The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

International Water
Management Institute

Improving Water and Climate Data and Decision Support Tools for Climate-smart Water Management in Ethiopia

Synthesis Report

Meron Teferi Taye, Abdulkarim H. Seid, Robel Tilaye, Sirak Tekleab, Mebruk Mohammed and Belete Berhanu

Improving Water and Climate Data and Decision Support Tools for Climate-smart Water Management in Ethiopia

Synthesis Report

Meron Teferi Taye, Abdulkarim H. Seid, Robel Tilaye, Sirak Tekleab,
Mebruk Mohammed and Belete Berhanu

The authors:
Meron Teferi Taye, Researcher – Transitioning Landscapes (meron.taye@cgiar.org) and Abdulkarim H. Seid, Country Representative – Ethiopia (a.seid@cgiar.org), International Water Management Institute (IWMI), East Africa and Nile Basin Office, Addis Ababa, Ethiopia
Robel Tilaye, Consultant, Addis Ababa, Ethiopia (robtilaye@gmail.com)
Sirak Tekleab, Assistant Professor at the Ethiopian Institute of Water Resources (EIWR), Addis Ababa University, Addis Ababa, Ethiopia (siraktekleab@yahoo.com)
Mebruk Mohammed, Assistant Professor (mebruk.mohammed@aait.edu.et) and Belete Berhanu, Associate Professor (belete.berhanu@aait.edu.et), Addis Ababa Institute of Technology, Addis Ababa, Ethiopia

Taye, M. T.; Seid, A. H.; Tilaye, R.; Tekleab, S.; Mohammed, M.; Berhanu, B. 2024. *Improving water and climate data and decision support tools for climate-smart water management in Ethiopia*. Synthesis report prepared by the Prioritization of Climate-smart Water Management Practices project. Colombo, Sri Lanka: International Water Management Institute (IWMI). 28p. doi: https://doi.org/10.5337/2024.205

Disclaimer: This publication has been prepared with care. Responsibility for opinions expressed and any possible errors lies with the authors and not the institutions involved. The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by IWMI, CGIAR, our partner institutions, or donors.

Cover photo: Borkena River, staff gauge location at Kemise, Amhara Region, Ethiopia (*photo*: Sitot Wassie)

Copyright © 2024, by IWMI. All rights reserved. IWMI encourages the use of its material provided that the organization is acknowledged and kept informed in all such instances.

Please send inquiries and comments to IWMI-Publications@cgiar.org

Acknowledgments

Project

This research study was undertaken as part of the *Prioritization of Climate-smart Water Management Practices* project, funded by the Bill & Melinda Gates Foundation, investment ID—INV-029027.

Collaborators

International Water Management Institute (IWMI)

Addis Ababa Institute of Technology, Addis Ababa, Ethiopia

Donor

Bill & Melinda Gates Foundation

The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of the donor.

Contents

Summary

Water is the medium through which most impacts of climate change on people's livelihoods and ecosystems are transmitted. Climate change can lead to increasing scarcity of water, intensify variability in rainfall and, thereby, river discharge; and exacerbate the severity of flood, drought and heatwave extremes. Reducing climate-induced water scarcity and enhancing climate resilience to water-related hazards requires well-thought-out actions that include water infrastructure development, putting in place adaptive institutional frameworks, and increasingly developing and employing innovations and future-oriented climate and water data and decision support systems. This report is one of the outputs of the study conducted by the International Water Management Institute (IWMI) as part of the project *Prioritization of Climate-smart Water Management Practices*. The aim of the study has been to develop recommendations for addressing two of the critical gaps identified for improving climate resilience of water resources management in Ethiopia, namely, (1) inadequate data and information on key hydrological variables that have led to a lack of recent knowledge on water availability, actual water use, water source types and potentials; and (2) a lack of decision support tools that would provide strategic and operational level information and capacity for risk-based planning and management of water resources. The report is based on an analysis of collected data, information gleaned through stakeholder consultations and a review of existing literature on climate and water data, and decision support tools in use in the Awash River Basin and at national level in Ethiopia. This synthesis report focuses on the technical aspects of climate and water data and decision support tools, while the institutional aspects are presented in Sanchez Ramirez et al. 2024.

This study conceptualizes climate-smart water management as having three reinforcing objectives: maximize the goods and services that can be produced from the limited water resources; minimize the impact of climate extremes — floods and droughts at multiple scales; curtail the impact of rainfall variability across scales, including small-scale agricultural producers, and enhance water resources planning and management at the basin scale.

Key challenges that have been identified include inadequate spatial coverage of hydrometeorological networks; short and, very often, intermittent river discharge data; almost nonexistent water use monitoring; fragmentation of data and inadequate capacity of skilled personnel. There are a number of ongoing efforts by the Ministry of Water and Energy with the aim of addressing these challenges. Weather forecasts are made regularly by the Ethiopian Meteorology Institute (EMI) with attempts to translate these forecasts into their potential impacts on agriculture, water and health. These forecasts and their translation into sector-specific implications need to be improved to make them actionable at lower spatial scales. There is also a need to improve the interoperability of databases and systems to minimize data fragmentation and ensure timely sharing of data.

This report presents a conceptual architecture of improved water and climate data and decision support tools, together with specific recommendations for improving hydrometeorological data collection networks, monitoring of agricultural water use, communication of information across scales and decision support tools. The recommendations are intended to provide input for ongoing discussions on improving climate and water data and decision support tools for climate-resilient water resources management in Ethiopia.

Introduction

Up-to-date information about the status and distribution of water resources is crucial for sustainable water resources planning and management. Increasing variability and change in hydrological processes coupled with the need for optimal allocation of water resources, further drive the need for robust data and information. This requires good coverage of hydroclimatic records that are adequate both in quality and quantity for different variables at multiple scales starting from watershed to basin and regional levels. The availability of forecast information at different temporal and spatial scales, as well as the evaluation of forecasts are necessary to plan the use of water resources and assess outcomes for different sectors. In Ethiopia, the Ministry of Water and Energy (MoWE) is mandated to collect, archive and provide climate and hydrological information for the public and various sectors. The Ethiopian Meteorology Institute (EMI) focuses on collecting and disseminating meteorological data.

Most of the data collection is dependent on ground-based hydrometeorological observations. EMI uses a couple of radars to monitor rainfall at a larger spatial scale. Some telemetry observations provide information on water levels at selected river basins which are managed by MoWE. Maintaining the existing hydrometeorological systems has become challenging due to various factors (such as security reasons, financial constraints, lack of skilled personnel, etc.) over the years. However, it is crucial to ensure the continuity of good quality data for proper management of water resources that have been affected by climate changes and anthropogenic activities. Data on natural variables such as rainfall, temperature and river flows, and anthropogenic activities such as river flow and groundwater abstractions need to be recorded and analyzed to avoid the depletion of limited resources for the current and future generations.

The Awash River Basin in Ethiopia is facing several challenges and threats to its water resources and sustainable development. Climate change is a major factor that affects the rainfall patterns, temperature regimes, evapotranspiration rates, runoff generation and groundwater recharge in the basin. These changes have implications for agriculture and water resources management in the basin. Moreover, the basin is undergoing rapid population growth, urbanization, industrialization, land use change, deforestation, soil erosion, water pollution and overexploitation of water resources. These factors have resulted in increased water demand and competition among different water users, such as the domestic, agriculture, industrial, environmental and energy sectors. Furthermore, the basin suffers from frequent floods and droughts that cause damage to people's lives, properties and infrastructure.

The objective of this report is to develop recommendations for improving data and decision support tools based on a review of the current status of water and climate data availability and the use of decision support tools for management and development of water resources. This report was produced under the project titled *Prioritization of Climate-smart Water Management Practices* led by the International Water Management Institute (IWMI). The research focuses on small-scale producers (SSPs), i.e., farmers, pastoralists and agropastoralists, for whom climate-smart water management practices are being explored and prioritized since they are primarily dependent on rainfed agricultural systems and small-scale irrigation practices. Good quality data and information are important to these SSPs in terms of monitoring and managing weather-related risks, optimizing crop growth and quality, reducing water and energy consumption and improving pest and disease control. Using such information, SSPs can improve their resilience and adaptation to climate change and variability, while enhancing their productivity and profitability.

Existing Situation

In this section, the report discusses the existing situation of water and climate data monitoring systems, databases, tools, and ongoing initiatives that work towards improving current gaps and challenges. The scope of assessment of existing tools and systems is primarily those that are designed to generate information for planning and decision-making by government ministries, mainly the Ministries of Agriculture, Water and Energy, and the Ministry of Irrigation and Lowlands.

Institutions

The Ministry of Water and Energy is mandated with hydrological data collection, analysis, monitoring of the hydrological cycle and providing reliable information that is practical for communities and other institutions to make appropriate decisions in different situations and seasons. The responsibility of actively managing water resources and implementing the integrated water resources management process is in the hands of MoWE. MoWE has a Water Resources Information and Geographic Information System (GIS) Desk, and a Water Resources Modeling Desk. It also has a unit within its structure that issues water resources use permits. The Ethiopian Meteorology Institute (EMI) is responsible for collecting various meteorological data, providing weather and climate forecasts and providing early warning and advisory services for various sectors.

