IWMI
International Water Management Institute

Project Brief

Achieving Balance: Understanding water use impacts for Sustainable Water Management of Lake Tana Basin, Ethiopia using Earth Observation Data

Summary

The Problem: *The Lake Tana basin was considered potentially rich in water resources and has been subjected to many developmental activities. However, the basin has been experiencing a significant hydrological change and use due to increased irrigation, water supply projects, interbasin transfers, and urbanization. Furthermore, limited data on water resources pose a significant challenge to the integrated management of water resources.*

The Approach: *The Digital Innovation for Water Secure Africa (DIWASA) initiative of the International Water Management Institute is motivated to address water data scarcity issues through the water accounting plus (WA+) framework. The WA+ is a tool that tracks water inflows, outflows, return flows, and storage, providing an in-depth understanding of water availability, distribution, and utilization within the Lake Tana Basin. The WA+ model was run from 2010-2020 to understand the impact of basin activities on water availability.*

The major findings:

- *The average basin precipitation is about 19.4 km³ of water into the basin. The major water users in the basin are agriculture (rainfed + irrigation) and lake evaporation. Together they consume about 12.7 km³ of water.*
- *The mean annual utilizable outflow (water left after meeting basin water demands that can be allocated for future use) in the basin is 4.8 km³/yr.*
- *The mean annual inter-basin water transfer from the Lake to the Tana-Beles hydropower plant is about 3.3 km³ for 2010-2020. This has led to a significant increase in the Beles River flows.*
- *Since the hydropower plant operation in 2010, a reduction in flow at Bahir Dar station, the natural outlet where the Blue Nile River commences, was observed.*
- *Our study indicates that the average inflows and outflows of the Lake were in balance (with a slightly positive average storage of 0.3 km³/yr). The impact of the interbasin diversions on the Lake is minimum during the average to above-average rainfall years but could affect negatively during the below-average year.*

Lake Tana is the largest Lake in Ethiopia, accounting for 50% of the country's freshwater resources. It also contributes more than 8% of the Nile's freshwater supply to the eastern Nile countries Sudan and Egypt, originating from Ethiopian highlands. The Lake is an essential source of natural resources, including water for domestic supply, irrigation and hydropower production, fisheries, grazing and water for livestock, and reeds for boat construction. It is also important for water transport and as a tourist destination. The Lake Tana basin has a total drainage area of 15077 km², of which the Lake covers 3062 km². More than 40 rivers feed the Lake; the major rivers are the Gilgil Abay from the south, the Ribb and Gumara Rivers from the east, and the Megech River from the north.

Lake Tana and its inhabitant (top) and the Lake crippled by water weed (bottom) (*photo*: Internet Sources).

Challenges in the Lake Tana Basin

The Lake and its basin have been identified as a hydropower and irrigation development region, which is vital for Ethiopia's economic growth. Despite its socio-economic significance, limited data on water resources poses a significant challenge for integrated and sustainable water resource management in the basin. About 62% of the basin is ungauged- observed flow data are unavailable (Figure 1). Even where data is available, determining who uses how much water remains challenging because of the hydrologic complexities of water supply and use in the basin. Moreover, the basin has been experiencing a significant hydrological change in water availability and use. Competition over water resources among irrigation, hydropower development, and ecosystem services in the basin is escalating.

The construction of Chara Chara weir in the Lake to regulate the lake level, inter-basin water transfer from the Lake to the hydropower plant, and expansion of small and large-scale irrigation schemes in the basin cause water scarcity and environmental problems (McCartney et al., 2009). While this lake basin has been widely researched (Kebede et al., 2006; Dessie et al., 2015; Tigabu et al., 2019), most research was focused on a single aspect of lake hydrology and did not provide information on the integrated impacts of the water uses in the basin. Therefore, a comprehensive water accounting of Lake Tana is essential for the integrated assessment and management of water sources in the basin.

