KoEF 08/2020

Analysis of Water Level Fluctuations and Implications on local Livelihoods in the Great Rift Valley Lakes of Kenya

GreatLakes

1. Mid-term Scientific Report (short version)

01.09.2021 – 31.08.2022

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Mid-term Scientific Report (short version)

KoEF Research Cooperation Project

Project Overview		
Project Title	Analysis of Water Level Fluctuations and Implications on Local Livelihoods in the Great Rift Valley Lakes of Kenya	
Acronym	GreatLakes	
Project Number	KoEF 08/2020	
Cooperating Countries	Austria / Kenya	
Reporting Period	01.09.2021 – 31.08.2022	
Coordinating Institution	Institute of Hydrology and Water Management, Department of Water, Atmosphere and Environment, University of Natural Resources and Life Sciences, Vienna (BOKU)	
Project Coordinator	Mathew Herrnegger	
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Partner Institution 1	Centre for Integrated Water Resources Management and Department of Biosystems and Environmental Engineering, Technical University of Kenya (TUK)	
Project Co-Coordinator	Luke Olang	
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Project Duration	01.09.2021 – 31.08.2024	
Duration in Months	36	
Branch(es) of Science[1] (max. 3)	Hydrology Climatology Geoinformatics	105304 105204 105403
Contribution to SDGs[2] (max. 3)	• Good Health and Well-being • Access to clean Water and Sanitation • Realization of Sustainable Cities and Communities	SDG-3 SDG-6 SDG-11

[1] http://www.statistik.at/kdb/downloads/pdf/OEFOS2012_EN_CTI_20190903_162012.pdf

[2] https://sustainabledevelopment.un.org/sdgs

Content

Abstracts

The Rift Valley lakes of Kenya are biodiverse ecozones, classified as RAMSAR wetlands of international importance and UNESCO World Heritage Sites. The lakes have witnessed significant water level rises in the last years, inundating the riparian areas. Homes, schools, hospitals, but also the basis for the local livelihoods and economy such as agricultural fields or tourism infrastructure are under water. Nearly eighty thousand households with 400,000 people are affected.

Potential causes are still under debate in the local media. It is speculated that underground seepage, the only outflow from the endorheic lakes, has been reduced by tectonic activities in the geologically highly active Rift Valley. Anthropogenic land degradation, leading to higher erosion and siltation rates, is also argued to have resulted in potential sealing and clogging of the underground water paths. A study by Herrnegger et al. 2021 recently presented evidence that an imbalance due to changes in rainfall and evapotranspiration characteristics, the major hydro-climatic drivers defining the water balance of the lakes, have with high confidence resulted in the lake water level increases.

The signal of rainfall increase must also be visible in changes in discharge and vegetation characteristics. To test these hypotheses, i) an analysis of the spatio-temporal discharge characteristics into the lakes and ii) an analysis of the spatio-temporal vegetation characteristics in the lake watersheds will be performed. Using erosion data from Schürz et al. 2020, iii) an analysis of the potential sedimentation rates and sedimentation depths will be conducted, with the aim to estimate possible effects of anthropogenic land degradation. An ecological catastrophe is expected, if the ongoing water level rises continue unabated, since the alkaline Lake Bogoria and freshwater Lake Baringo may merge. One objective of GreatLakes is therefore iv) an analysis of the overflow potential of Lake Bogoria towards Lake Baringo. To assess the implications of the inundations on local livelihoods and the socio-economic impacts of the lake level rises and to provide guidance for policy and decision makers v) an assessment of Flood Risk and Development of Anticipatory Flood Risk Maps will be conducted. Finally, vi) a prototype of a Hydrological Information System (HIS) for the GreatLakes project will be implemented for supporting better regulation, development and management of the concerned land and water resources.

Die Seen des Rift Valley in Kenia sind artenreiche Ökozonen, die als RAMSAR-Feuchtgebiete von internationaler Bedeutung und als UNESCO-Welterbestätten eingestuft sind. Die Seen haben in den letzten Jahren einen erheblichen Anstieg des Wasserspiegels erfahren, wodurch die umgliegenden Gebiete überflutet wurden. Häuser, Schulen, Krankenhäuser, aber auch Lebens- und Wirtschaftsgrundlagen wie landwirtschaftliche Flächen oder touristische Infrastrukturen stehen unter Wasser. Fast achtzigtausend Haushalte mit 400.000 Menschen sind betroffen.

Über mögliche Ursachen wird noch diskutiert. Es wird vermutet, dass die unterirdische Versickerung, der einzige Abfluss aus den endorheischen Seen, durch tektonische Aktivitäten im geologisch sehr aktiven Rift Valley verringert wurde. Auch anthropogene Landnutzungsänderungen, die zu höheren Erosions- und Verlandungsraten führt, könnte zu einer möglichen Versiegelung und Verstopfung der unterirdischen Wasserwege geführt

haben. Eine Studie von Herrnegger et al. 2021 hat vor kurzem Beweise dafür vorgelegt, dass ein Ungleichgewicht aufgrund von Veränderungen der Niederschlags- und Evapotranspirationscharakteristika, den wichtigsten hydroklimatischen Faktoren, die den Wasserhaushalt der Seen bestimmen, wahrscheinlich zu einem Anstieg des Wasserspiegels der Seen geführt hat.

Das Signal der zunehmenden Niederschläge muss sich auch in den Veränderungen des Abflusses und der Vegetationseigenschaften niederschlagen. Um diese Hypothesen zu überprüfen, wird i) eine Analyse der räumlich-zeitlichen Abflusscharakteristika und ii) eine Analyse der raum-zeitlichen Vegetationscharakteristika in den Einzugsgebieten der Seen durchgeführt. Unter Verwendung von Erosionsdaten aus Schürz et al. 2020 wird iii) eine Analyse der potenziellen Sedimentationsraten und Sedimentationstiefen durchgeführt, um mögliche Auswirkungen der anthropogenen Landdegradation abzuschätzen. Eine ökologische Katastrophe wird erwartet, wenn der anhaltende Anstieg des Wasserspiegels unvermindert anhält, da der alkalische Bogoria-See und der Süßwassersee Baringo verschmelzen könnten. Ein Ziel von GreatLakes ist daher iv) das Überlaufpotenzials des Bogoria-Sees in den Baringo-See zu analysieren. Um die Auswirkungen der Überschwemmungen auf die lokalen Lebensgrundlagen und die sozio-ökonomischen Folgen des Anstiegs des Seespiegels zu bewerten und der Politik und Entscheidungsträgern eine Orientierungshilfe zu geben, werden v) eine Bewertung des Hochwasserrisikos und die Entwicklung von vorausschauenden Hochwasserrisikokarten durchgeführt. Schließlich wird vi) ein Prototyp eines hydrologischen Informationssystems (HIS) für das GreatLakes-Projekt eingeführt, um eine bessere Regulierung, Entwicklung und Verwaltung der betroffenen Land- und Wasserressourcen zu unterstützen.

Narrative summary of the project

Background and motivation

In the recent past, there has been renewed calls by concerned local and international stakeholders on the rising water levels of the Great Rift Valley lakes of Kenya, inundating the surrounding areas thereby affecting ecological goods and services, and local livelihoods. Because many of the effected regions are biodiverse eco-zones, classified as UNESCO World Heritage Sites and RAMSAR Wetlands of international importance, there is furthermore renewed fear of an ecological catastrophe should the alkaline Lake Bogoria and freshwater Lake Baringo get merged from the ongoing inundations. Proxy evidence for the period 2010-2020 revealed increases in the inundated areas between 21 % and 123 % for Lakes Naivasha and Solai, respectively, when compared to changes in the period between 1984 - 2009. Herrnegger et al. (2021) have further illustrated that the mean annual rainfalls, over the same period, have increased by up to 30 %, with minimal increases of the actual evapotranspiration. The consequence of the water level changes has been huge, including submergence of local homes, schools and hospitals – supporting day-to day local livelihoods. The existing agricultural fields, tourism infrastructure and according to a governmental report about eighty thousand households and 400,000 people are equally been affected - directly or indirectly.

