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D.3 Synthesis Summary of Literature Review and Mapping

Provision of a scoping study to assess the current landscape of early warning and Impact-based Forecast initiatives across Africa

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1. Introduction

Work Package 1 (WP1) provides an overview of the current landscape of Early Warning Systems (EWS) and Impact-based Forecasting (IbF) in Africa, including initiatives and projects, literature, climate trends, datasets and data portals, exposure and vulnerability information, AI/ML tools, and capacity-building and training activities. These outputs are captured in the Reference Catalogue and the Data Catalogue, deliverables of WP1. This synthesis is written to support the scoping study in translating the WP1 deliverables into design choices for the next phases of the project, in particular the development of regional pilots and action plans. The synthesis is intended as a guiding document. It brings together the different information components of WP1 into an integrated regional perspective. The synthesis directly supports WP3 (hazard prioritisation), WP4 (sustainability and ownership), and WP5 (regional pilot design).

1.1 Scope and analytical approach

The synthesis brings together the different outputs produced under WP1 in a consistent way. Information on initiatives and projects is used to explore the level of operational experience and institutional embedding. Literature and climate trends are used to place current activities in a broader and more forward-looking context. Datasets and data portals are considered in terms of availability, accessibility, and potential usability. Exposure and vulnerability datasets are examined as key building blocks for impact-based approaches. AI/ML tools are included to illustrate possible directions for innovation, where these appear realistic and relevant. Capacity-building and training activities are used to reflect on institutional readiness and longer-term sustainability. Together, these components provide a broad basis for discussing strengths, gaps and opportunities.

The synthesis is structured around a regional perspective (Western, Eastern, Central and Southern Africa), reflecting that hazards, institutional ecosystems, and data landscapes differ substantially across the continent. Note that RCC boundaries are not always clearly defined and should not be taken as fixed regional delineations. Within each region, all SEWA priority hazards are addressed in a consistent way: droughts and dry spells, riverine floods, flash floods, thunderstorms, dust storms, wildfires and smoke, cyclones, and heatwaves. While flood-related initiatives dominate the evidence base, this synthesis explicitly acknowledges that imbalance. It uses this approach to identify blind spots and strategic opportunities, ensuring that SEWA's pilot development is not driven solely by existing technical maturity, but also by emerging needs and future risks.

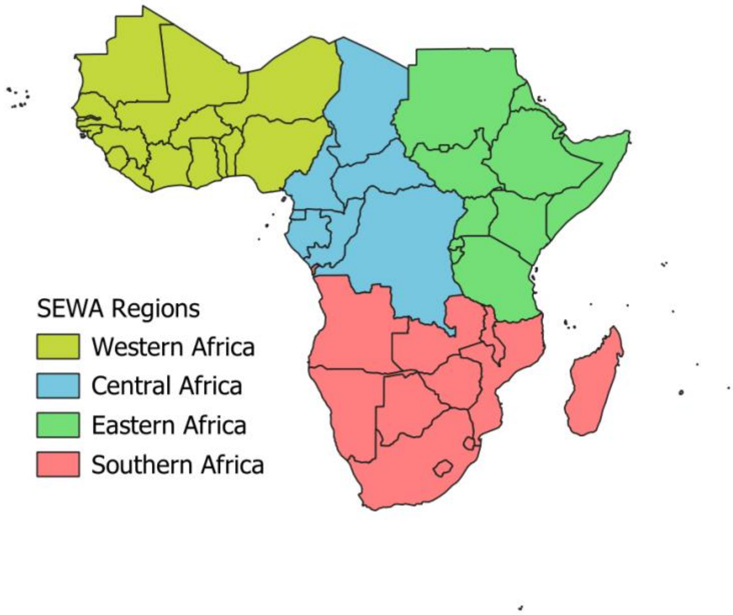


Figure 1: Map showing the 4 regions considered under the SEWA initiative.

2. Regional syntheses

2.1 Western Africa

Regional coordination and institutions

Western Africa benefits from a regional institutional framework. The AGRHYMET Regional Centre (AGRHYMET) provides continuity in regional monitoring, coordination, and capacity building, and supports knowledge exchange between national hydrometeorological services. AGRHYMET hosts the Regional Climate Centre (in demonstration phase since 2021) for West Africa and the Sahel (RCC-WAS) and convenes PRESASS, the regional seasonal climate outlook forum. The WMO Regional Specialized Meteorological Centre (RSMC) for West Africa, based in Dakar, contributes to the forecast process by providing severe weather guidance products to NMHSs.

