IFPRI Discussion Paper 02135

September 2022

Key Stakeholders and Actions to Address Lake Beseka's Challenges in Ethiopia

A social network approach

Dawit K. Mekonnen

Teferi M. Tensay

Seid Yimam

Tiruwork Arega

Ephrem G. Beyene

Wei Zhang

Claudia Ringler

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), a CGIAR Research Center established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. IFPRI's strategic research aims to foster a climate-resilient and sustainable food supply; promote healthy diets and nutrition for all; build inclusive and efficient markets, trade systems, and food industries; transform agricultural and rural economies; and strengthen institutions and governance. Gender is integrated in all the Institute's work. Partnerships, communications, capacity strengthening, and data and knowledge management are essential components to translate IFPRI's research from action to impact. The Institute's regional and country programs play a critical role in responding to demand for food policy research and in delivering holistic support for country-led development. IFPRI collaborates with partners around the world.

AUTHORS

Dawit K. Mekonnen (d.mekonnen@cgiar.org) is a Research Fellow in the Environment and Production Technology Division of the International Food Policy Resarch Institute (IFPRI), Addis Ababa, Ethiopia.

Teferi M. Tensay (teferemequaninte@gmail.com) was a consultant with IFPRI's Environment and Technology Production Division at the time of publication, Addis Ababa, Ethiopia.

Seid Yimam (s.yimam@cgiar.org) was a Research Officer with IFPRI's Environment and Production Technology Division at the time of publication, Addis Ababa, Ethiopia.

Tiruwork Arega (t.arega@cgiar.org) is a Resarch Officer with IFPRI's Environment and Production Technology Division, Addis Ababa, Ethiopia.

Ephrem G. Beyene (egmariam@yahoo.com) was a consultant with IFPRI's Environment and Production Technology Division at the time of publication, Addis Ababa, Ethiopia.

Wei Zhang (w.zhang@cgiar.org) is a Senior Research Fellow with IFPRI's Environment and Production Technology Division, Washington, DC.

Claudia Ringler (c.ringler@cgiar.org) is a Senior Research Fellow and Deputy Division Director in IFPRI's Environment and Production Technology Division, Washington, DC.

Notices

Abstract

Lake Beseka is a shallow, saline, endorheic lake in the East African Rift Valley of Ethiopia that has dramatically grown in size due to large-scale irrigation development in its catchment area. Recent artificial connections of the lake with the Awash River system to contain lake size have led to a series of changes and impacts on different water users, but are not reflected in lake and Awash River governance and institutions. Understanding who are the key actors affecting Lake Beseka and strengthening their linkages can help identify solutions that sustainably contain or reduce the lake's size, improve its water quality, and address costs to nearby and downstream populations as well as the environment. Thus, this study analyzed qualitative data collected from net-mapping – a network analysis that identifies actors or stakeholders as well as linkages and relative power positions among stakeholders. The resulting network reflects the complexity of the water governance system including upstream actors who affect the size and quality of the lake as well as downstream actors who suffer from adverse consequences. The Awash Basin Development Authority, Metehara Sugar Factory, regional bureaus, and federal ministries were identified as the most influential actors affecting how Lake Beseka is used and managed. Actors most affected by the lake expansion and quality problems such as downstream communities currently have no role in the governance of the lake. Metehara Municipality, woreda offices, research institutes, and farmers were considered to have moderate influence. Stakeholders who participated in the net-mapping workshops identified flooding, salinity, water-related conflict, and health effects as the four main challenges of the lake. The study suggests that developing multi-stakeholder partnerships or platforms across most influential and most affected actors could support a more comprehensive understanding of the multiple challenges Lake Beseka is posing. It could also foster the development of more integrated solutions that support the different stakeholders in the lake catchment area and the Awash River Basin.

Keywords: Lake Beseka; Awash Basin; Awash River; Water governance; Net-mapping

Acknowledgments

This work was funded by the University of Oxford (REACH Programme) and the CGIAR Research Program on Water, Land, and Ecosystems (WLE). The authors are grateful to participants of two facilitated workshops in Methera and Addis Ababa in Ethiopia as well as the 19 key informants who provided the information upon which this study is based. We are also grateful for comments received during the presentation of early findings at REACH's monthly research seminar. We also thank Metehara Sugar Factory Administration for their generosity in providing us access to their meeting facilities. Any and all errors are the sole responsibility of the authors.

Acronyms

ABA- Awash Basin Authority

ABD- Awash Basin Development Office

ANP- Awash National Park

BHCoM- Basin High Commission of Ministers

CBOs-Community Based Organizations (refereeing Fishery and Car washing Associations)

CWA-Car Washing Association

DWA- Dutch Water Authority

EIAR- Ethiopian Institute of Agricultural Research

Enterpri - Enterprises

Fed_Min - Federal Level Ministries GoE – Government of Ethiopia

Inv_Com - Investment Commission

KII- Key Informant Interview

KI- Key Informant

Loc_Aut - Local Authorities

MSF- Metehara Sugar Factory

MILs- Ministry of Irrigation and Lowlands

MoM- Municipality of Metehara City

MoWIE- Ministry of Water, Irrigation, and Energy (now Ministry of Water and Energy)

NGOs- Non-governmental organizations

Prod_use - Product Users

Reg_Bur - Regional Bureaus

Ser_prov - Service Providers

Uni_Res - Universities and research institutes

WoF- Woreda of Fentale

WUA- Water User Association

1. Introduction

Lake Beseka is a shallow, endorheic lake in the East African Rift Valley with high levels of salinity, alkalinity, and fluoride, rendering the lake waters unfit for human use. In the 1960s, Chloride (Cl) concentration reached over 5,000 mg/L owing to its unique geological and hydrogeological settings (Dinka, 2017; Talling, 1965). The lake has its own drainage basin and no natural outflow, but a man-made channel has been recently constructed to transfer some of the excess lake flows into the Awash River system. Importantly, the lake has grown dramatically in size since the 1960s (though a disruption to this upward trend started in 2014 likely due to the man-made channels) and is expected to continue to increase in size, thus growing the hydrological connections between the lake and the Awash River Basin.

Managing the expansion of Lake Beseka has become an inherently daunting task. The complexity arises from the interconnected nature of the lake catchment and the Awash Basin as well as from the numerous stakeholders utilizing the water from the two sources for different purposes, including for agriculture, livestock, domestic (self-supply and municipal services), and industrial water uses, as well as for retaining forests and natural areas. Existing governance approaches address the lake and the Awash River Basin in isolation, and thus fail to take into account the interconnected nature of Awash Basin and Lake Beseka's hydrology and the unintended social, economic, and environmental consequences of proposed solutions. A lack of joint consideration of the lake and the basin water uses in the presence of diverse stakeholders - with heterogenous streams of costs and benefits from lake level rises and proposed solutions - makes it difficult to achieve a win-win solution for all involved. Separate water governance activities are unlikely to identify solutions that support both users of Lake Besaka catchment and the Awash Basin simultaneously. A case in point is the two-tunnel engineering solution introduced at the bottom outlet of Lake Beseka to release excess water from the lake to the Awash River. While this engineering solution may have saved Metehara town from being submerged by the lake expansion, the tunnel has created new socio-economic problems for farmers and agro-pastoralists downstream of the lake. As the highly sulfuric and salty Beseka water dilutes with the freshwater from Awash River, it affects the quality of water that reaches farmlands in the lower parts of Awash River, aggravating soil salinity levels, and reducing cotton yield by up to 40 percent as compared to the cotton production irrigated with Awash River water alone (Hailu et. al, 2016).

While raising awareness about the tradeoffs of alternative solutions to the Lake Beseka crisis is a necessary step to managing the expansion of the lake, research is also needed to better understand the underlying causes of lake area expansion, the various damages and adverse effects from the expansion, as well as institutions to improve management of the now connected lake and Awash River systems. Central to this is to identify the key actors who influence lake water quality and quantity as well as the key actors impacted by these changes. A better understanding and mapping of the linkages among the key actors and their levels of influence could help develop cross-sectoral and spatially explicit solutions.

The remainder of the paper is organized as follows. Section 2 provides an overview of the literature on the hydrological developments of Lake Beseka. Section 3 presents the methodology used in the study. Section 4 summarizes lessons from key informants on the challenges and drivers associated with the hydrological developments. Section 5 discusses the results of the network analysis including the key actors, their linkages, and relative power over the future of Lake Beseka. Section 6 concludes on main findings of the study.