In this regard, and the dire need to put in place mitigate measures, strategic meetings have been organized by the Government of Kenya with a view to develop policy documents aimed managing the water level rises. Concerned experts have argued for possible geologic, anthropogenic and/or hydro-climatic reasons as possible causes of the water rises. Geologically, it has been speculated that underground seepage, the only outflow from the endorheic lakes, has been reduced by tectonic activity in the geologically highly active Rift. Changes in anthropogenic activities leading to land degradation is also argued to have resulted in potential sealing and clogging of the underground water paths due to higher siltation rates and increased sedimentation. The imbalance due to changes in rainfall and actual evapotranspiration characteristics, the major hydro-climatic drivers defining the water balance of the lakes, is also argued to have resulted in the lake water level fluctuations.

Objectives

A study by Herrnegger et al. 2021 recently presented evidence that an imbalance due to changes in rainfall and evapotranspiration characteristics, the major hydro-climatic drivers defining the water balance of the lakes, have with high confidence resulted in the lake water level increases. The signal of rainfall increase must also be visible in changes in discharge and vegetation characteristics. To test these hypotheses, i) an analysis of the spatio-temporal discharge characteristics into the lakes and ii) an analysis of the spatio-temporal vegetation characteristics in the lake watersheds will be performed. Using erosion data from Schürz et al. 20203, iii) an analysis of the potential sedimentation rates and sedimentation depths will be conducted, with the aim to estimate possible effects of anthropogenic land degradation. An ecological catastrophe is expected, if the ongoing water level rises continue unabated, since the alkaline Lake Bogoria and freshwater Lake Baringo may merge. One objective of GreatLakes is therefore iv) an analysis of the overflow potential of Lake Bogoria towards Lake Baringo. To assess the implications of the inundations on local livelihoods and the socio-economic impacts of the lake level rises and to provide guidance for policy and decision makers v) an assessment of Flood Risk and Development of Anticipatory Flood Risk Maps will be conducted. Finally, vi) a prototype of a Hydrological Information System (HIS) for the GreatLakes project will be implemented for supporting better regulation, development and management of the concerned land and water resources.

Narrative summary of project activities in the reporting period

The GreatLakes project commenced on 01.09.2021 and the current report documents one year of project activities from the commencing date until 31.08.2022. In summary, the first year was quite successful. In total, 11 travels and field visits were conducted by six team members. Work has commenced to meet the objectives above and plans are available for future progress.

The first online meeting between BOKU and TUK was held on 09.09.2021. Updates and meetings have taken place on a very regular basis, leading to a total of 16 meetings held in the first year. The aim of the meetings was to elaborate and discuss project objectives, topics and objectives of (PhD) students, financing of activities, general progress and issues and to guarantee that all team members have the same level of information. Regarding the funding scheme of KoEF and the focus on financing mobilities, an important task was also to plan objectives and logistics of the field trips and travels.

The first travel to Kenya by team members Gabriel Stecher and Mathew Herrnegger was accomplished in October 2021. COVID restrictions proofed to be no big issue and did not limit the activity. The aim of the reconnaissance mission was to meet project partners, to visit the study area and lakes, to perform measurements and to check reliability of river gauging stations and of satellite data on land cover, to pave the road to acquire hydrometeorological data and to meet potential stakeholders. Following a meeting with the team and the Deputy Vice-Chancellor for Academics, Research & Students of The Technical University of Kenya Paul Shiundu (Figure 1), the team continued to the study area. Lakes visited included Naivasha, Olbolosat, Solai, Nakuru, Bogoria and Baringo (Figure 3, Figure 8, Figure 9). Since data from river gauging stations (RGS) are going to be used (mainly objective i)), it was also important to visit RGSs in the study area, simply to assess the potential quality of the discharge time series (Figure 4, Figure 7, Figure 8, Figure 10, Figure 15). The team was joined by Dominic Wambua, a Water Resources Specialist at Assessment and Monitoring at the Ministry of Water and Sanitation. He performed hydrological measurements in the Rift Valley for many years and helped in compiling station lists and potential data relevant for GreatLakes. Also, the team logistically supported Vincent Odongo, currently a Postdoctoral Scientist at the International Livestock Research Institute in Nairobi, in retrieving water level measurements in Lake Baringo and Bogoria (Figure 3, Figure 5, Figure 6). Substantial support to the team was provided by Dennis Otieno, community leader and chairman of the Lake Baringo Information, Boat Tours and Divers self-help group. Gabriel Stecher was engaged in measuring electrical conductivity and temperature in visited water bodies, but also in qualitatively verifying satellite derived land cover data (objective ii and iii); Figure 2, Figure 8).

In February 2022, Thomas Pulka, who was nominated as an additional team member from

Austria, Gabriel Stecher and Mathew Herrnegger travelled to Kenya. The objectives included meeting with project partners and stakeholders, but also to again verify the quality of potential hydrometeorological measurement stations (objective i); Figure 15). Additionally, the team was joined by Peter Odwe, a Geospatial Engineer & UAV Mapping Expert and his assistant Fredrick Onyango from the School of Survey and Geospatial Sciences of The Technical University of Kenya. For objective iv) and v), very high-resolution digital surface models (DSM) are required and the plan was to acquire this data with an unmanned aerial vehicle (UAV) or drone. The team, with Sospeter Wekesa from TUK, met in Kampi Ya Samaki on 8 February 2022, where the first flight was successfully performed, also being an exciting event for the many bystanders and children of the community (Figure 11). On 9 February 2022 further flights were planned in detail for the northern area of Lake Bogoria around Loboi and Lorwok. The first data acquisitions and flight hours went very smooth (Figure 12). Unfortunately, the euphoric atmosphere changed instantaneously when the drone experienced a technical error and disappeared from the screen. After reconstructing the last known position and the potential crash site located at the south-eastern corner of the now flooded Loboi Health Center, around 350 m from the shore, a search and rescue mission was initiated. Young adults from the community volunteered to search, swimming in the alkaline water (and then asking for compensation), a boat was organized from Kampi Ya Samaki at Lake Baringo – around 50 minutes' drive in one direction. Higher ground was climbed to visually search for the crashed drone (Figure 13, Figure 14). All efforts were not successful. After a very long day, the mission was aborted and the search continued in the early morning of 10 February, which now included an extensive and systematic search by boat. Although the potential crash site was flooded, our hope was that the drone crashed onto one of the branches of scrubs and bushes, which were still above the water line. Luck was not on our side and the drone and data remained lost.

The team still visited the Waseges River Gauge 2EB10 (Figure 15) and the southern areas of Lake Baringo before heading back to Nakuru and Nairobi. Thomas Pulka stayed in Nairobi until 25 February and was responsible for the development and programming of a prototype of the GreatLakes Hydrological Information System (https://boku-hywa.shinyapps.io/GreatLakes_WebApp/) at TUK (Figure 16). One objective of the project is to make the knowledge gained from the hydro-meteorological analyses and project results available to the public with the help of a Hydrological Information System (HIS). The communication of the research results in this way will support the regulation, development and management of the affected land and water resources. The HIS is in a prototype stage and it is anticipated to add results generated in the project with time.