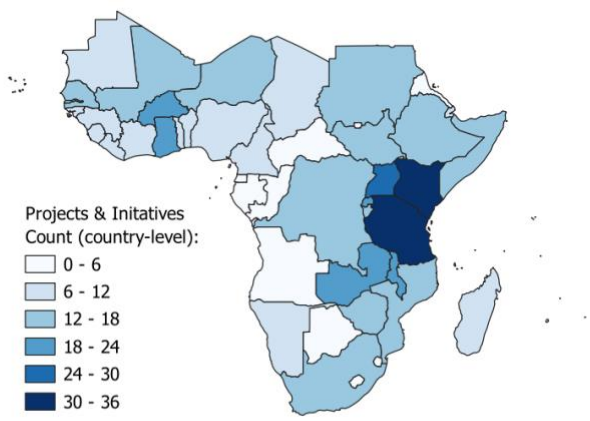


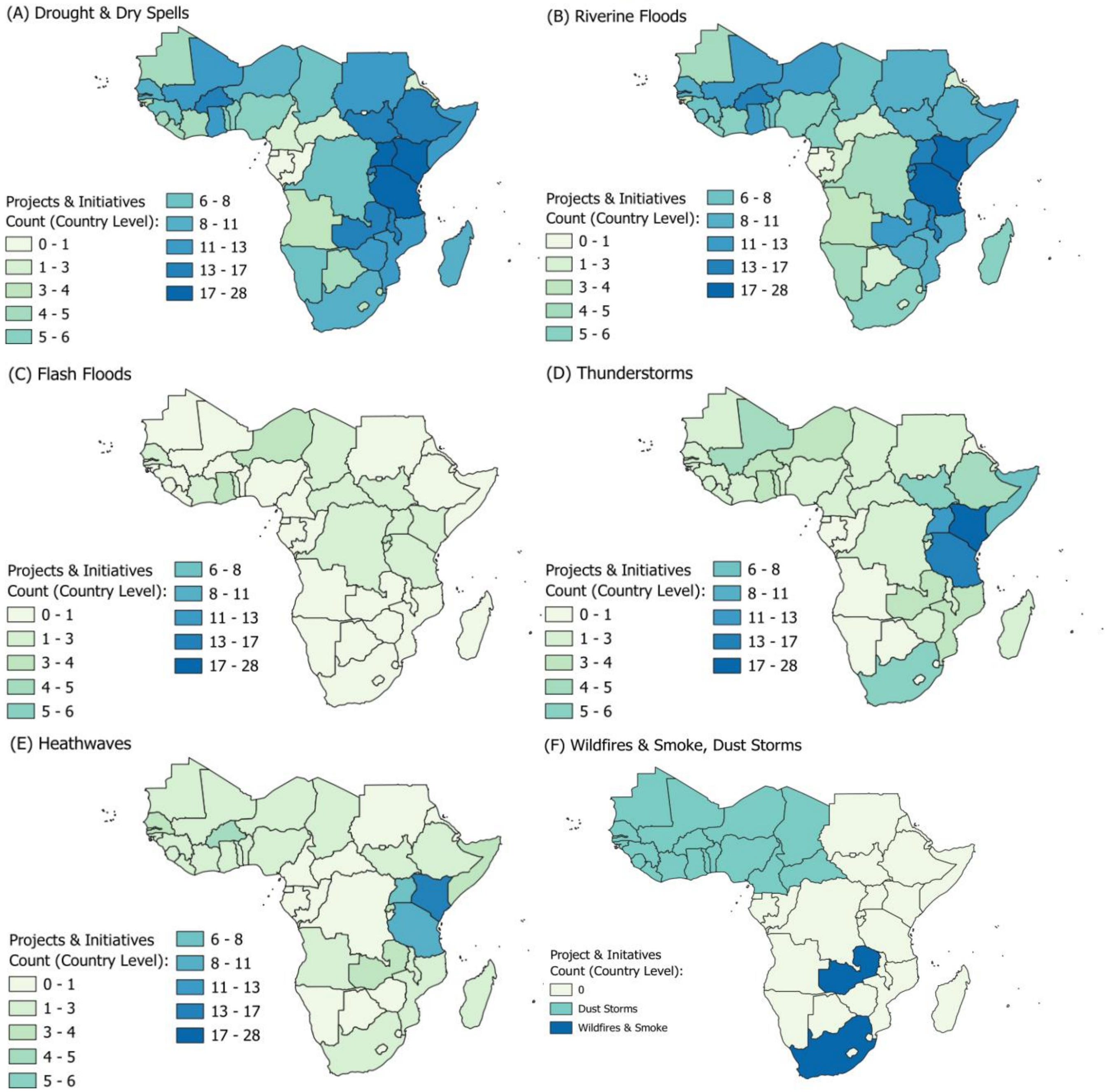
Figure 2: Map showing the country specific Project & Initiatives count based on the WP1 inventory.

Hazard profile and dominant contexts

Western Africa's hazard profile reflects a strong north-to-south gradient from arid and hyper-arid conditions in the Sahara, through the Sahel where drought, dust storms, and food security are the dominant early warning concerns, reflected in regional coordination mechanisms such as PRESASS and operational monitoring systems such as FEWS NET, to the more humid tropical south where riverine and flash flooding driven by intense convective rainfall and urban flood risk are the primary focus. This gradient operates at the sub-national level: Sahel countries such as Mali, Burkina Faso, and Niger document both drought and significant flood risk in their southern zones.

The WP1 inventory identifies 72 projects and initiatives for Western Africa, placing it second in inventory size after Eastern Africa (88) and ahead of Southern Africa (71), and nearly double to Central Africa (32). Activity spans 16 countries, with the highest concentration in Ghana (22 projects), Burkina Faso (20), Mali (17), and Niger (17). Countries with more recent investment are Liberia (10), Sierra Leone (10), and Guinea-Bissau (7). This distribution reflects what is recorded in the WP1 inventory; the reasons for concentration in these countries cannot be determined solely from this analysis. These investments are typically focused on strengthening climate information systems rather than on dedicated early warning systems (EWS). The hazard profile based on the focus hazards of the identified projects and initiatives is skewed: 51 riverine flood and 10 flash flood references (6 projects address both flood types), 45 droughts and dry spells, 15 thunderstorms, 7 heatwaves, 1 dust and smoke, and 0 wildfire references. This includes multi-hazard projects & initiatives.

This shows that Western Africa is heavily oriented toward flood and drought monitoring, forecasting, and warning, while heatwave, dust, and smoke, despite strong exposure in the Sahelian region, remain the least documented hazard types in the inventory. Western Africa, therefore, represents not a singular early warning context, but a combination of sub-regions with different dominant hazards and operating constraints.



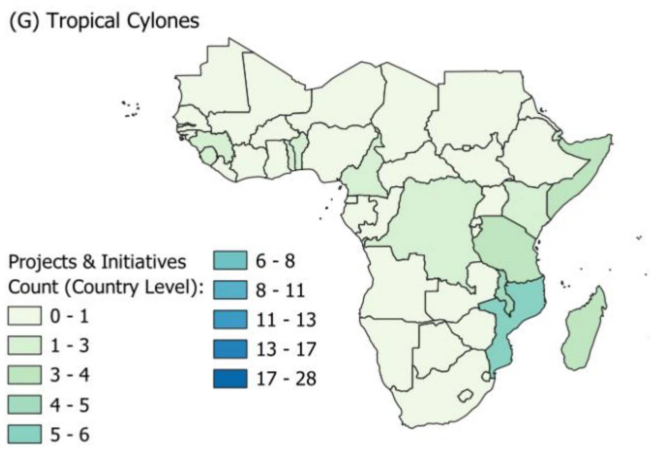


Figure 3: Number of projects and initiatives per country by hazard focus: (A) drought and dry spells, (B) riverine floods, (C) Flash Floods, (D) thunderstorms, (E) heathwaves, (F) Wildfires & Smoke and Dust Storms combined (each indicating a single project or initiative per country), and (G) tropical Cyclones. Counts are based on country-level mentions in the WP1 inventory and exclude projects with regional or continental scope. Projects addressing multiple hazards can contribute to more than one panel.

Climate trend and projections

These contrasting hazard contexts are not static: climate change is systematically amplifying both, increasing aridity and heat stress in the Sahel while raising the likelihood of intense rainfall and floods. In the Sahel, temperatures are rising faster than the global average, increasing evaporative demand and aridity, and multi-year droughts have become more frequent. Under higher warming levels, drought duration is projected to increase substantially in parts of the western Sahel (IPCC AR6). In coastal areas, evidence points to increases in intense rainfall associated with convection, with implications for both flash flooding and downstream riverine flooding (Taylor et al., 2017). Heat is emerging as a third major hazard. Projections indicate rapid growth in the frequency of extreme heat exposure and heatwave occurrence across Western Africa (Thiery et al., 2021). Despite this trajectory, heat-related early warning systems remain significantly less developed than those for drought and floods, creating a mismatch between evolving risk and early warning priorities. Changes in aridity and land–atmosphere conditions also interact with dust risk and air-quality impacts, reinforcing the relevance of sand and dust storm monitoring and early warning services.

