ECOWAS HYDROMET INITIATIVE

Strengthening Weather, Climate, and Water Services In West Africa

An Analytical Report

ECOWAS HYDROMET FORUM

Published by:

Economic Community of West African States (ECOWAS)

Humanitarian and Social Affairs Directorate ECOWAS Commission101 Yakubu Gowon Crescent
Abuja, Nigeria

September 2021

Internet: www.ecowas.int

Citation
Please cite the report as follows: ECOWAS 2021. ECOWAS Hydromet Initiative: Strengthening Weather, Climate and Water Services in West Africa – Analytical Report. Abuja. Translations—If you create a translation of this work, please add the following disclaimer along with the attribution: This translation was not created by ECOWAS, The World Bank or WMO and should not be considered an official translation. The World Bank shall not be liable for any content or error in this translation.

Acknowledgement
This analytical report was drafted as part of the collaboration between ECOWAS and The World Bank with technical support from the World Meteorological Organization (WMO) and the national hydrological and meteorological services of the 15 member states of ECOWAS as well as regional organizations in West Africa. The report was made possible and prepared in the context of the Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities Program, which is an initiative of the Organisation of the African, Caribbean, Pacific Group of States (OACPS), financed by the European Union (EU) and implemented by the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR). The World Bank team is grateful to the Organistion of the African, Caribbean, Pacific Group of States and the European Union as well as African Union Commission for their overall guidance and leadership to this program.

The report was prepared with the technical guidance and support. The ECOWAS team for the report was guided by Hon. Commissioner Agriculture, Environment and Water Resources Mr. Sekou Sangare with contributions from Johnson Boanuh, Bernard Yao Koffi, Sintiki Ugbe, Djeri Alassani, Mohammed Ibrahim, Raoul Kouame, and Adama Bagayoko. The WMO team consisted of Tania Gascon Bernard Gomez, Jean Baptiste Migraine, Nakul Prasad, Giacomo Teruggi, and Caroline Wittwer. The World Bank team for the report was led by Prashant Singh and Carl Dingel with contributions from Marcel Giovanni Prieto Castellanos, Ulrich Diasso, Mallam Soumaila Ibrahim, Thembi Kumapley, Jean Blaise Ngamini, Makoto Suwa, and Darcy Gallucio (editing). The economic analysis was conducted by Sonia Quiroga. The report was designed by UltraDesign.

The World Bank, ECOWAS Commission, and World Meteorological Organisations as well as all involved partners and consultants extend their gratitude and appreciation to the many stakeholders who in many different ways contributed to the study and the development of this report.

ECOWAS HYDROMET INITIATIVE:

Strengthening Weather, Climate, and Water Services In West Africa

An Analytical Report

Building Disaster Resilience in Sub-Saharan Africa
WORLD BANK GROUP
GFDRR
Global Facility for Disaster Reduction and Recovery
WORLD METEOROLOGICAL ORGANIZATION

Table of Contents

List of Figures

List of Tables

List of Boxes

Acronyms

ACMAD	African Center of Meteorological Applications for Development
ADCP	Acoustic Doppler Current Profiler
AfDB	African Development Bank
AGRHYMET	Regional Center for Training and Application in Agrometeorology and Operational Hydrology
AMCOMET	African Ministerial Conference on Meteorology
ANACIM	National Agency of Civil Aviation and Meteorology Services of Senegal
ASECNA	Agency for the Safety of Air Navigation in Africa and Madagascar / Agence pour la sécurité de la navigation aérienne en Afrique et à Madagascar
CILSS	Permanent Inter-State Committee on Drought Control in the Sahel
DRR	Disaster Risk Reduction
EAMAC	African School for Meteorology and Civil Aviation / École Africaine de la Météorologie et de l'Aviation Civile
ECOWAS	Economic Community of West African States
EMDAT	Emergency Events Database
GDP	Gross Domestic Product
GPC	Global Production Center
GTS	Global Telecommunications Systems
ICAO	International Civil Aviation Organization
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate Change
LCBC	Lake Chad Basin Commission
MESA	Monitoring for Environment and Security in Africa
MOLOA	West African Coast Observation Mission
MRU	Mano River Union
NBA	Niger Basin Authority
NHS	National Hydrological Services
NMHS	National Meteorological and Hydrological Services
NMS	National Meteorological Services
NOAA	National Oceanographic and Atmospheric Association
NPV	Net Present Value
OMVG	Gambia River Basin Development Organization
OMVS	Senegal River Basin Development Organization / Organisation pour la mise en valeur du fleuve Sénégal
PDNA	Post-Disaster Needs Assessment

PRESASS	Seasonal Climate Outlook Forum for SudanoSahelian Africa / Prévision Saisonnière en Afrique Soudano-Saharienne
PRESAGG	Seasonal Climate Outlook Forum for the Gulf of Guinea / Prévision Saisonnière du Golfe de Guinée
RCC	Regional Climate Center
RCOF	Regional Climate Outlook Forums
RSMC	Regional Specialized Meteorological Center
RTC	Regional Training Centers
UEMOA	West African Economic and Monetary Union / Union économique et monétaire ouest-africaine
UNECA	United Nations Economic Commission for Africa
VBA	Volta Basin Authority
WASCAL	West African Science Service Center on Climate Change and Adapted Land Use
WHOS	WMO Hydrological Observing System
WIS	WMO Information System
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization

Executive Summary

West Africa, increasingly affected by extreme weather and climate events, is realizing the importance of weather, water, climate and early warning services, jointly referred to as "hydromet" services, as a key element of disaster risk management and climate adaptation. West Africa's climate is projected to become more extreme with rising temperatures, prolonged heatwaves, delayed rains and extreme weather events. Hydromet disasters have increased in frequency and severity in West Africa in the last 30 years, affecting over 100 million people. West Africa's economy is vulnerable to climate risks, notably sectors such as agriculture, food security, energy production and transport. More than 70 percent of West Africa is dependent on rain-fed agriculture. With the global COVID-19 pandemic significantly impacting the region's shock-coping capacity, the vulnerability to climate risks is rising. Climate change may further impact hydropower, agriculture and food security, increasing disease and conflict for resources.

Acknowledging this, the Economic Community of West Africa States (ECOWAS) hosted the ECOWAS Hydromet Forum and Disaster Risk Reduction (DRR) Platform in 2018, with partners such as the World Bank and World Meteorological Organisation (WMO), to highlight the need for strengthening hydromet services for sustainable development as well as disaster and climate resilience. It also discussed the critical role of hydromet and early warning services in economic sectors, such as agriculture, water resources, health, air, marine and road transport and combating the socioeconomic impacts of disaster and climate risks. In 2021, the African Ministerial Conference on Meteorology (AMCOMET) updated its Integrated Africa Strategy on Meteorology.

The hydromet value chain shows that socioeconomic value is created when different elements in the value chain such as observation, analysis and forecasts of weather and climate as well as provision of services lead to decision-making and outcomes. As such, the value of a reliable and timely provision of data and services can only be realized if it leads to beneficial outcomes. Merely improving observation or forecast through technology will not always generate economic value unless the value chain facilitates decision-making. The ECOWAS Hydromet Initiative therefore covers the entire value chain from observations to end-user services. The term "hydromet services" is used for "meteorological, hydrological and climate services."

Status of regional hydromet services

Primary responsibility for hydromet services vests in the National Meteorological and Hydrological Services (NMHS). In addition, the ECOWAS region hosts several institutions that support policy coordination and technical capacity. These include the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) and the Regional Center for Training and Application in Agrometeorology and Operational Hydrology (AGRHYMET), African Center of Meteorological Applications for Development (ACMAD), Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA) and West African Science Service Center on Climate Change and Adapted Land Use (WASCAL). Gambia River Basin Development Organization (OMVG), Lake Chad Basin Commission (LCBC), Mano River Union (MRU), Niger Basin Authority (NBA), Senegal River Basin Development Organization (OMVS) and Volta Basin Authority (VBA) are river basin organizations in West Africa. WMO runs a regional specialized meteorological center (RSMC) in Dakar, Senegal, for early warning and severe weather forecasting over West Africa.

In 2020, ECOWAS and AGRHYMET agreed to collaborate more closely on hydromet policy and capacity development and to establish AGRHYMET as the Regional Climate Center (RCC) for West Africa and Sahel (designation by WMO pending). RCCs play an important role in capacity building and in climate outlook forums: AgroHydroClimatic Seasonal Forecast in SudanoSahelian Africa (PRESASS) and AgroHydroClimatic Seasonal Forecast in the Gulf of Guinea (PRESAGG). Currently, data-sharing pro-

tocols exist only between AGRHYMET and CILSS member states, and between river basin organizations and their respective member states. Stronger regional cooperation and collaboration underpinned by data-sharing agreements is a priority. Adequate and predictable funding has been absent in RCCs. Mostly, member states are often in arrears and funding remains sporadic and project-based. ACMAD and AGRHYMET depend on external finance for about 90 percent of their budgets. Lastly, coordination in disaster response remains largely ad-hoc.

Status of national meteorological and hydrological services

The service status of NMHS in the region is diverse. A categorization of their service status of weather, climate and water services as per WMO standards was conducted based on data collected, individual consultations with member states and a regional validation meeting in February 2020 in Dakar, Senegal. WMO (2015) defines four service levels: (a) basic, (b) essential, (c) advanced and (d) full. It shows that the National Meteorological Services (NMS) status of Guinea Bissau, Liberia and Sierra Leone is basic while Ghana, Nigeria and Senegal have advanced to full service status. In general, the National Hydrological Services (NHS) are substantially weaker than the NMS. Only one NHS (Nigeria) has advanced/full-service level, while seven are basic, with low staffing, low operational budgets and overall weak observation networks. Institutionally, nine NMSs are organized as agencies with some autonomy for example on staffing and budget and four as ministerial departments.

In West Africa, over 60 percent of data is collected manually by non-professional and voluntary staff. Consequently, it is of poor quality and cannot be used for real-time monitoring and early warning. The radar network is scattered and often defunct. Even less dense is the upper air station network and frequently launched radiosondes to feed into meteorological models. Many of the NMHS have outdated information and communications technology (ICT) infrastructure, whereas frequent power cuts and weak internet connection limit access to global data sets and operational capacity of NMHS. All ECOWAS member states reported challenges with adequate operation and maintenance of the systems.

Most NMS provide basic weather and climate observations, 1-to-3-day forecasts, services to the aviation sector (where applicable) and agrometeorological services. Most NHS provide basic stream water level monitoring. Customized services to sectors such as agriculture and hydropower are not widely available. Collaboration with private sector, beyond aviation, remains a pilot project. Regulatory frameworks for private sector initiatives are often vague. Socio-economic analysis shows that benefits to economic sectors like agriculture and energy production between $515 million and $1.4 billion over the life of investment (two-thirds of total benefits). Critical gaps remain with last mile connectivity, coverage of early warning systems and limited involvement of women and vulnerable groups as users and beneficiaries.

Objectives and expected outcomes of the ECOWAS Hydromet Initiative

Large programs are complex. Moreover, various ECOWAS countries have different modernization needs. Thus, the ECOWAS Hydromet Initiative is based on agreed objectives and outcomes. *The objective of the ECOWAS Hydromet Initiative is to strengthen national and regional hydromet services in West Africa to reduce disaster and climate risks of countries, communities, and businesses.*

The vision is that hydromet services in the region improve by at least one category or sustain advanced and full service status by 2030, and Regional Climate Centers have modernized to improve service to countries, communities and businesses in West Africa. A framework policy will reinforce data-sharing protocols to facilitate collaboration among countries and regional centers on hydromet services. The Initiative would support a common framework for monitoring and evaluation with the following outcomes:

Outcome 1: Institutions are strengthened to provide efficient hydromet services

» National hydromet services have adequate governance for operation, maintenance and service delivery.

- National hydromet services have adequate human resources, budgets and technical capacity to supports effective operation, maintenance and service delivery.
- Regional and National hydromet services share and exchange data and information.

Outcome 2: Hydromet information is effectively observed, managed and analyzed

- Observation networks are enhanced and modernized.
- ICT systems, database management and forecasting capacity are modernized.
- Regional entities are adequately equipped to provide hydromet services.

Outcome 3: Communities and businesses receive adequate hydromet services

- Flood and drought forecasting and early warning are improved, accessible and widely disseminated.
- Sector specific services are provided to climate sensitive sectors of the economy.
- Regional Climate Centers provide adequate services to member states.

Outcome 4: Research is integrated and coordinated across the region

- NMHS and early warning systems are continuously improved through applied research and partnerships with the academic sector.
- Hydromet services are continuously improved through applied research at regional level.

Outcome 5: The service status of hydromet services is actively monitored

- Coordination, monitoring and evaluation of ongoing initiatives are strengthened.
- Monitoring and evaluation of the operation from service providers to end users are effective.

Estimating investments needs and socioeconomic benefits

Investment needs are estimated at $324.5 million or $290 million at national and $34.5 million at regional level. At country level, investments needs range from $11 million for Guinea Bissau to about $44 million for Nigeria. For outcome 1, $56 million would be needed in support of institutional strengthening, including reinforcing regulatory frameworks, governance, operational capacity and capacity building. For outcome 2, $77 million in investments would cover establishing and modernizing the observation networks and basic services. A total of $127 million will be required for strengthening services to different sectors of the economy and early warning services under outcome 3. Lastly, $11 million would support applied research, academic networks and linking science with practical applications of outcome 4.

The socioeconomic analysis of the Initiative shows that the contribution of improved hydromet services to West Africa's socioeconomic development is expected to be high, particularly due to the potential benefits from improved management of agriculture and energy sectors and reduced impacts from droughts and floods. The benefit-cost ratio ranges from 7 to 10 for each dollar invested. The net present value of the expected benefits ranges between $770 million and $2,217 million depending on the applied discount rate. Comparing different countries, the highest return on investments is expected for Nigeria, the largest economy in the region. Burkina Faso, Cabo Verde, Côte d'Ivoire, Ghana, Guinea Bissau and Mali have a benefit-cost ratio higher than the regional average.

Recommendations

The ECOWAS Hydromet Initiative is owned and driven by the NMHS and regional institutions in West Africa aimed at sustaining the delivery of key weather, water, climate and early warning services to the population. With the ECOWAS Flood Risk Management Policy, a regional policy framework has now been formulated that promotes coordinated actions and investments in hydromet services, early warning systems and flood risk assessments; facilitates data exchange; and proposes coherent policy actions. Going forward, its implementation needs to be driven by the ECOWAS member states with sound implementation plans and coordinated actions by ECOWAS and other regional institutions.

With the adoption of AGRHYMET as the Regional Climate Center for West Africa and the Sahel under the auspices of ECOWAS, two strong institutions have teamed up in West Africa to develop regional hydromet applications and services, provide excellence in training and research and support data exchange. Strengthening the operational links between ECOWAS and AGRHYMET is thus a cornerstone of the ECOWAS Hydromet Initiative. Still AGRHYMET and many of the other technical organizations in the region depend for up to 90 percent on donor funding. Making the RCC for West Africa and the Sahel a success will therefore require a strong partnership with financial and technical partners, but most importantly the commitment (including financial contributions) of its member states.

Any regional collaboration on hydromet services is driven by the effective exchange of hydromet data between member states, with regional, technical organizations and complying with Global Basic Observation Network and related global requirements. The existing data-sharing mechanism between AGRHYMET and its CILSS member states should be effectively extended to cover all ECOWAS member states, ensure real-time exchanges among member states, and provide adequate technical solution to limit any potential, unintended use of shared data. The same counts for the effective exchange of information and collaboration of NMHS with institutions, communities and sectors in the respective country.

Rightsizing hydromet investments is crucial. Capital investments in any parts of hydromet systems, especially observation networks and ICT, require a corresponding increase in operation and maintenance budgets. The focus should be on upgrading and operationalizing the existing network instead of mere enlarging. A modernization of hydromet and civil protection system is feasible only when governments ensure operation and maintenance of the services, including annual budgeting for field monitoring and repair of stations.

Observation infrastructure, networks of weather radars, upper air stations and high-performance computing facilities are capital intensive, with high costs for engineering, operation and maintenance and are thus particularly for the smaller countries with basic service levels mostly out of reach. Levering economies of scale for infrastructure development, ICT and network operation, promoting cascading approaches for forecasting and twinning arrangements between countries can overcome these challenges and should be promoted and where possible institutionalized in the region. In addition, support for instrument calibration should be revived at the regional level, peer to peer learning and quality management systems be promoted.

Strengthening hydromet services in West Africa requires substantial investments and concerted support from governments, development partners and private sector. The ECOWAS Hydromet Initiative estimates investment needs of $324.5 million, and commitments from governments on operation and maintenance, staffing and training are prerequisite for making the envisioned outcomes of such investment sustainable. This calls for the maximizing finance, including grants, loans and public-private partnerships and ensure that the recovery from the COVID-19 pandemic enables the adequate provision of hydromet services to vulnerable communities. A phased approach, allowing incremental increase in capacity of national hydromet services, maybe a more realistic and durable way forward.

Putting the needs of women, vulnerable groups and other users of hydromet services and early warning systems in the center of the service development will be a critical success factor for the ECOWAS Hydromet Initiative. So far, only few NMHS have actively collaborated with them to jointly develop products and services and provide impact-based forecasting. With this regard NMHS are called to step up efforts to actively collaborate with user groups, vulnerable communities and ensuring that women are actively contributing to it.

Public-Private Engagement and collaboration with the private sector and academia to co-create and develop hydromet products and services remain limited to few specific applications in West Africa, whereas few countries have adequate regulatory frameworks in place that enable public-private engagements. At the same time, many private sector businesses (for example, cell phone providers) operate

in several countries in West Africa and networks of universities and research centers, such as WASCAL, have a footprint across many countries. It will thus be important to create an enabling environment for public-private engagements by implementing a conducive regulatory framework in a regionally coherent manner and jointly promote private sector business cases in hydromet services.

The ECOWAS Hydromet Initiative is aligned with WMO's Systematic Observations Financing Facility and coordinated with other ongoing investment projects and programs in West Africa, such as CREWS West Africa. The ECOWAS Hydromet Initiative is designed as a framework platform for governments, development partners and private sector to support hydromet services in the region in an integrated program facilitating incremental increase to modernizing hydromet services. It builds upon coordination among all partners and is based on a common monitoring framework with a set of agreed outcomes, outputs and indicators.

West African Farmer Raising A Full Watering Can From A Rural Well © Riccardo Lennart Niels Mayer | Dreamstime.com

CHAPTER 1

Introduction

West Africa is home to approximately 350 million people and is severely affected by the impacts of extreme weather and climate events. In 2018, the Economic Community of West African States (ECOWAS),[1] together with World Meteorological Organization (WMO), World Bank, Government of Côte d'Ivoire and other partners, hosted the first Hydromet Forum and Disaster Risk Reduction Subregional Platform ("forum"). The purpose was to discuss and set priorities on how weather, water, and climate information as well as disaster risk management strategies and services could be strengthened to achieve sustainable development and to reduce disaster and climate risk in the region.

Representatives from West African governments, academic institutions, regional and river basin organizations as well as global institutions (such as, UN agencies, development banks and bilateral partners, technical institutions, civil society, academia, the private sector and user groups) gathered 19-21 September 2018 in Abidjan, Côte d'Ivoire, for the first forum of this kind. The participants discussed the critical role of hydromet and early warning services for sectors that drive the region's economies, such as agriculture, water resources, health services, safe air, marine and road transport and for combating the socioeconomic impacts of disaster and climate risks. In this context, the term "hydromet" services is defined as meteorological (weather and climate) and hydrological (water resources) services. In this report, the organizations responsible for hydrological and meteorological services are referred to as National Hydrological Services (NHSs), National Meteorological Services (NMSs), or jointly National Meteorological and Hydrological Services (NMHSs).

The forum acknowledged that ECOWAS should play a leading role in developing a policy framework for weather, water, climate and disaster risk management services and ensure closer coordination as well as horizontal and vertical integration of policies and institutions in the region. With the upcoming ECOWAS Flood Risk Management Policy Framework, which is currently being discussed at member level, and the planned establishment of AGRHYMET as a Regional Climate Center for West Africa and the Sahel important steps have since then already been taken.

In 1992, ECOWAS convened the first meeting of the Committee of Directors of National Meteorological Services in Lagos, Nigeria, and initiated the ECOWAS Hydromet Program. The Conference of Heads of State and Government of ECOWAS adopted this Program in 1997 and mandated the Executive Secretary of ECOWAS to mobilize the necessary resources for its implementation. The first version of the ECOWAS Meteorology Program document was presented and adopted in Banjul, The Gambia, in May 2014.

In 2021, the African Ministerial Conference on Meteorology (AMCOMET) renewed its Integrated Africa Strategy on Meteorology. In its communiqué (box 1), the forum acknowledged the continued need for adequate investments in modernizing and integrating hydromet systems, from governments, development partners and the private sector. In this context, the idea of establishing a comprehensive ECOWAS Hydromet Initiative was acknowledged.

This report provides the analytical background on the status of the hydromet services in the region and provides an overview of the priorities and investment needs for strengthening and modernizing hydromet services in West Africa. The ECOWAS Hydromet Initiative identifies areas of synergy with existing programs and projects and formulates a regionally coherent strategy for funding hydromet services.

