



**BUSITEMA  
UNIVERSITY**  
*Pursuing Excellence*

**BUSITEMA UNIVERSITY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF WATER RESOURCES AND MINING ENGINEERING**

**FINAL YEAR PROJECT REPORT**

**APPLICATION OF SWAT MODEL IN ASSESSING THE EFFECT OF CLIMATE  
CHANGE ON WATER QUANTITY AND QUALITY**

**Case study: RIVER MALABA CATCHMENT**

**BY**

**NAME: OMANYO LAWRENCE**

**REG NO: BU/UP/2014/621**

**PHONE NUMBER: +256781797040**

**E-Mail: [lawrenceomanyo@gmail.com](mailto:lawrenceomanyo@gmail.com)**

**SUPERVISOR(S)**

**Main Supervisor: MRS. HOPE NJUKI NAKABUYE**

**Co-Supervisor: MR. MUGISHA MOSES**

*A final year project proposal Report submitted in partial fulfillment of the requirements for the award of a Bachelor of Science degree in water resources engineering of Busitema University*

## **ABSTRACT**

In this study case, nutrients were considered to be an important water quality concern in the River Malaba due to high eutrophication problem of Malaba river. Nitrogen and phosphorus are the two major nutrients originating from subsistence agriculture and livestock grazing. Increased N and P fertilizer application has enlarged N and P river Malaba through runoff and leaching making river Malaba water quality vulnerable to climate change and land use. Quantitatively, Malaba River is very vulnerable to climate change because it relies heavily on rainfall as its main flow contributor. This study's main objective was to assess the effect of climate change on water quantity and quality in Malaba River Catchment, Uganda and it was achieved by simulating the climate variables with calibrated SWAT model inputs for a period of 35 years from 1979 to 2013. The trend analysis was done by Regression test and its significance was determined using the T-test approach. SWAT model was successfully calibrated and validated with NSE of 0.93 and 0.90 respectively. Therefore, the Ministry of Water and Environment Uganda and other stake holders will be empowered with these results to carry out water resources management plan to prevent the effects that might rise from the high and low flows and also deterioration of water quality.

## **DECLARATION**

I **OMANYO LAWRENCE** solemnly declare that this final year project proposal report is a result of my own efforts and tremendous work done during the research period and it has never been submitted to Busitema University or any other institution of higher learning for any academic award.

NAME: OMANYO LAWRENCE

REG NO: BU/UP/2014/621

SIGNATURE: .....

DATE: .....

**APPROVAL**

This is to certify that this project proposal report was written under the guidance of my supervisors on the topic “*Application of SWAT Model in Assessing the Effect of Climate Change On Water Quantity and Quality*” and is now ready for submission to the department of Busitema University.

**Mrs. HOPE NJUKI NAKABUYE**

Main supervisor

Sign: .....

DATE: .....

**Mr. MUGISHA MOSES**

Co-supervisor

Sign: .....

DATE: .....

## **ACKNOWLEDGEMENT**

I would like to extend my sincere thanks to the almighty GOD who has gifted me with life and has enabled me to reach this academic height as he has been the provider of all the necessary requirements.

Great thanks to my beloved parents Mrs. **Akoth Jenipher** and the late Mr. **Epyat Benardo** for their financial and moral support, my uncles and family members I owe you a lot.

Let me convey my heartfelt appreciation to my supervisors, Mrs. Hope Njuki Nakabuye and Mr. Mugisha Moses for their advice as well their guidance during the preparation of this report.

