POLICY PAPER

How to improve forecast dissemination in the Blue Nile River Basin

Challenges, opportunities and ways forward

André Müller, Jan Frerichs and Kyra Baumann (adelphi research)
With support from Abuelgasim Musa (SMA), Modathir Zaroug (ICPAC),
and Gedion Asfaw (Independent Consultant)

SPONSORED BY THE
Federal Ministry of Research, Technology and Space

GRoW
WATER AS A GLOBAL RESOURCE

SPS Blue Nile

This Policy Paper is part of the project "SPS Blue Nile: A meteorological-hydrological forecasting system for the Blue Nile." SPS Blue Nile aims to enhance seamless forecasting and hydrological information services in the Blue Nile Basin, integrating short-range, sub-seasonal and seasonal outlooks to support climate-resilient agriculture, water resources management and disaster risk reduction.

The Policy Paper was developed by André Müller (adelphi research), Jan Frerichs (adelphi research) and Kyra Baumann (adelphi research) and is based on the work of the SPS Blue Nile project.

It was reviewed by Yasir Mohamed (IHE Delft Institute for Water Education), Gedion Asfaw (Senior Advisor on Water Resources Development and Transboundary Waters, Independent Consultant), Modathir Zaroug (Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC)), Abuelgasim Ibrahim Idriss Musa (Sudan Meteorological Authority), Hana Altom A. Mohammed (The Hydraulic Research Center (HRC) Sudan), Zablon Shilenje (World Meteorological Organisation (WMO)), Harald Kunstmann (Karlsruher Institut für Technologie (KIT)) and Titike K. Bahaga (Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC)).

Suggested citation: Müller, A.; Frerichs, J.; Baumann, K. 2025. How to improve forecast dissemination in the Blue Nile River Basin. Challenges, opportunities and ways forward. Berlin: adelphi research gGmbH

Publisher:
adelphi research gGmbH
Alt-Moabit 91
10559 Berlin
+49 (030) 8900068-0
office@adelphi.de
www.adelphi-research.de

Authors:
André Müller, Jan Frerichs and Kyra Baumann (adelphi research). With support from Abuelgasim Musa (SMA), Modathir Zaroug (ICPAC) and Gedion Asfaw (Independent Consultant).

Layout:
adelphi research gGmbH

Photo credits: Richard Mortel (CC BY-NC-SA 2.0)
Title: Blue Nile Gorge
Page: https://flic.kr/p/hbvMa6

Status: 23.03.2026

adelphi research

adelphi research is an independent think tank for environmental and development policy research and analysis. Our mission is to enable transformative change and to create a sustainable future for generations to come.

adelphi research, established in 2001 in Berlin, is a non-profit and independent institution. Our team of over 100 researchers specialises in analysing environmental, energy, and climate policies at both national and international levels. We're passionate about conducting transdisciplinary research projects that delve into environmental, development, and social policy matters. Additionally, we actively promote knowledge dissemination through lectures, publications, and events. Our aim is to reach a wide audience, sharing insights and raising awareness on topics related to nature, environmental and resource protection, as well as development cooperation on a national, European, and international scale.

adelphi research plays a crucial role in advancing environmental protection, social development, poverty reduction, peace-building, and fostering economic, political, and social participation in countries of the global South. We achieve this through the implementation of practical projects and the provision of scientifically grounded recommendations for action. Our aim is to make a meaningful impact and drive positive change in these regions

Contents

Executive Summary **1**

1 Introduction **3**

2 Background **5**

2.1 Who are the beneficiaries of forecasts? 5

2.2 Which actors are involved in dissemination? 6

2.3 How are forecasts being disseminated? 8

2.4 Is forecast dissemination effective? 8

3 Challenges and opportunities **10**

3.1 Infrastructure, technology and information 10

3.2 Communication channels, knowledge-sharing and co-production 11

3.3 Human Capital and Capacity-Building 13

3.4 Policy, Coordination and Governance 13

3.5 Finance 15

4 Recommendations **17**

References **21**

List of figures

Figure 1. The success factors for effective forecast dissemination 10

Figure 2. Key solutions for improving forecast dissemination 20

List of tables

Table 1. User groups and their needs 7

List of abbreviations

ATA	Agriculture Transformation Agency
EDRMC	Ethiopian Disaster Risk Management Commission
EMI	Ethiopian Meteorological Institute
EN-FFEWS	Eastern Nile Flood Forecast and Early Warning System
ENTRO	Eastern Nile Technical Regional Office
ESTAC	Ethiopia-Sudan Technical Advisory Committee
EWS	Early Warning System
GERD	Great Ethiopian Renaissance Dam
GHACOF	Greater Horn of Africa Climate Outlook Forum
HRC	Hydraulic Research Centre (Sudan)
ICPAC	IGAD Climate Prediction and Applications Centre
IGAD	Intergovernmental Authority on Development
MoAI	Ministry of Agriculture and Irrigation (Sudan)
MoWE	Ministry of Water and Energy (Ethiopia)
MOOC	Massive Open Online Course
NBI	Nile Basin Initiative
NCCD	National Council for Civil Defence (Sudan)
NECJOGHA	Network of Climate Change Journalists of the Greater Horn of Africa
NMHS	National Meteorological and Hydrological Services
SMA	Sudan Meteorological Authority
SOFF	Systematic Observation Financing Facility
WMO	World Meteorological Organisation

Executive Summary

Goal:

This policy paper explores the ways how climate and weather forecasts are communicated across the Blue Nile River Basin shared by Ethiopia and Sudan, and how governments, global and regional organisations as well as development partners can support existing systems and practices.

Focus:

It concentrates on the main beneficiaries of forecasts in the Blue Nile: Agriculture, dam operators and rural communities and seeks to find solutions that foster a cross-border approach and create mutual benefits for Ethiopia and Sudan. While focusing on forecast dissemination, this paper also addresses forecast development, as both depend on similar conditions for success.

Methods:

Based on workshops and interviews—conducted as part of the project SPS Blue Nile—and contributions from local scientists and practitioners, this policy paper examines governance systems, infrastructure, capacity and resources for communicating forecasts, and provides concrete actions for overcoming current challenges and leveraging major opportunities.

Core Messages:

Investing in early warning systems (EWS) offer a 10:1 return, averting millions in disaster damage, increasing the efficiency of dams like the Grand Ethiopian Renaissance Dam (GERD), and boosting agricultural productivity and rural livelihoods.

Despite significant advances in forecasting science globally, the Blue Nile Basin continues to face a critical implementation gap: **too few forecasts are translated into actionable information that reaches those who need it most. Poor dissemination is one of the key barriers**.

In **Sudan, forecast provision has deteriorated in recent years** due to the ongoing war, which has caused a near-total collapse of infrastructure. In contrast, **the primary challenge for Ethiopia's more advanced system is bridging the "last mile".**

A significant 'access divide' separates users: whilst dam operators and other industrial users have better—though far from ideal—access to forecasts, rural farmers, pastoralists, and communities remain critically underserved.

Realising the full benefits of forecasts requires considerable investment in infrastructure, human capacity, and communication systems, especially at local levels, as well as stronger cross-border cooperation.

While indispensable for now, reliance on donor support is fragile. Recent development aid cuts highlight the urgent need for sustainable funding models that include stronger government and private- sector commitment.

Recommendations (short version):

1. Move from donor-dependency to a **sustainable funding model by increasing national budget allocations and fostering private-sector investment**, prioritising investments that focus on long-term capabilities and a preventive rather than reactive approach, while ensuring essential forecast services reach everyone. Securing funding for Intergovernmental Authority on Development's (IGAD) Climate Prediction and Applications Centre (ICPAC) core operations and Sudan's remote forecasting—both highly vulnerable to current development aid cuts—is critical to sustain minimum forecasting services for many people in the basin, particularly in Sudan.
2. **Ensure minimum service provision in underserved and conflict-affected areas through a low-cost, high-impact multi-language radio in collaboration with local stations**—radio is the primary, and often only, source of information in these contexts—while gradually scaling up other technologies such as SMS alerts via expanded public-private partnerships with media companies as mobile phone connections and internet access become available. Additionally, leverage private-sector communication infrastructure for adjacent communities (e.g., provided by agricultural cooperatives who have relations to local farmers).
3. **Support multiple channels—including radio—to improve the reliability of forecast delivery in areas where governmental dissemination fails or is weak,** combining the use of informal methods such as door-to-door communication, supporting intermediaries such as extension workers and humanitarian NGOs, and advancing "last-mile" dissemination technologies like leaflets dropped in remote flood zones through drones. Channels must adapt to different target groups such as those including hard-to-reach pastoralists and requires specific offerings for women such as female journalists.
4. **Expand easily understandable forecasts tailored to local conditions and languages to more users** by fostering—yet rarely applied—co-production, systematic feedback, and impact monitoring. Harnessing digital tools and AI for multi-language translation, visualisation and forecast customisation is crucial to reduce

costs—a key constraint for scaling human needs-centred, highly applicable forecasts. Importantly, any communication strategy must recognise that even the best forecasts are worthless if they are unactionable or distrusted by users.

5. **Empower Blue Nile actors to operate forecast systems and dissemination independently by prioritising long-term capabilities and African leadership**, especially at the local level, by investing in proven capacity-building initiatives, promoting highly scalable training for intermediaries such as train-the-trainer programmes, and by establishing a twinning programme pairing Ethiopian and Sudanese hydro-meteorological staff for joint forecast development, professional-relationship building and peer-to-peer learning to immediately address the brain drain.
6. **Improve institutional coordination and governance at all levels**, especially with local-level institutions, and on meteorological issues—existing cross-border cooperation focuses primarily on hydrological data—by establishing a basin-wide Early Warning Task Force, formalising a cross-border agreement that includes data-sharing protocols (especially for GERD), and creating a centralised data and visualisation platform for the Blue Nile, possibly hosted by ICPAC.

Three Quick Wins

1) Set up a **Blue Nile Early Warning Task Force** for basin-wide coordination of hydro-meteorological forecasts, possibly under the umbrella of ESTAC.
2) Establish **a multi-language radio network partnering with local radio stations** for "last-mile" coverage.
3) Develop **a basin-wide early-warning data and visualisation platform** as "single point of truth" for forecasts, possibly hosted by ICPAC.