[1] Comprising of 15 member countries: Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Box 1. Communique of the ECOWAS Hydromet Forum and Disaster Risk Reduction Subregional Platform Abidjan, Côte d'Ivoire, 21 September 2018

We, representatives of ECOWAS Member State institutions, Members of the Bureau of AMCOMET and other stakeholders in building disaster and climate resilience; representing the Meteorology, Hydrology and Disaster Risk Management practices in West Africa, delegates at the ECOWAS Hydromet Forum and DRR Subregional Platform, convened from 19 to 21 September 2018 in Abidjan by ECOWAS and the Government of Côte d'Ivoire with the support of development partners.

Appreciate the hospitality and warm welcome accorded to the conference delegates by the government and the people of the Republic of Côte d'Ivoire and commend them for their commitment to disaster risk reduction. Recognize that 70 percent of disasters in the ECOWAS region are caused by severe weather and climate events; that hydromet (weather, water, and climate) services are transboundary and multidisciplinary; that there is increasing demand for customized weather, water, and climate services to build resilience in communities and economies and provide effective early warning for the ECOWAS region.

Are convinced that modernizing every aspect of the entire value chain of hydromet systems and services with advanced numerical weather prediction techniques will bring innovation to the ECOWAS region to better respond to end-user needs; further noting that targeted capacity building for national meteorological and hydrological services through an end-user oriented approach focused on service delivery and the last-mile connectivity is central to the provision of weather, water, and climate services for sustainable development and climate resilience.

Consider the comparative advantages, mandates, and capacities of different stakeholders, who collectively aim to enhance the production, delivery, and use of weather, water, climate, and early warning services to reduce extreme poverty and build shared prosperity by promoting socioeconomically sustainable development to cope with the impacts of climate change in the ECOWAS region.

Acknowledge the continued need for adequate investment in modernizing and integrating hydromet systems, programs, and partnership initiatives—such as the Africa Hydromet Program, a joint partnership of the World Bank, WMO, AfDB, and other organizations—and the current achievements in the ECOWAS region on effective climate outlooks and early warnings, notably the Harmonized Framework for Food Security, PRESASS, collaboration on weather, water, and early warning, informed by various national and regional policies.

Recognize that the private sector, academia, civil society, media, and other non-state stakeholders have a key role in strengthening regional and national hydromet, early warning, and disaster risk management services. Note the importance of hydromet and disaster risk management services for meeting the objectives of the ECOWAS DRR Strategy and ECOWAS DRR Plan of Action 2015–2030, ECOWAS Water Resources Policy, ECOWAS Environmental Policy, ECOWAS Agriculture Policy, ECOWAS Early Warning Strategy, ECOWAS Hydromet Program and building on the Africa Agenda 2063, and Sustainable Development Goals–Africa.

Programme of Action for the Implementation of the Sendai Framework for Disaster Risk Reduction, and the Paris Agreement commitments. Having considered the extensive discussions and recommendations of international, regional, and national stakeholders and experts who participated in the forum, we:

- Urge Development Partners, including the World Bank, the African Development Bank, European Union, and UN Organizations, among others, to scale up support for modernizing hydromet and disaster risk management services, according to the needs and priorities expressed by ECOWAS, CILSS, river basin organizations, and national governments in West Africa;

Box 1. Communique of the ECOWAS Hydromet Forum and Disaster Risk Reduction Subregional Platform Abidjan, Côte d'Ivoire, 21 September 2018

- Call for further support from the respective governments to ensure that national meteorological and hydrological and disaster risk management services (NMHS) have the necessary political and financial enabling environment to adequately perform their mandate, which underpins sustainable and resilient development of all sectors of the economy and all segments of society, particularly the vulnerable and the poor;
- Request relevant regional partners to work closely toward the convergence of meteorological, hydrological, and early warning systems and services; further request robust cooperation from other regional organizations working in the field to maximize synergy, economies of scale, and efficiency for the benefit of West African communities and populations;
- Call for a stronger horizontal and vertical integration of policies, strategies, and programs in support of weather, water, climate, and disaster risk management at the national, ECOWAS regional, and Africa continental levels. Also call for stronger collaboration among institutions and the promotion of partnerships, particularly among ECOWAS, CILSS, and river basin organizations, and for establishing CILSS/AGRHYMET as the Regional Climate Center for the ECOWAS and other communities in West Africa and the Sahel;
- Urge the promotion of a conducive environment for building and exchanging academic and research expertise, as well as continued professional education on weather, water, climate, and disaster risk reduction in ECOWAS Member States;
- Will promote robust and meaningful gender mainstreaming and the inclusion of youth, community based organizations in the design and implementation of integrated approaches for weather, water, climate, and disaster risk management services that support sustainable development;
- Reaffirm our support to promote national and regional ownership for strengthening national meteorological, hydrological, and disaster risk management services; further commit to ensuring that the modernization of hydromet services is included among the priorities in National Development Plans and to work with our respective governments and organizations to ensure sustained resourcing of this priority;
- Request the Commissioners of ECOWAS present at the forum to bring this Communiqué to the attention of the President of the ECOWAS Commission and the President of the ECOWAS Parliament for endorsement and action;
- Request the African Union Commissioner for Rural Economy and Agriculture and the Chair of the AMCOMET Bureau to bring this Communiqué to the attention of the Fourth Session of AMCOMET and the AU Heads of State and Government for endorsement and action; and
- Unanimously adopt this Communiqué to show collective commitment to supporting the development of sustainable and reliable weather, water, and climate services and their delivery to end-users in West Africa; fully considering national development priorities, regional and global meteorological strategies, and other relevant frameworks.

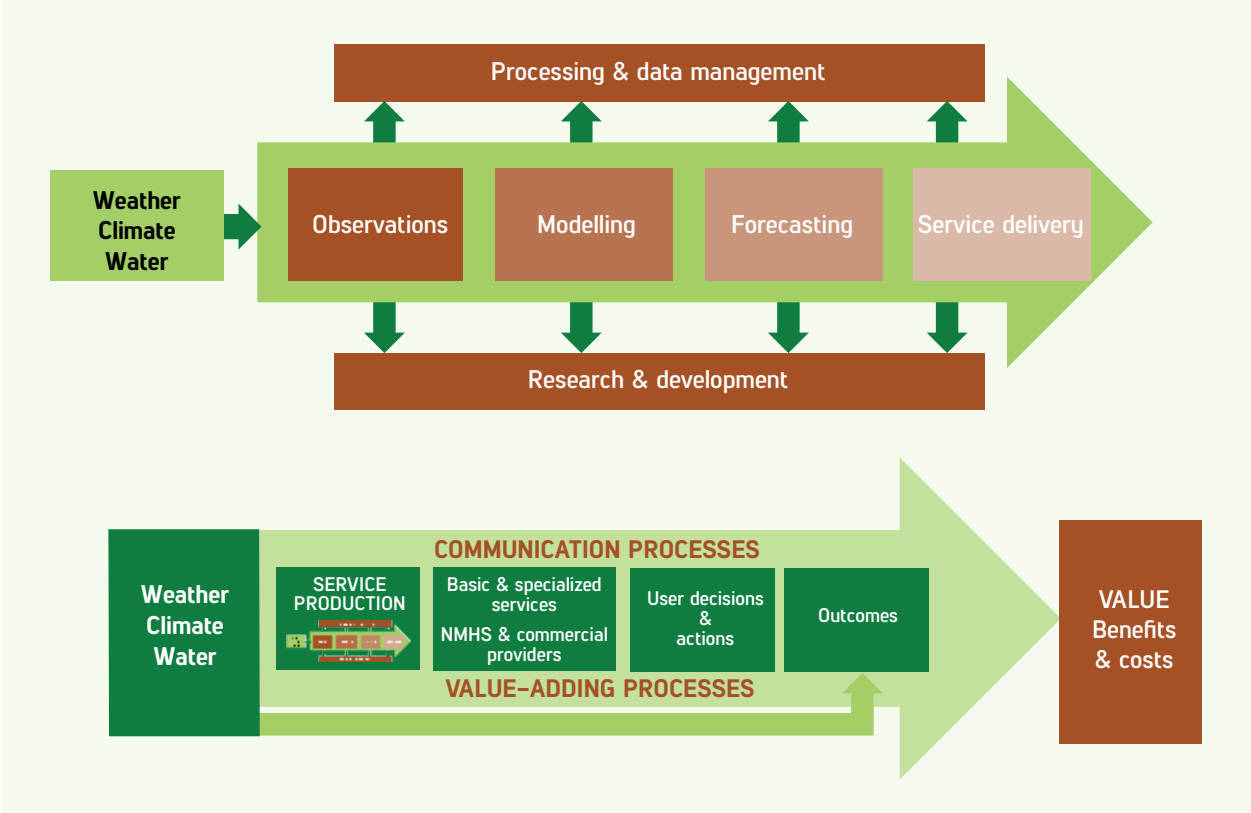
1.1 Hydromet Services Value Chain

Investing in hydromet services is commonly considered a priority "low regret" climate adaptation and disaster risk reduction strategy. While methodologies to assess the economic benefits of these investments are still evolving, the literature suggests that such activities can be extremely beneficial in terms of averting losses associated with climate hazards and enhancing the productivity of climate-dependent sectors such as agriculture, water resources management, hydropower and transport.

The hydromet value chain (figure 1 below) shows that value, in economic and social terms, starts with observation of climate through to decision-making and outcomes (WMO 2015a). As such, the value of an accurate, timely and relevant forecast can only be maximized if a beneficial value is achieved at the end of the process. Any project design on the modernization of hydromet and disaster risk management services should be designed around an effective value chain that links the monitoring and modeling with concrete services to different sectors of the economy and communities. Merely improving observations or forecasts, through improved technologies, for example, will not necessarily generate economic value unless the entire value chain process works to facilitate impacts and end-user decision-making.

The ECOWAS Hydromet Initiative is therefore set up to cover the entire hydromet value chain from observations to services and value creation for users. Before embarking on a project for the modernization of hydromet services it is thus important to fully understand the user and beneficiary perspective. Figure 1 illustrates the hydromet value chain (figure 1, above) as well as the components of the service production and delivery system (figure 1, below). They are used as a guidance throughout the analysis of this report.

FIGURE 1. Components of the service production and delivery system of National Hydromet Services (above); Hydromet value chain (below)[2]



[2] Source: WMO 2015a.

1.2 Benefits of Improved Hydromet Services

From a user perspective, hydromet services and early warning systems could be improved in many ways. For the moment, some countries in West Africa might not be issuing any official severe weather warnings. Flood forecasting is being piloted for some river basins, such as the Volta Basin and the Niger Basin. However, more can be done, with enormous potential for reducing the loss of lives, livelihoods and assets. Similarly, seasonal forecasts and pl anting and harvesting advisories could be significantly improved to enhance the productivity of farmers. Many countries, like Burkina Faso, Mali and Niger have strong and operational food security systems, whereas the use of climate information and its dissemination in the region are not yet as well established. In addition, different sectors of the economy, including water resources and hydropower, transport and aviation would benefit from improved hydromet services.

Table 1 summarizes the main beneficiaries, the potential benefits from hydromet services and the types of products and services required. Based on these general benefits, the report specifically assesses the benefits on four key areas, where a quantitative analysis can be carried out: (a) development of flood early warning system and its impact on avoided damages (for example, reduced damages to buildings and infrastructure); (b) better characterization of seasonal drought information and its impact on crop production; (c) capacity-building efforts oriented to hydromet services and its impact on productive sectors (for example, agriculture and energy); and (d) a general improvement of weather monitoring and forecasting and its impact on public decision-making.

TABLE 1. Overview of benefits from improved hydromet services

BENEFICIARIES	WEATHER AND CLIMATE SENSITIVITY	BENEFITS OF HYDROMET PRODUCTS AND SERVICES	TYPE OF PRODUCTS AND SERVICES REQUIRED	GAPS LIKELY TO BE FILLED
Rain-fed crop producers	Crop yields and pests are highly sensitive to variations in precipitation, evapotranspiration and temperature.	More targeted (date and quantities) application of pesticides, use of enhanced crop varieties, decisions related to the date of sowing and harvesting and post-harvest processing, market and prices of assets/terms of trade, management of pro-duction and market risks.	Seasonal climate outlooks; weather forecasts guiding sawing, application of pesticides, harvest and post-harvest.	Farmer-targeted forecasting; improved agrometeorological information; feedback mechanism with farmers; application of web and cell phone-based services; seasonal climate outlooks.

BENEFICIARIES	WEATHER AND CLIMATE SENSITIVITY	BENEFITS OF HYDROMET PRODUCTS AND SERVICES	TYPE OF PRODUCTS AND SERVICES REQUIRED	GAPS LIKELY TO BE FILLED
Irrigated crop producers	Availability of surface and groundwater water resources for irrigation. Irrigation management depends highly on precipitation, evapotranspiration, and temperature forecasts.	Water-efficient irrigation management based on accurate forecast of precipitation, ET and temperature and surface and groundwater availability; assets/ terms of trade, management of production and market risks.	Seasonal climate outlooks; hydrological forecasts (for flood prevention to avoid damage to infra-structure and pumps; surface and groundwater availability; hydrologic assessments and modeling to optimize irrigation; advisory services to water user associations.	Farmer targeted forecasting; improved agrometeorological and hydrological products (surface and groundwater availability, hydrologic assessments and modeling); hydrological information; feedback mechanism for farmers; application of web- and cell phone- based services; seasonal climate outlooks.
Livestock herders	Climate-sensitive fodder and water supply; weather and climate related livestock diseases.	Stocking of fodder reserves; provision of additional water supply; efficient vaccination campaigns.	Livestock sector-targeted weather forecasts and climate and climate-health outlooks.	Livestock sector-based information; web- and cell phone-based service applications; combined weather, climate and veterinary service applications;
Fishing (inland)	Dependency on water quality; fish stock impacted by droughts (low water levels, low oxygen) and floods (siltation).	Fishing operations and day-to-day management of stocks; water quality improvement.	Relevant information on water quality and levels; flood and low water level fore-casting; siltation information.	Siltation monitoring; combined weather, climate and fishing extension service applications; water quality monitoring, assessment and modeling.
Fishing (marine)	Increased level of storm surges in coastal waters.	Safer fishing operations and improved day-to-day operations of fishing boats in coastal waters.	Marine and coastal weather forecasts and storm warnings.	Dissemination and communication network with artisanal fisheries.
Hydropower	Water level and quality (sediments) and precipitation information are critical for a successful operation (water release, spilling, IDT curve).	Day-to-day operations maximizing hydropower output and optimizing water releases from reservoirs.	Water availability and water quality monitoring, modeling, assessments and forecast; precipitation and forecast and seasonal climate outlooks.	Dedicated services for hydropower operators; direct linkage to services from NHS to hydropower operator.
Aviation and Transport	Flight operation depends on accurate weather information.	Flight operations adhering to ICAO standards.	Aviation meteorology.	Global standard aviation meteorology.

BENEFICIARIES	WEATHER AND CLIMATE SENSITIVITY	BENEFITS OF HYDROMET PRODUCTS AND SERVICES	TYPE OF PRODUCTS AND SERVICES REQUIRED	GAPS LIKELY TO BE FILLED
Small and Medium Enterprises	Extreme weather and climate events impacting commercial operations, potential damages to stocks.	Targeting of products and services.	Integration of business data with weather and climate data to inform more effective supply chain management.	Weather and climate information and applications for small enterprises.
Extractive Industries	Small mine operations depend on ground water levels.	Improved day-to-day operations and environmental protection.	Mining-related information; ground water monitoring.	Industry-specific services; improved groundwater monitoring; environmental monitoring.
Urban Planning and Local Government	Population at risk of floods, droughts needs protection and relief provisions.	Timely evacuation of population; flood risk zoning and incorporation in spatial planning; long-term planning taking into account future climate risks.	Flood forecasting and early warning systems and community communication; long-term trend on extreme events and future climate projections.	Flood forecasting and early warning systems development; end-to-end communication of early warning information; better climate projections and use in planning.
Micro Insurance	Small enterprises at risk of extreme weather events.	More effective design of weather index insurance.	Long-term climate records and high-quality observation data with high granularity.	Quality control of and publicly available data; sustainable business model.
Civil Protection	Extreme weather and climate events impacting communities and leading to increased uncertainties and need for civil protection.	Improved early warning information, with increased lead time.	Early warning information for rivers in rural and urban areas and short- to medium- term forecasts for storm surge.	End-to-end early warning information and improved response capacity.
Health	Extreme weather and climate events impacting communities and leading to new diseases.	Improved early warning information, with increased lead time.	Early warning information for rivers in rural and urban areas and short- to medium-term forecasts for storm surge.	End-to-end early warning information and improved response capacity.

West African child pumping fresh water in a village in Bamako, Mali. © Riccardo Lennart Niels Mayer | Dreamstime.com

CHAPTER 2

Climate and Economy of the ECOWAS Region

ECOWAS is mandated to promote the regional cooperation and integration of its 15 member states. With approximately 350 million people (2015), the population of the region represents about 5 percent of the world's total population and with a growth rate estimated at 2.75 percent is projected to exceed one billion by 2059 (UN. 2015). About 40 percent of the ECOWAS population lives in poverty, on less than $2 per day. Population growth will lead to an increase in the needs for food security, water availability, social services and energy. The economy of the region is substantially based on non-mineral natural resources, with livelihood incomes largely derived from forest, wildlife, pastures, water and agricultural lands. The majority of West Africans live in rural areas, where traditional forms of agriculture, animal husbandry and fisheries remain some of the main activities. On average 80 percent of the ECOWAS population, notably in these rural areas, depends on climate-sensitive sectors of the economy. The region also derives a large part of its energy from hydropower and, in some cases, from fossil fuels. Therefore, the living conditions of the rural population and indeed the general population as well as the development of the region are seriously impacted by variations in climatic conditions.

In line with its mandate, ECOWAS has developed and implemented strategic plans and policies related to hydromet services and early warning. These include: Agriculture Policy (2005), Disaster Risk Reduction Policy (2006), Environmental Policy (2008), West Africa Water Resources Policy (2008), Regional Strategic Plan 2011-2015 (2010), Vision 2020 (2010), Humanitarian Action Plan (2012), Disaster Risk Reduction Actin Plan (2016) and Environmental Action Plan (2020-2026). It also includes the ECOWAS Flood Risk Management Strategy, which was adopted in 2021.

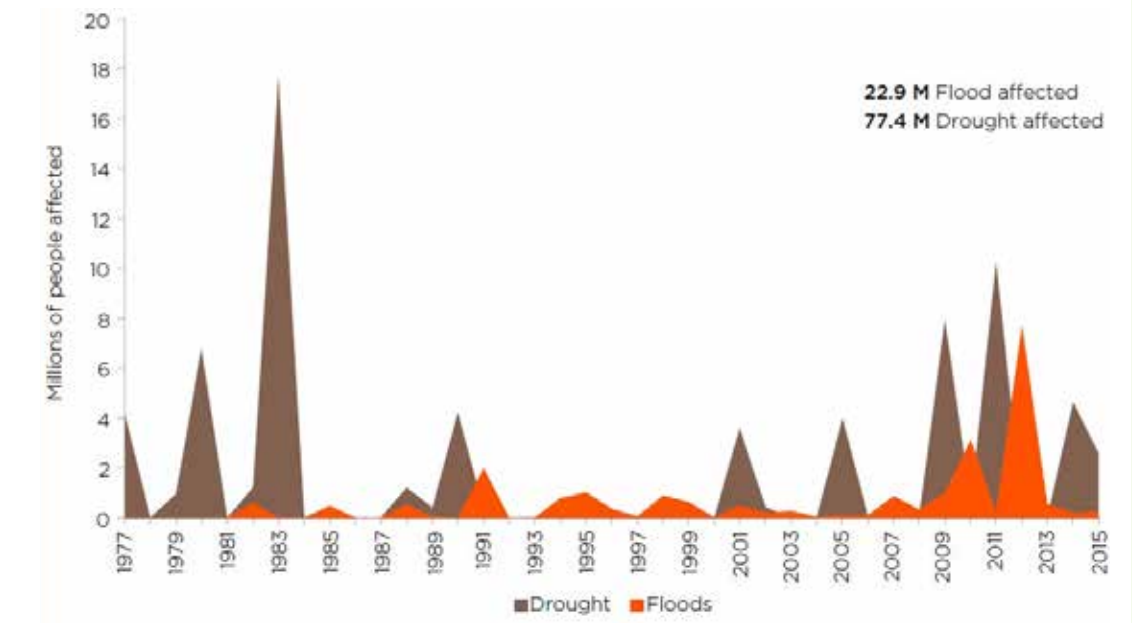
2.1 Climate and Disaster Risk Profile of West Africa

Over the last three decades, extreme weather and climate-related disasters have increased in frequency and severity in West Africa. According to the Emergency Events Database (EMDAT[3]) (2017), floods and droughts remain the most dominant and devastating disaster events in the region. Over 70 percent of the population in West Africa is affected at least once every two years by flood, dust/sandstorm or drought, the impacts increased by the high dependency of communities on rain-fed agriculture.[4] Droughts and floods affected 77.4 million and 22.9 million people, respectively, between 1977 and 2015 (figure 2).