From 25 - 28 May, Sospeter Wekesa and the newly nominated team member Nelly Cherono, visited the field with the objectives of (i) stakeholder consultations (Figure 18) and collection of relevant information, (ii) administration of key informants' questionnaires, (iii) acquisition of hydro-meteorological data and (iv) support for the drone flights (Figure 17). The stakeholders consulted include:

a) County Government of Baringo (Kabarnet)
b) Kenya Marine and Fisheries Research Institute (Marigat)
c) Kenya Coast Guard Service (Kampi ya Samaki)
d) Kenya Fisheries Department (Kampi ya Samaki)
e) Water Resources Authority (Kabarnet)

f) Baringo Tourism Department (Kampi ya Samaki)

A brief discussion with the stakeholders was done on some of the causes and effects of the rising levels of water in Lake Baringo and Lake Bogoria. The discussion included a short presentation to the Baringo County Government officials about the Great Lakes Project and its objectives. Key informants' questionnaires were also administered but all the stakeholders had busy schedules and thus requested to be left with the questionnaires so that they fill them at their convenience and send them via email. Hydro-meteorological data was obtained from Water Resources Authority in Kabarnet. The data obtained include: River discharge data and rainfall data. The data officer reported that the sedimentation data is available but in hard copy since the officer handling it is sick and has been on long term leave. Although the drone flights were delayed due to required documentation from the County, the team managed to collect data for two sites, as was planned. This included areas around Loboi and Logumukum.

Luke Olang visited Austria in July/August 2022 in the framework of GreatLakes. The aims of his visit included the preparation of this mid-term report, development and formulation of the work plan and objectives of the PhD students and the preparation of a framework for possible publications.

Apart from these summarized activities in the field, the team was also engaged in other work related to the project, which included the engagement of (graduate) students. Sospeter Wekesa and Nelly Cherono formulated their PhD objectives and workplan, with several iterations between Luke Olang and Mathew Herrnegger. Nelly Cherono successfully presented and defended her PhD proposal “Assessment of Causations of Water Level Fluctuations in the Great-Rift Valley Lakes of Kenya: The Case of Lake Baringo River Basin” at the School of Infrastructure and Resource Engineering on 31 May 2022 and in front of the Board of Post Graduate Studies on 26 June 2022. Sospeter Wekesa was engaged in the acquisition of the hydrometeorological data from different institutions. Currently, the acquired data sets are being processed and analysed. On 4 May Pierre Kray presented his Master Thesis topic on “Analysis of the potential overflow from Lake Bogoria towards Lake Baringo”, which is conducted within the framework of GreatLakes, at the MSc/PhD seminar of the Institute of Hydrology and Water Management. The aim is to finish the thesis by March/April 2023. The Master students Jürgen Rieger and Manuel Gartner are currently working on the “Assessment of temporal vegetation trends in watersheds of Rift Valley Lakes in Kenya” in the course of “Structural Exercises” of BOKU.

Mathew Herrnegger presented on “Hydroclimatic Analysis of Rising Water Levels in the Great Rift Valley Lakes of Kenya” (before the official project start on 08.06.2021) and “Ludwig von Höhnel and the Geography of Kenya at the end of the 19th Century” on 21 June 2022 at the MSc/PhD seminar of the Institute of Hydrology and Water Management. These works were (partially) done within GreatLakes and are related to the objectives of GreatLakes.

After several externl inquiries about the project and its aims, a Fact Sheet was prepared, which is available for download via the GreatLake HIS and the KoEF website of the project.

High-resolution terrain data is important for the research of GreatLakes (e.g. objective v)). Therefore, the proposal “Generation of anticipatory flood risk maps for the improvement of local livelihoods in the Great Rift Valley Lakes of Kenya” with the ID DEM_HYDR3478 was submitted to the German Aerospace Center (DLR). The proposal was successful and provides the project with a very high-resolution DEM covering the total study area. The acquisition would normally cost 10 000s of Euros. Also in this context, Gabriel Stecher was engaged in GIS analysis for the project (e.g. catchment and stream network delineation) and also performed analysis of the different DEMs, which are currently at our disposal.

Overall and although difficulties existed (see later sections in this report), the first project year was successful in fulfilling the objectives of the project.

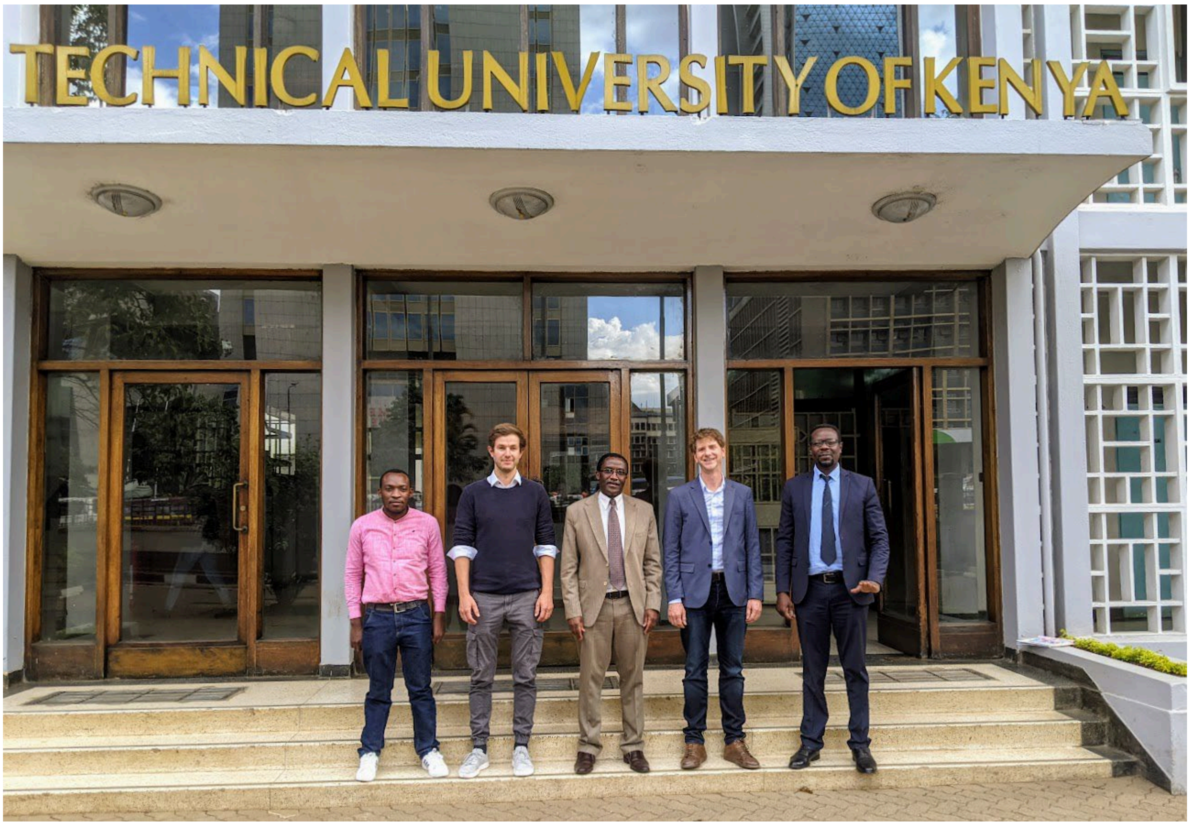


Figure 1: Meeting of team members with Deputy Vice-Chancellor (Academics, Research & Students) of The Technical University of Kenya Paul Shiundu on 22.10.2021

Figure 2: Electrical conductivity and water temperature measurements – Lake Bogoria (24.10.2021)

Figure 3: Lake Baringo: Flooded Soi Safari Lodge, incl. crocodile (left); retrieving water level measurements (right) (25./26.10.2021)

Figure 4: Perkerra River gauging station (2EE7B, left); Njoro River at Egerton University river gauging station (2FC19, right) (25.10.2021)

Figure 5: Organising a rubber boat at the Water Resources Authority in Nakuru (26.10.2021)

Figure 6: Retrieving water level measurement data in Lake Bogoria (26.10.2021)

Figure 7: Molo River Gauging Station (2EG03), including discussions with observer Silvester Maitano (26.10.2021)