Forecasting challenges

These hazard characteristics also create forecasting challenges across different time scales. Floods and severe storms are driven by organised convection (e.g., squall lines and mesoscale convective systems), producing highly localised, short-lived extremes that remain difficult to predict accurately in space and time, constraining short-lead warnings for flash floods and urban impacts (Burton et al., 2022). For drought and dry spells, the key challenge is translating probabilistic seasonal outlooks into actionable triggers for preparedness and early action, a well-recognised limitation in operational drought and food security decision support (FEWS NET). Dust forecasting is constrained by uncertainty in emissions and transport processes and is typically treated within specialised warning and advisory frameworks (WMO SDS-WAS). Wildfire and smoke warnings depend on combining meteorology with vegetation dryness and ignition conditions, so skill is often limited by non-meteorological drivers. For heat, forecast skill is generally higher than for rainfall, but operational warnings remain constrained by the limited use of heat–health thresholds (WMO/WHO heat–health guidance).

Major programmes and financing landscape

Major donor programmes support early warning development in Western Africa. The Climate Risk and Early Warning Systems initiative (CREWS) funds 7 country and regional projects (Burkina Faso, Guinea, Mali, Niger, Togo, Benin, and West Africa Regional). CREWS investments strengthen observation infrastructure, forecasting capacity at NMHSs, warning dissemination mechanisms, and community-level preparedness, typically covering multiple elements of the EWS chain within a single country project. The Severe Weather Forecasting Programme (SWFP) West Africa provides operational severe weather guidance products, supports forecaster training in synoptic analysis and nowcasting, and promotes impact-based forecasting practice through regional workshops and Training-of-Trainers programmes. Continental programmes also extend to the region: ClimSA strengthens climate services capacity and service delivery for decision-making across sectors, including disaster risk management, agriculture, and health; SAWIDRA is oriented toward strengthening disaster risk reduction capability, particularly through improved severe weather warning practice and the operational use of satellite-based information products.

Of the 72 projects, 28 remain at the project level, and 22 are operational, giving an operational share of 31%, below Eastern Africa (40%) and Southern Africa (50%). 13 projects cover the full EWS chain, while 37 address monitoring and forecasting, and 26 include response or preparedness components. Urban resilience programmes account for 7 projects, and transboundary flood management is concentrated in the Volta (3 projects) and Mono (2 projects) basins. The FANFAR project remains the only clearly identified regional-scale operational flood forecasting and alert system. This indicates that while Western Africa has a substantial number of initiatives, many remain project-based rather than institutionally embedded, and the translation from individual projects to coordinated, sustained regional services remains a key gap.'

Capacity building

Western Africa has a history of training supported by AGRHYMET, the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), covering both technical tools and broader EWS operation. The WP1 inventory identifies 16 training entries for the region, second to Eastern Africa (19), but structurally different. Training is delivered through 3 WMO RTCs (EAMAC, AGRHYMET, NiMet Lagos) and project-based workshops under SWFP, CREWS, and AICCRA. CREWS/SWFP workshops cover synoptic meteorology, nowcasting, severe weather forecasting, and impact-based EWS (including a Training-of-Trainers workshop in Dakar). AICCRA and AGRHYMET co-deliver training on extended seasonal forecasts for agriculture and water resources and on communicating seasonal forecasts through PRESASS. A dedicated flash flood guidance system (FFGS) training programme operates for the region. However, the training landscape lacks a permanent regional training academy comparable to ICPAC's Training Academy.

Western Africa's training is predominantly project-funded, meaning continuity depends on renewal of external support cycles. Training remains most strongly focused on flood and drought. Impact-based forecasting approaches are increasingly referenced, but only 2 projects with dedicated IBF training components are identified: RAPIDE (Strengthening Impact-Based Early Warning in Burkina Faso) and SWFP West Africa. This makes IbF the most underdeveloped EWS capability relative to the region's project volume.

Exposure, vulnerability, and impact-based warning

Exposure and vulnerability datasets for populations, settlements, and infrastructure are widely available through global products (e.g., WorldPop and the JRC Global Human Settlement Layer), but within the West Africa projects captured in the SEWA catalogue, exposure/vulnerability inputs are typically referenced in generic terms (e.g., "urban data", "flood risk data", "vulnerability assessments") and appear most often in project-based risk mapping and resilience studies rather than as maintained layers embedded in routinely updated operational EWS workflows.

Several NMHSs in the region do issue impact-based or CAP-based alerts: Ghana Meteorological Agency (GMet) publishes a daily 24-Hour Impact-Based Forecast on its products portal, and Météo Niger publishes CAP-formatted meteorological alerts (CAP/RSS feed with active and archived alerts) on its public warning page.

AI/ML and innovation

AI and machine-learning applications are emerging, particularly for rainfall nowcasting, NWP bias correction/post-processing, and seasonal forecast interpretation. The SWIFT programme has been a key driver, developing satellite-based nowcasting techniques for West African mesoscale convective systems. Operational uptake remains limited: the 6 identified AI/ML tools are concentrated in research and pilot settings, and none seem to be embedded in routine NMHS operations at scale. The WP1 findings suggest adoption is most likely where AI strengthens existing workflows rather than creating parallel systems.

Implications for SEWA pilot design

In summary, Western Africa combines regional institutions, a substantial project inventory (72 initiatives across 16 countries), and advanced technical capacity for drought and flood monitoring, forecasting, and warning. However, development remains fragmented, and the transition to sustained operational services is uneven.

The WP1 inventory shows that the region does not lack projects. It rather lacks consolidation and operational embedding. Several systems address similar hazards in overlapping geographies without clear integration into sustained national workflows or full EWS-chain implementation.

For SEWA, the strategic implication is therefore not to introduce additional stand-alone pilots, but to consolidate and align existing initiatives, prioritising those already operational or institutionally embedded (e.g., FANFAR, SWFP, RCC-WAS mechanisms).

Advice for pilot design

1. Build explicitly on operational systems rather than creating new parallel project structures.
2. Support the transition from project-level implementation to institutionalised national service delivery.
3. Integrate impact-based components into existing flood and drought monitoring architectures instead of establishing separate IbF tracks.
4. Recognise the north–south hazard contrast and avoid uniform regional assumptions in system design.
5. Consider underrepresented heatwave, dust storms & and smoke early warning.

For SEWA, the region is well-suited to testing how existing initiatives can be integrated into durable services with stronger impact-based components. Pilot design should explicitly recognise the north-south contrast and avoid assuming a uniform regional hazard context.