2. Overview of the hydrological developments of Lake Beseka: A review of the literature

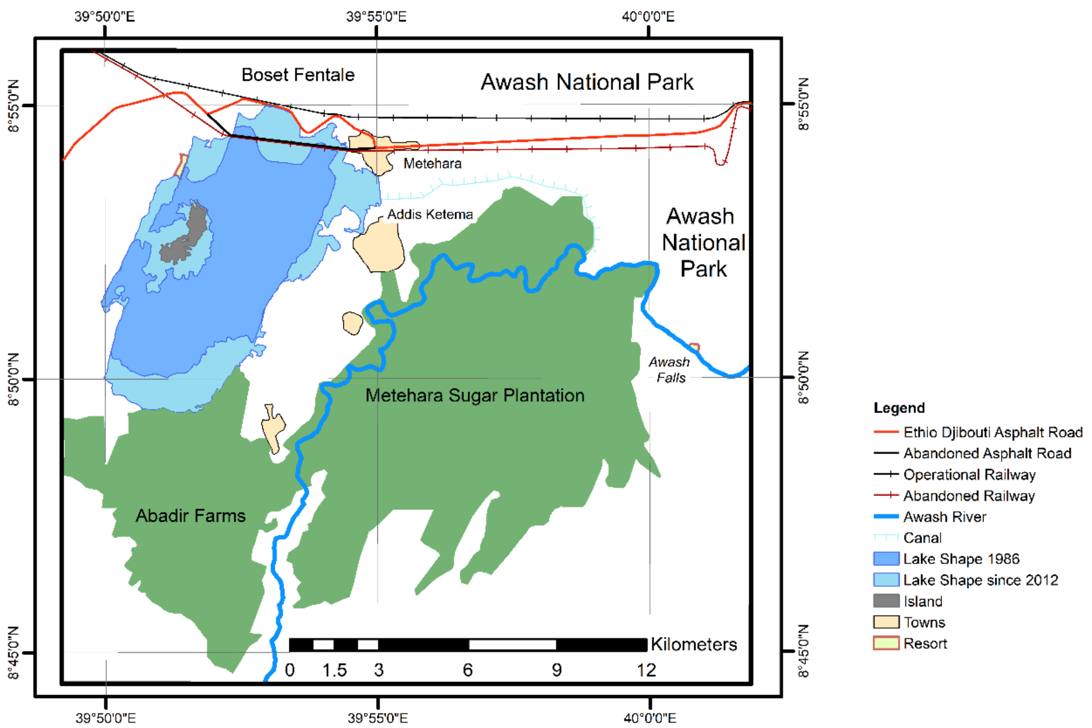
Lake Beseka is known for its historic expansion over half a century. The lake level was as small as 2.6 km^2 in the early 1960s and raised to its highest level of 54 km^2 in 2015 (Shishaye, 2015) and 46.7 km^2 in 2017 (Teffera et al., 2018). Researchers provide various reasons for the lake level rise. Prior studies revealed groundwater discharge as the main source of the lake level rise (Ayenew, 2004 & 2007; Goerner et al., 2009; Dinka, 2020). Other studies relate the source of the lake growth to the inflow from the hot springs around the lake and recharge from irrigation runoff or a combination of both (Zemedagegnehu et al., 1999; Klemperer and Cash, 2007, Dinka 2012). Alemayehu et al. (2006) and Kebede and Zewdu (2019) have detected the origin of increased groundwater discharge to the lake to be the nearby agricultural activities. Alemayehu et al. (2006) argue that the rapid increase in the size of Lake Beseka indicates rapid groundwater inflow from irrigated fields to the lake without significant outflow except evaporation. Kebede and Zewdu (2019) used dual Radon and isotope analysis to compare the chemical properties of the lake and the water used for irrigation and concluded that the main source of water responsible for the expansion of the lake is the excess irrigation water joining the lake through subsurface flows. Four largescale irrigation projects[1] have been introduced in the vicinity of Lake Beseka since 1965, and coincide with lake expansion. While the main Metahara farm is located at relatively lower ground and in a different catchment, three of the farms (Abadir Farms, Nura-Hira Farms, and Fentale-Boset) are located partially or completely within the surface and groundwater catchment of the lake (Kebede and Zewdu, 2019). The main irrigation water loss in these farms takes place from

[1] Metehara Sugar Estate (1965), Abadir Farms (1968), Nura-Hira Farms (1970), and Fentale-Boset irrigation farm (2007).

the conveyance (primary) and distribution (secondary) canals with field level losses accounting for only 10 percent of total loss (MWIE, 2014 cited in Kebede and Zewdu, 2019).

On top of the significant area expansion, the lake water is poor in quality, including high levels of salinity (Ayenew, 2007). The substantial growth in lake size along with its saline content causes multiple challenges to the Rift Valley and the Awash Basin communities (Dinka, 2020). For instance, the lake level rise had threatened Ethiopia's main highway and railway to Djibouti – the country's only access to sea transport – forcing the country to change the routes of the railway and the highway (Figure 1). The lake level rise also destroyed parts of Metehara town, inundated farming enterprises (such as Metehara Sugar Estate and Abadir farms), changed the lake ecology, raised the salinity of water for downstream users, and negatively affects wildlife in the Awash National Park (Ayenew, 2004; Dinka 2012; Dinka and Klik, 2019; Kebede and Zewdu, 2019). Moreover, the expansion of the lake discouraged investment and adversely affected social services in Metehara town (Belay, 2017).

Figure 1: Map of the study area



Source: Authors

Various efforts have been put in place by the Government of Ethiopia (GoE) and other entities to address Lake Beseka challenges. For example, water pumping, excavating canals, and discharging the lake water into the Awash River are some of the solutions introduced to control the lake level rise among others (Ayenew and Legesse, 2007; Dinka et al., 2009; Teffera et al., 2018). Currently, lake water is being discharged into the Awash River using two canals at the bottom outlet of the lake to contain lake level rise. The design calls for a discharge level of no more than 2 percent lake waters to 98 percent Awash River water. However, in practice, no proportion is maintained as the control gates of the canals are broken. As such, water flows without control from the lake to the river. The dilution of the lake with Awash River moderates the overflow and salinity problem of the lake and saved Metehara town from being submerged by lake water expansion. However, the release of lake water into the Awash River causes unintended consequences to the downstream communities.

The poor implementation of the release of lake waters into the Awash River has affected the river's water chemistry as well as downstream landscapes resulting in the deterioration of water quality, salinization and increased sodicity of soils, along with degradation of livestock watering and domestic uses (Yimer and Jin, 2020). The most affected fields are the Melka Sedi-Amibara irrigation project in the Middle Awash River valley north of Lake Beseka, and the farms in the Dubti-Asaiyata areas of the arid southern Afar (Ayenew and Legesse, 2007). Though some affected communities downstream are located in Oromia regional state, the same region where the lake is located, most communities and irrigated farms are located in the neighboring Afar Region. Both Melka Sedi-Amibara irrigation project and farms in Dubti-Asaiyata areas are in the Afar Region.

Owing to its poor water quality, the expansion of Lake Beseka, is significantly threatening the economic and environmental performance of the region (Awulachew, 2020). Mixing of the lake water with the freshwater in the Awash River affects the downstream hydrochemistry and aquatic ecosystems (Ayenew and Legesse, 2007), with negative impacts on the welfare of the downstream users. As Hailu et al. (2016) indicated, the discharge rate of Beseka water into the Awash River has affected the quality of the river, aggravated soil salinity, and reduced farm yield. Similarly, Yimer and Geberkidan (2020) reported that the toxicity level of fluoride in Lake Beseka was exceptionally high, likely due to minerals leaching from rocks, saline deposits, sewage, and wastewater from industries. The lake is also used for washing vehicles with discharge of heavy metals, is affected by agrochemical runoff, and is used as a source of effluent discharge from municipal garages, which all led to further deterioration of lake water quality (Abduro and Woldemichael, 2017). The future expansion of the highly saline lake may be concentrated towards the east and north-east direction due to the topography of the area which has the potential to displace Metehara town and impact the Metehara sugar plantation (Ayenew and Legesse, 2007; Awulachew, 2020).

While much has been written on the biophysical and selected socioeconomic impacts of poor lake management, little is known about governance and institutions that could improve lake management. The linkages and power dynamics among the main stakeholders around and affected by the lake need to be better understood to come up with comprehensive and long-lasting solutions to the lake expansion and related problems in and around the catchment of the lake.

3. Methodology

The study generated data through a combination of literature reviews, key informant interviews, and two facilitated workshops that generated social networks of key actors in the Lake Beseka-Awash River system.

3.1. Key Informant Interviews

We compared hydrological data on water quantity, quality, coverage, and timing that was collected from the literature and administrative data sources with the perception of experts from 19 organizations using Key Informant Interviews (KIIs)[2]. The KIIs were conducted at the local and federal levels. The key informants consulted for this study include government officials at different levels, universities, research institutes, private farms and farmers, the Awash Basin Development Authority, Awash national park, town and woreda administrations, user associations organized for income generation activities, tourism and wildlife conservation authorities, irrigation and hotel projects, and development organizations. Representatives of farmers were purposively selected based on recommendations from Metehara City administration and our scoping field visit before undertaking the interviews. The selected farmers are pioneers with a better awareness of the hydrological, economic, social and governance challenges related to the Lake Beseka water and were able to voice farmers' interests and concerns on issues related to the lake. We anonymized and coded key informants from KI-1 to KI-19 to retain anonymity of statements made. The names of participating organizations are provided in the annex.

3.2. Social network Analysis

Following Stein et al. (2011), our social network analysis follows three basic procedures. First, the study identifies the actors (nodes) to be considered in the study, which represent individuals

[2] As a procedure, in-depth Key Informant Interviews were conducted before the Focus Group Discussions and Net-mapping workshops. For the local level actors, we undertook KIIs on November 3 and 4, 2021. Following the KIIs, we completed the local level FGD/Net-mapping workshop on November 5, 2021 at the meeting hall of Metehara Sugar Factory in Metehara City. At the federal level, KIIs were conducted between November 15 and 23, 2021. The FGD with the federal actors/ institutions was held at ILRI campus, Addis Ababa on November 26, 2021.

or institutions. Second, the various types of relationships (ties) among the actors are identified. Third, the boundary of the network, i.e., which actors' attribute and relationship types the study is interested in is defined. Two sets of facilitated participatory workshops at the federal and local level were conducted to produce federal and local level social network maps and analysis by bringing together key informants who were interviewed individually before these workshops. This mapping of stakeholders, the fourth procedure in social network analysis, involves the listing, categorizing, and positioning of stakeholders that have influence on the hydrological and governance conditions of Lake Beseka.

