THE EFFECT OF DROUGHT AND LANDUSE DYNAMICS ON WATER LEVELS IN LAKE CHILWA, MALAWI

PATRICIA FUNNY LINOSI GOMANI

BU/GS18/MCC/9

A DISSERTATION SUBMITTED TO THE DIRECTORATE OF GRADUATE STUDIES, RESEARCH AND INNOVATIONS IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE IN CLIMATE CHANGE AND DISASTER MANAGEMENT DEGREE OF BUSITEMA UNIVERSITY

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Pursuing Excellence

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SEPTEMBER 2021

CERTIFICATION

The undersigned certify that they have read and hereby recommend for examination by Busitema University a dissertation/thesis titled: ***The Effect of Drought and Land use Dynamics on Water Levels in Lake Chilwa, Malawi,*** in (Partial) fulfilment of the requirements for the degree of Master of Science in Climate Change and Disaster Management Degree of Busitema University.

Prof. Moses Isabirye

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Date: 16/09/2021

Dr. Isaac Tchuwa

(Supervisor)

Date: 16/09/2021

DECLARATION
AND
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I, **Patricia Funny Linosi Gomani**, declare that this thesis is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

Signature:

DEDICATION

This Dissertation is dedicated to my husband Timothy Shaba who has provided academic, moral and financial support during my stay in Jinja, Uganda. My husband, I have fought a good fight, I have finished the race and I kept the faith.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CGIAR	Consultative Group for International Agricultural Research
CRIC	Committee for the Review of the Implementation of the Conventions
CRS	Coordinate Reference System
CSI	Consortium for Spatial Information
CSI	Committee on Science and Technology
DCCMS	Department of Climate Change and Meteorological Services
DEM	Digital Elevation Model
DPSIR	Driving forces, Pressure, State, Impacts and Responses
DrinC	Drought Indices Calculator
FAR	False Alarm Ratio
FB	Frequency Bias
FEWSNET	Famine Early Warning System Network
GCM	General Climate Models
GoM	Government of Malawi
G-REAM	Global Reservoir and Lake Monitor
GWP	Global Water Partnership
HSS	Heidke Skill Score
IDMP	Integrated Drought Management Programme
ILWIS	Integrated Land and Water Information System

IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LCBCCAP	Lake Chilwa Basin Climate Change Adaptation Programme
MGDS	Malawi Growth and Development Strategy
MK	Mann-Kendall
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NSO	National Statistics Office
PCC	Pearson's Correlation Coefficient
POD	Probability of Detection
QGIS	Quantum Geographical Information System
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SNHT	Standard Normal Homogeneity Test
SPI	Standard Precipitation Index
SRTM	Shuttle Radar Topographic Mission
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nation Development Programme
USDA	United States Development of Agriculture
WGS	World Geodetic System
WMO	World Meteorological Organization

SYMBOLS

°C	Degree Celsius
$F_n(x)$	Kolmogorov Smirnov test
H_0	Null hypothesis
K_c	Kappa coefficient
MS	Mean square
Q_i	Sen's slope
r	Pearson's Correlation Coefficient
R^2	R-squared
S	Mann-Kendall trend test
sd	standard deviation
SS	Sum of squares
$\bar{x}$	sample mean
α	Alpha
β	Beta
Γ	gamma function
Σ	Summation
$\surd$	Square root

GLOSSARY

Climate change: change in climate that persists for decades or longer, arising from either natural causes or human activity

Drought: the consequence of a natural reduction in the amount of precipitation received over an extended period, usually a season or more

Drought indicator: variables or parameters used to describe the drought conditions to track droughts such as precipitation, temperature, streamflow, and soil moisture and reservoir levels

Drought indices: calculated from assimilating drought indicators into a single numerical value

Endorheic Lake: a lake that does not drain into large water bodies like rivers connected to oceans

Groundwater recharge: a hydrologic process where water moves downwards from surface water to groundwater

Hydrological cycle: continuous circulation of water between ocean, atmosphere, and land in different states as gas, liquid or solid

Lake levels: a measured elevation of the lake surface with reference to the mean sea level

Land cover: the observed (bio) physical cover of the earth's surface

Land use change: the conversion from one land use to another or intensification of the present or current land use

Land use: are the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it

Vulnerability: the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Water balance: a mathematical expression that describes the flow of water in and out of a hydrological system such as a drainage basin or lake