Not forgetting my classmates

## LIST OF ACRONYMS

DWRM - Directorate of Water Resources Management

DEM - Digital Elevation Model

GLUE - Generalized Likelihood Uncertainty Estimation

HRU - Hydrological Response Unit

IPCC - Intergovernmental Panel on Climate Change

ISRIC - International Soils Reference and Information Centre

LH-OAT - Latin Hypercube One-factor-At-a-Time

MCMC - Markov chain Monte Carlo

IS- Importance Sampling

MWE - Ministry of Water and Environment

NBI - Nile basin Initiative

NSE - Nash-Sutcliffe Efficiency

NSI – Nash- Sutcliffe Index

ParaSol - Parameter Solution

PBias - Percentage Bias

PSO - Particle Swarm Optimization

$R^2$  - Coefficient of Determination

RMSE - Root Mean Square Error

SUFI - Sequential Uncertainty Fitting

SWAT - Soil and Water Assessment Tool

SWAT-CUP - SWAT Calibration and Uncertainty Programs

UNEP - United Nations Environment Programme

UNESCO - United Nations Educational Scientific and Cultural

WMO - World Meteorological Organization

FAO- Food and Agricultural Organization

NARO – National Agricultural Research Organization

GHG - Green House Gas

## LIST OF FIGURES

Figure 1; showing the greenhouse effect .....	6
Figure 2; showing single mass curve.....	29
Figure 3; showing SWAT model layout .....	36
Figure 4; showing DEM for River Malaba Catchment.....	37
Figure 5; showing land use in River Malaba Catchment .....	38
Figure 6; showing soil map for River Malaba catchment.....	39
Figure 7; showing slope classes for River Malaba Catchment .....	40
Figure 8; showing location of water quality sampling places .....	<b>Error! Bookmark not defined.</b>
Figure 9; showing Mbale Regional lab water quality results.....	<b>Error! Bookmark not defined.</b>
Figure 10; showing hydrological characteristics of River Malaba Catchment .....	44
Figure 11; showing sediment yield in-stream and upland of the catchment .....	45
Figure 12; showing the nitrogen cycle .....	46
Figure 13; showing calibration output.....	47
Figure 14; showing SWAT validation output .....	50
Figure 15; showing SWAT validation output .....	50
Figure 16; showing R-squared and NSI value for both calibration and validation .....	51
Figure 17; showing how Annual discharge has changed due to changes in Annual temperature.....	52
Figure 18; showing regression of Annual flow with annual temperature.....	52
Figure 19; showing Annual discharge change due to change in precipitation .....	53
Figure 20; showing progression of Annual precipitation with Annual flow.....	54
Figure 21; showing map indicating DO amount transported into R. Malaba at different reaches .....	55
Figure 22; showing Trend of Dissolved oxygen into R. Malaba .....	55
Figure 23; showing annual DO_IN variation with annual temperature.....	56
Figure 24; showing regression of DO_IN with temperature.....	56
Figure 25; showing map indicating DO amount transported out of R. Malaba at different reaches .....	57
Figure 26; showing Trend of Dissolved oxygen out of R. Malaba .....	57
Figure 27; showing annual DO_OUT variation with annual temperature.....	58
Figure 28; showing regression of DO_IN and temperature .....	58
Figure 29; showing map indicating CBOD_IN amount transported into R. Malaba at different reaches ...	59
Figure 30; showing Trend of CBOD transported into R. Malaba .....	59
Figure 31; showing annual CBOD_IN variation with annual temperature.....	60
Figure 32; showing Annual temperature regression with annual temperature.....	60
Figure 33; showing map indicating CBOD amount transported Out of R. Malaba at different reaches .....	61
Figure 34; showing Trend of CBOD_OUT in R. Malaba .....	62
Figure 35; showing annual CBOD_OUT variation with annual temperature.....	62
Figure 36; showing regression of CBOD_OUT with temperature.....	63
Figure 37; showing map indicating DO amount transported into R. Malaba at different reaches .....	63
Figure 38; showing Trend of TSS in R. Malaba .....	64
Figure 39; showing annual TSS variation with annual temperature.....	64
Figure 40; showing Progression of TSS with temperature .....	65



## LIST OF TABLES

Table 1: showing comparison of the three semi- distributed models .....	21
<b>Table 2; showing sources of datasets</b> .....	<b>28</b>
Table 3; showing parameters from sensitivity analysis and their ranks .....	48

