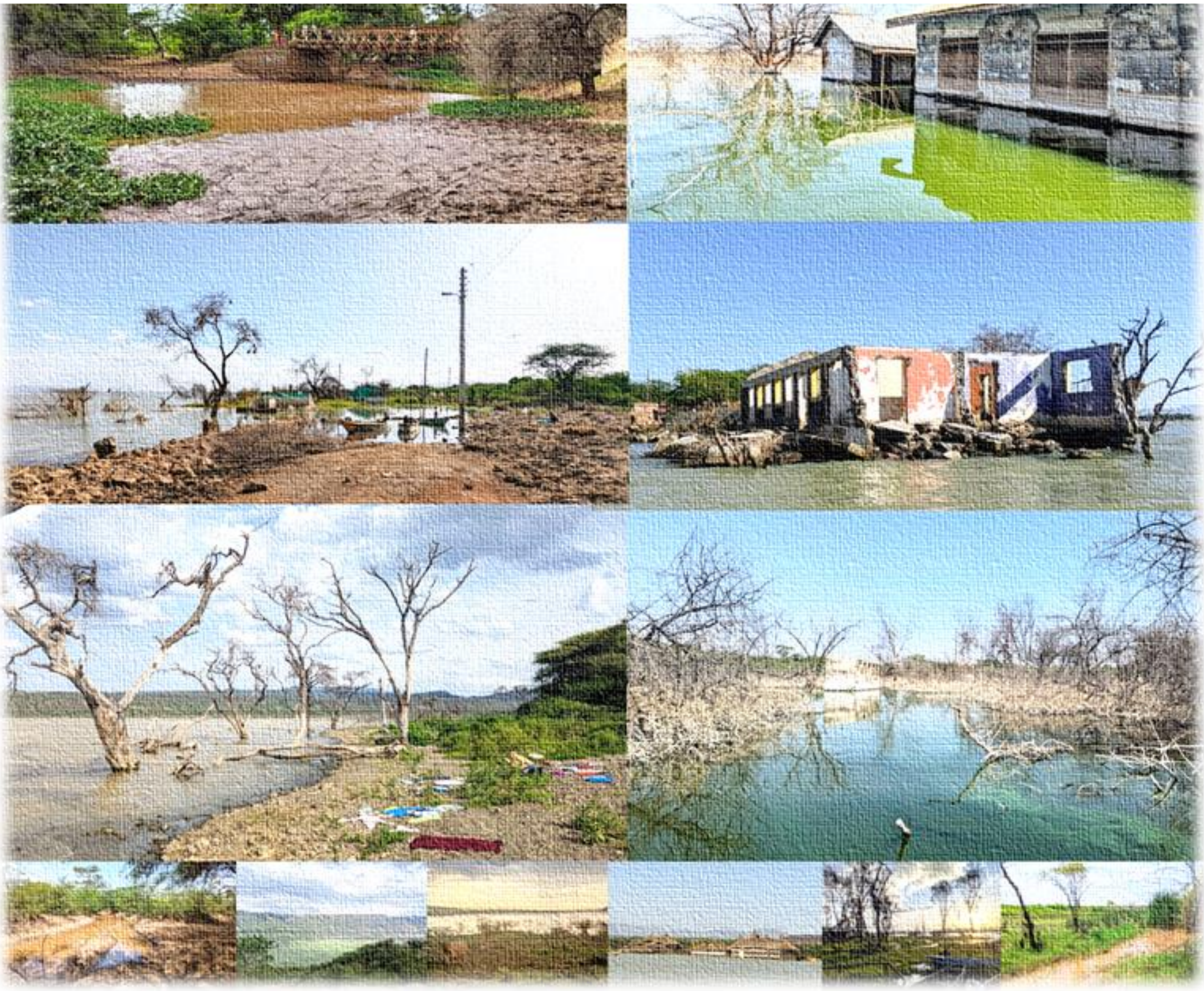
Water Level Rises in Lake Baringo of Kenya

Causes, Impact and Management

Policy Brief

TUK/BOKU/LB/Oct2024/1



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Cite as: Olang, L., Herrnegger, M., Cherono Kiplangat, N., & Stecher, G. (2024). Water level rises in Lake Baringo of Kenya: Causes, Impact and Management, Policy Document TUK/BOKU/LB/OCT2024/1.