3.2.1 Identifying network actors

To generate the actors (nodes) important in the governance of Lake Beseka, respondents were asked to recall and list their relations to other organizations. This list was compared to actor lists generated by talking to key informants with sectoral and specific expertise on Lake Beseka issues ahead of facilitated net-map workshops. The organizations range from community-based organizations (CBOs) to private companies, government organizations, and NGOs. By allowing each of the key informants to review the potential list of organizations, we developed a robust list of actors that are confirmed to have influence over Lake Beseka by the respondents. In total, 24 organizations (11 at the local and 13 at the federal level) were identified to potentially influence the hydrology and governance of Lake Beseka.

3.2.2 Identifying organizational relationships

We collected data on three different organizational relationship types separately for the national and for the local social networks. At the local level, we asked respondents to list the top three ''regular/long-term'' relation types with other organizations, linked to (i) cooperation; (ii) conflict; and (iii) formal reporting. Similarly, workshop participants at the federal level identified the following relation types: (i) policy and regulation; (ii) knowledge and information; and (iii) resource and finance. The workshops also recorded organizational attributes, including type of organization; level of influence, sectors (activities) the actors are engaged in (e.g., agriculture, livestock, forestry, etc.); and where the activities of the organizations take place (upstream or downstream of Lake Beseka).

3.2.3 Setting social network boundaries

One of the challenges in any social network analysis is defining the boundaries of the set of actors to be included in the study (Marsden, 2005). The problem arises because actors are not homogenous, and their network types do not have natural boundaries. Methodologically, it is important to decide where to draw the boundaries (Degenne and Forse, 2004). Leaving out relevant actors or delineating boundaries arbitrarily can lead to misleading results (Marsden, 1990).

The social boundary is well delineated in this study, since it directly links to the hydrology of Lake Beseka and its artificial inter-connection with the Awash River Basin. A total of 24 actors were selected based on their differences in (i) roles (policy, regulation, implementation, funding, and research), (ii) location (upstream or downstream of the lake), (iii) activities (agriculture, industry or service), and (iv) administrative levels (local or federal). These 24 actors, therefore, represent a cross-sectoral and cross-administrative levels and can be regarded as representative for this study. Following the selection of the 24 actors, we combined their attributes and relations data to define the network boundaries (see Marin and Wellman, 2010; Marsden, 2005). An actor was considered as part of the Lake Beseka network based on two criteria. The first was based on attribute criterion in that the actor directly uses Lake Beseka water for different purposes or indirectly influences other actors through its activities, such as grazing of animals, water storage, water withdrawals and discharge, and resource provision (see Falkenmark, 2003). The second was based on relational criteria including organizations with regular interactions with at least three other organizations that are part of the network (see Doreian and Woodard (1992) in Marsden (2005)).

In this study, workshop participants were first presented with a provisional list of organizations identified during the pre-study period. Respondents were then allowed to add actors to which they had relationships with or delete some that they thought were not relevant. This implies that the final boundary of the network is imposed by the workshop participants themselves. We can therefore assume that the responses from the 24 actors in this study, represent a sufficiently robust social network boundary that determined the hydrological and governance challenges of Lake Beseka.

3.2.4 Stakeholder mapping and analysis

After jointly exhausting the list, workshop participants at the local level mapped 11 stakeholders on a flip chart and grouped them into four categories[3] based on four attributes[4] and three relationship types[5]. Following the same approach, actors at the federal level mapped 13 stakeholders with the same attributes as the local stakeholders, but with different relationship types[6] due to their different perceptions from the local stakeholders (Annexes 1 and 2).

The three relationship types identified both at local and federal levels were coded as three adjacency matrices in excel (Annexes 3 and 4), with 11 rows and 11 columns (local actors) and

3 The categories are government organizations, private actors, community-based organizations, and NGOs/donors (civil society).
4 The attributes were based on 1) type of organization, 2) their influence, 3) sector engaged in, and 4) locations stakeholders operate in.
5 The relationships identified at the local level were: 1) cooperative, 2) conflict, and 3) report-to (formal).
6 The relationships identified at the federal level were: 1) policy and regulation, 2) knowledge and information, and 3) resource and finance.

13 rows and 13 columns (federal actors). For these relational data, the workshop participants listed, categorized, and added the relevant attribute data as a matrix with respectively 11 and 13 rows and one column for each attribute at the local and federal level. These data sets were then analyzed using UCINET and NetDraw software (Borgatti et al., 2002). UCINET software enables to convert the adjacency matrices into visual images that can easily be interpreted; measure structural network properties at three levels, i.e., actor, group, and whole network level. Furthermore, to identify the influential actors within the whole network, degree and between centrality were used as the relevant analytical tools (Freeman, 1978). Degree centrality identifies actors that have many direct relationships with other actors, while betweenness centrality identifies actors sitting on the shortest path between any two other actors.

Similarly, we used the network density indicator to measure the presence of general group cohesion or the extent of actors' relationship to each other within the whole network (Wasserman and Faust, 1994). To complement density measures, centralization was also used to measure the extent to which cohesion is organized around particular central actors (Scott, 2000). Finally, we applied the Newman-Girvan algorithm (Newman and Girvan, 2004) to identify the existence of cohesive subgroups (components) that interact more with each other than with other actors within the network. To further substantiate these network results, we also used evidence generated from the 19 KIIs, document reviews, and field observations.

4. Challenges and drivers associated with the hydrological developments: Lessons from Key Informant Interviews

Responses from Key Informant Interviews (KIIs) and workshops regarding the challenges and drivers of Lake Beseka's hydrological developments largely agree with the literature. Lake level changes of Lake Beseka was broadly attributed to two major factors: (i) hydrological factors, caused by the interconnectedness of the hydrological systems of Lake Beseka and the Awash River and; (ii) governance (institutional) factors associated with the various activities of stakeholders around the lake as well as the policy design, monitoring and evaluation, and enforcement capability of regulatory institutions mandated with the governance and management of water and land resources in the Lake Beseka watershed and the Awash River Basin.

4.1. Hydrological factors

Based on the information from KII participants, the Awash River faces abrupt fluctuations and anomalous hydrological behavior during different seasons of the year, which, in turn, affects the hydrological conditions of Lake Beseka as the lake interconnects with the river through the natural underground flows. This implies that changes in Awash River's water volume have far reaching implications on Lake Beseka and hence on the economic activities of stakeholders' dependent on the two water sources, particularly, in the upper and middle Awash basin. Using historical timelines, we asked KII participants to describe the hydrological changes of the lake over the years. The majority of KII participants noted that water quality and volume challenges were limited 30 years ago, but challenges worsened during the past 10 years, particularly between 2007 and 2014 following the implementation of the Fentale-Boset irrigation project that further increased the underground interconnectedness of Awash River and Beseka lake hydrological systems.

KI-1 and KI-15 noted that the implementation of the Fentale-Boset irrigation project unintentionally impacted Lake Beseka's historical hydrological condition over the last 15 years in two major ways. Firstly, it contributed to further expansion of the lake's size. Secondly, the quality of the lake's water significantly improved as more Awash River water is leaked into the lake through underground hydrological connections. As a result of this change, a farmer (KI-11) has started growing horticultural crops using Lake Beseka water, describing the change as "*God's miracle".* KI-11 further claims, "*I decided to invest 400, 000 Birr worth of capital into my plot, which was abandoned before, after observing the hydrological changes and experimentally researching the quality of the water to grow tomatoes, green peppers, maize, and chickpea*". Other local residents have started using the lake water for cleaning (clothes, cars, and open showers) and animal watering, which was impossible 10 years earlier. The change in water quality was not only confirmed by stakeholders residing in the immediate vicinity of Metehara town, but also as far as the downstream middle Awash basin, resulting in a more positive perception of stakeholders' in the Afar region in using the lake's water, along with Awash water, for irrigation and livestock watering.

Even though the Fentale-Boset irrigation project improved the lake's water quality by diluting its saline content, it also introduced unintended threats to Metehara city residents as the lake's water volume dramatically expanded resulting in the submergence of residential houses and businesses in the outskirts of Metehara town, according to KI-6. However, the "*engineering solutions*" by the Awash Basin Authority, specifically the development of two canals to facilitate the release of water from the lake to the nearby Awash River saved the city from total submergence (KI-1). The two canals were built in 2014 at the southern end of the lake to discharge 2 percent of Lake Beseka water into the Awash River. This technical solution has prevented further expansion of Lake Beseka and the volume remained at stable levels since then, explained KI-1. KI-1 further noted that although the canals controlled the expansion of the lake, this engineering solution brought a new type of water "*governance*" challenge as the Awash Basin authority could not properly apply the scientifically recommended mixing rate from the two water systems (2 percent Beseka added to 98 percent of Awash waters) due to "*head regulator*" damages at the two outlet canals. This, in turn, led to negative perceptions of the lake's role by downstream actors, particularly when the Awash River flow is low from March to June.

The key informants identified the following as major causes of lake level rise: the expansion of irrigation schemes upstream (with irrigation return flows growing lake size), leakage from the Awash River, increased recharge from hot springs and groundwater fluxes, lake neotectonisim, and increased surface runoff due to lack of vegetation cover, and climate change. The key informant statements are consistent with prior studies conducted in the Beseka area (such as Dinka, 2010 and Kebede and Zewdu, 2019).

4.2. Institutional and Organizational factors (water management and governance)

In addition to the hydrological drivers, factors driving the developments of Lake Beseka are also intertwined with governance challenges, such as institutions to manage lake levels and a supportive regulatory environment. Governance, according to Rogers (2006) includes both the formal and informal institutions and their various formal and informal interactions. Thus, analyzing governance requires considering the roles of ''political, social, and economic organizations and institutions (and their relationships), which are important for effective water management'' (Rogers and Hall, 2003).