The Ministry of Agriculture (MoA) is focused on generating information related to crops and livestock. The newly set up Ministry of Irrigation and Lowlands is expected to focus on irrigation development, but it is not clear what type of data it will collect. The Ethiopian Statistical Services (ESS), which used to be the Central Statistical Agency (CSA) is mandated with generating information on various agricultural activities for different seasons, including agricultural production and crop yields, land utilization and farm management practices, through its Annual Agricultural Sample Survey.

For further information on institutional setups for water and climate data, please refer to Sanchez Ramirez et al. 2024.

Water and Climate Data Monitoring System

Hydrometeorological monitoring networks - ground observations

MoWE has 541 streamflow gauging stations throughout the country, out of which 490 are operational (Nigussie et al. 2020). EMI, which is under MoWE, collects various meteorological data throughout the country. EMI has more than 1000 stations in Ethiopia, which are classified into four classes according to the standard classification of the World Meteorological Organization (WMO). Class 1: Rainfall, temperature (maximum and minimum), sunshine, radiation (some), humidity, wind speed (automatic); Class 2: Rainfall, temperature and wind speed; Class 3: Rainfall and temperature; Class 4: Rainfall. There is one radar that is currently operational in the Tana-Beles Sub-basin area, while more are planned to be functional. EMI maintains a national meteorological database that is continuously updated.

In the Awash Basin, more than 100 meteorological stations are present, with varying quality and quantity of data. Out of these, four are synoptic stations while twenty-three are primary stations. These types of stations measure variables such as rainfall, temperature, humidity, wind speed, solar radiation, sunshine hours and pan evaporation. For this study, data from more than 60 meteorological stations were collected from EMI. Most of the data came from Class 3 stations that collect rainfall and temperature information.

At MoWE, the river flow data collection for manually operated gauging stations depend on local observers. The observers are responsible for measuring the water level at the staff gauge twice a day — in the morning and evening — by noting the values in a recording book. Hydrological technicians from MoWE are responsible for conducting velocity measurements, in collaboration with local observers, at different gauging stations three times a year for high, medium and low flow periods. They are also responsible for collecting the recording books so that the data can be digitized at MoWE. MoWE is responsible for checking the quality of the collected data and updating rating curves. MoWE converts the data on water levels to estimated discharge and provides this information to those who need it upon request.

The Awash Basin is divided into twenty-one sub-basins based on hydrological considerations by MoWE, as shown in Figure 1. In the past, more than 60 river flow and lake-level stations with manual staff gauges were installed in the basin. Most of these stations are no longer functional. For the purpose of this study, more than 30 river flow gauging stations' data were collected from MoWE, and an analysis was conducted on the quality and quantity of these datasets and their current status.

Some of the river gauging stations in the Awash Basin date back to the late 1960s such as the gauges at the Awash Terminal (Dubti and Tendaho). However, for this study's purpose, we have limited the period of consideration to 1990–2015 to assess the quality and reliability of data for water management and hydrological modeling analysis. The existing river flow gauging stations used in this study are shown in Figure 1. In all stations, data from 2015 onwards were not available. This is due to the unavailability of discharge data at MoWE because rating curves had not been updated and velocity measurements were not conducted. The distribution of river gauging stations within the basin is not optimal for a detailed and accurate hydrological analysis. The stations were mainly established on tributary rivers, following road networks. Generally, in Ethiopia, more than 70% of the rainfall and streamflow gauging stations are located at the head catchments of river basins.

Moreover, the records are inconsistent, with a significant number of missing records. Almost all stations have more than 10% of missing data when computed at a daily timescale, while some stations have stopped functioning and

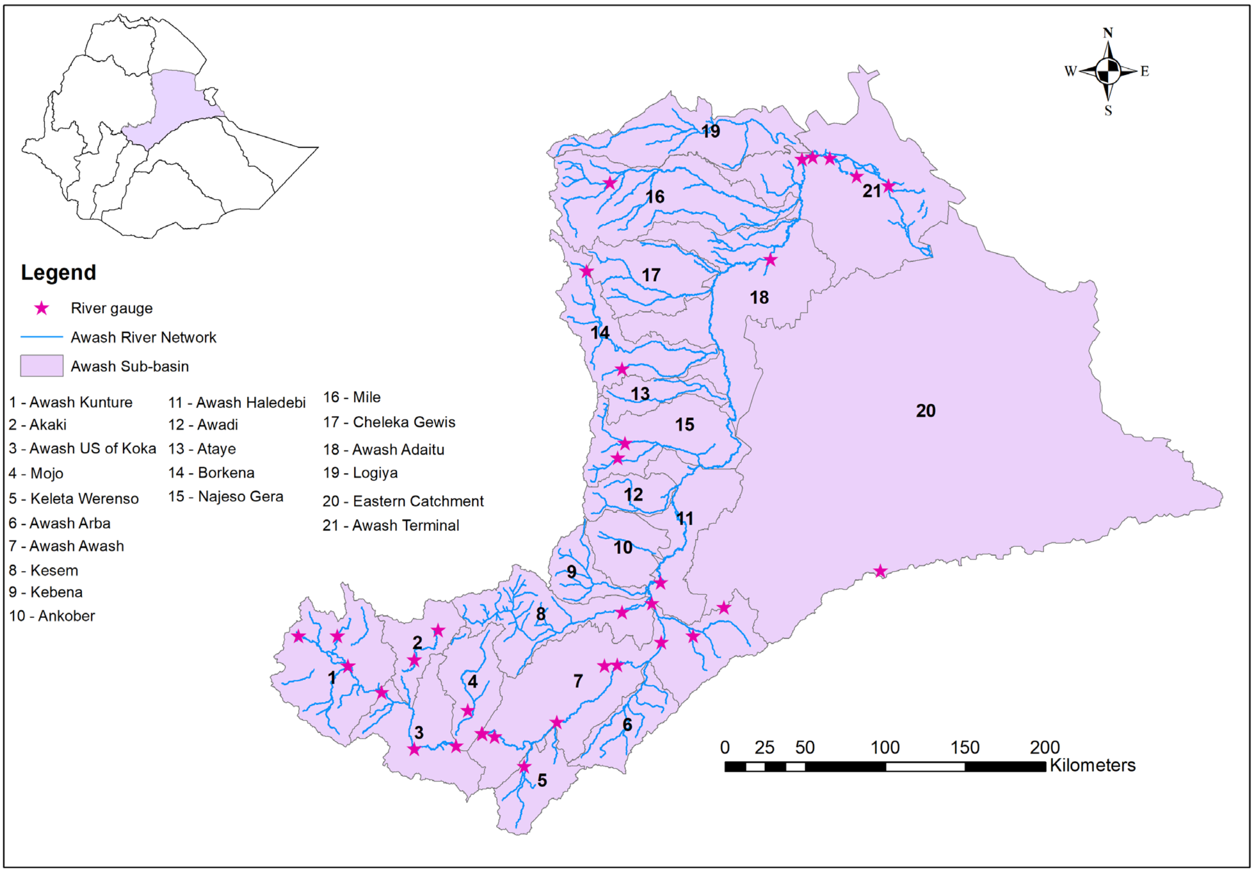

Figure 1. Location of the Awash Basin in Ethiopia, its 21 sub-basins and river gauging stations.
Notes: US - upstream

some are relatively new. On average, approximately 35% of daily data is missing in the selected gauging stations for the period between 1990 and 2015. Therefore, obtaining a long-term uninterrupted data record for different stations and a given period for the Awash Basin is difficult in the current situation. This has implications for the accuracy of hydrological modeling analysis and water balance estimations at sub-basin and basin scales.

The distribution of meteorological stations considered for this study is shown in Figure 2. The majority of these stations are Class 3 and Class 4, which focus only on rainfall and temperature data. Missing data are considerably high for relative humidity and sunshine hours in the primary stations that measure all variables. In terms of rainfall data, on average, daily data are found with approximately 30% of missing records. While efforts were made to use long-term time series starting from 1990 to 2021, some stations have data only from the mid-2000s, such as 2006. The lack of consistent and good quality long-term data is a challenge, especially for variables other than rainfall and temperature. Even for rainfall and temperature, the current network of meteorological stations in the basin is insufficient in terms of spatial coverage and does not meet the guidelines of the World Meteorological Organization (WMO). Such an inadequate distribution of stations is mainly related to the inaccessibility of most areas of the country.

Generally, hydrometeorological records are short in length and different periods have been recorded for different sub-basins. This makes a comprehensive assessment of the hydrology of the basin and hydrological modeling exercises of different sub-basins difficult.