2.2 Eastern Africa

Regional coordination and institutions

Eastern Africa benefits from a well-established regional institutional framework centred on the IGAD Climate Prediction and Applications Centre (ICPAC). ICPAC hosts the Regional Climate Centre function, convenes GHACOF (Greater Horn of Africa Climate Outlook Forum), operates the East Africa Hazard Watch platform, and runs a Training Academy for Early Warning Experts. This provides coordination and continuity and supports knowledge exchange between national services. RSMCs also play a key role: RSMC Nairobi (hosted by KMD) and RSMC Dar es Salaam co-lead SWFP-Eastern Africa, providing severe weather guidance to NMHSs.

At the same time, capacity and operational maturity remain uneven across Member States (identified during the workshop). ICPAC provides a strong regional backbone, but national expertise and routine operational embedding vary country by country

Hazard profile and dominant contexts

The region's early warning landscape has been shaped by major drought events, including the 2011 Horn of Africa famine, the 2017 drought, and the 2021–2022 drought. This history is reflected in drought-focused systems: the East Africa Drought Watch provides near-real-time monitoring using Earth observation, and the Eastern Nile Technical Regional Office (ENTRO) supports drought early warning functions for the Nile Basin (Nile DEWS). Heatwaves are increasingly included in multi-hazard frameworks, though dedicated heat–health early warning systems remain limited.

The WP1 inventory identifies 88 projects and initiatives in Eastern Africa, the largest inventory across all SEWA regions. Activity is concentrated in a small subset of countries (Tanzania, Kenya). This concentration is an observed data pattern from the inventory; the reasons cannot be determined solely from this analysis. The hazard distribution shows the most balanced hazard profile of any SEWA region, alongside a strong representation of thunderstorms (reflecting Lake Victoria's large water body risks and highland convection).

Flooding is predominantly riverine in character: 57 projects reference riverine floods and 4 reference flash floods (3 address both), compared to 51 drought and dry spell references, 31 thunderstorms, 25 heatwaves, and 11 tropical cyclones. Heatwaves and tropical cyclones are typically referenced within multi-hazard frameworks rather than as dedicated operational systems.

Flooding presents distinct challenges across settings, and the response remains distributed: riverine flooding along transboundary basins, particularly the Nile, is supported through ENTRO's flood forecasting and early warning functions. Urban flood warning approaches are emerging through city-focused pilots, and Lake Victoria thunderstorms pose acute risks to fishing communities and lake transport, addressed through initiatives such as the WISER HIGHWAY nowcasting project and CRESTI for maritime safety. In addition, landslides in highland regions, dust and air quality hazards in arid zones, severe weather, and climate-sensitive disease risks are increasingly recognised in national multi-hazard frameworks.

Although ENTRO provides structured flood forecasting and early warning functions for the Eastern Nile sub-basin, the WP1 inventory suggests that Eastern Africa does not yet have a single unified flood forecasting platform covering the full ICPAC region comparable in scope and operational integration to FANFAR in West Africa or SARFFGS in Southern Africa. Flood initiatives exist, but they remain basin-specific or programme-based rather than consolidated into a single regional operational framework.

Eastern Africa is a multi-hazard system: drought-dominant arid and semi-arid zones, convective storm regimes in highland and lake environments, and cyclone-affected coastal sub-regions operating under different hazard and forecast timescales.

Climate trends and projections

These hazard patterns are further shaped by a rapidly changing climate, which is amplifying both wet and dry extremes across Eastern Africa. Climate projections for Eastern Africa indicate increasing hydrological variability. Heavy precipitation frequency and intensity are projected to increase across much of the region (IPCC AR6, high confidence), while drought risk is also expected to persist and potentially intensify in parts of the Horn (particularly southern Ethiopia, Somalia, and eastern Kenya). This points to a future characterised by rapid transitions between dry and wet extremes and a growing relevance of compound events. Heat is projected to increase substantially, but remains under-addressed in operational early warning practice compared with drought and flood.

Forecasting challenges

These climate and hazard characteristics also create forecasting challenges. A fundamental constraint across all regions, including Eastern Africa, is the sparse in situ observation network: limited ground-based weather stations, very low radiosonde (upper-air) observation density, and limited radar coverage reduce forecast skill and constrain data assimilation in NWP models. In addition, Eastern Africa's complex topography, including the Ethiopian Highlands, the Rift Valley, and the Lake Victoria basin, creates sharp spatial gradients and mesoscale circulations, meaning large-scale climate drivers translate into rainfall in highly heterogeneous ways (Palmer et al., 2023). Rainfall variability reflects the seasonal migration of the ITCZ and Indian Ocean variability, including the Indian Ocean Dipole, alongside strong orographic controls on where convection initiates and how storms organise (Palmer et al., 2023; Blau & Ha, 2020). Much wet-season precipitation is delivered by deep convection, which has limited predictability beyond short lead times because small errors can rapidly amplify into large errors in rainfall timing and intensity (Craig et al., 2021). As a result, global forecast models often struggle to capture the location, timing, and intensity of rainfall over complex terrain and lake–land environments, and convection-permitting evidence shows that representing Lake Victoria-region convective systems remains demanding—leaving uncertainty that directly affects both flood warnings (extremes) and drought warnings (accumulated deficits) (van Lipzig et al., 2023).

Major programmes and financing landscape

Major donor programmes have strengthened capacity. CREWS supports the development of multi-hazard EWS across multiple Eastern African countries. A defining feature of the Eastern Africa landscape is the scale and continuity of WISER-supported activity. The WP1 inventory reflects a dense WISER footprint spanning service delivery, communication and uptake, observation strengthening, and nowcasting, contributing to both technical depth and coordination complexity across countries.

Of the 88 projects, a substantial share is classified as operational, but the WP1 inventory indicates that many initiatives remain programme/projects based rather than consolidated into sustained national workflows. The EWS chain coverage indicates that full-chain implementation exists, but is not uniform. Monitoring and forecasting dominate, while dissemination and response vary strongly between countries and project types.

Capacity building

Capacity building benefits from ICPAC's Training Academy and the integration of training into major programs such as WISER and CREWS. The WP1 inventory identifies 19 training entries for the region. Training delivery is not limited to ICPAC: it includes project and program workshops (e.g., WISER, CREWS), WMO-linked training activities, and partner-delivered short courses on forecasting, nowcasting, communication, and CAP-related implementation. SWFP-Eastern Africa is active in the region: KMD hosts RSMC Nairobi and co-leads the sub-programme alongside RSMC Dar es Salaam, with members including Burundi, Djibouti, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Tanzania, and Uganda. SWFP activities include severe weather forecasting training, NWP capacity building, and transition to impact-based forecast and warning services, supported through CREWS East Africa and the FINKERAT project.

Training continuity is comparatively strong at the regional level, but translation into sustained national operations remains uneven, especially for advanced approaches such as IbF, anticipatory action triggers, and routine integration of exposure/vulnerability layers.