1 Introduction

A region of humanitarian and geopolitical significance. Despite the cultural and natural heritage and diversity, the two countries of the Blue Nile, Ethiopia and Sudan, are frequently in the global spotlight due to cross-border tensions, civil conflicts, floods and famine.

Political stakes are high for the Blue Nile's waters. Contributing 60% of the river's total run-off—mostly from Ethiopia—the Blue Nile is vital for Ethiopia, Sudan, and Egypt. Sudan relies on its Roseires and Sennar dams for around 80% of its electricity generation and irrigation. Egypt receives 90% of its water from the Nile. Any changes to its flow regime can significantly impact all three countries, highlighting the unique challenges of transboundary water management in the region (NBI 2020).

Ethiopia has completed both the construction and filling of the GERD—Africa's largest dam—which is expected to supply a significant share of the country's electricity and provide a boost to its economy. The reservoir reached full capacity at the end of June 2025, with the official inauguration ceremony taking place on 9 September 2025. Since its plans were revealed in 2010, the GERD has been a persistent source of diplomatic tension among the three riparian states.

The Blue Nile region is highly vulnerable to climate change. Rainfall patterns have become increasingly variable, along with frequent droughts and floods, threatening agricultural systems and livelihoods. A single prolonged drought can devastate a herder's livestock or destroy a farmer's harvest. Pastoralist communities constitute 12-15% of Ethiopia's (Gebremeskel et al. 2019) and over 20% of Sudan's population (UNDP 2006). Rainfed agriculture dominates across the region, accounting for approximately 80% of Ethiopia's (Teferi et al. 2025) and 95% of Sudan's agricultural land (Mukhtar Hamid et al. 2023). Riverine and urban flooding is a further recurrent hazard in Sudan, while flash floods are common in many parts of Ethiopia and Sudan (Desta et al. 2024).

Robust, timely, and actionable climate information is critical to reducing climate change impacts. It underpins decision making in water resources management, agriculture, health, disaster risk reduction, and other areas of everyday life. Reliable weather and climate forecasting and EWS enables communities and governments to anticipate, prepare for, and respond to growing climate-related hazards, thereby minimising loss of life, economic damage, and long-term impacts on development—especially since millions of people in the basin depend directly on rainfall and are exposed to the impacts of floods.

The economic case for EWS is compelling. According to the Global Commission on Adaptation, every dollar invested in strengthening EWS yields an impressive tenfold return in economic benefits worldwide (UNDRR 2024). Despite this clear value, a mere USD 0.47 out of every USD 100 in global aid is directed towards disaster risk reduction—and this figure may decrease further as official development assistance declines—significantly undermining broader development objectives (Tzachor et al. 2023).

"[…] there is little point investing in smallholder farms if floods are simply going to wash away seeds, agrochemicals, and machinery." Dr Asaf Tzachor

High-quality forecasts are only part of the solution. Without effective dissemination that reaches those in need, even the most accurate forecasts remain ineffective and have little to no real-world impact. In regions such as the Horn of Africa, effective dissemination requires translating forecasts into multiple local languages, adapting to a scattered media landscape, varying levels of access, and building capacity so that people not only understand what actions to take, but also have the means to realise them. It is therefore crucial to improve the entire forecast chain—from data collection and the interpretation of forecasts to disaster risk preparedness and response.

Forecast development and dissemination in transboundary river basins are more complex than in national settings. The riparian countries must coordinate their interests, harmonise data standards, and align warning thresholds across diverse legal frameworks. Uneven technical capacities, political sensitivities, and language barriers complicate joint dissemination and operationalisation of EWS. In contrast, national settings benefit from unified governance and more streamlined communication channels between forecast providers and end users.

Despite advances in forecasting science, including improved model resolution and extended lead times, forecasts in the Blue Nile River Basin too often fail to be translated into actionable information and to reach those who need them most. Poor dissemination, alongside limited interpretation and trust issues, constitutes considerable barriers to realising the full potential of forecasts for farmers and pastoralists, rural communities, and local authorities, particularly at the "last mile". This gap reflects broader continental trends: only 40% of Africa's population currently has access to EWS (Chitate 2024; Gudoshava et al. 2024).

The reasons for low outreach and limited uptake of forecasts vary between Ethiopia and Sudan. While Ethiopia benefits from more advanced forecast

systems and a more structured, multi-level dissemination process, the ongoing civil war in Sudan has severely disrupted the country's forecast services. Both countries face common structural challenges: limited financial resources, shortages of skilled staff and fragmented institutional landscapes with unclear or overlapping mandates. Cross-border cooperation remains limited, further hindering the effective forecast dissemination between the two countries.

Purpose and Scope of this Policy Paper

Addressing national governments, regional organisations and international development partners, this paper aims to:

- Provide a structured overview of forecast dissemination in the Blue Nile region and crystallize its value for decision-makers and financiers—focusing on key beneficiary groups, including agriculture, rural communities and dam operation.
- Illuminate the current challenges and opportunities in forecast dissemination and offer targeted recommendations for scaling successful initiatives and supporting key stakeholders.

Structure of the Paper

Following an introduction outlining the status quo, the need for transformation, and the resulting challenges, the paper delves deeper into the background, covering the beneficiaries of forecasts, the actors involved in dissemination and the methods and effectiveness of forecast dissemination. The paper then explores the challenges and opportunities of dissemination in various aspects and concludes with a clear set of policy recommendations.

2 Background

2.1 Who are the beneficiaries of forecasts?

Agriculture

Target group characteristics: Smallholder farmers represent the largest user group in the region, comprising over 95% of Ethiopia's crop cultivation and managing around 80% of Sudan's farmland (Zerssa et al. 2021). **Pastoralists** constitute an additional 12-20% of the basin's population. Both groups predominantly inhabit rural and often remote areas.

Relevant forecast types: For subsistence farmers and pastoralists, seasonal and sub-seasonal forecasts are essential for planning planting schedules, grazing patterns and water use, while short-term forecasts enable immediate action during extreme weather events. Longer-range forecasts are especially critical for sustaining livelihoods in rainfed agricultural systems and mobile pastoral economies. The following forecast timescales are of relevance:

- **Seasonal (3–6 months):** Supports crop and livestock planning, including decisions on when and what to plant, and when and where to relocate livestock.
- **Sub-seasonal (2–4 weeks):** Enables timely adjustments to crop management practices and harvest scheduling.
- **Short-term (daily to real-time):** Informs immediate decisions, such as harvesting ahead of storms, clearing irrigation canals, and organising evacuations.

Expected impacts:

- **Higher productivity and yields**: In East Africa, farmers who received SMS-based weather advisories at **least doubled their yields** compared to seasons without forecast support (IFAD 2024).
- **Loss prevention**: In Kenya, early action based on drought forecasts **prevented livestock losses and maintained milk production at three times normal levels** during peak drought conditions (Tanaka 2021).
- **Practice change and cost efficiency**: In Niger, early warning advisories led **82% of farmers change their agricultural practices**, yielding an average of one tonne of millet per farmer annually —equivalent to approximately 110 USD (Seydou et al. 2023).

Rural communities

Target group characteristics: Rural communities are a key recipient group for forecasts, given their highly vulnerability to droughts, heatwaves, and floods. Many rural areas face significant risks from flooding and soil erosion, driven by steep terrain, increasing land pressure, and growing climate variability. While not examined in depth in this paper, **urban communities** generally benefit from comparatively better access to early warning information and tend to be less exposed to the most severe impacts of extreme weather events.

Relevant forecast types: For rural communities, short-term forecasts are most critical for enabling timely disaster response to floods and extreme weather events, while sub-seasonal and seasonal forecasts support broader preparedness planning. Although all forecast types are relevant, rapid alerts are especially vital for saving lives and protecting essential infrastructure in rural areas. Forecast types of greatest relevance include:

- **Flood forecasts (onset, extent, duration):** Essential for protecting lives, homes, and critical services in flood-prone communities.
- **Drought forecasts (seasonal and sub-seasonal):** Key for informing water rationing decisions and supporting health protection measures.
- **Short-term alerts (48–72 hours):** Enable rapid protective action, including the organisation of evacuations and the reinforcement of community infrastructure.

Expected impacts:

- **Damage reduction:** 48-hour flood warnings can reduce **overall flood damage by more than 50%** (Hallegatte 2012).
- **Lower disaster mortality:** Countries with weak EWS experience **disaster mortality rates nearly six times higher, and disasters that affect five times more people** than countries with stronger EWS coverage (UNDRR 2024).

Dam operators

Target group characteristics: The main dams in the Blue Nile Basin—the GERD and Tis Abay in Ethiopia, and Roseires and Sennar in Sudan—are managed by state-owned entities: Ethiopian Electric Power in Ethiopia and the Sudanese Electricity Distribution Company Ltd. in Sudan. These dams are critical for hydropower generation, irrigation, and river flow regulation. Dam operators must continuously balance competing demands, including power production, downstream water releases, sediment management,

and flood risk mitigation, within a highly seasonal and hydrologically variable river system.

Relevant forecast types: For dam operators, a combination of forecast types is essential, with seasonal forecasts guiding strategic planning and short-term forecasts enabling real-time operational adjustments. Key forecast types include:

- **Seasonal forecasts:** Crucial for scheduling reservoir filling and turbine releases well in advance, and for adjusting reservoir rule curves to optimise operations based on anticipated inflow conditions.
- **Sub-seasonal and weekly forecasts:** Support medium-term planning for power generation and downstream water allocation decisions.
- **Short-term forecasts (daily to 3-day):** Essential for real-time flow management, flood control operations, and maintaining minimum irrigation flows, particularly at downstream facilities such as the Sennar Dam.

Expected impacts:

- **Economic gains:** At Sudan's Upper-Atbara Dam Complex, the use of seasonal forecasts to guide drought-responsive reservoir operations avoided an **estimated USD 16.2 million in hydropower revenue losses** in a single example year (Portele et al. 2021).
- **Improved operational efficiency:** The adoption of advanced forecasts has been shown to benefit up to 94% of dams assessed, with 25% demonstrating significant operational gains relative to basic control rules (Lee et al. 2022).

