INCEPTION REPORT-Makerere University (MAK) – October 2018

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Water and livelihood resilience under changing climate(s) and extremes: Groundwater water and agriculture issues in the Lake Victoria Basin

1.0.Introduction

1.1.Relevance of the proposed activities to the needs and priorities of the selected case studies

A growing body of knowledge recognizes that the water resources in the Lake Victoria Basin (LVB) are increasingly stressed by global environmental change threatening the survivability of the vulnerable inhabitant population and the ecosystems (Kashaigili et al., 2015; López-Carr et al., 2016; Onyutha et al., 2016). A range of degradative processes signified by *insitu* unsustainable land use practices, declining water quality, high runoff and soil losses (Lufafa et al., 2003; Majaliwa, 2005) beyond the tolerable levels (< 5 t/ha/yr), land use and land transformations largely conversions from natural cover to small holder farming, increased rural urban transformations, *exsitu* sediment and nutrient loading into streams and Lakes all contribute to altering the horizontal and vertical water dynamic affecting the biogeochemistry, the ecosystem services and overall livelihoods systems and structures. Consequently, the LVB region is reported to be highly degraded.

The ecological and socio-economic processes in the Lake Victoria Basin have implications on water that transcend the region and span the entire Nile basin. Increasing concerns have been further raised owing to (a) climate change and variability. The key question is how climate change will impact on the ecological resources in the region. The hydrological processes in the LVB are largely erratic in time and space while the inter annual and decadal rainfall patterns are highly variable. Projections are indicative of temperature rise of between 2^{0}C to 2.5^{0}C by 2020 under the worst-case scenario. Rainfall is projected to increase in the region, but will be more extreme, episodic and intense (USAID, 2018). (b) Rapid population growth rates and their increasing direct demand water for various uses. The LVB region, home to about 40 million people, has one of the highest population growth rates (about 3.5% per annum) in Sub Saharan Africa (SSA) and the world in general. The climatic and demographic changes and shifts have a bearing on the resilience of both the systems and population in the Lake Victoria Basin, which will be addressed in this project.

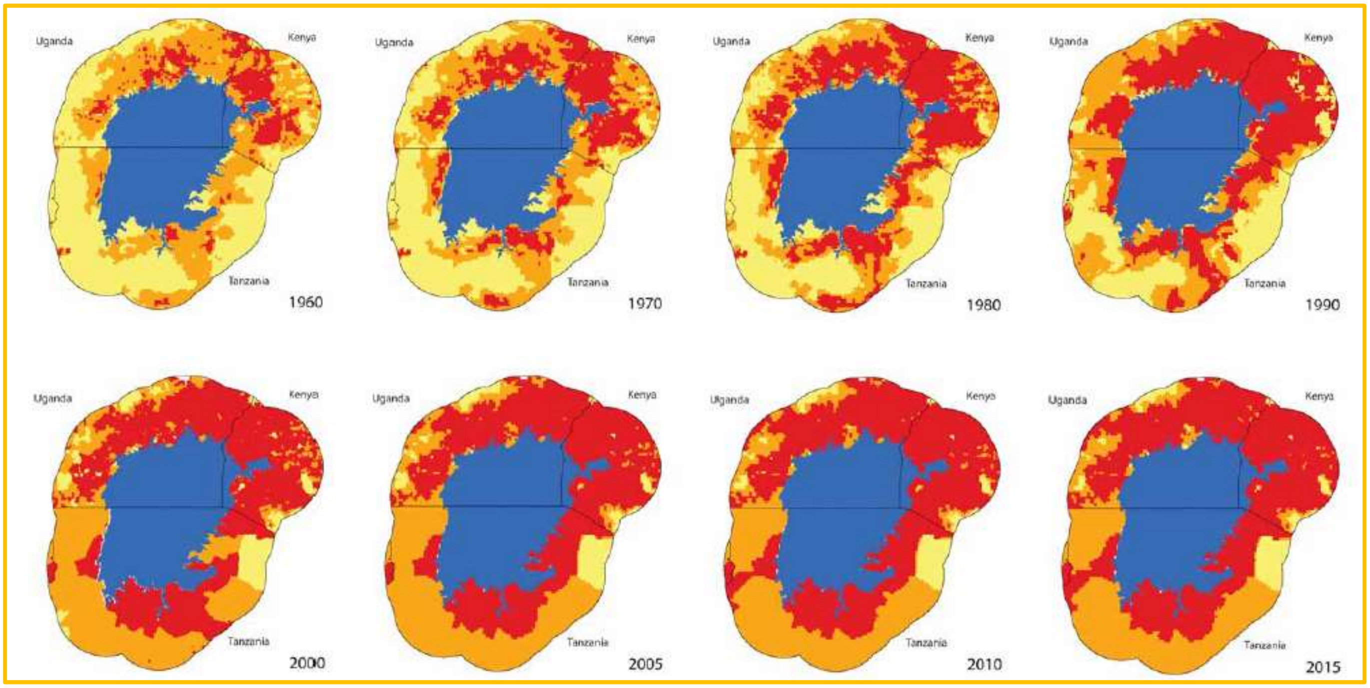


Figure 1: Spatial temporal patterns of population density in the Lake Victoria Basin. Source: UNEP (2016)