Exposure, vulnerability, and impact-based warning

Exposure and vulnerability datasets (population, settlements, agriculture, infrastructure) are widely available (e.g., WorldPop, JRC GHSL, SPAM, WorldCereal), but are still inconsistently integrated into routine operational warning workflows; hazard monitoring and forecasting are generally stronger than systematic impact translation. Regionally, ICPAC's East Africa Drought Watch supports drought situational awareness (EO + indicators + mapping), yet this does not automatically translate into nationally maintained exposure/vulnerability layers linked to day-to-day alerting. Several NMHSs now publish CAP-based warnings (e.g., Kenya and Ethiopia). Thresholds are often not tailored to the local context and are often based on WMO standards. Uganda publishes national advisories (e.g., agro-meteorological bulletins) and is reportedly upgrading toward CAP integration under CREWS support. Overall, the uneven operationalization of exposure/vulnerability layers limits targeted preparedness and consistent, impact-based warnings at scale in a rapidly changing risk context.

AI/ML and innovation

AI and machine-learning applications are emerging across nowcasting, forecast post-processing, and indicator development. Machine-learning-based drought indicators are incorporated into the East Africa Hazard Watch, but uptake across national services remains uneven, with adoption varying strongly between countries and rarely extending beyond pilot or experimental use.

Implications for SEWA pilot design

In summary, Eastern Africa combines strong regional coordination through ICPAC, the highest number of projects in the inventory (88 initiatives), and a balanced drought–flood profile. The WP1 inventory shows that the region lacks no initiatives. It faces coordination complexity and uneven national operational embedding.

Advice for pilot design

1. Build on ICPAC's coordination and training capacity, while explicitly targeting national operational embedding in lower-capacity Member States.
2. Scale impact-based approaches by integrating exposure and vulnerability layers into routine workflows, avoiding parallel IbF tracks where hazard monitoring is already strong.
3. Recognize sub-regional contrasts (arid drought regimes, lake/highland convection, cyclone-affected coastal zones) and avoid uniform regional assumptions in system design.

For SEWA, the region is well-suited to demonstrating how existing platforms and program investments can be embedded nationally. In addition, this region shows a relatively high level of readiness to move from EW to IbF forecasting systems.

2.3 Central Africa

Regional coordination and institutions

Central Africa's regional coordination for early warning is less consolidated than in Eastern, Western, or Southern Africa. The Climate Applications and Predictions Centre for Central Africa (CAPC-CA) serves as the Regional Climate Centre (in demonstration phase since June 2024) and convenes PRESAC (Prévision Saisonnière en Afrique Centrale), the seasonal climate outlook forum. The region lacks a multi-hazard platform comparable to East Africa's Hazard Watch. Cross-border operational early warning also remains limited. No dedicated RSMC for severe weather forecasting operates within the Central Africa sub-region; SWFP-Central Africa draws on contributions from global WMC centres.

The Lake Chad Basin is a notable exception, with a dedicated EWS spanning Cameroon, Chad, Niger, Nigeria, and the Central African Republic (Integrated Water Resources Management and Early Warning System for Climate Change Resilience in the Lake Chad Basin), while the Congo Basin is the focus of emerging early warning development.

Hazard profile and dominant contexts

Flood-related hazards are most prominent in the WP1 inventory for Central Africa. This is the most flood-dominated hazard profile of any SEWA region: 11 of 32 projects address flooding alone, while 3 focus solely on drought. The remaining 14 cover both hazards within multi-hazard frameworks. This indicates an imbalance. Drought risk is relevant in multiple Central African contexts, but it is weakly reflected as a dedicated EWS focus in the WP1 inventory outside multi-hazard programmes.

Urban resilience projects account for 6 of 32 entries, the highest share of any region. This reflects rapid urbanisation in flood-prone capital cities, where flash flood risk is the most immediate EWS demand. Riverine flooding is also significant in the Congo basin and in the Lake Chad and Logone–Chari basins, and is addressed by basin- and water-management initiatives. However, the region has only 1 clearly identified transboundary EWS project (Lake Chad Basin), compared to more transboundary projects in other SEWA regions.

Thunderstorms and severe weather are addressed largely through SWFP Central Africa. Heatwaves are referenced, but dedicated heat–health early warning is absent from the inventory. Other hazards, such as dust storms, wildfires, and tropical cyclones, are not prominent in the WP1 inventory for Central Africa, suggesting they might not be priority hazards in the region.

Central Africa, therefore, represents a less diversified multi-hazard early warning regime. It is primarily a flood-oriented landscape, operating under short lead times and constrained by limited observation density and limited regional consolidation. Within the region, DRC accounts for a large share of literature and project entries. Other countries, such as Gabon, Equatorial Guinea, and São Tomé and Príncipe, are notably underrepresented, which may reflect both actual activity levels and limitations in inventory coverage. Chad's placement in this region is a boundary decision: its northern territories are climatologically closer to the Sahel, and Chad spans both Sahelian and more humid southern zones.

Climate trends and projections

Climate projections for Central Africa indicate increasing risks from both heavy rainfall and heat extremes (IPCC AR6, high confidence for heavy precipitation increases at the continental scale). At the same time, rainfall projections for the Congo Basin show lower model agreement than in other regions, complicating long-term planning and infrastructure design. Rising heat extremes are more robustly projected and are likely to become an increasingly operationally relevant hazard, despite limited current EWS attention.

Forecasting challenges

Forecasting challenges in Central Africa are strongly shaped by observation gaps, sparse hydrometric networks, and the complexity of convection-dominated rainfall regimes (African Union, 2021; WMO, 2024). In the Congo Basin in particular, limited in situ observations constrain the evaluation and calibration of rainfall products and hydrological states, contributing to weak confidence in longer-lead rainfall signals and continued reliance on satellite and reanalysis proxies (Nicholson et al., 2021; Fatras et al., 2021). At shorter lead times, flash flood prediction remains highly sensitive to storm placement and intensity because triggering rainfall is often localised and convective, leaving limited tolerance for spatial and timing errors in guidance and warnings (WMO, 2024; Zhao et al., 2025). These constraints limit the feasibility of impact-based warning without stronger foundational monitoring and data integration (Hydromet Alliance, 2024).

Major programmes and financing landscape

Major donor programmes include CREWS projects (e.g., Cameroon, Chad, DRC), SWFP Central Africa (covering multiple countries), and continental programmes such as ClimSA, SAWIDRA, and ENACTS. In Central Africa, ClimSA primarily strengthens climate services capacity and uptake of seasonal information for DRM and sector planning; ENACTS strengthens climate data and monitoring for seasonal decision support; and SAWIDRA supports DRR-oriented early warning capacity. SAWIDRA is often linked to improving access to and use of satellite-based information for operational monitoring and warning-relevant products. In addition, World Bank investments are prominent, particularly for urban resilience and flood risk management. The region lacks a sustainable multi-year climate services programme, and the transition from externally funded initiatives to sustained operational services remains limited.