[3] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

[4] https://www.climatelinks.org/sites/default/files/asset/document/2017%20April_USAID%_20ATLAS_Climate%20Change%20Risk%20Profile%20-%20Sahel.pdf

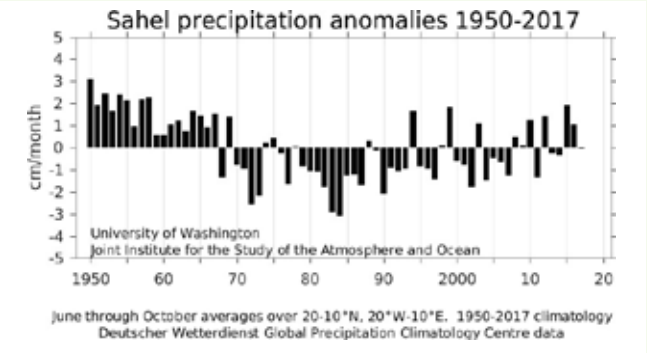
FIGURE 2. Flood and drought occurrence and impacts in West Africa[5]

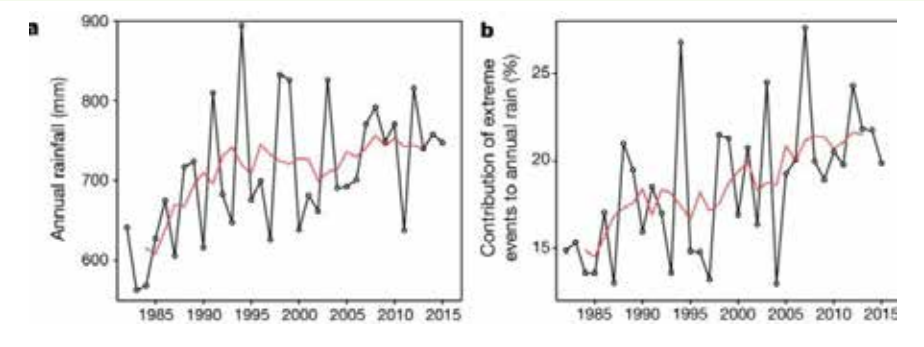


[5] Source: ECOWAS (2016).

According to the Intergovernmental Panel on Climate Change (IPCC. 2013), observed climate trends across West Africa already show an increase in temperature of 0.5 to 0.8 degrees Celsius (°C) for the period 1970-2010, with a greater increase of 1.5 to 2°C over the Sahel region. Although trends in rainfall are difficult to estimate and vary substantially at different locations, an increase in interannual and interdecadal rainfall variability over the Sahel regions has been noted. In addition, an increase in extreme events has also been observed (IPCC 2012) with heavy rainfall events having increased by 17 to 21 percent from the Sahel to the coasts (figure 3).

FIGURE 3. Precipitation anomalies and contributions of annual rainfall to extreme events[6]





[6] Source: Panthou et al. (2014).

According to different climate change projections, West Africa's climate will continue to become more extreme with rising temperatures, prolonged heatwaves, delayed start of the rainy season and extreme weather events. By 2050, the region is predicted to be exposed to a temperature rise of 1.5 to 3°C, with the greatest increase observed over the Sahel region. Consequently, an increase in the frequency and duration of heatwaves by 6 days to 28 total days is expected, with a greater increase in the east of the region. Heavy rainfall is expected to increase by 10 to 45 percent throughout most of the region. Other changes include delays in the start of the rainy season, an increase in dry spell duration by 4 days to 22 total days and an increase in sea level by to 45 centimeters (Biasutti and Sobel 2009; Lebel and Ali 2009).

Droughts: West Africa, particularly the Sahel, has experienced several "quasi-drought" conditions since the early 1970s. Continuous water deficits cause acute water shortages, low yields, food insecurity, desertification and the decimation of both livestock and wildlife. The impacts of droughts have considerably increased since 2007 and are projected to become more severe (IPCC 2012). Droughts could continue to affect water levels in reservoirs and lead to a decrease in electricity production, depressing economic growth and increasing poverty. The Global Assessment Report by the UN Office for Disaster Risk Reduction estimates annual losses due to drought between 1 and 10 percent of gross domestic product (GDP) and an increase in poverty by 17 percent (UNDRR 2019).

Floods and sea level rise: In West Africa, extreme rainfall events associated with floods have increased in the last two decades. In general, there are three types of floods: (a) flash floods, (b) riverine floods and (c) urban floods (dependent on the presence and performance of drainage networks). Floods in coastal areas also pose a threat to populations and natural ecosystems. These events affect both communities and in turn contribute partially to the erosion of coastal areas. Due to an increase in sea level, this type of flooding is expected to increase.

Table 2 summarizes the estimated economic losses to select ECOWAS economies between 1966 and 2018, as reported to EMDAT and through post-disaster needs assessments (PDNA) and other assessments.

TABLE 2. Total damages for floods reported in the ECOWAS region

COUNTRIES	TOTAL DAMAGES *1966–2018 ($ '000)*	TOTAL DAMAGES, *Base 2019 ($ '000)*
Benin	8,315	18,256
Burkina Faso	181,176	212,395
Cabo Verde	4,100	9,134
Ghana	163,629	662,035
Niger	272,039	315,872
Nigeria	922,422	1,056,874
Senegal	54,435	81,219
Sierra Leone	33,600	48,391
Togo	38,200	44,787

Source: Based on EMDAT database (1966-2018), PDNAs and other assessments for Burkina Faso (2009), Senegal (2009), Togo (2010), Nigeria (2013) and Ghana (2015).

2.2 Climate Sensitivity of West Africa's Economy

West Africa's economy is particularly vulnerable to climate risks, notably sectors such as agriculture and food security, energy production and transport. With more than 70 percent of the population in the ECOWAS region largely dependent on rain-fed agriculture for their livelihood, the region is extremely vulnerable to the effects of climate change. Agriculture in many West Africa countries employs more than 60 percent of the working population and contributes 35 percent of GDP (FAO and AfDB 2015; Matthew et al. 2010). At approximately 16 percent of exports, agriculture remains one of the largest source of ECOWAS external trade, generating revenue for the countries and supplying the primary source of income for vulnerable communities (IMF 2015; UNDESA 2011). Table 3 provides a comprehensive overview of key development indicators for the ECOWAS member states. Table 4 shows the most important harvested crops (cassava, maize, millet, rice and cotton) in each West African country as a percent of the country's total harvested area, based on 2010-2013 average.[7]

Agricultural activities are highly influenced by climatic parameters, including the onset of the rainy season, the end of the rainy season, dry spells and length of the rainy season. The most important of these is the spatial and temporal distribution of the rainfall amount recorded annually. The onset period of the rainy season is particularly important for planning agricultural activities, especially seeding. A lack of information on the start or cessation of a rainy season has historically led to crop failure and famine. Figure 4 illustrates this for the average maize yield for the period 1990-2010. Food availability could be threatened through direct climate impacts on crops and livestock from increased flooding, drought, shifts in the timing and amount of rainfall and high temperatures. It could be impacted indirectly by increased soil erosion from more frequent heavy storms or by increased pest and disease pressure on crops and livestock caused by warmer temperatures and other changes in climatic conditions.

[7] Reported by United National Environment Programme, 2015, from FAOSTAT database.

TABLE 3. Overview of key country indicators for ECOWAS member states

	POPULATION *2018 million*	RURAL POPULATION *2018 %*	GDP* *2018 $ billion*	GDP* PER CAPITA *2018 $*	AGRICULTURE *2014–18 AVG % of GDP*	EMPLOYMENT IN AGRICULTURE *2018 % of total*	LITERACY RATE *%*
Benin	11.5	53	10.3	897	22.6	41.9	42
Burkina Faso	19.8	71	14.1	712	29.7	29.6	41
Cabo Verde	0.5	34	2.0	3,760	7.4	13.8	87
Cote d'Ivoire	25.1	49	42.4	1,693	21.5	48.2	47
The Gambia	2.3	39	1.8	786	21.5	29.9	51
Ghana	29.8	44	53.8	1,807	19.8	35.7	79
Guinea	12.4	64	11.1	897	19.7	67.4	32
Guinea Bissau	1.9	57	1.2	622	46.2	68.6	46
Liberia	4.8	49	2.6	541	36.4	46.1	48
Mali	19.1	58	14.8	778	38.1	65.2	35
Niger	22.4	84	9.1	403	38.1	76.1	31
Nigeria	195.9	50	469.4	2,396	20.7	37.0	62
Senegal	15.9	53	24.5	1,547	14.9	33.1	52
Sierra Leone	7.7	58	3.6	473	57.6	59.0	43
Togo	7.9	58	5.3	676	24.2	35.3	64

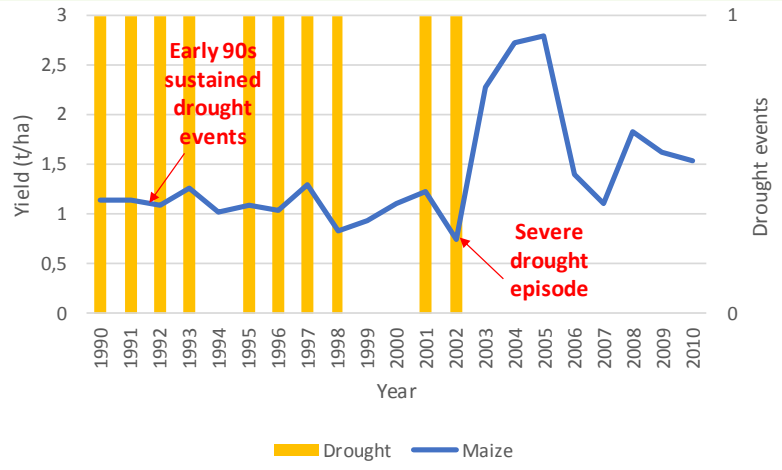
Source: World Bank (2020).
Note: *Gross domestic product (constant 2010 dollars).

TABLE 4. West Africa: Crop production as a share of the total harvested area

	Benin	Burkina Faso	Cabo Verde	Côte d'Ivore	Gambia	Ghana	Guinea	Guinea-Bissau	Liberia	Mali	Niger	Nigeria	Senegal	Sierra Leone	Togo
Millet	1%	19%		1%	30%	3%	8%	3%		30%	43%	6%	34%	2%	3%
Sorghum	3%	27%		1%	8%	4%	1%	4%		22%	19%	11%	6%	2%	13%
Maize	31%	12%		4%	9%	15%	14%	3%		11%		12%	5%	2%	32%
Cassava	9%		46%	5%	1%	13%	4%	1%	11%			12%	1%	22%	10%
Cow peas		18%	1%					1%		4%	30%	7%	5%		
Rice	2%	2%		5%	16%	3%	27%	22%	42%	11%		6%	5%	41%	4%
Yams	7%			11%		6%						5%			4%
Groundnuts	5%	6%		1%	29%	5%	6%	6%	1%	6%	5%	6%	37%	6%	3%
Cocoa				32%		24%			10%			3%		3%	6%
Oil, palm fruit	1%			4%	1%	5%	9%	2%	3%			7%		2%	1%
Seed cotton	9%	8%		3%			1%	1%		7%		1%	1%		5%
Cashew nuts	15%	1%		12%		1%		44%				1%	1%		
Sugar cane									4%						
Pulses	1%		2%		3%	4%	2%	1%	1%					75%	1%
Tomatoes	1%		40%			1%						1%			
Natural rubber			2%	2%					13%			1%			
Beans, dry	4%			1%		3%									13%
Sesame seed		2%			2%					1%	1%	1%			
Plantains				6%		5%	3%	3%	4%			1%			
Coconuts	4%							2%							
Fonio			3%				9%			1%					

Source: FAOSTAT (2015).

FIGURE 4. Drought Episodes and Senegal Maize Production per Harvested Area, 1990–2010[8]

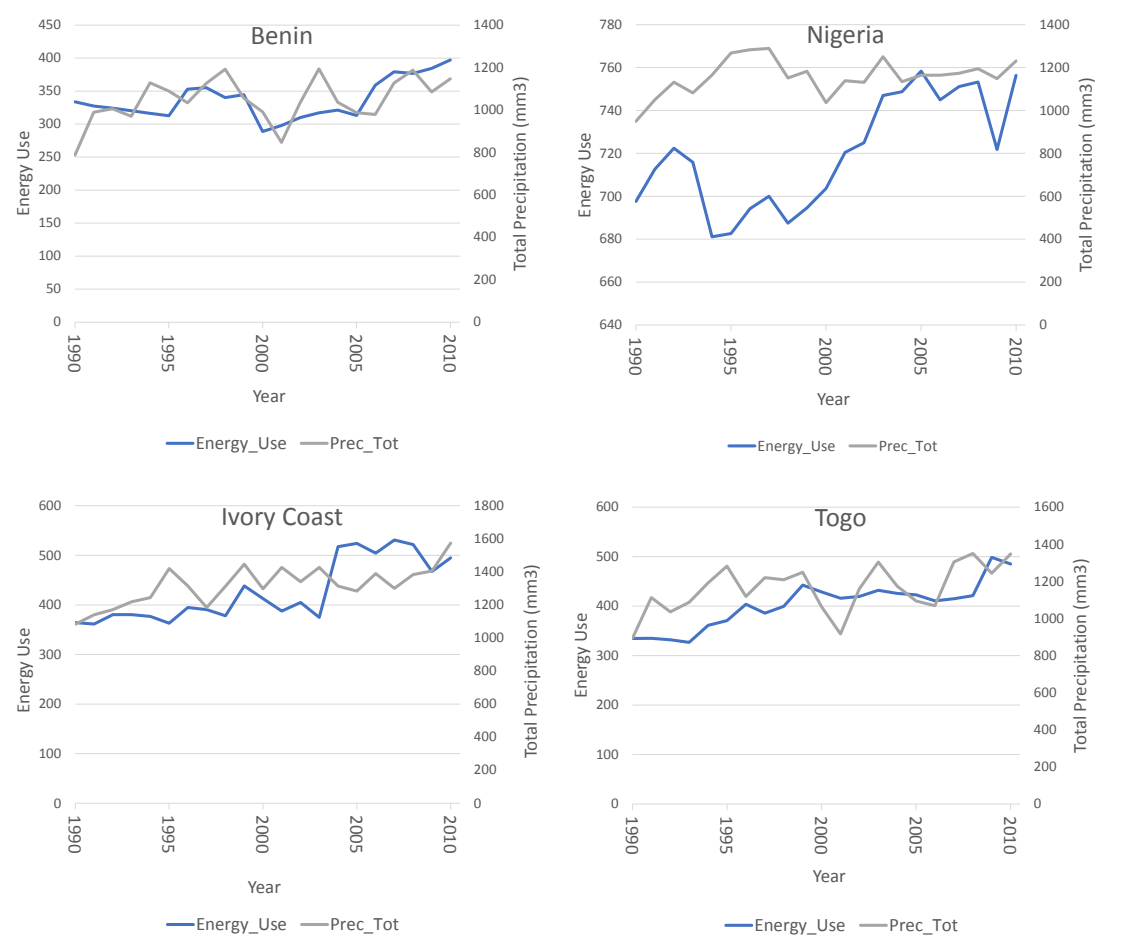


[8] Sources: Based on FAOSTAT crop data and Kamali et al. (2019).

In addition, a large part of the electricity on which the economy depends is generated from hydropower, which has been affected by climate conditions. Droughts can lead to low levels of water in the dams while floods and extreme rainfall can damage hydropower infrastructure. For example, in 2009 in Burkina Faso, extreme rainfall caused dam breakage and floods that produced serious damage downstream. For the energy sector, changes in energy consumption have been estimated through differences between the dry and the wet periods. Dry periods are related to warmer temperatures (for example, harmattan, bringing hot and dusty air from the Sahara to the coastal areas of West Africa) and thus higher demand for air-conditioning and cooling. An increase in regulation and more integrated water management will contribute to a reduction in the differential elasticity. Figure 5 shows the relationship between energy use and total precipitation for four countries: Benin, Côte d'Ivoire, Nigeria and Togo.

Meteorological services play an important role for the aviation and marine sector providing targeted services for airlines and ships, guaranteeing safety of travel and supporting the optimization of route planning. Income from landing fees at airports is, in addition, an important source of income for the meteorological services. In eight countries in West Africa, aviation meteorology is managed by the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA). On a continental scale air traffic in Africa is still relatively low compared to other parts of the world. Only 2.5 percent of the global air traffic is to, from or within Africa. The annual growth of passenger air traffic within Africa is projected at 5.8 percent annually between 2015 and 2035 (ICAO 2019).

FIGURE 5. Annual energy use and total precipitation in four ECOWAS countries, 1990–2010 (gigawatt hours and cubic millimeters)[9]



[9] Source: Based on World Bank data for electricity production from oil, gas, and coal sources as a percent of total energy and Tyndall Center data for total annual precipitation.

VillageTansaalga, Province du Lorum, Titao, l'Obervateur Moustapha, Sept 2019, Burkina Faso

CHAPTER 3

Status of Regional Collaboration on Hydromet Services in West Africa

ECOWAS is home to regional institutions and regional technical centers in the field of hydromet and early warning services. ECOWAS, the West African Economic and Monetary Union (UEMOA) and the Permanent Inter-State Committee on Drought Control in the Sahel (CILSS) set policies for the region and foster a stronger regional collaboration on exchanging information and developing joint services.

The African Center of Meteorological Applications for Development (ACMAD) and the Regional Center AGRHYMET[10] of CILSS function largely as Regional Climate Centers for West Africa. The Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) provides aviation-related meteorological services for some of the member states. The West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) is a network of regional universities. The West African Coast Observation Mission (MOLOA) a technical network and center on coastal management and forecasting. Organizations for the main regional river basins include: Gambia River Basin Development Organization (OMVG), Lake Chad Basin Commission (LCBC), Niger Basin Authority (NBA), Senegal River Basin Development Authority (OMVS) and Volta Basin Authority (VBA). In addition, the World Meteorological Organization (WMO) and global production centers (GPC) as well as United Nations Educational, Scientific and Cultural Organization (UNESCO) and other international organizations provide specific global expertise to the region. Table 5 illustrates the membership of countries in West Africa to those regional organizations.

3.1 Overview of Regional Organizations

WMO Global Production Centers

As a specialized UN agency, the World Meteorological Organization (WMO) supports its member states by creating a favorable environment for hydromet services rather than providing direct climate services. This includes technical guidance, coordination and frameworks for data collection and exchange [WMO Information System (WIS), WMO Integrated Global Observing System (WIGOS) and WMO Hydrological Observing System (WHOS)] and access to forecasting from global production centers. As part of the WMO Global Data-Processing and Forecasting System, the World Meteorological Centers[11] prepare meteorological analyses and forecast products and make them available to members as cost-effectively as possible. These products include predictions for averages, accumulations or frequencies over one-month periods or longer (usually three months) for the following variables: 2m temperature, precipitation, sea surface temperature, mean sea-level pressure, 500hPa[12] height, 850hPa and temperature.

Regional Climate Centers

West Africa has two main regional climate institutions. The African Center of Meteorological Applications for Development has already been certified by WMO as the continental regional climate center. The Regional Center for Training and Application in Agrometeorology and Operational Hydrology has been endorsed by ECOWAS as the Regional Climate Center for West Africa (2020) and is in the process of becoming accredited by WMO.

[10] AGRHYMET is in the process of being accredited as a regional climate center by WMO.
[11] World meteorological centers include: Australian Bureau of Meteorology, Environment Canada, China Meteorological Administration, European Center for Medium-Range Weather Forecasts, German Weather Service, Japan Meteorological Agency, Roshydromet, UK Met Office, and US National Weather Service.
[12] hPa = Hectopascal

TABLE 5. Membership of countries to regional organizations

COUNTRY	POLICY		REGIONAL CLIMATE CENTERS		RESEARCH AND TECHNICAL CENTERS			RIVER BASIN ORGANIZATIONS				
	ECOWAS	UEMOA	AGRHYMET	ACMAD	WASCAL	ASECNA	MOLOA	NBA	VBA	OMVS	OMVG	LCBC
Benin	■	■	■	■	■	■	■	■	■			
Burkina Faso	■	■	■	■	■	■		■	■			
Cabo Verde	■		■	■	■							
Cote d'Ivoire	■	■	■	■	■	■	■	■	■			
The Gambia	■		■	■	■						■	
Ghana	■		*	■	■		■		■			
Guinea	■		■	■				■		■	■	
Guinea Bissau	■	■	■	■		■	■				■	
Liberia	■		*	■								
Mali	■	■	■	■	■	■		■	■	■		
Niger	■	■	■	■	■	■		■				■
Nigeria	■		*	■	■		■	■				■
Senegal	■	■	■	■		■	■			■	■	
Sierra Leone	■		*	■								
Togo	■	■	■	■	■	■	■		■			
Mauritania			■	■		■	■			■		
Chad			■	■		■		■				■
Cameroon				■		■		■				■
Central African Republic				■		■						■

* As the Regional Climate Center for West Africa and the Sahel, AGRHYMET covers all ECOWAS member states.