This document was prepared in the frame of the scoping project "Lake Level Fluctuations and Implications on Local Livelihoods in the Great Rift Valley Lakes of Kenya | GreatLakes" (KOEF 08/2020). The project is financed by the Austrian Federal Ministry of Education, Science and Research for the period 2021-2024 within the framework of 'Cooperation Development Research' and is administered by OeAD-GmbH / Austria's Agency for Education and Internationalization.

High-resolution TanDEM-X terrain data is provided by the German Aerospace Center (DLR) and was awarded with the proposal ID DEM_HYDR3478.

Federal Ministry
Republic of Austria
Education, Science
and Research

GreatLakes
Water Level Fluctuations and Implications on Local Livelihoods in the Rift Valley Lakes of Kenya

Kooperation Entwicklungsforschung
Cooperation Development Research

KEY MESSAGES

I. The Lake Baringo Basin continues to experience lake level fluctuations, often affecting local people and livelihoods. However, the region remains unmapped and there is a paucity of in-situ hydro-meteorological observations from which objective information can be derived to support policy and management. Therefore, satellite remote sensing proxy datasets can support such analyses to inform regulation, management and development of water resource systems (Kenya Water Act 2016, CAP 372).

II. Analyses carried out using water level proxy datasets from the Database for Hydrological Time Series of Inland Waters (DAHITI) revealed drastic increases of the lake water levels between 2010-2020, corresponding to increased rainfalls patterns. The highest water level rise fell slightly below the tipping elevation upon which Lakes Bogoria would overflow and potentially merge with Lake Baringo. There is hence an urgent need to plan & develop frameworks for sustainable conservation to avoid the potential of such ecological catastrophe (Kenya Environment Management and Coordination Act, 1999 (CAP 378) & Kenya Public Health Act (CAP 242).

III. Since 2010, around 80 % of the households in the in the riparian sub-locations have been affected by floods, particularly in the southern parts of the basin. There is hence a need to develop (i) flood hazard and flood risk maps for riparian areas around Lake Baringo and (ii) institutional frameworks for applicable early flood management and flood warning schemes aimed at promoting timely responses to reduce damage. This will include the continuous need to strengthen local institutions through regular trainings on advanced monitoring tools for land and water resource management. Such initiatives will support national plans to implement all sustainable management measures under changing climate conditions, also in line with Target 17.9 of the 2030 Agenda of the Sustainable Development Goals (SDG).

BACKGROUND

In the recent past, most of the Great Rift Valley Lakes in Kenya have experienced water level fluctuations, with severe impacts on local people who depend on the land and water resources for their socio-economic livelihoods [Government of Kenya and UNDP, 2021]. The affected regions around the lakes are also important biodiverse eco-zones, designated as Wetlands of International Importance and World Heritage Sites. Between 2010 - 2024, water levels in Kenya's Rift Valley continued to rise, flooding surrounding riparian areas.

The freshwater Lake Baringo (Figure 1) has been severely affected by the lake water level rises. Additionally, there is fear of a potential cross mixing with the alkaline Lake Bogoria located on the immediate south. Given the proximity of the two lakes (17.5 to 33.2 km depending on water levels), and their different ecological status, cross mixing of the two water bodies could potentially affect ecosystem health, biodiversity and socio-economic livelihoods of the entire region [Government of Kenya and UNDP, 2021; Herrnegger et al., 2024].