Capacity building

Capacity building is primarily delivered through projects. SWFP Central Africa supports training in severe weather forecasting, and CREWS-funded training has focused on forecaster skills and flash-flood forecasting. PRESAC supports the co-production of seasonal outlooks through forum processes. Training on platforms such as MYDEWETRA has introduced national services to monitoring and forecasting tools. The WP1 inventory identifies 8 training entries for the region, the lowest of any region. Coverage is uneven across countries: training activity is most documented for DRC and Cameroon, while Central African Republic, Gabon, Equatorial Guinea, and São Tomé and Príncipe have minimal documented training in the inventory.

Training coverage is also narrow in scope relative to other regions, with limited evidence in the WP1 inventory of recurring training on IbF, anticipatory action, advanced GIS/remote sensing for DRM, or operational post-processing methods. Within the region, training documentation is most concentrated in DRC and Cameroon, which host the majority of CREWS/SWFP and MYDEWETRA activities; Central Arican Republic, Gabon, Equatorial Guinea, São Tomé and Príncipe, and the island states have minimal or no documented training coverage in the WP1 inventory."

Exposure, vulnerability, and impact-based warning

Exposure and vulnerability data are broadly available through global datasets but are not routinely integrated into operational systems. This limits impact-based warning, particularly for floods in urban settings where exposure patterns change rapidly and where targeted messaging requires reliable population and infrastructure information. A notable exception is Meteo Tchad, which issues CAP-based alerts through ClimWeb (meteotchad.org), representing one of the few documented instances of operational warning dissemination infrastructure in the region.

AI/ML and innovation

AI/ML applications appear less developed than in other regions, with only a small number of region-specific tools identified in the WP1 evidence base. This is consistent with the broader infrastructure pattern: without stronger observation and data integration, the foundational inputs needed for AI/ML-enhanced forecasting are not yet in place.

Implications for SEWA pilot design

In summary, Central Africa is characterised by weaker regional operational coordination, a dominant focus on flood hazards, and limited transboundary early warning despite the presence of major river systems. The WP1 inventory indicates that the region is still in a foundational build phase compared to other SEWA regions. As shown by fewer initiatives, lower operational embedding, and narrower hazard coverage.

For SEWA, the strategic implication is therefore not to introduce stand-alone pilots that depend on high observation density, but to strengthen foundations and consolidate entry points where there is traction. In addition, the relevance of drought and dry spells to EWS should be further investigated.

Advice for pilot design

1. Prioritise foundational monitoring and data integration as a prerequisite for scalable forecasting and impact-based warning.

2. Build on the strong flood focus by consolidating urban resilience initiatives into operational flash-flood warning workflows that NMHSs can sustain.

3. Use PRESAC/CAPC-CA as an anchor to develop seasonal decision-support pathways for drought and food security, addressing the current underrepresentation of standalone drought EWS in the WP1 inventory.

Central Africa is therefore best characterised as a low-density but high-need early warning landscape. It is flood-dominant, urban-focused, and constrained by foundational observation and operational service capacity. For SEWA, the region offers high-impact entry points where strengthening monitoring and consolidating urban flood warning can create durable progress without relying on parallel systems.

2.4 Southern Africa

Regional coordination and institutions

Southern Africa benefits from an established regional coordination framework through the SADC Climate Services Centre (SADC-CSC), which convenes SARCOF (Southern African Regional Climate Outlook Forum) and serves as WMO RCC (in demonstration phase since June 2024). Although the SADC's coordination role is strong, the institute faces capacity limitations in staffing (according to the workshop findings). The Regional Specialized Meteorological Centre (RSMC) in Pretoria provides severe weather forecasts and hosts the Southern Africa Regional Flash Flood Guidance System (SARFFGS). South Africa plays a central role through the South African Weather Service (SAWS). The Indian Ocean island states (Madagascar, Comoros, Mauritius, Seychelles, and Réunion) fall within the SADC footprint for climate services but also maintain distinct institutional relationships through the Indian Ocean Commission (IOC), which runs a dedicated hydromet programme. These islands have specific tropical cyclone hazard exposure that might warrant separate consideration within SEWA pilot design.

Southern Africa has made notable progress on transboundary early warning, particularly in shared basins. The WP1 inventory identifies several transboundary projects. The Zambezi Basin alone has three flood forecasting and early warning initiatives. The Cuvelai Basin is covered by CUVEWIS, providing cross-border hydrometeorological information for flood early warning between Namibia and Angola. The Songwe River Basin cooperation between Malawi and Tanzania adds a further cross-border system. In parallel, SARFFGS operates across multiple SADC countries, with dedicated national implementations, providing a WMO-standard flash flood guidance framework for short-lead flood warning.

With 71 projects, Southern Africa has the third-largest WP1 inventory, after Eastern Africa (88) and Western Africa (72). Activity is distributed across multiple countries, with project density in Malawi, Zambia, Zimbabwe, South Africa, and Mozambique. SADC regional programmes account for 7 projects. Notably, 35 of 71 projects (49%) are classified as operational, the highest share among SEWA regions.

This count of operational systems is concentrated in South Africa, which hosts SAWS, RSMC Pretoria, SARFFGS, ADEWS, and the SANSA fire monitoring system. The gap between South Africa's operational capacity and that of the wider SADC membership is a defining feature (determined during the workshops). This means Southern Africa is best characterised as an overall operationally mature region, but with uneven national embedding.

Hazard profile and dominant contexts

Southern Africa's hazard profile is characterised by both drought and flood risks. Drought is addressed through regional resilience initiatives (SADRI) and national drought monitoring systems (ADEWS in South Africa). Riverine and flash flooding are addressed through SARFFGS and community-based flood EWS initiatives in several countries. The inventory lists 9 flood-only, 10 drought-only, and 40 that address both. This is less balanced than Eastern Africa but more so than Western Africa or Central Africa.

Tropical cyclones are addressed in 11 projects, concentrated in the eastern and island portions of the region: Madagascar, coastal Mozambique, and the Indian Ocean island states, reflecting the Southwest Indian Ocean cyclone track. Cyclone risk is also central for island states and coastal zones and is explicitly addressed through ClimSA's Indian Ocean programming. Wildfires are operationally addressed through systems such as South Africa's Advanced Fire Information System (SANSA). Heatwaves appear in 8 of 71 projects, including WEATHER Project South Africa for heat–health research, a relatively large proportion compared to other regions.