Figure 8: Lake Solai (top left), Maji Matamu (2EA01, top right), Lake Olbolosat (bottom left & right), (27.10.2021)

Figure 9: Flooded trees and tented camp at Lake Naivasha (top), Rainfall measurement (bottom left) and water level measurement at Lake Naivasha Yacht Club (bottom left & right), (28.10.2021)

Figure 10: Malewa River gauging station (2GB05) (28.10.2021)

Figure 11: UAV flight preparations at Kampi Ya Samaki (top); areal image of the Lake Baringo in Kampi Ya Samaki, including submerged and damaged buildings (08.02.2022)

Figure 12: UAV flight preparations on a hill above Loboi (left); Lake Bogoria, including submerged trees and buildings (right) (09.02.2022)

Figure 13: Lake Bogoria: Drone search and rescue mission (top); potential crash site located at the south-eastern corner of the now flooded Loboi Health Center, around 350 m from the shore (bottom) (09/10.02.2022)

Figure 14: Lake Bogoria: Submerged Loboi Health Center (top); Destroyed pit latrines (bottom) (10.02.2022)

Figure 15: Waseges River gauging station 2EB10 in Sandai (top); Inlet for the Sandai irrigation scheme (bottom) (10.02.2022)

Figure 16: Thomas Pulka, who developed the GreatLakes Hydrological Information System prototype together with colleagues from TUK


Figure 17: UAV based data acquisition (27.05.2022)

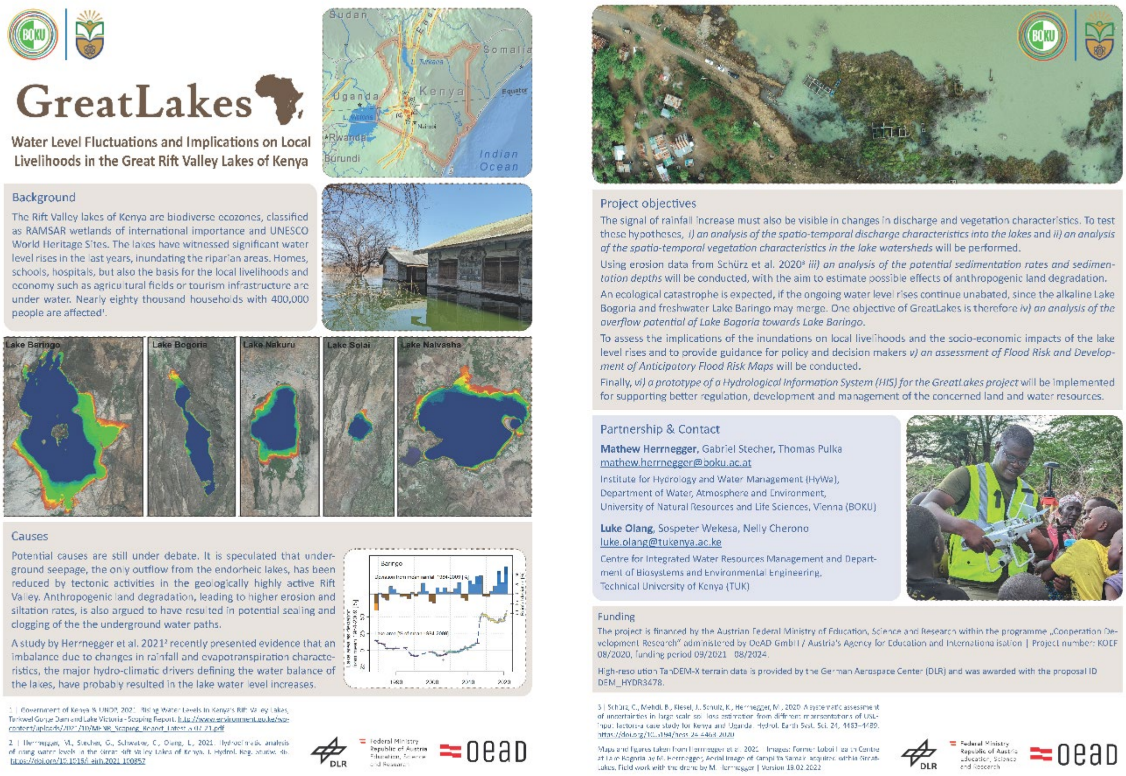

Figure 18: Meeting at the County Government of Baringo Offices in Kabarnet (left; 26.05.2022); Silted and destroyed school in Logumukum (right; 28.05.2022)

Overview of completed and started activities

This section gives a more detailed overview of completed and started activities and is an extension to the summary of project activities given above.

FACT SHEET

After several external inquiries about the project and its aims, a fact sheet was prepared (Figure 19). It is also available for download via the GreatLakes HIS and the KoEF website of the project.



GreatLakes

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

Background

The Rift Valley lakes of Kenya are biodiverse ecozones, classified as RAMSAR wetlands of international importance and UNESCO World Heritage Sites. The lakes have witnessed significant water level rises in the last years, inundating the riparian areas. Homes, schools, hospitals, but also the basis for the local livelihoods and economy such as agricultural fields or tourism infrastructure are under water. Nearly eighty thousand households with 400,000 people are affected[1].

Lake Baringo | Lake Bogoria | Lake Nakuru | Lake Solai | Lake Naivasha

Causes

Potential causes are still under debate. It is speculated that underground seepage, the only outflow from the endorheic lakes, has been reduced by tectonic activities in the geologically highly active Rift Valley. Anthropogenic land degradation, leading to higher erosion and siltation rates, is also argued to have resulted in potential sealing and clogging of the the underground water paths.

A study by Herrnegger et al. 2021[2] recently presented evidence that an imbalance due to changes in rainfall and evapotranspiration characteristics, the major hydro-climatic drivers defining the water balance of the lakes, have probably resulted in the lake water level increases.

Project objectives

The signal of rainfall increase must also be visible in changes in discharge and vegetation characteristics. To test these hypotheses, *i) an analysis of the spatio-temporal discharge characteristics into the lakes* and *ii) an analysis of the spatio-temporal vegetation characteristics in the lake watersheds* will be performed.

Using erosion data from Schürz et al. 2020[3] *iii) an analysis of the potential sedimentation rates and sedimentation depths* will be conducted, with the aim to estimate possible effects of anthropogenic land degradation.

An ecological catastrophe is expected, if the ongoing water level rises continue unabated, since the alkaline Lake Bogoria and freshwater Lake Baringo may merge. One objective of GreatLakes is therefore *iv) an analysis of the overflow potential of Lake Bogoria towards Lake Baringo*.

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Finally, *vi) a prototype of a Hydrological Information System (HIS) for the GreatLakes project* will be implemented for supporting better regulation, development and management of the concerned land and water resources.

Partnership & Contact

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

Figure 19: Fact sheet of the GreatLakes Project

DATA COLLECTION

Hydrometeorological Data

Significant effort has been invested in acquiring hydrometeorological data. This included meeting different responsible persons at different institutions, checking reports from NGOs, donor organisations and governmental institutions, but also visiting the river gauging stations in the area to know what data quality to expect. Table 1 shows a list of discharge and water level measurement stations, for which data was requested for. Currently, the received files are being processed and analysed.