## TABLE OF CONTENTS

ABSTRACT.....	i
DECLARATION .....	ii
APPROVAL .....	iii
ACKNOWLEDGEMENT .....	iv
LIST OF ACRONYMS .....	v
LIST OF FIGURES.....	vii
LIST OF TABLES .....	viii
CHAPTER ONE: INTRODUCTION .....	1
1.0 INTRODUCTION .....	1
1.1 BACKGROUND OF STUDY.....	1
1.2 PROBLEM STATEMENT.....	3
1.3 PURPOSE OF THE STUDY.....	3
1.4 JUSTIFICATION .....	3
1.5 OBJECTIVES OF THE STUDY.....	3
1.5.1 Main objective.....	3
1.5.2 Specific objectives.....	3
1.6 SCOPE OF STUDY .....	4
1.6.1 Conceptual scope:.....	4
1.6.2 Time scope:.....	4
1.6.3 Geographical scope: .....	4
1.7 Description of Study Area .....	4
CHAPTER TWO: LITERATURE REVIEW .....	5
2.0 LITERATURE REVIEW.....	5
2.1 Introduction .....	5
2.2 DEFINITION OF TERMS .....	5
2.2.1 Climate.....	5
2.2.2 Greenhouse Gas: .....	5
2.2.3 Greenhouse Effect: .....	6
2.2.4 Climate change:.....	7
2.3 Uganda’s Climate.....	7
2.4 General upshot of Water Resources in Uganda .....	7

2.5	Overview of Malaba River catchment.....	8
2.6	Climatic change overview .....	8
2.7	HYDRO CLIMATIC MODELS.....	19
2.7.1	Rainfall Runoff Modelling.....	19
2.8	Hydrological Model Selection .....	21
2.9	SENSITIVITY ANALYSIS OF SWAT MODEL PARAMETERS.....	22
2.9.1	Calibration of SWAT Model.....	23
2.9.2	Climate Customization in SWAT.....	24
2.9.3	Validation of SWAT model .....	24
2.9.4	Uncertainties .....	25
2.9.5	SWAT Model Key Equations .....	25
	CHAPTER THREE: METHODOLOGY .....	28
3.0	Preamble.....	28
3.1	Developing Relevant Spatial, Water Quality and Hydrological Datasets .....	28
3.1.1	Data Collection .....	28
3.1.2	Hydrological Data Preparation and Processing.....	29
3.1.3	Gap filling in stream flow data .....	29
3.1.4	Developing Water Quality data inputs.....	30
	Water quality survey and samples collection .....	30
3.2.0	.....	35
3.2.1	SWAT Model Setup .....	35
	SWATmodel layout.....	36
3.3.0	Collating the SWAT model outputs and developing adaptation strategies to climate change .....	40
	Collating SWAT model out puts .....	40
	Adaptation Strategies to Climate Change .....	41
	CHAPTER FOUR.....	44
4.0	RESULTS AND DISCUSSIONS .....	44
	SWAT Modelling.....	44
	SWATCUP work .....	47
	Sensitivity Analysis.....	47
4.1	Model Calibration .....	49

4.2	Validation of SWAT model.....	50
4.3	Collating the Model Outputs .....	51
	SWAT model performance evaluation .....	51
4.4	Water Quality Modelling SWAT model Results .....	54
	CHAPTER FIVE.....	66
	CONCLUSION AND RECOMMENDATIONS .....	66
	5.1 Conclusion.....	66
	5.2 Recommendations.....	66
	5.3 Further research .....	67
	REFERENCES.....	68

# CHAPTER ONE: INTRODUCTION

## 1.0 INTRODUCTION

This chapter includes the following; back ground to the study, statement of the problem, purpose of the study, objectives of the study, research questions, scope of the study which includes the conceptual scope, geographical scope and time scope and finally the significance of the study.

## 1.1 BACKGROUND OF STUDY

Water resources throughout the world are vital to socio-economic status, public health, quality of life and environmental sustainability of nations. However, the water resources are experiencing great stress due to global climate change and its awareness is being raised. Long-term climate change has been experienced at global, regional, and ocean basin scales, due to increasing concentration of greenhouse gases most especially carbon dioxide. These include changes in precipitation amounts and timings, arctic temperatures and different types of extreme weather like heavy rainfall, drought, and heat waves (IPCC, 2014)

