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Working Paper

Citizen Science in Community-based Watershed Management: An Institutional Analysis in Ethiopia

Likimyelesh Nigussie, Alemseged Tamiru Haile, John Gowing, David Walker
and Geoff Parkin

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Contents

Acronyms and Abbreviations

AWS	Automatic Weather Station
AWOS	Automatic Weather Observing System
BDA	Basin Development Authority
CBM	Community-based Monitoring
CD	Compact Disc
DA	Development Agent
DWS	Digital Wind System
ETB	Ethiopian Birr
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GEF	Global Environment Facility
GTP	Growth and Transformation Plan
IP	Innovation Platform
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
MoA	Ministry of Agriculture
MoWIE	Ministry of Water, Irrigation and Energy
MoWR	Ministry of Water Resources
NMA	National Meteorology Agency
O&M	Operation and Maintenance
PFM	Participatory Forest Management
RBO	River Basin Organization
SGW	Shallow Groundwater
SLMP	Sustainable Land Management Programme
SNNPR	Southern Nations, Nationalities, and People's Region
UAOS	Upper Air Observation System
WLRC	Water and Land Resource Centre
WMO	World Meteorological Organization
WUA	Water User Association

Summary

Agriculture is the mainstay of Ethiopia's economy contributing to 41.5% of the gross domestic product (GDP). Growth of the sector depends on efficient and sustainable use of natural resources such as water and land, which calls for the monitoring of these resources. Hydrometeorological monitoring can provide the information needed for early warning, and preparing and responding to weather-related natural disasters, thereby supporting development of the agriculture sector. In Ethiopia, the Basin Development Authority (BDA) and the National Meteorology Agency (NMA) are the two state organizations responsible for collecting hydrological and meteorological data, respectively. Through a proclamation in 2018, the Ministry of Water, Irrigation and Energy (MoWIE) delegated BDA to collect, process, analyze and disseminate hydrological data. It has been reported that BDA and NMA have limited capacity (financial, technological, human and others) to (i) set up new network stations; (ii) install modern equipment; (iii) rehabilitate existing stations; (iv) cover running costs of network stations; (v) conduct regular supervision of monitoring stations (e.g., to provide feedback and take corrective action on time, if needed); and (vi) monitor several hydrometeorological parameters. For these reasons, network stations under these organizations are sparsely distributed, causing data coverage issues across a country as diverse as Ethiopia. For example, even if BDA is responsible for managing the country's water resources, due to limited capacity, it tends to focus only on monitoring large rivers and does not take into consideration small rivers. However, data from small rivers in micro-watersheds are crucial for people's livelihoods and local water security.

Overall, the limited capacities of both BDA and NMA have an impact on the quality and continuity of data. These organizations are not represented at lower administrative levels (e.g., *woreda, kebele* and community levels), and there are no institutional arrangements in place that could facilitate engagement of the community, both of which lead to hydrometeorological data gaps in the country. Therefore, the authors suggest that institutionalizing engagement of communities (non-scientists) in hydrometeorological monitoring (citizen science approach) has the potential to address part of the data gaps in Ethiopia.

This study, therefore, examines the existing institutional arrangements for hydrometeorological monitoring and the practices followed by BDA and NMA. Also, it investigates the possibilities of embedding a citizen science approach into regular monitoring conducted by these organizations for addressing the hydrometeorological data gaps, particularly at micro-watershed levels. Data and information for the study were collected through a literature review, and in-depth discussions held with key informants at federal, regional, basin, sub-basin and network station levels.

Based on the assessments, adopting and institutionalizing a citizen science approach for some of the monitoring tasks could address part of the data gap issues in Ethiopia. According to key informants, there is potential to embed the approach into the institutional structure of the Ministry of Agriculture (MoA) for hydrometeorological monitoring of small rivers in micro-watersheds, due to the following reasons: (i) MoA has a high demand for hydrometeorological data from small rivers to be used for small- and micro-scale irrigation development, and for measuring the impacts of watershed development interventions on water resources; and (ii) MoA has an institutional structure from federal to community level that supports the engagement of communities in development interventions. However, effectively embedding the citizen science approach into regular monitoring of MoA depends on the clear distribution of mandates; developing legal, ethical, methodological and quality frameworks; and developing clear data sharing and incentive mechanisms involving all partners (e.g., MoWIE, NMA, BDA and MoA).

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Introduction

The Ethiopian economy is predominantly based on agriculture at the national and local level. During the 5 years of the first Growth and Transformation Plan I (GTP I) (2010/2011-2014/2015), the share of agriculture in gross domestic product (GDP) averaged 41.5% (National Planning Commission 2016). This agricultural economy is highly dependent on natural resources, including water resources. However, both agriculture and water resources are vulnerable to climate variability and environmental degradation. Studies have reported the extent of land degradation in Ethiopia and its impact on agricultural productivity (GIZ Ethiopia 2015), but its impact on hydrology is not well documented. Zemadim et al. (2013) highlighted that hydrometeorological monitoring for the provision of high-quality hydrological data is crucial to support decisions on sustainable land management and water allocation strategies, and for weather forecasts and early warnings.

In Ethiopia, the Basin Development Authority (BDA) and the National Meteorology Agency (NMA) have the mandate to collect hydrological and meteorological data, respectively. In November 2018, the Ministry of Water, Irrigation and Energy (MoWIE) delegated BDA to collect, process, analyze and disseminate hydrological data (FDRE 2018a).

BDA has the mandate to monitor all water resources in the country. However, due to limited capacity, hydrometeorological monitoring tends to focus on larger river basins (> 1,000 km^2) at basin and sub-basin levels, and leaves out smaller watersheds. Although monitoring of large river basins is appropriate for water resources assessment, it is inadequate for hydrological research that requires monitoring at much higher resolution (i.e., typically watersheds < 100 km^2) (Zemadim et al. 2013). Hydrometeorological data from small watersheds are needed for water resources planning and development at lower levels (such as community level) by various stakeholders, such as the Ministry of Agriculture (MoA), regional water/agriculture bureaus and *woreda*[1] water/agriculture offices. Also, in small watersheds, availability of water resources is crucial for people's livelihoods, and for water security at local and regional levels. Therefore, acquiring appropriate data is essential for water resources planning and management.

In addition, in small and micro- watersheds, where sustainable land management programs are implemented, hydrological monitoring of small rivers helps to identify the impact of the interventions on water resources. For example, the Sustainable Land Management Programme (SLMP) II is one of the main participatory watershed development programs implemented by the Government of Ethiopia. The program is designed to combat land degradation, protect natural resources and restore soil fertility in targeted watershed areas of Ethiopia. SLMP II was implemented in six regions, 135 watersheds/*woredas* (districts) and 937 rural *kebeles*[2] from 2014 to 2018 (FDRE and MoA 2014), with financial support from the World Bank, Global Environment Facility (GEF) and the Government of Norway. Although the Government of Ethiopia and development partners have invested heavily in this program, impacts of the interventions on water resources are not well understood due to the lack of hydrometeorological data from small watersheds.

Evidence shows that there are gaps in hydrometeorological data in Ethiopia due to limited coverage, and poor data quality and continuity (Haile et al. 2017). Some of the underlying causes of these data gaps are outdated and out-of-service gauging stations, inadequate equipment calibration, limited telemetry systems, lack of adequate or modern data acquisition and management systems, and weak national water quality, groundwater and sediment monitoring programs (NBI 2016). The most pressing hydrometeorological data gaps from small rivers in small and micro- watersheds are related to the (i) high cost of establishing and maintaining network stations, (ii) lack of appropriate institutional arrangements that govern data collection from water sources in small and micro-watersheds, and (iii) lack of institutional arrangements to facilitate community participation.