4.2.1. Organizational Factors

The KIIs highlight the influence of organizational factors in regulating practices and financing technologies that improve water use efficiency. All KII participants emphasized the need to improve the current inefficient furrow irrigation practice, using land leveling and well-functioning drainage systems, and recommended the introduction of modern technologies and best practices, such as drip irrigation and smart farming techniques that optimize irrigation water usage, such as devices detecting the required water moisture during irrigation (soil moisture sensors and wetting front detectors). KI-1-4, KI-7and KI-8, reported that the current irrigation efficiency rate is between 30 to 40 percent and needs significant improvement. According to KI-2, the Awash Basin Authority (the regulatory body) should introduce new strategies and regulations that force actors to start using modern irrigation technologies that change the current inefficient water use practices in the upper Awash (from Koka dam to Metehara Sugar Factory) and increase water security in the middle Awash (from Metehara City to Awash City). "*We need to adopt the latest irrigation technologies not just because the technologies are available, but because the technologies will solve the alarming salinity problem in the middle Awash and because the technologies prevent potential water conflicts between the upper and middle Awash*", claims KI-7 – an actor representing local administration.

To address the salinity problem several KIIs suggested the need to create a formal platform where stakeholders can exchange information and knowledge on best practices and technologies. "*We need to revitalize and integrate those good practices and trainings that used to be implemented by the Basin Authority to help address the salinity and land management challenges faced by stakeholders, such as the irrigation water management project and the annual river (ditch building) training provided every year by the Basin Authority"*, notes KI-3 – a representative of Awash Basin Development Office which is the successor of the Awash Basin Authority with similar mandates as the Authority, though not necessarily with similar powers. The expert further noted that "*crises are a good opportunity to promote water use efficiency*" and foresees better water use governance in the future.

However, adoption of modern irrigation technologies and practices is challenging as many KII participants reported. This is because problems in securing the required resources for new irrigation technologies, coupled with the unsustainable institutional arrangements of the Awash Basin Authority, pose significant constraint to the adoption of the technologies.

Although KII participants suggest the use of the latest irrigation technologies to promote water use efficiencies, the widespread adoption of the technologies will likely remain a challenge due to several constraints including affordability, availability, and complexity of the technologies. Irrigation technologies such as drip irrigation and soil moisture sensors are expensive and remain unaffordable for many of the small holder farmers in Beseka-Awash areas. In addition to high initial investment, the use of such technologies requires a skilled workforce, which will remain a challenge for the adoption of these technologies, reported many of the KII participants. Similarly, in large government and private farms, such as Metehara Sugar Factory and Amibara private farms, adoption of the latest irrigation technologies may require a change in the business model (planning process) of the estates. For example, decision making on irrigation technology procurement at the Metehara Sugar Factory requires a carefully planned budget that must go through a rigid process of multiple levels of approval through government procurement procedures and hence, adoption of the technologies takes time and considerable effort, explains KI-4 – a government entity.

Similarly, KI-1 also explained that investments in irrigation infrastructure are expensive undertakings for government organizations with limited resources. The initial investment cost for land leveling, canal building, and maintaining the drainage system to allocate water efficiently requires significant financial investment, putting the Awash Basin Authority, which is in charge of water allocation, in a difficult position. A few water allocation projects designed to promote water use efficiency have been funded by the Dutch Water Authority, such as Water Pricing and Blue Deal, but remain at a pilot stage partly due to a lack of trust on proper implementation of water allocations. "*One of the big problems is around consensus building, getting all WUA members aligned with each other before moving into the water allocation*", respondents highlighted as well as "*lack of trust*", which affects effective implementation of Awash Basin water management and governance organized by the Basin Authority.

4.2.2. Regulations (water management and governance) and stakeholders' attitudes

Water management and governance enforcement mechanisms like the regulatory environment, land tenure and stakeholders' perceptions on the regulations can have a notable impact on the adoption of efficient irrigation technologies and efficient water allocation. The majority of KII participants consider "*effective regulatory environment*" as the most important factor in determining efficient allocation of water in the Awash Basin. In addition, they consider policy and regulatory bodies' decisions on alternative solutions, such as wetland construction or dam building in the middle Awash Basin as an important factor determining their adoption of efficient irrigation technologies since return on investment on such efficient technologies will be higher with the proper governance and complementary investments such as dams that improve water security in the area.

In addition, KII participants also noted the need of protecting assets[7] and land tenure[8] as key factors in creating incentives for investment in new technologies and effective water governance. KII participants called for adaptive co-management[9], merging the formal and traditional governance systems, of the Awash Basin land and water resources as an effective governance system, instead of the current government-only institutional arrangement. KIIs also reported on the role of (WUAs); these are managed by the Awash Basin Authority. The establishment of WUAs follows a top-down approach and excludes small-scale farmers who are using Awash-Beseka water, i.e., individual farmers pumping water, using diesel generators, from the long ditches downstream of Lake Beseka as well as from the upper Awash River. "*The Awash Basin Authority should bring together these actors who are currently not part of the formal governance system"*, noted KI-2 – a representative of a federal ministry. However, other participants responded that the Authority is not effective in terms of enforcing its regulatory and water allocation mandates due to unstable institutional arrangements. For example, since November 2021, the authority is required to report to the newly established Ministry of Irrigation and Lowlands (MILs), which does not have local presence in the upper and middle Awash areas at the time of this study. But

7 For example, a resort that was under construction by an investor on Lake Beseka was completely damaged in 2018 by the local community.
8 Metehara Sugar Factory's farmland and Awash National Park's land have been misappropriated following the political instability in 2018.
9 In Afar communities, traditional resource governance is more common and effective than formal systems.

in the past, it used to report to the Ministry of Water, Irrigation, and Energy (MoWIE)[10] and was also an autonomous authority. Thus, a key informant suggested "*instead of imposing new institutional arrangements to the Authority, it will be more effective to identify and organize informal water users and build on existing WUA structures under the co-management of the Authority and these social structures, i.e., a polycentric institutional arrangement, instead of the existing central government management under the leadership of the Awash Basin Authority*".

4.3. Impacts of the lake's expansion on livelihood resources

Climate change is accelerating hydrological processes, including the interconnectedness of Lake Beseka and Awash River's underground water system, threatening the various livelihoods and infrastructures of Metehara town, according to town officials and researchers from Ethiopia's higher education and research institutions who participated in the KIIs. Based on the responses of key informants and using a hydrological challenge matrix of Lake Beseka (Table 2), we identified four major challenges that have the most serious impact on four important livelihoods activities (sectors), both upstream and downstream of Lake Beseka across various periods. The nature and severity of the hydrological challenges vary between upstream and downstream actors and based on the sectors stakeholders are operating in. For example, stakeholders downstream of Lake Beseka listed flooding, water salinity, water conflict, and human/animal health effects as the top four challenges caused by the hydrological and institutional/governance conditions of the lake. From this list, the majority of KII participants ranked water quality (salinity) and flooding as the top challenges, resulting in high sodium and salt concentration on farmlands and loss of many livelihood resources due to submergence of farmlands, residential and business properties, and public infrastructures downstream. For example, KI-5 (representing *the sugar factory nearby the lake*) *noted that "during the 2012 flooding, 12,000 households were displaced, Haroadi kebele*[11] *was completely submerged, and public service provision centers such as schools and clinics were destroyed - costing the Metehara town administration 2 million birr every year for providing temporary solutions" as the event recurs every year*. Similarly, KI-6 (representing Metehara town administration) reported that "*Gelcha kebele was completely swallowed by the expanding lake waters*". Likewise, KI-4 (representing a nearby national park) noted that *"the park lost 348 hectares of land due to the expansion of the lake"*. KI-8 (representing the national research system) noted that four flooding events were recorded between 1963 and 2012. Complementing the local authorities' feedback, KI-3 – representing Awash Basin Development- reported that "*900*

[10] Currently the ministry is renamed as Ministry of Water and Energy (MoWE) after its irrigation wing moved to the newly established Ministry of Irrigation and Lowlands.
[11] Kebele is the lowest admirative structure in Ethiopia, under woredas (districts).

hectares of farmland had been lost due to Lake Beseka expansion and the total economic cost as a result of the lake's hydrological expansion was estimated to be around USD 2.5 million every year".

Table 1: Major hydrological events of Lake Beseka

Year	**Events**
2020	Flood damaged livelihood resources
2017	Flood affected some plots
2016	Drought affected humans and animals
2014	Canal outlet built and started discharging Beseka water into the Awash River
2010	Beseka water naturally spilled over to Awash and totally submerged the pumping station installed on Lake Beseka
1999	Awash river overflowed
1994	Awash river overflowed

Source: Authors

In addition, KII participants were asked about the hydrological impacts of Lake Beseka on upstream and downstream stakeholders engaged in different activities. The majority of KII participants singled out seasonal flooding as the top challenge, mainly during the high flow of Awash River from July to October, and occasionally during medium flow levels of the Awash River from November to February. Water salinity problems, water conflict, and health effects on humans and animals were less pertinent challenges for KII participants upstream of the lake, compared to participants downstream of the lake.

KII participants also reported that Lake Beseka's water level varies, not only across years, but also within the different seasons of the year, with corresponding seasonal hydrological challenges. For example, during low flow in the Awash River (from March to June) flooding disappears as the number one challenge, and conflict emerges in its stead due to water scarcity. KII participants mentioned that conflicts between upstream and downstream stakeholders and between neighboring communities are increasing as a result of low rainfall. In addition, challenges regarding the enforcement of water allocation by the Awash Basin Authority, seasonal migration of wildlife from Awash National Park into the farmlands of Metehara Sugar factory, Amibara farms, and individual farmers is increasing over time according to KII participants.