African Center of Meteorological Applications for Development (ACMAD) provides weather and climate services for 53 countries in Africa. It was created in 1987 by the United Nations Economic Commission for Africa (UNECA) and WMO. ACMAD provides regular continental medium- to long-range weather and climate prediction; continental early warnings on drought, tropical cyclones and other extreme events; climate watch bulletins; services for different sectors (agriculture, health, water and energy) and contributions to climate research. It provides and coordinates specialized training programs and co-hosts the Regional Climate Outlook Forum (PRESASS[13] and PRESAGG[14]) for 18 countries in West Africa. ACMAD relies on the Monitoring for Environment and Security in Africa (MESA) stations for daily, three-day and 10-day weather forecasting. It uses long-range forecasting products from the global centers to provide seasonal forecasts to the continent. ACMAD relies on the SYNERGIE workstation for weather forecasting and the Climate Prediction Tool for seasonal forecasting. ACMAD has access to global weather forecasting products from the European Center for Medium-Range Weather Forecast, UK Met Office and Météo-France.

Regional Center for Training and Application in Agrometeorology and Operational Hydrology (AGRHYMET) was created in 1974 as a technical center of the Permanent Inter-State

[13] PRESASS: Seasonal Climate Outlook Forum for SudanoSahelian Africa / *Prévision Saisonnière en Afrique Soudano-Saharienne*
[14] PRESAGG: Seasonal Climate Outlook Forum for the Gulf of Guinea / *Prévision Saisonnière du Golfe de Guinée*

Committee for Drought Control in the Sahel (CILSS). Except for Mauritania and Chad, all other members[15] of AGRHYMET are also members of ECOWAS. It was designated as a WMO regional training center (RTC) in 1975, a role which was again renewed in January 2019. AGRHYMET is undergoing an accreditation process to become a WMO Regional Climate Center for West Africa and the Sahel. AGRHYMET provides a range of products and services, including seasonal forecasting and climate monitoring over West Africa, forecasting of agroclimatic parameters, hydrological monitoring and locust invasion, drought monitoring and desertification watch, food security advisory services and information dissemination across the Sahel. Other services include the development of decision-support tools, capacity building in climatology, agrometeorology, hydrology, crop protection, geomatics and remote sensing across Sahel countries. AGRHYMET produces and disseminates monthly and seasonal bulletins. It organizes training programs meteorologists, forecasters, agrometeorologists and hydrologists. These trainings include degree trainings (WMO class II and class I) and on-the-job-trainings in meteorology and hydrology. AGRHYMET has recently procured a high-performance computer to further improve weather forecasting and climate downscaling. It accesses the internet via satellite and assesses global forecasting information from global production centers.

Regional Specialized Meteorological Center (RSMC) was established by WMO and hosted by the National Agency of Civil Aviation and Meteorology Services of Senegal (ANACIM) in Dakar, Senegal, to improve early warning and severe weather forecasting over West Africa. It is implemented and managed by ANACIM and uses its staff and equipment to provide its members with climate analyses, long-range forecasts and predictions for the onset, intensity, and cessation of the rainy season. RSMC provides interpreted forecasts of specific weather and guidance on storm positions and it tracks forecasts for the areas affected by tropical storms. RSMC Dakar is designated by WMO as a RSMC for Severe Weather Forecasting and, therefore, leads the coordination and analysis of the available products and information for the daily Severe Weather Forecast Guidance in support of the NMHS in West Africa.

Research and Regional Technical Centers

Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) is an international public institution created in 1959 to provide air navigation services, aeronautical meteorological forecasting, maintenance of meteorological instruments, meteorological observation and transmission of meteorological information to the global production centers (for example, European Centre for Medium-Range Weather Forecasts, Météo-France, UK Met Office and National Oceanographic and Atmospheric Association). ASECNA trains meteorological forecasters in mostly francophone West Africa and conducts aviation meteorology in eight West African countries (table 6).

TABLE 6. Number of ASECNA experts serving in ECOWAS member states

	ADMINISTRATION	FORECASTERS	AIRLINE PROTECTION TECHNICIANS	OBSERVERS
Benin	3	6	6	6
Burkina Faso	3	7	9	16
Cote d'Ivoire	4	5	5	8
Guinea Bissau	3	2	4	5
Mali	3	8	10	30
Niger	2	9	7	17
Senegal	4	10	8	7
Togo	4	5	12	23

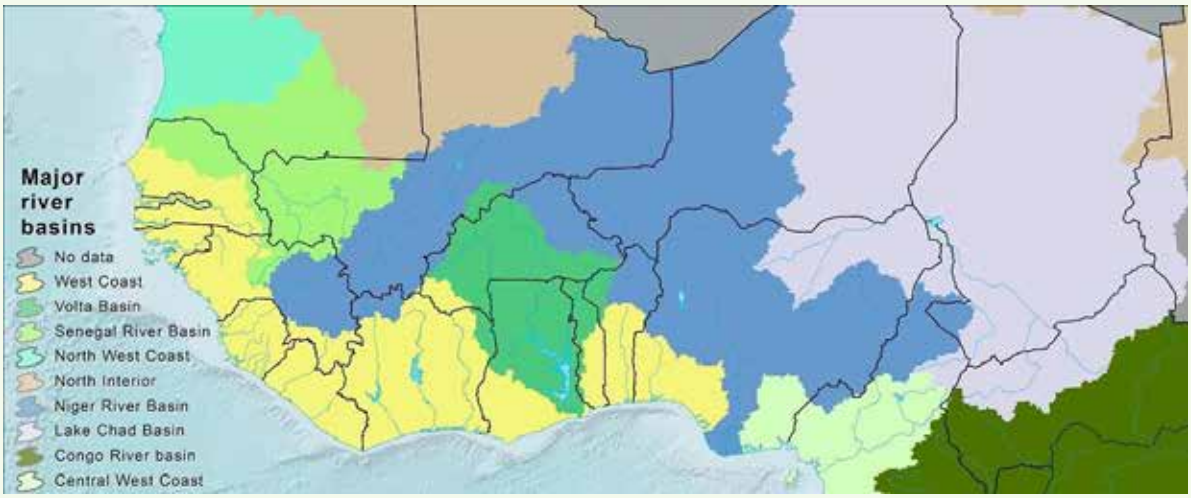
[15] Benin, Burkina Faso, Cabo Verde, Chad, Côte d'Ivoire, The Gambia, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, and Togo.

West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) is a research-focused climate service center designed to provide information and applied research to its West African member states: Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal and Togo. WASCAL has its headquarters in Accra, Ghana, and a competence center in Ouagadougou, Burkina Faso. WASCAL hosts 10 PhD programs on climate change at different universities in West Africa. The competence center includes a climate service unit which is charged with organizing an observation network in member states. The network should produce consistent and quality information on weather and the hydrological cycle and on changes in land use, human coping strategies and biodiversity shifts or loss.

River Basin Organizations

The ECOWAS region contains five major transboundary basins, each managed by a river basin organization comprising its riparian countries (figure 6): Gambia River Basin Development Authority (OMVG), Lake Chad Basin Commission (LCBC), Mano River Union (MRU), Niger Basin Authority (NBA), Senegal River Basin Development Authority (OMVS) and Volta Basin Authority (VBA). These organizations play coordinating roles among and support their member states in improving and maintaining hydrological observation and forecasting capacity.

FIGURE 6. Major rivers basins in the ECOWAS region[16]



[16] Source: CILSS (2016)

Niger Basin Authority (NBA) is West Africa's largest basin authority and is composed of nine countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger and Nigeria. NBA is an intergovernmental organization responsible for promoting cooperation among member states and contributing to improve the living conditions of its populations through sustainable management of its shared water resources and associated ecosystems. NBA supports its member with (a) monitoring of river discharge, through automatic stations installed by NBA and data integration for flow measurements, (b) data sharing and (c) hydrological modeling and forecasting.

Volta Basin Authority (VBA) was created in 2005 and is composed of six countries: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali and Togo. VBA has five key tasks: (a) promote an ongoing dialogue among stakeholders on the development of the basin; (b) promote the implementation of integrated water resources management and equitable sharing of benefits arising from their different uses; (c) authorize the exe-

cution of works and projects proposed that may have a significant impact on the water resources of the basin; (d) develop joint projects and works and (e) contribute to poverty reduction, sustainable development of states and parties, and better socioeconomic integration within the region. In terms of products, VBA does not produce any forecasting information.

Senegal River Basin Development Authority (OMVS) was created in 1972 with the mission of managing the availability of water and seeking means for a rational and coordinated use of the basin's resources. Its members are Guinea, Mali, Mauritania and Senegal. OMVS promotes joint infrastructure development, where member share the costs and benefits. It has the following objectives: (a) ensure food security for the populations of the basin and the subregion, (b) secure and improve people's incomes, (c) preserve the balance of ecosystems in the basin, (d) reduce the vulnerability of the economies of the member to weather and external factors and (e) accelerate the economic development of the member states.

Table 7 provides an overview of the products and services of the Regional Climate Centers, regional technical centers and river basin organizations. It also provides an indication of their respective budgets and relevant technical capacity.

TABLE 7. Products and services of regional institutions

INSTITUTION	SPECIFIC SERVICES, PRODUCTS AND APPLICATIONS	DATA-SHARING PROTOCOL WITH MEMBER STATES IN PLACE AND OPERATIONAL	SUPPORT TO MEMBER STATES WITH OBSERVATION NETWORK	USERS AND TARGET AUDIENCE	TRAINING AND RESEARCH PROVIDED TO MEMBER STATES
ACMAD	Annual State of African Climate; 10-day, monthly climate dia. bulletins. Daily: (Severe) Weather forecast, flash flood risk forecast. Weekly: Niger basin rainfall forecast.	No data-sharing protocol.	No observation network support to member states.	International partners, NMHS. Contributes to PRESASS and PRESAGG.	Training in specific meteorology applications.
AGRHYMET	10-day, monthly, seasonal bulletins for rainfall, onset, dry spells. Satellite-derived products Monthly: agriculture, hydrological, plant health bulletins.	Data-sharing protocol with CILSS member states.	Backup database for member states but not frequently updated; guidance on network expansion database management CLIDATA and other software.	ECOWAS, international partners, Ministries of Agriculture and Food Security, NMHS. Contribution to PRESASS, PRESAGG.	Tailored research and advisory services; training program for agro-meteorology; training for operation and maintenance.
ASECNA	Meteorological observation TAF (24-hr forecasting), METARs (30-minute forecasting); data transmission to GTS.	No formal data-sharing protocol. Data re-transmitted to GTS.	Servers for transmission and archiving calibration lab.	Aviation, NMHS.	Training on aviation-related meteorology.

TABLE 7. (continued)

INSTITUTION	SPECIFIC SERVICES, PRODUCTS AND APPLICATIONS	DATA-SHARING PROTOCOL WITH MEMBER STATES IN PLACE AND OPERATIONAL	SUPPORT TO MEMBER STATES WITH OBSERVATION NETWORK	USERS AND TARGET AUDIENCE	TRAINING AND RESEARCH PROVIDED TO MEMBER STATES
LCBC	Monitoring of river basin flows.	Protocol for sharing hydrological data with member states.	Backup database for member states; guidance on network expansion.	Ministry of Water, NHS.	Applied research on hydrological studies.
NBA	Monitoring of river basin flow. Monthly: hydrological bulletins, river flow forecasts	Protocol for sharing hydrological data with member states.	Guidance on network expansion; Regional Niger Basin Observatory.	ECOWAS, Ministry of Water, NHS. Contribution to PRESASS, PRESAGG.	Applied research on hydrological studies.
OMVG	Monitoring of river basin flows.	Protocol for sharing hydrological data with member states.	Backup database for member states; guidance on network expansion.	Ministry of Water, NHS.	Applied research on hydrological studies.
OMVS	Monitoring of river basin flows; data collection.	Protocol for sharing hydrological data with member states.	Backup database for member states; guidance on network expansion.	Ministry of Water, NHS.	Applied research on hydrological studies.
VBA	Observatory of Volta Basin.	Data-sharing protocol for hydrological data with member states.	Backup database for VBA member states; guidance on network expansion.	Ministry of Water, NHS.	Applied research on hydrological studies.
WASCAL	Research publications.	Data-sharing protocol on specific data.	Research-focused stations.	ECOWAS, NMHS, universities.	Research on climate and land use; Master of Science, PhD.

3.2 Country Perspective on Regional Collaboration

As the regional organizations mentioned above are member-based organizations, the perspective of their member states on hydromet and climate services is of particular importance. The member state perspective on regional collaboration was identified in focus group discussions during the preparation of the report.

ECOWAS: Member states call on ECOWAS to spearhead regional policy initiatives, coordinate hydromet and climate initiatives in the region, ensure complementarity with other initiatives and promote the regional economies of scale. In addition, member states refer to ECOWAS for resource mobilization to implement investments in hydromet services, monitor progress and establish a regional user platform for hydromet services.

Regional climate centers: Member states expect ACMAD and AGRHYMET to perform, among other, long-range forecasting, climate monitoring, data services as well as training and capacity building. These functions include interpreting and assessing long-range forecasting products from global production centers (GPC), generating regional tailored products and seasonal climate outlooks (Seasonal Climate Outlook Forum for SudanoSahelian Africa, PRESASS and Seasonal Climate Outlook Forum for the Gulf of Guinea, PRESAGG), performing regional climate diagnostics, establishing a regional historical reference climatology, implementing a regional climate watch facility and coordinating (degree and short-term) trainings. In addition, AGRHYMET and ACMAD should develop and improve regional weather and climate products, operate a calibration center for the region and provide technical assistance to NMHS.

Regional Basin Organizations: Member states look to river basin organizations to provide technical assistance for the collection, management and communication of hydrological data and to support flood and drought forecasting coordination on issues relevant for the respective basin. River basin organizations should support the implementation of regional efforts for flood and drought management under the coordination of ECOWAS.

WASCAL: Member states look to WASCAL to train Master of Science and PhD students in climate science and to extend this training across the ECOWAS region. WASCAL also leads research and development in hydrological forecasting, weather and climate modeling and development in hydromet tools and tailored products for operational services.

RSMC is expected to lead the development of numerical weather prediction over the region. As such, the center should provide high-resolution weather forecasting and forecasting of extreme weather events to the region. It should also get involved in the training of the staff of NMHS.

WMO is valued by member states for providing technical guidance related to meteorological and hydrological forecasts and assisting NMHS with guidance on and training in the installation, operation and maintenance of their hydromet infrastructure. WMO should also support the NMHS toward the integration into the global hydromet systems and the implementation of the relevant global protocols, such as Minamata Protocol.

3.3 Challenges and Opportunities of Regional Collaboration on Hydromet Services

In 2020 ECOWAS and AGRHYMET agreed to collaborate closely on hydromet policies and capacity building and to establish AGRHYMET[17] as the Regional Climate Center for West Africa and the Sahel (box 2). This institutional collaboration has produced notable opportunities, including: the provision of technical services, capacity building, data sharing and policy alignment.

Despite the number of regional institutions and the closer integration of the different institutions, many challenges remain and limit the full potential of a closely integrated landscape of weather, climate, water and early warning services. This includes (a) policies and data-sharing arrangements; (b) infrastructure, observation data management and forecasting capacity; and (c) institutional issues, including sustainable financing of the institutions involved.

(a) Policies and data-sharing arrangements

Absence of a data-sharing mechanisms across all ECOWAS countries: Sharing real-time and historic hydrological and meteorological data across countries and basins can improve forecasts and can strengthen the accuracy of global and regional models and applications such as flood forecasting. While evidence indicates that an open data policy can lead to broader use of data, thus maximizing socioeconomic benefits, concerns remain on the property of the relevant information, including foregone revenue from the use and application of the data. In addition, successful data-sharing mechanisms require adequate servers, transfer mechanisms, meta data and protocols. Within the ECOWAS region, a data-sharing agreement exists between AGRHYMET and its CILSS member states as well as within river basin organizations and the

17 AGRHYMET is in the process of being accredited as Regional Climate Center by WMO.

Box 2. Seasonal climate outlook forums

Agro-Hydro-Climatic Seasonal Forecasting in Sudano-Sahelian Africa is a regional climate outlook prediction and application process facilitated by ACMAD and AGRHYMET. ACMAD has organized the Regional Seasonal Climate Outlook Prediction (PRESAO) forum since 1998 throughout West Africa.

Initially, the forum was held annually, usually in May with July-August-September as the main target season. Starting in 2014, it was changed to late April to increase the lead time and thus the usefulness of the product. The seasonal forecast was split into an outlook for the Gulf of Guinea region given its bimodal rainfall regime (PRESAGG) and the Sudano-Sahel region (PRESASS). PRESASS constitutes 17 countries in West and Central Africa, namely: Benin, Burkina Faso, Cabo Verde, Cameroon, Central Africa Republic, Chad, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal and Togo.

During the forum, ACMAD focuses on the probabilistic forecast while AGRHYMET focuses on the agroclimatic characteristics. AGRHYMET also works closely with the ABN and VBA to provide seasonal forecasts for the hydrological network based on PRESASS. Figure B2.1 shows a hydrological forecast conducted during the 2019 PRESASS. Figure B2.2 maps the occurrence of low/high stream water levels in the different rivers.

FIGURE B2.1. Seasonal forecast for July–August–September 2021 in West Africa.

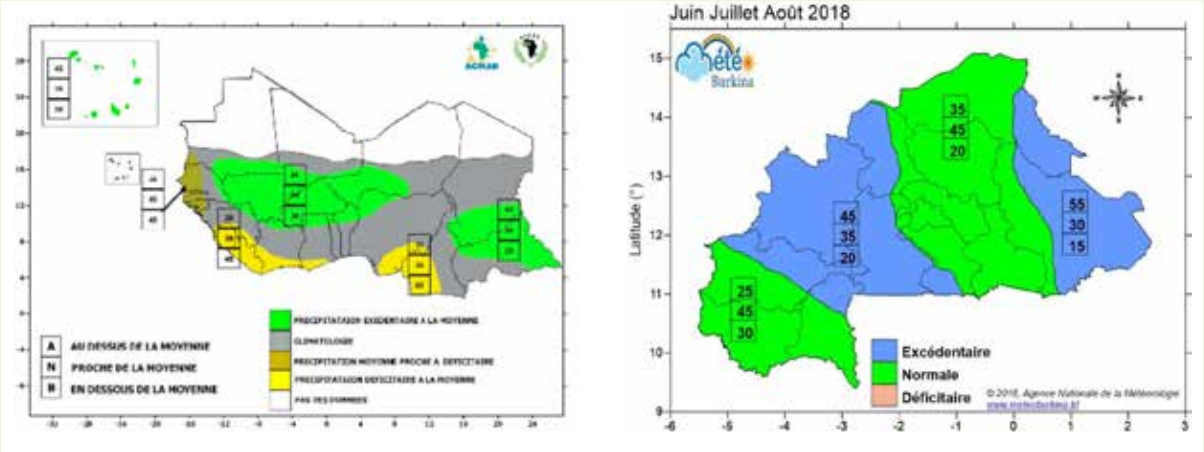
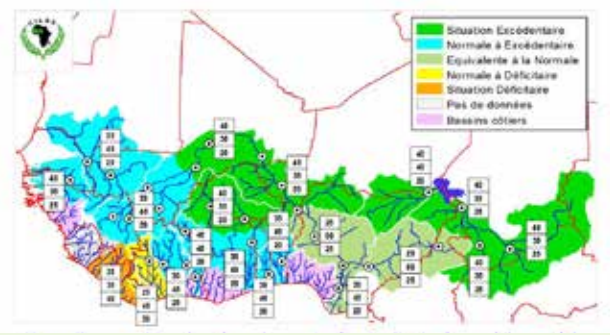


FIGURE B2.2. Seasonal forecast of mean stream flows of the principal basins of the CILSS/ECOWAS areas 2021 (source: ACMAD, 2021)



(Source: AGRHYMET, 2021[18]).

[18] AGRHYMET, 2021: PRESASS 2021 Seasonal forecasting forum on Agro-Hydro-climatic characteristics for the Sudanian and Sahelian zones

respective directorates of water resources. There is no data-sharing agreement or mechanism with ACMAD, the ECOWAS Commission, or among member states and regional technical centers.

Regulatory framework for regional early warning and regional emergency coordination: While ECOWAS has established a sound peace and security reporting system, a regional exchange of forecasting and early warning information related to natural hazards does not yet exist. With the formulation of the ECOWAS Flood Risk Management Policy, adopted in 2021, a coherent policy framework will be available to guide the region on exchanging information on flood risks and flood early warning. Yet, a lack of coordination among different departments as well as between institutions limits an effective exchange of forecasting and early warning information. Lastly, coordination on disaster response remains largely ad-hoc and scattered, whereas a roster of experts on disaster response and recovery planning is not in use.

(b) Infrastructure, observation, data management and forecasting capacity

Lack of ICT infrastructure and adequate data management system: Few regional organizations have adequate data-processing capacity, access to state-of-the-art models and applications or adequate training provision for member states' staff. Strengthening the data management and ICT capacity of regional technical centers, such as ACMAD and AGRHYMET, will notably benefit the smaller countries to access products and services from GPC instead of having to invest in high-performance computing capacity.

Lack of calibration capacity for observation equipment: Hydrological and meteorological sensors need frequent calibration to ensure accurate data recording. At least 10 NMHS have not been able to calibrate their instruments on a regular basis, due to the lack of capacity and the absence of a calibration unit for West Africa.

Absence of integrated meteorological and hydrological forecasting system in the region: Meteorological forecasts in the region are not able to capture the high spatial-temporal variability of mesoscale convective systems over West Africa, a continuing challenge, especially because of the low density of surface observation networks. The establishment of a regionally coordinated and integrated hydrological and meteorological forecasting system is essential for generating adequate products for warning systems. Capacity building efforts should be advanced at the regional level for short-, medium- and long-range forecasts and also for the development of specific end-user products.