Case studies conducted in Ethiopia demonstrated that community-based monitoring (CBM) can deliver valuable data on groundwater levels, spring flow and local streamflow from water sources in small and micro-watersheds (Haile et al. 2019; Zemadim et al. 2013; Walker et al. 2016). Haile et al. (2019) showed that 'citizen science' can be applied for the rapid assessment of water availability in ungauged micro-watersheds, with a focus

[1] *Woreda* is the third-level administrative division of Ethiopia.

[2] *Kebele* is the smallest administrative unit of Ethiopia.

on the monitoring of the shallow groundwater (SGW) resource and surface water resources. Citizen science refers to the participation of the general public (i.e., non-scientists, citizens or community members that volunteer) in the generation of new scientific knowledge, together with professional scientists (Buytaert et al. 2014). Similarly, Walker et al. (2016) demonstrated that non-specialists from local communities can collect high-quality hydrometeorological data for various applications to either supplement formal sources or provide time series data where no formal alternative is available. Also, Zemadim et al. (2013) indicated that the involvement of communities in establishing and contributing to network stations at a watershed scale is key to their reliability and a prerequisite for long-term sustainability.

Community-based approaches are not new to Ethiopia. They have been practiced in the country for the purpose of natural resources management, among others. For example, research that investigated water dynamics in Fogera and the Upper Blue Nile found a connection between farmers' perspectives on changes in water conditions in their socio-agricultural environment and related physical data assessed through satellite remote sensing analysis (Chemin et al. 2015). Also, a participatory forest management (PFM) study in southwestern Ethiopia revealed local people's long-standing traditions and participation in managing forest resources and maintaining biodiversity, thereby suggesting the potential for local communities to support participatory investigation and monitoring of natural resources (Dessalegn 2013).

Therefore, this paper aims to investigate the institutional arrangements in hydrometeorological monitoring practices of BDA and NMA in Ethiopia. Most importantly, the aim is to investigate the possibilities of embedding a citizen science approach to address data gaps (particularly at micro-watershed levels) into the data collection systems of these two organizations. The paper makes valuable contributions to the field of natural resources management, particularly for policy-makers, researchers and practitioners, who are involved in hydrometeorological monitoring and citizen science.

The authors gained valuable information from a previously conducted study (Nigussie et al. 2018), which investigated (i) the role of citizen science to enhance groundwater governance; (ii) the capacity of different members of the community to engage in groundwater management; and (iii) how the approach can enhance community empowerment and equity, especially among women.

Objectives of the Study

The aims of this study are to explore (i) the hydrometeorological monitoring practices in Ethiopia, and (ii) how a citizen science approach can be embedded in relevant organizations for hydrometeorological monitoring to address data gaps. The aim is to also enhance the understanding of the interrelationships between community-based approaches, hydrometeorological monitoring and organizations.

Specific objectives of the study are as follows:

- Investigate the institutional arrangements of hydrometeorological monitoring in Ethiopia.
- Understand the hydrometeorological monitoring processes and practices.
- Explore how a citizen science approach can be institutionalized for sustainable and effective hydrometeorological monitoring (particularly in small rivers in micro-watersheds to address data gaps).

Methodology

This study is based on data collected from relevant national agencies, river basin development offices, regional bureaus and network stations. The national agencies include MoWIE, MoA, NMA and BDA. Ethiopia is divided into 12 drainage basins, eight of which are river basins, one is a lake basin and three are dry basins, with no or insignificant outflow from the drainage system (Berhanu et al. 2014). For this study, data was collected for two river basins: Abbay Basin Development Office and Rift Valley Lakes Basin Development Office.

In order to identify possible ways of embedding community-based hydrometeorological monitoring in Ethiopia into regular monitoring conducted by BDA and NMA, primary and secondary data were collected and analyzed. Primary data were collected from interviews conducted (in person and via telephone) with key informants from relevant organizations, including MoWIE, MoA, NMA, BDA, Rift Valley Lakes Basin Development Office, Water and Land Resource Centre (WLRC), Abbay Basin Development Office and its Bahir Dar Branch, and West Amhara Meteorology Office (see Annex 1). Interviews were also conducted at community level with observers who conduct hydrometeorological monitoring for the *Water Security Risk Science: Local knowledge for participatory resource management* project of the REACH program[3]. The interviews with experts from MoWIE, NMA, MoA, Rift Valley Lakes Basin Development Office and WLRC were conducted in Addis Ababa, Ethiopia. Interviews with experts from the Abbay Basin Development Office, the Bahir Dar Branch office of Abbay Basin Development Office and West Amhara Meteorology Office were conducted in Bahir Dar, Ethiopia. Other observers were also interviewed in their relevant locations: Dangila and Ebinet *woredas* in Amhara region, and Boloso Bombe and Tembaro *woredas* in Southern Nations, Nationalities, and People's Region (SNNPR).

Interviewees were purposely selected based on their experience and knowledge on hydrometeorological monitoring processes and community-based approaches. The key informant interviews were conducted with the aid of a semi-structured questionnaire, which was developed based on the objectives of this study. Annex 2 provides the interview guide. Primary and secondary data were collected between October 2018 and January 2019. Secondary data were collected by reviewing documents such as books, journal articles, conference papers and reports.

Literature Review

Since the 1970s, participatory methodologies have been widely adopted in development practices. Impetus came from natural resources management initiatives and agro-ecosystem analyses, which are the focus for community-based participatory watershed management. Accumulated experience led to growing recognition that 'experts' do not have a monopoly on knowledge and local (indigenous) knowledge has value. Chambers (2008) reviewed this experience and concluded that 'who finds out', 'who learns' and 'who is empowered' are core questions. The challenge is to use the wide range of available participatory methods to generate quantitative as well as qualitative data.

In parallel, the practice of CBM in environmental management has emerged mainly through experiences in developed countries in response to growing environmental activism. To date, its successful adoption has been mainly in the domains of environmental quality and ecological monitoring. From the start, these initiatives have aimed to deliver quantitative data, but the level of involvement of non-scientists has often been restricted to data gathering rather than management actions (Conrad and Hilchey 2011). The challenge is to extend this experience to less-developed countries in a way that empowers local stakeholders.

When a community takes the responsibility to collect data on their local environment, citizen science can be denoted as CBM (Cunha et al. 2017) or participatory monitoring (Danielsen et al. 2005). Chambers (1994a, 1994b) showed how concepts of CBM and participatory monitoring also relate to other participatory learning approaches, which have significantly promoted the importance of community participation and involvement in development practices.

From these different approaches to participatory resource assessment and management practices, the emergence of the paradigm of 'citizen science' can be seen, whereby citizens are active participants in a scientific investigation. The nature of this participation has varied from data collection alone (i.e., CBM) to collection, analysis and use of data for decision-making about management of the environment. There is an emerging consensus that scientists simply using citizens as data collectors cannot be regarded as true 'citizen science', indicating the need for two-way interaction between citizens and scientists (Lakshminarayanan 2007).

The benefits and challenges of citizen science are identified by Conrad and Hilchey (2011). The fact that citizen science can play an important educational role is a benefit. Specifically, through active engagement of community members in scientific projects, communities are able to increase their scientific literacy and social capital, and have more influence on policy-makers. Also, the approach offers government agencies a cost-effective alternative to monitoring. The challenges tend to be related to three issues: (i) institutional issues, (ii) data collection issues, and (iii) data use issues. Challenges at the institutional level include a lack of interest from volunteers as well as funding and access to information. Issues also arise during data collection, which are identified as data fragmentation, data inaccuracy and lack of participant objectivity. There is a problem of mistrust (by the scientific community or government) due to concerns about data reliability. Information collected by community groups may not be taken seriously by decision-makers due to concerns about the reliability, non-comparability and completeness of the data. Many groups find their data are not used in the decision-making process, due to either data collection concerns or difficulty in getting the data to the appropriate decision-maker.