Table 1: Station list of hydrological stations

Lake	Waterbody	ID
Lake Bogoria	Lake	2EB07
Lake Bogoria	Lake	2EB10
Lake Bogoria	Lake	2EB01
Lake Bogoria	Wasenges	2EB06
Lake Bogoria	Wasenges	2EB8
Lake Baringo	Lake	2EH01
Lake Baringo	Lake	2EH1
Lake Baringo	Molo	2EG01
Lake Baringo	Molo	2EG03
Lake Baringo	Molo	2EG3*
Lake Baringo	Rongai	2EC02
Lake Baringo	Rongai	2EC03
Lake Baringo	Rongai	5BC05
Lake Baringo	Pekerra	2EE7A
Lake Baringo	Pekerra	2EE7B
Lake Baringo	Pekerra	2EE07A
Lake Baringo	Pekerra	2EE07B
Lake Baringo	Pekerra	2EE08
Lake Baringo	Endau	2EH03
Lake Nakuru	Lake	2FC04
Lake Nakuru	Lake	2FC4
Lake Nakuru	Enderit	2FC12
Lake Nakuru	Njoro	2FC06
Lake Nakuru	Njoro	2FC05
Lake Nakuru	Njoro	2FC16
Lake Nakuru	Njoro	2FC19
Lake Nakuru	Makalia	2FC11
Lake Nakuru	Baharini Springs	2FC

Lake	Waterbody	ID
Lake Elementaita	Lake	2FA10
Lake Elementaita	Mereroni	2FA09
Lake Elementaita	Mereroni	2FA08
Lake Elementaita	Mereroni	2FA8
Lake Naivasha	Lake	2GD06
Lake Naivasha	Lake	2GD6
Lake Naivasha	Karati	2GD02
Lake Naivasha	Malewa	2GB01
Lake Naivasha	Malewa	2GB02
Lake Naivasha	Malewa	2GB05
Lake Naivasha	Malewa	2GB03
Lake Naivasha	Turasha	2GC04
Lake Naivasha	Gilgil	2GA01
Lake Naivasha	Gilgil	2GA03
Lake Naivasha	Little Gilgil	2GA06

TanDEM-X

High-resolution digital terrain data is necessary for the work in GreatLakes. The German Aerospace Center (DLR) provides a 12-m DEM, which is however very costly. Therefore, a proposal “Generation of anticipatory flood risk maps for the improvement of local livelihoods in the Great Rift Valley Lakes of Kenya” was submitted to DLR and was awarded with the proposal ID DEM_HYDR3478. The high-resolution TanDEM-X terrain data is and will be used for mapping, delineating watersheds and rivers, but also in objective v)).

UAV-based data collection

The aim of the unmanned aerial vehicle (UAV) usage in this project is to derive very high-resolution digital surface models (DSM) as well as digital elevation models (DEM) for selected areas in the project area. Publicly available digital elevation models covering Kenya have coarse resolutions, ranging from 90 by 90 (MERIT) to 30 by 30 (SRTM) meters. However, for the project area we were able to acquire the TanDEM-X elevation model (see above), which provides a resolution of 12 meters per grid cell. While these products suite very well for most purposes (e.g. watershed delineation), we face limitations for some specific objectives of the project due to the low resolutions. Therefore, the derivation of high-resolution DEM from UAV´s is required for the detailed flood risk assessment for selected areas as well as for the assessment of the potential overflow risk of Lake Bogoria towards Lake Baringo.

Case studies

Since the UAV based data acquisition is limited by the possible overflown area, case study sites within the project area had to be selected. The three selected case study sites are located along the shores of Lake Baringo and Lake Bogoria. These areas are strongly affected by the rising water levels (Figure 20).

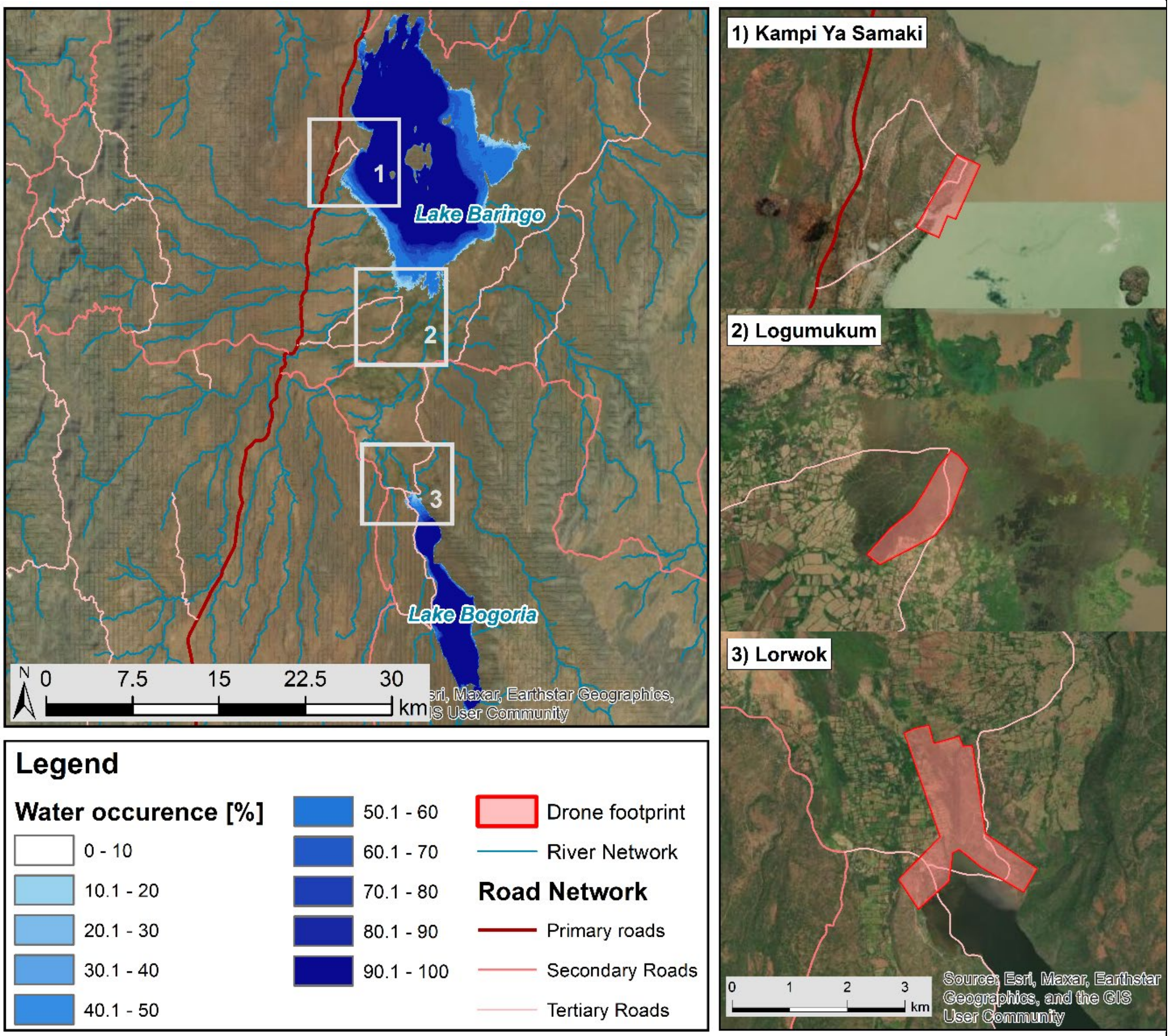

Figure 20: Study area of the selected UAV based data collections (left); UAV covered footprints (right

In Figure 20 an overview of the covered areas is shown. Kampi Ya Samaki is located on the western shore of Lake Baringo. In this settlement multiple private settlements including farming grounds, roads, and two Safari lodges are affected by flooding due to the increasing water levels. Additionally, the local hospital/health center was flooded and abandoned due to the flooding. Logumukum, at the southern shore of Lake Baringo, is another example of how the continuous flooding and resulting losses of land and infrastructure affect societies in the area. Apart from private settlements, agricultural land, roads, buildings and yards of a primary and secondary school are submerged. The third area covers parts of Loboi/Lorwok and the area north of Lake Bogoria. The area to the north of the lake covers the possible point of the potential overflow of Lake Bogoria. In Loboi the flooding caused the loss of multiple private houses, roads and infrastructure, as well as the loss of the local health center. Additionally, the main road to the Lake Bogoria National Reserve had to be abandoned and rebuild due to the rising lake levels.