Technical limitations in seasonal forecast: Models are weak in capturing the African monsoon features, whereas the forecasting abilities become weak beyond three days and seasonal outlooks cannot be downscaled to the local level. The same limitations often lead to holding the PRESASS outlook late, with a reduced window for stakeholders to take adequate actions. In recent years, there has been significant progress on the technical issues related to sub-seasonal to seasonal forecasting in West Africa.

Absence of archiving and verification systems and user guidelines: Neither ACMAD nor AGRHYMET has a well-structured user guide for seasonal forecasting, making it difficult for new experts to acquire the necessary forecasting knowledge and to verify long-term forecasts. Moreover, there is no database archiving system for seasonal forecast products, making it difficult to evaluate the PRESASS and PRESAGG despite having 18 years of data.

(c) Institutional issues, including sustainable financing

Unsustainable financing mechanism of regional hydromet bodies: AGRHYMET and ACMAD currently lack the resources to contract seasonal forecasting experts and depend largely on donor funding for the two regional climate outlook forums, PRESASS and PRESAGG. Often new funding has to be mobilized to organize the forums. Many of the regional organizations depend on member state contributions. However, with many of the contributing members in arrears, institutions like ACMAD and AGRHYMET depend on donor/external funding for about 90 percent of their activities, operations, trainings and staff salaries.

Staffing gaps capacity at AGRHYMET: AGRHYMET only has one technical staff member specialized in meteorological long-range forecasting. This falls below the minimum requirement to run a Regional Climate Center. Due to the lack of funding, there also is very high staff turnover.


Screens for radar monitoring in meteorological department . © Laarow | Dreamstime.com

CHAPTER 4

Status of National Meteorological and Hydrological Services

National Meteorological and Hydrological Services (NMHS) are the authoritative and main providers of weather, water, climate and related environmental services for a range of users to respond to relevant national, regional and global needs. NMHS assist them in reducing the risks of and deriving economic benefits from, the associated conditions. Across all countries, National Meteorological Services (NMS) observe, understand and predict the weather and climate and provide services in support of users.[19] National Hydrological Services (NHS) are responsible for monitoring water resources and providing services such as model-based forecasts for river water levels. In all ECOWAS countries, except The Gambia, NMHS are two separate entities under different ministries. Table 8 provides an overview of the status of NMS, whereas table 9 provides the same overview for the NHS.

TABLE 8. Status of observation network, products, services and capacities of National Meteorological Services

COUNTRY, *institutional set up*	STAFFING, *of which climatologists, forecasters, meteorologists observers*	SYNOPTIC TYPE, *agromet, climate, rainfall*	OTHER OBSERVATIONS	SERVICES AND FORECASTS PROVIDED	SERVICE BENEFICIARIES
Benin *Agency*	67 staff, *3 climatologists* *11 forecasters* *30 observers*	16 synoptic *39 agromet* *82 rainfall*		24-hour and seasonal forecasts Monthly and annual means	Agriculture, fisheries, general public, industry
Burkina Faso *Agency*	108 staff, *9 climatologists* *9 forecasters* *31 meteorologists* *2 observers*	20 synoptic (10 AWS) *132 agromet* *(63 AWS)* *212 rain gauges* *(195 AWS)*	1 radiosonde	24h/ 48h/ 7d/ seasonal forecasts 10d bulletin for agriculture alerts and warnings Dust forecast	Agriculture, general public
Cabo Verde *National Institute*	121 staff, *2 climatologists* *13 forecasters* *13 observers*	7 synoptic *14 climate* *270 rainfall*	1 air pollution 3 marine stations 1 ozone 1 upper air	24h/ 48h/ 7d/ seasonal forecasts Bulletins, rainfall charts	Disaster risk management (DRM), ENAPOR, fisheries, shipping
Cote d'Ivoire *Agency**	116 staff, *6 climatologists* *17 forecasters* *75 observers*	13 synoptic *31 agromet* *130 rainfall*		24h/ 48h/ seasonal forecasts Monthly/ annual means temperatures bulletins	Agriculture, (BTP), DRM, fisheries, general public, import/ export, industry

19 https://library.wmo.int/?lvl=notice_display&id=14283#.YFJt7J1Kj3k

TABLE 8. (continued)

COUNTRY, *institutional set up*	STAFFING, *of which climatologists, forecasters, meteorologists observers*	SYNOPTIC TYPE, *agromet, climate, rainfall*	OTHER OBSERVATIONS	SERVICES AND FORECASTS PROVIDED	SERVICE BENEFICIARIES
The Gambia *Department*	123 staff, *2 climatologists* *13 forecasters* *42 observers*	21 synoptic *8 climate* *25 rainfall*	1 marine station 2 pilot-sondes	24h/ 48h/ 10d/ seasonal forecasts	Agriculture, aviation, DRM, energy, shipping
Ghana *Agency*	572 staff, *2 climatologists* *45 forecasters* *195 observers*	22 synoptic *36 agromet* *23 climate* *72 rainfall*		24h/ 48h/ seasonal forecasts Monthly/ annual means	
Guinea *Directorate*	178 staff, *10 climatologists* *61 forecasters* *73 observers*	12 synoptic *6 agromet* *27 climate* *160 rainfall*	1 upper air	24h/ 48h/ seasonal forecasts Tides info	Agriculture, DRM, fisheries, general public, industry
Guinea Bissau *Institute*	48 staff, *6 climatologists* *12 forecasters* *10 observers*	*6 agromet* *8 climate* *50 rainfall* *(7 manual)*		24h/ seasonal forecasts Tides info, wind gusts	Agriculture, BTP, general public, maritime
Liberia *Directorate*	27 staff, *3 forecasters* *5 observers*	5 synoptic *6 agromet* *69 rainfall*			
Mali *Agency*	103 staff, *7 climatologists* *19 forecasters* *17 observers*	19 synoptic *37 agromet* *205 rainfall*	2 upper air, 1 radiosonde (2x/day) 1 pilot-sonde	24h/ 48h/ 10d/ seasonal forecasts 10d bulletin for agriculture	Agriculture, DRM, general public, industry
Niger *Directorate*	119 staff, *3 climatologists* *10 forecasters* *78 observers*	16 synoptic *3 agromet* *19 climatologic* *800 rainfall*	2 ozone	24h/ 48h/ 10d/ seasonal forecasts	Agriculture, DRM, general public, industry
Nigeria *Agency*	1,688 staff, *591 forecasters* *470 observers*	54 synoptic *1 agromet*	5 air pollution 12 marine 2 ozone 8 upper air	24h/ 48h/ 10d/ seasonal forecasts Climate review bulletin	Agriculture, aviation, energy, maritime, oil & gas, research, security, water
Senegal *Agency**	120 staff, *09 climatologists* *28 forecasters* *71 observers*	13 synoptic *12 agromet* *382 rainfall*	3 marine stations 4 radiosondes	24h/ 48h/ 10d/ (sub)seasonal forecasts EWS	Agriculture, BTP, DRM, energy, shipping, public services

TABLE 8. (continued)

COUNTRY, *institutional set up*	STAFFING, *of which climatologists, forecasters, meteorologists observers*	SYNOPTIC TYPE, *agromet, climate, rainfall*	OTHER OBSERVATIONS	SERVICES AND FORECASTS PROVIDED	SERVICE BENEFICIARIES
Sierra Leone *Agency*	48 staff, *1 forecasters* *31 observers*	10 synoptic *8 agromet*		24h/ 48h/ seasonal forecasts Monthly/ annual means	Construction, energy, DRM, general public, water,
Togo *Directorate*	67 staff, *10 climatologists* *13 forecasters* *23 observers*	25 synoptic *336 rainfall*		24h/ 48h/ seasonal forecasts Seasonal bulletin	Agriculture, BTP, DRM, energy, public services

Note: Based on self-reported data as of December 2019; * Department within an agency (SODEXAM in Cote d'Ivoire and ANACIM in Senegal).

TABLE 9. Status of observation network, products and services and capacities of National Hydrological Services

COUNTRY INSTITUTIONAL SET-UP	STAFF *of which hydrologists*	OBSERVATION NETWORK (SURFACE WATER)	OTHER OBSERVATIONS	SERVICES PROVIDED
Benin *Directorate*	8 staff *3 hydrologists*	4 Acoustic Doppler current profiler (ADCP)/current meters 10 limnigraphs with telecommunication 20 limnigraphs without telecommunication	2 echosounders	DRM Drought base flow Riverine and flash flood monitoring Streamflow monitoring Water resources assessments
Burkina Faso *Directorate*	14 staff *2 hydrologists*	8 ADCP/current meters 1 limnigraph without telecommunication 20 limnimetric scales	2 Boats/ Zodiac 1 Limnigraphs with telecommunication 14 Rain gauges	DRM Drought base flow Riverine and flash flood monitoring Streamflow monitoring Water resources assessments
Cabo Verde	no NHS dealing with surface water			
Cote d'Ivoire *Department*	13 staff *2 hydrologists*	148 limnigraphs without telecommunication		Hydrological data collection Riverine flood monitoring
The Gambia *Department*	40 staff *8 hydrologists*		2 Orpheus Mini	Hydrological data collection

TABLE 9. (continued)

COUNTRY INSTITUTIONAL SET-UP	STAFF *of which hydrologists*	OBSERVATION NETWORK (SURFACE WATER)	OTHER OBSERVATIONS	SERVICES PROVIDED
Ghana *Department*	29 staff *7 hydrologists*	10 limnigraphs without telecommunication 166 limnimetric scales		Drought base flow Flood forecasting (Volta) Hydrological data collection Water resources assessment
Guinea *Directorate*	182 staff *57 hydrologists*	193 limnigraphs without telecommunication		Hydrological data collection
Guinea Bissau *Directorate*	8 staff *3 hydrologists*	10 limnimetric scales		Hydrological data collection
Liberia *Department*	48 staff *2 hydrologists*	ADCP/current meter limnigraphs without telecommunication		Hydrological data collection
Mali *Department*	36 staff *3 hydrologists*	107 limnigraphs without telecommunication		Hydrological data collection
Niger *Department*	23 staff *18 hydrologists*	adcp limnigraphs without telecommunication limnigraphic scales		Hydrological data collection
Nigeria *Agency*	196 staff *76 hydrologists*	limnigraphs with telecommunication adcp limnimetric scales		Drought base flow Flood monitoring and streamflow (Niger) Water resources assessment
Senegal *Agency*	71 staff *2 hydrologists*	Thalimèdes Orpheus Mini Ecolog 800		Hydrological data collection Riverine flood forecasting (Volta)
Sierra Leone *Directorate*	4 staff	None operating		Hydrological data collection
Togo *Directorate*	4 staff *1 hydrologists*	72 limnigraphs with telecommunication 1 ADCP		Hydrological data collection Hydro-dynamic modeling (Mono, Volta)

Note: Based on self-reported data as of December 2019.

4.1 Challenges and Opportunities of National Hydromet Services

Based on an analysis of the service level of the National Hydromet and Early Warning Services and discussions with stakeholders in West Africa, commonalities that limit the provision of adequate services to beneficiaries at the country level have been identified. These challenges and opportunities of the National Hydromet and Early Warning Services relate to (a) governance, institutional arrangements and capacity building; (b) observation infrastructure and ICT; and (c) service provision and forecasting capacity.

(a) Governance, institutional arrangements and capacity building

Limited role of National Hydromet and Early Warning Services in decision-making: West African economies are sensitive to climate extremes and are being impacted by climate shocks; yet, hydromet services are often limited to a few sectors (such as, aeronautics, agriculture, and food security) in public decision-making. Hydromet information, including information on flood and drought risks, is often not taken into consideration in ensuring optimal production or planning, and the NMHS compete with many other sectors for support and funding. The pending ECOWAS Flood Risk Management Policy provides guidance to countries on assessing flood risks, strengthening flood forecasting and hydromet services.

Inadequate number of qualified personnel: Early warning systems are highly dependent on well-trained staff that master the latest forecasting techniques and services; however, the ECOWAS regions only has a few specialized training centers. WMO has established one regional training center in Lagos supporting primarily the English-speaking countries in (West) Africa and another in Niamey supporting primarily the French-speaking countries in (West) Africa. Still, the centers do not provide training and application that integrate medium- and long-range meteorological forecasting. In addition, many of the staff from NMHS have retired or are set to retire in the next five years, in many cases without a viable transition to new staff. A commitment to staffing by governments is essential for the provision of quality hydromet services.

Weak institutional structure and unsustainable financing: Nine out of 15 NMS and just two out of 13 NHS are set up institutionally as an agency, with some form of institutional autonomy on budgeting, expenditure and competitive salaries. Many countries recently transferred NMHS to an agency instead of a government department to increase the institutional funding base. On a cost-recovery basis, landing and overflight fees from airlines contribute to the income of the NMS. The role of private-sector financing and fee-for-service applications remains experimental.

(b) Infrastructure, observation, data management and forecasting capacity

Limited observation network and weak data-sharing mechanisms: In the ECOWAS region, more than 60 percent of data is still collected manually and handled by non-professional and voluntary staff. Consequently, the data are often of poor quality and cannot be used for real-time monitoring and early warning for phenomena with a short lead time. The radar network is scattered and often not operational, even less dense is the upper air station network and frequently launched radiosondes feeding into meteorological models. On the other hand, the advantages of automatic weather stations, modern and complex monitoring networks (such as, marine stations, ozone and air pollution stations) and radar systems are often offset by with high capital investment costs, as well as engineering, operation, maintenance and data-transmission costs. Currently, new technologies are being developed that can contribute to the nowcasting capability, such as lightning sensors and the use of the attenuation of microwave signals between cell towers.

Low ICT capacity and weak internet access: Many of the NMHS have outdated ICT infrastructure, often updated in a piecemeal approach based on resources available from different externally funded donor projects. In addition, frequent power cuts and weak internet connection limit the access to global data sets and operational capacity of the NMHS.

Lack of historic data and long-term data series that minimize the use of climate models: Historic climate and hydrological data have in many cases not yet been digitized; they remain in paper archives and thus are not accessible for climate modeling. Retrieving historic data, validating data using statistical methods and making these data accessible for climate and hydrological models will be important for building a sound analysis of trends, improving model accuracy and feeding relevant hydromet services.

Limited resources for operation and maintenance of the observation network: Financing operation and maintenance remains one of the biggest challenges for sustaining any observation network. Also, automated observation stations require batteries to be replaced, equipment to be calibrated and discharge measurements and rating curves to be updated with the related

operational budget for visiting remote field locations frequently. All ECOWAS member states reported challenges with conducting adequate operation and maintenance of the observation equipment.

Limited high-performance computing capacity: Even the NMHS that have a full or advanced service level, such as Ghana, Nigeria and Senegal, do not have high-performance computing capacity to run complex climate models. Regional coordinated investments in high-performance computing capacity and collaboration with the Regional Climate Centers to conduct such complex modeling may be an opportunity to reduce the costs for individual countries, while having the necessary facilities in the region.

Few countries use tailored models for hydrological and meteorological forecasts: Only a few countries in West Africa use tailored and locally calibrated models for numerical weather prediction, climate modeling and hydrological models for flood forecasting. For example, Ghana has established a hydrological-hydraulic mode for the Volta Basin to forecast water levels and discharge in the Volta Basin. However, models need to be frequently updated and calibrated to remain accurate as, for example, land use and river bathymetry change.

(c) Service provision and forecasting capacity

Low access of communities, especially women, to actionable weather, climate and water information: Many communities, notably rural areas, have no or only limited access to weather, climate, water and early warning information. Services are not accessible because of language barriers, weak communication channels or limited relevance of the information. Notably, women are often left out in the communication of hydromet and early warning information. Few of the NMHS have conducted active engagement with end users and specific user groups, such as farmers, women and vulnerable groups.

Lack of accurate, timely and actionable climate information: Given the climate vulnerability of the ECOWAS region, climate information still has a limited reach in national planning. One of the limiting factors is the lack of accurate and actionable weather, climate and water information, its accessibility to decision-makers' account and a limited understanding by the NMHS of end-user requirements.

Private sector initiatives remain at the pilot stage: Collaboration with the private sector, beyond the aviation sector, remains at the pilot stage. Examples include, among others, different agricultural service applications or a rain cell project using cell phone signal attenuation for rainfall estimations. Different models of private sector collaboration could be further explored, either where tailored products are supplied to specific services or where private sector firms collaborate with the NMHS for specific applications. The regulatory framework, including a sound data policy that would enable private sector initiatives, remains unclear in many countries.

Inadequate early warning and last mile communication: The use of early warning information, including flood forecasting and flash flood guidance, remains limited to specific locations. These locations include, for example, parts of the Volta and Niger Rivers for flood forecasting and cities like Accra where urban/flash flood guidance systems are being established. Many of the forecasting and early warning systems fall short of direct and actionable communication with communities and only provide information to other government agencies.

Limited effectiveness of integrated national and regional hydromet platforms and multi-hazards early warning: Climate and hydrological platforms, such as the Regional Climate Outlook Forums, are important for efficient information sharing and response coordination. Still, these platforms need to (a) improve their forecasting capacity and accuracy and (b) integrate regional issues, considering lessons learned and guidance for policy and decision-makers.

Research on weather, climate and water resources often not linked to practice applications: Several NMHS have set up research teams and are collaborating with research institutions at the national and regional level (for example, AGRHYMET and WASCAL). Nevertheless, research and development activities remain largely project focused and, in many cases, disconnected to operational applications.

4.2 Service Level of National Hydromet Services

WMO has developed a classification system to assist countries in better understanding the service requirements for the weather services, climate services and hydrology services and in identifying the needs of National Meteorological and Hydrological Services. This categorization defines four levels of service: basic, essential, full and advanced. Table 10 provides further details on the criteria defining the level of services, based on WMO (2015).

TABLE 10. WMO criteria for the four categories of National Meteorological and Hydrological Services

LEVEL OF SERVICE	WEATHER SERVICES	CLIMATE SERVICES	HYDROLOGY SERVICES	DESCRIPTION OF CAPACITY NEEDED TO MEET SERVICE LEVEL
Category 1 – Basic	» Weather observations » Weather data management » Interaction with weather data and product users	» Climate observations » Climate data management » Interaction with climate data and product users	» Hydrological observations » Hydrological data management » Interaction with hydrology data and product users	» Small network of quality controlled observations » Basic data processing, archiving and communication systems » Little or no backup/offsite storage, or contingency options » Rudimentary staff (observers and some meteorologists trained to BIP standards) » No 24/7 operation » Rudimentary QMS » No R&D
Category 2 – Essential	» Medium-range (synoptic scale) forecasts and warnings » Established links with media and DRR communities	» Seasonal climate outlooks » Climate monitoring	» Hydrological data products for design and operation of water supply structures » Water level and flow monitoring » Short-term flow forecasts (low flows) » Flood forecasting	» Able to integrate and take observations from other parties » Well-established protocols for emergencies, backup of data and minimum offsite facilities » Staff (observers and meteorologists trained to BIP standards) » 24/7 operation » QMS well established » Access most NWP data/ products from other centers » Small R&D » Some partnerships as junior members

TABLE 10. (continued)

LEVEL OF SERVICE	WEATHER SERVICES	CLIMATE SERVICES	HYDROLOGY SERVICES	DESCRIPTION OF CAPACITY NEEDED TO MEET SERVICE LEVEL
Category 3 – Full	» Specialized weather products for wide range of sectors » Well-integrated into DRR communities and mature links with media	» Specialized climate products » Decadal climate prediction » Long-term climate projections	» Seasonal stream flow outlooks » Specialized hydrology products	» Advanced observation equipment » Runs own NWP suite » R&D » Well-educated/trained staff » Own training group » Developed library and information services » Active partnerships with NMHS taking a leading role
Category 4 – Advanced	» Customized weather products » Weather application tools	» Customized climate products » Climate application tools	» Customized hydrology products » Hydrology application tools	» Advanced observations » Leading R&D » Well-developed ETR

Source: WMO (2015).

Based on the data collected in and the discussions and consultations with ECOWAS member states, the service level of the weather services, climate services and hydrology services was categorized (table 11). This categorization was validated by the NMHS in a regional meeting in February 2020 in Dakar, Senegal. In general, the weather and climate services are essential in nine countries, basic in three countries and advanced or full in three countries. The hydrological services show a weaker level of service, where seven countries have basic services, five essential services and just one country full services (two countries report not having a dedicated hydrological service: Cabo Verde and Guinea Bissau). A country-by-country comparison indicates that Guinea Bissau, Liberia and Sierra Leone have basic weather, climate and hydrology services. Nigeria, Ghana and Senegal have "full" weather and climate services, and Nigeria has advanced services and full "hydrological" services.