The issue of data quality is a barrier to participation and utilization of the data (Carlson and Cohen 2018). Quality

[3] https://reachwater.org.uk/

of observational data may relate to the equipment used in projects, poor understanding of citizen scientists and lack of commitment (driven by lack of time, access and funding, work/family commitments, poor health, etc.). These factors may necessitate adjustments to observation time or a temporary change in observer that will likely result in observational error (Walker et al. 2016; Geoghegan et al. 2016). Also, the quality of observational data may relate to the design and execution of sampling methods, training and quality assurance/quality control processes, the degree of good project management, data management and observer's management (Vann-Sander et al. 2016). Therefore, ensuring the quality of CBM is key for the uptake and use of data collected using the citizen science approach. One way of improving the quality of data is by understanding the motivation of volunteers to participate.

Literature on environmental volunteering frequently categorizes the motivation of participants as intrinsic (or inherently valuable or satisfying) or extrinsic (or leading to some other benefit, such as future career prospects). Since participation in citizen science is voluntary, participants need to be motivated. This is key to enhancing data quality and gaining the trust of participants (Kemper 2007; Vann-Sander et al. 2016). Incentives for citizen scientists can lead to deep, long-lived engagement and a high quality of output (Roy et al. 2012). Specific to hydrometeorological monitoring, the main incentive for communities to actively engage in such practices is understanding how the information collected relates to their livelihoods and ecosystems. Therefore, it is important to ensure that communities understand the data and what it highlights about the environment.

Specific to hydrological monitoring, it requires multipoint and continuous effort, because hydrological states and fluxes are highly variable in space and time. As a result, volunteer citizens may become reluctant to carry out repeated, frequent and long-term measurement (Lowry and Fienen 2013). Therefore, understanding motivations of the diverse and disparate communities participating in citizen science while designing projects is critical to maximize positive outcomes (Roy et al. 2012). Motivation may not be homogeneous among participants; individual differences (e.g., in age, gender, education level or country) may influence what motivates participants (and what does not) (Beza et al. 2017; Carlson and Cohen 2018).

Community engagement can have a positive effect on the decision-making process, if the science community and individuals benefit from the process (Vann-Sander et al. 2016). Also, it helps to gain a better understanding of the key issues of different stakeholders (Cunha et al. 2017).

Engaging the community in scientific processes has potential positive outcomes for communities, including the following:

- It breaks down barriers between stakeholders, such as communities, scientists, managers, decision-makers and others by building relationships (Woolley et al. 2016). Therefore, it prevents unnecessary misunderstandings about aims of the project (Zemadim et al. 2013).

- Early involvement of the local community (e.g., in site selection for monitoring) instills a sense of ownership of the equipment, and a sense of being a research partner as opposed to a subject (Walker et al. 2016).

- It enhances public awareness about the resources they monitor; instills ownership and acceptance of science and management; and creates an improved understanding of the roles they play in environmental sustainability. The benefits of engaging communities in environmental monitoring processes largely relate to the development concerns that gave rise to community participation and development approaches (Danielsen et al. 2010).

One mechanism for achieving positive outcomes for communities is through feedback. Delivering feedback to communities through visits as well as workshops can enhance their awareness and learning. Also, it helps to improve the quality of observational data. Feedback includes presenting the data collected by the community, highlighting what is revealed by the data, explaining what the data is used for, and giving the community the opportunity to ask questions and provide their own explanation for patterns in the data (Walker et al. 2016; Vann-Sander et al. 2016). Feedback can be delivered through Innovation Platforms (IPs) to communicate the research findings, and provide a forum for discussion of project concepts and learning (Zemadim et al. 2013). IPs are tools used to establish connections and networks between heterogeneous actors by creating a space for exchanging knowledge regarding a common problem, and developing and identifying local solutions to local problems (Cadilhon 2013).

Adopting CBM, such as a citizen science approach, also has positive outcomes on scientific processes, including the following:

- Facilitates local and international environmental monitoring, nature conservation, land-use planning and administration (Turrini et al. 2018; Buytaert et al. 2014).

- Provides opportunities to collect data efficiently at a small scale with high precision and accuracy. It helps to produce a large amount of data (especially data spanning large spatial or temporal extents), which would otherwise be laborious and costly or even impossible to obtain (Geoghegan et al. 2016; Vann-Sander et al. 2016).

- Improves the number of stations in areas with sparse and/or declining formal monitoring networks. In such areas, the approach helps to improve the spatial density of measurements by providing data of a sufficient quality to complement the ground observation datasets used to calibrate and validate gridded datasets (Walker et al. 2016).

- In cases where representativeness and resolution of the station distribution are not in line with the topography of the country, the citizen science approach helps to obtain additional information (e.g., taking photographs of land-use change, and recording of activities such as gravel extraction from riverbeds and flooding events) for only a marginal extra cost (Zemadim et al. 2013).

Although the topic of citizen science for environmental monitoring has gained attention, institutional dimensions of the approach for natural resources management are heavily understudied. Using Web of Science – a website which provides subscription-based access to multiple databases that provide comprehensive citation data – the authors searched titles of relevant publications using key words such as 'institution' AND 'citizen science' OR 'participatory approach' OR 'community based approach'. However, no relevant studies were found prior to December 2019.

Findings

Institutional Arrangements for Hydrometeorological Monitoring

In Ethiopia, MoWIE and NMA are government organizations mandated to collect, archive and disseminate hydrological and meteorological data, respectively. The institutional arrangements for monitoring hydrological and meteorological data are analyzed in this section.

Ministry of Water, Irrigation and Energy (MoWIE)

The Ministry of Water Resources (MoWR) in Ethiopia was established in 1995 by Proclamation No. 4/1995 (FDRE 1995). The name of the ministry has changed since its establishment, and is currently the Ministry of Water, Irrigation and Energy (MoWIE). Discussions held with key informants indicated that the ministry has been collecting hydrometeorological data since 1947, when the Abbay River study was started. Since then, it gathers, processes, analyzes and disseminates hydrological data and information to support decisions related to water resources development and management at basin and sub-basin levels.

Historically, the power given and duties assigned to the ministry in relation to hydrometeorological monitoring are clearly indicated in proclamation numbers 4/1995 (FDRE 1995), 256/2001 (FDRE 2001), 471/2005 (FDRE 2005), 691/2010 (FDRE 2010) and 916/2015 (FDRE 2015). Specifically, the proclamations indicate that the ministry is responsible for: (i) undertaking river basin studies, and determining the volume and quality of the country's available groundwater and surface water, and facilitating utilization of these resources; and (ii) ensuring the provision of meteorological services.

Being in charge of Integrated Water Resources Management (IWRM) planning in the country, the ministry adopted a river basin approach in its Ethiopian Water Resources Management Policy (1999) (MoWR 1999). Therefore, the River Basin Councils and Authorities Proclamation (Proclamation No. 534/2007) (FDRE 2007) provided a legal framework for establishing river basin organizations (RBOs) for each of the major river basins in the country. According to the proclamation, some of the functions to be carried out by the Federal Government (MoWR) were transferred to RBOs. Also, the proclamation enabled the establishment of a two-tier institutional setup for RBOs: River Basin High Councils (the highest policy and strategic decision-making body) and River Basin Authorities (the administrative/technical arm of the River Basin High Councils). According to MoWR (1999), the main aim of establishing the River Basin Authorities was to ensure "efficient, successful and sustainable joint management of the water resources of the basins through concerted efforts of the relevant stakeholders." Accordingly, three river basin development offices (Abbay Basin Development Office, Awash Basin Development Office and Rift Valley Lakes Basin Development Office) were created.