Climate trends and projections

Climate projections indicate increasing risks from multiple hazards. Heavy precipitation events are projected to intensify (IPCC AR6, high confidence), while continued warming is expected to amplify drought stress, especially in the southwest of the region. Tropical cyclones affecting the Southwest Indian Ocean are projected to become more intense, increasing the potential for extreme rainfall and coastal impacts. Heat extremes are projected to increase across the region and are likely to become a more dominant hazard over time, despite limited dedicated early warning capacity.

Forecasting challenges

Forecasting challenges include cyclone track and intensity prediction, convective rainfall over complex terrain, and interactions among multiple weather systems across a geographically diverse region. While the RSMC in Pretoria provides regional guidance, national capacity varies substantially across SADC members, contributing to uneven forecast use and warning consistency across borders.

Major programmes and financing landscape

Major donor programmes are active in the region. CREWS supports SWFP Southern Africa and 3-country projects (Malawi, Mozambique, Zambia), reflecting CREWS' more targeted investment in the region. WISER is present through multiple projects (e.g., WISER EWSA and WISER Zambia), supporting nowcasting and short-range forecasting development alongside community-focused early warning co-production. WISER EWSA (2023–2025) additionally delivered structured alert dissemination, community observer networks, and operational integration into SAWS. The World Bank supports both regional initiatives and national hydromet and resilience investments.

The Indian Ocean Commission (IOC) Hydromet Programme provides a dedicated regional hydromet framework for the Indian Ocean island states. Madagascar, Comoros, Mauritius, Seychelles, and Réunion are covered by supporting cyclone preparedness, climate services, and hydromet infrastructure development for member states with distinct hazard exposure and institutional arrangements separate from the SADC framework.

Impact-based forecasting is the most operationally embedded of any SEWA region. SAWS delivers operational impact-based forecasts and warnings as a routine national service, not as a project or pilot. Other providers of impact-based or CAP-based alerts in the region include the Malawi Meteorological Services, Zimbabwe's Meteorological Services Department, and the Zambia Meteorological Department. The observation infrastructure includes multiple projects, and Southern Africa is the only SEWA region where radar data are systematically referenced in the WP1 inventory, reflecting South Africa's radar network and its integration into regional forecasting. Copernicus C3S products and SEAS5 are referenced more often than in other regions.

Overall, the WP1 inventory suggests a relatively strong operational foundation, but continued reliance on targeted investments to extend operational methods and standards beyond South Africa into the wider SADC membership.

Exposure, vulnerability, and impact-based warning

As in other SEWA regions, exposure and vulnerability data are broadly available through global datasets but are not consistently integrated into operational systems. Where impact-based warnings are issued (e.g., SAWS), integration of exposure data into warning thresholds and messaging remains an area for development. This limits impact-based warning, particularly for cyclones and floods, where understanding exposed populations and critical infrastructure is essential for effective preparedness and response.

Capacity building

Capacity building has a distinctive structure. The WP1 inventory identifies 13 training entries, with a defining feature being university-based degree programmes, alongside specialised meteorological training (including SAWS-linked training) and programme-delivered workshops (e.g., WISER EWSA). However, training coverage is geographically concentrated in South Africa and does not extend evenly across the SADC membership, creating the same internal asymmetry that characterises the region's operational capacity. This reinforces a key implementation challenge: strong centres of expertise exist, but transfer into sustained national operations is uneven.

Implications for SEWA pilot design

In summary, Southern Africa benefits from established coordination through SADC-CSC and SARCOF, with concentrated operational capacity in South Africa and regional support through the RSMC and SARFFGS. The WP1 inventory indicates a comparatively mature operational landscape (50% operational classification). At the same time, it is identifying asymmetry in which South Africa's operational systems are not replicated across the wider SADC membership. Regional mechanisms exist and appear functional, but uptake and technical depth vary across countries. This results in uneven EWS coverage.

For SEWA, the implication is therefore not to create new stand-alone systems, but to extend existing operational mechanisms and reduce the gap between stronger and weaker national services.

Advice for pilot design

1. Build on existing regional operational systems (SARFFGS, RSMC Pretoria guidance, SAWS IbF practices) rather than creating parallel projects.
2. Prioritise homogenisation of service capacity across SADC by defining minimum operational requirements and practical pathways to reach them (methods, training, routines, and staffing models).
3. Extend impact-based forecasting by adapting SAWS methods and thresholds for wider Member State uptake rather than building separate IbF pilots that are not embedded in national workflows.
4. Use innovation and AI selectively to strengthen existing workflows (e.g., post-processing, bias correction, exposure overlays, decision-support automation).

For SEWA, the region is well suited to demonstrating how existing regional systems and operational practices can be rolled out into durable national service especially for cyclones, floods, drought and impact-based warning, while using targeted innovation to close remaining operational gaps.

3. Cross-cutting gaps and opportunities for SEWA pilot design

A first cross-cutting gap is the imbalance between hazard monitoring and impact-oriented decision support. Across regions, operational systems tend to be strongest in climate monitoring, seasonal forecasting, and hazard detection, while the translation of hazard information into decision-relevant warnings remains less developed. Exposure and vulnerability datasets are widely available through global products and, in some sectors, regional layers, but they are not routinely integrated into operational workflows. This limits impact-based warning and constrains targeted preparedness, especially in rapidly growing urban areas, informal settlements, and regions with high dependence on rain-fed agriculture. The gap is not primarily a lack of data, but a lack of standardised methods, institutional ownership data discoverability and exchange between institutions, and operational routines that make impact translation repeatable and trusted.

A second gap is sustainability and operational consolidation. Across the WP1 inventory, early warning activity is frequently project-driven, with parallel platforms, short-lived pilots, and fragmented tools that are difficult to maintain once external support ends. The transition from externally funded initiatives to sustained operational services remains limited in all regions, including those with strong regional hubs. This creates discontinuity in staffing, system maintenance, institutional learning, and it reduces the return on investment from training and technology upgrades. In practice, national services often carry multiple overlapping tools with inconsistent governance, limited resources for maintenance, and unclear sustainability pathways from pilot to national operations.

A third gap concerns forecasting performance for rainfall extremes. In multiple regions, the most damaging floods are driven by convection and mesoscale storm systems that remain difficult to predict at the required spatial and temporal scales for early warning. This limitation is partly due to the sparse observation networks and, consequently, a lack of data assimilation in numerical weather prediction models. These challenges also complicate drought monitoring, where rainfall deficits depend on the accumulation of uncertain rainfall estimates over time.

A fourth gap is multi-hazard balance. Drought and flood dominate operational early warning investment across all regions, reflecting recent crises and high societal exposure. Heat is rising rapidly and is increasingly recognized as an extreme hazard, yet dedicated heat–health early warning capacity remains limited. Dust storms represent another unevenly operationalised hazard, particularly across the Sahel, with impacts on health, transport, aviation, and agriculture. Dust is often treated as a secondary hazard or only incorporated through sector-specific applications. Other hazards, such as wildfire and smoke, compound floods, and thunderstorms, are addressed in selected settings but are not consistently integrated into multi-hazard operational practice. This creates a growing mismatch between evolving climate risk and the hazard coverage of operational systems.

