Funded by the European Union

Global Gateway

Implemented by ECMWF

D.12 Pathways to sustainability and ownership

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

HKV

Deltares

The Netherlands Red Cross 510

TAHMO

Table of Contents

1. Introduction

One of the earliest impact-based Flood Early Warning Systems was developed in 1992 for Sudan by Delft-Hydraulics, the predecessor of Deltares. This system was state-of-the-art at that time, it included rainfall estimation across the Blue Nile in Ethiopia through remote sensing technologies, integration of a real-time gauging and telecommunication system and a hydrological and hydrodynamic modelling system with real-time updating (data assimilation) of forecasting models.

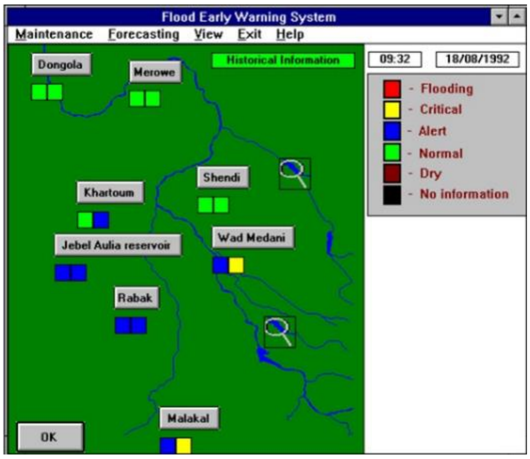


Figure 1-1 FEWS Sudan, the very early beginnings of impact-based flood forecasting systems in 1992 (Grijzen et al, 1992, Deltares, 2019).

Thirty years later we could ask ourselves if this pilot system was a success. If we look objectively at the facts, the answer could be yes: the system was operational for almost 20 years and even received an update in 2010. It was hosted locally at an institute in Ethiopia and remained operational. It provided regional flood forecasts and provided hydrologists with information on when water levels reached critical levels.

But this is only one possible angle we can take, we can also ask ourselves if the organization where the system was hosted had the right mandates and responsibilities? If the whole flood forecast chain was able to effectively disseminate warning messages? In many examples, mandates and responsibilities lie with actors or stakeholders that do not have full ownership of systems and/or there is ambiguity on mandates and roles for disseminating early warning messages.

This report and its recommendations are based on the workshops and interviews conducted during the SEWA IBF scoping study (as reported in WP1 and WP2 reports). These interviews also touched upon how we can ensure a sustainable uptake of the SEWA pilots. In addition, it is based on the experiences of the whole consortium over the past 30 years in developing flood and drought early warning and/or impact-based forecasting systems across the globe. For example, during this time, many pilot forecasting applications have been developed. Examples include systems where impact-based forecasting (IBF) was enabled for riverine floods, flash floods, droughts, storm surge and other hazards. Many of these pilots were successful and are being or were transitioned into operational IBF systems. But for each success story, there are numerous applications that were discontinued after the pilot phase had ended. Transitioning from a pilot system to a fully operational system is a significant process in its own right. This process requires careful guidance, using change management principles to ensure the transition is inclusive and co-creative.

This report starts with a brief overview of prior efforts and past role of AUC and RCC's without duplicating what was written and collected in previous work packages. The compute infrastructure is discussed in depth including opportunities and bottlenecks, followed by discussing technical capacity building/training needs. The last three chapters deal with sustainable pathways, including ensuring ownership of developed pilots including assessment of risk and sensitivities.

2. Review of prior efforts

This chapter reviews some projects listed in/by WP1 (D3 and D6, HKV et al., 2026) with respect to success, sustainability and limitations. Of the catalogued projects from WP1 (D3 and D6, HKV et al., 2026), 50+ are classified as "Completed" with no evidence of follow-on programs or embedded systems, and 5 have unclear status. However, it is difficult to draw conclusions regarding sustainability based on this, as the outcome may have resulted from the prior project aims and/or setup. And on the other hand, while some of the projects are listed as a success from a sustainability perspective, they may not necessarily be successful from other perspectives (e.g. ownership, continuous development, etc.).

2.1. Examples of Successes — sustainability after project end

PUMA → AMESD → MESA → GMES & Africa (EU, 2003‑present):

Each phase built on its predecessor in terms of infrastructure, institutional relationships, and trained personnel. This is the strongest example of sustainability by design. Also, this led to the establishment of the African Space Agency (AfSA) in 2023.
https://au.int/GMESAfrica/background

WISER–EWSA (UK/DFID, 2023–2025):

WISER EWSA is a program focused on improving the use of weather and climate information services for decision-making in Southern Africa, with focus on nowcasting and early warning for farmers and urban communities. In WISER_EWSA nowcasting, short-range forecasting and warning systems have been operationally embedded at ZMD (Zambia), INAM (Mozambique) and SAWS (South Africa) and this includes an economic sustainability model.
https://www.metoffice.gov.uk/services/government/international-development/weather-and-climate-information-services-wiser/wiser-africa/early-warnings-for-southern-africa-ewsa

VFDM / VOLTALARM (Adaptation Fund/WMO, 2019–2024):

This project was completed in June 2024, but the VOLTALARM platform remains operational. A Phase 2 proposal has been submitted to the Adaptation Fund for Ghana and Côte d'Ivoire.
https://wmo.int/activities/projects/project-portfolio/integrating-flood-and-drought-management-and-early-warning-climate-change-adaptation-volta-basin

ENACTS (IRI/Columbia University):

ENACTs is an initiative that focuses on improving the availability, quality, and accessibility of national climate data by blending station observations with satellite and reanalysis data to produce high-resolution climate datasets and user-oriented climate information products. The methodology for merging station and satellite data has been institutionalized at NMHSs in 13+ African countries. ICPAC now independently develops map rooms without IRI support.
https://iri.columbia.edu/resources/enacts/

ClimWeb (WMO/NORCAP):

ClimWeb is an open-source platform for climate information and CAP warnings and is now operational at 27+ institutions including in Ghana, Niger, Chad, Ethiopia, Malawi, South Sudan.
https://github.com/wmo-raf/climweb

