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Workshop Report

Digital Twin for effective flood response at Dolo Ado district, Somali Region of Ethiopia

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Front cover photo: IWMI's Mariangel Andarcia Garcia presenting on digital twins at the codesign workshop (Photo: Elizabeth Wamba/IWMI)
Back cover photo: The IWMI team analyzes a map using specialized software (Photo: Mitchell McTough/IWMI)

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Acronyms

AAFDRMC	Addis Ababa Fire and Disaster Risk Management Commission
DT	Digital Twin
DRMB	Disaster Risk Management Bureau
EDRMC	Ethiopian Disaster Risk Management Commission
EMI	Ethiopian Meteorology Institute
IWMI	International Water Management Institute
MoWE	Ministry of Water and Energy
NGO	Non-Governmental Organization
UNHCR	United Nations High Commissioner for Refugees
WFP	World Food Programme

Summary

Collaboration between CGIAR and the World Food Programme (WFP) has enabled more proactive, data-driven interventions to protect people against the impacts of conflict and climate shocks. This collaboration has been extended to digital innovations for flood preparedness and early warning in a fragile environment in Ethiopia through this study. Flood preparedness and early warning can be improved by providing timely, accurate warnings to all stakeholders. However, several challenges affect flood preparedness and early warning, particularly in fragile and conflict-affected environments. This project aims to overcome these challenges by scaling a Digital Twin (DT) for flood early warning in these environments. DT is a virtual replica of a physical object. It helps to monitor what is happening in real time, issue accurate, timely flood warnings and share relevant flood-related information so that stakeholders act before a flood occurs. It also brings together information from multiple data sources, including ground-based data sensors and satellites, detailed elevation data for the study site and flood forecasting models. It is the future aim of the DT to serve as a convening tool, fostering conversations and negotiations for stakeholder collaboration, the integration of humanitarian development strategies, disaster preparedness, planning and response and a strategic tool for climate adaptation and sustainable land-use planning.

The Dolo Ado Floodplain Digital Twin (DT) co-design workshop aimed to generate innovative ideas and collaboratively design a DT platform to enhance flood preparedness and early warning in the Dolo Ado district of the Somali Region, Ethiopia. Key stakeholders from disaster risk management, climate service providers, humanitarian organizations, and water resource specialists collaborated to ensure the design reflected their user needs and data requirements for addressing flood risk in the district. They represented local, national, and international organizations. The DT is expected to benefit refugees, internally displaced people and the host community in the study site, including women, children, and marginalized communities. The co-design workshop took place on June 26th and 27th of 2025.

The workshop helped identify and categorize potential DT users and outline their challenges and needs through interactive discussion. Prioritization of data requirements, generation of ideas to overcome priority challenges and identification of the DT host organizations were key outcomes. This study will serve as a reference for future design thinking works, expanding the approach on conflict sensitivity (e.g., preventing resource tensions) and integrating women, youth, and vulnerable groups into the co-development and use of digital tools.

1. Workshop Proceedings

Workshop Objectives

The co-design workshop objectives were to meaningfully involve key stakeholders in the design of a Digital Twin (DT) platform to enhance flood risk preparedness and early warning at Dolo Ado district, tailored to the diverse user needs and data requirements. The DT platform will integrate real-time data, support decision-making, and address user needs.

Specifically, the workshop was aimed at:

- Reach a common understanding with key stakeholders about the scope of the DT.
- Identify the roles of each end-user category in flood preparedness and early warning.
- Understand the needs of each potential end user of the DT.
- Identify potential solutions to address the needs of DT end users.
- Agree on how the data needed for the DT can be sourced.
- Describe how the DT can be designed to help end users solve the identified problems.

Participants

The workshop participants represented diverse organizations including the Disaster Risk Management Bureau (BRMB) at district and regional levels, municipality of Dolo Ado town, Ethiopian Meteorology Institute (EMI), World Food Program (WFP), United Nations High Commissioner for Refugees (UNHCR), Ministry of Water and Energy (MoWE), sector offices at district and regional levels, researchers from the International Water Management Institute (IWMI), and local research centers and universities.

Structure of the workshop

Day 1: morning session – The main objective of this session was to better understand the status of flood preparedness and early warning in Ethiopia, and particularly in the Dolo Ado district. This was achieved through presentations from various relevant stakeholders and IWMI, as well as panel discussions, which served as an entry point to reach a common understanding with key stakeholders about the scope of the DT. WFP and the Addis Ababa Fire and Disaster Risk Management Commission (AAFDRMC) shared their experience in planning and implementing the Anticipatory Action (AA) system for flood risk management. Panelists from EMI, WFP, IWMI, Bahir Dar University, and the Somali Regional State - Water Resource Development Bureau discussed the current state and challenges of flood preparedness and early warning and identified priority flood risk data and tools. They also provided suggestions to improve early flood warning and communication to reduce flood impact. Following the panel discussion, the concept of a DT was presented, including a demonstration of DT applications. The programs for Day 1 and Day 2 are given in Annex 1.

Day 1: Afternoon session – The objective of this session was to identify strategies for filling data gaps for the DT, and the roles, needs and challenges of each category of end users in flood preparedness and early warning. Preliminary observation of the flood-prone site and flood hazard data was presented to indicate data availability and gaps. It covered drone observations made as part of the project, remote-sensing-based flood maps, and river bathymetry data collection in the Dolo Ado district. This was followed by a series of group activities applying Design Thinking, a human-centered, iterative, and problem-solving methodology focused on understanding user needs and developing innovative solutions. It involves five core stages: Empathize, Define, Ideate, Prototype, and Test. This approach emphasizes collaboration, creativity, and a deep understanding of the user's perspective to create solutions that are desirable, feasible, and viable. During the afternoon, the initial breakout activity led participants to identify and categorize end users of the DT, describe their roles and responsibilities, identify their challenges and needs and prioritize the main challenges they face in flood preparedness and early warning.

Day 2: Morning session – On the second day, the workshop participants identified the potential solutions to address the needs of DT end users. The discussions in group breakouts continued on the second day. The workshop participants explored potential ideas to address challenges, with a strong focus on user outcomes to help them achieve their goals and respond to priority challenges. The ideas were then evaluated and prioritized using an impact-effort diagram, which is presented in Section IV. Some initial prototyping work on the Digital Twin platform was displayed to the audience to elicit feedback and confirm alignment with stakeholder priorities. The workshop was closed with a discussion on the way forward, focusing on potential host organizations, capacity building needs, and the formation of a core group of stakeholders for active engagement in the DT development, ensuring the solution is built with the support and engagement of a diverse and empowered team with a continuous feedback loop.

Presentations on the project and workshop, anticipatory actions for flood resilience, proposed DT solution and the next steps are given in annexes 2, 3, 4 and 5, respectively. Photos from the co-design workshop are in Annex 6.

Problem Definition

The participants identified a lack of data, poor coordination among stakeholders and the absence of real-time flood forecasting for effective early warning dissemination as key challenges that limit their preparedness and early warning to flood risks.

The stakeholders identified the following as key to improving preparedness and early warning to flood risks:

- Timely and accurate data at an appropriate spatial scale.
- Tools to support decision-making processes in flood risk preparedness and early warning.
- A workable flood forecasting model to translate rainfall forecasts to flood forecasts of adequate lead times to respond to early warnings.