TABLE 11. Categorization of National Meteorological and Hydrological Services in the provision of weather, climate and hydrological services

COUNTRIES	WEATHER SERVICES	CLIMATE SERVICES	HYDROLOGY SERVICES
Benin	Essential	Essential	Essential
Burkina Faso	Essential	Essential	Basic
Cabo Verde	Essential	Essential	n/a
Cote d'Ivoire	Essential	Essential	Basic
The Gambia	Essential	Essential	Basic
Ghana	Full	Full	Essential
Guinea	Essential	Essential	Basic
Guinea Bissau	Basic	Basic	n/a
Liberia	Basic	Basic	Basic
Mali	Essential	Essential	Basic*
Niger	Essential	Essential	Essential
Nigeria	Advanced/Full*	Advanced/Full*	Full
Senegal	Full	Full	Essential
Sierra Leone	Basic	Basic	Basic
Togo	Essential	Essential	Essential

* To be confirmed

Village de Dougri Noogo, Province du Lorum, Titao, Repiquage du riz par une femme de la localite, Sept 2019, Burkina Faso

CHAPTER 5

Programmatic Approach for Modernizing Hydromet Services

The analysis highlighted in the previous chapters the strategic importance of hydromet and early warning services for West Africa. The current service level of the region's NMHS leaves for most countries substantial gaps to respond to the growing demand of adequate services based on sound observations. At the global level, the WMO has launched the Systematic Observations Financing Facility to support countries in generating and exchanging basic observational data based on the Global Basic Observing Network (WMO, 2020). In line with these global initiatives, a programmatic approach for modernizing hydromet services in the ECOWAS region has been formulated. This chapter highlights the programmatic approach for modernizing hydromet services in West Africa, defines objectives, outcomes and output and makes recommendations for its implementations.

5.1 Proposed Objectives and Outcomes of the ECOWAS Hydromet Initiative

The ECOWAS Hydromet Initiative is a comprehensive program addressing the modernization of hydromet services in West Africa, ensuring programmatic support along the entire hydromet value chain from observations to service improvements. Experience from previous projects shows that hydromet projects should address the entire hydromet value chain, be sizable enough to have a transformative and sustainable impact and support the necessary institutional reforms. Acknowledging the complexity of large projects and programs, the diversity of the member states in terms of modernization needs and recognizing different opportunities for financing of hydromet services (from the perspective governments, hydromet services, donors and the private sector), the formulation of a commonly agreed set of objectives and outcomes, a common framework for monitoring and evaluation as well as a coherent approach and strategy on policies and regional collaboration have been formulated. As such the ECOWAS Hydromet Initiative invites partners at the national, regional and global level to contribute to this initiative.

The objective of the ECOWAS Hydromet Initiative is to strengthen national and regional hydromet services in West Africa to reduce the disaster and climate risks of countries, communities and businesses.

The vision is that by 2025 (and in an extended timeframe until 2030) all hydromet and early warning services in the ECOWAS region have improved their service level to essential or have improved (or maintained) their service level by one category. Regional Climate Centers have sustained and modernized their operation providing adequate services to the countries, communities and businesses in West Africa. A regional policy framework ensures that information and data are adequately exchanged and that countries and Regional Climate Centers collaborate on hydromet and early warning services in areas of mutual interest.

This chapter describes the expected outcomes of the ECOWAS Hydromet Initiative based on the following building blocks: (a) addressing capacity building and institutional reforms, (b) aiming at the modernization of the network, observation equipment and ICT capacity and (c) strengthening service delivery and providing support to communities to ensure that hydromet services are widely adapted and used.

5.1.1 Outcome 1: Institutions are strengthened to provide efficient hydromet and early warning services

Activities related to outcome 1 aim at strengthening the capacity of national and regional hydromet services, with adequate governance structures, capacity building as well as information and data sharing. NMHS would be supported to strengthen their collaboration with the private sector, for example by strengthening frameworks for public-private engagement and seizing opportunities for private sector

involvement with the aim to assist countries with a better service provision. Activities would be grouped along three (sub-)outcomes:

Outcome 1.a: National Hydromet and Early Warning Services have an adequate governance structure in place that supports effective operation, maintenance and service delivery. Activities supporting this outcome would include, among other, institutional audits and support to services to become administratively and financially more sustainable. This, may include, for example, the formulation of a concept of operations, building upon earlier completed work under the Global Framework for Climate Services (GFCS). Ten out of 15 countries have so far established National Frameworks for Climate Services (NFCS). With regard to public-private engagement, some countries, such as Ghana, have initiated a relevant policy framework that facilitates the collaboration with the private sector or public-private engagement. Under this outcome, countries may be supported to strengthen their policy framework for public-private engagement. In addition, notably Guinea Bissau and Liberia and other countries with NHS categorized as "basic" may need additional support for renovating and in some cases constructing new buildings for the operation of the services.

Outcome 1.b: National Hydromet and Early Warning Services have adequate human resources and capacity that supports effective operation, maintenance and service delivery. Activities supporting this outcome include degree and short-term training. Training activities would be conducted largely through the Regional Climate Centers and training centers: AGRHYMET, ACMAD, African School for Meteorology and Civil Aviation (EAMAC) and WASCAL. Training may include basic meteorology, forecasting, remote sensing and satellite applications, severe weather forecasting (including the use of WMO Severe Weather Forecasting model and global and regional specialized centers), hydrology and flood modeling, maintenance and operation of observation equipment, information and communication technology, database management, data processing, quality control and analysis, geographical information systems and remote sensing.

Outcome 1.c: Information among regional centers and NMHS is efficiently used and shared. Activities supporting this outcome will include coordination activities among regional entities and National Hydromet and Early Warning Services, development of joint products and services (for example, regional severe weather forecasting) as well as the implementation of data-sharing arrangements. The support to data-sharing arrangements may include the extension of the existing data-sharing arrangements that are, for example, available between CILSS countries and CILSS and its AGRHYMET regional center, but also regional efforts and support to enhance the data exchange in the context of the Global Basic Observing Network.

5.1.2 Outcome 2: Hydrological and meteorological information is effectively observed, analyzed and managed

Activities related to outcome 2 largely support the enhancement and modernization of the observation network and ensure that observed data are analyzed, managed and shared for the relevant applications. Activities would be grouped along three (sub-)outcomes:

Outcome 2.a: Observation networks are enhanced and modernized. Activities will focus on strengthening (rehabilitating stations, addressing critical observation gaps) and modernizing (automizing, enabling real-time data transmission through cell phone network) the meteorological observation network (automatic weather stations, rain gauges, standard equipment), agrometeorological network, hydrological observation network [updating rating curves, enabling telemetry, calibrating instrumentation and equipment, procuring new equipment (for example, acoustic Doppler current profiler, bathymetric instruments, sediment measurement instruments and current meters)]. The investments related to the modernization of the observation network should be proportional to the capacity of the National Hydromet Services for its operation and maintenance and should be done in phases. In addition, countries like Guinea Bissau, Liberia and Sierra Leone may initially require investments to establish a basic operational network of synoptic stations and agrometeorological stations as well as the required transmission of data through the cell phone network and related server and data management capacity. Where necessary, spare parts will be procured for weather radars with the aim to reactivate parts of the weather radar network in West Africa.

Together with the extension of the existing lightning detection networks in the ECOWAS region, it aims to enable the use of "proxy-radars" in the region (notably lightning technologies). In several countries, more advanced monitoring networks would be supported, including air quality monitoring, upper air stations/radiosonde stations and marine stations. Air quality monitoring is of growing relevance for the urban centers with concentrations of industrial, household and traffic-related air pollution and the consequent impacts on health and well-being of its inhabitants. As few existing radiosondes are operating, the aim would be to have, at least, the countries with advanced service level to operate some of the radiosondes with the required two readings per day. In this context, not only the generation of data but also the sharing and accessibility of observed data will be important. Where necessary, countries will be supported to exchange basic observational data based on the Global Basic Observing Network (GBON). Lastly, focus would be on strengthening the operation and management capacity of the NMHS.

Outcome 2.b: ICT systems, database management and forecasting capacity are modernized. Activities will support the modernization of the ICT infrastructure, allowing the efficient management of data, its exchange between different institutions at the national level and, where possible, the integration of external data. An ICT system that is well-integrated and covers the relevant databases for hydrological, meteorological and climate data management should be established where this is not yet in place. Access to global production centers resources requires reliable internet access. In some of the countries with basic service levels and limited internet accessibility, the focus would be on establishing the facilities for adequate internet access. Concretely, the supported activities include the installation of geographical information system labs, work stations, installation of computers and software for numerical weather prediction, hydrological forecasting and user applications. Notably, with regard to data analysis, numerical weather prediction and hydrological modeling, a set of activities would be supported to strengthen the data-processing capacity (servers, internet access, cloud computing facilities, satellite data receivers, networking and electricity back-up) that go hand in hand with providing access to the relevant software application combined with training on the latest models and software applications.

Outcome 2.c: Regional entities are adequately equipped to provide hydromet and early warning services. Activities would focus on the Regional Climate Centers, technical centers and river basin organizations to allow them to have better data management ICT facilities (in some cases high performing computers) to have adequate processing capacity for seasonal climate outlooks, severe weather forecasting and guidance on flood and drought forecasting.

5.1.3 Outcome 3: Communities and businesses receive adequate hydromet information and early warning

Activities related to outcome 3 support mainly the development of sector-specific service applications while strengthening existing early warning systems and services. Activities would be grouped along three (sub-)outcomes:

Outcome 3.a: Flood and drought forecasting and early warning are improved, accessible and widely disseminated. Activities would focus on improving the lead-time and accuracy of severe weather and climate forecasts and outlooks as well as flood monitoring and forecasting. Activities include the improvement of numerical weather prediction and flood modeling and forecasting for major river basins and cities and urban agglomerations, such as Abidjan, Accra, Lomé, Cotonou and Lagos. Activities also include the engagement of the end-user community and implementing training activities (for example, workshops and round tables). Of relevance will be impact-based forecasting that would link forecasting directly to guidance on potential impacts. A particular focus would thereby be on ensuring the last mile connection to vulnerable communities, notably through improving communication and warning applications targeted to women, youth and vulnerable communities.

Outcome 3.b: Sector-specific services are provided to climate sensitive sectors of the economy. Activities will support the establishment of sector-specific applications, notably related to agriculture, by enabling applications for specific commercial crops (for example, cotton and cacao) as well as local farming communities. Other sector specific applications relate to health, energy,

transport and water resources management. This would build upon the ongoing experience in the aviation sector and include new partnerships with private sector operators, such as regional airlines. In countries where ASECNA has the responsibility for aviation meteorology, it is assumed that investments in sector-specific services for aviation may not be required. For the hydrological services, sector-specific needs would include integrated water resources management plans and sector-specific strategies (for example for hydropower and dam operations). Public-private collaboration may play an important role for the development of specific applications and is becoming increasingly important in West Africa, where several applications are already being tested. An example is the collaboration with cell-phone operators to use the cell phone tower signal attenuation for mapping rainfall through the *Raincell* project. Others include examples of collaboration with the agriculture sector, mining, hydropower operators and the insurance industry. Activities will thus support countries to explore and develop business cases for public-private collaboration to strengthen and sustain the service provision and maximize socioeconomic benefits.

Outcome 3.c: Regional Climate Centers provide adequate services to member states. Building upon the experience in seasonal climate outlooks and forecasting as well as on the harmonized framework for food security, activities will support regional entities in providing adequate services to member states, and, where appropriate, directly to communities and businesses.

5.1.4 Outcome 4: Research is integrated and coordinated across the region

Under outcome 4 activities will focus on strengthening the applied research capacity of both Regional Climate Centers as well as some of the countries with advanced service levels.

Outcome 4.a: National Meteorological and Hydrological Services and Early Warning Systems are continuously improved through applied research and partnerships with the academic sector. Activities summarize support for applied research in meteorology, climatology and hydrology. This would for example include support for downscaling relevant climate models and linking National Hydromet Services to regional and global research programs. Support for research-related programs would be particularly relevant for the most advanced NMHS in the region, namely Ghana, Nigeria and Senegal. More active engagement with the academic sector and academic networks in the region, such as the West Africa Science Service Center on Climate Change and Adapted Land Use (WASCAL), would be needed as well.

Outcome 4.b: Hydromet and early warning services are continuously improved through applied research at regional level. In addition, the gap between research at universities and WASCAL and application centers such as NMHS, ACMAD and AGRHYMET has been narrowed. This includes the improvement of hydromet forecasting and modeling systems.

5.1.5 Outcome 5: The status of hydromet services is actively monitored

Activities under outcome 5 focus on the coordination of activities in the region and regional monitoring that allows joint coordination and tracking of activities at the regional level.

Outcome 5.a. The coordination, monitoring and evaluation of ongoing initiatives related to hydromet services are strengthened. ECOWAS will be supported in the coordination to monitor ongoing actions and to keep track of achievements. Ongoing initiatives and achievements will be evaluated each year. An update of the categorization of each service (weather, climate and hydrology) will be established and investment plans updated. In addition, this will ensure that investment priorities are tracked, and resources are mobilized and available for the implementation of the initiative.

5.2 Summary of Country Investment Needs

Based on the surveys conducted and discussions with all NMHS of the ECOWAS member states and considering available cost estimates from projects in West Africa, investment needs were estimated for countries and regional organizations along the proposed outcomes. It is important to note that these are order of magnitude estimations, whereas concrete investment planning at country and regional level would provide more concrete information on the investment needs considering preferences, investment opportunities and constraints.

The investment needs are estimated at $324.5 million, supporting interventions in member states and at the regional level with the aim to gradually improve and sustain service levels. The investment needs include $290 million for the member states and $34.5 million in support of regional institutions.

The country-level investments are largely based on the self-defined needs of the country and guidance related to the service level of the countries' climatological, hydrological and meteorological services. For example, Guinea Bissau, Liberia and Sierra Leone were categorized as having a "basic" service level so that the focus of their activities would be on fundamental institutional strengthening, establishing basic observation and ICT network, renovation of buildings and establishment of essential early warning services. On the other end of the range, Ghana, Nigeria and Senegal have the most advanced service levels. They already have well-established services and would thus need to focus on complementing observation networks (including spare parts for its existing radar observation network) and reinforcing services for climate-sensitive sectors of the economy. While Cabo Verde has a well-established NMS, it has no specific service responsible for surface water hydrology. Likewise, the country also requires a storm tracking capability through the deployment of marine stations in the waters surrounding the islands.

For the estimation of country-level investments, not only have the country level needs been considered but also the capacity of the governments to sustain the investments and cover the expenses for operation and maintenance. In addition to the specific self-defined needs of the countries, additional criteria were considered, notably: (a) categorization of hydrological services; (b) national services' responsibility for aviation meteorology; (c) need for marine services as a coastal country; (d) relevance of agriculture for livelihoods and the economy; and (e) income level of the country. These key criteria are summarized in table 12.

TABLE 12. Country categorization and background on hydromet services and beneficiary needs

COUNTRY	INCOME LEVEL*	CATEGORIZATION OF HYDROMET SERVICES			RELEVANCE OF BENEFICIARY SERVICES		
		Climatology	*Meteorology*	*Hydrology*	*Coastal/ Landlocked*	*Aviation Services*	*Employment in Agriculture (%)*
Benin	Low	Essential	Essential	Essential	Coastal	ASECNA	41.9 %
Burkina Faso	Low	Essential	Essential	Basic	Landlocked	ASECNA	29.6 %
Cabo Verde	Lower middle	Essential	Essential	–	Coastal	National	13.8 %
Cote d'Ivoire	Lower middle	Essential	Essential	Basic	Coastal	ASECNA	48.2 %
The Gambia	Low	Essential	Essential	Basic	Coastal	National	29.9 %
Ghana	Lower middle	Full	Full	Essential	Coastal	National	35.7 %
Guinea	Low	Essential	Essential	Basic	Coastal	National	67.4 %
Guinea Bissau	Low	Basic	Basic	–	Coastal	ASECNA	68.6 %
Liberia	Low	Basic	Basic	Basic	Coastal	National	46.1 %
Mali	Low	Essential	Essential	Basic	Landlocked	ASECNA	65.2 %
Niger	Low	Essential	Essential	Essential	Landlocked	ASECNA	76.1 %
Nigeria	Lower middle	Advanced/ Full	Advanced/ Full	Full	Coastal	National	37.0 %
Senegal	Lower middle	Full	Full	Essential	Coastal	ASECNA	33.1 %
Sierra Leone	Low	Basic	Basic	Basic	Coastal	National	59.0 %
Togo	Low	Essential	Essential	Essential	Coastal	ASECNA	35.3 %

* World Bank (2019).

The investment needs are disaggregated by country and outcome and presented in the table 13. At the country level, investments range from $11 million for Guinea Bissau to about $44 million for Nigeria. For outcome 1, investments would cover $56 million in support of institutional strengthening, including developing guidance on the regulatory frameworks and governance of the NMHS, reinforcing the operational capacity and building human resource capacity. For outcome 2, investments would cover $77 million for establishing and modernizing the observation network. A large part of the investments, in total $127 million, would be required for strengthening the provision of services to different sectors of the economy and for establishing early warning related products. Lastly, $11 million would be required for applied research, academic networking and linking science with practical applications in weather, climate and water services.

The estimation of investment needs does not yet include investment projects, which are planned or have recently been launched, such as the Strengthening Climate Resilience in Mali Project. The total investment needs may, thus, change once those investments have been included.

TABLE 13. Estimated investment needs by country and outcome

COUNTRY	TOTAL ($)	Institutions and Training		Observation and ICT Equipment		Early Warning Services and Services		Research	Monitoring & Evaluation, Project Management
		1.a ($)	1.b ($)	2.a ($)	2.b ($)	3.a ($)	3.b ($)	4 ($)	5 ($)
Benin	17,333,000	2,070,000	1,035,000	4,344,000	850,000	3,800,000	3,600,000	500,000	1,134,000
Burkina Faso	19,303,000	2,790,000	1,260,000	4,060,000	830,000	5,900,000	2,700,000	500,000	1,263,000
Cabo Verde	13,195,000	1,220,000	1,035,000	3,446,000	830,000	2,800,000	2,500,000	500,000	864,000
Cote d'Ivoire	21,825,000	2,790,000	1,665,000	4,912,000	830,000	5,800,000	3,900,000	500,000	1,428,000
The Gambia	14,488,000	2,760,000	2,070,000	2,180,000	830,000	2,800,000	2,400,000	500,000	948,000
Ghana	23,636,000	1,320,000	2,070,000	4,050,000	650,000	7,100,000	5,400,000	1,500,000	1,546,000
Guinea	17,548,000	2,840,000	1,260,000	3,470,000	830,000	4,300,000	3,200,000	500,000	1,148,000
Guinea Bissau	11,134,000	2,200,000	1,620,000	1,775,000	810,000	2,400,000	1,600,000	–	729,000
Liberia	14,332,000	3,500,000	810,000	1,874,000	810,000	4,000,000	2,400,000	–	938,000
Mali	19,783,000	2,840,000	810,000	4,309,000	830,000	6,900,000	2,300,000	500,000	1,294,000
Niger	19,652,000	2,120,000	1,035,000	4,261,000	850,000	6,900,000	2,700,000	500,000	1,286,000
Nigeria	44,420,000	1,240,000	2,880,000	14,254,000	540,000	11,400,000	8,200,000	3,000,000	2,906,000
Senegal	21,872,000	1,320,000	1,440,000	7,031,000	650,000	4,100,000	4,400,000	1,500,000	1,431,000
Sierra Leone	15,029,000	3,350,000	1,035,000	2,851,000	810,000	3,600,000	2,400,000	–	983,000
Togo	16,066,000	2,750,000	810,000	2,605,000	850,000	4,300,000	3,200,000	500,000	1,051,000
TOTAL	**289,616,000**	**35,110,000**	**20,835,000**	**65,422,000**	**11,800,000**	**76,100,000**	**50,900,000**	**10,500,000**	**18,949,000**

* Estimated at 7 percent.

5.3 Summary of Regional Investment Needs

Regional-level investments summarize actions in support of Regional Climate Centers, research centers and river basin organizations, enabling the provision of robust hydromet services to the ECOWAS region. Investments at the regional level contribute to the same outcomes as the proposed investments at the national level and are summarized in table 14. A large part of the resources would be required for institutional strengthening, which includes support for strengthening governance arrangements, including guidance and support for cost recovery and arrear clearances of member state contributions to AGRHYMET, ACMAD and other membership-based organizations. For AGRHYMET, ACMAD and WASCAL investments under outcome 1.3 would also include resources to facilitate short- and long-term training programs for experts from member states. Investments under outcome 3.3 would facilitate feasibility studies and piloting shared products and services, for example, to extend and sustain the Regional Climate Outlook Forums, severe weather forecasting and shared marine services or the establishment of a regionally managed network of radars. The operational climate centers in the region (AGRHYMET, ACMAD and RSMC Dakar) would be supported to improve their ICT infrastructure and data management capacity and service delivery capacity to enable service provision to member countries. The five river basin organizations in West Africa (LCBC, NBA, OMVG, OMVS and VBA) would require resources to sustain and extend river basin observatories, facilitate data exchange and support member states with forecasting of floods and water levels in the basins. Investments under outcome 4 support regional climate research initiatives and are matched with investments at the national level. This would particularly benefit WASCAL, AGRHYMET and ACMAD to support applied research, for example, on downscaling climate models for West Africa. Lastly, ECOWAS would facilitate coordination, harmonization of policies as well as monitoring and evaluation.