Data collection

After intensive preparations and coordination with our colleagues from the Technical University Kenya in autumn 2021 we planned to carry out the drone flights and the data collection in February 2022. During the preparation period we acquired the needed licenses of the Kenya Civil Aviation Authority (KCAA) to conduct the UAV based data collection. Since the area is outside of the National Reserve, we did not acquire the licenses from and the Kenya Wildlife Service (KWS). The aim was to first test and then use the UAV at all selected study areas to collect the data needed to derive the high-resolution DEM. In Figure 21 some impressions right before our first flight mission in Kampi Ya Samaki are shown.

Figure 21: Establishing the UAV landing and take-off site (left); set up of the GNSS Modul (right)

The first test flight and data collection were successfully carried out on 8 February 2022. The next day we started collecting data with the UAV in Loboi/Lorwok. During the data collection some serious failure of the drone occurred and the drone crashed while flying. After the crash we immediately searched the possible area of the crash extensively using the GPS track of the drone. Since the last recorded GPS point was located above the water surface it was very likely that the UAV sunk into the water. Even after two days of extensive search we were not able to locate and retrieve the collected data and drone. Without the drone we were not able to collect all the UAV data for the other areas as planned. The data collection of the remaining areas was therefore conducted by our colleagues from TUK during the field work in May 2022. Here we were able to gather the data needed to derive the high-resolution DEM for Lorwok and Logumukum.

Derived data

Based on the derived orthophotos during the data collection field work it is possible to calculate the DEM in a postprocessing step. To derive the DEM we used the very well know software Agisoft. Depending on the UAV flight height the derived DEM shows a resolution between 4 to 6 cm per pixel. This allows us to investigate the topography in a very high detail. Especially, buildings, walls, roads and other infrastructure are represented very accurately. Also, other features of the landscape (e.g. hills) are represented in a very high detail. This will be an advantage compared to the other available DEM`s (MERIT; SRTM TanDEM-X), especially to derive anticipatory flood risk maps. In Figure 22 below, a comparison of the different data showing terrain elevation is represented for the Loboi/Lorwok area.

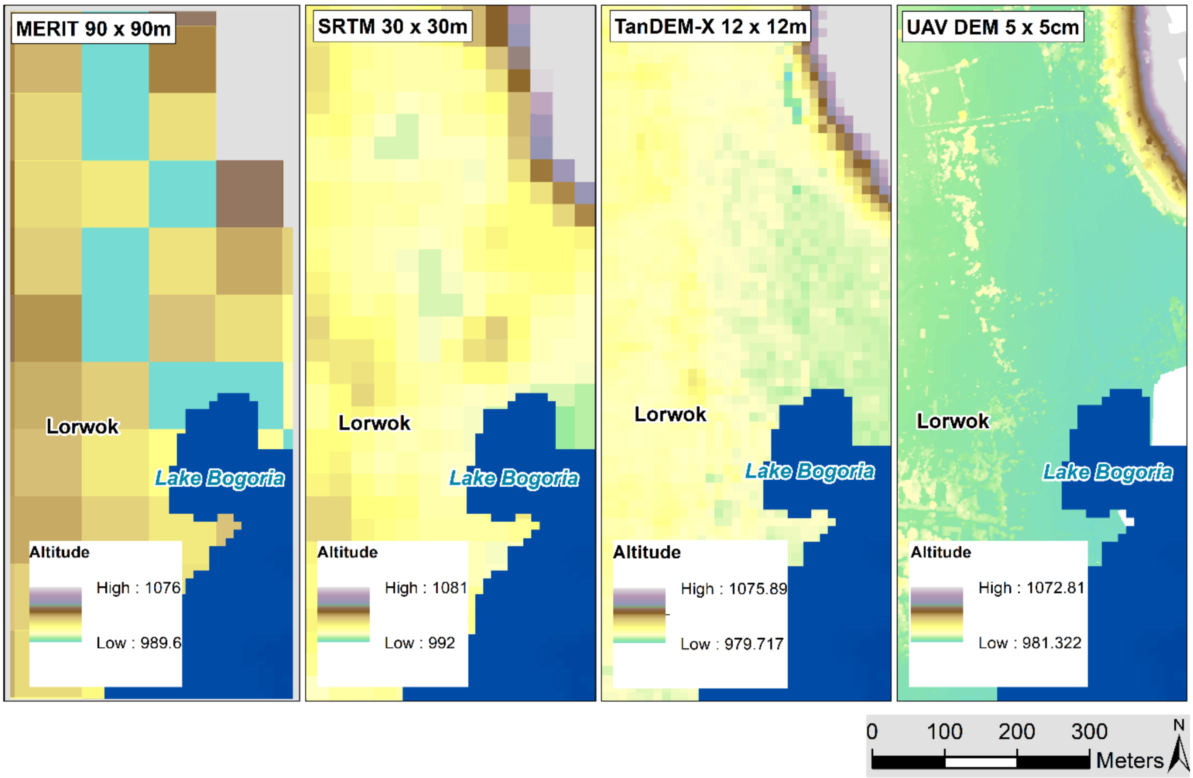

Figure 22: Comparison of the available DEM´s with the UAV based DEM

In Figure 23, the three-dimensional dense point cloud, based on the collected orthophotos is shown. They were computed in the highest possible accuracy. The created point clouds serve as a basis for the calculation of the high-resolution DEM for the selected areas. The final resolution of the individual DEM´s are 4.22 cm at Kampi Ya Samaki, 4.35 cm in Lorwok and 5.1 cm in Logomukum. The slight differences for the individual areas can be explained by various factors, including flight height of the drone or the time of the flight. In Figure 23, the previously flooded areas as well as the flooded areas at the time of the data collection are clearly visible. In Loboi/Lorwok, the previously flooded shores (brownish area) and the abandoned buildings as well as the flooded main road can be seen. Likewise, similar areas are present in Kampi Ya Samaki and Logomukum. At the Logomukum UAV scene one can also see the submerged school building (large u-shaped) and flooded roads.