The pattern of rainfall is unevenly distributed across the world and is governed by atmospheric circulation patterns and moisture availability. These two factors are affected by temperature so the pattern of rainfall is expected to change due to changing temperature. The changes include the type of precipitation, the amount, the intensity and the frequency. Rainfall has increased by 0.2 to 0.3% for every decade in the African tropics (10°N to 10°S) with a decrease in the Northern Hemisphere subtropics (10°N to 30°N) throughout the 20th century by approximately 0.3% per decade. Rise in temperatures has caused the melting of ice and glaciers on mountain tops. Mountain Rwenzori is one of a few mountains in Africa with a permanent ice-cap. Current studies have exposed that the ice cap on this mountain has decreased significantly. About 82% of the Mt Kilimanjaro 1912 ice cap in Kenya has melted and by 1990, 40% of Mt Rwenzori had receded Compared to 1955 recorded cover (United Nations Environment Programme, 2013). These changes have been attributed to global warming (Trenberth *et al.*, 2013). Increasing global average air and ocean temperature can change the type of rainfall during winter season (Mantua, Tohver and Hamlet, 2010)

Several climate change standards and classifications have been developed to evaluate and quantify these issues over the past two decades. The Intergovernmental Panel on Climate Change(IPCC)

## REFERENCES

- Abbaspour, K. C. *et al.* (2007) 'SWAT-CUP Calibration and Uncertainty Programs for SWAT', *The fourth International SWAT conference*, pp. 1596–1602. doi: 10.1007/s00402-009-1032-4.
- Alamdari, N. *et al.* (no date) 'Assessing the Effects of Climate Change on Water Quantity and Quality in an Urban Watershed Using a Calibrated Stormwater Model'. doi: 10.3390/w9070464.
- Arnold, J. G. *et al.* (2012) 'SWAT : Model use , calibration , and validation'.
- Bartlett, M. S. *et al.* (2015) 'Stochastic rainfall-runoff model with explicit soil moisture dynamics', *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science*, 471(2183), p. 20150389. doi: 10.1098/rspa.2015.0389.
- Beven, K. (2012) 'Hydrological Similarity, Distribution Functions and Semi-Distributed Rainfall–Runoff Models', *Rainfall-Runoff Modelling*, pp. 185–229. doi: 10.1002/9781119951001.ch6.
- Beven, K. J. (2000) 'On the future of distributed modelling in hydrology.', *Hydrological Processes*, 14(16–17), pp. 3183–3184. doi: 10.1002/hyp.325.
- Change, C. and Heritage, W. (no date) 'reports 22'.
- Delespaul, P. (2013) 'Consensus over de definitie van mensen met een ernstige psychische aandoening (EPA) en hun aantal in Nederland', *Tijdschrift voor Psychiatrie*, 55(6), pp. 427–438. doi: 10.1176/appi.ps.201500058.
- Fukunaga, D. C. *et al.* (2015) 'Application of the SWAT hydrologic model to a tropical watershed at Brazil', *Catena*, 125, pp. 206–213. doi: 10.1016/j.catena.2014.10.032.
- Golmohammadi, G. *et al.* (2014) 'Evaluating Three Hydrological Distributed Watershed Models: MIKE-SHE, APEX, SWAT', *Hydrology*, 1(1), pp. 20–39. doi: 10.3390/hydrology1010020.
- Gupta, H. V. and Kling, H. (2011) 'On typical range, sensitivity, and normalization of Mean Squared Error and Nash-Sutcliffe Efficiency type metrics', *Water Resources Research*, 47(10). doi: 10.1029/2011WR010962.
- Hammouri, N., Abdulla, F. and Abu, H. (2015) 'ASSESSING THE IMPACTS OF CLIMATE CHANGE ON WATER', (c).
- Helton, J. C. and Davis, F. J. (2002) 'Illustration of sampling-based methods for uncertainty and sensitivity analysis', in *Risk Analysis*, pp. 591–622. doi: 10.1111/0272-4332.00041.
- Ippc (2013) 'Working Group I Contribution to the IPCC Fifth Assessment Report, Climate Change 2013: The Physical Science Basis', *Ippc*, AR5(March 2013), p. 2014. doi: 10.1017/CBO9781107415324.Summary.
- IPCC (2014) 'Climate Change 2014 Synthesis Report Summary Chapter for Policymakers', *Ippc*, p. 31. doi: 10.1017/CBO9781107415324.
- Lederer, J. *et al.* (2015) 'The generation of stakeholder's knowledge for solid waste management

planning through action research: A case study from Busia, Uganda', *Habitat International*, 50, pp. 99–109. doi: 10.1016/j.habitatint.2015.08.015.