TABLE 14. Regional investments

COUNTRY	INSTITUTIONAL STRENGTHENING Outcome 1.3	OBSERVATION AND ICT Outcome 2.3	EWS AND SERVICES Outcome 3.3	RESEARCH Outcome 4.2	COORDINATION, MONITORING & EVALUATION Outcome 5	TOTAL
ECOWAS	1,000,000				3,000,000	4,000,000
AGRHYMET	4,000,000	2,000,000	2,000,000	1,000,000		9,000,000
ACMAD	2,500,000	2,000,000	1,000,000	1,000,000		6,500,000
RSMC Dakar*	500,000	2,000,000	2,000,000			4,500,000
ASECNA	500,000		1,000,000			1,500,000
RBO**	500,000	500,000	2,000,000	1,000,000		4,000,000
WASCAL	2,500,000			2,500,000		5,000,000
TOTAL	11,500,000	6,500,000	8,000,000	5,500,000	3,000,000	34,500,000

* Regional Specialized Meteorological Center.
** River Basin Organizations (LCBC, NBA, OMVG, OMVS and VBA).

5.4 Estimating Operation, Maintenance and Staffing Needs

Hydromet services are an important public good function and, in most countries, supported by the government or through public-private partnership arrangements. The proposed investments in strengthening hydromet and early warning services require sufficient operation, maintenance and personnel. For example, the number of meteorological forecasters working 24/7/365 depends on the number of desks-to-staff per shift. The optimum number is seven per

desk. This number considers annual leaves, sick leaves and training absences. Five staff per desk is the strict minimum, imposing a restriction of staff member absences, training, overload and/or increase overtime costs. As an example, Togo currently has four forecasters at DGMN, who are doing frequent forecast. To ensure a 24/7/365 operation of the forecasting system and services, at least 12 staff would be required on a three-shift rotation. This means that an additional eight meteorological forecasters should be recruited and tasked for the analysis of data sets from land, sea, air, NWP and remote sensing. Many other countries in the region face a similar situation. In addition, many of the existing staff in the National Hydromet Services are close to retirement in the coming years, leaving a substantial gap of expertise in some of the countries. Still a clear estimation of the staffing needs to ensure and sustain the operation of the National Hydromet Services is difficult to estimate.

Table 15 summarizes the self-estimation of the NMHS for recruiting additional required staff. While financial and technical partners can support to

TABLE 15. NMHS self-estimation of staffing needs by 2025 (extended timeframe until 2030)

	National Meteorological Service				National Hydrological Service				Hydromet Services	
	All Staff	Only Fore-casters	All Staff	Only Fore-casters	All Staff	Only Hydro-logists	All Staff	Only Hydro-logists	All Staff	Both Forecasters and Hydrologists
COUNTRY	2020		2025*		2020		2025 (self-estimation of add. staffing needs)		2020	2025 (self)
Benin	67	11	63	10	8	3	0	0	75	10
Burkina Faso	58	27	0	0	14	2	48	15	72	15
Cabo Verde	108	13	43	9	n/a	n/a	n/a	n/a	108	9
Cote d'Ivoire	112	16	52	7	16	2	52	8	128	15
The Gambia	66	13	57	10	30	8	56	10	96	20
Ghana	362	45	60	30	60	7	74	15	422	45
Guinea	178	61	145	40	182	57	50	15	360	55
Guinea Bissau	47	12	36	6	8	3	19	4	55	10
Liberia	27	3	0	9**	48	2	11	0	75	9
Mali	84	19	13	2	36	3	28	5	120	7
Niger	138	10	27	5	25	18	0	0	163	5
Nigeria	1,713	591	0	0	260	76	232	96	1,973	96
Senegal	122	28	0	0	71	4	0	0	193	0
Sierra Leone	48	1	73	12	4	1	21	3	52	15
Togo	93	7	45	7	4	1	34	2	97	9
TOTAL	**3,223**	**857**	**614**	**147**	**766**	**187**	**625**	**173**	**3,989**	**320**

* Self-estimation of additional staffing need.
** No self-estimation reported; nine additional forecasters would be required to meet the minimum of 12 forecasters.

some extent the training of forecasters, hydrologists and early warning specialists, the annual salaries would need to be taken up by the respective NMHS and thus governments. The self-reporting from the National Hydromet Services indicates nearly 4,000 staff working for the hydromet services in the region, of which about 857 meteorological forecasters and 187 hydrologists. Based on self-estimations and not taking budget constraints into account, the National Hydromet Services estimate that the recruitment of an additional 1,240 staff would be required for the time horizon 2025 and the extended time horizon until 2030. Nevertheless, if only the recruitment needs of meteorological forecasters and hydrologists are considered, an estimated 320 additional staff would be required to join the services in that time frame. Collaboration with the private sector or public-private collaboration as well as with universities and research institutes may present an opportunity to attract and sustain talent in the national hydromet community.

The annual operation and maintenance budget in Table 16 is here estimated at 10 percent of the investment costs for the hydromet observation, vehicles and ICT equipment (except for radar spare parts and upper air stations for which the operation and maintenance budget has already been considered). In total, more than $10.4 million would be required per year for the entire ECOWAS region. In short, the operation and maintenance costs and additional staffing costs can be substantial and should be worked out in more detail to ensure that any proposed investments can at the end also be sustained. It is important to note that the analysis of socioeconomic benefits and costs has not considered the existing and additional staffing costs.

TABLE 16. Operation and maintenance budget estimations plus additional personnel to be recruited

COUNTRY	ESTIMATED ANNUAL OPERATION AND MAINTENANCE BUDGET REQUIREMENTS ($)
Benin	636,000
Burkina Faso	653,000
Cabo Verde	537,000
Cote d'Ivoire	772,000
The Gambia	421,000
Ghana	795,000
Guinea	623,000
Guinea Bissau	401,000
Liberia	499,000
Mali	696,000
Niger	693,000
Nigeria	1,591,000
Senegal	911,000
Sierra Leone	580,000
Togo	599,000
TOTAL	**$10,407,000**

Analysis of groundwater information in Burkina Faso, World Bank, 2013 (Jean Baptiste Migraine, World Bank. 2013)

CHAPTER 6

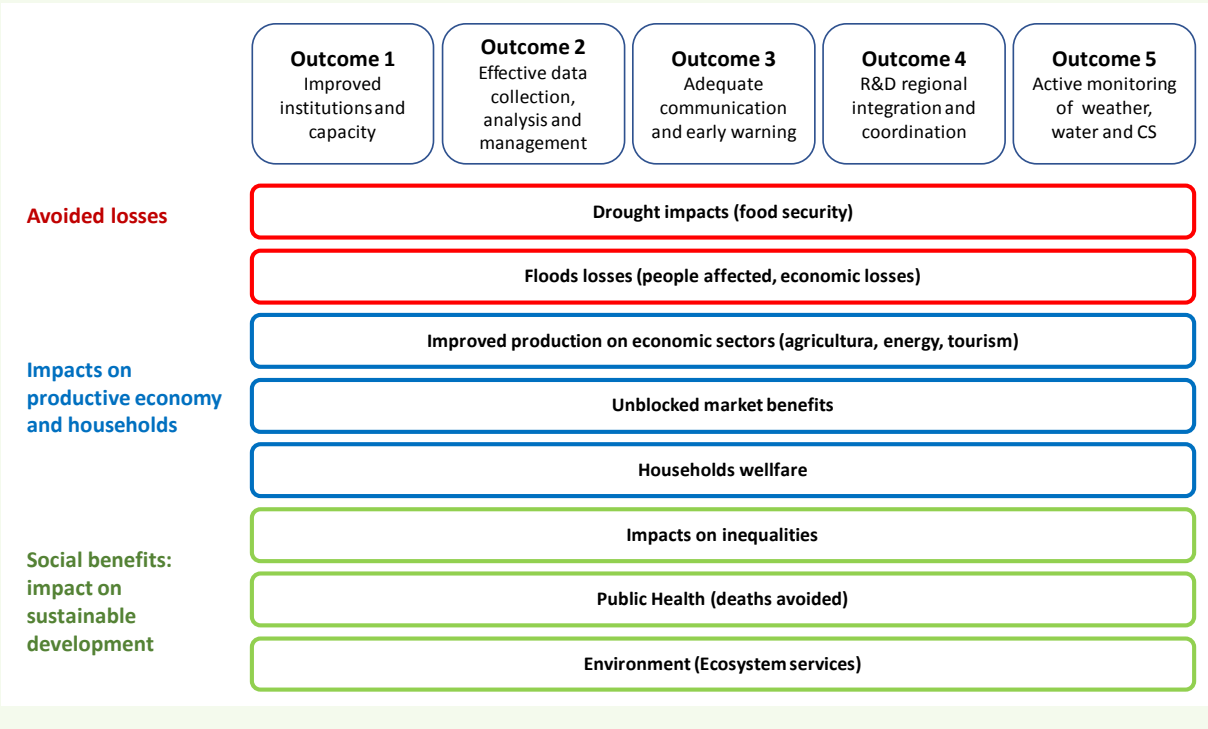
Analyzing Sustainability, Costs and Benefits of Investments

The importance of hydromet and early warning services for the economy and livelihoods in West Africa is highlighted at the beginning of the report. In this chapter, the economic benefit from the proposed investments under the ECOWAS Hydromet Initiative are identified and the financial and economic viability of the proposed investments is determined in a socioeconomic benefit analysis.

The socioeconomic benefit analysis aims to quantify the benefits from strengthening and modernizing hydromet services by conducting simulations on the potential benefit and estimating key financial indicators such as benefit-cost ratio and net present value of the proposed investments. The analysis will provide decision-makers with estimations on the benefits derived from the different aspects of the ECOWAS Hydromet Initiative, including those aspects not directly productive but socially desirable and with an indirect impact on the region economy and development.

Since hydromet information is critical to a very large number of sectors and generally accrues benefits to society (table 1), the economic consequences are complex to analyze. Therefore, the proposed evaluation focuses on concrete impacts related to the five proposed outcomes of the ECOWAS Hydromet Initiative. Figure 7 summarizes the proposed framework for the economic analysis, linked to the main affected sectors and some specific impacts.

FIGURE 7. Proposed framework for economic analysis



On the one hand, direct economic impacts affect productive sectors, such as agriculture, energy and tourism, and can be measured through market information. On the other hand, other impacts, such as deaths avoided, general societal welfare, fewer inequalities and improved health, can also generate economic value even if they are not based on an economic activity. Therefore, market and contingent valuation information were combined for the proposed economic analysis. In addition, qualitative information will be needed for a complete picture of all benefits.

6.1 Methodology for the Socioeconomic Analysis

Table 17 outlines the methods applied to evaluate each of the potential benefits. The evaluation is not intended to provide an analysis of all the areas where hydromet information could be beneficial, but rather to focus on four key areas where we can carry out quantitative analysis: (a) development of early warning systems for floods risk management and its impact on avoided damages, such as building and infrastructure damages; (b) a better characterization of seasonal drought information and its impact on crop production; (c) capacity-building efforts oriented to hydromet services and their impact on productive sectors, such as agriculture and energy; and (d) a general improvement of weather monitoring and forecasting and its impact on general public decisions.

TABLE 17. Methods and databases for analyzing quantitative benefits

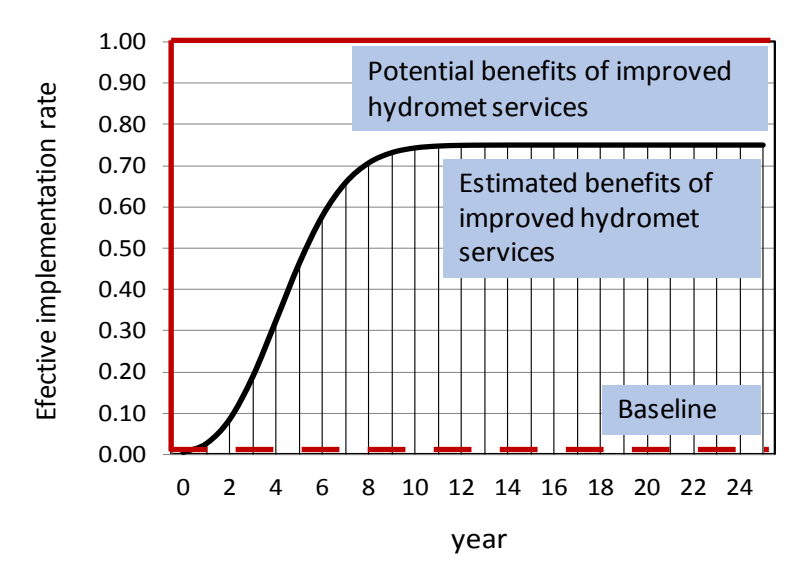
POTENTIAL BENEFITS	INDICATORS TO ANALYSE	PROPOSED METHOD	DATA
Reduction of flood damages	Analysis of frequency of flood events in the countries, average losses per affected person and damage reduction ratio due to improvements in disaster risk management	Avoided damages	EMDAT, Desinventar, PDNAs
Reduction of drought impacts	Drought impacts on crop production	Cost–loss model (improved water management)	EMDAT, SPI[20], FAO
Improved economic production (agriculture, energy, tourism)	Change in productivity	Production functions (estimated elasticity)	FAO, World Bank,
Unblocked market benefits	Change in GDP	Computabile general equilibrium model	GTAP global database
Household welfare	Change in Willingness to Pay (WTP)	Transfer knowledge (similar regions)	Literature review
Reduction of disaster derived mortality	Deaths due to climate impacts	Qualitative assessment	EMDAT

[20] Standard Precipitation Index calculations in Kamali et al (2019

Different analysts, countries and agencies have different views on the correct discount rate to use for the cost-benefit analysis. Zhuang et al. (2007) studied discount rates used for public projects around the world and found rates from 2 to 15 percent, with lower rates more common in developed countries and higher rates more common in developing countries. The World Bank provides discount rate guidance in its *Handbook on Economic Analysis of Investment Operations* (Belli et al. 2001), noting that it has traditionally applied discount rates in the 10 to 12 percent range. Other major multilateral development banks also tend to use rates in this range (Zhuang et al. 2007). WMO (2015a) provides a more detailed discussion of the choice of discount rates. In this analysis, a 12 percent rate of discount as an upper bound and then conduct sensitivity analysis using a lower bound of 3 percent.

The benefits of any such project would presumably last much longer; therefore, a 25-year analysis period was chosen to develop the aggregated estimates. With a higher discount rate (for example, 12 percent), benefits more than a couple decades out have minimal present value. The maximum effectiveness rate of the investments is not achieved in a linear trend, but a path of accumulating improvements has been defined (up to 75 percent at the end of the period). Figure 8 shows the effective implementation rate used in this study, based on a binomial cumulative function.

FIGURE 8. Effective implementation rate considered in this study



Benefit-cost analysis estimates were established using a 3 and 12 percent discount rate as lower and upper bounds and using the estimated annual benefits and costs as the baseline. Table 18 and Figure 9 summarize the results of the socioeconomic benefits calculations.

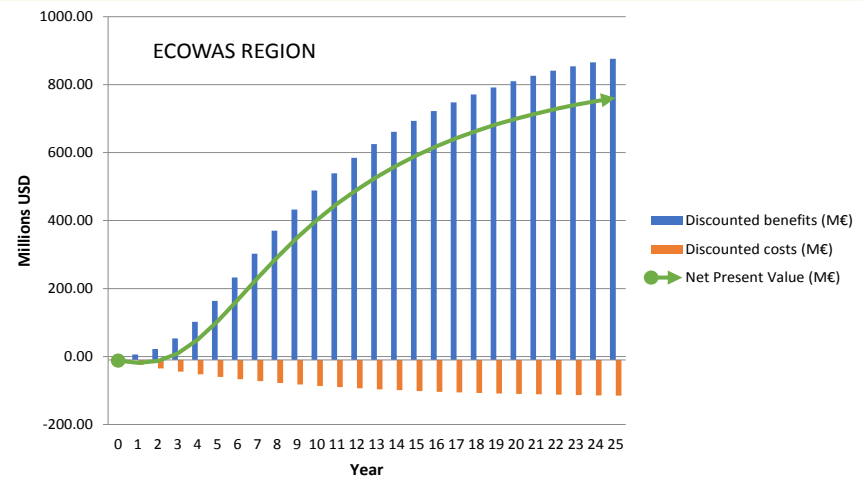
6.2 Conclusions of the Socioeconomic Analysis

The results of this analysis show that the contribution of hydrological and meteorological information to socioeconomic development in ECOWAS member states is expected to be very high, particularly due to the potential benefits for the increased productivity of agriculture and energy sectors and their contribution to GDP. Disasters related to water, especially floods, have played an important role in evaluating the improvement of hydrological and meteorological information. This study has not considered the numbers of deaths from an economic perspective, but only in terms of their social impacts. As this report has avoided valuing life in economic terms, the estimates presented can be considered conservative. The net present value of the expected benefits for ECOWAS ranges between $770 and $2,217 million, supporting the conclusion that hydromet information is critically important and that investments in the hydromet sector are expected to be highly profitable in the West African region.

TABLE 18. Baseline socioeconomic benefits for hydromet modernization in ECOWAS, actualized 25 years (%, $ millions)

	BENEFIT ESTIMATES *Actualized 25 years*		
DISCOUNT RATE (%)	**3.0%**	**7.0%**	**12.0%**
Flood-avoided damages	$900.00 million	$548.2 million	$324.3 million
Drought crop yield response	$485.75 million	$295.9 million	$175.1 million
GDP unblocked growth (agriculture, energy improved decisions)	$945.9 million	$576.1 million	$340.8 million
Willingness to Pay (WTP) for seasonal climate services	$124.3 million	$75.7 million	$44.8 million
Net Present Value (actualized 25 years)	$2,216.8 million	$1,331.6 million	$770.2 million

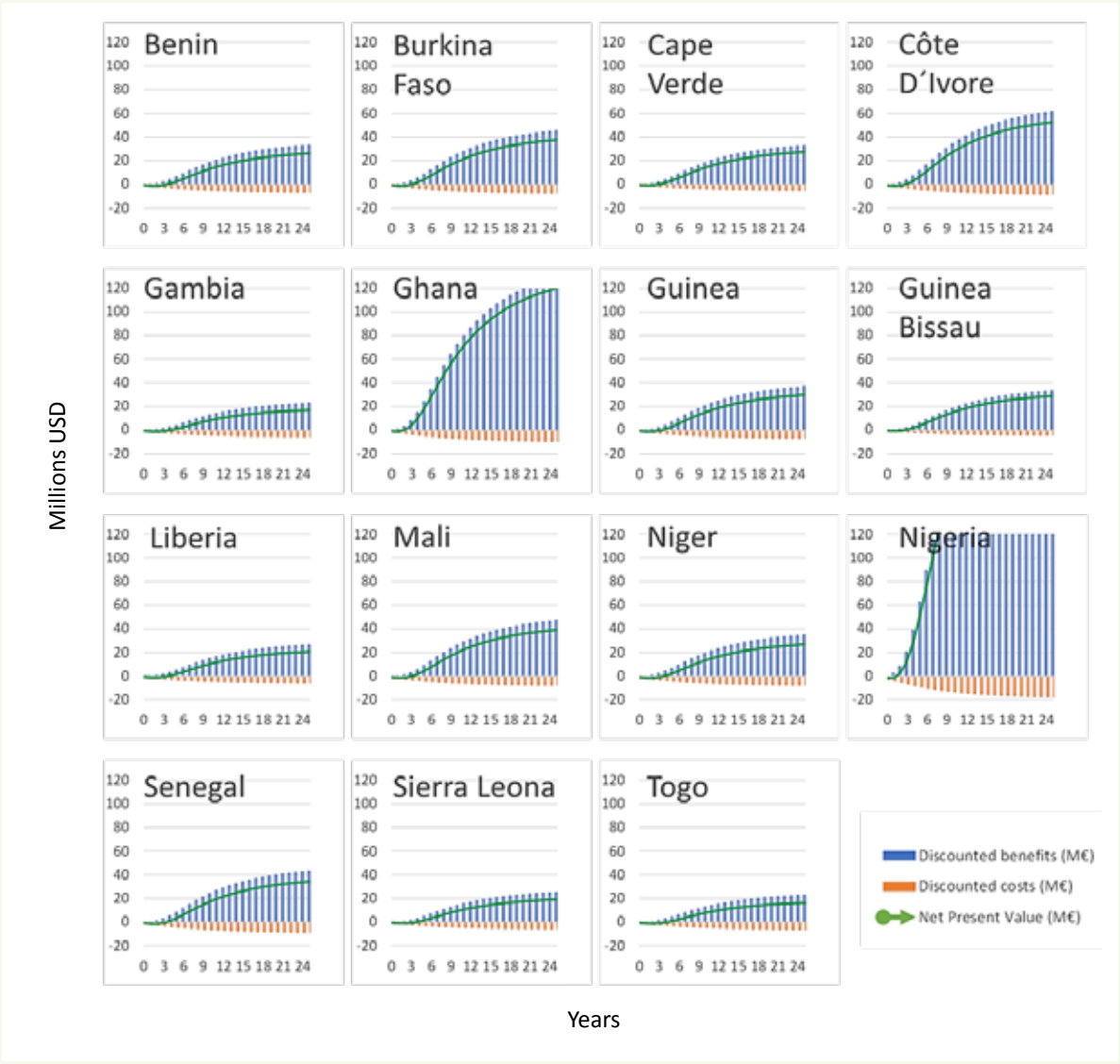
FIGURE 9. Discounted costs and socioeconomic benefits and net present value for hydromet modernization in ECOWAS



6.3 Regional Comparison

To provide insights on the regional distribution of the benefits, country level net present values (NPV) are presented in figure 10. For a clearer comparison of the countries in the region, the graphs are shown for the same range of values (fixed scale). In the ECOWAS region, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria and Senegal appear to have the greatest net benefits in the medium term from modernization of hydromet and early warning services. However, all countries in the region show significant potential since the investment seems to be recovered after three to four periods and the net present value of benefits is significant in all countries. Ghana, Guinea, Guinea Bissau, Liberia and Senegal have large potential benefits associated to flood-averted damages, while Burkina Faso and Niger gain more due to improved climate services dedicated to cope with drought. Nigeria has higher benefits associated to unblocked economic growth in the agriculture and energy sectors. Willingness to pay reflects the current structure of incomes in the ECOWAS region.