Telemetry

MoWE has plans to upgrade the current manual river flow monitoring systems to telemetry systems that provide real-time river stage data in different parts of the country. MoWE started using telemetry systems in the Lake Tana Sub-basin with the support of the World Bank a decade ago. The piloted Hydrological Information System (HIS) in the Tana and Beles sub-basins includes modernization of hydrological monitoring. The Basin Information System (BIS) set up for the Lake Tana and Beles sub-basins has 7 Class 1 meteorological stations, 1 weather radar and 29 hydrological stations. Automatic rain gauges with water level sensors have been installed in the Lake Tana Sub-basin, and some are still operational.

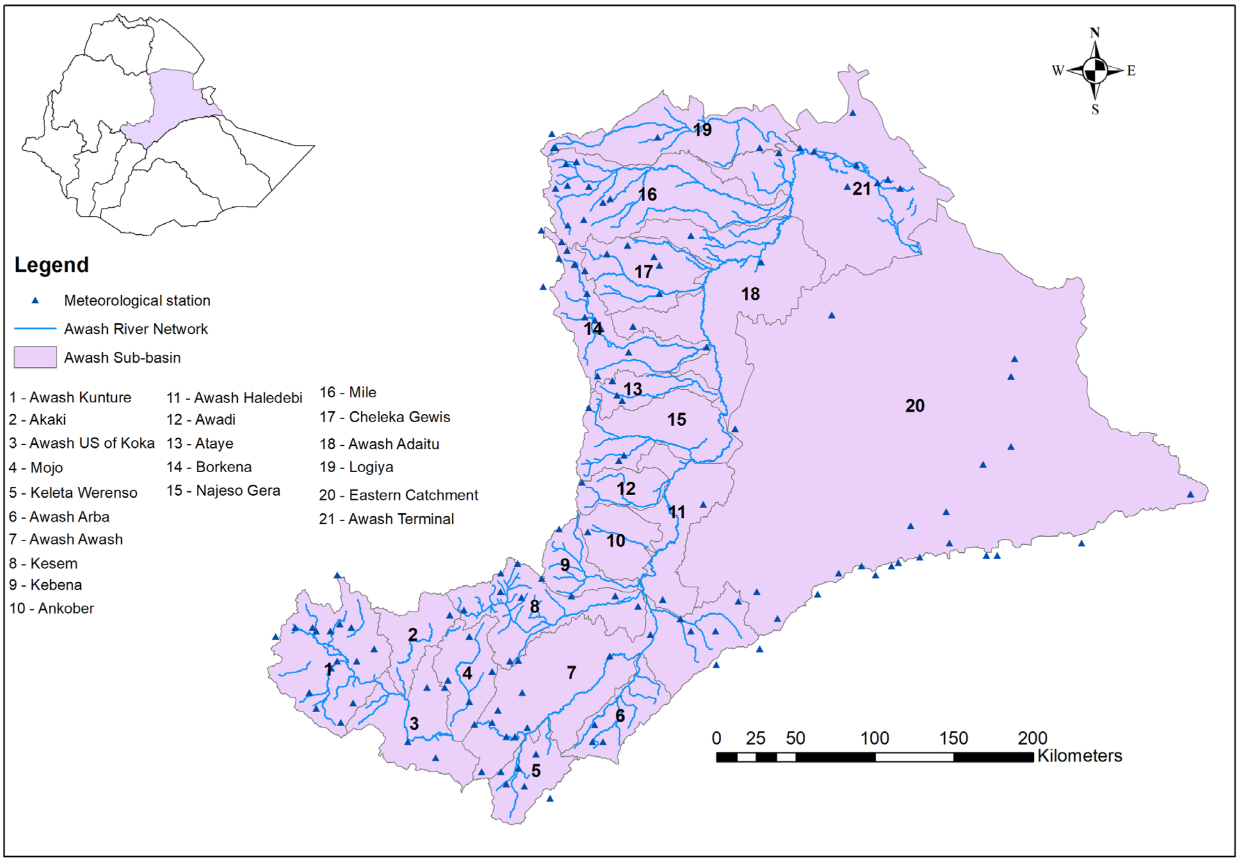

Figure 2. Location of the Awash Basin in Ethiopia, its 21 sub-basins and meteorological gauging stations.

Notes: US - upstream

There are data centers at MoWE and Abbay Basin branch offices. These data centers use the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) database management system, the Supervisory Control and Data Acquisition (SCADA) system, and the web portals of MoWE and Abbay Basin branch offices. The system collects, analyzes and validates the data, and disseminates information through its decision support system interface. Such types of advanced systems are challenged by vandalism of the telemetry stations and the sensors, breakage due to floods and landslides, a lack of skilled experts who can use the system and translate data into usable information for different stakeholders, and a lack of rating curve development for each station in converting water level measurement to discharge.

There are a few telemetry stations in the Awash Basin. They are located at Hombole, Awash-Awash and Tendaho, mainly focused on obtaining information for reservoir operations. However, the exact number of telemetry stations and information on their functionality were not available for this research. It is important to maintain these systems given that manual observations are challenged by various factors.

To this end, MoWE announced recently that it is working with the Ethiopian Telecom to build a system that can modernize a data collection and sharing system through cloud infrastructure and digital solutions. This will enable river flow measurements through telemetry systems and allow easier access to meteorological data from shared data centers. Such advanced systems are expected to effectively manage water resources, optimize distribution and improve service access while reducing water wastage.

Database

HYDATA

The HYDATA database system developed by the UK Centre for Ecology & Hydrology was installed in Ethiopia two decades ago. The HYDATA analysis software is a very useful software for hydrological data processing, storage and quality control. It is used for surface water data to check the quality of data (through various statistical and other analyses), fill gaps (through regression analysis and use of time series), generate statistics, calculate rating equations, and convert water level data into discharges and volumes. Most hydrological data types stored in the database are descriptions that provide information on catchment locations, observational stations, rating curve equations and water quality parameters. When users request data, MoWE provides this information by extracting it from the HYDATA database. However, currently, MoWE is phasing out the use of HYDATA and has plans to replace it with a new system.

Water Resources Audit

Given the lack of information on water use and various types of infrastructure, MoWE collaborated with the Water and Land Resource Centre (WLRC) of Addis Ababa University to conduct a water resources audit in 2022. The Water Resources Audit (WA) is an inventory of water infrastructure and water use. The audit was prepared based on field data collected in 134 *woredas*[1] in the Abay (Blue Nile) Basin, 117 *woredas* in the Awash Basin, and 108 *woredas* in the Rift Valley Basin (WLRC 2023).

The infrastructure covered by the audit includes dams, water diversion structures, wells/boreholes, dikes and hydropower generation facilities. The types of uses covered in the audit include those for irrigation, urban and rural water supply, livestock and the hospitality industry. Irrigation water uses have been estimated based on available data collected and assumptions made regarding irrigation efficiencies for different types of irrigation technologies.

The audit also covers data on lakes, wetlands, land use and land cover (LULC), long-term monthly hydroclimatic variables (rainfall, temperature and evapotranspiration) and flood vulnerability maps. A Water Audit Information System (WAIS) has been developed — which is not yet open to the public — providing features for query, visualization and data entry (by personnel maintaining the system).

Groundwater database

Groundwater monitoring is at an early stage in Ethiopia. Unlike the river monitoring network, there is no permanent network for measuring or estimating groundwater levels, abstraction, and quantity and quality changes. Water level measurements are commonly done when boreholes are drilled, while some well fields are equipped with water meters. There was an effort to establish a groundwater database in 2005 by MoWE. The Ethiopian National Groundwater Database (ENGDA) was established in 2005 under the Ethiopian Groundwater Resources Assessment Programme (EGRAP) to archive and disseminate groundwater data. The groundwater database was developed as part of the project *Hydrogeological Mapping for Climate Resilient WASH in Ethiopia* by MoWE with the support of Acacia Water. An online version of the database is available on the website of Acacia Water[2]. The database provides hydrogeological maps at the *woreda* level and recommended drilling sites for developing groundwater. The database comprises borehole data from 32,000 shallow wells and 20,000 deep boreholes. MoWE is currently working to integrate the groundwater database with other databases to create the Basin Water Information System for the country.

Climate Information Services

Overview

Ethiopia has a National Framework for Climate Services (NFCS) that provides climate information as per the World Meteorological Organization's (WMO) Global Framework for Climate Services (GFCS). EMI is the secretariat of the NFCS. This framework was adopted on a national scale for Ethiopia in 2021 (NMA 2021). It was developed and agreed upon by many of the line ministries that required climate information. The information was needed for agriculture, water, energy, health, disaster risk reduction and environmental sectors. The goals of the framework can be summarized as:

- Reducing the vulnerability of society through the provision of climate information and services
- Advancing key national and global development goals
- Mainstreaming the use of climate information and services
- Strengthening the engagement of providers and users of climate services
- Maximizing the utility of existing climate service infrastructure

This framework is expected to be implemented from the national to the *woreda* level. The climate services provided by EMI are on a seasonal scale in which they issue 4-month climate outlooks three times a year. There is a face-to-face meeting between EMI and the sector's representatives and stakeholders to discuss these outlooks. The focus of the outlooks is on providing climate information so that locust invasion prevention, harvest times, dam operations, malaria

[1] *Woreda* is the third-level administrative division of Ethiopia.
[2] https://mowe.acaciadata.com

control, and early action for drought and floods can be planned a season ahead. The sectors are expected to use this information and translate it into their respective sector's planning and management. There is an evaluation of the 4-month outlook at the end of the season before issuing the next outlook.

