**FACULTY OF ENGINEERING**

**DEPARTMENT OF AGRICULTURAL MECHANIZATION & IRRIGATION ENGINEERING**

**FINAL YEAR PROJECT REPORT**

# A PREDICTIVE MODEL FOR QUANTIFYING THE COMBINED EFFECT OF LAND USE CHANGE AND CLIMATIC VARIABILITY ON SEDIMENTATION IN MALABA SUB CATCHMENT.

**By**

**OLOGE HECTOR DANIEL**

BU/GS21/MID/10

**This Dissertation is submitted to the Directorate of Graduate studies, Research and Innovations as a Partial Fulfilment of the Requirement for the Award of the Degree of Masters of Science in Irrigation & Drainage Engineering of Busitema University**

MARCH 2024

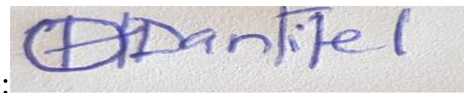
## ABSTRACT

This research aimed at using SWAT as a predictive model to assess the impacts of historical, current, future climate change and land use land cover changes on sedimentation in Malaba sub catchment. Four scenarios were modeled in SWAT during this study, the first scenario focused on historical (1990 to 2005) sedimentation and flow in the catchment. The second scenario focused on the current (2006 to 2020) sediment yield and flow in the catchment. Calibration and validation were done using SWAT CUP software version 5.1.6. The calibrated and validated model was then used to further simulate two future scenarios. The two future scenarios used projected land use data and projected weather data. Land use data was projected using Clerk Labs TerrSet software while weather data was projected using the Statistical Downscaling Model (SDSM)version 4.2 considering RCP 4.5 and RCP 8.5. The third scenario focused on flow and sediment yield of 2023 to 2035. The fourth scenario focused on flow and sediment yield of 2036 to 2050. The results obtained from climate change analysis indicated un even changes to occur from 2020 to 2050, rainfall over the catchment is expected to increase by an average of 19.6% (RCP 8.5) and 18% (RCP 4.5), maximum temperature is expected to increase by 1.02°C (RCP 8.5) and 0.85°C (RCP 4.5), minimum temperature is expected to increase by an average of 0.5°C (RCP4.5) and 0.75°C (RCP 8.5) Land use change results indicated that from 2020 to 2050 cropland is expected to increase from 65% to 72.32% of the total catchment area by 2050 while built-up area is expected increase from 2.26% to 3.67%. Forests are expected to reduce from 6.5% to 1.9% of the catchment area while water bodies (streams, wetlands and swamps) are expected to reduce from 3.3% to 1.42%. Average annual Sediment yield is expected to generally increase from 2431.4 tons/km$^2$/year (1993 to 2020) to an average annual sediment yield of 3147.6 tons/km$^2$/year from 2020 to 2050, that is to say an increase of 29.5%. The average rate of annual sediment yield increase is estimated at 1.056% per year. Therefore, mitigation measures should be adopted to ensure sustainable management of the catchment. The study findings of this research shall be relevant for planning, design and management of reservoirs, dams, irrigation systems and sustainability of eco systems in the catchment.

## DECLARATION

I Ologe Hector Daniel, do declare that this thesis is my own original work and has never been submitted to any University or to any other institution for funding or partial fulfillment for any award of master's degree.

Ologe Hector Daniel

Signature: ……………………………………………...

Date…5th/03/2024………………………………………………………………….

## APPROVAL

This dissertation is submitted as a partial fulfillment for the award of Degree of Masters of Science in Irrigation & Drainage Engineering of Busitema University, with our approval as the Academic Supervisors.

**Dr. Joseph Ddumba Lwanyaga**

Lecturer

Department of Water Resources Engineering

Faculty of Engineering and Technology

Busitema University

Signature……………………

Date 2023-12-15……………………

**Eng. Badaza Muhammed**

Lecturer

Faculty of Engineering and Technology

Busitema University

Signature……………………

Date 17/01/2024

## DEDICATION

I dedicate this dissertation to my parents Mr. and Mrs. Obbo Gideon Ologe in honor to their unmeasurable love, encouragement and supported rendered to me during this process.

I also dedicate my dissertation to my Dear loving wife who has guided and encouraged me to remain focused amidst the struggles.

However, I also dedicate my university supervisors notably Dr joseph Ddumba Lwanyaga, Eng. Badaza Muhammed.

Lastly, I dedicate my dissertation to my friends notably Prof Watmon Titus Bitek, Oketcho Yoronimo, Maseruka Benedictto and Wanamama Goefrey.

