Impact of water abstraction on the water balance of Lake Ziway, Ethiopia

Demelash Goshime\textsuperscript{1,4, *}, Alemseged Haile\textsuperscript{2}, Rafik Absi\textsuperscript{3}, Béatrice Ledésert\textsuperscript{1}

1 University of Cergy Pontoise (UCP), Institute of Doctoral studies at Science and Engineering, Civil Engineering, 95000 Cergy, France
2 International Water Management Institute (IWMI), 5689, Addis Ababa, Ethiopia
3 ECAM-EPMI Graduate School of Engineering, 95092 Cergy-Pontoise, France
4 Laboratory of Geosciences and Environment (GEC), 95000 Cergy, France

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Introduction

- Significant change has been observed in the water level of different Rift Valley Lakes in Ethiopia, as a result:
  - Natural processes
  - and human activities
- However, lack of data is a major challenge in the estimation of actual water abstracted for irrigation Remote sensing products
- Previous studies estimate irrigation water demand from a crop that requires the highest amount of water using national statistics, reports and climatic database
- The hydrology of many lakes has been relatively well documented
- However, the hydrology of Lake Ziway is not well documented in scientific literature as compared to other lakes
Introduction

- Most of them focused on the water budget of the lake under the natural conditions.
- However, there is no study that quantitatively estimated actual water abstraction from the lake and its impact on the water level based on WAS.
- The exact magnitude of water withdrawal and its impact on the water level from available studies are uncertain.
- The aim of this study is to estimate water withdrawal from the lake and its impact on lake water level using water balance modelling approach.
Study Area

Legend
- Rain gauge stations
- River Gauge
- Lake Level
- Stream network
- Lake Ziway
- Lake Ziway Subbasin
Lake Ziway

- In the Central Rift Valley lakes basin (CRV)
  - 7°00’-8°30’ N & 38°00’-39°30’ E
  - Catchment Area: 6700 km²
- Elevation
  - Vary between: 1600-4200 m.a.s.l.
- Annual Rainfall: 650-1400 mm
  - 60% in July to September
- Mean temperature: 13.5-22.5°C
- Major rivers:
  - Meki and Katar rivers
  - Average annual runoff volume = 675 MCM
Datasets

- Meteorological data (1984-2016)
  - 20 Stations (Rainfall, Temp(max/min), humidity, Wind speed, Sunshine)
- Digital Elevation Model (DEM)
  - 30m x 30m resolution
- Land use/land cover
- Water abstraction survey (WAS) Data
- Daily Stream flow (1984-2016)
  - At Abura, Meki, Fite, Chuifa and Sagure
- Satellite Rainfall Data (1984-2016)
  - Climate Hazards Group Infrared Precipitation (CHIRP) dataset ([http://chg.geog.ucsb.edu/data/chirp/](http://chg.geog.ucsb.edu/data/chirp/))
Materials and Methods

- This study is based on the assessment of existing and satellite hydro-meteorological dataset, water abstraction survey, and review of published studies.
- We applied the hydrological model output coupling with water balance modelling and field surveys.
- The methodologies followed in this study are:
  1. We estimated water abstraction for all abstraction points based on Water Abstraction Survey (WAS).
  2. We evaluated the water balance components of the lake under the natural condition on a monthly time steps.
  3. The implication of existing and future water abstraction on the water level was evaluated using a water balance modelling approach.
Impact of water abstraction

- First, the amount of water abstracted was measured using a bucket with a known size. Then, the inflow and outflow water balance components of the lake were determined at monthly time steps including water abstraction.
- After all water balance terms estimated a spreadsheet water balance model is developed to simulate lake volume.
- The lake volume was then converted to lake level using the bathymetric relationships.
- Three development scenarios were built: existing development (ED), likely future development (LD) and full development potential (FD).
Impact of water abstraction

- The BS is the natural simulated water level from 1986-2000 without water abstraction.
- ED, LD and FD scenarios 2000, 3100 and 5000 ha of irrigate land withdrawing water from the lake.
- This, first we assessed the lake water balance without and with water abstraction components.
- Then, we simulated the lake volume (corresponding lake level) for the baseline natural condition and scenario development.
- The isolated impact of water withdrawal from the lake on the water level will be estimated from the net difference between the simulated for natural and scenario condition.
Water Abstraction