2. Design Thinking Process

This study employed a design thinking approach, building on the work of Garcia Andarcia et al. (2024), who co-designed a Digital Twin (DT) for water resource management in the Limpopo River Basin. The methodology was adapted and scaled to co-design a DT for flood preparedness and early warning in the Dolo Ado District, Somali Region, Ethiopia. The design thinking process consisted of four main steps:

Empathy Building (Steps I & II):
The initial stages focused on developing empathy with potential end users of the DT (Sinansari et al. 2023). This involved engaging with users to understand their needs, challenges (pains), and desired outcomes (gains) in depth. A role-play was used to step into users' perspectives and ensure a user-centred approach.

Problem Identification (Step III):
Priority problems and challenges related to flood preparedness and early warning were identified in collaboration with end users. This step also included generating potential solutions to address the identified challenges.

Solution Evaluation (Step IV):
The participants evaluated proposed solutions based on the effort required and the anticipated impact of implementation. This evaluation helped prioritize actionable interventions for the DT design.

This iterative, user-centred methodology ensured that the resulting Digital Twin was tailored to the specific needs and context of the Dolo Ado District.

I. Identification and Categorization of the DT End Users (Empathize Stage)

Rooted in the Empathize stage of the Design Thinking methodology, the workshop participants were invited to develop a deep understanding of potential users of the Digital Twin (DT) for the Dolo Ado District (Table 1). This involved dividing the workshop participants into five groups, with each group creating detailed **personas,** as described in Step II, for a selected end user to capture the challenges, gains/needs, frustrations, and desires of the different user groups involved in flood risk preparedness and early warning. The approach involved brainwriting (generating ideas on paper rather than verbally), organizing each group member's ideas, and prioritizing them through consensus within each group. The personas helped to ensure that the DT design would effectively address the challenges faced by these diverse stakeholders dealing with floods. In stage I of the design thinking process, the workshop participants listed several end users in the DT of Dolo Ado district and categorized them into 7, as shown in Table 1.

Table 1. End users of the Digital Twin and their categorization

List of end users	Category
NGO, humanitarian UN agencies (WFP, UNHCR, OCHA, Red cross), Security agencies, Banks, donors	Development partners
Transit centers, refugee camps	Refugee and Internally Displaced People
Urban, pastoral, agropastoral, farmer associations	Host community

Agricultural (small private investors), Business community, Insurance companies	Private sectors
Regional, Zonal, district, municipality, Refugees and Returnees Service (RRS), Disaster Risk Management Bureau (DRMB), Ethiopian Disaster Risk Management Commission (EDRMC), Ethiopian Meteorology Institute (EMI), Ministry of Agriculture (MoA), Ministry of Health (MoH), Ministry of Water and Energy (MoWE)	Government administrators, policy makers (regional and national level)
Agriculture, water, pastoral, health, and disaster risk management bureaus	Technical institutions at regional level
Jijiga University, regional and district level research centers, IWMI	Research centers and universities

II. Understanding User Challenges and Expectations

Each workshop participant group selected one main end user of the DT for the remaining co-design activities. The main end users identified by each of the five groups were characterized through a role-playing exercise that captured their experiences as described here. During the role-play, group members stepped into the shoes of the selected end user to understand their perspective during the preparation and response to an extreme flood event in the Dolo Ado district. The participants simulated interviews with potential users about their feelings and the various challenges that affect their ability to act, in terms of flood preparedness and early warning. The interview was designed to record not only key pains (challenges and problems), but also potential gains (benefits and opportunities) facing users in flood preparedness and early warning based on their experience. The following 5 personas were developed by the workshop participants, who were divided into five groups:

Usman: Expert at the district Disaster Risk Management Bureau

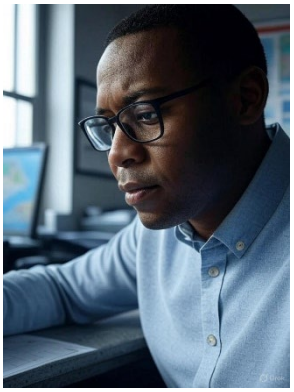

Figure 1. Expert at the district Disaster Risk Management Bureau (DRMB)
Source: AI generated

- **Profile**: Usman is a middle-aged Ethiopian man and flood expert working at the Disaster Risk Management Bureau (DRMB) of the Dolo Ado District in the Somali region of Ethiopia (Figure 1). He is responsible for providing flood early warning to the community and supporting evacuation to reduce the flood impact. He faces several challenges that prevent him from effectively undertaking his responsibilities. Some key observations from the interview process:
    - **Frustration and hopelessness to support the community:** - Usman feels frustrated and hopeless because he could not support the community before, during and after floods due to the many challenges he faces in undertaking his roles and responsibilities as a flood expert.
    - **Loss of lives, infrastructure damage, and displacement:** He felt sad to see the direct and indirect impacts of the flood on lives and livelihoods in the Dolo Ado district.
- Pains:
    - **Delays and low accuracy in early warning**: Usman often fails to issue timely early warnings to the community because he does not receive such information well ahead of an anticipated event with adequate accuracy.
    - **Low capacity to evacuate people**: Delays in early warning systems mean alerts reach communities and authorities too late, leaving little time to plan and carry out evacuations. This rushed process undermines the effective evacuation efforts. A recent extreme flood event in the Dolo Ado district made Usman realize that the district's DRMB lacks adequate capacity to support the movement of people from flood-affected sites to evacuation centers. These centers are characterized by inadequate space, water supply and sanitation services.
    - **Lack of accessibility**: Usman lacks confidence to support the evacuation of the community during floods because the shortest and safest paths from the flood-affected sites to the evacuation sites have not been identified and mapped yet.
    - **Lack of opportunity to improve knowledge and skills in flood early warning**: He has low access to capacity building opportunities and documents to enhance his capacity to support the flood-prone communities.
- Gains:

- **Improved flood forecasting and early warning system:** Usman believes that access to timely and accurate flood forecasts enables him to contribute to reducing the catastrophic impact of flooding in Dolo Ado district.
- **Identifying additional evacuation centers**: He indicated that the flood damage can be reduced by increasing the capacity of evacuation centers.
- **Prioritize flood hotspot sites:** He emphasized the identification and prioritization of flood hotspot sites to enable issuing flood warnings to the right people at the right time.