Liu, Y. and Gupta, H. V. (2007) 'Uncertainty in hydrologic modeling: Toward an integrated data assimilation framework', *Water Resources Research*. doi: 10.1029/2006WR005756.

Mantua, N., Tohver, I. and Hamlet, A. (2010) 'Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State', *Climatic Change*, 102(1–2), pp. 187–223. doi: 10.1007/s10584-010-9845-2.

Matsuno, T. (1966) 'Quasi-geostrophic motions in the equatorial area', *Journal of the Meteorological Society of Japan*, 44(February), pp. 25–43. doi: 10.1002/qj.49710644905.

'Ministry of Water and Environment Water and Environment Sector Performance Report' (2016).

Nandozi, C. S. *et al.* (2012) 'Regional climate model performance and prediction of seasonal rainfall and surface temperature of uganda', *African Crop Science Journal*, 20(s2), pp. 213–225.

Nkonge, L. K. *et al.* (2014) 'Comparison of two Calibration-uncertainty Methods for Soil and Water Assessment Tool in Stream Flow Modeling', 1(2), pp. 40–44.

Nsubuga, F. N. W., Namutebi, E. N. and Nsubuga-Ssenfuma, M. (2014) 'Water Resources of Uganda: An Assessment and Review', *Journal of Water Resource and Protection Water Resources of Uganda: An Assessment and Review. Journal of Water Resource and Protection*, 6(6), pp. 1297–1315. doi: 10.4236/jwarp.2014.614120.

Van Overschee, P. and De Moor, B. (1994) 'N4SID: Subspace algorithms for the identification of combined deterministic-stochastic systems', *Automatica*, 30(1), pp. 75–93. doi: 10.1016/0005-1098(94)90230-5.

Qiang, C. *et al.* (2010) 'Analysis of SWAT 2005 Parameter Sensitivity with LH-OAT Method', *HKIE Transactions Hong Kong Institution of Engineers*, 17(3), pp. 1–7. doi: 10.1080/1023697X.2010.10668197.

'Quantitative risk assessment of the effects of climate change on selected causes of death , 2030s and 2050s' (no date).

Sellami, H. *et al.* (2013) 'Parameter and rating curve uncertainty propagation analysis of the SWAT model for two small Mediterranean catchments', *Hydrological Sciences Journal*, 58(8), pp. 1635–1657. doi: 10.1080/02626667.2013.837222.

Srinivasan, R. *et al.* (2012) 'Swat: m', 55(4), pp. 1491–1508.

Suliman, A. H. A. *et al.* (2015) 'Comparison of Semi-Distributed, GIS-Based Hydrological Models for the Prediction of Streamflow in a Large Catchment', *Water Resources Management*, 29(9), pp. 3095–3110. doi: 10.1007/s11269-015-0984-0.

Tadross, M. *et al.* (2009) 'Growing-season rainfall and scenarios of future change in southeast

Africa: Implications for cultivating maize', *Climate Research*, 40(2–3), pp. 147–161. doi: 10.3354/cr00821.

Trenberth, K. E. (2011) 'Changes in precipitation with climate change', *Climate Research*, 47(1–2), pp. 123–138. doi: 10.3354/cr00953.

Trenberth, K. E. *et al.* (2013) 'Global warming and changes in drought', *Nature Climate Change*, 4(1), pp. 17–22. doi: 10.1038/nclimate2067.

United Nations Environment Programme (2013) 'Africa without ice and snow', *Environmental Development*, 5(1), pp. 146–155. doi: 10.1016/j.envdev.2012.10.003.

Zhang, D. *et al.* (2015) 'Improved calibration scheme of SWAT by separating wet and dry seasons', *Ecological Modelling*, 301, pp. 54–61. doi: 10.1016/j.ecolmodel.2015.01.018.