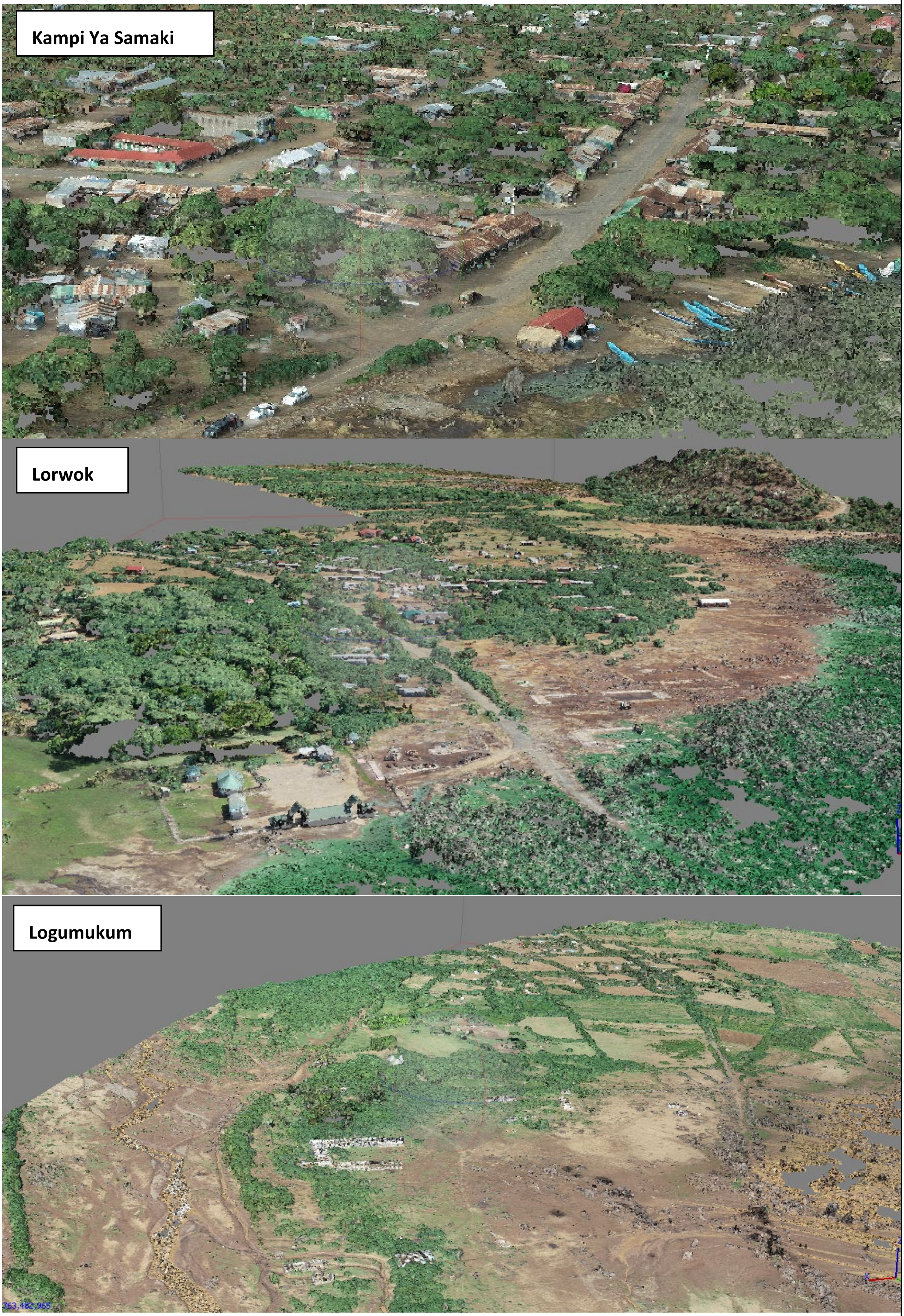

Figure 23: Three-dimensional illustration of the selected areas

ENGAGEMENT OF GRADUATE STUDENTS

PhD Students

Currently, two students from the TU-K have been engaged as PhD students to undertake their studies with partial support from the project funds. The support includes provision of funds for fieldwork data collection and participation in student exchange visits at the BOKU to gain further insights and delve further into their specialized topics of study. Gender considerations were made in the selection of the students, with one female and one male applicant filtered for the opportunity. The study titles, objectives and current status of study of the selected students are as follows:

Nelly Cherono - Assistant Lecturer, Department of Civil Engineering

Tittle of Study:

Assessment of Causations of Water Level Fluctuations in the Great-Rift Valley lakes of Kenya: The Case of Lake Baringo River Basin

Specific Objectives:

- Evaluate spatiotemporal variation in Land use/ Land Cover in Lake Baringo Basin
- Evaluate the impacts of climate variability and land use/land cover changes on soil erosion, sediment yield and streamflow in lake Baringo Basin
- Determine the damage potential of the rising lake levels in the riparian regions of Lake Baringo

Current Status

Presented and defended her PhD proposal at the School of Infrastructure and Resource Engineering on 31 May 2022 and in front of the Board of Post Graduate Studies on 26 June 2022.

Sospeter Wekesa - Senior Researcher, Centre for IWRM

Tittle of Study:

Investigating the Sensitivity of Rift Valley Lakes to shifting Hydro-Climatic Regimes

Specific Objectives:

- Examine historical changes in the lake levels and the hydro-meteorological factors in the lake catchment areas;
- Establish the relationship between hydro-meteorological factors and lake levels considering close and open lake systems,
- Assess the sensitivity of the lake level rise to different hydro-meteorological factors and provide an approach for prediction of lake levels.

Current Status

In the reporting period, Sospeter Wekesa was undertaking baseline data collection towards identification of the study.

Master students at BOKU

MSc-Thesis “Analysis of the potential overflow from Lake Bogoria towards Lake Baringo”

The MSc-Thesis of the Master Student Pierre Kray “Analysis of the potential overflow from

Lake Bogoria towards Lake Baringo", which uses data, information and knowledge of GreatLakes, was presented at the MSc/PhD seminar of the Institute of Hydrology and Water Management in May 2022. Pierre Kray is a student of the Master programme "ENVEURO - Environmental Science. Soil, Water, Biodiversity", which is a two-year double-degree programme, which Pierre is conducting at the Swedish University of Agricultural Science (SLU, Sweden) and the University of Natural Resources and Life Sciences Vienna (BOKU). The objectives of the thesis are to (i) delineate and assess the sill point (location and elevation), after which Lake Bogoria would start to flow towards Lake Baringo, to (ii) estimate the necessary additional lake volume of Lake Bogoria until an overtopping would occur and (iii) to assess necessary changes in catchment rainfall, so that a sustained flow towards Lake Baringo can be reached. The work is progressing well. However, due to personal reasons, the finalization of the thesis is only anticipated by March/April 2023.

Structural Exercises on ""Assessment of temporal vegetation trends in watersheds of Rift Valley Lakes in Kenya"

Herrnegger et al. (2021)[3] show that changes in hydroclimatic conditions and increases in rainfall can explain the lake level rises. Herrnegger et al. (2021) used the CHIRPS rainfall data set for analysing the spatio-temporal rainfall trends in the catchments of the Rift Valley Lakes. Although some ground stations were used to check the plausibility of CHIRPS, uncertainties remain, since CHIRPS strongly relies on remotely sensed data. The signal of rainfall increase must also be observable in the vegetation characteristics in the region. Based on this hypothesis, the work by the Master students Jürgen Rieger and Manuel Gartner analyses the temporal changes and trends in vegetation cover using the NDVI (Normalized Difference Vegetation Index). The work "Assessment of temporal vegetation trends in watersheds of Rift Valley Lakes in Kenya", which is conducted in the course of "Structural Exercises" of BOKU, will be finalized by the end of September 2022. Preliminary results at the same time suggest, that vegetation cover has increased over time and that this in accordance with the hypothesis. The work is a preliminary assessment of objective ii) (analysis of the spatio-temporal vegetation characteristics in the lake watersheds), where more in-depth analysis will be performed.

QUESTIONNAIRE SURVEY

To assess flood exposure and vulnerability the following preliminary questionnaire was prepared.

Flood Exposure and Vulnerability in the Region of Lake Baringo, Kenya

Key Informants Questionnaire

A. General Information

1. Survey date:………………………………………………………
2. Survey area:…………………………………………………………..
3. Name of Interviewee:…………………………………………………
4. Occupation:……………………………………………………..……

[3] Herrnegger, M., Stecher, G., Schwatke, C., Olang, L., 2021. Hydroclimatic analysis of rising water levels in the Great rift Valley Lakes of Kenya. J. Hydrol. Reg. Stud. 36. https://doi.org/10.1016/j.ejrh.2021.100857

5. Address: ……………………………………………………………..…….

B. Causes of Flooding

1. Which year did the current flooding begin?...

2. What is the frequency of flood occurrence in the area?..

3. What do you think are the causes of flooding?..

C. Impacts of Flooding

1. What economic activities have been affected by floods?.....................................

2. How many people have been displaced so far?..

3. Apart from financial and economic losses, what were other (severe) effects of the flooding experienced in the area?......................

4. Can the damage be quantified in monetary terms?..

5. Were the people living in close proximity to the lake aware of the risk?...............

6. Do you think the lake levels will decrease in future?

D. Mitigation Measures

1. What measures have been taken to prevent flooding and by who?........................

2. How are people adopting to the floods?..

3. What is the approximate distance between the lake and the affected?

- Infrastructure…………………………………………
- Buildings (Residential and Commercial) …………………………….
- Farm lands…………………………………………………

GREATLAKES HYDROLOGICAL INFORMATION SYSTEM

One objective of the project is to make the knowledge gained from the hydro-meteorological analyses and project results from GreatLakes available to the public with the help of a Hydrological Information System (HIS). The communication of the research results in this way will support the regulation, development and management of the affected land and water resources.