Abdihadir: Coordinator of the local disaster risk experts' team

Figure 2. Coordinator of local expert team
Source: AI generated

- **Profile**: Abdihadir is a middle-aged Ethiopian man. His responsibility is to coordinate the disaster risk experts working in the Dolo Ado town, the Somali region of Ethiopia (Figure 2). He faces challenges in coordinating the team to respond effectively to extreme flooding.
- Pains:
  - **Access to reliable information about flooding**: Abdihadir has limited access to timely, accurate flood warning information, which has hindered his ability to coordinate the disaster risk team in effectively protecting the flood-affected community. Additionally, the disaster risk team, led by Abdihadir, has not been documenting and reporting real-time flood characteristics and damages. Therefore, he struggled to rapidly and properly allocate the limited resources for flood recovery.
  - **Lack of flood forecast model:** The lack of a flood forecast prevented Abdihadir from properly coordinating the disaster risk team well ahead of an upcoming flood event, according to the available financial and human resources.
  - **Lack of functional early warning system**: Abdihadir believes that the lack of a functional early warning system is one of the main reasons for the high flood impact in Dolo Ado district. The existing Indigenous practice of flood forecasting remains un-integrated with scientific methods in flood early warning.
  - **Weak flood protection:** Abdihadir highlighted the underdeveloped flood protection measures in Dolo Ado due to limited budget and a lack of attention to flood risk.
  - **Lack of awareness to respond to early warnings:** Abdihadir emphasized that the lack of awareness of the community hinders flood risk reduction because of limited actions in response to a flood early warning.
  - **Limited communication channel for early warning**: Lack of an appropriate communication channel (e.g., access to mobile phones and low technology literacy) affected his ability to coordinate the disaster risk reduction team. Because of not using digital technology, the flood forecast, and early warning information are not updated and disseminated automatically to the community.
- Gains:
  - **Workable forecast model with adequate lead time**: Abdihadir needs a workable flood forecast model with adequate lead time for the community to prepare for an anticipated flood event. He recommends that the flood forecast model indicates the different hazard levels across districts to improve the effectiveness of disaster risk reduction efforts.
  - **Scenario-based forecasting based on return periods**: He suggested that a scenario-based flood forecast, including hazard and exposure levels, could help him effectively coordinate his team in responding to the flood.
  - **An automated dashboard that allows users, including community members, to feed data**: He mentioned the importance of an automated dashboard that provides flood information and allows the local community to enter actual flood hazard and flood data. He believes the data from the local community can inform recalibration of the flood forecast model.

Jemila: Head of water supply bureau

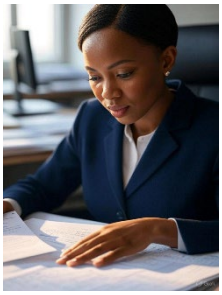

Figure 3. Head of the Water Supply Bureau
Source: AI generated

- **Profile**: Jemila is a middle-aged Ethiopian woman and the head of the water utility bureau for Dolo Ado town, in the Somali region of Ethiopia (Figure 3). She faces several challenges while supplying potable water to the community.
- Pains:
    - **Inadequate funding:** Jemila identified funding shortages as a major challenge hindering her bureau and teammates' efforts to provide clean water to Dolo Ado town. Lack of funding is also affecting her efforts to provide adequate clean water for flood-displaced people, maintain flood-affected water supply infrastructures and protect these infrastructures from flood damage.
    - **Lack of collaboration for early warning dissemination:** Jemila's previous flood experience indicates that weak cooperation between government and non-government agencies is hindering the dissemination of timely, accurate early warning information to protect water supply infrastructure.
    - **Lack of appropriate data and experts in local government agencies:** Jemila is often concerned about the lack of experts to document and report flood hazard and impact data to inform flood adaptation and awareness-raising efforts.
    - **Not recovering from the 2023 flood:** Jemila indicated that the community and her officemates have not yet recovered from the 2023 flood impact. Consequently, she feels that this undermines their capability to cope with the next flood event.
- Gains:
    - **Be prepared for the next flood**: Jemila feels the importance of improving flood preparedness for the next extreme flood event.
    - **Enhance coping mechanisms**: She suggested building coping capacity by targeting vulnerable groups.
    - **Strengthen the early warning system**: Jemila believes the early warning systems need to be strengthened for better flood preparedness.
    - **Put coordination in place**: She indicated that coordination among different local and federal stakeholders (e.g., MoWE, EMI, National Disaster Risk Management Commission, health, disaster, and development partners) can substantially help reduce flood damage.
    - **Prioritize flood in resource allocation**: She noted the need to prioritize flood preparedness and mitigation during resource allocation.

Mengistu: Expert in the district Disaster Risk Management Bureau (DRMB)

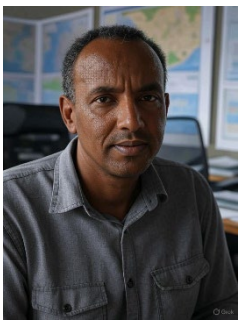

Figure 4. Expert in the district Disaster Risk Management Bureau (DRMB)
Source: AI generated

- **Profile:** Mengistu is a senior expert working in the district Disaster Risk Management Bureau (DRMB) in Dolo Ado town, Somali region of Ethiopia (Figure 4). He faces challenges in carrying out his responsibility to improve the effectiveness of flood risk management.
- Pains:
    - **Data Gap**: Mengistu notes that the data gap is one of the challenges that hinder his ability to contribute to flood risk management. These datasets are particularly relevant to seasonal rainfall forecasts, hydrological indicators (water level and discharge), and detailed flood maps, which are critical for real-time flood monitoring, providing early warning and rapid responses to flood impacts.
    - **Poor Infrastructure development:** Mengistu emphasized that the poor infrastructure development (e.g., roads) hampers his efforts to provide emergency response to flood-affected people. Emergency responses are also affected by unreliable telecom and internet coverage and frequent power cuts during extreme flood events.
    - **Resource allocation:** Mengistu stated that the lack of proper resource allocation to stakeholders working in early warning systems, community training, or basic protective infrastructure hampered their ability to perform their duty in flood risk management.
    - **Technical capacity limitation**: Many local sectors lack comprehensive flood literacy, both in understanding science and applying practical risk-reduction measures. Even when data is shared, it is rarely in formats that support quick decision-making, visual mapping, or risk communication with communities. Overall, Mengistu's suggestion is to build the technical capacity of local experts to enhance the effectiveness of flood risk management.
    - **Lack of coordination and collaboration**: Lack of coordination among key stakeholders hinders the ability of Mengistu's teammates to contribute to effective flood risk management. These

stakeholders are from government departments, NGOs, and humanitarian agencies that are involved in flood preparedness and early warning. Because of a lack of synergy, valuable resources are duplicated, and critical gaps remain unaddressed.

- Gains:
  - **Support to planning and preparing anticipatory action:** Mengistu needs a system developed for anticipatory action. The system can potentially support flood-vulnerable communities by providing guidelines for self-preparedness and rapid responses during flooding.
  - **Access to timely data and information**: He suggested developing a dashboard that can integrate and provide access to all flood-relevant datasets in the district. The dataset in the dashboard can be categorized as pre-flood, during and post-flood data.
  - **Sound and coordinated resource allocation**: He believes in the importance of allocating limited resources properly across the different stages of flood risk management and different stakeholders (local individuals, groups and other stakeholders) to ensure the sustainability of anticipatory actions.
  - **Improve data accuracy for early flood warning systems**: Mengistu emphasized the need to improve the accuracy of input datasets to enhance the reliability of early warning information to be disseminated to the community.