CREWS:

CREWS consistently builds on existing national and regional structures. Linkage with GCF funding (Burkina Faso, Togo) extends the financing horizon.
https://crews-initiative.org/

ClimSA (EU, €85M):

This project is focusing on strengthening of climate services through existing RCCs (ICPAC, AGRHYMET, ACMAD, SADC-CSC). 31 decision-support tools have been developed; Standard Operating Procedures were institutionalized (and tested at SARCOF-27).
https://wmo.int/activities/projects/project-portfolio/intra-acp-climate-services-and-related-applications-climsa

Africa Hydromet Program (World Bank, $312M phase 1):

This project is focused on operational infrastructure in 15+ countries; 26 million people reached. New warning systems in Mozambique (Zambezi/Limpopo) and Niger are developed.
https://www.worldbank.org/en/region/afr/brief/hydromet-in-africa

2.2. Examples of Limitations

There are also some limitations that can be learned from past projects. Below are some examples also derived from WP1 (D3 and D6, HKV et al., 2026) .

Maintenance of equipment:

Project budgets often cover procurement but rarely 5–10 years of maintenance. Once this time is up, NMHS budgets cannot absorb recurring costs, and equipment is not being repaired or used anymore. ECCAS found that hydromet equipment in much of Africa is outdated.

Research → operational:
CONFER (H2020, 2020–2024):

This project focused on co-production of seasonal forecasts for East Africa with ICPAC. Operational tools integrated at ICPAC; a follow-up project ACACIA is ongoing. However, the question remains whether maintenance can be sustained without research funding.
https://confer-h2020.eu/

Overall, Horizon Europe projects can deliver interesting research that can improve pilot or operational services, but they seem in general not a suitable instrument to support and maintain pilots or operational applications.

African SWIFT (UK GCRF, completed):

This project resulted in improved understanding of tropical weather processes but forecasting tools require ongoing scientific support that African NMHSs may not be able to provide independently. https://africanswift.org/

3. Role of AUC and RCCs

3.1. Role of AUC

For long-term sustainability, the involvement of the AUC is critical, as they are responsible for providing coordination and strategic leadership for implementation across the continent. AUC leads the work related to the enhanced implementation of policy frameworks. This includes several activities aimed at strengthening coordination and engaging in high-level policy processes and dialogues across the continent.

Aligning the SEWA pilots in one way or another with AMHEWAS program led by AUC seems logical. Note, however, that the AMHEWAS platform is viewed by SEWA workshop participants as sometimes bypassing WMO procedures and undermining the principle that only national institutions should issue official warnings. Furthermore, there is competition for projects between these continental and regional institutions and the NMHSs. Stronger collaboration with NMHSs should be reinforced, with a clear role for AUC ensuring high-level policy commitment.

The partnership between the AUC and the RCCs is already strong, with the AUC focusing on policy and coordination while RCCs provide technical expertise and operational support. Under ClimSA, this collaboration plays a key role in ensuring that every Response Emergency Center (REC) is supported by a functioning RCC. ACMAD's role as the continental climate centre is equally important, particularly because disaster events do not respect political boundaries and therefore require cross-regional engagement.

Improving access to data remains a priority. The AUC works on strengthening data-sharing policies, recognizing that many national networks remain weak or incomplete. While the AUC does not seek to build a central data repository, it is essential that regional and global climate centres receive the data they need. Collaboration with WMO and Global Production Centres (GPCs) such as ECMWF is therefore vital, as their NWP models depend on high-quality ground observations. Ensuring that Member States share data, and in turn receive useful products from the GPCs, creates a mutually beneficial collaboration that supports forecasting and early warning. However, AMHEWAS and RCC's platforms do not share their forecasting data, only visualizations, which limit NMHSs to using rather than postprocessing and tailoring this data.

Beyond the immediate project period, the AUC has an important role in supporting sustainability. Through coordination and capacity building, the AUC can help implementing partners align efforts and avoid duplication. Policy frameworks, strategies, and guidelines provided by the AUC contribute to sustaining program outcomes by guiding member states in implementation.

3.2. Role of RCCs

The WMO Regional Climate Centres (RCCs) are transitioning into centres of excellence (CoEs) mandated to generate high-quality regional-scale climate products to support development and delivery of effective climate services at a national scale for the benefit of WMO Members. RCCs bridge the gap between information available at global and national scales.

Especially in Africa, where heterogeneity is observed in terms of capabilities between different countries and NMHSs, having a strong regional body for exchange of knowledge, practical skills and the use of data interfaces and digital tools can be a great benefit for regional knowledge exchange.

Each RCC organizes its own Regional Climate Outlook Forum (RCOF) and produces regional climate products. ACMAD then consolidates these into the African Continental Climate Outlook Forum (ACCOF), bringing together all RCCs and key users to produce a continental bulletin. After this, the AUC breaks down the information into sectors through five continental working groups, covering:

1. Climate services and food security/agriculture

2. Health
3. Infrastructure and transport
4. Water management
5. Additional thematic areas as needed

These groups help the AUC develop policy briefs that support anticipatory action and ensure that climate information becomes more impactful for decision-makers.