In relation to hydrological monitoring, Article 9 of the proclamation (Proclamation No. 534/2007) (FDRE 2007) assigned powers and duties to Basin Authorities as follows:

- *Collect, compile, analyze and disseminate information for proper planning, administration and steering of water resources in the basin* (Article 9.6).

- *Develop and use a river basin model in order to guide and support its basin water resources strategic planning and water administration functions* (Article 9.7).

In the most recent proclamation (Proclamation No. 1097/2018) (FDRE 2018a), the power and duties in relation to hydrometeorological monitoring remain with the ministry. Article 33.14(c) of the proclamation indicates the Basin Development Authority (BDA) as one of the executive organs that is accountable to MoWIE. BDA is responsible for collecting, compiling, analyzing and disseminating information for proper planning, administration and steering of water resources in basins (Proclamation No. 1097/2018, Article 32.5[k] [FDRE 2018a], and the Council of Ministers Regulation No. 441/2018, Article 5.10 [FDRE 2018b]). According to FDRE (2018b), BDA is also responsible for the following:

- *Develop and manage basin information system* (Council of Ministers Regulation No. 441/2018, Article 5.14).

- *Study and implement flood protection forecasting and early warning works. Protect and save lives and properties in case of flood and drought, by implementing various flood protection and drought mitigation measures in coordination with relevant bodies* (Council of Ministers Regulation No. 441/2018, Article 5.18).

As a result of the restructuring (by the proclamations/regulations), the basin development authorities (BDAs) (Abbay, Awash and Rift Valley Lakes Basin) were renamed as 'basin development offices' and became branch offices of BDAs at the federal level. Figure 1 illustrates the institutional arrangements for hydrological monitoring in Ethiopia.

As shown in Figure 1, at the federal level, the BDA is solely responsible for establishing hydrological monitoring networks, and for collecting, compiling, analyzing and disseminating hydrological data and information. Specific responsibilities of the BDA include: (i) identifying sites, (ii) conducting field visits to check suitability of the locations, (iii) conducting community dialogue and discussions with local authorities regarding establishment of sites, and (iv) identifying observers. These activities are carried out by the BDA using three methods: (i) on their own; (ii) through their branch offices, and (iii) through basin development offices. Therefore, BDA exchanges information with basin development offices, branch offices and network stations. Specific to hydrological data, BDA receives the data from different sources: (i) directly from telemetric network stations, and (ii) from basin development offices and branch offices in the case of manual network stations and data loggers.

At basin level, with support from the BDA, basin development offices are responsible for initiating and supporting the establishment of network stations in their respective basins. At sub-basin level, sub-basin offices and branch offices are responsible for implementing the plans of the basin development offices and BDA, respectively. Basin development offices receive hydrological data within their basins: (i) directly from telemetric network stations, and (ii) from sub-basin offices and branch offices in the case of manual network stations and data loggers. Sub-basin offices and branch offices are responsible for implementing plans by the BDA and basin development offices, including the provision of training to observers, and supporting the establishment of, and gathering data from, network stations. Also, they are responsible for gathering data from network stations by (i) collecting printed copies of records from observers and paying their salaries, and (ii) downloading data from data loggers.

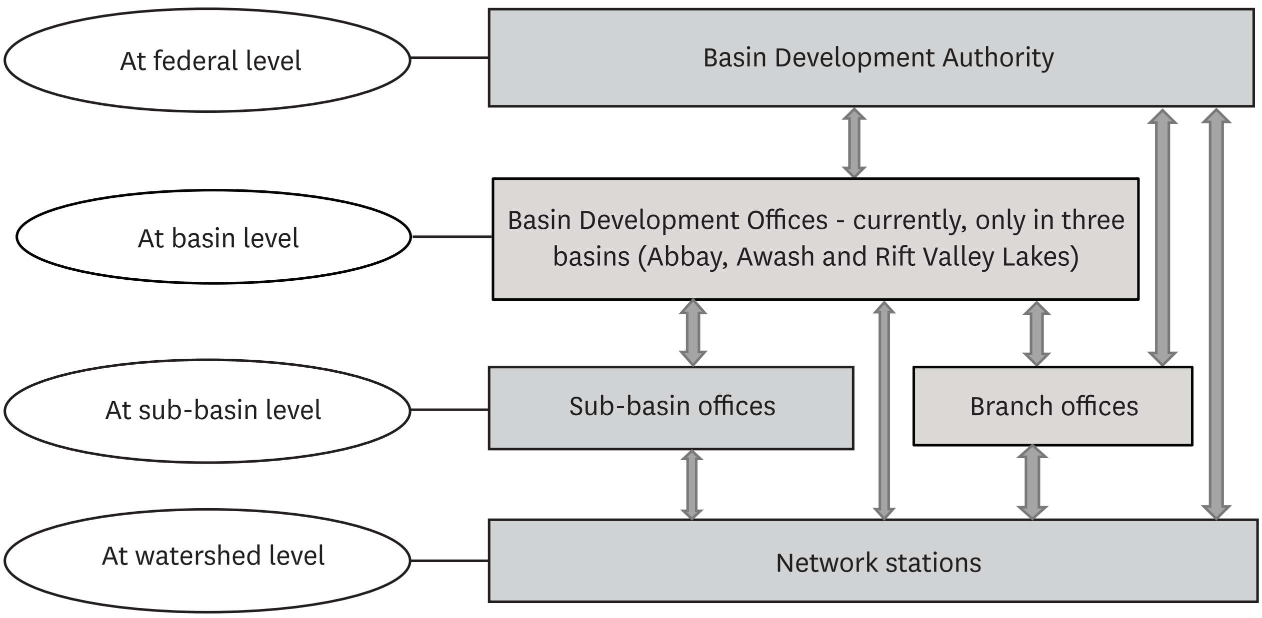

Figure 1. Information flow of hydrological monitoring data in Ethiopia.

Key informants indicated that the hydrological parameters measured include streamflow-related parameters (primarily river/lake water levels and river discharge), sediment load, groundwater and water quality. Among these, the monitoring of water quality, sediment transport in rivers and groundwater in Ethiopia is in its early stages (NBI 2016).

Discussions with key informants indicated that, by the end of 2018, the number of operational hydrological stations owned by BDA and distributed over the country's river basins was 490, of which about 50 stations are telemetric. These network stations are distributed across 10 river basins: Abbay, Awash, Baro-Akobo, Afar-Danakil, Genale-Dawa, Mereb, Omo-Gibe, Tekeze, Rift Valley Lakes and Wabe-Shebele. There are no network stations in Ogaden and Ayisha river basins, as they are dry basins. The number of operational hydrological stations (490) does not include additional stations established by the three basin development offices (Abbay, Awash and Rift Valley Lakes Basin) and other stakeholders. On average, BDA sets up approximately 10 new stations every year.

According to key informants, there are network stations established by stakeholders such as research organizations and universities for modelling and other purposes. For example, in order to meet the demand for hydrological data from small rivers in small and micro-scale watershed developments, MoA sometimes monitors small rivers during the critical dry season (once or twice per season). Although the design of water supply schemes (such as irrigation) is better with the use of data that is continuously collected, this is not possible due to the lack of resources to conduct continuous monitoring and hence data collected during the first or second instance are used.

Similarly, the International Water Management Institute (IWMI) and Newcastle University have hydrological stations set up for the rapid assessment of water availability in ungauged micro-watersheds, with a focus on monitoring shallow groundwater (SGW) and surface water resources (Haile et al. 2019). Also, WLRC has observatories/network stations that monitor hydrological parameters which are mainly used to understand the impacts of watershed development interventions on soil retention/reducing soil erosion in certain watersheds[4] .

However, these network stations have a short life span of usually 2-5 years (during the lifetime of the project). When projects that monitor the network stations reach closure, there is no state organization to takeover and continue monitoring of these stations, due to the limited capacity to cover running costs of the stations. Such stations are taken over by government authorities in a few instances, such as when the location of the network stations owned by stakeholders/projects match the locations identified by BDA or basin development offices for setting up network stations.