Early warning and weather forecast

EMI is mandated to collect all types of meteorological data and provide early warnings and forecasts for the country. These forecasts are regularly generated by EMI for all of Ethiopia and made available to various users through several channels, including the EMI website. EMI provides forecasts at different temporal scales, from hours to seasons. The daily (short-range) and 10-daily (medium-range) weather forecasts are issued for the country by administrative zones. The workflow starts with the synoptic and primary stations collecting hourly and 3-hourly data, which are then transferred to EMI's headquarters. The data is further analyzed at headquarters, and daily and 3-daily forecasts are issued. The information they provide is mainly focused on rainfall and temperature forecasts.

For short-range forecasts, 3-daily forecasts are issued for cities, providing weather information on rainfall and temperature in cities and towns of Ethiopia. EMI generates numerical weather predictions using the Mesoscale Modeling System (MM5) and the Weather Research and Forecasting (WRF) model. The WRF forecasts are available on the EMI website as images. Forecasts are given as narratives per administrative zone and include an advisory for the agriculture and water sectors. The rainfall forecast is provided as moderate, heavy, very heavy and exceptional rainfall. The forecasts are issued primarily in Amharic and English languages. This information is also provided through the Telegram application for those who have subscribed to the EMI social media.

There are also long-range (mid-season to seasonal) forecasts. They are mainly useful for the primary rainy season, from July to September. The long-range forecasts are based on an analog-year method for the type of rainfall expected before the season starts. EMI issues information on expected heavy rainfall locations and potential flooding areas if the forecast expects above-average rainfall. If the forecasted rainfall is below average, information is provided for the agriculture and water sectors to manage their resources. The water sector uses this information and utilizes its own method to forecast the amount of water expected in different basins and dams and provides the necessary advisory for water user communities.

Sectoral information on climate

The main communication method of EMI's forecasts to other sectors is through its bulletins. The bulletins are prepared for three major sectors: agriculture, health, water and energy. The results of the weather forecasts and their implications for key sectors considered are issued in the form of bulletins, which also provide recommendations. EMI provides the Agro Bulletin on the current weather situation concerning agricultural practices. These are provided on 10-daily, monthly and seasonal timescales to minimize risks, increase efficiency and maximize yield for farmers. For the Hydromet Bulletins, the seasonal timescale is used, and they are mostly focused on dams, reservoirs and any practices that are occurring on main and sub-river catchments. The Health Bulletins are provided on a monthly scale and convey information on malaria outbreaks and general human comfort conditions that can also be useful information for tourists.

Communication channels other than bulletins are advancing to social media platforms. For those who can access Telegram and Facebook, the information is provided on these channels. However, these are difficult to access for SSPs and people in rural areas due to internet connectivity issues and limited capacity to read and understand the forecasts.

EMI has also developed a drought monitoring system based on satellite data and ground observations. They use drought indices such as the aridity index and the standard precipitation index (SPI) to monitor potential drought situations and issue early warnings and advisories. There are other efforts on drought early warning information provision in Ethiopia. For instance, the web portal of the Famine Early Warning Systems Network (FEWS NET) provides access to various products and services such as monthly reports, maps, alerts and outlooks that cover drought-related issues. Similarly, the IGAD Climate Prediction and Applications Centre (ICPAC) provides climate information and services for disaster risk management and sustainable development in Eastern Africa. This information is accessed by decision-makers in different sectors.

Decision Support Tools

Tools used by EMI for forecast and advisory

The suite of models, tools and forecasts produced by other centers that EMI uses to generate short-range to seasonal weather forecasts are listed below:

- The Weather Research and Forecasting (WRF) model[3]: a mesoscale numerical weather prediction system used to generate short-range forecasts.
- The Copernicus Climate Change Service[4] (C3S): a system for providing climate information and seasonal forecasts, which is based on data from several climate prediction systems, including those of the Euro-Mediterranean Center for Climate Change (CMCC), The European Centre for Medium-Range Weather Forecasts (ECMWF), the German Weather Service (DWD) and Météo-France.
- The North American Multi-Model Ensemble (NMME): an experimental multi-model seasonal forecasting system consisting of coupled models from US modeling centers and The Canadian Meteorological Centre (CMC).

The forecasts provide information on precipitation and temperature and their distribution across the country. An important element of climate services is providing advisory services for key sectors. The services include weather forecasts, agrometeorological, hydrological and health outlooks compiled in the form of bulletins and assessments of past forecasts. The set of indicators/indices that are used to capture sector-specific implications are the following:

- Water Requirement Satisfaction Index (WRSI) that is used to monitor (and predict) crop performance
- Rangeland Water Requirement Satisfaction Index
- Moisture index (MI) for monitoring the level of moisture stress in the soil
- Normalized difference vegetation index (NDVI) used for vegetation and crop health monitoring
- Temperature-humidity index (THI) to monitor malaria outbreaks
- Thermal index to monitor heat stress conditions for humans and cattle

Based on the information available from EMI, the Livelihoods, Early Assessment and Protection (LEAP) tool is used to assess the impacts of the forecasted weather on crops and thereby evaluate disaster risk. LEAP was developed by the Government of Ethiopia and the World Food Program (WFP) to strengthen the capacity of the country and its relevant institutions to manage risks posed by climate hazards to food security. LEAP is a software that uses crop and weather information to estimate future crop yield reductions.

Potential impacts of forecasted weather on agriculture are compiled in agrometeorological bulletins (in short, Agromet Bulletins). A screenshot of the Agromet Bulletin from October 13, 2023, is shown in Figure 3. A typical agrometeorological bulletin provides information on moisture status, rainfall amount, agrometeorological conditions and impacts on agriculture in the forecast period. Further, the bulletin provides broad recommendations for dealing with the forecasted implications for agriculture. However, these recommendations are not detailed enough for specific geographic regions. Therefore, the bulletins may not be the right place for very specific information.

Information was not available at the time of writing this report on tools used to estimate the impacts of the forecasted weather on water and health. However, bulletins are also generated on health and water, such as the Hydrological Bulletin.

Tools for reservoir management

MoWE uses the weather forecasts from EMI to estimate inflow into major dams and assess water availability in the coming season. The information is then used to guide targeted water releases from dams. This practice is mainly done in the Awash Basin with the Koka dam, located in the upstream part of the basin. The Water Evaluation and Planning (WEAP) model is used to plan the allocation of water based on the amount of water in the reservoir. The allocation targets energy production and irrigation water use for the downstream users during the dry season. Details on the workflows for the use of WEAP and/or any other similar allocation tool to support reservoir water allocation were not available to the research team at the time of writing this report.

---

[3] https://www.mmm.ucar.edu/models/wrf

[4] https://climate.copernicus.eu/

Figure 3. Seasonal agrometeorological bulletin of the Ethiopian Meteorology Institute.

Irrigation Management Information System of Ethiopia (IMISET)

In the agriculture sector, there is a national web-based information system on irrigated agriculture known as the Irrigation Management Information System of Ethiopia (IMISET[5]). The system was developed by the Ministry of Agriculture (MoA) and MoWE with the support of the Food and Agriculture Organization of the United Nations (FAO). As the name implies, its primary purpose is to support monitoring the performance and status of irrigated agriculture, and decision-making. This system collects, analyzes and disseminates data and information on irrigated land area, location, water use and production. The information is organized into eight categories (also known as indicators). These are:

1. Irrigated area – this is organized by different types of irrigation systems, ownership types, scale and agroecology
2. Problematic schemes
3. Agricultural water use – this covers total freshwater withdrawal for irrigation, agricultural water use from nonconventional water sources, water use efficiency and irrigation water requirement
4. Scheme crop production
5. Household crop production

[5] https://imiset.netlify.app/#/

6. Socioeconomics – this is information about factors such as irrigation beneficiaries, water user associations and gender roles within those associations, water charges and irrigation technologies
7. Environment – compiled information on areas affected by salinity or waterlogging
8. Cost – this indicator covers information such as investment cost, cost of study and design, operation and maintenance costs

This system attempts to tackle the problems observed in irrigation development in Ethiopia, which is uncoordinated with a lack of systematic data collection and unreliable information on irrigation potential and the performance of existing irrigation schemes. It was designed to provide comprehensive information on irrigation schemes (or areas), including water withdrawal, water use and water use efficiency. It provides an interactive platform whereby users can run queries to generate information for specific areas and livelihood zones.