An assessment of the current capacities of the RCCs shows that, although significant efforts are being made, several critical elements still need to be established before RCCs can fully function as centres of excellence. Many of these capacity gaps extend beyond the scope of existing projects; however, there remains space for targeted support. From interviews, there were several suggestions made to enhance the RCCs capacities, as well as recommendations from the AUC:

- **Improve the connection and partnerships with African universities**: Having capable and proficient staff is one of the corner stones of becoming a CoE. It is therefore recommended that RCCs form and have strong partnerships with local African universities. A strong connection with universities will also be beneficial for attracting highly skilled young experts. For example, ICPAC has MoUs with some universities—for example in Nairobi and Dar es Salaam—where students take meteorological courses. These MoUs strengthen the relationship between the RCC and universities and help ensure that trained graduates can support the work of met services and climate centres.
- **Internships**: Another suggestion is to allow students taking meteorological courses to do internships at RCCs. This improves the relationship between RCCs and universities and helps build future capacity
- **Ownership of model development:** One suggestion is to develop RCCs capacity on meteorological forecasting and hydrological modelling, so they have full control over future model developments and the capacity to develop modelling tools themselves. This will ensure that ownership of modelling activities lies with RCCs and not externally.
- **Use latest technology**: Several RCCs continue to rely on outdated tools for their daily operations, particularly for medium- and long-range weather forecasting. This technological gap affects the quality and timeliness of services. With the rapid evolution of digital technologies, there is a clear need to support RCCs in transitioning to modern, cloud-based systems. For example, while previous initiatives initially requested procurement of servers and high-performance computing systems, many of these functions can now be performed more efficiently and cost-effectively through cloud solutions. Supporting this transition would also reduce the financial and maintenance burden associated with physical infrastructure.
- **Provide training and capacity building on AI**: Advances in artificial intelligence (AI) present an important opportunity to enhance the quality of RCC products. Capacity-building efforts can therefore focus on training personnel in cloud-based and AI-supported tools that improve forecasting accuracy, data processing, and product development.
- **Strengthen human resources**: A further challenge relates to human resources. RCCs face significant staffing shortages, limiting their ability to absorb new technologies and sustain operational activities. Continued engagement with Regional Economic Communities (RECs) and relevant partners will be essential to identify appropriate mechanisms to strengthen human resource capacity and ensure long-term institutional resilience.

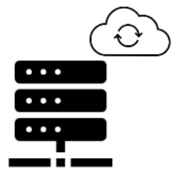
Overall, transforming of RCCs into sustained CoEs will require a combination of updating technological systems, enhancing technical skills, and strengthening of human and institutional capacity. A last recommendation is to leverage the connection with the AUC to work with regional partners to identify effective and sustainable pathways for addressing these needs.

Funded by the European Union
Global Gateway
Implemented by ECMWF

4. Cloud infrastructure use

This chapter gives an assessment of cloud infrastructure use: including opportunities, bottlenecks, and regional needs related to accessing and scaling cloud-based platforms to inform future sustainability and operational planning.

The sustainability of an impact-based forecasting system is mainly dependent on how and where systems are hosted and who provides funding. It is important to understand that there is a design decision to be made, where systems can be hosted locally – on a server at an RCC or NMHS – or in the cloud. Advantages and bottlenecks of both options are described in the following chapter.



Problems around IT infrastructure and hosting were mentioned by many of the stakeholders involved. Technically, three different solutions exist for hosting of systems: 1) local hosting, 2) cloud-based hosting, or 3) a hybrid hosting solution. Which solution will work best depends on the capacity of individual RCCs and NMHSs. Generally, many NMHSs expressed preference for local hosting of servers, while for RCCs cloud-based options might be preferred.

- *Local hosting*: includes installation of software on a local server, which means that a physical server and server-room need to be present within an institute. Successfully hosting of an IBF system, means requirements in terms of availability of IT staff and IT infrastructure need to be met, which are described in the next chapter.
- *Cloud-based hosting*: As an alternative, software can also be hosted in cloud-environments. Examples of cloud-based solutions are Microsoft Azure, or Amazon Web Services (AWS). From a technical point of view, cloud solutions provide similar capabilities as local hosting options, with the main difference that they are hosted on an external platform. Bottlenecks are often accessibility of cloud services through a stable internet connection and the continuous availability of funding. A specifically relevant option for SEWA pilots is the **European Weather Cloud (EWC)**, a community cloud platform jointly operated by ECMWF and EUMETSAT. Unlike commercial providers, the EWC is designed for the meteorological community and its use within SEWA is actively planned, with support from both ECMWF and EUMETSAT on both infrastructure access and data. Importantly, EWC access is not limited to the SEWA project duration and can be granted for considerably longer periods, directly addressing long-term sustainability concerns.
- *Hybrid hosting*: Another option could be a hybrid hosting solution, where some components are installed locally and others in the cloud. An example is a forecasting system which is installed on a local server, but specific components, like data archives and exports, are hosted in the cloud. By splitting these components, data continuity and operational resilience are improved. Cloud-hosted components remain accessible even when local servers fail, experience power outages, or lose network connectivity, all of which are documented challenges.

4.1. Local hosting

Opportunities:

The main opportunity for local hosting is that it provides a true ownership of IBF systems by the hosting institutions. Additionally, it can provide a great learning experience, which can lead to improved capacity development on IT knowledge. Instead of outsourcing the task of hosting IT components externally, it requires institutes to develop their own capacity to manage IT systems and servers.

An example of a locally hosted system, was the Flood Early Warning System for Accra (FEWS Accra), in this case three institutions, the Ghana Meteorological Agency (GMet), Ghana Hydrological Authority (HYDRO) and the Water Resource Commission (WRC), each bought a server and other IT equipment funded through a World Bank initiative, the hydrological impact-based forecasting system was installed on each of the servers.

Despite the project being a success, problems and issues around IT were plenty:

- Insufficient internet bandwidths
- Problems with Windows licenses
- Limited implementation of cyber security measures
- Frequent power outages, which led to unavailability of servers
- Problems with overheating of servers and server crashes
- Difficulties setting up basic IT components, such as FTP servers and Reverse Proxies.

However, by opting for a local installation, it meant that IT issues had to be addressed and resolved together with IT staff from local African consultants. This led to a significant increase in IT knowledge and skills of each institute and improved capacity of agencies on hosting IT systems. The easier solution would have been to host systems in the cloud, but it would have been a missed opportunity as a joint learning experience. Local hosting, if done successfully, can be a great learning experience for institutions involved.

Bottlenecks:

Nevertheless, there are bottlenecks for hosting forecasting systems locally. Running an operational forecasting system on a server requires several functional elements to be in place, apart from technical requirements (available hardware, servers, OS, required software). The main goals here are **operational availability**, ensuring that the system runs and is accessible 24/7 with 99% uptime, **redundancy**, ensuring back-up measures are in place in case of server malfunctions and **procedures**, having capable staff and procedures in place to support the first two goals.