The water accounting plus (WA+) Framework

The Water Accounting Plus (WA+) framework is an open-source framework that uses publicly available remote sensing data for tracking water inflows, outflows, return flows, and storage, providing an in-depth understanding of water availability, distribution, and utilization (Karimi et al. 2013). This is a modified version of a simplistic water accounting framework (Molden and Shaktivadivel, 1999). The WA+ employs a mass water balance approach assuming that outflows from the basin are associated with net inflows and depletions through ET processes that can be measurable. Therefore, the advantage is that it is no longer necessary to measure withdrawals and return flows as the depletion can be obtained directly from remote sensing measurements. The present study quantifies the water accounts for the Lake Tana basin based on the information generated from the resource base sheets.

Water accounts for Lake Tana Basin from 2010 to 2020

The International Water Management Institute carried over a water accounting assessment within the Digital Innovations for Water Secure Africa (DIWASA) program. The Helmsley Charitable Trust funds this program. The WA+ results for 2010 – 2020 show that the average precipitation contribution in the basin is about 19.4 km³. The long-term mean annual utilizable outflow (water left after meeting basin water demands which can be allocated for future use) is 4.8 km³/yr. The exploitable water, a portion of the net inflow that is not evaporated and is available for downstream use and withdrawals, is 9.2 km³. It is important to note that all exploitable water is not available for use as

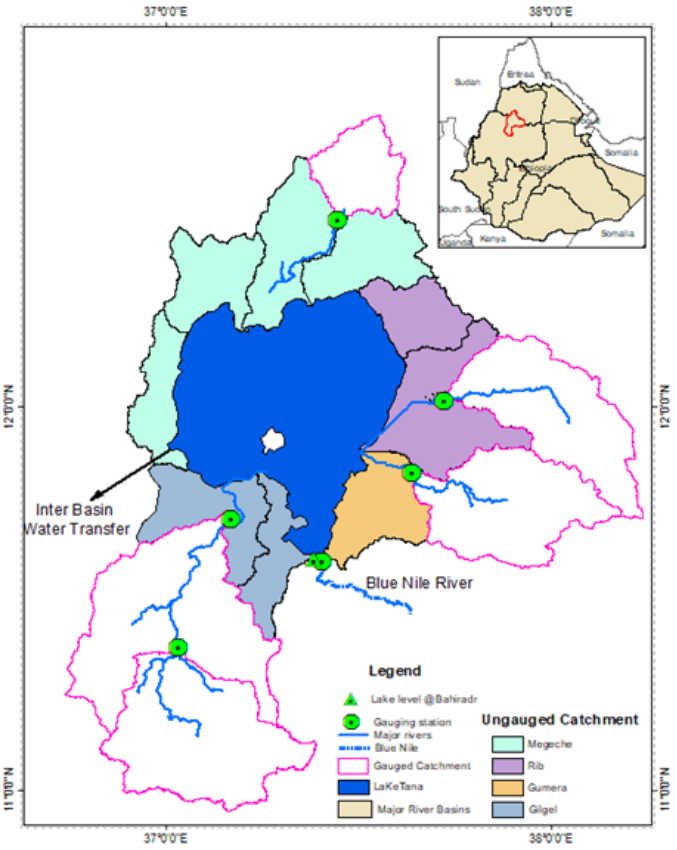

Figure 1. Location Map of the Lake Tana Basin.

part of it must be reserved to meet downstream water rights requirements. The reserved flow, a significant indicator of the overall water health in the basin, is estimated to be 0.6 km³ which is not sufficient for the environmental flow requirement for the downstream Blue Nile waterfall, which requires 0.86 km³ on average (McCartney et al., 2009). Proper management of reserved flow is crucial for maintaining the ecosystem service of Lake Tana Basin.