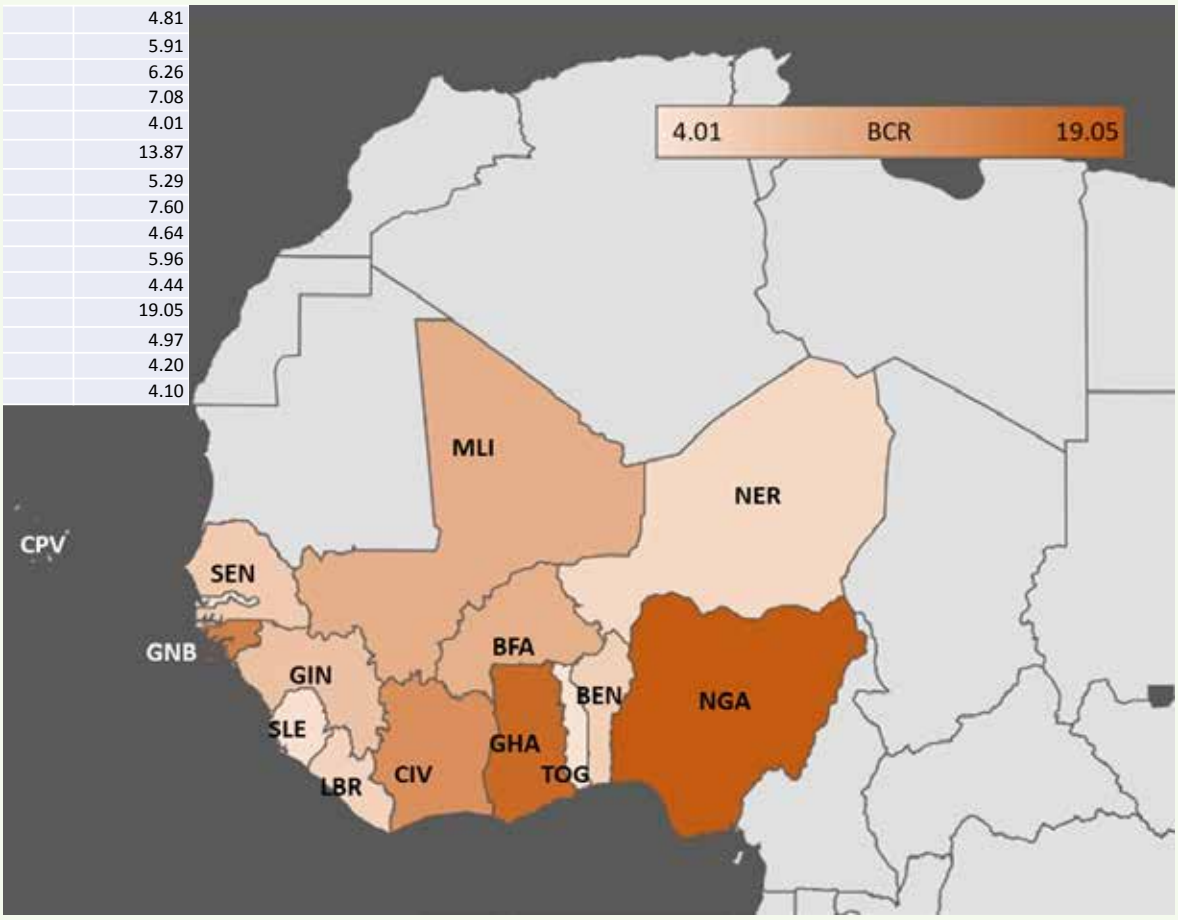
FIGURE 10. Discounted costs, socioeconomic benefits and net present values for hydromet modernization for ECOWAS countries (12 percent discount rate)[21]



[21] Source: Authors (2021).

Figure 11 shows estimated values of the benefit-cost ratio by ECOWAS member state (that is, the investment profitability). Nigeria and Ghana have the highest returns at around $19 and $14 of profitability for every $1 of investment, respectively. Burkina Faso, Cabo Verde, Côte d'Ivoire, Ghana, Guinea Bissau and Mali have above-average benefit-cost ratios, while the remaining countries have a very substantial $4 of profitability for every $1 of investment.

FIGURE 11. Benefit–cost ratio for Hydromet Services Improvement Initiative in ECOWAS region (country–level comparison)



CHAPTER 7

Conclusions and Recommendations

In recent years, many countries in West Africa have made substantial progress on the modernization of their hydromet and early warning services. Now, some West African countries are on a critical junction to sustain these services and to improve their delivery for a meaningful impact to communities and the economy. As such, the modernization of the region's hydromet services is feasible and an important contribution for the climate smart and resilient development of the ECOWAS region. From the analysis of the status of hydromet services, the identification of investment needs and the socioeconomic benefit analysis, the following conclusions can be drawn:

- The status and service level of the NMHS in the region is very diverse. Three NMS – Guinea Bissau, Liberia and Sierra Leone – have a basic service level, while Ghana, Nigeria and Senegal have an advanced or full service level. In general, the NHS are substantially weaker than the NMS. Only one NHS (Nigeria) has a full service level, whereas seven have a basic service level. This is also reflected in the lower staffing, lower operational budget and overall weaker observation network. Regarding the institutional arrangements, nine of the NMS are organized as an agency allowing some form of financial and managerial autonomy, whereas only two of the NHS are organized as agencies.
- Most NMS provide basic and essential weather and climate observations, including 1-to-3-day forecasts, services to the aviation sector (where applicable) and agrometeorological services. Most NHS provide basic services related to monitoring of surface conditions, notably water level monitoring. Nevertheless, basic services related to adapted and timely meteorological and hydrological forecast to support warning decisions for disaster risk reduction, as well as specialized services for specific producer groups (for example, commercial cotton farmers) or sectors of the economy (for example, hydro-power generation) are not yet widely available. As the socioeconomic benefit analysis highlighted, unblocking GDP growth, notably related to agriculture and energy production, contributes to about two-thirds of the estimated benefits of hydromet services (between $515 million and $1.4 billion over the lifespan of the investments).
- Critical gaps remain for last mile communication and coverage of the early warning systems in urban areas. While instruments, such as impact based forecasting, developing forecasting and early warning products based on user needs and adapted communication protocols have been tested in pilot projects, they are not yet widely rolled out. So far, only a few NMHS have actively collaborated with vulnerable communities and women to jointly develop and co-create products and services.
- Investment needs at national and regional level are estimated at $290 million and $34.5 million, respectively. The socioeconomic benefit analysis shows that the contribution of improved hydromet information to the region's socioeconomic development is expected to be very high, particularly due to the potential benefits of improved management for the agriculture and energy sectors and reduced impacts from floods and droughts. The benefit-cost ratio is $7 to 10 of profitability for each $1 of investment. The NPV of the expected benefits ranges between $770 million and $2,217 million depending on the chosen discount rate, supporting the conclusion that hydromet investments are expected to be profitable. Nevertheless, the costs for staffing are not considered in this analysis.
- Comparing different countries, the highest return on investments is expected for Nigeria, by far the largest economy in the region; other countries with a benefit-cost ratio higher than the regional average are Burkina Faso, Cabo Verde, Côte d'Ivoire, Ghana, Guinea Bissau

and Mali. With a regional initiative, such as the ECOWAS Hydromet Initiative, investments still need to be tailored to the country specific needs to maximize the impact of the modernization.

» WMO-accredited centers such as Regional Climate Centers (RCCs), Regional Training Centers (RTCs), Regional Specialized Meteorological Centers (RSMC), Regional Instrument Centers (RICs) and Regional WIGOS Centers (RWCs) play an important role, notably for the training and capacity building of meteorologists and hydrologists. An improper implementation of the data-sharing agreement in West Africa hampers the full role of the regional and global centers. In addition, the funding of these centers is precarious, depending largely on project-based funding.

7.1 Recommendations for Strengthening Hydromet Services in West Africa

From the analysis on the status of the hydromet services in the region and discussions with stakeholders in the region, notably the NMHS, recommendations to strengthen and modernize hydromet services include:

Strengthen policies, regional collaboration and data sharing

» The ECOWAS Hydromet Initiative should be owned and driven by the NMHS and regional institutions in West Africa aimed at sustaining key weather, water, climate and early warning services to the population. With the ECOWAS Flood Risk Management Policy, a regional policy framework has now been formulated that promotes coordinated actions and investments in hydromet services, early warning systems, flood risk assessments and data exchange. Going forward, its implementation needs to be driven by the ECOWAS member states with sound implementation plans and coordinated actions by ECOWAS and other regional institutions.

» Any regional collaboration on hydromet services should be driven by the effective exchange of hydromet data between member states, with regional and technical organizations and in compliance with global reporting requirements, such as the Global Basic Observation Network. The existing data-sharing mechanism between AGRHYMET and its CILSS member states should be effectively extended to cover all ECOWAS member states, ensure real-time exchanges among member states and provide adequate technical solutions to limit any potential, unintended use of shared data.

» With the signed memorandum of understanding between AGRHYMET and ECOWAS, two strong institutions have teamed up in West Africa to strengthen policies, develop regional hydromet applications and services, provide excellence in training and research, and support data exchange. Still, AGRHYMET and many other technical organizations in the region depend for up to 90 percent on donor funding. Making the proposed Regional Climate Center for West Africa and the Sahel a success will, therefore, require a strong partnership with financial and technical partners, but most importantly the commitment (including financial contributions) of its member states.

» The major river systems in West Africa are transboundary. Forecasting and managing river floods should, thus, be considered in a transboundary context and involve the river basin organizations. Using, for example, common hydrological-hydraulic modeling approaches for flood forecasting, with integration of data and information from up- and downstream parts of the basin, would support integral monitoring and availability of data, information and products at the transboundary level. The ECOWAS Water Resources Policy as well as the upcoming ECOWAS Flood Risk Management Policy can provide a common framework to advance the transboundary monitoring of floods.

Invest in sustaining and modernizing the observation and ICT infrastructure, ensure operation and maintenance and leverage economies of scale in the region

» Rightsizing hydromet investments is crucial. Capital investments in any part of hydromet systems, especially observation networks, require a corresponding increase in operation and maintenance budgets. The focus should be on upgrad-

ing and operationalizing the existing network instead of mere enlarging. The modernization of a hydromet and civil protection system is feasible only when governments ensure operation and maintenance of the services, including annual resources for field monitoring and station repairs.

» Observation infrastructure, networks of weather radars, upper air stations and high-performance computing facilities are capital intensive, with high costs for engineering, operation and maintenance. They are, thus, mostly out of reach for most ECOWAS member states, but particularly for the smaller countries with basic service levels. Levering economies of scale to develop infrastructure, operate ICT and networks, promote cascading approaches for forecasting and establish twinning arrangements between countries can overcome these challenges and should be promoted and, where possible, institutionalized in the region. In addition, support for instrument calibration should be revived at the regional level, peer-to-peer learning and quality management systems be promoted.

Focus on impact and cultivate a hydromet service culture

» Putting the needs of women, vulnerable groups and other users of hydromet services and early warning systems in the center of the service development will be a critical success factor for the ECOWAS Hydromet Initiative. So far, only a few NMHS have actively collaborated with them to jointly develop products and services and to provide impact-based forecasting. In this regard, NMHS are called to step up efforts to actively collaborate with user groups and vulnerable communities and ensure that women are actively involved.

» Agriculture is the backbone of the economies in West Africa and the main source of livelihoods for a large part of the population, notably women. Strengthening the hydromet service provision to the agricultural and rural communities, both commercial and subsistence farmers, will be important for the modernization of the NMHS. Considering the high analphabetism rate in some countries and limited agricultural extension network, more needs to be done to effectively reach these communities and to provide actionable and adequate services, notably for women and vulnerable farming communities.

» The coverage of early warning systems for floods, droughts and extreme weather events is very scattered in West Africa and in many cases lacks effective communication with the affected communities. Investing in early warning systems for urban areas (mostly for flash flood) and river floods will be important to deliver on avoiding flood losses.

Ensuring sustainability of the investment outcomes

» Public-private engagement and collaboration with the private sector and academia to co-create and develop hydromet products and services remain limited to a few specific applications West Africa, where few countries have adequate regulatory frameworks in place to enable public-private engagements. At the same time, many private sector businesses (for example, cell phone providers) operate in several countries in West Africa and networks of universities, such as WASCAL, have a footprint across many countries. It will thus be important to create an enabling environment for public-private engagements by putting in place a conducive regulatory framework in a regionally coherent manner and jointly promote private sector business cases in hydromet services.

» There would need to be clear institutional roles, mandates and protocols for the organization and operation of hydromet and early warning services. Technical activities, like meteorological and hydrological observation and monitoring, meteorological forecast, hydrological and hydraulic modeling to support forecasting, and bathymetric surveys, should be done under the guidance of the institution with the appropriate mandate and technical authority. These institutions should contribute in a cooperative and organized way to develop and implement flood early warning systems and to establish warning systems for different hydroclimatic hazards.

7.2 Recommendations for Implementation

The ECOWAS Hydromet Initiative provides a framework to support national- and regional-level investments for strengthening hydromet services in a coordinated manner. The Initiative leverages benefits from a strong regional policy framework, including agreements on data sharing, capacity building and economies of scale. The following recommendations are proposed for its implementation:

- Strengthening hydromet services in West Africa requires substantial investments and concerted efforts from governments, development partners and private sector. The ECOWAS Hydromet Initiative estimates investment needs of $324 million, and commitments from governments on operation and maintenance, staffing and training are prerequisite for making the envisioned outcomes of such investment sustainable. This calls for maximizing finance, including grants, loans and public-private partnerships, and ensuring that the recovery from the COVID-19 pandemic enables the adequate provision of hydromet services to vulnerable communities. A phased approach, allowing an incremental increase in capacity of NMHS, may be a more realistic and durable way forward. Detailed investment planning at the national level would still be necessary.
- The modernization of hydromet and early warning services in West Africa should complement and leverage ongoing initiatives, such as the Global Framework for Climate Services, CREWS West Africa, Strengthening Climate Resilience in Mali Project (World Bank and Green Climate Fund) and West Africa Food System Resilience Program (World Bank). The ECOWAS Hydromet Initiative would be fully aligned with WMO's Systematic Observations Financing Facility and provide a framework for partners to contribute to the modernization of hydromet services. The Initiative also can benefit from a close alignment with regional and national initiatives in support of water resources management, agriculture and food security, urban development and regional initiatives such as the Great Green Wall initiative.
- The ECOWAS Hydromet Initiative should be considered as a framework and open platform for governments, development partners and private sector to support hydromet services in the region in a coherent program, facilitating an incremental increase to modernize hydromet and early warning services. Starting with enhanced coordination among all partners would be an important point of departure to turn the ECOWAS Hydromet Initiative into practice.
- The ECOWAS Hydromet Initiative is unlikely to be successful as the effort of a single partner or organization with a large project management structure.
- The ECOWAS Hydromet Initiative would be owned by the NMHS and regional organizations and coordinated with the support of ECOWAS and WMO. Developing a common monitoring framework with a set of commonly agreed outcomes, outputs and indicators across the ECOWAS region will be an important element for the coordination of the initiative.

References

ACMAD. 2021. Seasonal Climate Outlook Bulletin valid for March-April-May and April-May-June 2021 of the Gulf of Guinea Countries of Africa (Niamey, 26th February 2021). Available online: http://acmad.net/rcc/atelier/bulletin_PRESASS08_eng.pdf

AGRHYMET. 2021. PRESASS 2021 Seasonal forecasting forum on Agro-Hydro-climatic characteristics for the Sudanian and Sahelian zones Forum régional sur les prévisions saisonnières agrohydro-climatiques pour les pays de la zone soudanosahélienne From April 26 to 30, 2021 Final Communique and Recommendations. Available online: http://agrhymet.cilss.int/wpcontent/uploads/2021/05/Communique_final_PRESASS_2021_EN.pdf

Belli, P., J. Anderson, H. Barnum, J. Dixon and J.-P. Tan. 2001. "Economic Analysis of Investment Operations." World Bank Institute, Washington DC.

Biasutti, M., and A.H. Sobel. 2009. "Delayed Seasonal Cycle and African Monsoon in a Warmer Climate." *Geophysical Research Letters* 36 (23): L23707.

CILSS. 2016. Landscapes of West Africa – A Window on a Changing World. U.S. Geological Survey EROS, 47914 252nd St, Garretson, SD 57030, United States

ECOWAS (Economic Community of West African States). 2005. "Agriculture Policy." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2006. "ECOWAS Disaster Risk Reduction Policy." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2008. "The West Africa Water Resources Policy." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2010. "ECOWAS Vision 2020." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2012. "ECOWAS Humanitarian Action Plan." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2016. "ECOWAS Disaster Risk Reduction Action Plan." Abuja, Nigeria.

ECOWAS (Economic Community of West African States). 2018a. Proceedings of the ECOWAS Hydromet Forum and DRR Subregional Platform, Abidjan Côte d'Ivoire. Abuja, Nigeria.

EMDAT (Emergency Events Database). 2017. Louvain, Belgium: Université catholique de Louvain, Centre for Research on the Epidemiology of Disasters.

FAO and AfDB (African Development Bank). 2015. Agricultural Growth in West Africa. FAO ISBN 978-92-5-108700-8.

FAO. 2019. *Main results and metadata by country (2006–2015).* World Programme for the Census of Agriculture 2010. FAO Statistical Development Series No. 17. Rome. FAOSTAT (Food and Agriculture Organization Data). 2015. Food and Agriculture Organization of the United Nations, Database (accessed 2015): http://www.fao.org/faostat/en/#home

GTAP (2020). Global Trade Analysis Project. Database GTAP8.1. In Internet: https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx (accessed October 15, 2020).

ICAO (International Civil Aviation Organization). 2019. "Aviation Infrastructure for Africa Gap Analysis – 2019, Priority Evaluation Items for Airline." PowerPoint Presentation. Montreal.

IMF (International Monetary Fund) 2015. Global monitoring report 2014/2015: Ending poverty and sharing prosperity. Washington DC: International Monetary Fund.

IPCC. 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, New York, US, pp. 1535.

Kamali, B., K.C. Abbaspour, B. Wehrli and H. Yang. 2019. "A Quantitative Analysis of Socio-Economic Determinants Influencing Crop Drought Vulnerability in Sub-Saharan Africa." *Sustainability* 11 (21): 6135.

Lebel, T., and A. Ali. 2009. "Recent Trends in the Central and Western Sahel Rainfall Regime (1990-2007)." *Journal of Hydrology* 375 (1-2): 52-64. https://doi.org/10.1016/j.jhydrol.2008.11.030

Matthew et al. 2010. Agricultural sector and economic development: The Nigerian experience. *Journal of Management and Enterprise Development*, 7(2), 1117–1677.

Niger Basin Authority. Year. [cited on p. XX, Box 2]. Niamey, Niger.

Panthou, G., T. Vischel and T. Lebel. 2014. "Recent Trends in the Regime of Extreme Rainfall in the Central Sahel." *International Journal of Climatology* 34: 3998-4006.

IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). Geneva: Intergovernmental Panel on Climate Change.

UN (United Nations). 2015. [cited on page 7].

UNDRR (UN Office for Disaster Risk Reduction). 2019. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland.

UNDESA (UN Department of Department of Economic and Social Affairs) Population Division. 2011. World Population Prospects: The 2010 Revision. Highlights and Advanced Tables. United Nations Publications, New York, NY, USA.

UNDESA (United Nations, Department of Economic and Social Affairs), Population Division. 2015. *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables.* Working Paper No. ESA/P/WP.241

WMO (World Meteorological Organisation). 2015. "WMO Capacity Development Strategy and Implementation Plan: ANNEX 5: Categorization of National Meteorological and Hydrological Services." Geneva, Switzerland.

WMO (World Meteorological Organisation). 2015a. "Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services." WMO-No 1153. Geneva, Switzerland.

WMO (World Meteorological Organisation). 2020. The gaps in the Global Basic Observing Network (GBON) . Geneva, Switzerland. https://alliancehydromet.org/knowledge/the-gaps-in-the-global-basic-observing-network-gbon/

World Bank. 2019. World Bank Country and Lending Groups. Washington DC.

World Bank. 2020. Databank Database. In Internet: https://databank.bancomundial.org/databases. Washington DC.

Zhuang et al. 2007. "Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey." Manilla, Philippines: Asian Development Bank.

Mission OSCAR (Observing System Capability Analysis and Review), Visite de la station Synoptique de PO, Octobre 2017, Burkina Faso. WMO, 2017


CEDEAO
ECOWAS