2.2 Which actors are involved in dissemination?

Cross-border and regional actors

Regional organisations play an essential role in forecast development and dissemination across the Blue Nile region. The ICPAC provides weekly and seasonal climate outlooks for East Africa, including the Blue Nile Basin, and supports the National Meteorological and Hydrological Services (NMHS) with data, tools, and capacity building. The World Meteorological Organisation (WMO) enhances national capacities through technical support, trainings, and initiatives such as Early Warning 4 All, aiming to make EWS universally accessible through digital transformation.

Basin-scale water management institutions focus primarily on flood forecasting and cross-border hydrological information sharing. The Eastern Nile Technical Regional Office (ENTRO)—a regional body mandated to support joint water management for Egypt, Ethiopia and Sudan—operates the Eastern Nile Flood Forecast and Early Warning System (EN-FFEWS), a real-time platform providing daily and seasonal flood forecasts to relevant ministries and authorities in Ethiopia and Sudan. ENTRO is the most important institutional actor at the basin scale; however, its engagement with drought forecasting is very limited (Ahmed, 2020).

The Nile Basin Initiative (NBI) serves as the key institution for overseeing transboundary water management across the broader Nile Basin. It consolidates hydrological outlooks through its Regional Expert Working Group and disseminates these assessments to member states. However, its basin-wide forecasts are of limited direct relevance to the Blue Nile sub-basin specifically.

The Ethiopia-Sudan Technical Advisory Committee (ESTAC) plays a central role in facilitating cross-border hydrological data exchange, supporting dam operations and disaster preparedness, particularly in relation to Sudan's Roseires Dam and Ethiopia's GERD. Its contribution to forecast development and dissemination, however, remains limited in scope.

Several initiatives focused on East Africa also make important contributions to forecast dissemination in the Blue Nile region. Programmes such as the Famine Early Warning Systems Network (FEWS NET) and the African Multi-Hazard Early Warning System, alongside international research collaborations, provide specialised datasets, modelling tools, and targeted alerts that enhance early warning and support broader resilience.

National government institutions

A network of governmental entities underpins forecast dissemination in Ethiopia and Sudan. In both countries, effective weather and flood early warning relies on structured collaboration between ministries, governmental agencies, and disaster risk management bodies, supported by humanitarian organisations and community-level partners.

NMHS play a central role in developing and disseminating forecasts. Drawing on national observation networks and downscaled data, these agencies produce national forecasts and distribute them to key actors, like ministries and the media. In Ethiopia and Sudan, the relevant NMHS are the Ethiopian Meteorological Institute (EMI) and the Sudan Meteorological Authority (SMA).

In both countries, national dissemination further involves a range of sectoral ministries. Ethiopia's Ministry of Water and Energy (MoWE) and Sudan's Ministry of Agriculture and Irrigation (MoAI) are among the most significant, overseeing the management and dissemination of climate

information and ensuring its integration into sectoral preparedness and response efforts. Overall, ministries in both countries work in close partnership with the SMA and EMI, research centres, disaster risk management bodies, humanitarian organisations, and local authorities to coordinate preparedness, response, and the dissemination of early warning information.

Specialised disaster risk management bodies coordinate a multi-sectoral disaster preparedness and response. The Ethiopian Disaster Risk Management Commission (EDRMC) and Sudan's National Council for Civil Defence (NCCD) are responsible for sharing early warnings across all administrative levels. These bodies activate anticipatory measures, coordinate response activities, and work closely with humanitarian organisations to ensure timely and effective action.

Humanitarian Organisations, civil society and businesses

International humanitarian organisations play an increasingly important role in forecast dissemination, particularly in Sudan. The World Food Programme and the International Federation of Red Cross and Red Crescent Societies triangulate official forecasts with field observations to deliver actionable information to affected communities and coordinate humanitarian assistance. The Sudanese Red Crescent Society coordinates disaster responses at the state level, receiving forecast information from the MoAI and SMA while maintaining extensive community networks. Together, they participate in disaster risk management institutions and serve as critical information bridges to remote communities where national systems are strained or absent.

Local organisations provide essential last-mile connectivity. In Sudan, organisations such as DARAJA (meaning "Resurgence") develop community-specific forecast products using special iconography and local languages. These are issued as community warnings and disseminated via local radio, megaphone patrols, and youth volunteers conducting door-to-door alerts—ensuring reach into communities that formal dissemination channels frequently fail to serve.

Academic and research institutions contribute significantly to forecast development and capacity building in both countries. In Ethiopia, the Ethiopian Institute of Water Resources at Addis Ababa University collaborates with EMI on flood EWS and citizen science initiatives. In Sudan, the Hydraulic Research Centre (HRC) functions as the dedicated research arm of the MoAI, focusing on flood forecasting and water resources management.

Private sector engagement represents emerging potential, particularly in Ethiopia. Agribusinesses that receive climate information from governmental sources provide tailored guidance to their customers and suppliers, creating market-driven dissemination channels that complement formal systems. Mobile network operators, including Ethio Telecom and Safaricom, offer platforms for forecast dissemination. However, adoption remain limited in rural areas.

Table 1. User groups and their needs

User Group	Primary Forecast Needs	Critical Timeframes	Preferred Channels	Key Barriers
Smallholder Farmers	Planting dates, rainfall timing, extreme weather alerts	Seasonal (planting), sub-seasonal (management), short-term (harvest)	Radio, extension agents, community meetings	Low literacy, limited mobile access, language barriers
Pastoralists	Drought forecasts, grazing conditions, water availability	Seasonal (movement planning), sub-seasonal (grazing adjustments)	Radio, community networks, mobile SMS (where available)	Mobile network gaps, remote locations, nomadic lifestyle
Dam Operators	Inflow forecasts, extreme precipitation, sedimentation	Seasonal (reservoir planning), short-term (flood control)	Web portals, email bulletins, direct data feeds	Data sharing limitations, political sensitivities
Rural Communities	Flood warnings, drought alerts, heat stress	Short-term (evacuation), seasonal (preparedness)	Radio, loudspeakers, community leaders, NGOs	Electricity access, language diversity, poverty limitations

2.3 How are forecasts being disseminated?

Radio remains the primary dissemination channel across the Blue Nile Basin, particularly among rural communities with low literacy rates. For example, smallholder farmers typically rely on local radio stations broadcasting in regional languages. In Ethiopia, farmers are regularly exposed to forecast information through radio even when their main purpose is entertainment, making it a powerful channel for reaching audiences who may not actively seek out forecast content (Bedelian 2024; Kayusi 2024).

Television plays a comparatively limited role in rural forecast dissemination, with greater relevance in urban areas and among institutional users. Government institutions in both countries use television for official announcements during extreme weather events; however, poor electricity access and limited television ownership in rural areas constrain its outreach potential. In Sudan, already limited television coverage has been further reduced by the ongoing conflict, making radio even more critical as a channel for public communication and early warning.

Climate outlook forums constitute an important platform for structured forecast dissemination and stakeholder dialogue. Platforms such as the Greater Horn of Africa Climate Outlook Forum (GHACOF), National Climate Outlook Forums, and sub-national workshops bring together representatives from countries, sectors, and academia, alongside both producers and users of climate information. By facilitating cross-sectoral exchange, these forums play a key role in tailoring climate information to the specific needs of different user groups, translating seasonal forecasts into actionable guidance for sectors including agriculture, water resources management, health, and disaster risk management.

Print media and bulletin distribution serve primarily institutional users and educated urban populations. ENTRO's technical bulletins, for example, are distributed via email to national focal points to enable institutional coordination. However, these formats rarely reach rural communities directly and typically require intermediary translation and redistribution to have broader impact.

Email, newsletters and websites, while important communication tools, are similarly concentrated in urban areas among government institutions and businesses. The websites of EMI, SMA, ENTRO and ICPAC serve as important sources of timely forecasts and hydrological and climate outlooks—though, their primary users tend to be institutional stakeholders with comparatively better access to forecast information.

Mobile phone-based services, particularly SMS, hold significant potential to bridge the "last mile" gap and reach vulnerable rural communities that are least served by traditional dissemination channels. Pilot programmes using SMS and WhatsApp for forecast dissemination are already underway in some areas. However, limited internet access and low smartphone penetration continue to hinder the scaling of WhatsApp and other internet-reliant messaging applications beyond urban and peri-urban areas.

The use of social media platforms for forecast dissemination is becoming increasingly popular, filling gaps in both countries. Facebook is the most widely used platform for this purpose, filling the gaps where traditional channels fall short, especially during emergencies. However, social media reach remains constrained by internet access requirements, leaving large segments of the rural population, particularly in remote areas, effectively excluded from this channel.

2.4 Is forecast dissemination effective?

Forecasts are often disseminated with insufficient lead time or reach end users too late to enable effective action—a challenge that is more acute in Sudan than in Ethiopia. The Gambela Floods of September 2023, which displaced over 25,000 people despite three-day advance warnings, highlight the persistent gaps between national EWS and at-risk communities. While ENTRO's forecast accurately predicted the event, inadequate communication and institutional coordination meant the warnings failed to reach—or sufficiently mobilise—vulnerable populations in time.

Even when forecasts reach their intended recipients, technical comprehension represents a significant further barrier, particularly in remote and marginalised areas. Across the Blue Nile Basin, dozens of languages are spoken, complicating dissemination, though communication in practice tends to rely on a smaller number of dominant regional languages. Moreover, striking the right balance between clarity and scientific rigour presents persistent difficulties, as the level of detail required

for informed decision-making differs considerably across user groups (GNDR 2025).

Receiving and understanding forecasts does not guarantee that recipients are able to act on it. Even if smallholder farmers comprehend forecast implications, they may lack the financial resources to implement recommended adaptations—such as purchasing improved seeds or livestock feed—a constraint likely affecting a significant proportion of the basin's population. For example, limited access to grazing lands due to land degradation, agriculture expansion, and conflicts restricts pastoralists' ability to act on early warnings by moving livestock elsewhere.