Since the software infrastructure was completed, MoA has been working on populating the IMISET with data. IWMI works closely with MoA to generate actual water use by crops using the datasets from FAO's Water Productivity Open-access portal (WaPOR[6]), thereby estimating water use efficiency. MoA has commissioned a study to collect data on irrigation scheme performance, which will then be used to populate the system. The study is being undertaken by the Ethiopian Institute of Agricultural Research (EIAR).

Ethiopian Digital AgroClimate Advisory Platform (EDACaP)

The Ethiopian Digital AgroClimate Advisory Platform (EDACaP) is a web-based resource aimed at providing information to improve crop management decisions and reduce production risks at seasonal and sub-seasonal timescales. On this platform, information on the weather forecast, seasonal climate predictions, El Niño-Southern Oscillation (ENSO) predictions for the next 3 months and seasonal agroclimatic advisory-based crop-climate models are provided. The ENSO predictions are taken from the International Research Institute (IRI). The weather forecasts provide five-day and weekly information for selected locations. It is not clear whether these forecasts are synchronized with the forecasts generated and issued by EMI. The EDACaP website mentions that the seasonal predictions are based on the NextGEN forecast system; however, the link to the predictions does not work. Similarly, the agroclimate advisory link does not provide additional information. In the AgroAdvisory tools, there is a link for downloading their app, although no additional information is provided. The app is also not available on the Google Play Store.

The EDACaP team is developing a new website[7] through which users can access information for the geographic location (*kebele*[8]) of their interest. The system provides the precipitation probability in the selected area based on historical data for sub-seasonal forecasts. Weather station data is also provided for long-term monthly averages and annual trends. This new website is expected to replace the earlier version with better information and interactivity. At the time of writing this report, the website was still under development.

The partners for the EDACaP platform are the Ministry of Agriculture and the Ethiopian Meteorology Institute, with funding from donors such as the World Bank, the European Commission, the International Fund for Agricultural Development (IFAD) and the Ethiopian Government. The focus is on maize and wheat crops at the moment. However, there is a plan to reach up to five crops to provide the advisory service for with the EDACaP approach.

Challenges of Data Availability

Ground Observations

Hydrological data

Compared to hydrological data (rivers, lakes, groundwater, etc.), meteorological data are better available in Ethiopia. While MoWE is mandated to collect hydrological data, due to several challenges, there is limited or no data availability in most places. The ministry experienced several organizational restructurings that impacted proper data collection and management (Haile et al. 2023). For instance, river velocity measurements have substantially decreased during organizational changes (Donauer et al. 2020) and rating curves have not been updated for several years. This has implications for any type of research or development activity that is supposed to be conducted in the country.

---

[6] https://data.apps.fao.org/wapor/?lang=en
[7] https://edacap.ethioagroclimate.net/#/Home
[8] *Kebele* is the smallest administrative unit of Ethiopia.

The additional reasons for the paucity of data measurements are a lack of staff capacity and financial constraints. The ministry has more than 400 river gauging stations. To cover all stations, it will require substantial financial resources and well-trained staff who can conduct river velocity and stage measurements during important seasons. Furthermore, all necessary equipment to conduct measurements needs to be available in good quality and sufficient quantity to cover the number of stations throughout the country. However, these essentials are not in place in the required amount. Maintenance of stations, rehabilitation of nonoperational locations and training of rivers that have changed courses are not being conducted as much as required.

Other types of datasets such as groundwater data, water abstraction and lake levels are mostly nonexistent. The lack of data spans all spatial scales from basin to sub-basin to learning watersheds that were selected for this project. Collecting data of good quality and quantity requires an enormous effort, and the ministry in its current state, with its limited staff and financial and logistics resources, finds this an overwhelming challenge.

Meteorological data and information

Data from the meteorological stations are available for purchase through EMI. The challenge of missing data is also an issue with meteorological stations. The primary stations have better data quality than other types of stations. Precipitation and temperature data are also better than data pertaining to other variables such as relative humidity and solar radiation.

The information provided by EMI in bulletins is produced solely by the institute. The possibility of co-production has been explored but not yet implemented. EMI is challenged because the sectors' needs are not always clear. The bulletins also require improvement to provide more relevant information for the end users.

There is a limitation on the communication channel. The information barely reaches the grass-roots level where SSPs are. The forecasts are still coarse at zonal scales, and accessibility for lower administrative units, SSPs and communities is a challenge.

Key challenges

Some of the technical challenges of hydrometeorological data in the Awash Basin can be summarized as follows:

- Spatial coverage: Ground-based hydrometeorological data have limited spatial coverage due to the uneven and sparse distribution of observation stations across the basin. Some areas may have no or few observation stations, while others may have a dense or redundant distribution of observation stations. This creates gaps and inconsistencies in the spatial representation of weather and water conditions in the basin. This highlights that the stations' configuration is not optimal.
- Temporal coverage: Ground-based hydrometeorological data have limited temporal coverage due to the irregular and discontinuous recording of observation data over time. Some observation stations may have long or short periods of missing or incomplete data, while others may have continuous or consistent data. This creates gaps and inconsistencies in the temporal representation of weather and water conditions in the basin.
- Data quality: Some hydrometeorological data have low quality due to various sources of errors or uncertainties, such as instrument malfunctions, human errors, environmental disturbances, etc. This is exacerbated by the lack of maintenance activities for measurement stations.
- Data accessibility: Hydrometeorological data may be less accessible due to institutional arrangements, limitations in technical capacities and financial resources. Some observation data are difficult or impossible to access.
- Station adequacy: The current distribution of hydrometeorological stations is not optimal, as mentioned above. The country is planning several projects that have already started and are due to start in the future. These projects require up-to-date information at different temporal and spatial scales. This is not currently available.

Data users' perception

To obtain the perspectives of various data users, questionnaires were prepared and distributed to a diverse set of experts and stakeholders who were interviewed for this project. These people ranged from the district level to the federal level. The assessment was focused on the current practices in the availability and use of water resources data and decision support tools.

Problems identified by data users for the Awash Basin include:

- Chronic shortage of recorded data for many areas of interest, inconsistent information on the location of records, and human-induced recording errors.
- Slow process of digitizing manually recorded hydrological and meteorological data which makes their real-time or near real-time use impossible.
- Lack of organized information on water users and water abstraction at several locations in the basin. With significant environmental degradation and change, a lack of water abstraction information can bias estimates of water availability.
- Design and decision analysis are made under an acute lack of relevant hydrometeorological data.
- Information and data generated during the construction of different water projects are not properly stored and managed due to the lack of a central database. Many reports and data that can be crucial for future projects are found in the hands of private individuals and are missing from relevant government institutions.
- There is an overabundance of caution in designing water infrastructure projects, which is driven by the lack of data and the need to avoid failure. This makes projects financially expensive. Hence, the lack of reliable hydrometeorological data may have a significant economic impact on a national scale.
- The use of satellite remote sensing data is limited in different government institutions.

Ongoing Efforts

This section summarizes information on projects or initiatives that are currently under implementation to enhance data, decision support tools and information systems in the spaces of water, climate, food and energy.

Water and Climate Change Services for Africa (WACCA)

This is a program led by the Swedish Meteorological and Hydrological Institute (SMHI) under the goal 'International Development Cooperation' with the aim of strengthening the development of climate and water information services in Ethiopia. It is a capacity development project for the hydrometeorological sector. It involves three government institutions — MoWE, EMI and the Ethiopian Disaster Risk Management Commission (EDRMC). The work of WACCA in Ethiopia focuses on:

- enhancing meteorological information services,
- enhancing hydrological information services,
- enhancing disaster risk communication and action,
- enhancing data management and Information and Communication Technology (ICT), and
- sustainable institutions and cooperation.

Basin Scale Resilience Initiative for Ethiopia (BASRINET)

This is a project that is being implemented by MoWE with the support of the Italian Government, which is in its first year of implementation. The project's geographic scope covers the (lower) Awash and Wabi Shebelle river basins. One of the specific objectives of the project is to implement a basin hydrological information system to support efficient decision-making. The scope of the hydrological information system covers the following:

- Strengthening hydrological data collection stations and installing new ones at strategic locations.
- Establishing a geospatial database on water and water-related resources for use at the basin and federal level (MoWE).
- Establishing a surface water and groundwater resource management system.
- Enhancing software systems to improve the management of basin information.
- Developing a web-based system for the dissemination of hydrological and meteorological information.

National Integrated Water Resources Management Program (NIWRMP)

This is a new initiative by MoWE to harmonize and enhance water resource management interventions on a national scale. This was initiated because of the observed fast degradation of water resources and inadequate coordination and collaboration among stakeholders. The program plans to bring more resources for the implementation of the integrated water resources management (IWRM) approach adopted by the ministry. It is expected to move into implementation before the end of 2023. The program is partially funded by the Government of the Netherlands. The program has nine components, one of which is the basin and hydrometeorological information systems.