Life Saver: Expert at the Ethiopian Disaster Risk Management Commission (EDRMC)

Figure 5. Expert at Ethiopian Disaster Risk Management Commission (EDRMC)
Source: AI generated

- **Profile**: Life Saver is the nickname of an expert working in the Federal Disaster Risk Management Commission (Figure 5). He is a middle-aged Ethiopian man with 20 years of work experience. His responsibility is to serve and save the flood-vulnerable community. He identified some of his main challenges when serving the community.
- Pains:
  - **Coordination challenge:** Life Saver mentioned that the fragmented activities of stakeholders and the lack of a properly functioning collaboration platform affected his efforts to serve the flood-vulnerable community.
  - **Inadequate information about flood risk**: He emphasized the importance of accurate and timely information for enhanced flood preparedness and early warning. This information includes flood early warning, real-time monitoring, and locations of flood-affected areas.
  - **Lack of real-time data:** Based on his experience in serving the flood-vulnerable community, Life Saver is enthusiastic about receiving real-time flood data. He emphasized that real-time data can also be used to recalibrate the flood forecast model, enabling prioritization of sites based on flood magnitude. Additionally, real-time data can inform flood index insurance, facilitating rapid recovery response. Life saver identified a lack of a common dashboard as a bottleneck for the community to upload real-time flood data to inform flood risk management.
- Gains:
  - **Alert early warning message**: Life Saver suggested setting up a flood alert system to enhance the preparedness of the community.
  - **Evidence-based decision**: He believes in evidence-based decision-making as it builds trust among stakeholders, the community, and other end users of DT. Therefore, the weather and flood forecast model can be calibrated and validated using local real-time data to inform decisions during the preparation of flood anticipatory actions.
  - **Integrate community knowledge with scientific methods:** Life Saver suggested integrating community knowledge and responses with scientific evidence to enhance the capacity to serve the flood-vulnerable community.

III. Problem Statements and Big Ideas to Solve the Problem

Moving through to the Define and Ideate stages of the Design Thinking methodology, the workshop participants identified the priority problems or challenges facing the group's proposed persona and applied a brainwriting technique (writing down ideas in silence instead of speaking) using the 6-3-5 Method. This approach allowed participants to contribute equally to addressing the priority problems. Since this method favors quantity (of ideas) over quality, this report describes only the key ideas as prioritized by each individual group.

Usman: Expert at the district Disaster Risk Management Bureau

The priority for Usman is to support the community by providing timely and accurate flood early warning. He believes that improving flood early warning systems saves lives and livelihoods. The following key ideas are considered to allow Usman to deliver practical early warning information to the community:

- Improving the input data of a rainfall-runoff model to increase the accuracy of flood forecasting.
- Identify vulnerable groups (e.g., susceptible areas for prioritizing evacuation and early warning dissemination, and evacuation sites).
- Strengthening local-level early warning coordination via DT: It is essential that community-based early warning committee members have access to tools and their outputs. This can involve devising an efficient early warning communication/dissemination considering access to technology.
- Capacity building for tool users, including the community.

Abdihadir: Coordinator of the Local Disaster Risk Experts' team

The priority for Abdihadir is to develop a workable flood forecast model to support the community in flood preparedness and evacuation during a disaster. In Dolo Ado, the evacuation is being positioned as an anticipatory early action—triggered before impacts occur based on forecast confidence. He believes that the workable flood forecast model supports effective coordination of the disaster risk reduction team. The following ideas are perceived to enhance Abdihadir's capability to coordinate his team effectively:

- Data preparation: flood extent maps for various return periods, physical exposure data, and time series river discharge data, exceptional rainfall data in different percentiles (90%, 95%, and 99%).
- Data processing: flood-related database of the area of interest.
- Model development: adapt or customize a workable global model, including ground station data.
- Ample lead time for effective anticipatory action activation.
- Water level data from community or citizen science.
- Automation (a dashboard that allows data provision and data entry).

Jemila: Head of the Water Supply Bureau

Jemila indicated the need to address the lack of flood mitigation measures to reduce the flood damage to water supply structures. The following ideas are believed to allow Jemila to effectively protect the water supply scheme from flooding and provide drinking water to flood-displaced people:

- Establishment of a strong early warning system.
- Capacity-building for the community-based early warning committee.
- Resettling of the flood-affected population to a safe and preserved area.
- Proper land use system (buffer zone restoration).
- Resilience infrastructures for water supply.
- Strong coordination between relevant partners.

Mengistu: Expert in the District Disaster Risk Management Bureau (DRMB)

Mengistu's priority is to improve the effectiveness of flood risk management. He believes that improving flood preparedness, planning, and implementing anticipatory actions, as well as effective recovery from flood disasters, can improve flood risk management in the Dolo Ado district. Mengistu will benefit from the following ideas:

- Installation of hydrological and meteorological gauging stations by MoWE.
- Harnessing Indigenous knowledge, including elders' skills in weather forecasting alongside scientific approaches, can benefit the study area.
- Meaningful engagement of citizen scientists to monitor river water level, flood extent and weather can support early warning systems.
- Capacity building in accessing and using the global dataset for the Dolo Ado district.
- Improving the communication channel and data-sharing mechanism via the dashboard.
- Building institutional partnerships for data sharing, collaborating with international humanitarian agencies and private sectors that operate in the area for sharing the data that they have, and facilitating capacity building.

Life Saver – expert in the Ethiopian Disaster Risk Management Commission (EDRMC)

The priority for Life Saver is to improve flood risk management by issuing early flood warnings with a lead time of 3 to 7 days. This requires the following actions:

- Development of a dashboard.
- Installation of automatic weather stations.
- Installation of telemetric gauge stations.
- Access to rainfall forecasts.

- Preparation of GIS maps of flood-affected infrastructures.

IV. Evaluating, Clustering and Sorting Ideas

The suggested ideas to address the priority problems of each potential DT end user were evaluated using a 2x2 Matrix tool with Impact and Effort axes (Table 2). This helps to prioritize ideas that have high impact in enhancing flood preparedness and early warning with low effort to design and implement (usually designated as quick wins) and to stimulate the pursuit of the highest impact ideas, which may require more detailed analysis due to perceived effort (also known as big bold ideas). The effort required to implement each idea and its impact on flood preparedness and early warning are categorized qualitatively in Table 2.

Table 2. Impact/Effort Matrix

Impact	Low Effort	High Effort
High	• Identify flood vulnerable areas and community to prioritize during the early warning and response stage. • Evacuation centre identification. • Dissemination of early warning information. • Flood risk map. • Exceptional rainfall data. • Flood discharge data (timeseries). • Proper land use system in the city and buffer zone. • Community awareness. • Flood modelling and evaluating mitigation. • Community based flood early warning system. • Understandable communication channel. • Low-cost scalable water level sensor. • Portable device with relevant apps. • Skill building for data usage and manipulation. • Citizen Science (Community based monitoring). • Building institutional partnership for data sharing. • GIS maps of flood affected infrastructures.	• Improve input data accuracy for flood forecasting. • Strengthening local early warning system. • Capacity building to different stakeholders. • Workable flood forecast model. • Create buffer zone. • Climate resilient infrastructure • Urban drainages. • Resettlement of the community. • Improve connectivity (internet and cellular network). • Installation of hydrological and meteorological stations. • Establish database (Historical and updating). • Development of dashboard. • Hydrological and Hydrodynamic model. • Rainfall forecast provision. • Installation of telemetric gauges.
Low	• Distribution of non-food items. • Indigenous knowledge. • Socio-economic data. • Other flood related data.	

Source: Authors' creation based on the ideas generated by the workshop participants

V. Showcasing preliminary prototype work

As the co-design and ideation workshop advanced to its final stages, in alignment with the Prototyping and Test stages of the Design Thinking methodology, the technical team from IWMI, represented by the lead architect Hugo Retief, demonstrated some initial components and features of the prototype being developed. These preliminary outputs allowed workshop participants to provide valuable feedback and to reinforce their commitment to help design a solution that meets their key requirements. The demonstration showed the DT capabilities to build trust across stakeholders (e.g., through data transparency, inclusive participation and citizen science) by pooling data together from different sources, using easy-to-understand visualizations, and providing interactive exploration of

flood-related data, including options to respond to floods. Figure 6 shows the demonstration of flood inundation using the Digital Twin of the Dolo Ado site.