Practically this translates into a set of requirements, which can guide the decision to host a system locally. The suggestion is to conduct a formal evaluation with all the stakeholders in the pilot (RCCs, RSMCs) to check if these requirements are met.

- **IT personnel and staffing:** organizations are required to have a well-trained IT system administrator. This is someone who knows how to keep a server running operationally, who (1) can adjust the server configuration, (2) ensures back-ups are made of server components, (3) sets-up HTTPS proxies for external access and can assist with setting up FTP servers.
- **Internet connection:** The local server should have a fast and reliable internet connection. Especially with impact-based forecasting systems, where often large volumes of data need to be shared, a fast and reliable internet connection is mandatory to ensure data between different systems can be transmitted.
- **Proximity to data:** Many different data sources will be imported into the system. Usually, this data is also available in other systems. Proximity to data means data doesn't need to be transmitted over internet but can be shared through internal networks which will provide better latency. This requirement can also be met if the internet connection is sufficiently fast.
- **Fire safety regulations**: Basic fire safety measures need to be in place, such as a well-ventilated, cooled server room to avoid overheating of components. And availability of fire detection and firefighting equipment. Available fire extinguishers should be based on carbon dioxide to avoid damage to equipment.

- **Back-up generators and UPS:** To ensure operational availability of servers. Each server needs to be equipped with a UPS (Uninterruptable Power Supply), which serves as a back-up in case of a power outage. Since power outages can last for multiple hours, additional back-up generators need to be in place to ensure continuous power supply. Procedures need to be in place, so that back-up generators are activated when there is a power outage.
- **Availability of frequent back-ups**: It is recommended to make frequent back-ups of server components, at least once a day. Daily back-ups are stored for a week and weekly back-ups are stored for at least a month. This ensures when server components fail, back-ups are available for continuity of systems.

If one of these requirements are not met, it is suggested that a solution is provided to mitigate the risk, or that alternatives, such as cloud-based hosting solutions are explored as a solution.

4.2. Cloud-based hosting

As an alternative, the pilot impact-based forecasting systems can be hosted in a commercial cloud environment, such as Microsoft Azure, or Amazon Web Services. Although technically a lot is possible and there are less issues around IT infrastructure, there are still several challenges which should be taken into consideration.

- **Data policies**: One of the main reasons for not opting cloud-based hosting solutions, are national data use and data storage policies. This is the case in various countries in the world, where national policies often mandate organizations to store data nationally. When having an impact-based forecasting system for floods, for example, local and national impact data is critical for providing accurate warnings. Therefor data policies need to be taken into account in the decision-making process for deciding to go for a cloud-based hosting option.
- **Recurrent costs**: cloud-based hosting options come with recurrent costs, depending on the size of the system and the required components costs vary between 700-1500 euro per month. These costs should be accounted for and it should be clear at the start of the pilot, who is covering these costs.
- **Internet Connectivity**: Even when cloud-hosting options are chosen, organizations might still struggle with poor internet connections and therefor limited accessibility to the forecasting system. It is recommended to check internet bandwidth of NMHSs and RCCs to understand if this is an issue.
- **Technical expertise:** Cloud based systems still require maintenance. The question is who is going to perform maintenance tasks, if these are local institutes, it means they need to be trained on the use of cloud services and cloud-based server management.

European Weather Cloud

European Weather Cloud (EWC) can provide cloud-based solutions and can be considered a key option for SEWA pilots. One of the advantages of the EWC is that it allows NMHSs to share resources and run applications close to where the data is produced, reducing the need for transferring large volumes of data. This is particularly relevant for African partners, where international bandwidth constraints make large data downloads over external connections a practical bottleneck. By offering "data-proximate" computing, the EWC allows users to process data directly in the cloud, improving efficiency and reducing the need for local infrastructure.

An advantage is that it provides seamless access to many datasets from both EUMETSAT and ECMWF, including satellite, model, and reanalysis data, which can be accessed by end-users for operational weather forecasting and AI based forecasting applications. An additional advantage is operational resilience. EWC hosted components remain accessible even when local infrastructure fails, including during power outages, server crashes, or local network disruptions. This resilience argument supports EWC as at minimum a backup or hybrid layer even where local hosting remains a primary choice.

For the pilots there is a use-case for using the EWC, depending on the application or type of system that is developed. If a pilot requires large volumes of meteorological forecast data there is a clear benefit for running the system in the cloud and distributing derived forecasts or products to end-users in Africa. However, when impact-based forecasting systems require a local component, such as a local hydrological model or local impact thresholds, a hybrid approach may be more appropriate, with EWC handling data-intensive components such as ingestion of meteorological data and product dissemination, while local infrastructure handles components that require proximity to in-country data.

Towards an African Weather Cloud

Several participants mentioned the need to develop IT knowledge and capabilities in Africa. One opportunity is working towards a joint African Weather Cloud, hosted by one of the RCCs, supported by experiences and technical capability from European partners and the AUC. This would ensure ownership by African partners, providing cloud-based hosting options in Africa, while simultaneously providing an opportunity for stronger collaboration between European and African institutes on cloud-based hosting options for meteorological applications. In addition, it may lower barrier of data (sharing) policies as data stays in Africa.

4.3. Partnerships with local consultants

Challenges around IT capacity and knowledge of IT-infrastructure were flagged by many African partners to be limiting their capacity for solving IT related issues. One solution that proved to be effective with prior projects, was having African institutes forming partnership with local African IT consultants (e.g. as in Ghana, https://www.hkv.nl/en/projects/flood-early-warning-system-for-greater-accra-ghana/). Through this partnership, IT consultants provided technical support for IT components and offered knowledge exchange and capacity development. As many national agencies face a high throughput of IT staff, having an external partner for continuous support helped in keeping knowledge of critical systems in place.