The plan for the basin and hydrometeorological information systems is to ensure that water resource development, use and management are based on accurate information on resource availability, variability and quality. This includes information on climate, hydrology, water resources, watersheds and socioeconomic activities in a basin or sub-basin. All information at a basin is planned to be centrally archived and shared through a data protocol. In addition, forecast information on extreme hydrological events (such as drought and flooding) is to be generated and disseminated through early warning systems for all stakeholders at the required levels.

The expected outputs of the basin and hydrometeorological information systems are as follows:

- An improved hydrometeorological network; basin information, forecasting and monitoring system
- An improved data sharing and information system installed
- An effective water use and allocation system implemented

Strengthening national hydrometeorological services, recalibration of hydrological monitoring stations, improving technologies used at the stations, and supporting flood and drought forecasting and early warning systems are all aspects that are included in the basin and hydrometeorological information component of the program.

Ethiopian Irrigation Atlas

An Ethiopian Irrigation Atlas is being prepared by the Ministry of Irrigation and Lowlands (MILLs) with World Bank support. The Atlas is designed as a collection of interactive online maps that display datasets at the local and regional levels. The online system also provides tools for estimating irrigation potential, streamflow and evapotranspiration. Further, the system provides links to global datasets on watersheds, groundwater and soil moisture.

Integrated Database (iBasin)

MoWE is developing an integrated database known as iBasin. It is expected to bring together the separate databases on surface water and groundwater resources. It will also include water quality and water use information. The iBasin database is envisioned to have the following components when completed:

1. Surface Water Data Management
    a. Covering telemetric, radar sensor and other device data from surface water monitoring sites, manual staff gauge data and meteorological data
    b. Integration with CUAHSI for Abay River Basin Development Office data
    c. Import functionality for ADCON telemetry data
    d. Integration with automated data loggers installed in the Rift Valley Basin Development Office
    e. Integration of tools for time series, rating curve calculations and editing rating curves
    f. Tools for sediment data management, time series and sediment rating curves
    g. Data export for further analysis

2. Groundwater Data Management
    a. Groundwater registration and tools for analyzing pumping test data
    b. Import functionality for various groundwater databases
    c. Integration with groundwater device data
    d. Data export to various formats for further analysis

3. Water Quality Data Management
    a. Defining water quality monitoring sites
    b. Defining water quality parameters
    c. Registering water quality monitoring data with laboratory results
    d. Import functionality for water quality data from various other databases
    e. Analysis
    f. Export functionality for further analysis

4. Basin Data Management
    a. Registration and analysis of basin data
    b. Importing basin data from other databases
    c. Reporting analysis of basin data
    d. Export of basin data for further analysis

Key Recommendations for Improving Ethiopia's Water and Climate Data and Decision Support Tools

Conceptual Architecture of an Improved Water and Climate Decision Support System

Given that Ethiopia's development is mainly tied to its water resources, the need to adapt to ongoing and future climate change is an undeniable reality. The project suggested the adoption of climate-smart water management practices for Ethiopia after assessing various aspects of the Awash River Basin, which has highly utilized water and has been impacted by frequent climate extremes. The project conceptualizes climate-smart water management with three main aspects. It involves maximizing the goods and services we can produce from the limited water resources; minimizing the impact of climate extremes — floods and droughts at multiple scales; minimizing the impact of rainfall variability on small-scale producers and enhancing water resources planning and management at the basin scale. To achieve the goals of climate-smart water management, one of the strategies is to improve the availability of and access to climate and water information services. Likewise, improving decision support tools that can provide information for different users and decision-makers is an important step towards adapting to changes that occur due to climate.

Box 1: Climate-smart Water Resources Management

Climate-smart Water Resources Management comprises of actions that lead to:

- maximizing the goods and services produced from the limited water resources,
- minimizing the impact of climate extremes — floods and droughts at multiple scales, and
- minimizing the impact of rainfall variability on the economy across scales, such as small-scale producers.

The objectives for improving data and decision support tools are related to what Ethiopia desires for its future regarding water management systems. The various national plans (e.g., the Climate Resilience and Green Economy [CRGE] strategy, National Adaptation Programmes of Action [NAPA]) indicate that Ethiopia's development is linked to the efficient use of water resources for various sectors (NMA 2007; EPA 2011; FDRE 2021). For example, accelerating irrigation, enhancing resilience of rainfed agriculture, balancing water demand and supply, and monitoring and management of extreme cases, are some of the water-related development plans. These plans and efforts must be supported by data-driven informed decision-making and the systems have to be adaptive to climate change and robust against climate shocks.

The improved data and decision support tools have various users and purposes. On a national scale, users would, for example, need to understand areas of low agricultural productivity where food insufficiency would be a problem. They would benefit from maps that identify hot spot locations, such as *woredas*, to closely monitor the situation and provide the necessary support for the communities. This can apply to rainfed systems, for example, by providing information on water availability or scarcity, crop types and where they should grow which crop in correlation with rainfall occurrence or lack thereof. Similarly, for livestock systems, information on the location of feed and water availability will be necessary to support pastoralists. In terms of extreme cases such as floods, forecasts of rainfall and river flow situations are important at multiple scales. Such information has to be provided at an appropriate scale and with timeliness to avoid damage to life and property.

Data and decision support tools may need to cover a number of key attributes. For instance, relevant temporal and spatial resolutions are important to conduct different analyses such as storage capacity, water use efficiency and others. The types of data that are useful for climate-smart water management include streamflow time series, groundwater level, actual irrigation water use, water productivity, crop water use, extent of land degradation, land-use change, flood and drought risk locations and magnitude, etc. For disaster risk management and long- and short-term planning and management of resources, coordinated arrangements among institutions are important. Integration among sectoral databases and coordination among institutions help to facilitate the collection, analysis and provision of reliable data in an understandable format for various users.

The objective of decision support tools is to provide relevant information for various decision-makers on the status of water and the climate of different spatial locations to support operational and management decisions. The recommendations in this section target the types of tools needed. It is not focused on the design specifications in terms of software and other technologies. The purpose of such tools is to refine forecasts, operational information at a seasonal scale and disaster preparedness and provide year-to-year information for users. In this advanced age, such provision of information would be possible by using advanced digital technologies such as machine learning, artificial intelligence and big data analysis. The digital tools should be able to accommodate new advancements and produce information in various formats for specific users.

A simplified conceptual architecture of a system for improving data and decision support tools for climate-smart water management is given in Figure 4. It indicates that the different sources of data, such as ground observations, earth observation data and other types of data sources, including surveys, are the initial components of the system. Analytical capabilities are required to investigate the collected data for relevant information that could be interpreted for decision-making. These different datasets and information have to be communicated to various data users. The communication channels are also different. For example, early warning information can be transmitted using formal means such as television and radio and new systems such as social media. Appropriate communication channels are important for the uptake of data and information by different users.

Generally, the system can be designed to perform the following tasks:

- First, collect and store data on water resources from a variety of sources, such as sensors, satellites, ground observations and surveys.
- Analyze large datasets to identify trends and patterns, potential problems, hot spot locations and various solution options in current and future situations.
- Cover targeted users at multiple scales. A simplified description of the types of users is given in Table 1.
- Visualize and communicate the results in an understandable format for various stakeholders and decision-makers.

Figure 4. Proposed conceptual architecture of a system for improving data and decision support tools.

Notes: IR – Infrared; SWIR – Short Wavelength Infrared

Table 1. Types of hydroclimate data, users and tools.

Hydroclimate information users	Purpose of data and information	Type of data	Type of tools
Policymakers (national level)	Formulation of policies and strategies for water scarcity hot spot areas and prioritizing investments for solutions Making decisions on the allocation of resources	National and basin-level information for strategic planning • Long-term average water and climate data • Land use situation • Future projections or forecasts for short- and long-range climate and water information • Emergency locations for droughts and floods	• Web-based infographics and maps • Dedicated dashboards providing key policy-relevant information
Basin administration office experts	Making water allocation decisions; prioritization of measures for maximizing water use efficiency; disaster preparedness	Basin-level information for operational management of resources • Actual irrigation water use • Streamflow time series and groundwater level • Water productivity • Land degradation extent	Modeling tools that can simulate current and future situations • Seasonal and temporal variation maps and figures
District-level experts at water, agricultural and irrigation offices	Catchment management planning and water allocation; planning the locations and extent of small-scale irrigation projects Supporting water user associations Planning, design and implementation of small-scale water infrastructure (irrigation schemes, water harvesting structures)	District-level information for monitoring and operating of resources • Crop water use • Location of irrigation schemes and their water extraction • Location of pastures	Excel-based tools that can provide information in an easy-to-understand format
Development agents and community-based organizations	Planning, design and implementation of small-scale water infrastructure (irrigation schemes, water harvesting structures)	Farm-level information • Soil moisture at the farm • Water application	Color-based risk information (e.g., for flood warning)

Tendaho dam, Afar, Ethiopia. *Photo:* Sirak Tekeleab

Data and Decision Support Tools for Water Availability Monitoring

Water availability includes both surface water and groundwater resources. In addition to rivers, lakes, wetlands and groundwater, there is a need to monitor water availability in small and large reservoirs. Given the lack of data on these variables and the various challenges mentioned in the previous sections, one of the recommendations is to improve the station configuration for river flows and the monitoring system. The other is to provide decision support tools that are user-specific. For instance, one of the use cases is rainfed agriculture. Such a tool will provide users with timely and accurate information about rainfall patterns to plan the type of crop and feed to be planted and when to plant them. It can provide information on the potential use of additional water through irrigation if expected rainfall is below the requirements of crops. Such information would assist users in optimizing farm inputs and labor resources by identifying optimal crop schedules. The other use case can be for livestock systems, in providing information on water availability for pastoralists. The tool can generate information on where to find water and feed for their livestock.

