of little to no benefit to the users.
4. **Internet connectivity** - Due to COVID-19, SARCOF was held online in 2020 and 2021. The virtual format of SARCOFs poses many challenges because of bad connectivity resulting in experts missing parts of training. It is proposed that experts be given incentives or facilitation in order to get good internet connections, while work towards enhancing the internet connectivity of the NMHSs should also be made a priority.
5. **Individual capacity** – Many of the individual capacity challenges and gaps have been highlighted throughout this report. On the job training and secondments at RCCs are needed to accelerate knowledge transfer of methods, tools and products, and interpretation skills at national and local levels.
6. **Computing (infrastructural) capacity** – Although most NMHSs have access to high performance computing (HPC) services, cloud computing is only possible currently in South Africa, however, there are possibilities to support cloud computing and increase computing capacity in SADC-CSC and SADC NMHSs.

Other aspects essential for regional and national climate services provision included: methods and tools for data rescue, indices generation, statistical and dynamical downscaling, model outputs interpretation, impact-based forecasting, new products development, forecast formatting, verification, evaluation and performance assessment, quality assurance and control, drivers detection and analysis, and predictors definition and identification.

6. Conclusions

Regarding governance of climate services in terms of implementing national climate plans and priorities, capacity assessments of key stakeholders and leveraging resources from partners, about 80% of the NMHS are actively doing so, whereas there are still a few countries like DRC that are facing challenges. There are about of 36% of the NMHSs that indicated not getting technical assistance, especially from the Global Producing Centres of WMO (GPCs). Member states are still not taking full advantage of the available capacity development initiatives from WMO and other organizations or partners. In terms of observing networks, the situation needs attention, even though most countries do have Automated Weather Stations (AWS) which were provided by through various initiative (e.g. SASSCAL project), maintenance and regular real-time operation is still challenging.

Competency Area 1 – Data and data management

Data handling and data management currently one of if not the greatest challenge for the SADC NMHSs. There are gaps and inhomogeneity in the data, mostly because most, if not all, NMHSs in the region do not have trained and qualified data managers. Even though CLIMSOFT is used, there is limited capacity on its use and most members lack skill in using statistical software like R-Instat, R Language, SPSS, ClimPACT and MYSQL, to assist in managing the data in an efficient way. Therefore, priority should be given to have competent experts to manage the databases and to establish a support desk for CLIMSOFT users.

Competency Area 2 - Climate data processing and derived products

Climate data monitoring appears to be a big challenge in the region. Most members are at the basic and essential level. Change in the format of the input data makes climate monitoring tools difficult to use by country experts who usually lack skills in data reformatting. Climate monitoring support desks at RCCs should help to raise the capacity of NMHSs to essential and advanced categories.

Competency Area 3 - Climate model outputs and forecasts interpretation

Regarding climate model outputs_the SADC NMHSs and SADC-CSC issue seasonal rainfall outlooks every year during the last week of August and first week of September. Currently the region is using the Climate Forecasting Tool (CFT) which was developed under the SAWIDRA project by SADC-CSC. The tool simplifies the SYSTAT process, which uses linear regression. The tool uses both the linear regression and the multi linear regression using the Artificial Neural Network (ANN). This has been a great improvement since this allows experts to try out different predictors to use for predicting the rainfall and temperature. The tool can issue both regional and station forecasts and presents the skills of the forecast. The other tool being used since the onset of SARCOF is the Climate Predictability Tool (CPT). Usually, experts are advised to run their own statistical models before looking at what the global modeling centres are giving in terms of precipitation forecasts. Verification of the SARCOF forecasts has been conducted for years, however standard and user relevant verification schemes are still to be fully implemented. User driven verification should facilitate the forecast understanding, interpretation and use in climate sensitive sectors. The NMHSs also only use visual methodology for verification of their outlooks, however they are open to be trained in other available quantitative forecast assessment methods like RPSS. In general, members do not provide sub-seasonal forecasting useful important information such as onset, cessation, and dry and wet spells. The documentation and monitoring of drivers of climate variability and their predictability, use of teleconnections and known climate interactions within and outside SADC, are still limited in the region. For example, the consideration of seasonal cyclone activity in the Indian Ocean, which is linked to rainfall over southern

Africa, would improve the quality of climate services. Interpretation of operational global forecasting systems outputs are limited due to unavailable or inaccessible documentation of studies on models' products intercomparison and comparison with observations of features and phenomena driving the southern Africa climate variability and change.