## ACKNOWLEDGMENTS

I would like to take this opportunity to thank my supervisors Dr. Lwanyaga Joseph Ddumba and Eng. Badaza Mohammed and Prof Titus Bitek Watmon for the good academic guidance rendered during my research study.

I will always pray to the Almighty God to bless them abundantly.

Secondly, my appreciation goes to my friends, family, parents who helped me in getting the support required notably Aiko sarah, Maseruka S Benedictto, Kajubi Enock, Wanamama Geoffrey, Namonye Sam, Gilbert Ndiwandinda. For their encouragement and offering right advice and guidance.

Above all, grate thanks go to the Almighty God for keeping me safe and healthy to be able to finish the research successfully.

## TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

## NOMENCLATURE.

| | |
|---|---|
| AOGCMs | Atmosphere Ocean General Circulation Models |
| AR | Annual Report |
| CMI | Climatic Moisture Index |
| DEM | Digital Elevation Model |
| DWRM | Directorate of Water Resources Management |
| ENSO | El Nino Southern Oscillation |
| ESDMs | Empirical statistical downscaling models |

| | |
|---|---|
| FDC | Flow Duration Curve |
| FMI | Finnish Meteorological Institute |
| GCM | Global Circulation Model |
| GHG | Green House Gases |
| GLUE | Generalized Likelihood Uncertainty Estimation |
| HADCM3 | Hadley Centre Coupled Model, version 3 |
| HADGEM | Hadley Centre Global Environmental Model, version 1 |
| HRU | Hydrological Response Unit |
| ICSU | International Council of Scientific Unions |
| IGBP | International Geosphere Biosphere Programme |
| IPCC | Intergovernmental Panel on Climate Change |
| IS | Importance Sampling |
| ISRIC | International Soils Reference and Information Centre |
| LAM | Limited Area Models |
| LARS-WG | Long Ashton Research Stochastic Weather generator |
| LH-OAT | Latin Hypercube One-factor-At-a-Time |
| LOCA | Localized constructed Analogs |
| MAKESENS | Mann-Kendall Test and Sen's Slope Estimate |
| MCMC | Markov chain Monte Carlo |
| MNPD | Ministry of National Planning and Devolution |
| MWE | Ministry of Water and Environment |

| | |
|---|---|
| NBI | Nile basin Initiative |
| NSE | Nash-Sutcliffe Efficiency |
| NWP | Numerical Weather Prediction |
| ParaSol | Parameter Solution |
| PBias | Percentage Bias |
| PSO | Particle Swarm Optimization |
| $R^2$ | Coefficient of Determination |
| RCM | Regional Circulation model |
| RCPs | Representative Concentration Pathways |
| RMSE | Root Mean Square Error |
| SDSM | Statistical Downscaling Model |
| SRES | Special Report on Emissions Scenarios |
| 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 |
| WWAP | World Water Assessment Report |

# CHAPTER ONE: INTRODUCTION

## 1.1 Background of the study

River sediment yield is directly influenced by climate and land use variation (Guo *et al*., 2018). In most developing countries, the effects of land-use change are today manifesting through accelerated rates of soil erosion (Duveiller *et al*., 2020; Schürz *et al.*, 2020). Globally, surface soil is being eroded from river basins at a rate of 60 billion tons per year, this results in 24 billion tons of sediment being released into the world's water bodies and almost 25 billion tons of soil being removed from agricultural land (Deltares, 2018). Urbanization, agriculture, and deforestation are just a few of the everyday anthropogenic activities that have altered spatial and temporal changes in land use and cover (Deltares, 2018). River sedimentation and stream flow are normally affected by changes in land use and land cover (Deltares, 2018).

Understanding and predicting sedimentation in river systems is a crucial global concern due to its impact on water quality, aquatic life, flood risks, and reservoir lifespans(Aljumaily et al., 2023). Land use and land cover, and climate change play significant roles in the amount of sediment entering rivers. As such, predictive models are essential tools in quantifying the intertwined effects of these factors. In Africa, where land degradation, deforestation, and climate change are major challenges, these models are particularly important for understanding the dynamics of sedimentation(Dibaba et al., 2021). Historical climate change has been observed and further changes are anticipated (Alava *et al*., 2018). According to the Intergovernmental Panel on Climate Change (IPCC), the average temperature on the planet has increased by about 0.6 degrees Celsius over the past century, and it is expected to further increase by 4 degrees by the end of the 21$^{st}$ century (Allen *et al.,* 2018). Sedimentation and increased nutrient loads of rivers in Uganda has increased due to unsustainable farming practices and other poor land management practices like deforestation (Mubiru et al., 2017). Sediment discharge is one of the main water quality concerns in integrated watershed management, a proper identification of sediment sources is therefore important to the success of watershed conservation programs (Yongbo et al.,2015). A comprehensive understanding of land-use changes processes and their future trajectories is essential for the development of land-use management plans required for conservation of ecological resources (Stanly *et al.,* 2022).