Figure 6. Demonstration of flood inundation using the Digital Twin of the Dolo Ado site

3. Conflict Sensitivity and Inclusivity

A conflict-sensitive approach and inclusivity will be at the core of the Digital Twin (DT) initiative. It is essential that the DT explicitly addresses conflict sensitivity—such as proactively preventing resource-related tensions—and ensures the meaningful integration of women, youth, and vulnerable groups throughout both the development and application (e.g., accessing warning information) of the DT. Conflict sensitivity will be addressed by building on the integrated host community vulnerability framework (Adam-Bradford et al. 2024).

Citizen science, recognized as a high-impact and low-effort solution, should be designed and implemented with these same principles. Volunteer recruitment and engagement for citizen science-based flood monitoring and community-based early warning systems (CBFEWS) must deliberately address community power dynamics (Nigussie et al., 2025), ensuring that women, youth, and vulnerable groups are not only included but empowered to participate fully. Nigussie et al. (2025) indicated that CBFEWS reduces dependence on external entities, enhances local decision-making capabilities, and promotes a sense of ownership, empowerment, and trust.

To achieve this, future project phases must incorporate more intentional and robust measures to promote both conflict sensitivity and inclusivity. The design of the DT, as well as all capacity development and training activities, should clearly demonstrate how these critical issues are integrated, ensuring that conflict sensitivity and inclusivity are embedded in every aspect of DT design, training and citizen science engagement, going forward.

4. The Way Forward

Workshop participants discussed the way forward, building on a brief presentation by the WFP team as presented in the Annex. It was suggested that IWMI can host the DT during the development phase. Considering MoWE and the EMI have the mandate to provide and archive flood risk-related data and tools, it was suggested to continue discussions with the two organizations to better understand their requirements for hosting the DT. MoWE and EMI can be capacitated to roll out the DT to other flood-affected sites. Under this study, IWMI and WFP will continue to enhance their partnership to achieve more effective, resilient outcomes by leveraging the strengths of each organization.

The participants suggested enhancing the community capacity through a citizen science program and strengthening the capacity of relevant governmental organizations so that they can develop their own DT for other sites. It was recommended to establish a core group that will continuously contribute to ideas during the DT development. Potential members of the core group include IWMI (lead of the development of DT), MoWE and EMI (Government lead partner), the advisory group of Anticipatory Action National Technical Working Group (AA–NTWG) (Advisory Group), Somali region DRMB, the regional Water Bureau and Dolo Ado Administration, and WFP and UNHCR.

The next steps include the following:

- IWMI will initiate discussions with MoWE and EMI to identify the pre-requirements and support required to host the DT.
- The data voids for the DT development will be filled through collaboration among all end users, with MoWE providing observed river discharge data, EMI providing climate data and IWMI setting up a rainfall-runoff model in a simulation mode to simulate historical floods. The rainfall-runoff model will be further developed in 2026 to serve as a flood forecast model.
- IWMI will simulate the 2023 flood using a hydrodynamic model of the Genale-Dawa Rivers' reach at the Dolo Ado district.
- IWMI will prepare a prototype DT model of the Dolo Ado district, incorporating characteristics of the 2023 extreme flood and the long-term simulated river discharges.

- IWMI and WFP will co-organise a follow-up workshop in November 2025 to present progress and gather end users' feedback on the DT development and identify co-design priority activities for 2026.
- A collaborative approach will be followed to investigate and generate evidence on how the DT reduces costs, supports anticipatory action and aligns with humanitarian donor priorities.

The application of the DT can be extended to fragile environments beyond Ethiopia, to enhance resilience against diverse climate and human-induced shocks. Projects by the CGIAR Food Frontiers & Security program, along with other initiatives in fragile and conflict-affected settings (FCAS) operating in countries such as Jordan, Sudan and Nigeria, offer an excellent opportunity to adapt the DT approach. This adaptation is particularly pertinent for rapidly expanding urban areas, island nations facing sea-level threats and regions experiencing conflict.

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Annexes

Annex 1. Workshop Program for Day 1 and Day 2

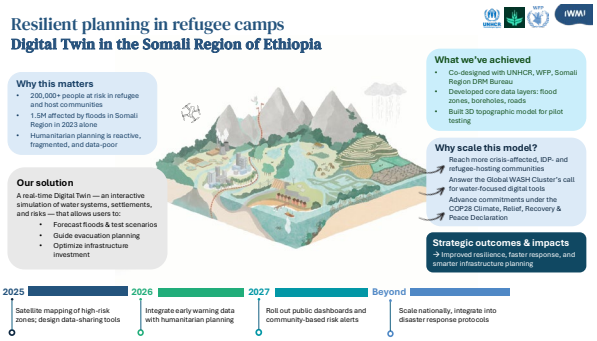
Day 1

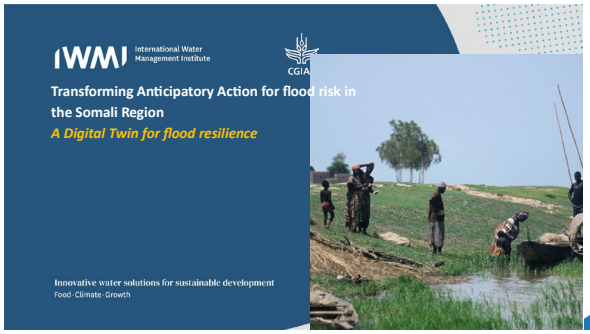
Time	Theme	Actors/Facilitators
8:30 AM – 9:00 AM	Arrival and Registration	Rahel M. (IWMI)
9:00 AM – 9:15 AM	Welcoming and Opening Remark; and about the project	Abdulkarim Seid (IWMI)
09:15 AM – 09:45 AM	Anticipatory Actions for flood resilience: experience from Addis Ababa and the Somali region	Yared Damtew (AAFDRMC) Abiy Wogderes (WFP)
09:45 AM – 10:45 AM	Multi-stakeholder panel discussion on existing data, tools and processes (what is being used, how are they used, why) improve flood risk mitigation in the Dolo Odo area; where the challenges faced in addressing flood risks? What are the key gaps?	IWMI
10:45 AM – 10:15 AM	Group Photo and Health Break	
11:15 AM – 11:30 AM	About the co-design workshop and expected outcome.	Mariangel Garcia Andarcia
11:30 AM– 1:00 PM	The proposed solution: Presentation on Digital Twin – the foundational technology underpinning Digital Twin solutions, and showcase some existing Digital Twins of natural environments.	IWMI Mariangel Garcia Andarcia Hugo Retief Paulo Silva
1:00 PM – 2:00 PM	Lunch Break	
2:00 PM – 2:30 PM	Preliminary observations: - Mapping of past flooding incidents - Drone observation of the flood prone area	Alemseged T. H. Mitch McTough
2:30 PM - 3:00 PM	Breakout/facilitated interactive session: - Identify end users of the DT - Describe the roles and responsibilities of each category of end users of DT in effective flood preparedness and response in the Dolo Ado district.	5 group formation based on roles and responsibilities • Mariangel Garcia Andarcia • Paulo Siva • Hugo Retief • Alemseged T. H.
3:00 PM - 5:00 PM (coffee will be served)	Breakout/facilitated (Role play).: - Understanding the need of each potential end user of the Digital Twin to improve resilience against floods. - Prioritize main challenges that each category of end user encounters in flood preparedness and response in the district.	
05:00 – 05:30 PM	General discussion	Breakout groups
05:30 PM	Closing	Abdulkarim H. S.