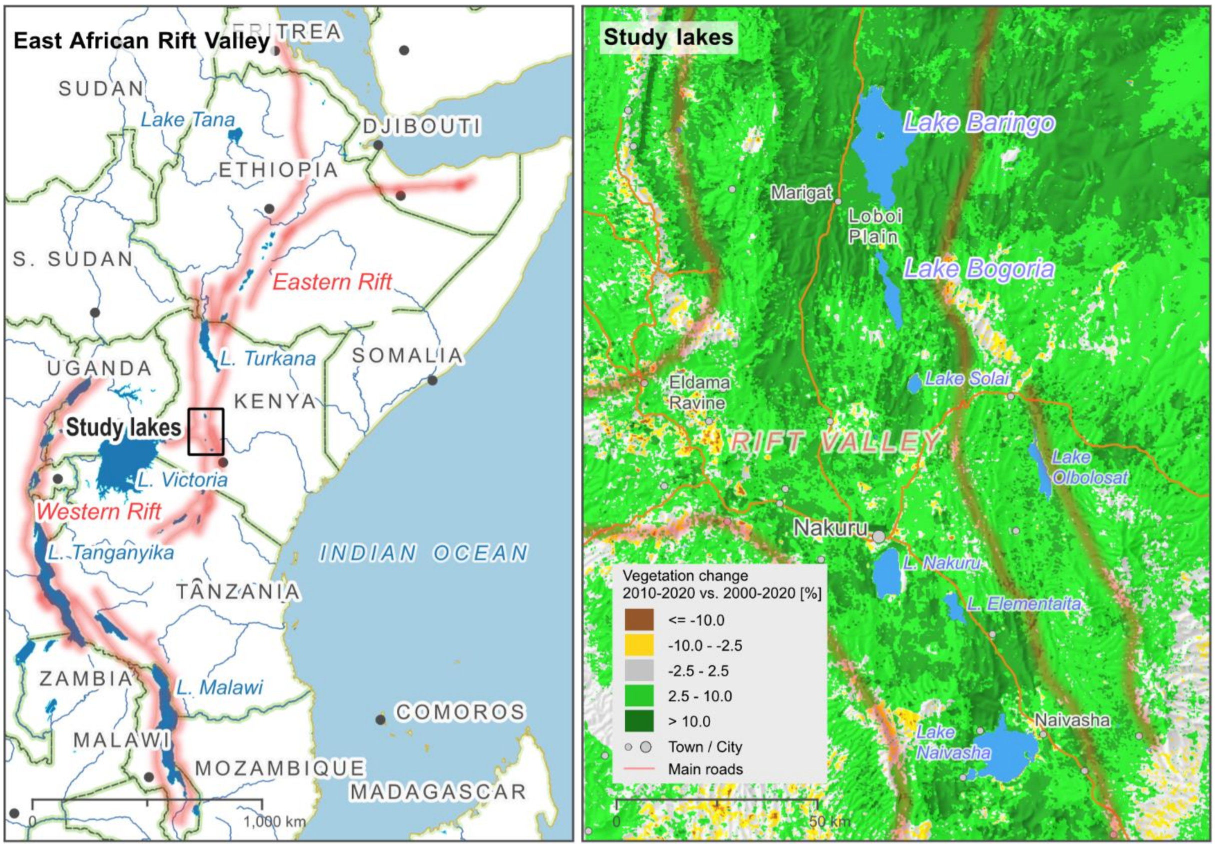

Figure 1: Left: Location of Lake Baringo in the East African Rift Valley. Right: Rift Valley lakes of Kenya. In the background, the vegetation changes between 2010–2020 and 2000-2020 are shown using the Normalized Differential Vegetation Index (NDVI) as a proxy. Around Lake Baringo increases in vegetation of over 10% are visible [Herrnegger et al., 2024].

Although the causes of water level fluctuations have been subject of much speculation, recent studies have shown that the water level fluctuations could be associated with changes in hydro-climatic patterns [Wambui et al., 2021, Herrnegger et al., 2021].

However, and given the ongoing debate about changes in land use and land cover as well as groundwater flow patterns, there remains the need to explore the potential role and effects, and their possible contribution to the lake water level fluctuations if any. In this policy brief, we provide recommendations based on a scoping study undertaken in Lake Baringo between 2020 and 2024. The brief is intended to highlight key findings of the study, as a basis for future works while proving a strong foundation for policy support and appropriate catchment management for the region.

METHODS AND NEW TECHNOLOGIES

[1] DAHITI Database

The Database for Hydrological Time Series of Inland Waters (DAHITI) was used to derive surface areas, water levels and volume variations in Lake Baringo between 1984-2024. The database employs satellite altimetry and hypsometric models to derive the water level variables (Figure 2). DAHITI was developed by the *Deutsches Geo-dätisches Forschungsinstitut der Technischen Universität München* (DGFI-TUM) [Schwatke et al., 2019].