# REFERENCES

Al, A. et. (2018). Predicting the impact of climate change and the hydrological response within the Gurara reservoir catchment, Nigeria. *Journal of Water and Land Development*, *51*, 129–143.

Allen et, al, 2018. (2018). Climate Controls on Runoff and Low Flows in Mountain Catchments of Western North America. *Water Resources Research*, *54*(10), 7495–7510.

Barasa, B., Kakembo, V., & Karl, T. (2022). Characterization of artisanal gold mining activities in the tropics and their impact on sediment loading and stream flow in the Okame River catchment, Eastern Uganda. *Environmental Earth Sciences*, *75*(14).

Barker, I., & Turner, A. (2011). Integrated land use and water management. *Irrigation and Drainage*, *60*(SUPPL. 1), 27–34.

Boix-Fayos, C., Martínez-Mena, M., Arnau-Rosalén, E., Calvo-Cases, A., Castillo, V. A. (2006). Measuring soil erosion by field plots: Understanding the sources of variation. Earth Sci. Rev., 78, 267–285.

Chakrapani, G. J. (2005). *Factors controlling variations in river sediment loads*. *88*(4).

Deltares, 2018. (2018). Improved Understanding of the Link Between Catchment-Scale Vegetation Accessible Storage and Satellite-Derived Soil Water Index. *Water Resources Research*, *56*(3), 1–22. Aljumaily, H., Hayder, G., Yussof, S., & Ali, R. H. (2023). Artificial Intelligence Techniques for Predicting Water Quality Parameters and Management in a Complex River System: A Review. *Advances in Science, Technology and Innovation*, *October 2022*, 11–19.

Deltares, 2018. (2018). Improved Understanding of the Link Between Catchment-Scale Vegetation Accessible Storage and Satellite-Derived Soil Water Index. *Water*

Dibaba, W. T., Demissie, T. A., & Miegel, K. (2021). Evaluation of Best Management Practices in Highland Ethiopia, Finchaa Catchment. *Land*, *10*(650).

Guo. (2018). *D.6.1*: Impact assessment methodology for technical, operational, environmental and societal impacts and list of KPIs. 768994.

Huang, X. (2019). The Effect and Mechanism of Vegetation Cover and Rainfall Change on Runoff and Sediment Yield in Du Watershed, China. Ph.D. Thesis, Huazhong Agricultural University, Wuhan, China.

Imeson, A.C., & Lavee, H. (1998). Soil erosion and climate change: The transect approach and the influence of scale. Geomorphology, 23, 219–227.

IPCC. (2018). Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre–Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty; rld Meteorological Organization: Geneva, Switzerland,; p. 32.

IPCC. Climate change (2014). Synthesis report. In Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Pachauri, R.K., Meyer, L.A., Eds.; Core Writing Team, IPCC: Geneva, Switzerland, 2014; p. 151.

Jansen, I.M.L., & Painter, R.B. (1974). Predicting sediment yield from climate and topography. J. Hydrol., 21, 371–380.

Khoi, D.N.,& Suetsugi, T. (2014). Impact of climate and land-use changes on hydrological processes and sediment yield—A case study of the Be River catchment, Vietnam. Hydrol. Sci. J. 59, 1095–1108.

Langbein, W.B., & Schumm, S.A. (1958). Yield of sediment in relation to mean annual precipitation. EOS, 39, 1076–1084.

Li, Z.Y., & Fang, H.Y. (2017). Modeling the impact of climate change on watershed discharge and sediment yield in the black soil region, northeastern China. Geomorphology, 293, 255–271.

Lü, X.X., Ran, L.S., Liu, S., Jiang, T., Zhang, S.R., & Wang, J.J. (2013). Sediment loads response to climate change: A preliminary study of eight large Chinese rivers. Int. J. Sediment Res. 28, 1–14.

Martin, J.M., & Meybeck, M. (1979). Elemental mass-balance of material carried by major world rivers. Mar. Chem.7, 173–206.

Montgomery, D.R. (2007). Soil erosion and agricultural sustainability. Proc. Natl. Acad. Sci. USA, 104, 13268–13272.

Montgomery, D.R., & Brandon, M.T. (2002). Topographic controls on erosion rates in tectonically active mountain ranges. Earth Planet. Sci. Lett.,201, 481–489.