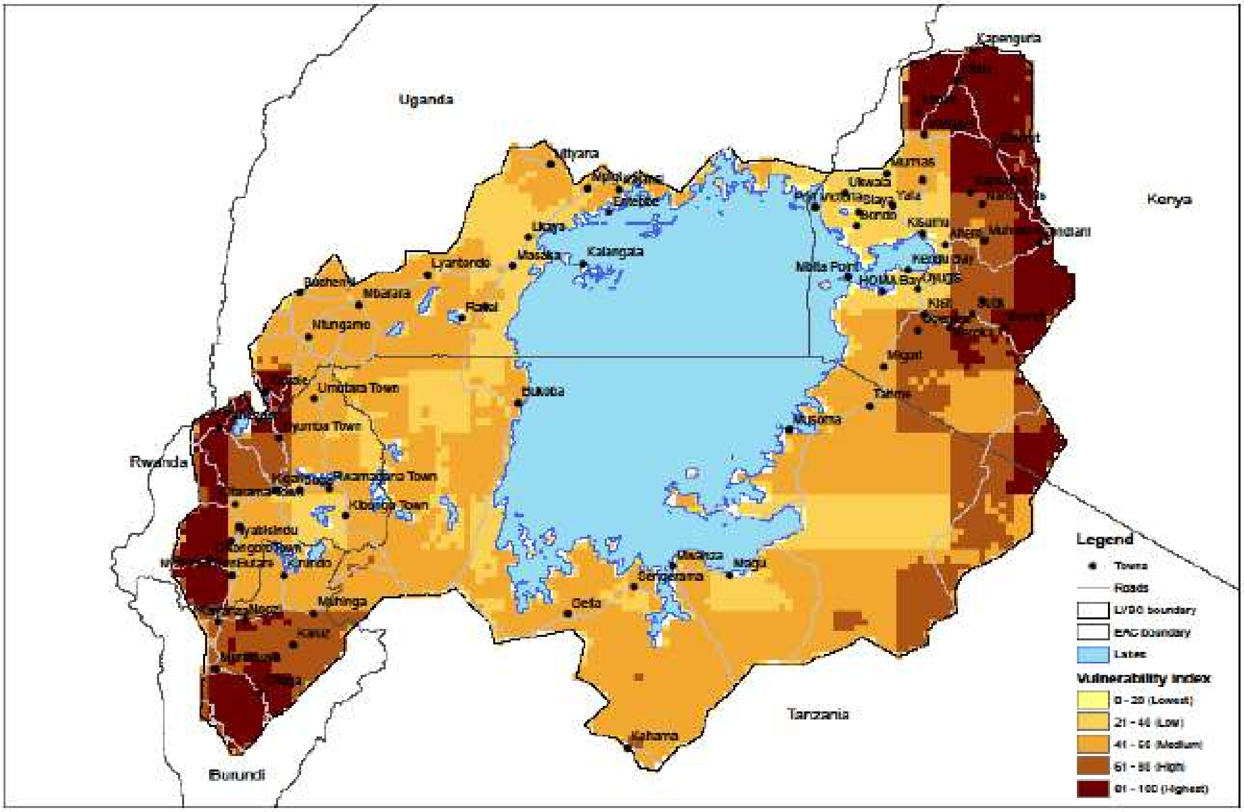


Figure 2: Water Stress vulnerability map for the Lake Victoria Basin projected for 2050 under RCP 4.5. Increasing vulnerability is foreseen under changing climatic conditions. Source: USAID (2018).