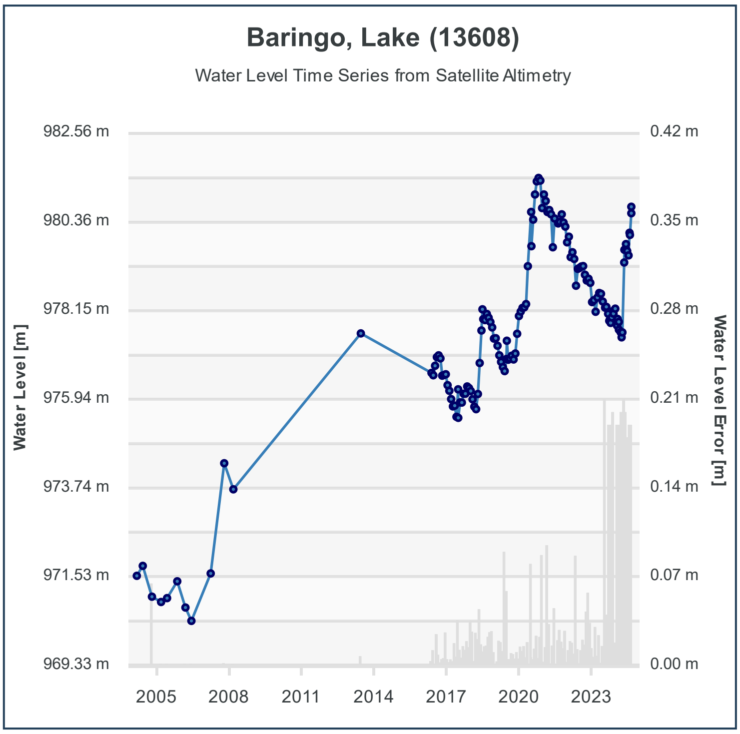

Figure 2: Baringo Water Level from Satellite Altimetry covering 2004 to 1. September 2024. The recent increase in lake level in 2024 is clearly visible.

[2] Drones and Satellite Data

Drone flights (Figure 3) were carried out around Lakes Baringo and Bogoria to capture the elevations and topographic information of selected hot-spots area at very fine resolution (~ 5 cm). This was important to assess the possibility of the two water bodies cross-mixing in cases of large floods. Additionally, the

TanDEM-x Digital Elevation Model (DEM) with a spatial resolution of about 12 m [Wessel, 2018] and other spatial datasets were employed for detailed geomorphological analysis and derivations of lake surface area in cases of water level rises.

Figure 3: Flight preparations of a drone used to acquire high-resolution areal images and terrain information.

The Rainfall Climate Hazards Group InfraRed Precipitation with Station data [CHIRPS; Funk et al., 2015] and ERA5-Land re-analysis datasets were used to derive hydrological variables required for evaluation of the water balances.

[3] The ICR Hydrological Approach

A novel hydrological approach known as the 'Integrated Catchment Response' was developed and applied to relate changes in lake volumes to potential changes in the water balance and inflows over a time period [Herrnegger at al., 2021]. This provided a new way to understand the temporal extent to which the water balance components of the catchment fluctuated, leading to changes in lake volumes.

CONTRIBUTION OF NEW TECHNOLOGIES

[1] Water level fluctuations and Hydro-climatology

Using the novel approaches, it was clear that changes in the lake water levels conformed to changes in the regional hydro-climatic patterns. Trends in the water levels indicated a shift when the magnitudes of the catchment rainfalls increased. In the period 2010−2020, rainfall increased by around 30 % for the Baringo and Bogoria catchments (Figure 4). In Nakuru, Elementaita and Naivasha, the rainfall increases were lower and amount to 21 %, 25 % and 25 % respectively. After 2018, annual rainfall partially increased by even more than 50 %.