Table 2: Hydrological challenge matrix of Lake Beseka

Sectors	Downstream hydrological challenges				Upstream hydrological challenges			
	Flooding	Water quality	Water security	Health Effects	Flooding	Water quality	Water security	Health effects
Agriculture	3	3	3	3	2	0	1	0
Livestock	3	2	3	2	2	0	1	0
Industrial use	3	2	0	0	1	0	1	0
Service use	2	0	0	0	1	0	1	0

(3 = significant; 2 = medium; 1 = low; 0 = no impact)

Source: KIIs.

KII participants at the local level also predicted that the hydrological challenges of Lake Beseka will get worse in the future due to poor quality of the lake water resulting from high PH and salinity levels of the water.

Declining crop productivity and the adverse health effects for animals and humans because of Lake Beseka water quality were also raised during the KIIs. For example, KI-3 (Awash Basin Development) and KI-7 (representing local administration) explained that irrigated crops can deal with salinity levels of 250-750 µmhos[12]; but levels in farmlands around Lake Beseka are much higher due to the high and increasing salinity levels of groundwater. This renders plots unsuitable for irrigated crop production after two years of production, jeopardizing the efforts of innovative farmers who started to grow horticultural crops with lake water. The poor quality of Lake Beseka water has been well documented (Dinka et al., 2015; Dinka, 2017). Private and community-based stakeholders, such as individual farmers and fishermen, also reported that they are highly vulnerable to the hydrological challenges of Lake Beseka as their livelihood depends on the lake, including outflows from the lake. KII participants reported that, unlike upstream actors, crop production downstream depends on (1) the effective enforcement of water allocation managed by the Awash Basin Authority, and (2) the optimal dilution and discharge rate of Lake Beseka water to the Awash River. Farmers located in Afar Regional State downstream of the Awash River noted that the authority is not effective in enforcing its water allocation mandates and in discharging water from Lake Beseka optimally. This has resulted in the reduction of water quality and quantity reaching downstream farmers, particularly during the dry season between November and May.

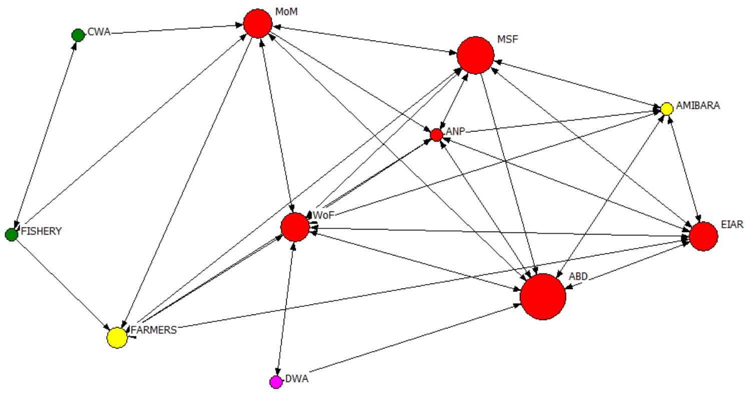
[12] Micromhos/cm at 25 degrees C.

5. Results from the social network analysis

5.1. The structure of Lake Beseka's governance network (federal and local level)

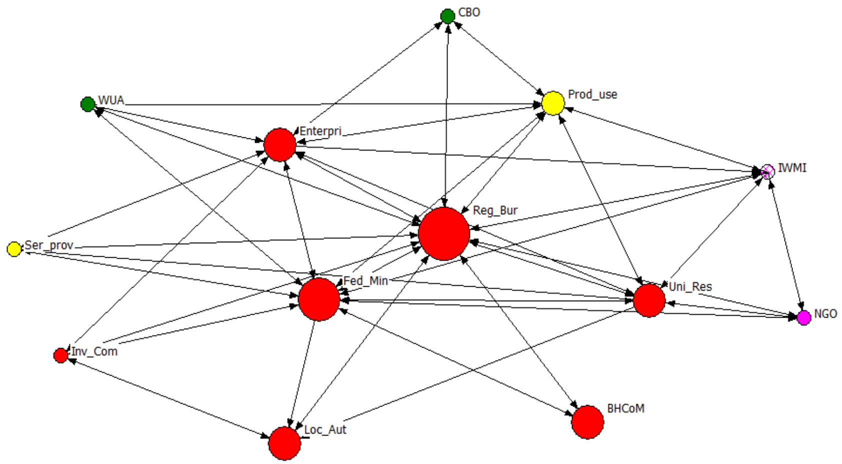
Figures 2 and 3 present the network of actors that have direct or indirect influence on Lake Beseka's water governance system, at the local and federal levels, respectively, based on the two facilitated workshops. Figure 2 depicts 11 actors that directly influence the governance system of Lake Beseka at the local level. Two private sector actors (local farmers and Amibara farms) and two community-based organizations (fishermen and carwash associations) representing producers and service providers interact with six government actors that have local administration (district and town administration), sugar cane production (Metehara Sugar Factory), and research roles, as well as with one NGO that provided some funding to the water governance system through the Awash Basin Development Authority. Figure 2 and Table 3 further show how actors directly influencing Lake Beseka are very loosely connected through 26 reciprocated collaborative ties, resulting in a low network density of 0.209 as compared to government-centered hierarchal top-down links with density of 0.236 from 28 formal ties. Moreover, the relationships of actors at the local level are characterized by conflict with a density of 0.164 from 18 ties.

Figure 2: Local governance network based on 11 actors



Source: Authors' Mapping. Legends for the actors are provided in the list of acronyms.

Figure 3: Federal governance network based on 13 actors



Source: Authors' Mapping. Legends for the actors are provided in the list of acronyms.

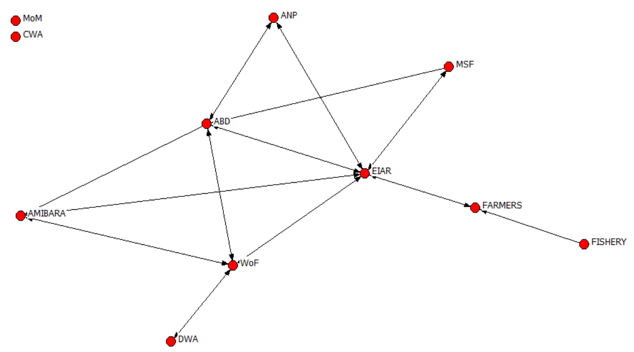
Table 3: Summary of network measures at the local level

Type of social network relationships	Size (No.)	Ties (No.)	Density (d)	Degree of Centralization (%)
Cooperative	26	23	0.209	44.4
Conflict	18	18	0.164	41.1
Reports to (formal)	28	26	0.236	54.4

Source: Authors' computation.

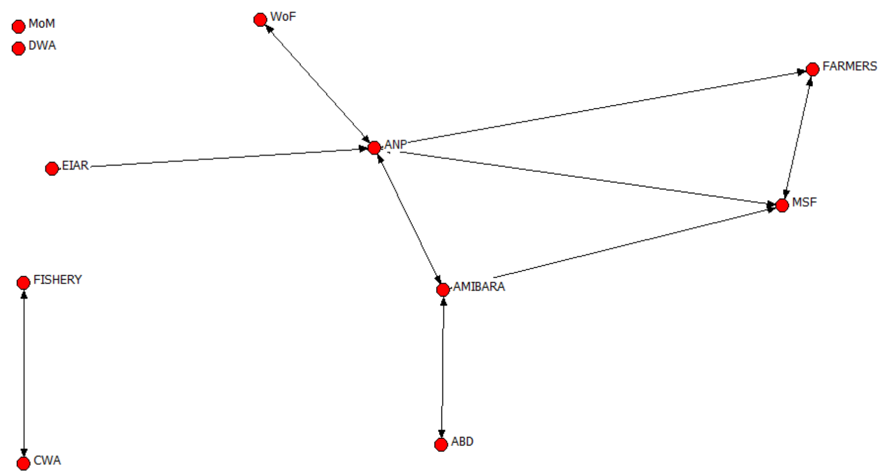
Most collaborative ties come from stakeholders in the government sector (Ethiopian Institute of Agricultural Research (EIAR) and Awash Basin Development Office (ABD) that have a long tradition of formal linkages among each other and to the local administrative authorities (Woreda/district of Fentale). On the other hand, the local communities who have the natural right on the lake, i.e., the two CBOs and farmers are disconnected from Lake Beseka's governance system. Only farmers and fishermen from the same village interact regularly without these government actors (Figure 4). Moreover, no collaborative relationship exists between the two CBOs; rather they have only conflictive relationships (Figure 5). Most of the conflictive relationships involve three government actors. These are: (i) Awash National Park (ANP) with Metehara Sugar Factory (MSF), Amibara private farms, farmers, EIAR and Fentale woreda on wildlife protection; (ii) MSF with Amibara commercial farmers and small-scale farmers on resource competition; and (iii) ABD with Amibara farms on water allocation.

Figure 4: Collaborative relationships of local stakeholders



Source: Authors' mapping. Legends for the actors are provided in the acronyms.

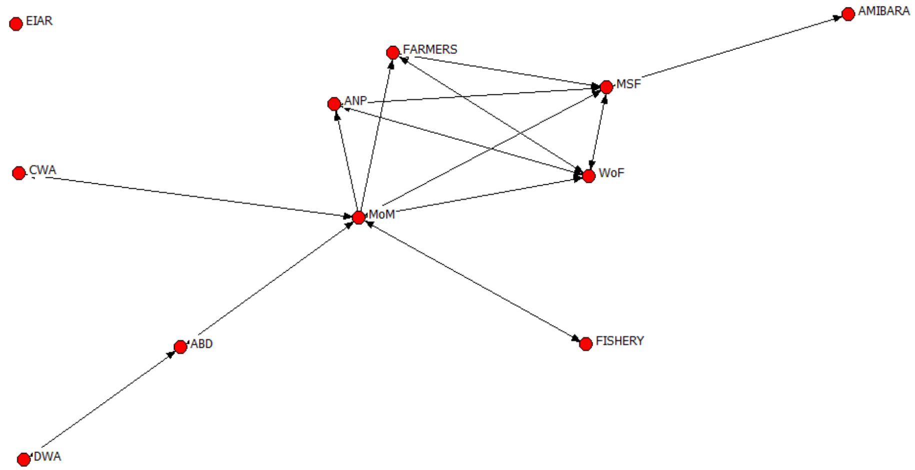
Figure 5: Conflicting relationships of local stakeholders



Source: Authors' mapping. Legends for the actors are provided in the acronyms.