4.4. Recommendations

- Decide between local hosting of a pilot system and cloud-based hosting together with African institutes who will perform the hosting.
- If opting for local hosting, ensure that a review is done on IT capabilities of relevant institutes and that a conversation was held on knowledge exchange.
- If opting for commercial cloud-based hosting (e.g. Microsoft Azure, Amazon Web Services), ensure that a discussion is held on long-term funding after the pilot has ended, and on data policies which might prevent partners from sharing data outside country borders.
- If opting for the EWC, the sustainability question is different; access is allocation-based rather than commercially billed, so the discussion should focus on maintaining an allocation (access terms and duration) beyond the project period.
- The EWC could be considered a primary solution for many applications that require significant volumes of meteorological data.
- Consider EWC as a resilience or backup layer even where local hosting is the primary choice, particularly for data archiving and product dissemination that need to remain available during local infrastructure failures
- It is recommended to perform a formal review on IT capacity and IT knowledge among NMHSs and RCCs to understand which different hosting option might be most suitable.
- Partnerships between local IT consultants and NMHSs might be useful for sharing knowledge on IT related questions and develop local capacity and ownership.

Funded by the European Union · Global Gateway · Implemented by ECMWF

5. Technical capacity building needs

Technical capacity building needs, including training at regional level and knowledge transfer within the regions at national level.

Training and capacity building should be an integral part of a sustainable pilot. Without proper training, operational staff will not be skilled to work with tools and products developed under the scope of the pilots. There is an open question around how training should be organized on a regional and national level.

During stakeholder interviews and regional workshops, several conversations were held on capacity building and needs for regional centers and national agencies. From these conversations two topics emerged as being important to the success of the pilots: 1) Training on back-end IT components of the systems and 2) training in operational procedures for working with the IBF pilot systems.

5.1. IT training

For a sustainable uptake of the pilots as a fully functional operational system, end-users should be able to support and maintain IT components of the developed systems independently. This requires IT staff of RCCs and NMHSs to have the knowledge to maintain technical components without external support. Nevertheless, IT training components are often neglected or only cover specific components of the systems. The recommendation is that IT training is provided on all levels, even including topics on basic IT skills such as server administration, setting up Virtual Machines, FTP servers, IT infrastructure networks etc.

Having an operational environment can be challenging, with ongoing issues like unreliable internet connectivity and power outages. Past experiences with impact-based forecasting projects in Africa shows that this aspect is often neglected. Skilled IT staff should be prioritised, as IT infrastructure forms the backbone of the regional pilots.

5.2. Operational procedures training

For sustainability, it is critical that end-users understand how the pilot fits within their standard operational procedures (SOPs) and receive sufficient training on this. A challenge here is that SOPs of individual organizations are not necessarily aligned/synchronized , e.g. between RCCs and NMHSs. Different national agencies/NMHSs will have a different level of maturity in working with SOPs.

SOP training could be an integral part of the execution of the pilots. These trainings should be focused on practical applications and skills, e.g. generating reports, analysing a flood or weather forecast or disseminating warnings.

It should also be noted that SOPs probably already exist within many organizations. The introduction of a new IBF system or pilot will most likely also introduce new procedures. Which means that procedures will change or need to be adapted. Updating or changing SOPs should formally be addressed and part of the pilot to ensure sustainable uptake of the systems.

5.3. High turnover of IT staff

Staff turnover, especially on IT staff, can be high within institutes, which creates challenges for continuity. IT staff could receive training on back-end server components and IT infrastructure and leave organizations after the pilots are finished. One recommendation to ensure consistency in sharing of knowledge, it to ensure all training modules are available in a standard format, modular, and available on an online e-learning platform. This ensures that new staff have access to all prior learning materials and can easily be brought up to speed. Another recommendation is to improve relationships with universities in Africa focusing on computer science and technology. There are a lot of young experts, who are well trained, and might provide additional knowledge. Training needs to be repeated and continuously updated, including both forecasting staff and IT personnel. Participants mentioned one-off training sessions were rarely sufficient.

Regarding training and capacity development, the CoEs or RCCs could also play a role. Roles might vary between RCCs, depending on their capacity and knowledge, but it is important that they remain closely linked to the national meteorological services. Trainings should focus on demonstrating practical ways of working. A recommendation here is to organize a testbed for each pilot. The testbed would include a simulation exercise, where all participants follow and use the IBF system, according to their own SOPs and training materials. Training engagements do not need to be large-scale. Targeted, well-designed trainings can be effective if they follow requirements from users.

5.4. Recommendations

- Training and capacity building should be an integral part of the pilots as without proper training, operational staff will not know how to embed the developed systems in operational procedures.
- It is important to include training on operational procedures and usage of the developed tools in an operational setting. This includes aligning tools with SOPs, simulation exercises of past events and testbeds.
- Turn-over of staff needs to be considered during training exercises, where trainings should be included in formal training programs of institutes.

6. Suggest pathways to ownership

The challenge with pilot projects is that their goal is to prove that a certain technology, system or process is suitable or provides a solution to a problem. This means that after a pilot is finished, a process should be started to move from pilot phase to fully operational phase. In this chapter we identify three approaches, which will smoothen this process and allow a smoother transition towards long-term sustainable pilots.