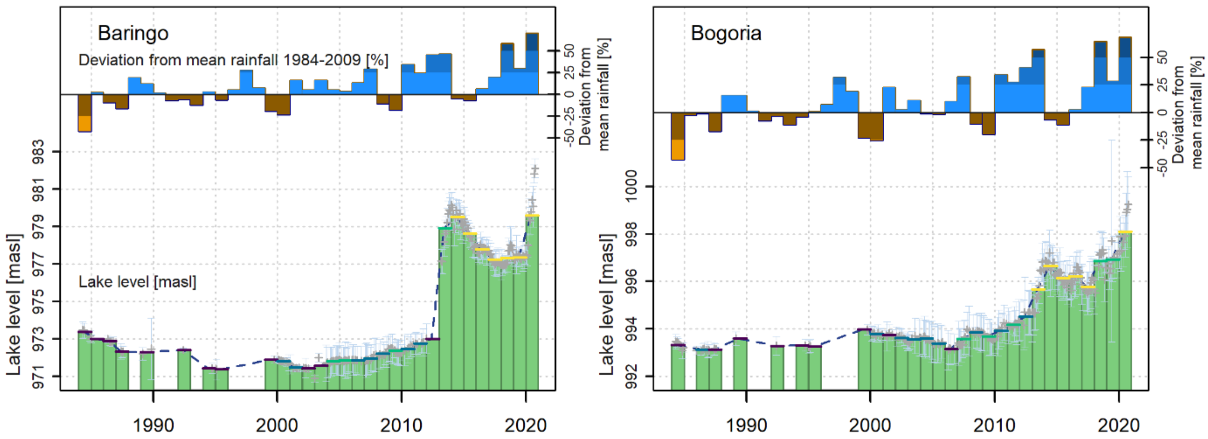

Figure 4: Lake levels and deviation of annual rainfall from the average rainfall 1984-2009 [Herrnegger et al., 2021].

By examining data collected from the Marigat station, located approximately 30 km northwest of Lake Bogoria, substantial shifts in the rainfall quantity and temporal distribution since 2010 are found (Figure 5Figure 4). Mean annual rainfall has more than doubled and the variability has also substantially increased, making planning based on the well-known rainfall seasons more difficult. These extraordinary changes, which have not been previously examined, particularly in relation to the ongoing elevation of lake levels, underscore the unique nature of this hydrometeorological phenomenon in the Rift Valley.

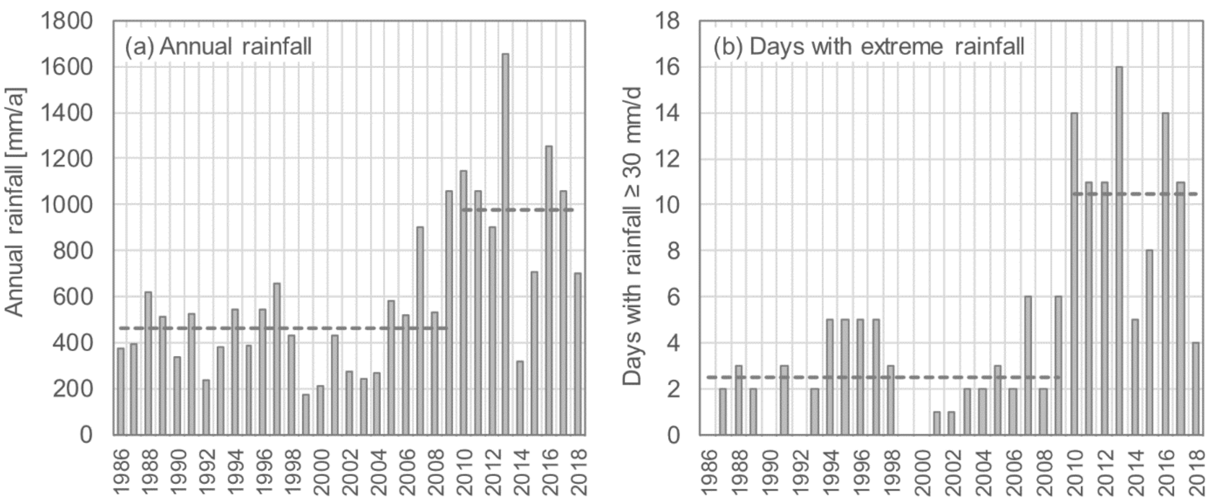

Figure 5: Left: Annual rainfall sums for Marigat. Before the lake level rises, the average annual rainfall in Marigat was 463 mm/a. After 2010, the mean increased to 978 mm/a or +111%. Right: Number of days per year with intense rainfall. Although the number of days with rainfall decreased by around 20% between 1986-2009 and 2010-2018, the days with intense rainfall increased by nearly 320%. The dashed lines show long-term averages of 1986– 2009 and 2010–2018.

[2] Lake Baringo Flood Risk Assessment (FRA)