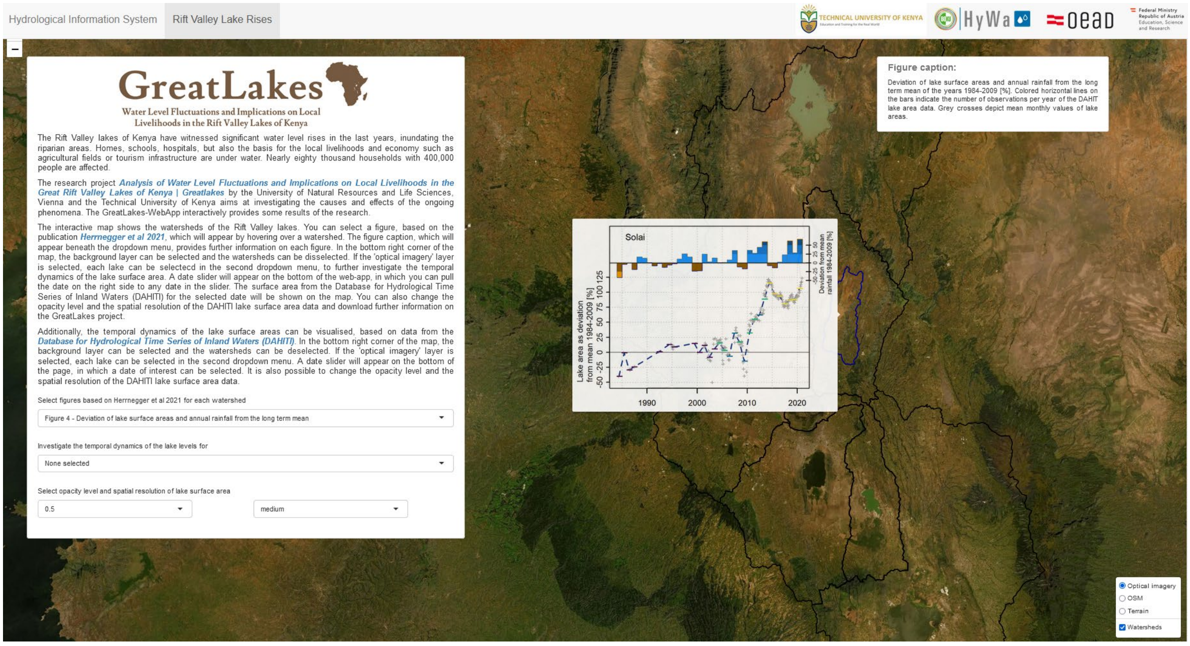

Figure 24: Screenshot of the GreatLakes HIS prototype with high-resolution optical satellite image of the study lakes in the background. In the middle, results from Herrnegger et al. (2021) are displayed.

Figure 24 shows a screenshot of the current GreatLakes HIS interface. The HIS was developed in the programming language R - Software for Statistical Computing - and hosted via a server from shinyapps.io (RStudio, 2020, R Core Team, 2020). The R Shiny Package (Chang et al., 2020) includes a variety of JavaScript wrapper functions and thus allows for "reactive programming", i.e. a dynamic interface that offers different possibilities to visualize the research results of the GreatLakes project depending on the user's interaction. The interactive map shows the watersheds of the Rift Valley lakes. Based on the publication of Herrnegger et al. (2021), different images can be selected from a drop-down menu in the specifications panel on the left. If the mouse is moved over a lake catchment after the selection, the graph of the respective catchment appears. According to the selected figure, a description of the displayed graphs appears at the top right of the map. This allows the research results to be displayed interactively, for each affected catchment area.

In the lower right corner of the map, high-resolution satellite images (Optical Imagery), an Open Street Map Layer (OSM) or a terrain layer (Terrain) can be selected as the background layer and the lake catchments can be switched on and off. When the Optical Imagery layer is selected, each lake can be selected from the second drop-down menu to examine the temporal dynamics of the lake surface (Figure 25). A date slider is displayed at the bottom of the web app, where the date can be dragged from the right-hand side to any date in the timeline. The map then displays the lake area of the selected Rift Valley lake from the Database for Hydrological Time Series of Inland Waters (DAHITI, Schwatke et al., 2020) for the selected date. In addition, further information about the GreatLakes project can be downloaded.

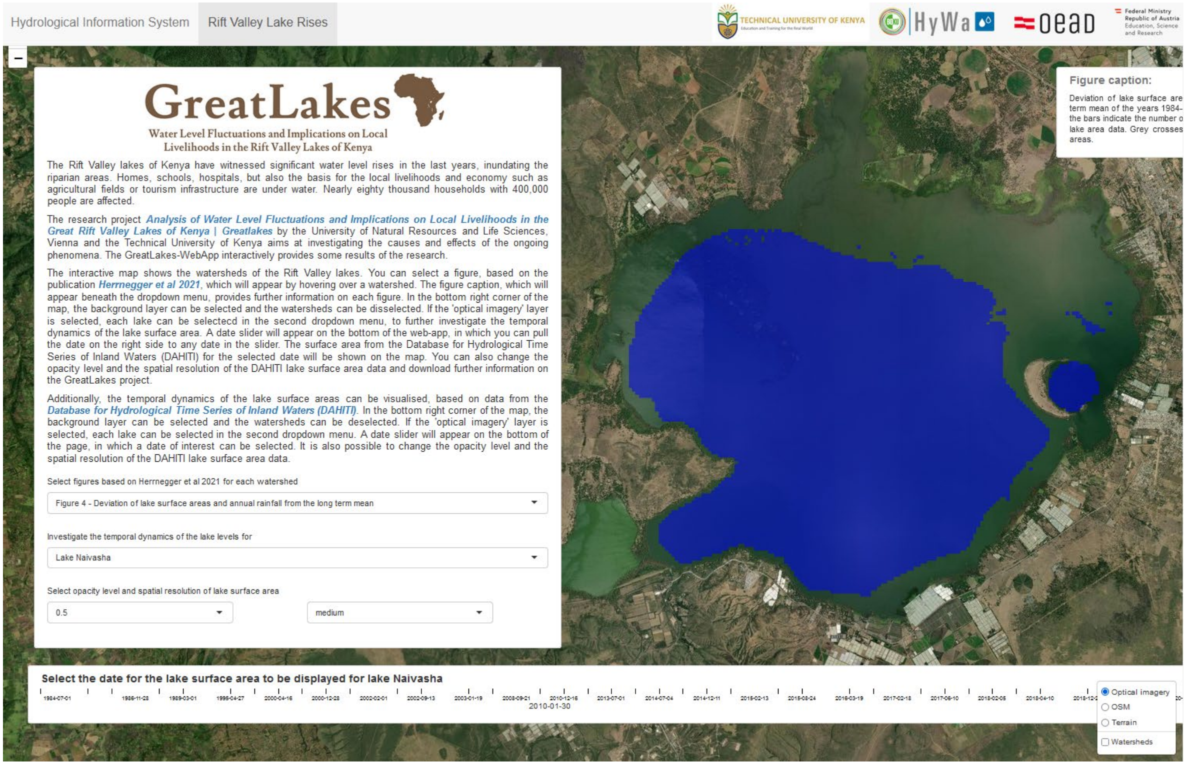

Figure 25: The GreatLakes HIS prototype showing the water surface of Lake Naivasha for the selected date 30.01.2010.

References for the HIS

Chang, W., Cheng, J., Allaire, J., Xie, Y., McPherson, J., 2020. shiny: Web Application Framework for R. R package version 1.5.0.

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