According to key informants, hydrological stations in Ethiopia are sparsely distributed across basins and sub-basins, mainly due to limited capacity (financial, human, institutional and others). Limited capacity for hydrological monitoring leads to data gaps in terms of coverage, continuity and quality. For example, although BDA has the mandate to manage the country's water resources, it focuses on monitoring large rivers, while data from small rivers are missing. However, hydrological data from small rivers are needed for water resources planning and management at micro-watershed levels, particularly to improve livelihoods and water security of the local community.

Key informants also indicated that BDA has limited capacity to set up monitoring stations, install modern equipment, and to cover operation and maintenance (O&M) costs. In addition, it has limited budget to cover costs for regular supervision (i.e., for checking for quality and ensuring continuity of data collection). Supervisors from branch offices are responsible for visiting network stations (without prior notice) to check the performance of observers, and identify the need for maintenance and repair. Observers may be negligent or lose interest, if supervisors from branch offices do not make frequent visits (due to limited capacity) and do not take any (or immediate) action when problems are reported, and this may lead to data quality issues. Other reasons for hydrological data gaps are theft, vandalism, loss of measuring devices due to floods, lack of complete facilities and services from branch offices, and the inability to conduct successive trainings on hydrological stations for observers. Also, some areas face challenges in meeting the criteria needed to set up a network station, such as topography, road access, availability of residents nearby to participate as observers and others. These are some of the reasons for hydrological data gaps in Ethiopia.

National Meteorology Agency (NMA)

In Ethiopia, meteorological observations started in the nineteenth century, mainly by European missionaries. In the 1950s, meteorological services were linked to the aviation sector and later began to encompass other sectors such as agriculture and water resources (Lemma and Getachew 2018). Officially, the National Meteorology Agency (NMA) was established on December 31, 1980, under Proclamation No. 201/1980 (Provisional Military Government of Socialist Ethiopia 1980). In accordance with this proclamation, some of the mandates of the Agency included establishing and operating a national network of meteorological stations; collecting all meteorological data (including data collected by any person in the country); organizing and analyzing meteorological and related information; and observing weather, issuing warnings on adverse weather conditions and controlling atmospheric air pollution.

[4] http://www.wlrc-eth.org/project-component/observatories

Key informants indicated that the Meteorological Data and Climatology Directorate (under NMA) and meteorological branch offices (at regional and subregional levels) are responsible for meteorological data monitoring (Figure 2). Through its network stations, the NMA measures a total of 26 parameters. It monitors rainfall, temperature, wind speed and direction, air temperature, humidity and barometric pressure, among others.

At federal level, the Meteorological Data and Climatology Directorate (under NMA) is responsible for overall meteorological data collection, analysis, processing, archiving and sharing. It is also responsible for initiating and supporting the establishment of network stations. NMA collects meteorological data directly from its telemetric station, manual network stations located in Addis Ababa, and its 11 meteorological branch offices (Adama, Tigray, East Amhara, Bahir Dar, Afar, Jimma, Bale Robe, Hawassa, Gambella, Jigjiga and Asosa) located across the country at regional and subregional levels. By the end of 2018, NMA had a distribution of 1,275 conventional stations of different categories and 270 telemetric stations. Telemetric stations include Automatic Weather Station (AWS), Digital Wind System (DWS), Automatic Weather Observing System (AWOS), Upper Air Observation System (UAOS), satellite receiving system, radar and others. Also, NMA collects data on weather phenomena across the country at 4 x 4 kilometer resolution data, by processing data from satellites and network stations. NMA is responsible for generating such data and sharing it with users, including its meteorological branch offices, especially in areas where there are few network stations.

The meteorological branch offices of NMA are responsible for (i) identifying sites; (ii) conducting field visits to check suitability of the locations; (iii) conducting community dialogue and discussions with local authorities about the establishment of sites; (iv) identifying observers; (v) delivering trainings to observers; (vi) supervising network stations and observers on a regular basis; and (vii) collecting meteorological data from network stations within their boundaries, sharing the data with NMA and conducting data quality checks.

The network stations at NMA are further classified into four classes: First class (synoptic stations), Second class (principal or indicative stations), Third class (ordinary stations), and Fourth class (rainfall recording stations). The latter two classes are differentiated by the number of parameters they measure. Fourth class stations measure rainfall once a day. Third class stations measure rainfall and temperature (maximum and minimum) once a day and twice a day, respectively. Usually, the parameters measured at the first and second class stations include rainfall, temperature, atmospheric water content, actinography, sunshine duration, wind speed, barometric pressure and cloud type visibility. The main difference between synoptic and principal stations is that observations are taken every one hour at synoptic stations and every 3 hours at principal stations.

Like hydrological data, meteorological data in Ethiopia is challenged by data gaps. Reasons for these gaps include the topography of the country, limited road access and limited capacity to set up new network stations. Data from manual network stations have quality issues caused by errors from various sources and data discontinuity (missing data). The root causes of data quality issues are linked to the lack of honesty and commitment, and due to weak or no institutional linkages between manual network stations and formal and informal organizations at district, subdistrict and communal levels.

In summary, gaps in the existing institutional arrangements suggest that citizen science could be a way forward to close some of the following observed data gaps:

- Data coverage issues caused by the limited number and sparsely distributed network stations.
- Data quality and continuity issues from manual network stations caused by: (i) limited capacity to carry out regular supervision and absence of institutional arrangements; (ii) limited capacity to rehabilitate existing stations; and (iii) limited institutional arrangements at *woreda/kebele* levels to enable the monitoring of network stations.

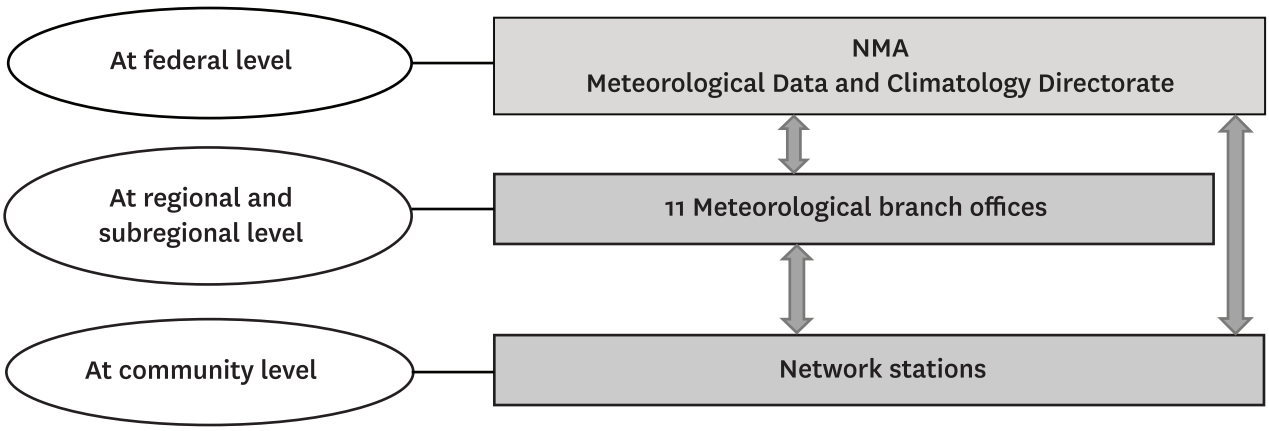

Figure 2. Information flow of meteorological monitoring data in Ethiopia.

Community Engagement Processes for Hydrometeorological Monitoring

Hydrometeorological monitoring by both the BDA and NMA involves some level of community engagement. The processes of establishing monitoring stations and community engagement by these institutions are discussed in this section.