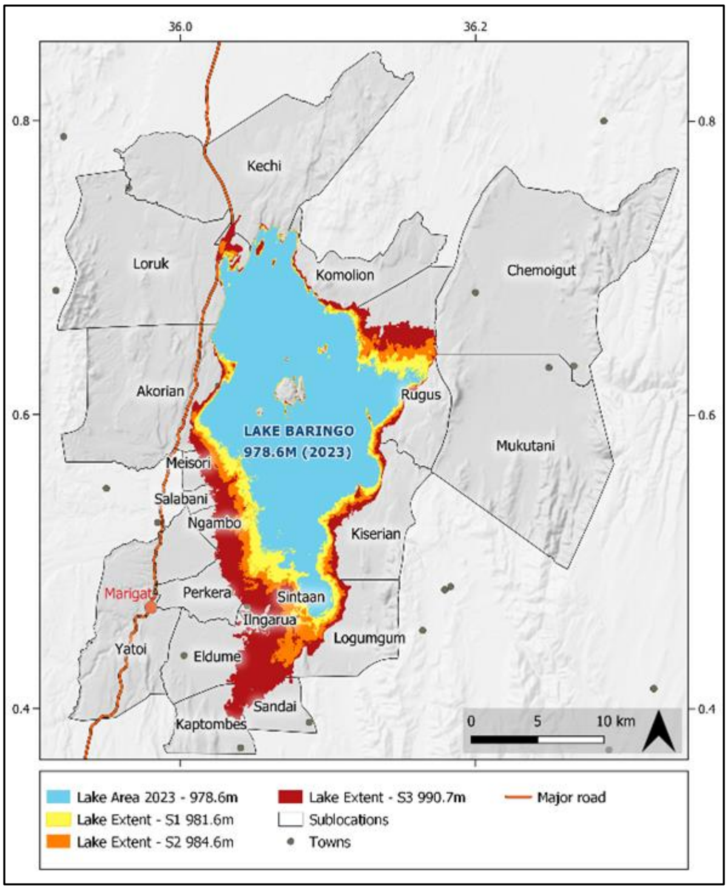

Figure 6: Flood hazard extent for three lake level scenarios [Cherono et al., submitted].

In 2020, floods in the region led to destruction of property (buildings, roads, crops and livestock) estimated to the tune of US$ 906,000. About 80 % of the households in the riparian sub-locations have been affected since 2010, more so in the southern region of the Basin. Flood risk analysis of the area to establish the hazard extent, exposure and vulnerability for three conceptual lake level scenarios indicated that about 19,000 households could be directly affected if the lake water levels rise to the maximum possible height of 990.7 m (sill point of Lake Baringo). Such an increase would lead to an estimated loss of about US$40 million. There is hence the need for adoption of new developed approaches in the county and country at large for use in the management of the affected people, land and water resources.

THE POTENTIAL OF CROSS-MIXING

It was noted that the Lake Bogoria water level rises in 2020 stood at approximately 999.5 m. Relative to this height, a 0.7 m increase in the lake level would have been sufficient for the lake to reach the tipping point elevation of about 1000.2 m, triggering an overflow and cross mixing with Lake Baringo (Figure 7). In 2023, however, the water levels of Lake Bogoria declined by 1.5 m from its highest level in 2020, thereby reducing the risk of such an overflow significantly.

Generally, in Kenya, the average rainfalls are forecasted to decrease under conditions of climate change. However, as climate patterns change, extreme