A lack of systematic monitoring prevents forecast providers from understanding whether their forecasts translate into effective action. In many cases, government institutions do not know whether forecasts were disseminated effectively or acted upon—meaning that the adequacy of communication may only become apparent in the aftermath of a disaster. This absence of feedback loops represents a structural gap in the forecast chain that significantly impedes learning and improvement.

Dam operators, government institutions, agri-businesses, and urban populations tend to have better access to forecast information. Access is generally better in Ethiopia than in Sudan, where the ongoing conflict has severely impaired the entire dissemination chain. While industry users generally benefit from better access, decision-makers in water resource management continue to face significant challenges, including limited access to forecasts and insufficient technical capacity to interpret and apply them effectively, including those involved in GERD operations (Blum et al. 2019).

Across the basin, rural communities frequently lack reliable electricity and internet access, particularly in Sudan, sustaining dependence on radio and limiting the reach of digital forecast delivery. In some remote regions, even radio access cannot be assumed. For example, highland smallholders in Ethiopia generally benefit from access to agricultural extension agents and timely forecasts, whereas lowland pastoralists frequently fall outside areas with mobile phone coverage and may miss SMS-based alerts. Similarly, upstream dam operators receive regular forecast updates, while downstream communities often depend on infrequent radio broadcasts, creating major gaps in information access (ICPAC 2023, Teshome 2019).

Marginalised groups and vulnerable communities face compounding barriers. Rural women, pastoralists, and those in remote areas contend with language obstacles, limited mobile phone ownership, and weak telecommunication infrastructure. In Sudan, conflict-affected populations and internally displaced persons receive particularly limited forecast coverage. In 2024, only 39% of Sudanese households reported receiving an early warning, with rural women and displaced populations falling notably below the national average (UNDRR 2025).

3 Challenges and opportunities

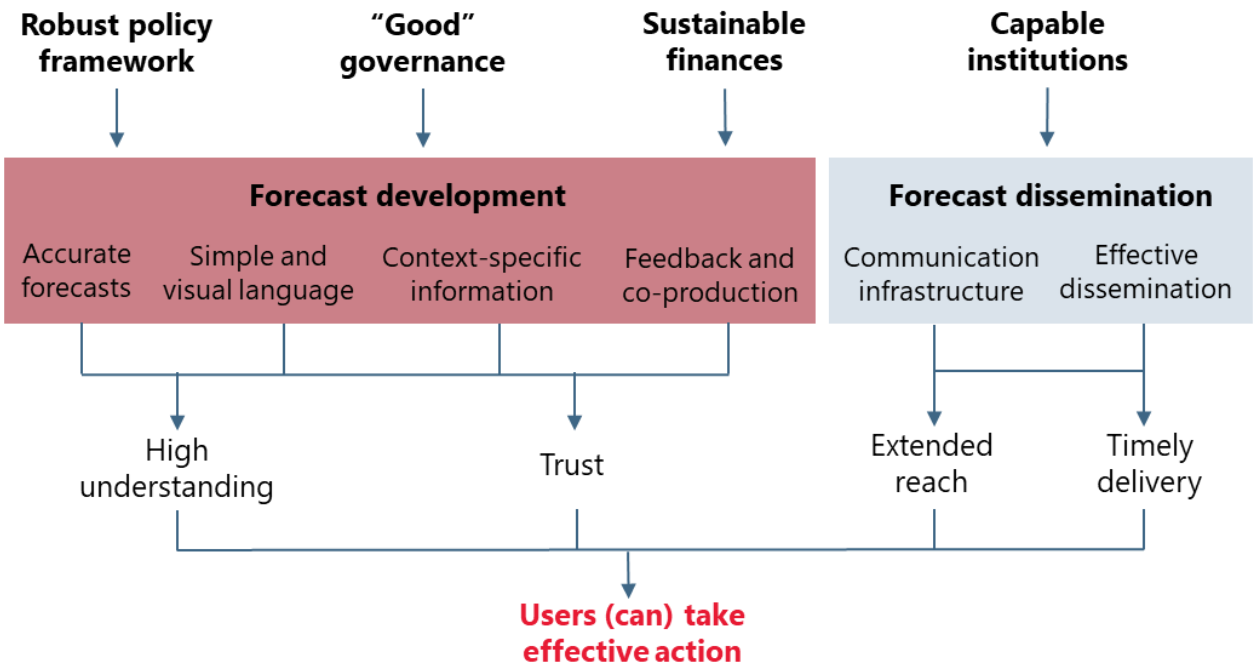


Figure 1. The success factors for effective forecast dissemination

3.1 Infrastructure, technology and information

Africa's weather forecasting systems, including those in the Blue Nile region, lag behind those of the Global North. Ethiopia and Sudan present stark contrasts in infrastructure and technological capacity, both of which are critical to effective forecast dissemination.

Sudan faces severe constraints as a direct consequence of the ongoing conflict that began in April 2023. The SMA has been forced to operate remotely, with some of its staff hosted by ICPAC in Nairobi, Kenya. Most meteorological stations have been damaged, critically impeding observational data collection and the provision of reliable forecasts. This remote operation represents a fundamental rupture in the data-to-service chain, with severe implications for data rescue, model calibration, and forecast verification.

Although Sudan has achieved some noteworthy developments under deeply precarious circumstances—including the launch of a new SMA website—forecast **dissemination remains highly fragmented, frequently delayed, and has deteriorated markedly since the onset of the conflict.**

In Ethiopia, forecast systems are more advanced, benefitting from more reliable infrastructure, stronger institutions and a structured, multi-level dissemination system that enables broader and more timely forecast delivery.

The path forward differs between the two countries. In Sudan, meaningful improvement to forecast dissemination will remain severely constrained without an end to the conflict and infrastructure rebuilding. In Ethiopia, the main challenges lie in modernising infrastructure, improving forecast accuracy, and ensuring consistent last-mile delivery to remote farming and pastoralist communities.

Decentralised, low-cost technologies offer opportunities to supplement sparse official dissemination networks in both countries. These include community-managed weather stations and citizen-science initiatives, such as mobile applications enabling reporting of local conditions, including rainfall and river levels, which are particularly valuable in remote or conflict-affected areas where formal infrastructure is absent or unreliable.

Investments should prioritise building operational capacity alongside the provision of equipment and technology, to ensure long-term effectiveness and avoid "white elephant" projects. The AMMA project, for example, demonstrates that

targeted investment, including performance-based funding, enables African agencies to meet international observation standards (Lamptey et al. 2024).

Limited access to telecommunications and electricity in remote and conflict-affected areas presents significant structural barriers to reaching the "last mile".

Ethiopia's expanding internet penetration and growing smartphone access are improving forecast dissemination. In contrast, Sudan's conflict-devastated infrastructure has caused widespread telecommunications blackouts, forcing communities and institutions to rely on traditional channels and costly satellite connectivity.

Mobile phone access remains limited across both countries, and smartphone penetration is still very low. Sudan's **mobile phone penetration stands at approximately 42%, compared with 64% in Ethiopia**, with significantly lower adoption rates in rural areas in both countries. Internet access—whether mobile or fixed—lags even further behind mobile penetration. Since 2023, the **conflict in Sudan has caused a 20% decline in mobile connections and widespread internet blackouts**, while Ethiopia has recorded 11% growth in mobile connections and rapid expansion of mobile internet users (World Bank 2025).

Women-headed households report lower rates of radio and mobile phone ownership, amplifying last-mile communication gaps and further restricting access to early warning messages (Enough Project 2013; ICPAC 2023).

Mobile money platforms (e.g., Telebirr, M-PESA) and **SMS-based alerts** are expanding in reach and hold significant potential for broadening the dissemination of climate information**.**

Expanding access to mobile phones, internet, and television in underserved areas would be highly beneficial for forecast dissemination. However, this ambition is constrained by deep-rooted factors, including limited electricity access and affordability, and must therefore be understood as a significant long-term endeavour.

Online platforms and tools for dissemination are decentralised and have impractical user interfaces, hindering access and the usefulness of forecasts.

More than 20 hydrometeorological platforms operate across East Africa. The lack of interoperability and coherence among them poses a major challenge for effective forecast and disaster risk communication, as navigating such a fragmented landscape is impractical for most users. A **regional visualisation platform hosted by ICPAC** could unify these fragmented systems, providing integrated climate hazard information, and strengthening early warning across the Blue Nile Basin (WMO 2025).

While Information and Communication Technology tools hold considerable potential for making forecasts more accessible and easier to use, effectively deploying these tools—including internet and mobile services—represents a substantial operational challenge for providers like ENTRO (Ahmed 2020).

Promising initiatives are emerging that demonstrate the potential of tailored, sector-specific forecast services. The Agro-Advisory Platform in Ethiopia (ATA 2023), for example, successfully translates raw meteorological data into actionable advice for farmers and pastoralists. However, the broader **impact of such initiatives across Africa is generally constraint by project-based funding and insufficient integration into national systems** (Lamptey et al. 2024).

3.2 Communication channels, knowledge-sharing and co-production

Dissemination can be irregular and unpredictable, however, utilising diverse and complementary channels can help mitigate the effects of inefficient systems.

As long as formal channels remain unreliable, especially in Sudan, it is crucial for users to **use multiple channels** that encompass SMS, social media and radio, as well as offline methods like community loudspeakers. Some pastoralist communities in the Horn of Africa still rely exclusively on **non-digital methods** (Bedelian 2024).

Intermediaries are central for reaching the "last mile" and making forecast information accessible. In Ethiopia, traditional authorities serve as intermediaries between formal institutions and local communities. Agricultural extension agents, often serving multiple villages simultaneously, provide crucial links between technical forecast information and the practical decision-making needs of farmers.

Targeted outreach and dedicated female intermediaries, including female journalists, women's groups and female extension agents, are essential for reaching woman farmers, who typically have less access to forecasts information. Expanding the number of female intermediaries increases the likelihood that weather and climate information reaches and serves all community members equitably, irrespective of gender (Jelagat, 2023).