Basin Development Authority (BDA)

At policy level, the Government of Ethiopia promotes the participation of communities in natural resources management. The Ethiopian Water Sector Policy (2001) supports the active participation of communities in water resources management. Particularly, section 2.2.13.A(4) fosters "*the participation of user communities in water resources management by supporting the establishment of appropriate institutional framework from regional to the lowest administrative structure and promote decentralized after management*." Also, section 2.2.10 promotes "*the full involvement of women in the planning, implementation, decision making and training as well as empower them to play a leading role in self-reliance initiatives*" (MoWR 2001).

Experts at BDA are responsible for identifying suitable sites for setting up network stations. Sites are selected based on ten criteria, including road accessibility and availability of local observers. Once a site is identified, experts make scoping visits to learn about the area and find potential observers. Observers are identified based on criteria such as a person's literacy (e.g., a student or priest), distance between their residence and the water source to be monitored, and their ability to be physically present in the area.

Subsequently, experts inform relevant officials from government administration offices at district (*woreda*) and subdistrict (*kebele*) levels, through a letter or verbally, about their plans to establish network stations. This mainly focuses on providing details of the plans to establish a network station and organize meetings with stakeholders in the area, including representatives from the police, military, elders, youth, women, religious leaders and clan leaders (in the case of pastoral communities). The meetings with stakeholders are organized to: (i) raise awareness about the network stations so that they can share information with the public, and (ii) ensure communities are responsible for protecting the equipment from theft and vandalism. Discussions will also be held to select suitable observers from those identified during the scoping visits.

Observers play a key role in hydrological monitoring processes, and the importance of their work is highlighted during meetings. BDA provides a reasonable incentive to encourage their participation and ensure the collection of quality data. Therefore, once identified and recruited, observers and their families receive a half-day of training. Families and friends of observers also provide support towards establishing, monitoring and maintaining the network stations, and are remunerated for their services. In some stations, there are family members who have been working as observers for a long period of time (e.g., 40 or 50 years). The training delivered to observers and their families is focused on what data to collect, how to read the instruments and when to collect data. After the training, observers are provided with protocols for recording the data they collect.

Looking into the gender dimensions of participation as observers, the involvement of women is limited due to structural barriers, such as the male-dominated culture (e.g., where the mobility of married women is controlled by their spouses), workload, illiteracy, low self-confidence and fear of gender-based violence. According to key informants, women are reluctant to participate in monitoring tasks that require traveling during the night and through forests, due to the fear of gender-based violence.

Based on discussions with key informants, the following key findings are related to the community engagement processes for hydrometeorological data collection:

- Although observers have incentives for collecting hydrometeorological data, other community members have earned little or received no benefit for their involvement in this task. Engaging communities in hydrometeorological monitoring, particularly those from lowland watersheds, could provide better access to information for disaster risk reduction and early warning. For example, observers located around flood-prone areas of the Awash River Basin are provided with mobile phones and top-up cards to enable the sharing of information on rainfall and water levels with branch offices. This helped relevant government offices and communities living in flood-prone areas to mitigate flood risks and enable early warning.

- Workload, limited awareness of the significance of hydrometeorological data, low incentive, and lack of peace and security (in some areas) are some of the reasons for data quality issues. In order to improve the quality of data, quality checks are conducted by comparing data with the nearest station. Also, data quality trainings are delivered to observers, and regular supervision is carried out every 3 months. In some cases, experts from branch offices make surprise visits to stations to check how observers are monitoring and recording data. However, this is constrained by the limited budget and availability of a vehicle.

- Protecting the equipment from theft and vandalism is an issue. Sometimes, equipment is deliberately damaged by adults (when they have issues with observers) and children (for fun), and this could be one reason for data continuity issues.

National Meteorology Agency (NMA)

Experts at NMA are responsible for identifying suitable sites for setting up meteorological network stations. Once manual network stations are established, observers from the community will be identified and recruited for data collection.

For the monitoring of third class and fourth class stations, observers who are literate (e.g., students or priests) are selected. These observers are part-time staff who receive a daily wage ranging from ETB 8 to ETB 20 for working during the weekends. Observers for first class and second class stations are those who have completed secondary school and work on a full-time basis during weekdays. Other criteria for selecting observers are honesty as well as living close to the network stations (for efficient use of time and resources or being an employee of the institute where the stations are hosted). This is mainly the case with network stations that are established in school compounds and other government offices. In third class and fourth class stations, observers usually receive support from family members and their friends at times when they are unavailable to collect data. Also, their family members and friends contribute labor when needed, especially during establishment and O&M of the network stations. In addition to collecting data, observers and their families are responsible for checking the functionality of monitoring instruments and maintaining fences around the stations.

Upon recruitment, observers receive training on the parameters to be measured, and instructions on how to read, record and report data in monitoring instruments. Observers for first class and second class stations receive three days of training, whereas those for third class and fourth class stations receive one day of training because they only measure a small number of parameters. After the training, observers are provided with protocols for recording data.

Key informants indicated that data from manual network stations have quality issues due to low incentive, lack of commitment and irregular supervision. Due to limited budget, experts from branch offices supervise observers only twice a year. To minimize errors, NMA implements the quality control procedures of the World Meteorological Organization (WMO) and conducts quality checks on data received from manual network stations and branch offices. Quality checking of data received from manual network stations is undertaken at various levels, including at stations (during data collection and recording), branch offices, and at federal level (during encoding, processing, archiving and transmitting data). Branch offices have staff responsible for checking the quality of data collected from observers. In addition, there is a team that checks the quality of data before it used.

Based on discussions held with key informants, regardless of some level of community engagement in hydrometeorological monitoring, data gaps remain an issue. There are two main reasons for these data gaps. First, the limited understanding of observers about the benefits of hydrological and meteorological monitoring for communities. Except in a few cases, where the data collected by the observers are used for early warning (e.g., in the case of flood-prone areas), these data serve little or no purpose to communities residing near the station. Second, according to key informants, observers perceive the incentives (daily wage rate) for monitoring tasks to be low. This calls for the need to explore other incentive mechanisms to encourage observers and communities residing around the network stations to engage in monitoring tasks, as this will help to partly address the issue of hydrometeorological data gaps in the country.

Data Sharing, Access and Use by BDA and NMA

The following section discusses the process of hydrometeorological data archiving, access and use by BDA and NMA.

Basin Development Authority (BDA)

In Ethiopia, hydrological data from large rivers are collected for several purposes: (i) IWRM, (ii) weather forecasting (mainly linked to planning and management of water in reservoirs), and (iii) early warning (mainly linked to mitigating risks such as floods). In line with this, Negash (2012) indicated that hydrological data are mainly used for IWRM, such as water allocation decisions (for irrigation, hydropower and others), weather forecasting, early warning, etc.

Observers collect and record hydrological data from manual network stations. Every 3 months, technicians (from branch offices, basin development offices and sub-basin offices) take printed copies of the data to the branch offices.

At branch office level, technicians conduct data quality checks and share the printed copies with the relevant organizations (BDA, basin development offices or sub-basin offices). Technicians are also responsible for downloading hydrological data from data loggers. Unlike manual network stations, telemetric network stations automatically collect and send high-quality, real-time data every 15 minutes to the central data system. According to key informants, data from telemetric stations are perceived to be of a high quality because they are set (calibrated) to measure the parameters and send data automatically. However, establishing telemetric network stations requires a high initial investment cost.

Data from BDA are available on request and are provided in accordance with the organization's data policy. Within BDA, there is a unit responsible for assessing and approving requests for data. Several methods are used to share the data, e.g., as a compact disc (CD), sent via the internet, radio or phone, or delivered in person. Users of hydrological data include research institutes, universities, consulting firms, students, road authority, and the health, agriculture and natural resource sectors. Both BDA and NMA collaborate with these organizations for various purposes, including development planning and intervention, research, training, etc.