- The amount of annual water withdrawal from the lake for irrigation and domestic purpose revealed 38 Mm³ volume of water to irrigate 2000 ha of agricultural lands for three seasons per each year.
Water abstraction for development scenario

- Estimate of Monthly water abstraction

[Bar chart showing monthly abstraction amounts for different scenarios (ED, LD, FD)].
Lake Water Balance

- The monthly average simulated water balance components of Lake Ziway from 1986 to 2000 result revealed that rainfall, river inflow and evaporation constitute 33, 60 and 83% of the annual water balance of the lake, respectively.

- This indicates that the river inflow contributes the major Lake inflow and evaporation over the lake surface accounts the major lake water loss.

| Water Balance    | Inflow | Outflow | Water Abstraction |
|------------------|--------|---------|-------------------|
|                  | R      | Q_M     | Q_K   | Q_U  | Evap | Q_out | Irrigation | Domestic |
| This study (2019)| 338    | 233     | 380   | 81   | 832  | 171   | 37         | 1.26     |
| Vallet-Columb et al. (2001) | 335 | 273     | 418   | 50   | 832  | 157   | -          | -        |
| Ayenew (2004)    | 323    | 265     | 392   | 48   | 890  | 184   | 28         | -        |
| Jansen et al. (2007) | 327 | 274     | 411   | -    | 774  | 185   | 27         | 1.31     |
| Desta et al. (2017) | 356 | 262     | 394   | -    | 854  | -     | 41         | -        |
Lake water level simulation for natural condition

- The simulated monthly lake levels reasonably fit the pattern of observed water level up to 2000. However, for a recent period (after 2000) the simulated lake level significantly deviated from the observed counterparts.

- The main attribution factors are:
  - Variation of any of the water balance terms
  - Human activities (e.g. pumping water abstraction for irrigation)
  - Climate change
The simulated monthly water level for the three scenarios was not reasonably followed the baseline lake level over the simulation period.
Summary of simulation results for each pathway from 1986-2000

| Scenario | Mean annual lake balance term | Change from the baseline |
|----------|-------------------------------|--------------------------|
|          | Water Level (m.a.s.l) | Area (km²) | Volume (MCM) | WL Change (m) | Area change (%) | Volume change (%) |
| BS       | 1636.18 | 442.24   | 1529.50      |               |                |                  |
| ED       | 1635.82 | 424.35   | 1367.49      | -0.36         | -4.0           | -10.6            |
| LD       | 1635.61 | 415.49   | 1278.53      | -0.57         | -6.1           | -16.4            |
| FD       | 1635.25 | 403.95   | 1124.10      | -0.94         | -8.7           | -26.5            |
Impact of water abstraction

- The result indicates the mean annual lake level, volume and surface area decreased during water abstraction.
- For existing development (ED)
  - Water level decrease by = 0.36 m
  - Volume decrease = 162 MCM
  - Surface area = 18 km²
- For Likely future development (LD)
  - Water level decrease by = 0.57 m
  - Volume decrease = 251 MCM
  - Surface area = 27 km²
- For future full development (FD)
  - Water level decrease by = 0.94 m
  - Volume decrease = 405 MCM
  - Surface area = 38 km²
Concluding Remarks

- This study indicated that an accurate estimate of actual water withdrawal and its impact on the water level can be estimated using WAS and water balancing approach, respectively.

- As a result of 37 Mm$^3$ annual water withdrawals from the lake for irrigation, the mean water level and volume of Lake Ziway drop by 0.36 m and 162 Mm$^3$, respectively.

- If full planned development pathway to be implemented the water level and surface area of the lake drop by an additional 0.37 m and 11 km$^2$, respectively. This consequently will yield to a significant reduction in the volume of the lake by 405 MCM, which accounts for 26% reduction of average lake volume.

- Our study indicates that water abstraction directly from the lake has a significant impact on the water level, volume and surface area of the lake. The water level change also further reflected in the temporal variation on the climate change trend.

- Further studies should incorporate future climate change impact assessment.
Thank you for your attention!!