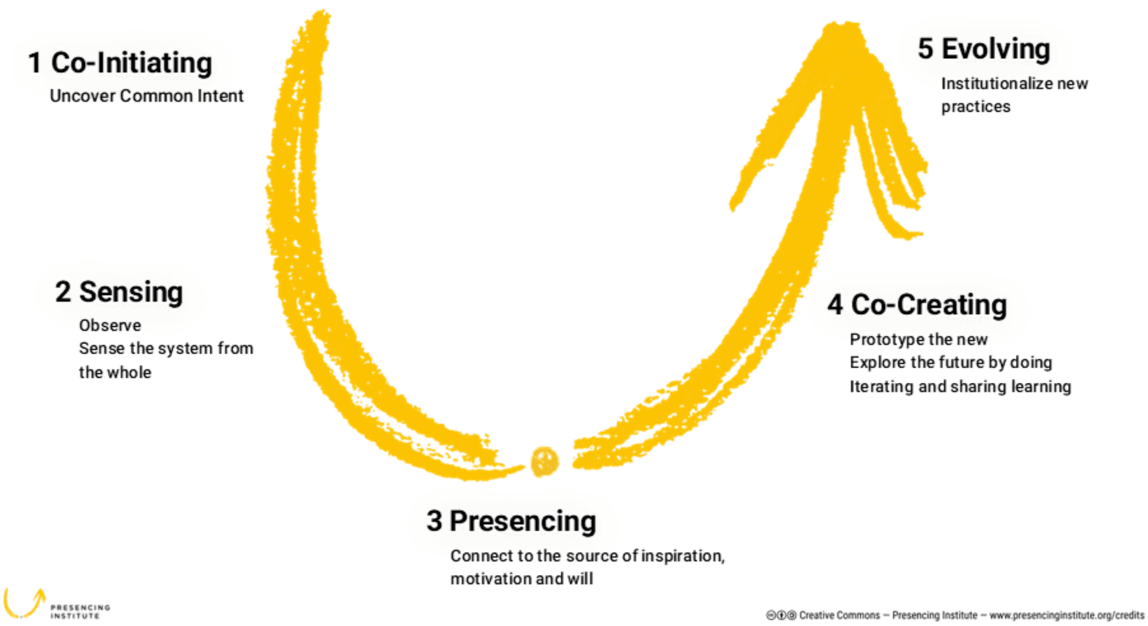
In the following sections we will discuss some of the recommendations for navigating the political and institutional sensitivities surrounding past experiences, local perceptions of externally funded initiatives, and the need to build trust, transparency, and co-development into the next phase. One of the main recommendations that was also mentioned by the AUC and other stakeholders, is the use of co-development and co-creation during the execution of the pilots which is also a strong component from Theory U, which is briefly described below as reference as it is deemed to be a useful concept for the SEWA pilots. The second part of this chapter discusses the (possible) role of the AUC in the process.

6.1. Theory U

One method for navigating systematic changes, in a co-creative, sensitive, collaborative and inclusive way, is by following a method called Theory U. Theory U, developed by Otto Scharmer at MIT, is a change management framework and leadership methodology designed to address complex, systemic challenges by shifting awareness from ego-system to eco-system. It facilitates transformation by guiding individuals and groups through a profound new way of working.

Theory U has been used by leaders, organizations, and communities to foster collaboration and navigate times of uncertainty or disruption. Some key case studies and examples are a program by UNDP on Building Systems Change Leadership, by UNDCO on Accelerating Transformation through SDG Leadership Labs and within the Red Cross Red Crescent on Activating a Transformational Learning Culture movement. (see https://www.presencing.org/theoryu and Medium, 2024)

In practice, it could be a very useful approach for the SEWA program to navigate political sensitive areas. An example of one of the Theory-U trainers is Martin Kalungu-Banda, who worked in 2006 under Nelson Mandelas leadership and assisted many organizations in navigating difficult systematic changes.



The U-process consists of 5 distinct phases, where the journey through the "U" involves moving down the left side to let go of old patterns and moving up the right side to create new ones:

1. **Co-Initiating (Building a Shared Intention):** Identifying the issue and building common ground among stakeholders to see the system's larger potential.
2. **Co-Sensing (Observing & Sensing):** Going to the places of most potential, listening with an open mind and heart, and observing without judgment to understand the current reality.
3. **Presencing (Connecting to Source):** The bottom of the U; "presencing" is a blend of *presence* and *sensing*. It involves retreating to reflect, letting go of old mental models, and connecting to a deeper source of knowledge.
4. **Co-Creating (Prototyping):** Moving up the right side to act quickly, experimenting with prototypes, and learning from failure to bring new ideas to life.
5. **Co-Evolving (Embodying):** Scaling successful innovations, embedding them into the community or organization, and performing at a new level.

Theory U follows several principles, which form the core of the programs philosophy:

- **Systemic Change:** Rather than quick fixes, Theory U targets the root causes of systemic problems.
- **The Three Instruments:** Utilizing the open mind (curiosity), open heart (compassion), and open will (courage).
- **Overcoming Obstacles:** Addressing the three main inhibitors to change: the voice of judgment, the voice of cynicism, and the voice of fear.
- **Leading from the Future:** Shifting focus from reacting to the past to sensing and acting on emerging future opportunities.

6.2. Ownership through identifying Champions

The Champion is an individual who has technical expertise, but also enough political power within organizations to influence decision making for long-term support. Typically, the presence of a *"Champion"* is one of the key indicators for ensuring the future operationalisation of a pilot.

The Champion is a person who has technical expertise, but also enough political power within organizations to ensure there is organizational support. Typically, the Champion is responsible for roadmap development, prioritization of technical improvements and operational uptake of the system. It is important to note that a Champion is not appointed but it is often an intrinsic motivation and role that fits within one's work profile and personality.

The Champion is critical for the success of a pilot, since they provide:

- **Advocacy**: Pilot projects are usually a first phase into moving towards an operational system. The impact of this is that the pilot needs to prove that it provides a solution to an issue, or problem that an end-user is facing. This also means that at the end of a pilot, decision makers need to be convinced of the usefulness and effectiveness of the pilot system, for long-term uptake. The Champion plays a critical role, advocating for the results of the pilot internally, they have strong contacts with higher management and can influence decision making to continue the pilot after the project ends. The influence of a Champion makes implementation easier and quicker; they are the experts in their field and have the power to make important design choices.

- **Technical supervision**: At the same time Champions possess technical knowledge to guide the technical developments of the pilot system. This includes experience with software development skills, such as SCRUM, Continuous Improvement (see next section) and Roadmap development. As a result, they not only know how to advocate progress on a political level but also know how to translate requirements into technical roadmaps. This ensures that there is a uptake of the activities that need to be executed.
- **Operational embedding**: To be effective, pilot forecasting systems need to be turned into operational systems,s meaning that user manuals need to be aligned with Standard Operational Procedures within organizations. Especially for pilot projects, this can pose a challenge. Introducing a new system usually means that the way of working changes. The Champion needs to convince forecasters of the advantages and ensure that they understand the changes that are implemented and understand why it is important to follow new procedures.