Day 2

Time	Theme	Actors/Facilitators
09:00 – 09:15 AM	Recap from Day 1	Participants
09:15 AM – 11:00 AM	Generate ideas and solutions: (i) describe the potential solutions to respond to priority challenges identified by the end users using the Digital Twin, and (ii) evaluate feasibility of implementing the proposed solutions and the effect/impact of implementing the proposed solutions.	5 group formation based on roles and responsibilities Mariangel Garcia Andarcia Paulo Siva Hugo Retief Alemseged T. H.
11:00 AM – 11:15 AM	Health Break	
11:15 AM – 12:00 PM	Presentation by each group followed by discussion	Group representatives
12:00 PM – 01:00 PM	Next steps (interactive discussion): - Hosting the Digital Twin - Capacity building needs for hosting the DT - Core group for co-development of the Digital Twin	WFP
01:00	Closing Remark	Abdulkarim Seid (IWMI)

Annex 2. Presentation Slides on the Project and the Co-design Workshop





The Somali Region and Flood Risks

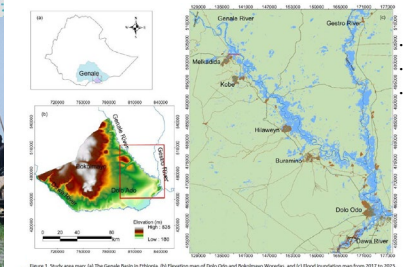


Figure 1. Study area map: (a) The Genale Basin in Ethiopia, (b) Elevation map of Dolo Ado and Bokolmayo Woredas, and (c) Flood inundation map from 2017 to 2023.

Increasing impacts of floods

- **2015**: 210,600 people affected
- **2019**: 200,000 people affected
- **2023**: 1.5 million people affected

The barriers to effective flood preparedness

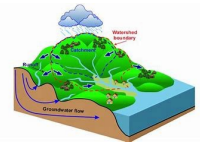
- Lack of reliable tools and data to translate rainfall forecasts into specific flood impacts
- Inaccurate or insufficient flood risk maps
- Poor accessibility to granular topographic data (e.g., elevation models)
- Inadequate coverage of hydro-meteorological stations in flood-prone areas

The proposed Digital Twin

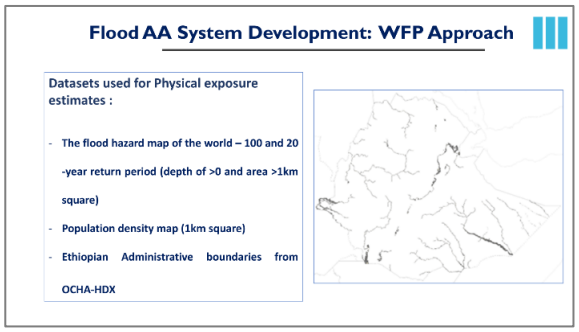
- **Serve as convening Tool for multi-Stakeholder Collaboration -** for joint flood analysis and response planning.
- **Planning Anticipatory Actions**: The DT will play a crucial role in anticipatory flood management, allowing agencies to plan targeted interventions and flood mitigation actions in advance.
- **Strategic Tool for Sustainable Land Use Planning**: Beyond emergency response, the DT can be used as a strategic tool to develop long-term, sustainable land use plans for floodplains.

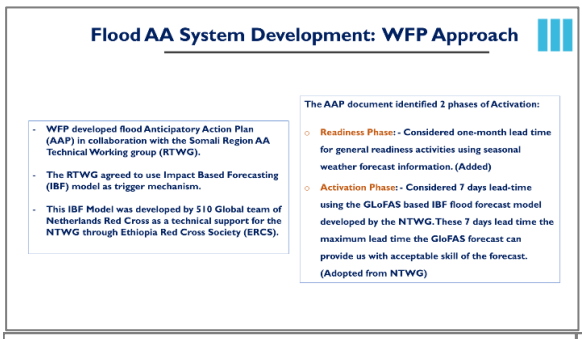
The key components

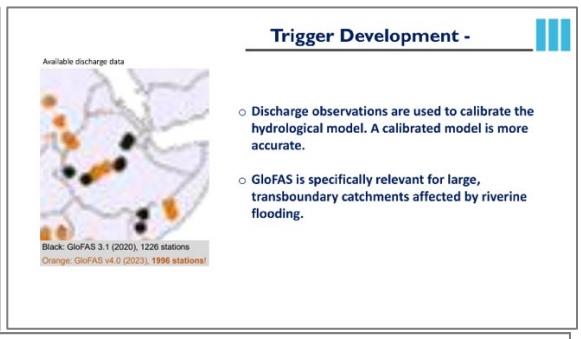
- **High-Resolution 3D Model of the Floodplain**: to serve as the base layer for all flood predictions and analyses in both the spatial analysis as well as the hydrodynamic flood modeling.
- **Real-Time Sensor Network**: for monitoring monitor flood risks in near-real time.
- **Event Forecasting Model**: for the entire contributing catchment area that feeds into the tributaries and streams in the selected flood prone region.
- **Hydro-Dynamic Model**: to translate flood hydrographs into practical, actionable information, including: **Areal extent** of flooding, **Flood depth and Flood duration**:
  - **Integrated AI chatbot (or agent)**
  - **Damage Assessment module**
  - **Scenario builder**
  - **Warning communication and feedback system**

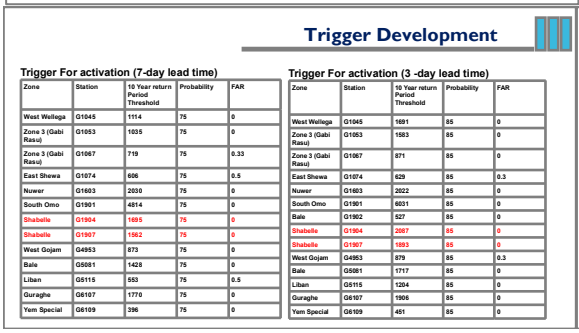


Annex 3. Presentation Slides on Anticipatory Actions for Flood Resilience (WFP)