Increasing multi-channel access would further benefit from strategic partnerships between ENTRO, EMI, and others, including with television broadcasters and telecommunications companies**.** **Public-Private Partnership pilots,** as demonstrated by pilot initiatives in Ethiopia's sesame sector, **offer relevant and replicable precedents for expanding dissemination reach.**

Strengthening the capacity of humanitarian organisations is equally important, given that they often cover the "last mile" that governments struggle to reach. By translating technical forecasts into local languages and leveraging their on-the-ground presence to disseminate warnings through trusted community networks, these organisations bridge critical information gaps, particularly vital in conflict-affected areas.

Dissemination strategies must be grounded in social realities, user needs and an understanding of gender roles. Elderly and marginalised groups may, for example, require oral or community-based communication due to literacy constraints or technology barriers (Jelagat 2023).

The cost of accessing weather and climate information can prevent rural communities from doing so. Cost-sharing mechanisms offer one practical means of addressing this barrier—for example, through collective sharing of forecast-related expenses, financial support from government agricultural agencies that themselves benefit from improved forecast uptake, or governments subsidising such as tax waivers on access tools and software (Sansa-Otim 2022).

Forecasts are often too technical for non-specialist audiences. Targeted translation, plain language, and innovative tools can help overcome these barriers.

Smallholder farmers, pastoralists and other rural users often struggle to understand and act on forecasts due to limited literacy, contextual knowledge, and inadequate translation. A further challenge lies in calibrating the level of technical detail: some users require only a single summary indicator, such as the probability of an adverse event, while technical experts in water management, for example, need more comprehensive information to support robust decision-making.

ENTRO's flood bulletins and some of ICPAC's forecast products, for instance, remain **highly technical and are available only in a limited number of languages, including Arabic, English and French, thereby excluding significant user groups**. Providing tailored forecasts and translations into multiple language is, simultaneously, more resource-intensive and costly.

Many forecasts also lack sufficient context-specific detail, with spatial resolution that is too broad or insufficient sensitivity to local conditions—a main reason why farmers rarely use forecasts for agricultural decisions (Feleke 2020).

Visual communication tools, including icons, can make forecasts more accessible, actionable and improve comprehension, trust, and follow-up action. For example, farmers respond more readily to simple, categorical forecast formats (such as "above normal," "normal," or "below normal") than to complex probability distributions. Intuitive visual symbols, such as a bent tree to represent strong winds, can improve comprehension.

To make weather and climate information accessible to those without technical backgrounds, **glossaries and dictionaries produced in local languages** offer a valuable resource. Kenya's Swahili climate dictionary provides a model for this approach (Jelagat 2023).

Short, concise explanatory videos, such as those produced by ICPAC to explain illustrations and provide advisories for farmers, have demonstrated greater effectiveness than text-based communication**.** Despite their potential reach diverse audiences, dissemination via short-form videos remains limited, partly due to the resource intensity of production.

Emerging applications of artificial intelligence (AI) hold transformative potential for making forecasts more accessible and actionable at scale. AI should be actively fostered to reduce the costs of resource-intensive processes highlighted in this paper, including translation and content adaptation. AI-powered tools such as chatbots can provide instant, localised responses in colloquial languages, while AI-driven dashboards can significantly reduce reliance on technical text (Camps-Valls et al. 2025).

Especially among illiterate rural populations with limited climate-related knowledge, forecasts are misunderstood and distrusted. This can be addressed through engaging local leaders, promoting co-production and systematically integrating feedback.

Mistrust in forecasts is widespread across the region, affecting not only rural populations with limited climate-related knowledge, but also regional decision makers involved in water management. Contributing factors include perceptions that forecasts issued by NMHS may be subject to political influence as well as contradictory forecast messaging from different national sources, which can further aggravate trust issues (Blum et al. 2019).

Co-production workshops represent a key pathway for gathering feedback and bridging the gap between technical providers and end-users,

ensuring that forecast services are user-focused, timely and actionable**.** Users excluded from co-production processes tend to encounter greater difficulty in understanding and applying forecasts. Forecast providers like ENTRO **could improve co-production through direct engagement with flood-affected communities**, including field visits and structured consultations, to develop more context-specific and locally responsive solutions.

Co-production can be further enriched by formally **integrating indigenous and local knowledge with scientific forecast methods.** Pastoralist communities, for example, possess sophisticated traditional forecasting practices. A system that respectfully combines these two knowledge systems would help build trust and generate more locally relevant and culturally resonant forecast information.

While co-production has gained traction across the region in recent years, **it remains a resource-intensive process that requires careful planning and sustained commitment**. Smart digital tools offer promising avenues for scaling co-production approaches in a more cost-effective manner (Gudoshava et al. 2024).

Systematic impact monitoring is crucial for assessing whether early warnings translate into timely, life-saving action, yet this is rarely done systematically. By tracking whether warnings reach vulnerable communities and result in preparedness measures, governments and development partners can identify gaps and iteratively refine dissemination strategies. Achieving this, however, will require a significant strengthening of current monitoring efforts by the relevant institutions.

3.3 Human Capital and Capacity-Building

Institutional capacity and resources—one of the most decisive barriers to effective forecast dissemination—vary between countries and administrative levels but are overall lacking across actors.

A shortage of skilled personnel remains a persistent and acute challenge—not only for institutions operating in the Blue Nile Basin, but across Africa more broadly—and appears to be most pronounced at the local and sub-national levels. In Sudan in particular, **skilled staff are lost through various reasons**, further weakening institutional knowledge and continuity. **Brain drain constitutes one of the most significant structural constrains** on improving forecast dissemination.

Systematic investment in talent development, education, and institutional partnerships is essential to stem this brain drain, support young researchers, and connect their work to decision-making processes relevant to forecast dissemination (Dike et al. 2018). The **African SWIFT project offers a best-practice case for effective capacity building**: by linking universities with NMHS, delivering hands-on training, and integrating user needs and end-user feedback into its design, it demonstrates what targeted, sustained investment can achieve (Gudoshava et al. 2024).

Within the region, **WMO, ICPAC, and others provide a range of dissemination-specific capacity building offerings**, including targeted training programmes and massive open online courses (MOOCs) for journalists on climate reporting. **Several additional initiatives exist that contributes to this landscape**—such as the Network of Climate Journalists of the Greater Horn of Africa (NECJOGHA) and IGAD's Media Awards to Spotlight Excellence in Climate Journalism—though the scope remains limited.

Investing in **scalable training programmes, materials and platforms**, including MOOCs and train-the-trainers programmes, can broaden access for a wider range of actors and institutions (Jelagat, 2023). Given that capacity-building efforts cannot reach all relevant actors, the **focus should be on empowering intermediaries**—including extension agents, editors, and local media leaders.

3.4 Policy, Coordination and Governance

Both Ethiopia and Sudan have national policies for flood early warning and disaster risk management in place, yet significant implementation gaps remain.

Ethiopia's policy framework for disaster risk management is comparatively more advanced, as reflected in its National Framework for Climate Services, which aims to integrate climate information across key sectors like agriculture, water, and disaster risk reduction. This builds on the 2013 National Disaster Risk Management Policy, which marked a decisive shift from a reactive, relief-oriented model towards a more comprehensive, multi-hazard approach.

Sudan's key policy document is its National Adaptation Plan (2016), which established a framework for reducing climate-related risks across sectors. Progress on implementing this plan and on developing a national framework for climate services has, however, been severely hampered by the ongoing conflict. More recently, the government's attention has necessarily focused on immediate crises, with an Emergency Response Preparedness Plan (2022) outlining coordination

arrangements for sudden-onset disasters such as floods. Sudan has also developed a Climate and Weather Rescue Plan aimed at rebuilding and sustaining weather and climate service capacity.

Despite these instruments, policy **reform and implementation is needed**. Governments should, for example, enforce restrictions on settlement construction and other investments in high-risk flood zones, and where such settlements already exist, relocation options must be actively explored.

Unclear mandates, institutional fragmentation and overlaps at the national scale stall progress.

In both Sudan and Ethiopia, **institutional roles and responsibilities for forecast dissemination remain unclear, leading to confusion, duplication and inaction.**

In Sudan, **flood-related responsibilities are distributed across multiple ministries without clear delineation**. In Ethiopia, while the MoWE is officially tasked with leading flood disaster management, this role is fulfilled in practice by the EDRMC.

Institutions responsible for dissemination are often under-resourced and weaker at the sub-national level, significantly impairing local forecast dissemination. In Ethiopia, for example, disaster risk management is organised under Woreda-level (district) agricultural offices, where dissemination systems are often poorly structured due to skill shortages, high staff turnover and constrained budgets (Teshome 2019). Moreover, both **forecast development and dissemination tend to prioritise the agricultural sector**, at the expense of end-users in public health, water resources management, and other sectors.

Coordination between key government institutions, across political and administrative levels, and with international bodies and NGOs, remains weak.

This affects all stages of the forecast chain, from development through to dissemination, and is particularly deficient at the interface between national government institutions and local-level institutions and communities**.**

Coordination across different timescales presents a particular governance challenge. For instance, agricultural ministries, require seasonal forecasts for planting decisions, while disaster management agencies need 72-hour flood warnings to initiate evacuations. The absence of a central, multi-agency body capable of translating a unified forecast into sector-specific actionable guidance represents a major governance gap.

In Ethiopia, **data sharing and collaboration between governmental institutions and ENTRO remain largely informal and have yet to be institutionalised** (Teshome 2019). Similarly, coordination between Sudanese ministries, particularly between the Agriculture Ministry and the SMA, is insufficient. Coordination between **government entities and non-governmental actors such as the Red Cross and Red Crescent, is also frequently weak, as is the relationship between extension agents** providing agro-advisory services and the farming communities they serve (Tesfaye et al. 2020).

ICPAC and WMO are key actors working to strengthen institutional collaboration and align policy frameworks across the region. For example, ICPAC facilitates **coordination between NMHS** through joint forums, particularly the GHACOFs, and through shared early warning platforms.

A dedicated, lean and agile "Blue Nile Early Warning Task Force" may represent the most suitable institutional mechanism for addressing this. With representation from both countries' meteorological, hydrological, and key user agencies, including those responsible for agriculture and energy, such a body could harmonise warning protocols and coordinate transboundary responses. Convening this body under a neutral party such as ENTRO or ICPAC would help to manage political sensitivities and ensure equitable representation.