<u>Competency Area 4 - Quality Assurance</u>

Climate services monitoring and evaluation is a huge challenge in the region, with climate services quality assurance not being done by the majority of the NMHSs. This significantly hinders the provision of high-quality climate services. There is a real need to train climate services quality managers and a need to implement the Quality Management and Certification Process for Climate Services. Support can be provided through relevant expert teams to conduct assessments of compliance with regulations and guides, and to provide supervised assessment of compliance with manuals and guidelines.

<u>Competency Area 5 - User Interface</u>

And lastly, SADC members and SADC-CSC have tried to communicate climate services to the climate sensitive sectors. In some cases, this is done by trying to explain the forecasts in simple terms, while some members have developed software for modelling the impact of the seasonal rainfall outlook on hydrology. A lot still needs to be done on developing online and in-person user-interface platforms. For the agriculture sector, the Participatory Integrated Climate Services for Agriculture (PICSA) methodology, developed by the University of Reading, is available. Some member NMHS like Malawi, Lesotho and Zambia have started implementing it and it has helped raise farmers' understanding and appreciating the forecast and being able to make decisions and plans for the upcoming season. It is recommended to roll out PICSA across all the member states so to close the gap between Meteorology and Agriculture. Gaps still exist in health, energy and hydrology, that need to be addressed. The communication is sometimes limited to presentation of probabilistic forecasts products with little efforts to estimate and explain potential impacts of the predicted phenomena or hazards. Gaps are to be filled on documenting and communicating climate variability and its driving factors, predictability of the drivers, and systematic assessment of operational forecasting systems. User interfaces are needed for different sectors of the GFCS at RCOFs, including focus groups discussions and meetings for different sectors, which would aid the development of bespoke services and sharing of value demonstrated case studies. Other aspects related to communication include the need for forecasting testbeds and demonstrations and improved communication of uncertainties and limitations in forecasting methodologies (e.g. little consideration for seasonal forecast of drivers of intra seasonal climate variability). Formal agreements between climate services providers, intermediaries and users can be developed and regularly updated for sustainable climate services communication business models. Applications tools are often essential to process climate products and provide application relevant variables (e.g. water levels above a threshold for floods or below a threshold for drought impacts).

7. Action plan

The table below shows the recommendations and the actions regarding training material, along with suggested partners and projects who could support each action.

Climate Service Competency area	Training Material Recommendations	Action by (institution, projects)
1. Data and data management		
	a. Advanced training of Meteorologists on data rescue and management.	ACMAD, SADC-CSC and WMO (ClimSA)
	b. Develop Support Desk for CLIMSOFT, with data rescue functions in all Climate Data Management Systems (CDMS)	University of Reading and ACMAD (ClimSA)
	c. Advanced training on descriptive statistics, using statistical tools like R-Instat, SPSS, R-language, ClimPACT, RClimDEX and python. Provision of operational manuals.	University of Reading, MO, BSC (FA)
	d. ARG's to be connected to the WMO or regional data Dissemination System or through EUMETSAT	WMO, EUMETSAT/EUMETCAST (ClimSA)
	e. In-depth training on PCA and other data homogenization techniques. (Note that the need for identification of standard observational data sets and common reference periods have also been highlighted as essential under the CLIMSA Project))	MO, BSC, University, WMO (FA)
2. Climate data processing and derived products		
	a. Advanced training in mapping software like QGIS and Surfer. Avail operational manuals.	ACMAD, SADC-CSC (ClimSA)
	b. Propose need based products including, drivers on an intra-seasonal scale.	MO (FA)
	c. Statistical methods such as the analysis of daily precipitation profile and analog years.	ACMAD (FA)
	d. Organize training on quality processes for climate monitoring, with standardized documented procedure for the region's climate monitoring.	WMO, ACMAD, SADC-CSC (ClimSA)
	e. Training on use of most of the monitoring Indices.	ACMAD, SADC-CSC (ClimSA), BSC (FA)
	f. Assist SADC-CSC and member states to produce their seasonal forecasts in ASCII format in order to make use of the drought forecast product in the DMS tool that was developed during the MESA project.	MO, ACMAD (FA), WMO, ACMAD (ClimSA)
	g. Train other SADC NMHS with the Climate Data Tool (CDT), or synergize the DMS and CDT tools into one tool that provides all products for climate monitoring.	SADC-CSC (ClimSA)