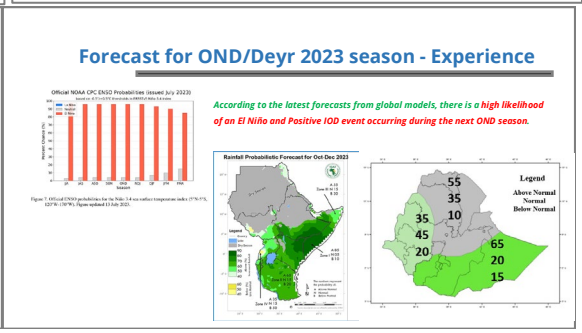


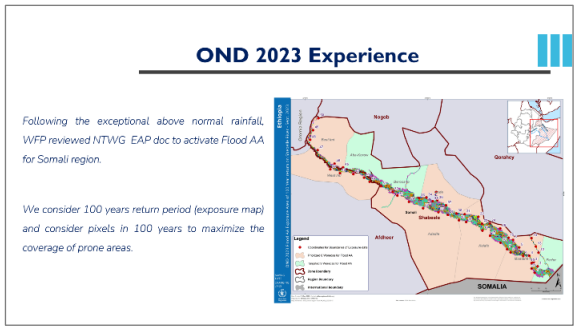


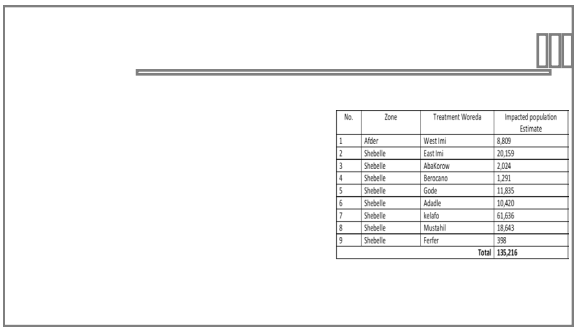


Zone	Station	10 Year return Period Threshold	Probability	FAR
West Wellega	G1045	1114	75	0
Zone 3 (Gabi Rasu)	G1053	1035	75	0
Zone 3 (Gabi Rasu)	G1067	719	75	0.33
East Shewa	G1074	606	75	0.5
Nuwer	G1603	2030	75	0
South Omo	G1901	4814	75	0
Shabelle	G1904	1895	75	0
Shabelle	G1907	1562	75	0
West Gojam	G4953	873	75	0
Bale	G5081	1428	75	0
Liban	G5115	553	75	0.5
Guraghe	G6107	1770	75	0
Yem Special	G6109	396	75	0

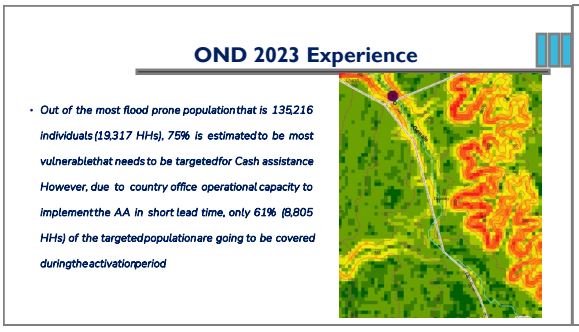
Zone	Station	10 Year return Period Threshold	Probability	FAR
West Wellega	G1045	1691	85	0
Zone 3 (Gabi Rasu)	G1053	1583	85	0
Zone 3 (Gabi Rasu)	G1067	871	85	0
East Shewa	G1074	629	85	0.3
Nuwer	G1603	2022	85	0
South Omo	G1901	6031	85	0
Bale	G1902	527	85	0
Shabelle	G1904	2087	85	0
Shabelle	G1907	1893	85	0
West Gojam	G4953	879	85	0.3
Bale	G5081	1717	85	0
Liban	G5115	1204	85	0
Guraghe	G6107	1906	85	0
Yem Special	G6109	461	85	0

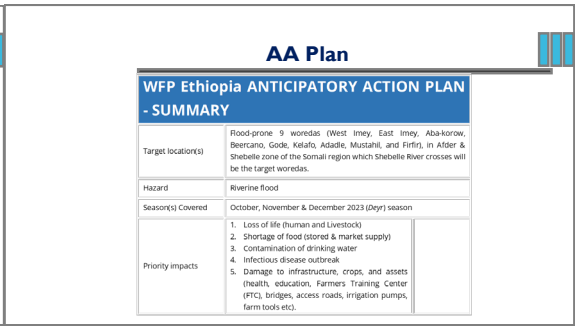






No.	Zone	Treatment Woreda	Impacted population Estimate
1	Afder	West Imi	8,809
2	Shebelle	East Imi	20,159
3	Shebelle	Abakorow	2,024
4	Shebelle	Berocano	1,791
5	Shebelle	Gode	11,835
6	Shebelle	Adadle	10,420
7	Shebelle	kelafo	61,636
8	Shebelle	Mustahil	18,643
9	Shebelle	Ferfer	398
		Total	135,216





Target location(s)	Flood-prone 9 woredas (West Imey, East Imey, Aba-korow, Beercano, Gode, Kelafo, Adadle, Mustahil, and Ferfer), in Afder & Shebelle zone of the Somali region which Shebelle River crosses will be the target woredas.
Hazard	Riverine flood
Season(s) Covered	October, November & December 2023 (*Deyr*) season
Priority impacts	1. Loss of life (human and Livestock) 2. Shortage of food (stored & market supply) 3. Contamination of drinking water 4. Infectious disease outbreak 5. Damage to infrastructure, crops, and assets (health, education, Farmers Training Center (FTC), bridges, access roads, irrigation pumps, farm tools etc).

AA Plan

Proposed Anticipatory Actions (AAs)	1. Dissemination of riverine flood early warning information. 2. Evacuation of human, animal & moveable livelihoods assets. 3. Prepositioning and pre-distribution of food, nutrition supplies, medical supplies, water purification chemicals and other non-food items. 4. Cash based transfers to smooth consumption, support market functioning, public works (e.g., for clearing drainages and help households to purchase essential supplies. 5. Health and hygiene training and awareness raising. 6. Construction/maintenance of physical flood protection structures around homesteads, standing crops and facilities.
Number of planned tier-1 beneficiaries by scenario (min and max)	**Mild:** **Moderate:** 93,031 beneficiaries/13,290 HHs for early warning and 69,773 beneficiaries /9,968 HHs for cash-based transfers. **Severe:** 135,216 beneficiaries/19,317 HHs for early warning and 101,412 beneficiaries /14,487 HHs for cash-based transfers.
Budget needs by scenario (USD) (min and max)	**Mild:**

Targeting and Registration

Exclusion Criteria

Number	Exclusion Criteria	Explanation
1. 2.	Households who own means of transport to generate income Household headed by a civil servant or civil servant pensioner	Households who own means of transportation to generate income, for example, Bajaj, truck, car, motorcycle. Household headed by a civil servant or civil servant pensioner
3. 4.	Households enrolled in the PSNP programme Household owning greater than 5 camel or 10 cattle or 30 shoats.	Households enrolled in the PSNP programme Household owning greater than 5 camel or 10 cattle or 30 shoats.

Inclusion Criteria

Number	Eligibility CRITERIA	Explanation
1	Households headed by a person with a disability	The Household head has a physical, listening, visual, or mental disability, which impacts their ability to contribute to the household's income and economic welfare.
2 3	Household headed by a chronically ill person Households with malnourished Pregnant and Lactating Women	The household head is chronically ill to the extent of being unable to regularly contribute to his/her household's income, including providing food for his/her household. A person is chronically ill when they are ill for at least 3 months. The pregnant and lactating Women (PLW) must have been screened and indicated to be malnourished by a competent health official; proof of this is required. The proof may be a card issued by the Ministry of Health or a register maintained by a health Extension worker.
4	Households with malnourished children	The malnourished child must have been screened and indicated to be malnourished by a competent health official; proof of this is required. The proof may be a card issued by the Ministry of Health or a register maintained by a health Extension worker.