Cross-border institutions and cooperation mechanisms exist, but significant institutional improvements are needed—particularly with regard to the sharing and quality of meteorological data.

Despite the existence of formal transboundary institutions—including NBI, ENTRO, ESTAC—**cross-border collaboration is limited, particularly on meteorological data exchange,** and this gap impairs forecast dissemination and early warning.

During significant flood events in Sudan in 2020 and again in 2025 following the completion of the GERD, **communication between Sudan and Ethiopia was minimal**—although some exchanges of data on daily reservoir levels and releases both the GERD and Roseires Dam did occur between 2022 and 2025 under the auspices of ESTAC. As a result, **Sudanese authorities lack reliable access to data on GERD storage levels and release schedules**, undermining their flood early warning capacity.

At the transboundary level, the **most critical policy gap is the absence of a legally binding cross-border agreement** on the long-term operation of the GERD, including provisions for the systematic exchange of hydrological and dam operation data.

Data sharing and collaboration between ENTRO and national institutions, particularly the NMHSs, are also insufficient. It is therefore

recommended that ENTRO formalises its engagement with the EDRMC and establishes structured arrangements with EMI and other relevant institutions to facilitate this.

National sovereignty concerns continue to limit the ability of regional organisations like ENTRO and ICPAC to lead transboundary cooperation efforts.

Finally, to ensure a **coherent and effective regional response**, it is crucial that national dissemination efforts in both Ethiopia and Sudan are aligned with broader Nile Basin strategies and with the work of the NBI. The Nile Basin Discourse, a civil society organisation with an extensive grassroots network, is currently developing a **comprehensive flood and drought information dissemination strategy,** to guide NBI's flood and drought forecasting system, representing a valuable entry point for broader alignment.

3.5 Finance

Besides being chronically scarce, funding prioritises reactive relief over preparedness, is project-based, and neglects local-level efforts.

Limited financial resources remain a severe major bottleneck, driven by factors including low awareness of the benefits of early warning among national governments, and competing national funding priorities—a challenge particularly acute at the local level and in Sudan, where domestic tax revenues are minimal.

Reliance on **project-based funding** makes it difficult to maintain, upgrade, and expand early warning infrastructure and operations, and prevents successful pilot initiatives from scaling up into long-term, sustainable programmes.

Most available funding is reactive—disbursed only in the aftermath of disasters rather than in advance—which increases overall costs, perpetuates cycles of loss for vulnerable communities, and diverts resources away from the long-term development of capacity and infrastructure.

While **forecast-based financing,** which enables the release of funds prior to a disaster event, is being piloted by various agencies across Africa, **its adoption remains limited in scope.**

Over-reliance on donor funding poses a significant risk to the long-term sustainability of recent improvements in forecast dissemination.

Numerous initiatives in Ethiopia and Sudan are predominantly dependent on short-term funding from donor countries, including the United Kingdom and Italy. Sudan's dependence on Italian donor funding, for example, raises concerns that access to cloud services, servers, and related infrastructure may be lost when this support ends.

Similarly, without sustained donor funding, **several of ICPAC's essential regional activities, including the GHACOFs, risk becoming financial unviable**.

Many of the WMO's regional capacity-building projects, which are critical to strengthening NMHS, are likewise financed through time-limited donor funds. This dependence on ad-hoc external financing, rather than integrated national budgets, **undermines the development of self-sustaining, locally owned EWS**.

Forecast-related funding should focus on enabling actors across the forecast chain to operate independently, reducing dependence on external donor support and achieving long-term self-reliance.

Donor funding should therefore **prioritise strengthening local capacity and career development** for operating infrastructure and enhancing forecasting and dissemination skills over investments that are concentrated solely on physical infrastructure and centralised technology.

Setting clear standards for partnership, governance, and African leadership, and making **long-term support contingent** on **successful delivery and performance,** can enhance the sustainability and accountability of donor-funded interventions (Lamptey et al. 2024).

Innovative financing models offer promising pathways forward. Ethiopia's Systematic Observations Financing Facility (SOFF) is a global initiative that aims to strengthen climate adaptation by collecting, processing and making data available, thereby improving weather forecasts and EWS. SOFF demonstrates how **global finance mechanisms and private partnerships** can sustain and expand observational systems through performance-based funding. Prioritising **African-led, context-specific solutions**—as exemplified by SOFF and the Climate Risk and Early Warning Systems (CREWS) initiative—is more sustainable than externally driven approaches. However, this orientation may at times conflict with donor objectives, such as supporting domestic companies or promoting the export of technologies from donor countries.

While the private sector holds significant potential to fill gaps left by governments, its engagement in climate services remains limited and presents both opportunities and challenges.

Private sector actors, including telecommunications providers, agro-dealers, insurance companies, banks, and media organisations, **have the potential to compensate for scarce public funding** and to create more sustainable, commercially anchored EWS models. The private sector can make profits from forecasting by focusing on development, delivery, and especially

marketing. When implemented successfully, this approach can generate lasting expertise and strengthen EWS in ways that are worth replicating across Africa (Parker et al. 2022).

Agro-dealers, for example, maintain direct relationships with farmers and, through their participation in Participatory Scenario Planning workshops, can effectively disseminate seasonal advisories and provide guidance on seed selection and agricultural techniques (Jelagat, 2023).

Private sector engagement currently remains low, however, with limited outreach, particularly in Sudan, where the ongoing conflict has further constrained commercial activity and service delivery.

At the same time, companies based in the Global North are increasingly delivering advanced weather forecast products in Africa, which risks bypassing African agencies and limiting local capacity development. Greater support for African-led private-sector development—including objective evaluation of existing partnerships and stronger advocacy by African governments—by African governments is therefore needed to ensure that private sector growth contributes to, rather than undermines, local capacity (Parker et al. 2022).

Although various capacity building programmes are offered by ICPAC, WMO and others, further expanding and deepening these efforts remains indispensable for improving forecast dissemination.

Centres of excellence, in particular African universities and WMO Regional Training Centres, can train large numbers of specialists, as demonstrated by the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) programme (Lamptey et al. 2024).

To foster practical skills and cross-border collaboration, **twinning or mentorship arrangements could prove highly effective**. Pairing staff from EMI with their Sudanese counterparts, currently hosted at ICPAC, for joint forecast development, for example, would build professional relationships, foster mutual trust, and facilitate peer-to-peer learning. This approach could also help to mitigate the brain drain challenges identified earlier in this paper.

The media plays a pivotal role in the dissemination of weather and climate information—the multiplier effect of well-communicated forecasts through widely accessed channels can be considerable. The media should therefore be engaged throughout the climate services chain (Jelagat, 2023).

Specialised training programmes covering all relevant forecast timescales are essential to equip journalists with the skills needed to simplify complex technical information and communicate it effectively to diverse audiences. While progress has been made in communicating climate information more broadly, significant gaps persist in the public interpretation of forecasts and in the understanding of probabilistic forecast formats.

Africa continues to **rely on externally developed, predominantly Western, forecast systems** that are not adequately tailored to local conditions, including across the Blue Nile region. Models are often run on global reanalyses and satellite rainfall datasets, while dam operators may utilise ensemble forecasts that have not been co-developed with national NMHS. Addressing this dependency requires sustained investment in African-led, context-specific forecast development and capacity building.

4 Recommendations

1. Increase sustainable finances for forecasting from governments, development partners and the private sector, particularly for long-term operations and at the local level, yet avoid overreliance on ODA.

- **ICPAC, WMO, and other regional actors** should sustain and intensify their efforts to raise awareness among **national governments of the critical benefits** of EWS and **advocate for increases in budget allocations,** particularly to sub-national and local-level institutions. In Sudan, given the current situation this may be particularly challenging, given low tax and other revenues are available.
- **All relevant actors** should treat the support of ICPAC's core functions and Sudan's capacity to sustain remote forecasting operations as a top priority, to ensure continuity of minimum service provision.
- **Governments** need to **establish enabling framework conditions for private sector engagement** that attract investments, including foreign capital, while promoting the growth of regional businesses and locally developed solutions and capacity.
- **Development partners** need to provide **increased multi-year core funding instead of short-term, project-based grants,** while governments need to pursue strategies to reduce their current over-reliance on donor funding, which poses significant long-term sustainability risks to forecast systems across the basin.
- **Development partners** should **prioritise funding towards initiatives that build African leadership and strengthen local capabilities** to operate forecast systems autonomously, avoiding technology-only approaches and "white elephant projects".

2. Ensure a minimum level of infrastructure and operations in underserved areas and among marginalized populations, especially in Sudan, by focusing on radio solutions first.

- **All relevant actors** should support **the development of a multilingual radio network that establishes partnerships with local radio stations**—in remote areas where radio remains the only reliable accessible medium, which provides a low-cost, high-impact solution for expanding last-mile forecast coverage.
- **Development partners** should support **infrastructure investments to gradually expand easily scalable last-mile dissemination solutions** such as SMS-based alert systems, in parallel with the expansion of electricity access and internet connectivity.
- **Development partners** should urgently assist Sudan in **maintaining essential operational infrastructure throughout the current conflict**, including office space, equipment, internet access, and computational capacity, which is particularly critical given the SMA's severe constraints in maintaining minimum service provision, especially if support from its main donor, the Italian development agency, ends.
- **The private sector** should be actively encouraged to **utilise existing communication infrastructure to support forecast dissemination** and early warning outreach to surrounding communities (e.g. agricultural co-operations can utilise their communications networks to disseminate forecasts to adjacent rural and urban communities).

3. Expand the reliability of dissemination to underserved and marginalised populations in remote areas—and where government efforts are weak or fail—through multi-channel dissemination systems adapted to local context.

- **All actors should invest in informal dissemination channels**, including community radio, youth volunteer networks, and door-to-door alert systems, in areas where formal channels are unlikely to improve in the near term, **as well as intermediaries engaged in "last mile" dissemination should be actively supported** (e.g., community representatives in known flood risk zones should be equipped and trained to operate early warning facilities), and innovative technologies such as drones for distributing leaflets in flood-affected areas.
- **Governments should establish structured partnerships with private media companies** to scale up phone and television-based solutions (e.g. as piloted in Ethiopia's sesame sector through Public-Private-Partnerships).
- **Development partners** should **make a proportion of their funding on measurable improvements in "last-mile" outreach** to ensure that forecasts reach

marginalised and hard-to-reach remote communities.