Identifying who the Champions are within organizations will be a critical part of ensuring the success of the pilots. Without the availability of champions, internal uptake will become challenging and difficult within organizations.

6.3. Introduction of Continuous Improvement

It took most modern countries not months, not years, but decades to go from pilots to full end-to-end impact-based forecasting systems. One of the key principles that made this decade long transition possible, was the use of Continuous Improvement.

The term continuous improvement comes from software development and is also called a continuous improvement process (abbreviated as CI). It means that there is an ongoing effort to improve products, services, or processes. It implies that you do not start from scratch but gradually updates the system and add innovations when they come up. (https://en.wikipedia.org/wiki/Continual_improvement_process)

CI means that the focus is on "incremental" improvements over time, but it doesn’t mean that an organization cannot leap-frog or implement new innovations at once. A good example is the national flood forecasting system for the UK, hosted by the Environment Agency and UK MetOffice. A first version was developed around 2000, but with CI, continuous improvements were implemented over the past 25 years.

Every year the system is updated in terms of functionality and performance, e.g. hydrological models are updated regularly or replaced occasionally. Local impact and disaster information was added in the system. Gradually the system was developed further, till most recent versions, where it contains over 8000 telemetry automatic observation stations and over 100 hydrodynamic and hydrological models.

In practice, CI means that every year core components of the forecasting system are evaluated and improved upon where necessary. Telemetry networks are expanded, (hydrodynamic) models are updated and impact/exposure and vulnerability data is gathered of past events. Based on the status of the system, a plan is made for the coming year and improvements are implemented. The result is a continuous cycle of gradual improvements, where impact-based forecasting systems get better and better.

Many organizations in the world do not embed CI in their way of working. Sometimes due to capability issues, sometimes simply because continuous funding is lacking. And with forecasting pilots there is a tendency start with new system, tools rather than building on existing ones. However, CI is a skill that can be learned. Organizations can be trained to embed CI processes in their organizations and will be one of the critical skills for ensuing ownership of software and systems.

The recommendation is therefore to introduce CI way of thinking in the SEWA IBF pilots. The focus here should be that ownership ultimately lies with African partners, therefor they should be leading the CI design process and decide which activities consultants or other organizations would take on. One important comment is that working with CI will be completely new for many institutions and will require support and a lot of trust when doing so.

One caveat of working with CI, is that it needs to be clear who the end-user is and which organization has the mandates to operate and maintain the pilot system after the pilot has ended. When there is ambiguity, or when multiple organisations are responsible for maintaining and supporting the system, using CI can become a challenging and political process. That is why it is suggested to ensure clarity on who the end-user is of the system, so that true ownership can take place by institutes.

6.4. Examples of Continuous Improvement

Most advanced flood forecasting agencies in the world, including the National Weather Service in the US, the Dutch Water Management Centre, the Environment Agency in the UK and the Australian Bureau of Meteorology, have some form of Continuous Improvement process in place. Below is a brief introduction to what this process could look like.

An impact-based flood forecasting system contains several components, such as

- Observation networks and automated telemetry systems
- Meteorological numerical weather predictions
- Hydrodynamic/hydrological models to produce water level/discharge forecasts
- Information on impact of a flood (historical data/exposure/vulnerability data), linked to impact thresholds.

For each of these components, CI can be applied to set priorities and determine what investments or improvements need to be made. Decision makers, then follow the - Plan, Do, Check, Act - approach, where activities are planned, executed, validated to check if they work according to the specifications set and integrated in the impact-based forecasting system.

Below are examples of activities that typically take place:

- **Monitoring**: An organization might have 100 automatic weather stations and 20 water level stations, out of those stations 30 might be offline due to specific issues. With CI the decision is made to fix the broken stations and procure 10 additional water level gauges near critical locations.
- **Weather forecasting:** an NWP datafeed might predicting convective rainfall inaccurately, with CI it was determined that this year, the organization will prioritize data assimilation techniques to improve the NWP quality and invest in the use of AI.
- **Modelling:** Additional hydrological data became available from a measurement campaign, hydrological models are updated and recalibrated using historical flood events.
- **Impact information:** The past year there were 2 major flood events in the country. The impact of the flood events was assessed and resulted in renewed thresholds for which citizens will receive flood alert or flood warning messages.

6.5. User-centred design process and testbeds

During the design and development of the regional pilots following user-centred design principles will be key for sustainable uptake of the pilots. User centric means that end-users are included in the design process of the pilot and that the pilot is connected to existing working processes within organizations.

Following User Centered Design processes during the development of the pilots is critical to ensure that the pilots are aligned with practical issues or problems that NMHSs or RCCs are facing. It means that the pilot solves a problem from a user and that the work processes from that user are clear. An example of implementing user centric design could mean that the generation of a (drought/flood/river) bulletin is automated, which is used by an organization to communicate the impact of a hazard. Another example is sending out policy bulletins for longer lead time events (e.g. seasonal or sub-seasonal), which can help organizations to be seen as politically important.

Including user-centric design (UCD) in the definition of pilots is critical because it will shift the focus from purely technical functionality to how the system fits into real-world human workflows, thereby increasing the chances of adoption and success. By incorporating UCD early on, pilots can identify usability issues, validate user needs, and avoid costly redesigns later in the development process.

When the pilots are designed with user needs in mind, they are more intuitive, leading to higher satisfaction and engagement. Pilots that ignore the users (NMHS)'s perspective often have limitations in ownership and uptake, as users usually abandon tools that do not fit within their workflows. Alternatively, new working processes or procedures can also be introduced, but these should be carefully discussed with NMHSs. If the pilot introduces new procedures, important consideration needs to be given to training and institutional embedment of these procedures.

During the pilot it is also recommended to organize testbeds, which include the simulation of historical events (e.g. previous floodings or droughts), where procedures are tested live. This would mean that national agencies use the pilot system in an operational setting, which allows for testing in the "wild," evaluating if the system functions effectively alongside other tools in the NMHSs daily work environment.