Station configuration – river flows

The current river flow stations are mostly located close to main roads, even if major rivers do not exist. Most stations are also upstream of the sub-basins. Some stations are located at intermittent streams. Rehabilitating the existing nonfunctional stations or replacing them with new stations at relevant locations is important to better quantify the water resources of the basin. As per MoWE, the 21 sub-basins of the Awash Basin do not have gauging stations at their outlets and points of the confluence of major tributaries. One option would be to include stations at their outlet to properly understand the sub-basins' water availability. The other option would be to locate irrigation areas and place flow stations before and after irrigation schemes. This would help to understand the amount of water available for irrigation and the amount of water leaving the system. Based on this method we have recommended an additional 12 stations to be included in the Awash Basin. The proposed locations are shown in Figure 5. The locations were chosen after looking at the possibility of access to roads and potential areas for stable flow measurement. As for meteorological stations, there is a need to locate stations to represent the different agroclimatic zones, rainfall regimes and livelihoods.

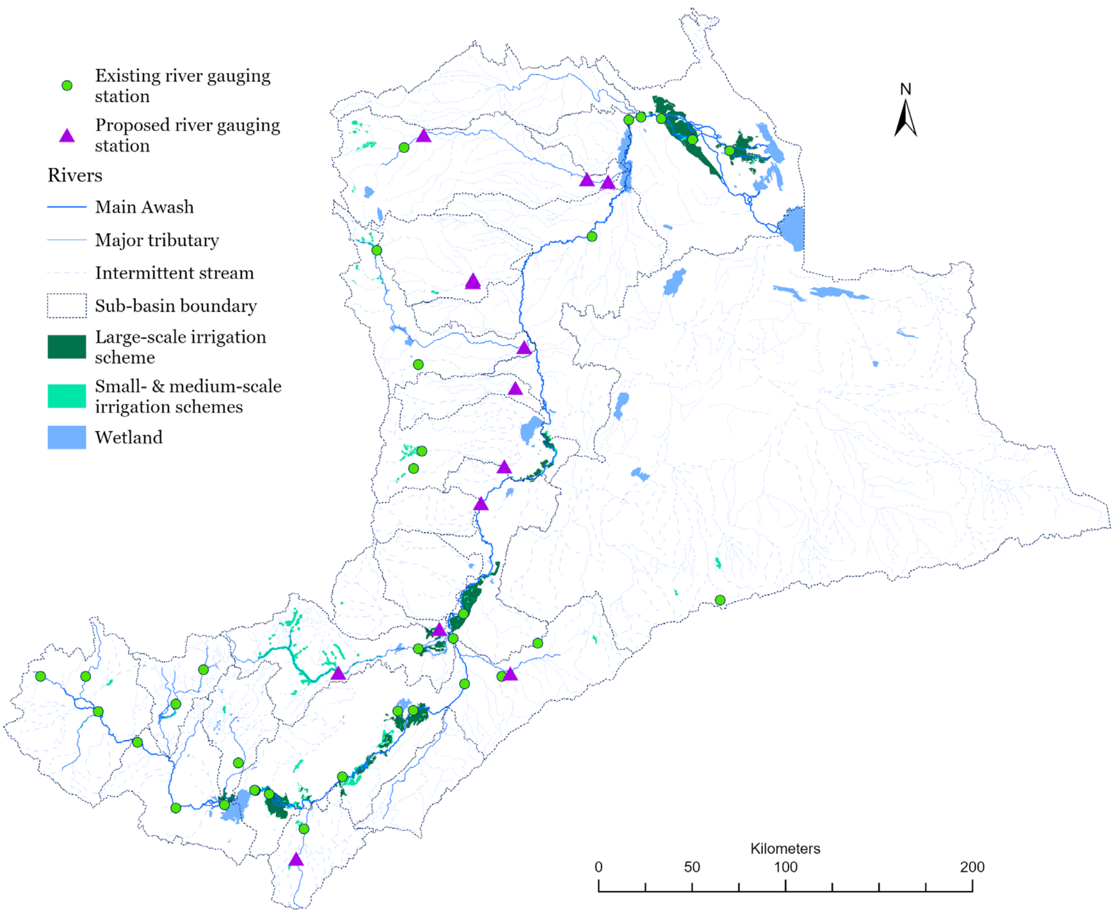

Figure 5. Location of additional river flow stations for the Awash Basin along with the existing gauging stations.

Enhancing river flow data monitoring

Given that the number of river flow stations is beyond the managing capability of MoWE due to its limited financial capacity and skilled personnel, it is important to identify stations that are critical in different river basins. This is the concept of "Benchmark stations" that is common in developed countries (Stahl et al. 2010). A set of criteria that have been identified by Whitfield et al. (2012) to choose the location of reference gauging stations can be adopted in Ethiopia. Once these stations are identified, properly maintaining the stations and continuously measuring the required river flow is important. This project also recommends the selection of Benchmark stations for the Awash Basin and setting up the necessary infrastructure for continuous measurement. This is important to calibrate and validate data collected by telemetry systems in some locations.

To enhance the process of river flow data monitoring, MoWE or other partner institutions would need to invest in the quality of the data observers. This is a critical aspect since most stations are covered by manual measurements. Training the observers and providing appropriate incentives is important to obtain good quality data (Donauer et al. 2020). For instance, making their job financially attractive for the technicians at basin offices is crucial for obtaining good quality data. Also, providing frequent supervision and feedback to observers is important to avoid them filling in the data without actual observations. In addition, the capacity of staff at the ministry and basin offices must be improved to process the hydrological data in the appropriate format and conduct the necessary quality checks on data coming from field observations.

Researchers and other interested data users can make a case for properly measuring hydromet data from an economic point of view. Showing the economic value of data is important to avoid constructing large and unnecessary infrastructure, placing water projects in the wrong locations and providing unsubstantiated advice to the government and public about potential investments. Taye et al. (2023) listed potential research activities that can support streamflow monitoring in Ethiopia. MoWE can work on engaging researchers and universities to collaborate on data generation, quality checks, rating curve developments and the use of remote sensing to improve the hydrological data situation in Ethiopia. For instance, Haile et al. (2023) and Taye et al. (2022) demonstrated how reversing the unavailability of streamflow data in the Lake Tana Sub-basin of Ethiopia is possible by supporting the basin office.

Dedicated groundwater monitoring

Groundwater information such as its level, aquifer property and spatial extent are unclear in Ethiopia as mentioned earlier. Groundwater level monitoring in the Awash River Basin, and generally in Ethiopia, is nonexistent. Data on groundwater are key for understanding the availability of groundwater resources and assessing groundwater-surface water interaction. Given that there is advocacy to use groundwater for irrigation, drinking and industries, there has to be a dedicated groundwater monitoring system in Ethiopia. This will help in providing proper services to the irrigation sector and industries that depend on groundwater. The network design for groundwater monitoring has to be done in an optimal way to understand the characteristics of aquifers. Monitoring of aquifer storage capacity, recharge rate, water quality and discharge rate is important to using groundwater for different purposes. Otherwise, with the current practice, depletion of the limited resources is inevitable.

A decision support tool for groundwater can support the possibility of conjunctive use. The tool will have to identify areas that are suitable for conjunctive use of groundwater and surface water. It has to support decisions on the scope of groundwater extraction, estimate the size of the irrigable area with conjunctive use, estimate the groundwater levels after extraction and determine the aquifer recharge-recovery rate.

Data and decision support tools on water use monitoring

Water use monitoring is limited to drinking water sources in some cities. Other than that, water use is not properly monitored in Ethiopia. In the Awash Basin, where there are many irrigation schemes, the amount of water used for irrigation is not known. Water use monitoring for agriculture from surface water and groundwater sources should be obligatory in order to avoid overexploitation by users. At the small-scale irrigation level and in the Lake Tana Sub-basin, irrigation water use was monitored in selected schemes, which showed water scarcity at the local level and in the dry season (Taye et al. 2021). Such types of efforts need to be institutionalized and important schemes have to be monitored regularly in the Awash Basin and in other parts of the country where irrigation is increasing. Standardized, user-friendly tools (e.g., excel-based tools) would be important for district-level experts to monitor irrigation water withdrawals.