- **All actors** should **support community-level disaster preparedness campaigns** that raise awareness of forecast availability, potential early warning and inherent uncertainties, and actively support communities in interpreting forecasts and translating them into timely protective action (e.g. through short podcasts in local languages and small on-site symposiums).

4. Improve accessibility of forecasts that remain overly technical and difficult to interpret for illiterate and poorly educated groups—leading to distrust and inaction.

- **Forecast providers** should systematically work towards **translating forecast products beyond primary languages**, **simplifying technical language for non-specialist audiences, and integrating visual aids**, building on positive examples such as ENTRO's locally adapted iconography or ICPAC's short-form videos.
- **Forecast providers** should **broaden co-production processes, establish easily accessible feedback mechanisms and systematic impact monitoring, to continuously improve systems and services**, particularly by engaging women, who generally have poorer access (e.g. by promoting women's representation in local EWS committees).
- **Development partners** should **support research projects focused on scaling AI solutions for forecast development, translation and visualisation, as well as their adaption to local conditions and user contexts**—as logistical and resource constraints impede the ability of forecast providers to tailor products to the diverse needs, which is why they remain misunderstood and untrusted.

5. Empower long-term capabilities and leadership of Blue Nile actors, especially within local governments and communities.

- **All actors** should foster a **cultural shift from reactive towards anticipatory approaches**, building on initiatives already driven by organisations like ICPAC. This requires more systematic investment in the long-term resilience of target communities, allowing them to better prepare for and cope with extreme weather events.
- **Development partners** should support **targeted measures to address the brain drain affecting Sudan's institutions**, for example by temporarily supplementing competitive salaries for key personnel within the SMA and other critical institutions. High staff turnover and persistent recruitment challenges in government institutions are among the most significant threats to effective and sustainable forecast dissemination.
- **All actors** should support the development of **scalable training and capacity building programmes**, including MOOCs and train-the-trainers programmes, and support a **twinning or mentorship programme** that pairs EMI staff with their Sudanese counterparts (hosted at ICPAC) for joint forecast development, professional relationships building and peer-to-peer learning**.** This relatively low-cost approach would directly contribute to mitigating the brain drain by maintaining a core of skilled experts, fostering regional collaboration, and strengthening institutional resilience within the SMA.
- **Governments** should increase **incentives for journalists** to specialise in weather and climate reporting and provide sustained **support to relevant journalistic initiatives and networks** such as the NECJOGHA, the Nile Basin Discourse, and infoNile—which already has significant and growing audience across the region.

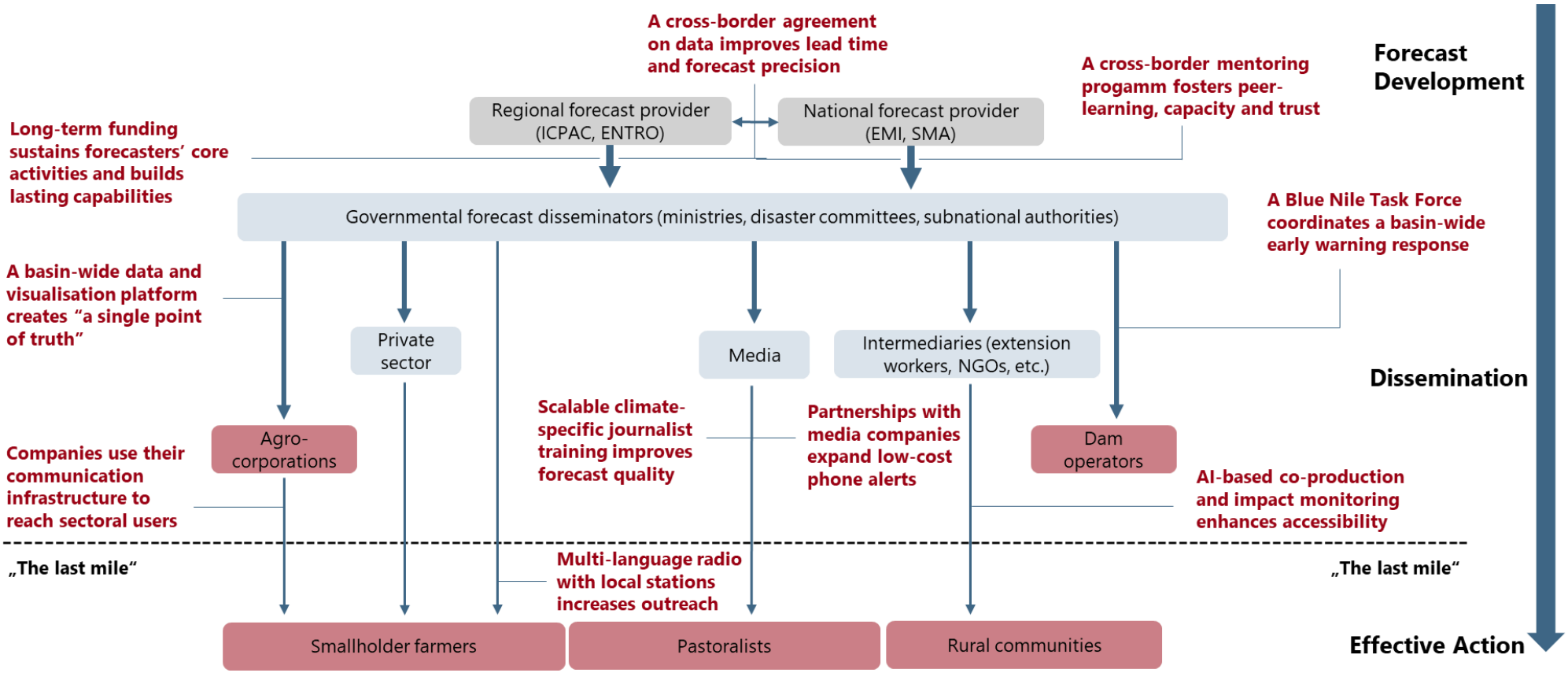
6. Improve institutional coordination and governance at all levels, especially at the transboundary scale and with local level actors.

- **Development partners** should actively support efforts to break the deadlock in cross-border **institutional cooperation—moving beyond existing hydrological data exchange** to encompass meteorological forecasts and to address persistent coordination gaps across time scales—a lean and agile **"Blue Nile Early Warning Task Force"** should be considered, representing both countries' meteorological, hydrological, and key user agencies and is tasked with harmonising warnings and coordinating transboundary early warning responses, convening under the auspices of ESTAC.
- **Governments** should strengthen currently weak **coordination with local-level institutions and humanitarian organisations** by establishing systematic feedback mechanisms and ensuring that local actors are meaningfully integrated into the entire forecast chain.
- **All relevant actors** should work towards **formalising a legally grounded data-sharing agreement focused on the GERD**, covering the exchange of hydrological and operational data to facilitate dam safety monitoring and flood forecasting, while ENTRO should deepen it collaboration with national entities, particularly

EDRMC and NCCD, and formalise partnerships to ensure seamless data sharing and coordinated early warning action. Implementing streamlined Standard Operating Procedures can improve disaster preparedness and response capabilities.

- **All actors** should support the development of a **regional early warning data and visualisation platform**, potentially hosted by ICPAC, that provides decision-makers with a "single point of truth" and enables faster, more coordinated cross-border alerts, including forecast products specifically addressing the transboundary scale of the Blue Nile Basin.

Figure 2. Key solutions for improving forecast dissemination



References

Agriculture Transformation Agency (ATA) (2023). Digital agro-climate advisory platform: Annual Report. Link: https://www.ata.gov.et/wp-content/uploads/2023/05/Digital-Agro-Climate-Advisory-Platform-Annual-Report-2023.pdf

Bedelian, C. (2024). How climate information services (CIS) can help pastoralists in the Horn of Africa. SPARC. Link: https://www.sparc-knowledge.org/sites/default/files/documents/resources/how-climate-information-services-can-help-pastoralists-in-the-horn-of-africa_policy-brief.pdf

Blum, A. G., Zaitchik, B., Alexander, S., Wu, S., Zhang, Y., Shukla, S., Alemneh, T. and Block, P. (2019). A grand prediction: Communicating and evaluating 2018 summertime upper Blue Nile rainfall and streamflow forecasts in preparation for ethiopia's new dam. Front. Water, Sec- Water and Human Systems. Volume 1 – 2019. doi: https://doi.org/10.3389/frwa.2019.00003

Camps-Valls, G., Fernández-Torres, M.-Á., Cohrs, K.-H., Höhl, A., Castelletti, A., Pacal, A., Robin, C., Martinuzzi, F., Papoutsis, I., Prapas, I., Pérez-Aracil, J., Weigel, K., Gonzalez-Calabuig, M., Reichstein, M., Rabel, M., Giuliani, M., Mahecha, M. D., Popescu, O.-I., Pellicer-Valero, O. J., Ouala, S., Salcedo-Sanz, S., Sippel, S., Kondylatos, S., Happé, T., and Williams, T. (2025). Artificial intelligence for modeling and understanding extreme weather and climate events. Nature Communications, 16, 1919 (2025). doi: https://doi.org/10.1038/s41467-025-56573-8

Chitate, A. (2024). How early warning systems and parametric insurance can build climate resilience in Africa. World Economic Forum. Link: https://www.weforum.org/stories/2024/07/early-warning-systems-parametric-insurance-climate-resilience-africa/

Desta, G., Legesse, G., Ahmed, M. I., Muluneh, A., and Birhanu, B. (2024). Assessing flood risks and exploring opportunities for flood-based farming in the dry lowlands of Ethiopia. Front. Sustain. Food Syst. Sec. Land, Livelihoods and Food Security. Volume 8 (2024). doi: https://doi.org/10.3389/fsufs.2024.1348094