It is important to determine who the grassroots end-users are, and who operational end-users are. Operational forecasters may include NMHSs and RCCs, while grassroot end-users are more focused on dissemination and response. It is important to clearly define who or what counts as an end-user, as these institutions also interact with their own users. Without a clear client, it is difficult to determine the needs of the end-users.

The pilots should be co-created and user-centered. This involves collaboration both between European and African partners, and between African partners and the end-users themselves. In this way, the work becomes genuinely user-driven and founded upon local issues, ensuring that it addresses the most urgent needs from organisations on the ground.

6.6. Recommendations

- One recommendation is that user engagement becomes a key component of the pilots. This includes identifying who the Champions are within organizations and ensure that they are leading the execution of the pilots. Ultimately these Champions should both have technical skills as well as political leverage and mandate
- The recommendation is to introduce Continuous Improvement (CI) way of working in the SEWA pilots. CI allows organizations to gradually improve systems over time through incremental steps.
- When CI is applied as a way of working, mandates need to be clear to ensure a smooth execution of the pilot.
- NHMSs need to have a roadmap / strategy for their early warning or IBF services and ‘take the lead’ to ensure that external funded projects align with the NHMSs own roadmap rather than following external project agenda
- Ensure that user-centric design is at the core of the pilots. Where there is a clear definition of who the end-user is. This includes starting with an inception/design phase, where goals are defined.
- It is recommended that there is overlap between who the end-user is and who takes on ownership of the systems, once the pilots have ended.
- Ensure that the pilots include testbeds, for testing real-life events, e.g. with a simulation exercise of an historical event.
- Theory U concept can be used to ensure this user -centric design

7. Risk and sensitivity analysis

7.1. Alignment of Roles and Mandates

Sustainability begins with understanding the roles and mandates of institutes involved in SEWA and ensuring that the pilots follow these mandates. For a sustainable pilot, it is therefore important that roles and mandates between Centres of Excellence (CoEs), RSMCs, RCCs and NMHSs are clear.

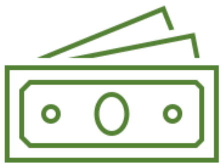
Due to the regional scope of the IBF pilots (regional pilots do not necessarily target regions, they can also target multiple countries independently), there are likely multiple organisations who will play a role during the development and operational phase. Typically, in a pilot, the end-user (e.g. a forecasting agency) would determine what roles and mandates would be leading as they are the end-user of the pilot. Workshop participants and stakeholders addressed this issue and highlighted that the different roles and responsibilities between institutions are often not fully clear in pilot applications. For SEWA pilots, it is important to make this clear from the beginning to avoid ambiguity around how resources should be balanced between the regional and national levels.

Based on what has been observed, all projects under SEWA place significant importance on national agencies. In the end, national agencies have the mandate to disseminate warnings and are responsible for doing so. Nevertheless, there is a diversity between NMHSs, where both national contexts as well as capacities might differ. As a result, products and services should be carefully conceived and organised, taking user engagement on a national level into account. This diversity might also create challenges in coordination and coherence; one national agency might have developed more capacity than others and this should be taken into consideration.

It is therefore important to recognise that CoEs, RSMCs, RCCs, and national agencies each play distinct but complementary roles. Clarifying these roles, especially in terms of who hosts services, who maintains them, and who benefits from them—is essential for long-term sustainability.

7.2. Funding and political support

Structural, long-term funding is at the corner stone of any sustainable impact-based forecasting system. This means that a conversation is to be held regarding the exit-strategy of the SEWA initiative. In this strategy, decisions need to be made on institutional embedment, technical support, funding needs and how this is organized after the program is finished. Practically it means that technical agencies will require funding beyond the scope of the pilots.



A sensitivity here is that many NMHSs are part of national ministries and therefore funding will need to be arranged on a ministerial level. Agencies could face sudden budget cuts when political interest declines after political shifts. This creates challenges with the continuity of the pilots with an example of decrease in funding on IT infrastructure, staffing and others.

There are opportunities for solutions at the political level by engaging with the AUC and through the AUC to create political awareness on country level. Based on experiences by stakeholders working in Africa, the connection with the AUC could be leveraged to ensure political engagement and funding.

An added challenge is that NMHSs are often not engaging directly with ministers, whereas the AUC has established mechanisms for dialogue with ministries through policy frameworks and other formal processes. Therefor leveraging these policy frameworks is recommended for advocacy on the importance of funding for the SEWA pilots.

7.3. Recommendations

- Follow the WMO guidelines on mandates during the execution of the pilots. Ensure that mandates align with the WMO roles and responsibilities.
- As an example, this could mean the RCCs are responsible for hosting, while NMHSs are end-users of the forecasting systems and pilots.
- Make sure that NMHSs are included in the design and co-creation process, as they are ultimately responsible for distributing warnings.
- First work on trustful working relationships before trying to enforce data sharing.
- An integral strategy for institutional embedment is necessary for the SEWA Pilots.
- Ensure sufficient funding is available for maintaining the pilots beyond the SEWA program, by organizing support on a ministerial level.
- Utilize the existing connection with the AUC to organize political support.
- Ensure that policy makers and politicians are aware of the impact and importance of the early warning/early action agenda.

A References

Deltares, 2019. Everybody-needs-good-neighbours, Online https://oss.deltares.nl/web/delft-fews/-/everybody-needs-good-neighbours,(last access 28/04/2026).

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, HKV et al., March 2026.

D6 Interactive map or dashboard deliverable, Provision of a scoping study to assess the current landscape of early warning and Impact-based Forecast initiatives across Africa, HKV et al., March 2026.

Grijsen, J.G. , X.C. Snoeker, C.J.M. Vermeulen, M.A.M. El Nur, Y.A. Mohamed, 1992.An information system for flood early warning, , Floods and flood management, 263–289, Chapter in Fluid Mechanics and its Applications,Springer

Medium, 2024. Online https://medium.com/presencing-institute-blog/un-sdg-leadership-labs-answering-the-urgent-call-for-transformational-change-0dcb0f07750f (last access 28/04/2026)