	h. Familiarize with the MESA DMS tool for drought monitoring and provide support for the software to be upgraded on a regular basis as the satellite data formats keep changing.	SADC-CSC (ClimSA)
	i. Invest in more case studies and research, and cascading of such down to all meteorologists.	FA case study lead institutions
	j. NMHS should be encouraged to have Climate Watch Office (CWO) dedicated to Climate Monitoring and early warnings.	WMO, SADC-CSC (ClimSA)
3. Climate model outputs and forecasts interpretation		
3a. Verification	a. Tools for Evaluation of forecast performance and interpretation of performance products over SADC region, operational models intercomparison and comparison with observations, User relevant forecast evaluation,	MO, BSC (FA)
	b. Training material on verification by comparison of model outputs with observations should be implemented by intercomparisons using other verification methods such as ROC, RPSS, BSS and Reliability diagrams.	WMO, UK Met Office, ACMAD (FA)
	c. Development of training material on forecast evaluation and organization of training sessions for NMHS Regional centres and their users.	WMO, ACMAD (FA and ClimSA)
	d. Produce manual on Verification procedure for SARCOF /SWIOCOF	BSC (FA), WMO (ClimSA)
3b. Seasonal Forecast	a. Training on how to produce seasonal forecasts, and forecast uncertainties, model intrinsic predictability analysis and operational predictive skills in global models.	WMO, MO, BSC ACMAD (ClimSA, FA)
	b. Tools for Model outputs intercomparison	WMO, UCT, BSC ACMAD (FA)
	c. Look into CFTs use in Africa and further for users on statistical seasonal forecasts.	WMO (ClimSA)
	d. Advanced training to be done on drivers, predictors, predictability, CPT and understanding and interpretation of the model skill outputs.	ACMAD (ClimSA), MO (FA)
	e. Support to develop and train surveys on the provision and use of seasonal forecast	ACMAD and SADC-CSC (ClimSA), Lead institutions of FA case studies
3c. Sub-seasonal forecast	a. Training in sub-seasonal forecasting and implementation of the whole process, by introducing the production of climate monitoring and forecasting information on a scale of one to two weeks using intra-seasonal products like MJO, Rossby waves, Kelvin, Velocity potential and stream functions.	ACMAD (FA, ClimSA), WMO (FA, CREWS)
	b. Need also to include precipitation variability and extreme analysis, composites, trends and analog analyses.	ACMAD (FA, ClimSA)

	c. The SARCOF 22 presentation on *"downscaling and monitoring forecasts"* to be investigated detail and cascaded down to the SADC NMHS.	UCT under FA, CLIMSA
	d. The SARCOF 22 presentation on *"Statistical downscaling of GCM outputs using Bias Correction Spatial Disaggregation (BCSD) method"* needs to be made operational for the SADC-CSC.	UCT, MO, BSC (FA), SADC-CSC (CLIMSA)
4. Climate services quality assurance		
	a. Invest in Training for Quality Management and Certification Process for Climate Services.	MO, WMO (ClimSA)
	b. Organize training on quality processes for climate monitoring.	WMO, ACMAD (ClimSA)
	c. Standardized documented procedure for the Region to do Climate Monitoring.	ACMAD, WMO (ClimSA)
	d. Support NMHS staff assessment.	WMO, ACMAD (ClimSA)
	e. Support the assessments of compliance with regulations and guides, and to provide supervised assessment compliance to its manuals and guides.	WMO (ClimSA)
	f. Develop operational procedures and questionnaires on addressing different user needs.	SADC-CSC (ClimSA)
	g. Support to organize staff assessment performance and training on climate services competencies.	WMO (ClimSA)
	h. Assist member states in setting up help desks for climate services	WMO (ClimSA)
5. Climate services communication (User-Interface)		
	a. Develop tools or models to provide user specific products for agriculture, water, health, energy and DRR.	Mozambique Water Department (Hydrology), FA case study lead institutions
	b. Support to develop websites for sharing climate information with users.	ACMAD (ClimSA and FA), SADC-CSC (ClimSA)
	c. Meteorologists to be trained in hydro meteorology and agrometeorology in order to produce tailor made products and advisories for climate sensitive sectors.	
	d. Organize training for meteorologists and meteorological users on PICSA. All SADC countries to implement the use of PICSA.	University of Reading, SADC-CSC (ClimSA)
	e. Support to develop materials and conduct training on surveys and evaluation material and their analysis.	Lead institutions of FA case studies
	f. Support (equipment and training) SADC countries to comply with the interfacing requirements of the GFCS and on the concepts and applications of service delivery frameworks and systems.	WMO

	g. Research Institutions to present their findings to NMHS and improve on their partnership, by implementing their research findings in order to improve on climate services by NMHS.	ACMAD, SADC-CSC (ClimSA), Lead institutions of FA case studies
	h. document and communicate on skill of forecasting systems, support SARCOF/SWIOCOF collaboration, organize focus group discussions and meetings of specific sector users, organize testbeds and demonstrations, facilitate establishment of formal arrangements for sustainable service delivery	Lead institutions of FA case studies, ACMAD, SADC-CSC and WMO (ClimSA, SWIFT),

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