1.2.Scope of the work

The activities, implemented in the wider framework of the WACONI (Water and Cooperation within the Nile river basin) project, will focus on WEFE nexus assessment in the Lake Victoria basin (LVB). The scientific scope of the work to be undertaken manifest in the activities stated below and the formulated objectives. The work will entail modelling to elicit discharge and water quality aspects, land use and land cover trajectories with related impacts, crop sensitivities to climate change and water stress. Spatially, the work will be undertaken in the Lake Victoria Basin. The Lake Victoria Basin spans an area of approximately 250,000 km^2, including five countries. Much of the work will be premised on desktop and literature review, coupled with collection of secondary data in relevant agencies in the five countries. The realization of the planned work and activities is partially premised on provision of specified data by ICPAC (Nairobi). Specific tasks will be:

1. To report a spatial database on water uses by source and sector within a scenario based analysis under different climate pressures and management practices;

2. To understand baseline conditions on agriculture (including livestock and fisheries) by gathering and processing data and by-products (land use and coverage, local practices, seasonal patterns) at LVB scale;

3. To assess the efficiency of selected agriculture practices (Sustainable land management: e.g contours, river bank stabilization, gully plugins) on water balance and surface water quality

1.3.Scientific activities

The specific objectives of the study are to;

1. Determine the trends in climate change and variability on medium timescales – extreme events. Data and scenarios for this objective will generated by ICPAC (Nairobi)

2. Assess the dynamics of ground water storage and recharge capacities under changing conditions in LVB

3. Determine the sensitivity of selected crops to water and climatic stressors in the LVB

4. Assess the implications of land use and climate change on water quality

1.4.Outcomes in form of deliverables

The expected outcomes from this case study are;

a) Inception report, detailing job scope, objectives, scientific activities and overall work plan, including risks and mitigations plan

b) Report and baseline spatial database on hydrology and water uses by source and sector (i.e. agriculture, water supply) coupled with land use and cover, based on local and public domain data sources and aimed at supporting analysis and modelling activities at LVB scale.

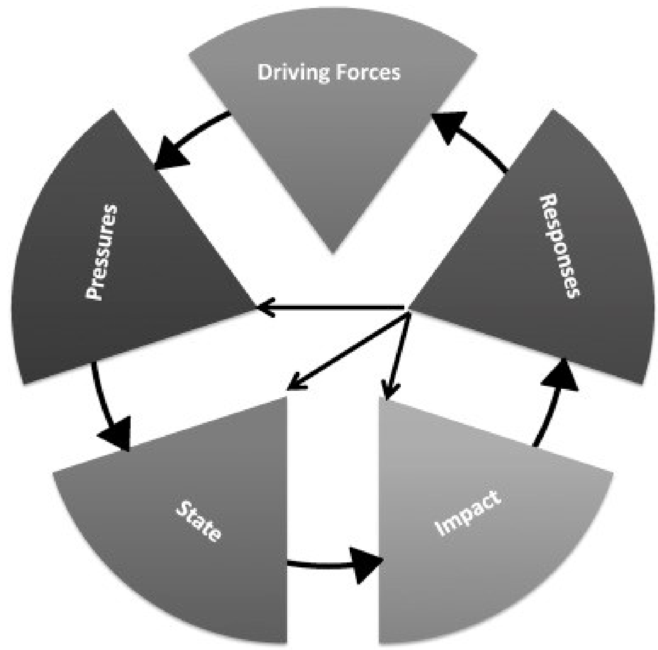
c) Comprehensive Assessment Report on WEFE nexus (current and future scenario), including the design and implementation of a water quality and crop modeling framework, at LVB scale.

d) Dissemination material (presentations on theory, practice, baseline database, model design and implementation, analysis outcomes

e) Trends and trajectories in land use and climatic changes in the LVB established, including estimated water uses and land cover

2.0. Methods and methodologies, including data and tools availability

The project is cognizant of both the physical and social resilience issues obtaining in the Lake Victoria Basin and thus the need to jointly address them. In this respect, we will adopt the DPSIR Model (Drivers – Pressure – State – Impact – Response) as the overarching guiding framework for implementing the activities of the case study. The DPSIR Model constitutes five nodes facilitating cause-effect analysis of relationships between interacting components of complex social, economic and environmental systems coupled with managing information flow between the parts. This is more appropriate in light of the situation obtaining in the Lake Victoria basin including rapid demographic changes, land use and cover conversions, heavily ecosystem dependent livelihoods. While the DPSIR model gives the overall conceptual framework, specific objectives will be addressed as follows;



Objective I: Climate Change and variability/Extreme events – Sensitivity and uncertainty analysis:

This objective seeks to understand the historical trajectories of climate as well as futuristic climatic conditions. The first step will therefore be collection and collating of available climatic data, focusing largely on rainfall and temperature data. For this objective, much of the work will be undertaken by ICPAC in line with the overall agreement. We expect to get downscaled data at finer resolutions that can enable us undertake catchment level studies and simulations to understand impacts. ICPAC will supply the data and scenarios and other datasets required for impact assessment studies. Once the data is obtained, appropriate steps will be undertaken to decipher trajectories. Time series analysis will be undertaken to understand trends. Extremes will be assessed using the annual maxima series (AMS) techniques (Nagy et al., 2017; Tiwari et al., 2015). The outputs from this activity will enable us to further understand the expected changes, their spatial configurations and occurrence of extreme events with a bearing on surface and ground water dynamic. The outputs from this objective, particularly the downscaled and projected climatic conditions will also be used as inputs for other objectives.