There are many industries in the Awash Basin; however, their water use is unknown. While MoWE and other government institutes provide licenses to industries to use groundwater, the license is not dependent on a threshold amount more than which water should not be extracted. This is because the amount of use is not monitored. Monitoring their water use is important to avoid depletion of groundwater resources, which are usually used by industries.

Data and decision support tools for disaster preparedness

Proactive measures to mitigate the impacts of extreme cases such as floods can be taken when information on weather and river flow forecasts are available. Extreme cases of floods and droughts require timely information to properly prepare before the disaster hits. Efforts that are made by EMI on early warning systems can be improved to provide disaggregated information to users. Information on flood extent mapping, soil moisture estimation and water storage monitoring are important to prepare for extreme cases. Given that ground observations are difficult to obtain during extreme cases such as floods, the use of remote sensing products has become highly relevant. The communication channels and methods will have to be improved to address all kinds of users. For instance, forecast information should be made site-specific as much as possible.

A decision support tool for floods will have to identify the most likely and costly flood events based on historical data and future climate projections. Flood risk maps for areas that are most likely to be flooded will need to be produced. This information can be used to prioritize flood risk mitigation efforts. The effectiveness of different flood mitigation measures, such as levees, dams and floodplain management can be tested in the system, and the most cost-effective method can be selected. In the case of water infrastructure used for flood control, the tool can provide information on operational optimization to reduce the flood risk.

A decision support tool for droughts primarily identifies areas that are at risk of drought based on different factors and provides early warning. Once areas are identified, drought management measures, such as water conservation, irrigation scheduling and crop selection can be suggested using the information from the tool. The tool can also assist in evaluating the effectiveness of drought management measures. For instance, by monitoring drought conditions in real time, the tool can identify the most efficient ways to use water by prioritizing water use for different purposes.

Data on water investment planning and infrastructure management

A tool that can be used for investment planning and infrastructure management will have to include multi-objective optimization and trade-off analysis to identify synergies among sectors and minimize negative impacts on the environment, for example. This can assist in providing water allocation in space and time for various water users and sectors. It can provide information under multiple hydrological and climate change scenarios and resource demand situations. Thus, the tool will have to include basin-wide water allocation analysis that considers multiple water use performances, performance trade-offs between alternative management options and the uncertainty of water supply and demand.

The decision support tool can support the strategy of promoting climate-smart integrated water storage, management and use by providing decision-makers with information about how different basin planning options may impact water availability in the Awash Basin under different climate and water demand scenarios. This tool can also support the strategy of enhancing participatory water resources planning and management by providing stakeholders with a platform for evaluating different basin planning options.

Data Sharing and Integrated Databases

Although there are various efforts to generate water and climate-related data, the unavailability of a coordinated and integrated system or database hinders proper data sharing. It also creates a situation where similar efforts are made by different institutions. Data sharing requires its own guidelines and rules. A common guideline is proposed to be produced for all relevant ministries to adhere to, and in the absence of such an overarching guideline, the ministries may produce their own guidelines which can then be streamlined for common use. In the context of climate-smart water management, all sectors, for example, can provide data for a common project or a specific problem that has to be solved in coordination.

Having an integrated database will be helpful for quality control of the different data types that are gathered by different organizations. For this to happen, there needs to be an agreed-upon institutional arrangement among the different institutions that are engaged in water and climate data generation and collection. The existing situation has challenges of nonexistent data sharing and management policies, overlapping mandates among institutes and a lack of analytical skills and tools to convert the available data into useful information. Solving the institutional, governance and policy challenges will be the first step towards realizing integrated databases that work for all relevant ministries and institutes.

References

Donauer, T.; Haile, A.T.; Goshime, D.W.; Siegfried, T.; Ragettli, S. 2020. *Gap and opportunity analysis of hydrological monitoring in the Ziway-Shala Sub-basin, Ethiopia*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Working Paper 192). https://doi.org/10.5337/2020.210

EPA (Environmental Protection Authority). 2011. *Ethiopia's Climate-Resilient Green Economy: Green economy strategy*. Addis Ababa, Ethiopia: Federal Democratic Republic of Ethiopia. 200p. Available at https://www.mofed.gov.et/media/filer_public/9e/23/9e23b2bc-0f3f-4035-ac8a-f0009b5b704a/crge_strategy.pdf (accessed on November 1, 2023).

FDRE (Federal Democratic Republic of Ethiopia). 2021. *Updated Nationally Determined Contribution*. Addis Ababa, Ethiopia: Environment, Forest, and Climate Change Commission, Federal Democratic Republic of Ethiopia. 48p. Available at https://faolex.fao.org/docs/pdf/eth215805.pdf (accessed on November 1, 2023).

Haile, A.T.; Geremew, Y.; Wassie, S.; Fekadu, A.G.; Taye, M.T. 2023. Filling streamflow data gaps through the construction of rating curves in the Lake Tana Sub-basin, Nile basin. *Journal of Water and Climate Change* 14(4): 1162–1175. https://doi.org/10.2166/wcc.2023.372

Nigussie, L.; Haile, A.T.; Gowing, J.; Walker, D.; Parkin, G. 2020. *Citizen science in community-based watershed management: An institutional analysis in Ethiopia*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 25p. (IWMI Working Paper 191). https://doi.org/10.5337/2020.207

NMA (National Meteorological Agency). 2021. *National framework for climate services – Ethiopia: Coordination guideline*. Addis Ababa, Ethiopia: National Meteorological Agency, Ministry of Water, Irrigation and Energy, Federal Democratic Republic of Ethiopia. 22p. https://hdl.handle.net/10568/117451

NMA. 2007. *Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia*. Addis Ababa, Ethiopia: National Meteorological Agency, Ministry of Water Resources, Federal Democratic Republic of Ethiopia. 96p. Available at https://unfccc.int/resource/docs/napa/eth01.pdf (accessed on November 1, 2023).

Sanchez Ramirez, J.C.; Seid, A.H.; Tafesse, M.; Adamseged, M.E.; Abseno, M.M. 2024. *Improving institutional arrangements for strengthening water and climate data and analytic tools in Ethiopia*. Synthesis report prepared by the Prioritization of Climate-smart Water Management Practices project. Colombo, Sri Lanka: International Water Management Institute (IWMI). 28p. https://doi.org/10.5337/2024.210

Stahl, K.; Hisdal, H.; Hannaford, J.; Tallaksen, L.M.; van Lanen, H.A.J.; Sauquet, E.; Demuth, S.; Fendekova, M.; Jódar, J. 2010. Streamflow trends in Europe: Evidence from a dataset of near-natural catchments. *Hydrology and Earth System Sciences* 14(12): 2367–2382. https://doi.org/10.5194/hess-14-2367-2010

Taye, M.T.; Zimale, F.A.; Woldesenbet, T.A.; Kebede, M.G.; Amare, S.D.; Tegegne, G.; Mekonnen, K.; Haile, A.T. 2023. Priority research topics to improve streamflow data availability in data-scarce countries: The case for Ethiopia. *Hydrology* 10: 220. https://doi.org/10.3390/hydrology10120220

Taye, M.T.; Haile, A.T.; Genet, A.; Geremew, Y.; Wassie, S.; Abebe, B.; Alemayehu, B. 2022. *Data quality deterioration in the Lake Tana Sub-basin, Ethiopia: Scoping study to provide streamflow and water withdrawal data*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 32p. (IWMI Working Paper 204). https://doi.org/10.5337/2022.208

Taye, M.T.; Haile, A.T.; Fekadu, A.G.; Nakawuka, P. 2021. Effect of irrigation water withdrawal on the hydrology of the Lake Tana sub-basin. *Journal of Hydrology: Regional Studies* 38: 100961. https://doi.org/10.1016/j.ejrh.2021.100961

WLRC (Water and Land Resource Centre) 2023. *Water Audit Project final report*. Addis Ababa, Ethiopia: Water and Land Resources Center, Addis Ababa University.

Whitfield, P.H.; Burn, D.H.; Hannaford, J.; Higgins, H.; Hodgkins, G.A.; Marsh, T.; Looser, U. 2012. Reference hydrologic networks I. The status and potential future directions of national reference hydrologic networks for detecting trends. *Hydrological Sciences Journal* 57(8): 1562–1579. https://doi.org/10.1080/02626667.2012.728706

International Water Management Institute

CGIAR

IWMI is a CGIAR Research Center

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 15 countries and a global network of scientists operating in more than 55 countries.

International Water Management Institute (IWMI)
Headquarters
127 Sunil Mawatha, Pelawatta
Battaramulla, Sri Lanka

Mailing address:
P. O. Box 2075
Colombo, Sri Lanka
Tel: +94 11 2880000
Fax: +94 11 2786854
Email: iwmi@cgiar.org
www.iwmi.org