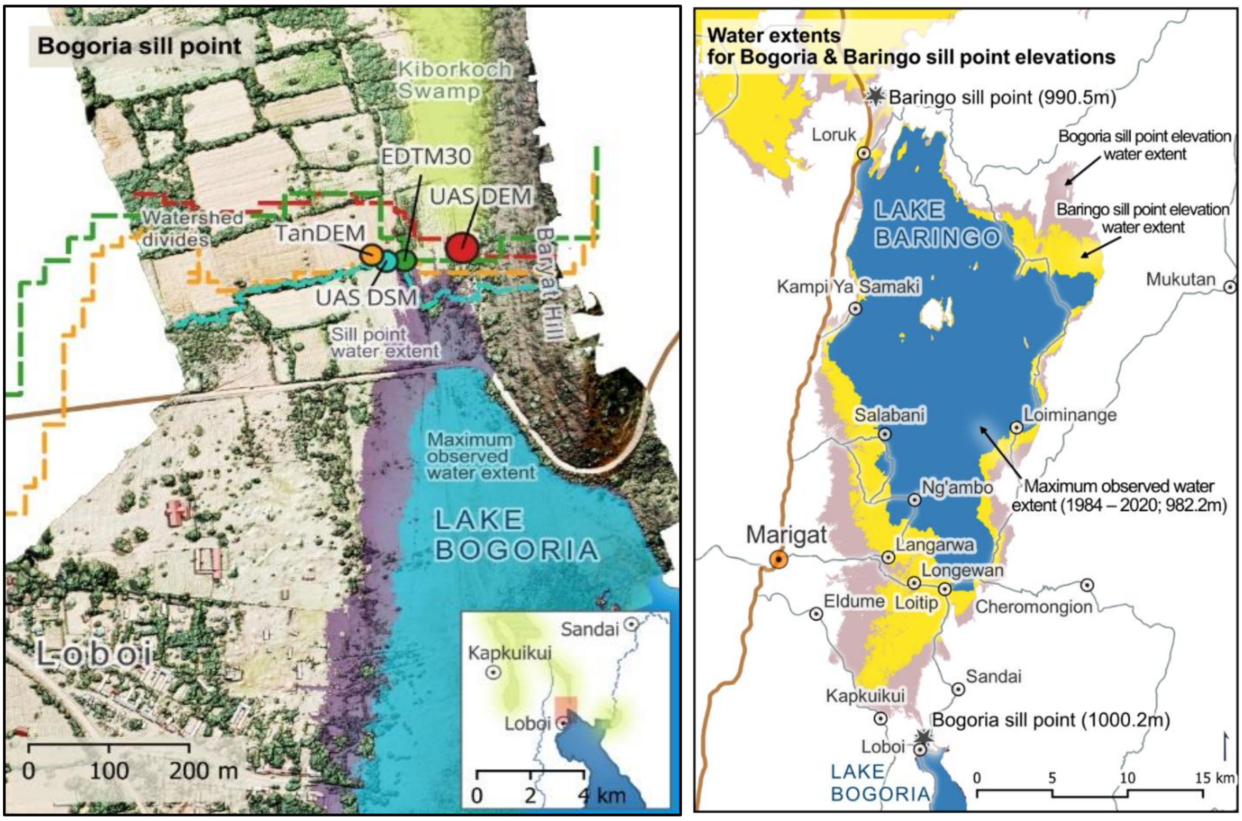

Figure 7: Left: Sill point location in the north of Lake Bogoria. Right: Water extents for Lake Bogoria and Lake Baringo spill point elevations. The water extent of the Lake Bogoria spill point elevation is hypothetical since the spill point elevation of Lake Baringo would be reached earlier and would overflow beforehand [Herrnegger et al., 2024].

rainfall events, which often lead to major floods, are projected to increase, also as witnessed in 2024, which lead to a significant increase of the Lake Bogoria water level. Therefore, the risk of the sill point being exceeded cannot be ruled out. To avoid such eventualities, if any, structural flood mitigation measures may provide a possible option for water resources management.

BARRIERS TO ADOPTION OF NEW TECHNOLOGY

- Lack of trained personnel in the field, coupled with limited cooperation between the affected communities due to security status of the area. This limits communication chains between affected stakeholders and the relevant authorities at local, district and national levels involved in the management of vulnerable water and natural resources.
- Lack of detailed Flood Hazard and Flood Risk Maps as well as missing Flood Management Plans to provide information on potentially affected communities and infrastructure as well as management of the situation in case water levels continue to rise.
- Lack of detailed, locally based tools for continuous in-situ monitoring of hydro-meteorological conditions (river discharge and stage, lake water levels, rainfall and other meteorological variables), but also severe limitations

in data sharing. This is coupled with limited infrastructure to support coordinated data collection, analysis and translation of research results into practice.

- Financial limitations due to allocations to other urgent emerging issues (i.e. poverty reduction) deemed to require urgent intervention by the relevant authorities. This level of neglect may become endemic in the medium to long term.

ACTIONS REQUIRED TO IMPROVE ADOPTION

- Development of Flood Hazard and Flood Risk Maps as well as Flood Management Plans, considering local conditions.
- The need to install and maintain in-situ hydrological sensors capable of measuring river discharge and stage, lake water levels, rainfall and other meteorological variables. Ideally, each sub-catchment should have consistent measurements, including real-time transmission.
- Development and adoption of local approaches that are appropriate to the catchments, and the entire region. This requires the urgent need to develop and maintain the existing data infrastructure for management and sustainability.
- Recognition and greater emphasis on the impacts of climate change and variability on floods, people and infrastructure. This will promote preparedness and prioritization.
- Improved management through the establishment of disaster risk reduction sectors aimed at rapid response in the event of flooding affecting people and property.
- Further research through the development of multi-stakeholder partnerships at local, national, regional and international levels. Such partnerships should be embedded in policy for sustainability beyond the project life cycle

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