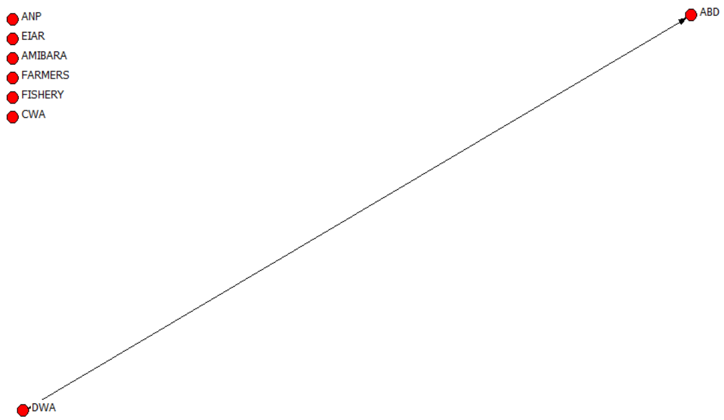
In the formal relationships, if one eliminates the administrative government entities of Municipality of Metehara City (MoM) and Woreda of Fentale (WoF) followed by the nearby sugar factory (MSF), the overall connectivity of the formal network decreases significantly (Figure 6a and 6b). The stakeholder map, thus, reflects that government actors not only connect all the other actors upstream of Lake Beseka, but also actors downstream of the lake. The important role of government actors, mainly ABD, is confirmed through both KIIs and net-mapping at the local level, where respondents indicate that ABD is influential (Figure 2) in the governance and allocation of water both upstream and downstream of Lake Beseka.

Figure 6a: Collaborative relationships of local stakeholders



Source: Authors' mapping. Legends for the actors are provided in the acronyms.

Figure 6b: Conflicting relationships of local stakeholders



Source: Authors' mapping. Legends for the actors are provided in the acronyms.

To examine the different social network types at the local level, we calculated the density and centrality measures for two group of local stakeholders (upstream and downstream actors) and for the whole local network based on the three relationship types identified during the workshops. The density is comparatively low within the whole local network across all the three network types ranging between 0.164 to 0.236 (Table 3). The density within downstream stakeholders is relatively higher for the formal and conflictive relationships but lower for the cooperative relationship types (Table 4) as compared to the combined density calculated for all local stakeholders (both up and downstream) in these two network categories (Table 3). This suggests that the cooperative linkages within stakeholders downstream of Lake Beseka are lower than the cooperative relationships between downstream and upstream stakeholders considered as a whole. However, the cooperative relationship within upstream stakeholders (Table 4) is higher than the cooperative relationships within downstream stakeholders (Table 4) or as compared with the whole cooperative local network (Table 3). This implies that upstream stakeholders have less conflicts or challenges over the lake water compared to downstream actors (Table 3), implying that the water quality and water quantity stress downstream of the lake deteriorates the potential for cooperative linkages among downstream stakeholders.

Table 4: Summary measures by location of stakeholders

Type of social network relationships	Downstream stakeholders		Upstream stakeholders	
	Ties (No.)	Density (within)	Ties (No.)	Density (within)
Cooperative	2	0.100	7	0.233
Conflict	4	0.200	2	0.067
Reports to (formal)	7	0.350	4	0.133

Source: Authors' computation.

Furthermore, the high values of degree centrality within each type of relationships suggests that many ties are mediated through a few central actors (see Figures 2 and 3). The centralization indexes for the local level are low within any of the three relation types (cooperative, conflict, reporting). Overall, the network measurements (Table 3 and 4) and the network map (Figure 2) suggest that formal relationship types (reporting) regarding the governance of Lake Beseka are much more common within the government sector than relationship types important for co-management of Lake Beseka issues, such as cooperative or conflictive relationship types, which are dominated by private and community-based organizations. The network measures in Table 3 and the map in Figure 2 also suggest that the management and governance of Lake Beseka issues are centered around few actors (Awash Basin Authority and Metehara Sugar Factory as rated by net-mapping workshop participants). Table 3 summarizes the analysis of the social network measures at the local level. Further investigation of the subgroup reveals that the local network can be categorized into three clusters, i.e., cooperative, conflict and formal. Importantly, these clusters follow local network boundaries indicating that geographical locations matter for building networks of collaborative or conflictive relations. For example, the collaborative relationships MSF has with farmers, local authorities, and Worrer research center or the conflictive relationships ANP has with MSF and farmers is due to their geographic proximity.

The density of relationship types gives some insights into the extent to which actors have a high level of social capital and/or social constraints. The density of cooperative relationships is 0.21 (Table 3), implying that only 21 percent of all the possible ties are present. The cooperative network's low density implies that other actors influencing Beseka lake are there but not known, and hence key connections are missing in the governance system of the lake.

5.2 Federal level interactions in the multilevel governance

Stakeholders operating at the federal level have a broader view on how higher-level policy and regulatory bodies influence Lake Beseka's issues across scales. Through the federal level workshop, done separately from the local level workshop, we mapped federal stakeholders into three categories based on their roles. The first category constituted policy and regulatory stakeholders with indirect influence on Lake Beseka. The second category constituted higher-level implementation stakeholders that directly influence Lake Beseka. The third category is a set of actors that influence resource use through financial flows. Based on these categories, we calculated the mean connectivity within each category and between the three categories. The result shows that the density in the direct influence stakeholders' category was 0.20, reflecting the low connectivity among the implementing stakeholders. In contrast, the higher-level actors interact about three times more, having a density of 0.67, suggesting that this denser network allows for a greater flow of shared information, and greater possibilities of finding collaborative partners. The mean connectivity between the direct implementing stakeholders and policy and regulatory categories is 0.22, considerably lower than within category of policy and regulatory stakeholders, but almost the same as that of direct implementing stakeholders. The result suggests that the network is not well integrated across spatial and administrative scales.

During the workshops, we asked the participants "Which stakeholders can influence Lake Beseka's hydrological and governance conditions and what is their level of influence?". Accordingly, stakeholders' influence over Lake Beseka's management and governance issues were ranked by the number of influence towers that workshop participants assigned to each stakeholder. The higher the tower, the more influential the actor was perceived to be. The following scale was applied during the net mapping workshop: No/low influence (0-1); Moderate influence (2-3); High influence (4-5). Through this exercise, the Awash Basin Authority and Metehara Sugar Factory were identified as the most influential local actors with respective influence ratings of 5 and 4, followed by the Metehara City Municipality, Woreda Offices, EIAR and farmers with moderate influence. The two CBOs (Fishery and Car washing Associations), private enterprises (Amibara farm), NGOs (Dutch Water Authority), and Awash National Park have no/low influence when rated against the three governance attributes (cooperative, conflict, and reporting). Similarly, for federal stakeholders, the two most influential actors identified were: regional bureaus and federal ministries (policy and regulatory bodies) each scoring an influence level of 5 and 4, respectively; followed by local authorities (implementers); universities and research institutes; Basin High Commission of Ministers; and government enterprises each scoring 3. The size of the nodes in Figures 2 and 3 in section 5.1 reflect this relative influence towers of the actors for the networks at the local and federal levels.

6. Conclusions and implications

To improve the understanding of Lake Beseka's hydrological and governance challenges, this study brought together a diverse set of experiences and stakeholders consisting of government authorities, private sector, community-based organizations, and civil society. As the study demonstrates, the institutional arrangements characterizing the management of Lake Beseka is as complex as its hydrological drivers. Combining key informant interviews and the Net-Map approach, our study improves the understanding of how the network of stakeholders is structured, providing insights into entry points for improving the challenges around Lake Beseka.

To build effective networks that foster active and cross- sectoral interactions in the Awash Basin, new (or reform of existing) institutional arrangements should start from existing bases of cooperative relationships that are identified in this study. Such institutional arrangements may include establishing an alternative water governance system that shifts away from the traditional government-centered system under the leadership of the Awash Basin Authority towards a co-management regime as suggested by the stakeholders. This new institutional arrangement, according to the KIIs and workshop participants, would more likely lead to sustainable solutions in terms of reducing conflict and enhancing cooperation over the utilization and governance of Lake Beseka. A social network approach is used in this study to analyze the roles and influences of individual stakeholders and their collaborative and/or conflicting relationships that characterize the lake. As such, the type of social network analysis that has been performed here, can serve as a 'ground' to; 1) better inform future project designs to address the lake's challenges, 2) identify relevant stakeholders for input in future project designs 3) support the development of effective strategies for reducing lake inflow and pollution, and to (4) enable programming on conflict sensitive issues, such as water allocation and wildlife management.

Our results suggest that the development of potential solutions to the challenges of Lake Beseka need to anchor on the following pre-existing local institutional conditions.

a) Recognizing the existing informal networks of stakeholders

A key finding is that local (both informal and formal) leadership structures play a key role in the management and governance of land and water resources in the Awash Basin. In the two workshops, stakeholders noted that informal and formal local authorities are performing the role of "brokerage" connecting CBOs, private actors, and enterprises who use Lake Beseka and the Awash River for different purposes. For instance, indigenous peoples' leadership (common in Afar communities) plays a key role in deciding on land and water uses in the middle Awash. Taken together, the implication is that receiving these local actors' input (feedback) regarding potential solutions and project design is crucial since communicating the benefits of the project to the local communities is the institutional function of these local stakeholders.