Dike, V. N., Addi, M., Andang'o, H. A., Attig, B. F., Barimalala, R., Diasso, U. J., Du Plessis, M., Lamine, S., Mongwe, P. N., Zaroug, M., and Ochanda, V. K. (2018). Obstacles facing Africa's young climate scientists. Nature Climate Change 8, 447–449. doi: https://doi.org/10.1038/s41558-018-0178-x

Enough Project (2013). Humanitarian needs assessment in Sudan's Blue Nile State. Link: https://www.enoughproject.org/files/BlueNile_HumanitarianNeedsAssessment.pdf

Feleke, H. G. (2020). Investigating and assessment of weather forecasting needs of smallholder farmers for climate change adaptation in the Central Rift Valley of Ethiopia. In: International Research in Environment, Geography and Earth Science (pp. 16) Publisher: Book Publisher International. doi: 10.9734/bpi/ireges/v4

Food and Agriculture Organisation (FAO) (2018). Horn of Africa: Impact of early warning early action. Protecting pastoralist livelihoods ahead of drought. Link: https://openknowledge.fao.org/server/api/core/bitstreams/a3cf04e8-d65b-4bf2-9203-a190fc58efd0/content

Gebremeskel, E. N., Desta, S., and Kassa, G. K. (2019). Pastoral development in Ethiopia: Trends and the way forward. World Bank Group. Link: https://www.celep.info/wp-content/uploads/2019/07/2019-Esayas-et-al-Pastoral-devt-in-Ethiopia.pdf

Global Network of Civil Society Organisations for Disaster Risk Reduction (GNDR) (2025). Localising early warning systems & anticipatory actions through CSOs. Global survey analysis report. Link: https://www.gndr.org/wp-content/uploads/2025/06/LEWS-Global-findings-survey-report.pdf

Gudoshava, M., Otieno, G., Koech, E., Misiani, H., Ongoma, J. G., Heinrich-Mertsching, C., Wachana, C., Endris, H. S., Mwanthi, A., Kilavi, M., Mwangi, E., Colman, A., Parker, D., Mutemi, J. N., Machio, P., Omay, P. O., Ombai, P., Anande, D., Kondowe, A., Mugume, I., Ayabagabo, P., Houssein, H. Y., Waiss, M. S., Abeshu, B., Kayoya, E., Sharawe, M. N., Bahaga, T., Todd, M., Segele, Z., Atheru, Z. and Artan, G. (2024). Advances, gaps and way forward in provision of climate services over the Greater Horn of Africa. Front. Clim., Sec. Climate Services, Volume 6. doi: https://doi.org/10.3389/fclim.2024.1307535

Hallegatte, S. (2012). A cost effective solution to reduce disaster losses in developing countries: Hydro-meteorological services, early warning, and

evacuation. Policy Research Working Paper (6058). The World Bank. Sustainable Development Network.

ICPAC (2023). Greater Horn of Africa climate outlook forum report.

IFAD (2024). Early warning systems help small-scale farmers prepare for climate change. Link: https://www.ifad.org/en/w/rural-voices/early-warning-systems-help-small-scale-farmers-prepare-for-climate-change

Jelagat, J. (2023). Strengthening communication of weather and climate information in Eastern Africa. ICPAC. Link: https://icpac.medium.com/strengthening-communication-of-weather-and-climate-information-in-eastern-africa-6aff011ef8ee

Kayusi, F. (2024). Climate information is useful at local level if people get it in good time: How African countries can build systems to share it. The Conversation. Link: https://theconversation.com/climate-information-is-useful-at-local-level-if-people-get-it-in-good-time-how-african-countries-can-build-systems-to-share-it-244765

Lamptey, B., Sahabi Abed, S., Gudoshava, M., Mutemi, J., Bopape, M.-J., Adefisan, E. A., Igri, M. P., Sanda, I. S., Ndiaye, O., Parker, D. J., Dougill, A. J., Fink, A. H., Knippertz, P., Woolnough, S. and Kolstad, E. W. (2024). Challenges and ways forward for sustainable weather and climate services in Africa. Nature Communications 15, 2664 (2024). doi: https://doi.org/10.1038/s41467-024-46742-6

Lee, D., Ng, J. Y., Galelli, S., and Block, P. (2022). Unfolding the relationship between seasonal forecast skill and value in hydropower production: A global analysis. Hydrology and Earth System Sciences, 26, 2431–2448. doi: https://doi.org/10.5194/hess-26-2431-2022

Mohammed Ahmed, R. A. (2020). Final report: Flood forecasting and early warning system (FFEW) assessment for Sudan. Flood Forecasting and Early Warning Enhancement Project. ENTRO.

MukhtarHamid, E., Henry, M., Jalal, R. and Kumar, V. (2023). Cultivated cropland extent in Sudan – July to September 2023. A comparative analysis. Link: https://storymaps.arcgis.com/stories/6a54ed0c923d489e91b318fee15b8cf9

Nile Basin Initiative (NBI) (2020). State of the river Nile Basin. Water Security in the Nile Basin 2021. ISBN: 978-9970-444-05-2

Parker, D. J., Blyth, A. M., Woolnough, S. J., Dougill, A. J., Bain, C. L., de Coning, E., Diop-Kane, M., Foamouhoue, A. K., Lamptey, B., Ndiaye, O., Ruti, P., Adefisan, E. A., Amekudzi, L. K., Antwi-Agyei, P., Birch, C. E., Cafaro, C., Carr, H., Chanzu, B., Clarke, S. J., Coskeran, H., Danour, S. K., de Andrade, F. M., Diakaria, K., Dione, C., Diop, C. A., Fletcher, J. F., Gaye, A. T., Groves, J. L., Gudoshava, M., Hartley, A. J., Hirons, L. C., Ibrahim, I., James, T. D., Lawal, K. A., Marsham, J. H., Mutemi, J.N., Okogbue, E. C. Olaniyan, E., Omotosho, J. B., Portuphy, J., Roberts, A. J., Schwendike, J., Segele, Z. T., Stein, T. H. M., Taylor, A. L., Taylor, C. M., Warnaars, T. A., Webster, S., Woodhams, B. J. and Youds, L. (2022). The African SWIFT project: Growing science capability to bring about a revolution in weather prediction. Bulletin of the American Meteorological Society, 103, 2, E349–E369. doi: https://doi.org/10.1175/BAMS-D-20-0047.1

Portele, T. C., Lorenz, C., Dibrani, B., Laux, P., Bliefernicht, J., and Kunstmann, H. (2021). Seasonal forecasts offer economic benefit for hydrological decision making in semi-arid regions. Scientific reports 11, 10581. doi: https://doi.org/10.1038/s41598-021-89564-y

Sansa-Otim, J., Nsabagwa, M., Mwesigwa, A., Faith, B., Owoseni, M., Osuolale, O., Mboma, D., Khemis, B., Albino, P., Ansah, S. O., Ahiataku, M. A., Owusu-Tawia, V., Bashiru, Y., Mugume, I., Akol, R., Kunya, N. and Odongo, R. I. (2022). An assessment of the effectiveness of weather information dissemination among farmers and policy makers. Sustainability, 14(7), 3870. doi: https://doi.org/10.3390/su14073870

Seydou, T. H., Agali, A., Aissatou, S., Seydou, T. B., Issaka, L., and Ibrahim, B. M. (2023). Evaluation of the impact of seasonal agroclimatic information used for early warning and farmer communities' vulnerability reduction in Southwestern Niger. Climate, 11(2), 31. doi: https://doi.org/10.3390/cli11020031

Tanaka, Y. (2021). What does it take to reduce flood and drought risks and build climate resilience in Eastern Africa? UNDRR. Link: https://www.preventionweb.net/news/what-does-it-take-reduce-flood-and-drought-risks-and-build-climate-resilience-eastern-africa

Teferi, E., Kassawmar, T., Bewket, W., Zeleke, G., Ayele, G. T., O'Donnell, G. and Walsh, C. (2025). Rainfed agriculture in Ethiopia: A systematic review of green water management pathways to improve water and food security. Front. Agron. Volume 7. doi: https://doi.org/10.3389/fagro.2025.1418024

Tesfaye, A., Hansen, J., Radeny, M., Belay, S., & Solomon, D. (2020). Actor roles and networks in agricultural climate services in Ethiopia: A social network analysis. Climate and Development, 12(8), 769–780. https://doi.org/10.1080/17565529.2019.1691485

Teshome, W. (2019). Final report: Flood forecasting and early warning system (FFEW) assessment for Ethiopia. Flood Forecasting and Early Warning Enhancement Project. ENTRO. Link: https://nilebasin.org/sites/default/files/2023-09/23%2520EN%2520FFEW%2520Flood%2520Forecasting%2520%2526%2520Early%2520Warning%2520System%2520Assessment%2520-%2520Ethiopia.pdf

Tzachor, A., Richards, C. E., Gudoshava, M., Nying'uro, P., Misiani, H., Ongoma, J. G., Yair, Y., Mulugetta, Y. and Gaye, A. T. (2023). How to reduce Africa's undue exposure to climate risks. Nature, 620(7974), 488–491. doi: 10.1038/d41586-023-02557-x

United Nations Development Programme (UNDP) (2006). Nomads' settlement in Sudan: Experiences, lessons and future action (Study 1). Link: https://www.undp.org/sites/g/files/zskgke326/files/migration/arabstates/NOMADS-SETTLEMENT-IN-SUDAN.pdf

United Nations Office for Disaster Risk Reduction (UNDRR) (2024). The triple dividends of early warning systems and climate services. WMO. Link: https://www.preventionweb.net/news/triple-dividends-early-warning-systems-and-climate-services

World Bank (2025). Empowering Ethiopians by laying the digital foundations for economic growth. Link: https://www.worldbank.org/en/results/2025/06/30/empowering-ethiopians-by-laying-the-digital-foundations-for-afe-economic-growth

World Meteorological Organisation (WMO) (2025). A new era of regional coordination for early action in the Nile Basin countries. Link: https://wmo.int/media/magazine-article/new-era-of-regional-coordination-early-action-nile-basin-countries

Zerssa, G., Feyssa, D., Kim, D.-G., and Eichler-Löbermann, B. (2021). Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. Agriculture, 11(3), 192. doi: https://doi.org/10.3390/agriculture11030192