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ABSTRACT

Climate change and land use change are the most important factors that determine the hydrological processes of the catchment. Drought occurrences triggered by climate change coupled with inappropriate changes in land use are known causes of the lake water level fluctuations through changes in precipitation, evaporation and streamflow processes. The study investigated the effect of drought and land use/ land cover dynamics on Lake Chilwa water level fluctuations in Malawi during the years 1989 to 2016. It used a quasi-experimental design and quantitative research approach. Rainfall and temperature data from six stations of Chanco, Chikweo, Naminjiwa, Ntaja, Makoka and Zomba RTC and lake water levels data from four stations of Kachulu, Mposa, Namanja and Swang'oma in the basin were used for trend analysis. Furthermore, 12-month SPI time series data were derived from rainfall using DrinC software. Land use change was assessed using the extracted catchment shapefile in QGIS 2.18 with Trends Earth plugin from 2001-2015. NDVI time-series data were downloaded from Famine Early Warning Systems Network Climate Engine for land cover trends. Hydro-meteorological trends were tested using the Mann-Kendall trend test. The effect of drought and land use/land cover trends on lake water levels was assessed using a two-way ANOVA test. The quantitative land cover change detection between 2001 and 2015 revealed that cropland, grassland, water bodies and other lands declined by 1.71%, 2.36%, 7.95% and 5.32% respectively; while tree-covered areas, artificial areas and wetland expanded by 14.15%, 84.41% and 19.10% respectively. The SDG 15.3.1, land degradation indicator for improved, stable and degraded land was 6.08%, 74.20% and 17.84% correspondingly. NDVI trend increased insignificantly with a maximum of 0.6782 in 2015/16 and minimum of 0.5493 in 1993/94. Annual mean lake levels trend decreased significantly with MK (-0.354), Sen's slope (-0.035) and p-value (0.010 <0.05); while annual mean temperature trend increased significantly with MK (0.57), Sen's slope (0.032) and p-value (0.0001<0.05). However, the annual mean rainfall trend decreased insignificantly with MK (-0.103), Sen's slope (-3.256) and p-value (0.466>0.05). Lake Chilwa basin had experienced twelve drought years between 1989-2016. Two-way ANOVA results revealed no interaction effect between drought and land cover trends on lake water levels as the p-value (0.6584>0.05) and R-squared of 0.1720. Therefore, the Standardized Precipitation Index and Normalized Difference Vegetation Index are not good indicators of the Lake Chilwa water level fluctuations.

Keywords: drought, land use dynamics, lake water levels, Lake Chilwa basin

CHAPTER ONE

1.0 INTRODUCTION

This chapter presents a general background of the study. It provides the problem statement, research objectives, research hypothesis, originality and contribution to the new knowledge, the significance of the study, scope and the theoretical and conceptual framework of the study.

1.1. BACKGROUND

Water resource availability in any region is influenced by complex natural interactions between climatological conditions and natural hydrological cycle processes (Kaunda, 2016). Climate change which is triggered by global warming further exacerbate this interaction and affects water resources availability through changes of water balance elements such as rainfall, evapotranspiration and runoff (Ngongondo, et al., 2015). Lakes are good sentinels of global climate change because these are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere (Kaunda, 2016). Many lakes particularly the endorheic lakes are undergoing seasonal or long term fluctuations in water levels (Kolding and Zwieten, 2011).

Endorheic basins and lakes are landlocked drainage networks where water does not drain into large water bodies such as rivers connected to oceans (Sawe, 2017). These lakes experience water losses through water percolation underground and evapotranspiration; the level of evapotranspiration is generally higher than precipitation in arid and semi-arid areas (Yapiyev, et al., 2017). An Endorheic basin does not have enough inflow and depends mainly on rainfall and any loss of water either by evaporation or seeping leads to immediate shrinking of the lake (Sawe, 2017). Majority of the endorheic lakes are shallow and saline as the evaporative concentration process leads to progressive salt accumulation over thousands of years. Thus, endorheic lakes are very important climate indicators because of the high sensitivity of their physical, chemical and isotopic parameters to the variations of climatic factors such as precipitation and temperature, resulting in lake water level fluctuations (Frondini, et al., 2019).

In recent decades, drying out of lakes is among the major global environmental changes observed around the World. For example, drying has taken place in the Aral Sea in Central Asia,

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