Moreover, our study estimated that the total lake outflow for 2010-2020 is about 5.9 km³, of which only 44% (2.6 km³) flows out of the natural outlet at Bahir Dar, and the rest, 56% (3.3 km³) is diverted from the Lake for hydropower development (figure 2) outside the basin. The diversion to the Beles River has caused increased flows in the river and has led to some negative impacts on rural livelihoods (Annys et al., 2019).

As a result of the diversion, since the commissioning of the hydropower plant in 2010, we estimated that the mean annual outflow measured at Bahir Dar reduced from 4.1 km³ (129 m³/s) over 2000-2009 to 2.6 km³ (82 m³/s) for 2010-2020. Since the reduction in Bahir Dar outflows only accounts for 1.5 km³, the rest of the 1.8 km³/yr is removed from the Lake.

Based on the lake balance model, we estimated that the average inflows and outflows of the Lake were in balance (with a slightly positive average storage of 0.3 km³/yr). The impact of the interbasin diversions on the Lake is minimum during the average to above-average rainfall years. Still, it could affect negatively during the below-average year due to the sensitivity of the Lake to rainfall fluctuations (Kebede et al., 2006). However, the impact of additional water diverted from the Lake and the reduction in the natural outflow on Lake Tana water levels, basin water resources, and ecosystems downstream of Bahir Dar should be the focus of future studies. The water account outputs will be available as story maps and a water accounting dashboard for various stakeholders to address the basin's water resources management challenges.