National Meteorology Agency (NMA)

Meteorological data are collected for observing and studying the state of the atmosphere, and land and ocean surface; preparing weather analyses, forecasts and early warnings; and for other related applications. Once the meteorological data are collected from manual network stations by observers, printed copies of the data are sent to branch offices every month. Branch offices clean, archive and share the data with NMA. At the national level, the Meteorological Data and Climatology Directorate, under NMA, is responsible for checking the quality of the data prior to archiving, analyzing and dissemination. Data from NMA are available on request (on a daily, monthly or yearly basis) and provided in accordance with the organization's data policy. NMA charges a fee for providing services, but this is not applicable to organizations that are authorized by the agency to obtain free services.

NMA produces several bulletins (monthly, seasonal and annual) to disseminate climate information to a wide range of users. However, the benefits of such bulletins to local communities are limited. For example, even though NMA provides weather forecasts at zone level, this does not meet the needs for such information at district (*woreda*), subdistrict (*kebele*) and community levels.

In relation to water, the NMA hydrometeorological bulletin provides current weather information for operation and management of dams and reservoirs. Such bulletins: (i) aid effective planning and decision-making to minimize risk; (ii) help to monitor dams and reservoirs; (iii) make early assessments of annual and seasonal water availability; and (iv) support the management of surface water and groundwater and community-based flood early warning.

Conclusion

The Basin Development Authority (BDA) and National Meteorology Agency (NMA) are the two state organizations in Ethiopia with the mandate to collect hydrological and meteorological data, respectively. These organizations are challenged by limited capacity and other constraints to deliver adequate and high-quality data.

Currently, gaps in hydrometeorological data in the country are linked to limited coverage, poor data quality, and data discontinuity issues. Partly, data gaps are linked with the limited capacities of these organizations. Data coverage issues are mainly caused by the limited capacities of BDA and NMA to set up new network stations, rehabilitate existing stations, install data loggers and, in some instances, to cover the running costs of network stations. This limitation leads to the following issues:

(i) There are a limited number of network stations and these are sparsely distributed.

(ii) The main focus is on monitoring large rivers without considering small rivers in micro-watersheds (which are crucial for people's livelihoods and local water security).

(iii) Irregular supervision of monitoring stations leads to data quality and discontinuity issues, and lack of interest from observers.

(iv) Absence of an organization with a clear mandate to conduct hydrometeorology monitoring at lower levels (*woreda*, *kebele* and community levels).

Therefore, one way of addressing the issue of limited capacity to enhance the coverage and quality of hydrometeorological data from small rivers is to improve the engagement of volunteer communities (by embedding citizen science into regular monitoring tasks).

Recommendations

This section highlights how a citizen science approach can be embedded into organizations to address the issue of hydrometeorological data gaps, particularly at micro-watershed level. An example is given where the approach was pilot tested by a project in Ethiopia. Box 1 explains the processes of adopting a citizen science approach for hydrometeorological monitoring, the benefits and challenges, and perceptions about the approach. Potential institutional arrangements are also suggested for embedding the approach into the existing regular monitoring system for collecting hydrometeorological data.

Box 1. Using a citizen science approach for hydrometeorological monitoring in Ethiopia.

The *Water Security Risk Science: Local knowledge for participatory resource management* project is jointly implemented by the East Africa office of the International Water Management Institute (IWMI) and Newcastle University, UK, and funded by the REACH program. The project pilot tested a citizen science approach for the rapid assessment of water availability in two micro-watersheds in Ethiopia: (i) Branti micro-watershed located in the Upper Blue Bile Basin, and (ii) Wutame micro-watershed (covering an area of 2.4 km^2) located in the Omo Basin near Areka town. The focus of the assessment was to monitor the availability of shallow groundwater (SGW) in Branti, and to provide data and information to evaluate the impacts of the Sustainable Land Management Programme (SLMP) in Wutame. A citizen science approach was adopted to conduct the water availability assessment. To introduce the approach, a set of activities were implemented and tested. These included consultations at various levels, delivery of training, installation of instruments, and data and information generation. Two consultation workshops were held with stakeholders at national level. The first workshop was held at the inception of the project to create awareness about the citizen science approach, define criteria for site selection and identify potential sites. This workshop helped to establish a platform to share experiences and findings. The second workshop was held after one year to receive feedback on the findings.

During the first workshop, potential sites were identified. Later, consultations were held with the Ministry of Agriculture (MoA), SLMP and district-level experts to select suitable sites. In the selected sites, transect walks were conducted to assess hydrological data and information gaps, interact with the community, and select gauging sites based on technical criteria. Subsequently, consultations were held with representatives from the community to discuss the hydrology of both micro-watersheds, identify volunteers, set incentives for observers and demonstrate monitoring instruments. The criteria used to select volunteers were willingness, literacy, living close to monitoring sites, commitment and freedom of mobility. The identified volunteers (observers/citizen scientists) received training and were provided with data recording sheets in the local language for each monitored variable. 'Para-hydrologists' from district-level offices were also selected. A para-hydrologist is a community member who, although not formally (university) trained in the physical sciences or engineering, has acquired a sufficient basic understanding of hydrological principles and techniques, and is recognized within the community as a competent person (Walker et al. 2019). Four and three years after the citizen science approach was implemented in Branti and Wutame, respectively, an assessment was carried out using focus group discussions (FGDs) with community members to understand the perceptions about the importance of hydrological data monitoring, willingness of citizens to participate, and the level of involvement without incentives. Accordingly, participants from Branti indicated that citizen science helped them to get information about: (i) the range of groundwater level fluctuations and the extent of well deepening, and (ii) variability of groundwater and river water levels to determine appropriate water-lifting technologies[5].

Findings from the assessment highlighted that the main factor that drove willingness to participate was the belief that data collected via the citizen science approach can be used by the community to better utilize their water resources. However, willingness and participation of the community are challenged by workload (particularly for women), illiteracy, and the need for additional information to convince people about the importance of citizen science in collecting hydrometeorological data. Participants in the FGDs indicated that they need incentives for the time and labor spent to conduct monitoring and suggested monetary incentives. However, observers/communities, who have a better understanding of the benefits of collecting hydrometeorological data, are willing to enhance their engagement without additional incentives. Citizen scientists stated that they gained a better understanding about the behavior of streamflow and groundwater in their micro-watershed. Poor road access (especially for river monitoring during heavy floods) was one of the challenges to monitor SGW in Branti. Also, the brief training at the inception of the project was insufficient to enable interpretation of data in order to inform the community. Thus, frequent training and demonstration about the significance of the data are suggested to highlight the benefit of hydrometeorological monitoring to the community.

Source: Haile et al. 2019.

[5] The authors of this paper suggest that improving community understanding about water resources requires a mechanism to provide more frequent feedback from observers/researchers to community members.

The citizen science approach involves the engagement of volunteers (non-scientists) in the generation of scientific knowledge. Therefore, embedding the approach into regular monitoring systems requires a structure down to the community level. With the current institutional arrangements, BDA and NMA do not have structures that enable monitoring at lower levels (woreda, kebele and community levels). However, based on discussions with key informants, there is potential to embed the approach into the institutional structure of MoA for hydrometeorological monitoring of small rivers in micro-watersheds, due to the following reasons:

- MoA has a high demand for hydrometeorological data from small rivers to be used for small- and micro-scale irrigation development, and for measuring the impacts of watershed development interventions on water resources.

- MoA has an institutional structure from federal to community level, focusing on natural resources management. In some projects carried out by MoA, such as SLMP II, the structure extends to community level and can be used as an entry point to engage communities in hydrometeorological monitoring.