A fifth gap relates to interoperability and shared standards. Across the inventory, platforms and workflows vary widely in data formats, metadata quality, and the way warning thresholds, verification, and uncertainty are communicated. This limits cross-border comparability, makes replication expensive, and prevents regional institutions from scaling successful approaches across member states. It also complicates the integration of emerging methods such as AI/ML, which are most likely to be adopted where they strengthen existing operational workflows (e.g., bias correction, post-processing, nowcasting guidance) rather than introducing parallel systems with new dependencies.

SEWA is well-positioned to focus less on launching new standalone platforms and more on strengthening the enabling conditions that allow early warning improvements to persist and scale, building where possible on established continental and regional investments such as ClimSA and related programmes. This includes:

- operationalising impact-based workflows through standardised methods for linking hazard information to exposure and vulnerability
- designing governance and handover pathways that convert project outputs into sustained services;
- interoperable data and modelling pipelines that align with existing platforms and can be adopted across countries and regions.

In all regions, pilot design will benefit from explicitly recognising sub-regional hazard contexts and institutional capacity differences, rather than assuming a uniform regional approach.

4. Connection to other work packages

This synthesis is written as an enabling document for the next SEWA phases. It does not prescribe priorities or pilot choices. Its role is to provide an evidence baseline so that decisions in the next work packages are traceable to the WP1 inventory and consistent across regions and hazards. The regional profiles and continental gaps are therefore intended as inputs to design discussions, not as definitive conclusions.

WP4 (sustainability and ownership), the synthesis highlights that early warning development remains widely project-driven and that the transition to sustained operations is uneven, including in regions with strong regional hubs. It identifies recurring enabling conditions that determine whether pilots can persist: governance and handover pathways, institutional embedding, operational routines and resourcing, and data access and maintenance responsibilities. It also underlines that impact-based approaches depend on stable ownership and update mechanisms for exposure and vulnerability inputs, not only on models.

WP5 (regional action plan design), the synthesis frames each region as a distinct early warning ecosystem with different institutional entry points, hazard priorities, and data and capacity constraints. It provides a basis for selecting pilots that strengthen existing workflows rather than creating parallel platforms, and for targeting cross-cutting gaps where standardisation and interoperability can enable scaling. In this sense, the synthesis supports WP5 in defining regional action plan objectives.

5. Closing remarks

This synthesis translates the WP1 catalogues into a regional and multi-hazard perspective to support the transition from inventory to design choices. It shows that a substantial foundation already exists for early warning in Africa, particularly for drought monitoring, seasonal outlook processes, and flood-related initiatives. At the same time, several structural gaps recur across regions: impact translation remains less mature than hazard monitoring, many systems remain project-driven with unclear pathways to sustainable operation, forecasting challenges and observation gaps limit warning value, heat is rising as a major hazard without comparable operational systems, and interoperability limitations constrain scaling across regions.

The implication for SEWA is that added value is most likely to come from strengthening the enabling conditions for durable, usable services, building where possible on established continental and regional investments such as ClimSA and related programmes. This includes operationalising pragmatic impact-based workflows, strengthening governance and handover pathways, and supporting interoperable data (FAIR) and modelling pipelines that align with existing platforms. As WP3–WP5 progress, this synthesis can serve as a shared baseline for consortium discussion and partner engagement, helping ensure that hazard prioritisation, sustainability choices, and pilot designs remain coherent and grounded in the WP1 evidence base.

6. References

African Union Commission, & World Meteorological Organization. (2022). Integrated African strategy on meteorology (2021–2030): Investing in weather, water, climate and early warning services for sustainable development. African Union Commission / WMO.

Alliance for Hydromet Development, & World Meteorological Organization. (2024). Hydromet gap report 2024. Alliance for Hydromet Development / WMO.

Bachmann, K., Keil, C., & Craig, G. C. (2020). Predictability of deep convection in a convection-permitting ensemble forecast system. Monthly Weather Review, 148(1). https://doi.org/10.1175/MWR-D-19-0045.1

Blau, M. T., & Ha, K.-J. (2020). The Indian Ocean Dipole and its impact on East African short rains in two CMIP5 historical scenarios with and without anthropogenic influence. Journal of Geophysical Research: Atmospheres, 125(16), e2020JD033121. https://doi.org/10.1029/2020JD033121

Burton, R. R., Blyth, A. M., Cui, Z., Groves, J., Lamptey, B. L., Fletcher, J. K., Marsham, J. H., Parker, D. J., & Roberts, A. (2022). Satellite-based nowcasting of West African mesoscale storms has skill at up to 4-h lead time. Weather and Forecasting, 37(4), 445–455. https://doi.org/10.1175/WAF-D-21-0051.1

Intergovernmental Panel on Climate Change. (2021). Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou, Eds.). Cambridge University Press. https://doi.org/10.1017/9781009157896

Nicholson, S. E., & Klotter, D. A. (2021). Assessing the reliability of satellite and reanalysis estimates of rainfall in Equatorial Africa. Remote Sensing, 13(18), 3609. https://doi.org/10.3390/rs13183609

Palmer, P. I., Wainwright, C. M., Dong, B., Maidment, R. I., Wheeler, K. G., Gedney, N., et al. (2023). Drivers and impacts of Eastern African rainfall variability. Nature Reviews Earth & Environment, 4, 254–270. https://doi.org/10.1038/s43017-023-00397-x

Taylor, C. M., Belušić, D., Guichard, F., Parker, D. J., Vischel, T., Bock, O., Harris, P. P., Janicot, S., Klein, C., & Panthou, G. (2017). Frequency of extreme Sahelian storms tripled since 1982 in satellite observations. Nature, 544(7651), 475–478. https://doi.org/10.1038/nature22069

Thiery, W., Van de Walle, J., Lange, S., et al. (2021). Intergenerational inequities in exposure to climate extremes. Science, 374(6564), 158–160. https://doi.org/10.1126/science.abi7339

van Lipzig, N. P. M., Van de Walle, J., Belušić, D., Berthou, S., Coppola, E., Demuzere, M., et al. (2023). Representation of precipitation and top-of-atmosphere radiation in a multi-model convection-permitting ensemble for the Lake Victoria Basin (East-Africa). Climate Dynamics, 60(11–12), 4033–4054. https://doi.org/10.1007/s00382-022-06541-5

World Meteorological Organization. (2024). 2024 state of climate services. World Meteorological Organization.

World Meteorological Organization, & World Health Organization. (2015). Heatwaves and health: Guidance on warning-system development. WMO / WHO.