Objective II: Assessing dynamics of ground water storage and recharge capacities under changing conditions

This objective will entail (a) simulation of ground water storage and recharge (b) (c) evaluating the water use. For the ground water storage, we will use the Community Land Model (CLM version 4). CLM does hydrologic modeling and has a lumped groundwater scheme, which can allow simulation of groundwater storage and recharge. The model will be set up at a regional scale covering East Africa and results for the specific catchment of study will be extracted. The CLM modeling will potentially be enhanced with the WEAP-MIKESHE_MODFLOW model over Uganda to help in better simulation of groundwater flow. WEAP is an open source model developed by SEI and simulated both the physical changes as well as water use and consumption scenarios (Birhanu et al., 2018; Hadded et al., 2013). It is an allocation model that looks at the water supplies and demands under different scenarios. It is being set up at Makerere University through a collaboration with Prof. Brian Thomas of Pittsburg University (USA) and calibration processes are currently ongoing. In order to have insights on the utility based on the human use and demands, we will undertake a watergap analysis (Amin et al., 2018). Spatial data on the inventory of existing ground water resource will be obtained from the Water Resources Management Directorate of Uganda. Modeling and simulations will be undertaken to understand dynamics under existing conditions and futuristic conditions. The implementation of this objective will be premised also on outputs from objective I.

Objective III: Assessing the sensitivity of crop yields to water and climatic stressors

This objective will help gain improved understand how yields of selected important crops are sensitive to water and climatic stressors. To attain this, we will use the FAO developed Aquacrop model, the crop-water productivity model. AquaCrop simulates the yield response of herbaceous crops to water and is particularly well suited to conditions in which water is a key limiting factor in crop production. The model takes into consideration a number of parameters including management routines and can also be run in a GIS environment. Soil data will be obtained from the National Agricultural Research laboratory (NARL-Kawanda), while baseline crop data is expected to be obtained from the National Agriculture Research Organization (NARO) of Uganda. Climatic data for the model will be covered under objective I. Management practices will be obtained from literature and where necessary consultations with the relevant agriculture and water extension workers in the target catchment. Crop yield simulations will be conducted under both current and future climatic conditions.

Objective IV: Implications of land use and climate change on discharge and water quality

For this objective, we plan to use two models namely; (1) the semi-distributed model Soil and Water Assessment model (SWAT) and related GUIs (ArcSWAT and SWATgrid) (2) Soil water model: Hydrus-1D. We will collect satellite imagery data and determine the Normalised Difference Water Index (NDWI). This will give spatial and temporal insights on surface water across the selected catchment. Secondly, we will also determine the land uses in the study area. The land use data, coupled with climatic data, soil data, topography, stream flow data etc will be input in a calibrated SWAT model to assess the implications on land use and climate on discharge and water quality. Since SWAT uses hydrological response units taking into consideration land use, topography and climate, we will assess the land uses contributing to stream pollution loading. The assessment will consider limited water quality parameters including TSS, P, N. Futuristic conditions will be assessed up to 2030.

3.0.Work plan with milestones

The project will be implemented in 18 months spanning 2018-2019. The planned activities and milestones are indicated below.

Work plan and milestones

No.	**Activity description**	**2018**	**2019**		**Output**
		Oct-Dec	**Jan-Mar**	**Apr-Jun**	
1	Indication of the datasets				Datasets
2	Imagery data compilation				Imagery datasets
3	Secondary data compilation				Secondary data
5	GIS databases and secondary				Spatial datasets
6	Literature review				Data inventory
7	Developing study designs				Instruments
8	Model set up and running				Model set up
9	Training assistants				
10	Catchment visits				Field report
11	Climate downscaling and plotting				Trajectories
12	Spatial modeling				geodatabases
13	Manuscript development				Manuscript
14	Progress Report				Report
15	Final report				Final report

4.0.Risk and mitigation plan

A range of risks are foreseen as follows

- Provision of good and timely climatic and imagery data by ICPAC. Climatic and some spatial data is expected to be obtained from ICPAC, which is expected to facilitate hydrological database construction, modelling and climatic scenario development. It is assumed that there will be good cooperation and all the required data will be obtained in time. In case of limitations, efforts will be undertaken to solicit for some data from national agencies such as the Uganda National Meteorology Authority and AGMIP teams.

- The objectives are quite ambitious. We will try to leverage from existing resources at Makerere University including attaching some students to undertake some tasks as part of their studies.

- The realization of the stated objectives is also premised on institutional stability, creating a conducive environment for delivery of the project outputs and outcomes.

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