- MoA also has platforms at different levels that can be used as an opportunity for learning and sharing. These platforms work in a coordinated manner to effectively plan and implement watershed interventions. At *woreda* and *kebele* levels, the platforms include representatives from sector offices to guide IWRM at lower levels. At community level, the platform is responsible for mobilizing communities to participate in development interventions, and for encouraging a bottom-up approach that will help communities to develop a vision and a sense of ownership of the resources and activities.

- Under the MoA structure, there are development agents (DAs) at *woreda* level; they can serve as para-hydrologists (who can potentially supervise observers and be trained to interpret the data collected for the benefit of the community).

- There is a memorandum of understanding between MoA and MoWIE for the collection of hydrometeorological data from small rivers in micro-watersheds. This can be strengthened if MoWIE can delegate part of its power and duties in relation to hydrometeorological monitoring to MoA. Article 8.2 of the Ethiopian Water Resources Management Proclamation (Proclamation No. 197/2000) gives MoWIE the authority to "where necessary, delegate its powers and duties to the appropriate body for efficient execution of its duties" (FDRE 2000).

Embedding the citizen science approach into the MoA structure for effective hydrometeorological monitoring of small rivers in micro-watersheds calls for strong linkages between MOWIE and MOA, which will require the following:

- Clear distribution of mandates between the two organizations.

- Coordination between the water and agriculture sector offices at all levels.

- An ethical, legal, methodological and quality framework.

- Clear data archiving, access and sharing policies.

- Sufficient budget and follow up.

- Clear incentives for volunteers and the community participating in monitoring tasks.

- Pilot testing the approach in a few districts, subdistricts and communities before it is widely implemented, in order to identify the opportunities and challenges.

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Annex 1. List of Key Informants.

No.	Name	Designation, Organization
1	Yewondwosen Mengistu	Director General, Abbay Basin Development Office
2	Birlew Abebe	Bahir Dar Branch Office Head, Tana Sub-basin Office
3	Nigatu Melsie	Service Center Director, West Amhara Meteorology Office
4	Bantyigegn Melese	Observer, Meteorology Station in Dangila *woreda*
5	Wondimu Tadios	Rift Valley Lakes Basin Development Office
6	Medhin Melse	Meteorology expert, Areka Agricultural Research Institute
7	Solomon Kebede	Hydrologist, Ministry of Water, Irrigation and Energy (MoWIE)
8	Semunesh Golla	Director, Hydrology and Water Quality Directorate, MoWIE
9	Daniel Berhanu	Hydrology Researcher, Water and Land Resource Centre (WLRC)
10	Admassu Kassa	National Meteorology Agency (NMA)
11	Zeleke Belay	Senior Irrigation and Drainage Engineer, Ministry of Agriculture
12	Mussie Alemayehu	Irrigation Engineer, Ministry of Agriculture
13	Yidnekachew Gebremariam	Senior Monitoring and Evaluation Expert, SLMP II
14	Hailu Hundie	Ministry of Agriculture
15	AddisAlem Genet	Master's student, Arba Minch University
16	Dawit Bunduro	Natural Resources Management Expert, Agriculture Office, Boloso Bombe *woreda*
17	Teklu Duguno	Food Security Head, Agriculture Office, Tembaro *woreda*
18	Addisu Mulu	Irrigation Expert, Agriculture Office, Dangila *woreda*

Annex 2. Key Informant Interview Guide.

The following questions provided a guide for the key informant interviews:

A. Which government organizations are most suited to promote the citizen science approach?

- Are you familiar with citizen science and is the approach used by your organization? If so, please explain how your organization uses the approach.
- What is the mandate of your organization in relation to hydrometeorological data?
- Who collects such data? How often are these data collected? Who is responsible for managing such data? How long has it been since the organization started generating these data? Are there changes in data management?
- How is the data collection or monitoring coordinated? At federal, regional, *woreda*, *kebele* or community level?
- What are these data used for? in your organization? by others?
- What are the costs and benefits of collecting/monitoring such data?
- How do you train people in the acquisition and use of such data?

B. What are the institutional challenges of embedding citizen science into regular hydrometeorological monitoring conducted by BDA and NMA in Ethiopia?

- Do you consider that coverage of the data collection network is adequate to allow for proper planning and monitoring of watershed interventions?
- What are the challenges in maintaining continuous coverage from the data collection network?
- Has the network expanded or shrunk in recent times (e.g., in the last 10 years)?
- Do you see any benefit in adopting a citizen science approach?
- What do you see as the main challenges to adopting a citizen science approach?

C. How can connections between citizen science and data collection, archiving and sharing be established and strengthened to monitor hydrometeorological data in the country?

- Is there collaboration between your organization and other sector ministries/offices in relation to the monitoring of hydrological data? What is the nature of this collaboration?
- Who has access to these data? How easily do you share these data with other organizations, the general public, etc.?

D. What opportunities and capacities exist for actors (e.g., existing community-based initiatives that can support citizen science, water user associations (WUAs), SLMP or natural resource committee) at different scales and levels (community, *kebele*, *woreda*, etc.) to embed the citizen science approach?

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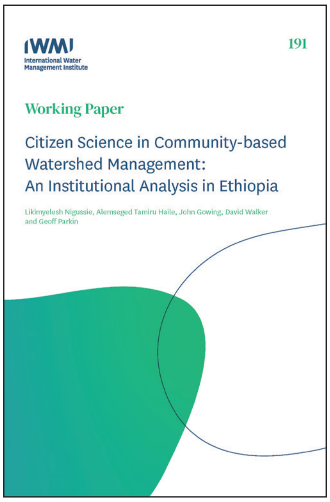

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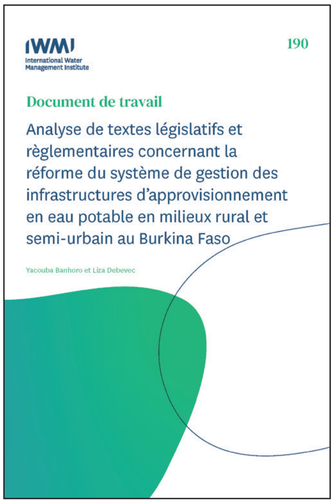

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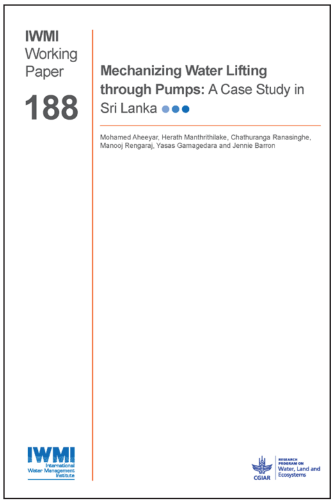

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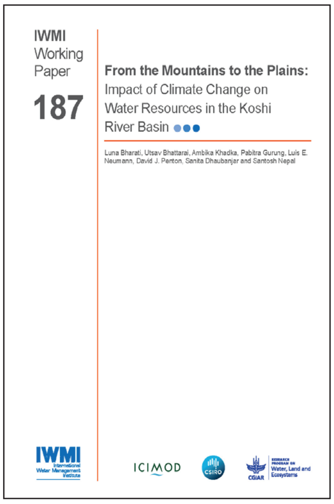

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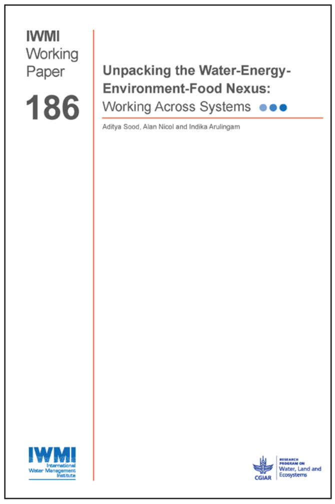

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