CHALLENGES AND OPPORTUNITIES

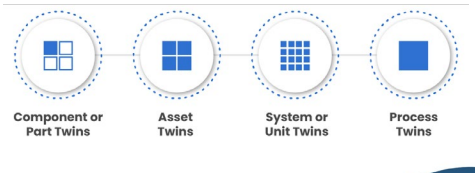
CHALLENGES:

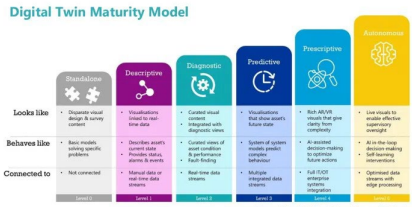
- Lack of calibrated GloFAS station data for the basin – Ethiopia part
- GloFAS is specifically relevant for large, transboundary catchments affected by riverine flooding and needs customized models.
- Operational delays due to shortened lead-times – Stopping MECHANISM
- Harmonization of Methodologies
- The need to have Multi Hazard approach – including Human induced hazards.

OPPORTUNITIES:

- The government is supporting to develop multi hazard AA.
- Availability of Research Institutes like IWMI to support development of Models.

Annex 4. Presentation Slides on the Proposed Digital Twin Solution

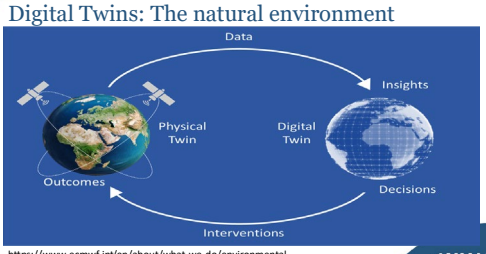




Digital Twins: The natural environment

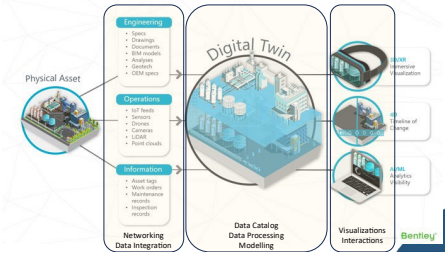
Source: NASA

Digital Twins: The natural environment



https://www.ecmwf.int/en/about/what-we-do/environmental-services-and-future-vision/destination-earth

Digital Twins: endless potential, complex architecture



Annex 5. The Next Steps

NEXT STEPS

I - Hosting the Digital Twin

Development Phase

- It is better if a digital twin (DT) is hosted by a **DEVELOPER** at development phase that offers substantial advantages for developers, allowing for virtual testing, performance optimization, and safer development cycles.
- IWMI at the centre of the development phase and better if it is hosted by IWMI.
- IWMI need to sign MoU's with MOWE and EMI on data sharing for DT.

Roll out Phase

- Roll out of the developed DT through government institution.
- MoWE and EMI are at the key institutions for the roll out.
- MoWE and EMI will decide where to HOST considering hosting capacity (PRESMISES vs CLOUD)

NEXT STEPS…..

II – Capacity Strengthening needs on DT

- The project needs to have a CS component in all phases of the project. Focus on government partners.
- Sustainability of the developed system is critical – use of open data source etc to avoid if not minimize cost implications after handover.
- Capacity building that allows government to recalibrate if needed.

NEXT STEPS…..

III – Core group for co-development of DT

Core Group

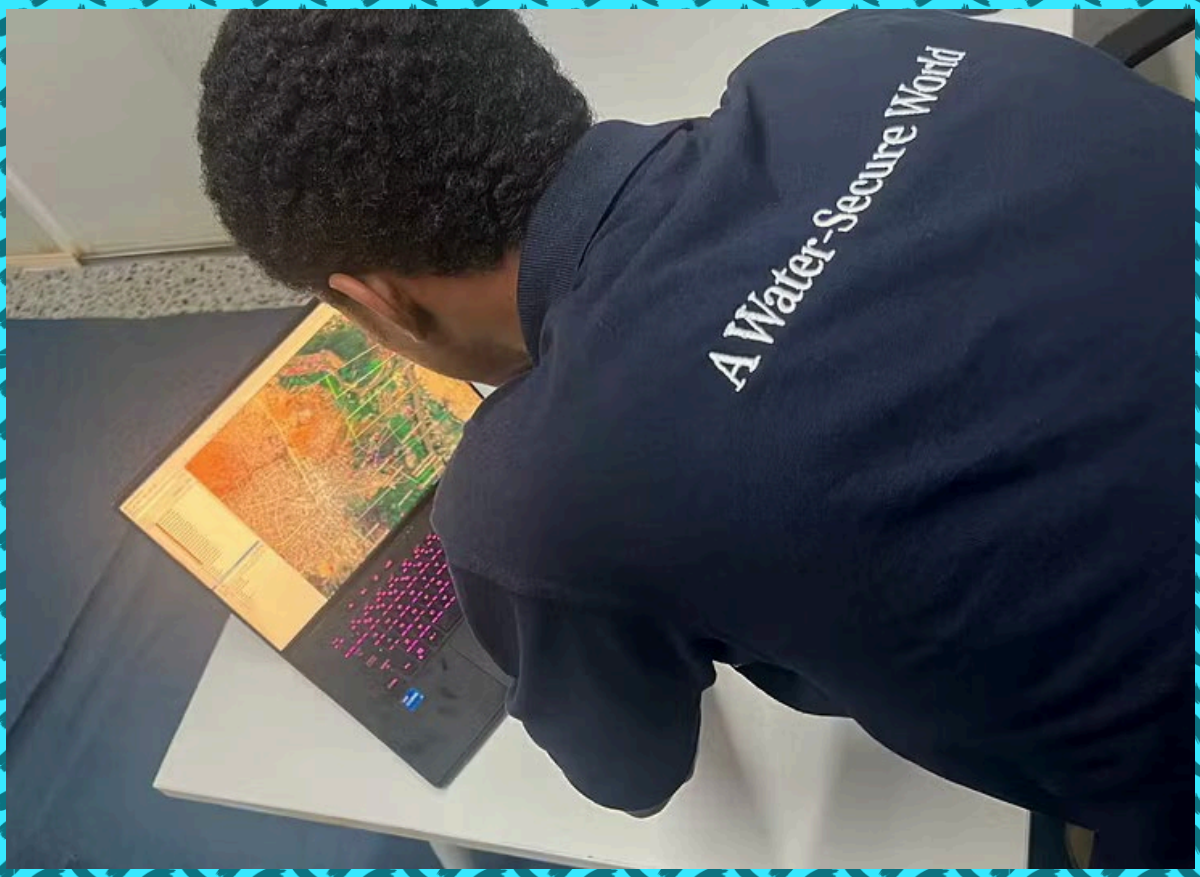
The primary core group focused on the development and adoption of digital twin for flood hazard.

This consortium brings together government, research institution like IWMI, to develop the DT through standardization, research, and collaborative projects.

Potential CORE GROUP :

- **IWMI – Lead of the development of DT**
- **MoWE/EMI – Government lead partner**
- **AA - NTWG – Advisory Group**
- **Somali region /** DRMB, BoWater and DoloAdo Administration
- **WFP**
- **UNHCR**

Annex 6. Photos from the Co-design Workshop



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