Recurring conflicts represent a key feature of the relationships between upstream farming (upper Awash) and downstream semi-pastoral (middle Awash) communities. Conflicts become serious mainly in the dry season, when the flow of the Awash River decreases, private farms are faced with water scarcity, and pastoralists are forced to bring their livestock to nearby private farms. Few collaborative ties exist between these two groups due to the WUA being coordinated by the Awash Basin Authority and its exclusion of small-scale farmers and semi-pastoralist communities. On the one hand, the Authority is ineffective in enforcing water allocation rules. On the other hand, there are many informal individual water users such as small-scale farmers and semi-pastoralists, who have strong ties with indigenous people leadership but no interactions with the formal WUAs. These informal water users, according to the KIIs and workshop participants, would have a negative effect on the existing formal institutional mechanism for water allocation since they are not constrained by the water allocation decisions of the formal institutional mechanism, providing disincentive for the formal actors to abide by the rules and water allocations of the formal system. This, in turn, may hinder the development of trustful relationships between stakeholders in the Awash Basin with potentially far-reaching implications. Existing water conflicts may persist, unless these informal stakeholders are recognized during the design of new projects.

b) Building on existing relations of stakeholders

Our analysis demonstrates that it is crucial to consider existing social structures in future projects aimed at bringing sustainable solutions to the challenges of Lake Beseka. While consultations with influential stakeholders such as the ABD and MSF are essential to ensure effective governance of the lake and the Awash River, local government authorities (Metehara town Municipality and Fentale Woreda) and the Regional Offices often cut across sectoral issues and their involvement could further facilitate the effective management and governance of land and water resources in the Awash Basin. Due to their unique position and long history of research engagement in Lake Beseka issues, Worrer research center and universities (Samara and Addis Ababa) could potentially mediate between science, policy, and implementation across local and federal levels. Finally, local NGOs and external donors have helped mobilizing communities on issues related to natural resources management and are well positioned to finance the activities of both local and federal stakeholders.

This implies future projects intended to address the expansion of Lake Beseka should recognize and integrate stakeholders and existing social network structures into an inclusive and coherent framework. To better connect missing but important stakeholders at different levels of governance, there is a need to include the informal water users into the existing, fragile WUAs. A new institutional arrangement could bring together formal and informal water users and be responsible for managing land and water resources at the local level. However, irrespective of the Awash Basin Authority's mandate regarding the governance of the water in the basin, the current WUA is highly centered around the authority with less emphasis on a polycentric institutional arrangement that involves co-management of the basin by the authority and the stakeholders. On the other hand, downstream KII respondents report that water allocation during the dry season is unfair to them and most often upstream stakeholders and informal water users are not following water allocation rules. The reason for this is lack of enforcement capacity of Awash Basin Authority that encourages unregulated use of water from the Awash River and Lake Beseka.

c) The status-quo is not sustainable

Although several efforts have been implemented in the past to arrest the increase of Lake Beseka, the only structure that currently exists is the two canals that were constructed in 2014 to release water from the lake to the nearby Awash River. However, the canal's gates are non-functioning, and it is not clear who oversees water releases. Moreover, lake inflows are larger than the capacity of the canals to the river. As such the canals can only slow down the rate of increase but not solve the lake expansion problem. Thus, additional carefully designed interventions are needed. For example, KII participants across sectors proposed alternative solutions at the basin level that included wetland development outside Awash National Park, dam building in the middle Awash basin, improving water use in upstream irrigation schemes, and desalinization or leaching of Beseka water. Moreover, KIIs also proposed potential solutions at the individual farmer level, including introducing salt tolerant crop varieties (wheat, cotton), water efficient irrigation technologies (drip irrigation, mulching, revisiting the current furrow length, and land levelling), better land tenure security, and water harvesting technologies to cope with climate hazards. The costs, benefits, and stakeholders' willingness to pay or contribute to such solutions need further detailed studies. Research is also needed to assess the potential tradeoffs of alterative proposed solutions in environmental, economic, and social performance so as to minimize unintended consequences of the solutions on downstream communities and other under-represented stakeholders.

References

Abduro, F. and WoldeMichael, 2017. Determination of heavy metals concentrations within the ever-growing Lake Beseka, Ethiopia using spectrophotometric technique. African Journal of Environmental Science and Technology 11: 146-150.

Alemayehu, T., Ayenew, T. and Kebede, S., 2006. Hydrogeochemical and lake level changes in the Ethiopian Rift. *Journal of hydrology*, *316*(1-4), pp.290-300.

Awulachew, M.T., 2020. Overview to Potential Sources, Soil Salinization and Expansion Level of Lake Basaka, Central Rift Valley Region of Ethiopia. *Journal of Water Resources and Ocean Science*, *9*(4), pp.71-76.

Ayenew T. (2007) Water Management Problems in the Ethiopian Rift: Challenges for Development. *African Journal of Earth Science*, 48: 222–36.

Ayenew, T. & Legesse, D. 2007. The Changing Face of the Ethiopian Rift Lakes and Their Environs: Call of the Time. *Lakes & Reservoirs: Research and Management,* 12: 149–165.

Ayenew, T., 2004. Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. Regional Environmental Change 4, 192–204.

Belay, D. 2017. Environmental Impact Analysis of Infrastructures Development and Lake Beseka Expansion on the Integrity of Fentale-Metehara Blister Caves in the Main Ethiopian Rift. MSc Thesis, Addis Ababa University.

Borgatti, S.P., Everett, M.G., Freeman, L.C., 2002. Ucinet 6 for Windows: Software for Social Network Analysis. Analytic Technologies, Harvard MA.

Degenne, A., Forse, M., 2004. Introducing Social Networks. Sage, London. Diani, M., Bison, I., 2004. Organizations, coalitions, and movements. Theory Soc. 33, 281–309.

Dinka, M. O., 2012. Analyzing the extent (size and shape) of Lake Beseka expansion (Main Ethiopian Rift Valley) using remote sensing and GIS. *Lakes & Reservoirs: Research and Management*, **17**: 131–141.

Dinka, M. O., 2010. Analyzing the Extents of Beseka Lake Expansion and Soil and Water Quality Status of Metehara Irrigation Scheme, Awash Basin (Ethiopia). PhD Dissertation submitted to BOKU University, Vienna, Austria.

Dinka, M.O., Loiskandl, W. and Ndambuki, J.M., 2015. Hydrochemical characterization of various surface water and groundwater resources available in Matahara areas, Fantalle Woreda of Oromiya region. *Journal of Hydrology: Regional Studies*, *3*, pp.444-456.

Dinka, M.O., 2017. Analysing the temporal water quality dynamics of Lake Basaka, Central Rift Valley of Ethiopia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 52, No. 1, p. 012057). IOP Publishing.

Dinka, M.O., 2020. Estimation of groundwater contribution to Lake Basaka in different hydrologic years using conceptual net ground water flux model. *Journal of Hydrology: Regional Studies*, *30*, p.100696.

Dinka, M.O., Loiskandl, W. and Furst, J., 2009. The expansion of highly saline Basaka Lake and its effects on the sustainability of Matahara Sugar Estate. In *Proceedings of the 34th–WEDC International Conference; Addis Ababa, Ethiopia. Refereed Paper* (Vol. 296, pp. 571-579).

Falkenmark, M., 2003. Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges. Phil. Trans. R. Soc. B, 2037–2049.

Freeman, L.C., 1978. Centrality in social networks conceptual clarification. Social networks, 1(3), pp.215-239.

Goerner, A., Jolie, E. and Gloaguen, R., 2009. Non-climatic growth of the saline Lake Beseka, main Ethiopian rift. *Journal of arid Environments*, *73*(3), pp.287-295.

Hailu, E.K., Abate, B. & Hordofa, T. 2016. Effect of Blended Irrigation Water Quality 0n Soil Physico-Chemical Properties and Cotton Yield in Middle Awash Basin Ethiopia. *International Journal of Water Resources and Environmental Engineering*, 8: 1-10.

Kebede, S. and Zewdu, S., 2019. Use of 222Rn and δ18O-δ2H isotopes in detecting the origin of water and in quantifying groundwater inflow rates in an alarmingly growing lake, Ethiopia. *Water*, *11*(12), p.2591.

Klemperer, S.L. and Cash, M.D. 2007. Temporal geochemical variation in Ethiopian Lakes Shala, Arenguade, Awasa, and Beseka: Possible environmental impacts from underwater and borehole detonations. Journal of African Earth Sciences 48:174–198.

Marin, A., Wellman, B., 2010. Social network analysis: an introduction. In: Carrington, P., Scott, J. (Eds.), Handbook of Social Network Analysis. Sage, London.

Marsden, P.V., 2005. Recent developments in network measurement. In: Carrington, P., Scott, J., Wasserman, S. (Eds.), Models and methods in social network analysis. Cambridge University Press, New York.

Marsden, P.V., 1990. Network data and measurement. Annual review of sociology, pp.435-463.

Newman, M.E. and Girvan, M., 2004. Finding and evaluating community structure in networks. Physical review E, 69(2), p.026113.

Rogers, P.P., 2006. Water governance, water security and water sustainability. Water crisis: myth or reality, pp.3-36.

Schiffer, E., Hartwich, F., Monge, M., 2010. Who has Influence in Multistakeholder Governance Systems? Using the Net-map Method to Analyze Social Networking in Watershed Management in Ghana. International Food Policy Research Institute, Washington DC.