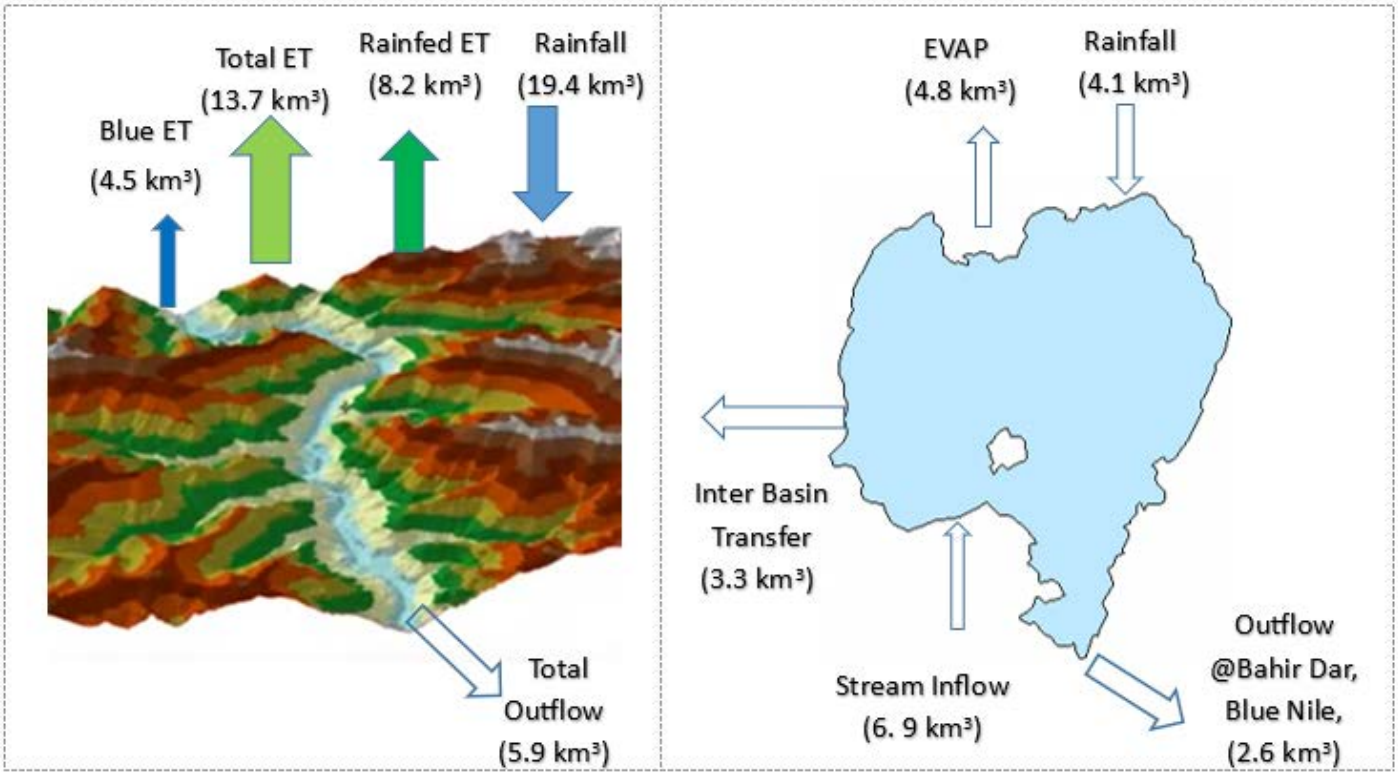

Figure 2. Water Accounts for Lake Tana Basin (left) and Lake water balance components (right) for the period 2010-2020.

References

Annys, S., Adgo, E., Ghebreyohannes, T., Van Passel, S., Dessein, J., & Nyssen, J. (2019). Impacts of the hydropower-controlled Tana-Beles interbasin water transfer on downstream rural livelihoods (northwest Ethiopia). *Journal of Hydrology*, *569*, 436-448.

Dessie, M., Verhoest, N. E., Pauwels, V. R., Adgo, E., Deckers, J., Poesen, J., & Nyssen, J. (2015). Water balance of a lake with floodplain buffering: Lake Tana, Blue Nile Basin, Ethiopia. *Journal of Hydrology, 522*, 174-186.

Karimi, P., Bastiaanssen, W. G., & Molden, D. (2013). Water Accounting Plus (WA+)–a water accounting procedure for complex river basins based on satellite measurements. *Hydrology and Earth System Sciences*, *17*(7), 2459-2472.

McCartney, M. P., Shiferaw, A., & Seleshi, Y. (2009). Estimating environmental flow requirements downstream of the Chara Chara weir on the Blue Nile River. *Hydrological Processes: An International Journal, 23*(26), 3751-3758.

Molden, D., & Sakthivadivel, R. J. I. J. (1999). Water accounting to assess use and productivity of water. *International Journal of Water Resources Development*, *15*(1-2), 55-71.

Tigabu, T. B., Wagner, P. D., Hörmann, G., & Fohrer, N. (2019). Modeling the impact of agricultural crops on the spatial and seasonal variability of water balance components in the Lake Tana basin, Ethiopia. *Hydrology Research*, *50*(5), 1376-1396.

Acknowledgments

The authors gratefully acknowledge The Leona M and Harry B. Helmsley charitable trust for their financial support and Tanmoy Bhaduri (Communications Consultant, IWMI) for preparing the layout of the brief. The authors' views are their own and do not necessarily reflect the views of the funding agency.

Contacts

Abdulkarim Seid, Country Representative, IWMI, Ethiopia (a.seid@cgiar.org)
Naga Velpuri, Senior Researcher - Water Accounting and Productivity, IWMI, Sri Lanka (n.velpuri@cgiar.org)
Kirubel Mekonnen, Consultant, IWMI, Ethiopia (k.gebreyesus@cgiar.org)

IWMI Ethiopia

East Africa and Nile Basin Office
C/o ILRI Ethiopia Campus, PO Box 5689,
Addis Ababa, Ethiopia.

Tel: +251 11 6172000/6457222/23
Fax: +251 11 6464645/6172001
Email: iwmi-ethiopia@cgiar.org

IWMI
International Water Management Institute

CGIAR
IWMI is a CGIAR Research Center

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 14 countries and a global network of scientists operating in more than 30 countries.

International Water Management Institute (IWMI)

Headquarters
127 Sunil Mawatha, Pelawatte,
Battaramulla, Sri Lanka

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

Published: August 2023