Scott,J., 2000. Social Network Analysis: A Handbook (2nd ed.), Sage, London

Shishaye, H.A., 2015. Challenges in Lake Beseka, Ethiopia. Conference: Ethiopia Welcome Function Organized by the Australian Awards.

Stein, C., Ernstson, H. and Barron, J., 2011. A social network approach to analyzing water governance: The case of the Mkindo catchment, Tanzania. Physics and Chemistry of the Earth, Parts A/B/C, 36(14-15), pp.1085-1092.

Talling, J. and Talling, I., 1965. The chemical composition of African lake waters.

Teffera, Z.L., Li, J.H., Debsu, T.M., Menegesha, B.Y., 2018. Assessing land use and land cover dynamics using composites of spectral indices and principal component analysis: a case study in middle Awash subbasin, Ethiopia. Appl. Geogr. 96, 109–129.

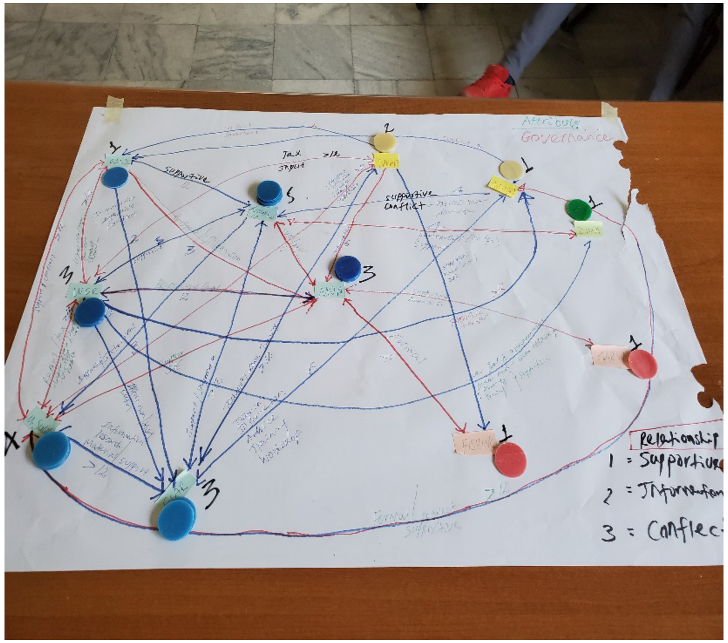
Yimer, A.Y. and Jin, L. 2020. Impact of Lake Beseka on the Water Quality of Awash River, Ethiopia. American Journal of Water Resources 8: 21-30.

Yimer, Y.A. and Geberkidan, A., 2020. The pollution status of Awash River basin (Ethiopia) using descriptive statistical techniques. *American Journal of Water Resources*, *8*(2), pp.56-68.

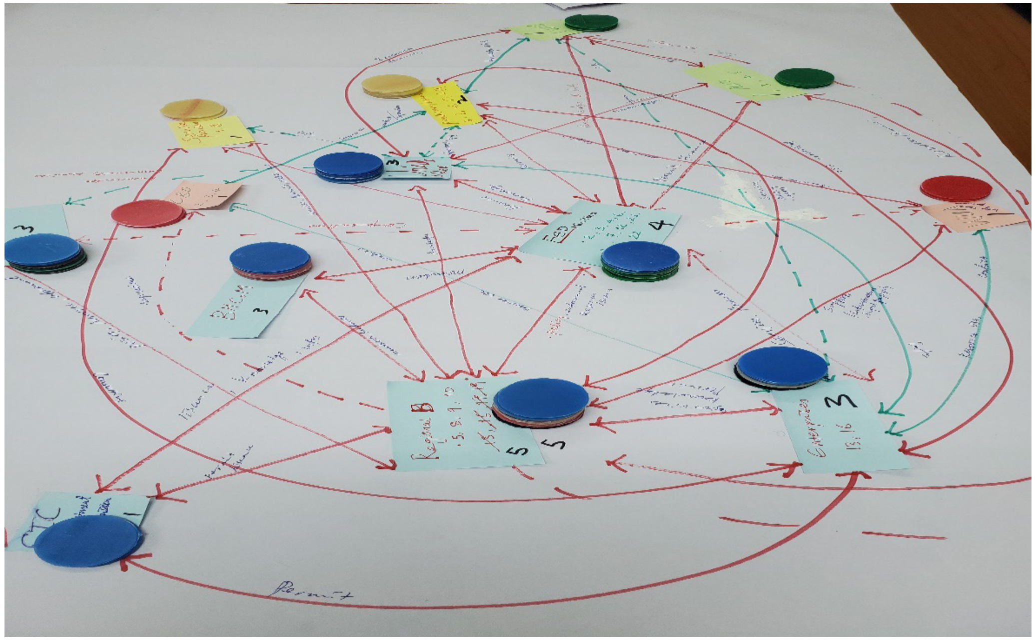
Zemedagegnehu, E., Travi, Y. and Aggarwal, P., 1999. Application of environmental isotopes to determine the cause of rising water levels in Lake Beseka, Ethiopia. IAEA-SM-361/12P

Annexes

Annex. 1: Local stakeholder mapping in facilitated workshop



Annex. 2: Federal stakeholders mapping in facilitated workshop



Annex 3: Adjacency matrices of local stakeholders

ID	MoM	WoF	ANP	EIAR	ABD	MSF	AMIBARA	FARMERS	FISHERY	CWA	DWA
MoM	0	0	0	0	0	0	0	0	0	0	0
WoF	0	0	0	1	1	0	1	0	0	0	1
ANP	0	0	0	1	1	0	0	0	0	0	0
EIAR	0	1	1	0	1	1	1	1	0	0	0
ABD	0	1	1	1	0	0	1	0	0	0	0
MSF	0	0	0	1	1	0	0	0	0	0	0
AMIBARA	0	1	0	1	0	0	0	0	0	0	0
FARMERS	0	0	0	1	0	0	0	0	0	0	0
FISHERY	0	0	0	0	0	0	0	1	0	0	0
CWA	0	0	0	0	0	0	0	0	0	0	0
DWA	0	1	0	0	0	0	0	0	0	0	0

Annex 4: Adjacency matrices of federal stakeholders

ID	Fed_Min	Reg_Bur	Loc_Aut	Uni_Res	BHCoM	Inv_Com	Enterpri	WUA	CBO	Ser_prov	Prod_use	NGOs	IWMI
Fed_Min	0	1	1	1	0	0	1	0	0	0	0	1	0
Reg_Bur	1	0	1	0	0	0	0	1	0	1	0	1	0
Loc_Aut	0	1	0	0	0	0	0	0	0	0	0	0	0
Uni_Res	1	0	1	0	0	0	0	0	0	0	0	1	1
BHCoM	0	0	0	0	0	0	0	0	0	0	0	0	0
Inv_Com	0	0	0	0	0	0	0	0	0	0	0	0	0
Enterpri	1	0	0	0	0	0	0	1	1	0	1	0	0
WUA	0	1	0	0	0	0	1	0	0	0	1	0	0
CBO	0	0	0	0	0	0	1	0	0	0	1	0	0
Ser_prov	0	1	0	0	0	0	0	0	0	0	0	0	0
Prod_use	0	0	0	0	0	0	1	1	1	0	0	0	0
NGOs	1	1	0	1	0	0	0	0	0	0	0	0	1
IWMI	0	0	0	1	0	0	0	0	0	0	0	1	0

Annex 5: list of consulted stakeholders

Actors/Institution	Type of institution	Level	Responsibility
Awash Basin Authority (K-1)	Government	Local	Responsible for water flow and management of the entire Awash basin
Ministry of Water Irrigation and Energy (K-2)	Government	Federal	National level governing body for the water and energy sector as a whole
Awash Basin Development (K-3)	Government	Federal	Responsible for water flow and management of the entire Awash basin
Awash National Park (K-4)	Government	Local	A park responsible for wild animals and their habitat located in the park within the river basin
Metehara sugar factory (K-5)	Government	Local	Responsible for vast sugar plantation and pressing factory
Metehara town administration (K-6)	Government	Local	governing body of Metehara town
Fentale woreda administration (K-7)	Government	Federal	Governing body of Fentale district where the Beseka lake, the town and the surrounding area are located
Ethiopian Institute of Agricultural Research (K-8)	Government	Federal	Federal body responsible for knowledge generation through practical research in the area
National Tourism Organization (K-9)	Government	Federal	Tourism actor that can be positively or negatively affected
Ethiopian Wildlife Conservation Authority (EWCA) (K-10)	Government	Federal	Federal body responsible for all national parks
Local farmers (K-11)	Private	Local	Local small-scale farmers that can be positively or negatively affected
Private farmers around Amibra (K-12)	Private	Local	Large scale private farmers around lower part of the basin
Private Lodges and Hotels (K-13)	Private	Local	Hospitality actors that can be positively or negatively affected
International Water Management Institute (K-14)	NGO/research institute	Federal	International body responsible for knowledge generation through practical research in the area
Addis Ababa University (K-15)	Educational institution	Local	Academia responsible for knowledge generation through practical research in the area
Fentale-Boset Project (K-16)	Community (Government)	Local	Large scale government irrigation project that changes the water catchment system of the lake
Youth Car-Washing Associations (K-17)	Community based organization	Local	Small scale car washing service that can be positively or negatively affected
Fisherman Associations (K-18)	Community based organization	Local	Small scale fishermen that can be positively or negatively affected
Dutch Water Authority (K-19)	Donor	Federal	International body responsible for practical projects that helps to enhance optimal use of water resource in the area

ALL IFPRI DISCUSSION PAPERS

All discussion papers are available **here**

They can be downloaded free of charge

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
www.ifpri.org

IFPRI HEADQUARTERS
1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org