Mahmood et al. (2016). Load forecasting, dynamic pricing and DSM in smart grid: A review. *Renewable and Sustainable Energy Reviews*, *54*, 1311–1322.

Megersa et al, 2023. (2023). The role of land use/cover type in influencing hydrological component of a watershed in Chancho and Sorga Sub-watersheds, East Wollega Zone, Oromia, Ethiopia. *IOP Conference Series: Earth and Environmental Science*, *1016*(1).

Nearing, M.A., Jetten, V., Baffaut, C., Cerdan, O., & Couturier, A. Hernandez, M., Le Bissonnaise, Y., Nicholsa, M.H., Nunesf, J.P., & Renschlerg, C.S. (2005). Modeling response of soil erosion and runoff to changes in precipitation and cover. Catena, 61, 131–154.

NBL, 2015. (2015). Use of modeling to protect, plan, and manage water resources in catchment areas. *Environmental Science and Pollution Research*, *23*(16), 15841–15851.

Peng, H., Jia, Y.W., Qiu, Y.Q., Niu, C.W., & Ding, X.Y. (2013). Assessing climate change impacts on the ecohydrology of the Jinghe River basin in the Loess Plateau, China. Hydrol. Sci. J.58, 651–670.

Phan, D.B., Wu, C.C., & Hsieh, S.C. (2011). Impact of climate change on stream discharge and sediment yield in northern Viet Nam. Water Resour.

Shi, Z.H., Huang, X.D., Ai, L., Fang, N.F., & Wu, G.L. (2014). Quantitative analysis of factors controlling sediment yield in mountainous watersheds. Geomorphology, 226, 193–201.

Sinha, R.K., & Eldho, T.I. (2018). Effects of historical and projected land use/cover change on runoff and sediment yield in the Netravati River basin, Western Ghats, India. Environ. Earth Sci., 77, 111.

Stockwell, J.D., Doubek, J.P., Adrian, R., Anneville, O., Carey, C.C., Carvalho, L., Domis, L.N.D.S., Dur, G., Frassl, M.A., & Grossart, H.P. (2020). Storm impacts on phytoplankton community dynamics in lakes. Glob. Chang. Biol. 26, 2756–2784.

Syvitski, J.P.M. (2003). The influence of climate on the flux of sediment to the coastal ocean. In Proceedings of the Oceans. Celebrating the Past ... Teaming toward the Future (IEEE Cat. No.03CH37492), San Diego, CA, USA, 22–26 September 2003.

Thrasher, B., Maurer, E.P., McKellar, C.,& Duffy, P.B. (2012). Technical note: Bias correcting climate model simulated daily temperature extremes with quantile mapping. Hydrol. Earth Syst. Sci. 16, 3309–3314.

Vaighan, A.A., Talebbeydokhti, N., & Bavani, A.M. (2017). Assessing the impacts of climate and land use change on streamflow, water quality and suspended sediment in the Kor River Basin, Southwest of Iran. Environ. Earth Sci. 76, 543.

Van, O.K., & Govers, G.; Desmet. (2000). Evaluating the effects of changes in landscape structure on soil erosion by water and tillage. Landsc. Ecol. 15, 577–589.

Walling, D.E. (2009). The Impact of Global Change on Erosion and Sediment Transport by Rivers: Current Progress and Future Challenges; United Nations Educational, Scientific and Cultural Organization: Paris, France; pp. 1–26.

Walling, D.E., & Fang, D. (2003). Recent trends in the suspended sediment loads of the world's rivers. Glob. Planet Chang. 39, 111–126.

Wang, H., Saito, Y., Zhang, Y., Bi, N., Sun, X., & Yang, Z. (2011). Recent changes of sediment flux to the western Pacific Ocean from major rivers in East and Southeast Asia. Earth Sci. Rev. 108, 80–100.

Wang, M., Hamilton, D.P., McBridea, C.G., Abellc, J.M., & Hicksa, B.J. (2018). Modelling hydrology and water quality in a mixed land use catchment and eutrophic lake: Effects of nutrient load reductions and climate change. Environ. Modell. Software, 109, 114–133.

Van Rompaey, A. J. J., Govers, G., & Puttemans, C. (2018). Modelling land use changes and their impacts on soil erosion and sediment supply to rivers. *Earth Surface Processes and Landforms*, *27*(5), 481–494.

Zabaleta, A., Meaurio, M., Ruiz, E. I. (2014). Simulation climate change impact on runoff and sediment yield in a small watershed in the Basque Country, northern Spain. J. Environ. Qual, 43, 235–245.

Zhang, X.C., & Liu, W.Z. (2005). Simulating potential response of hydrology, soil erosion, and crop productivity to climate change in Changwu tableland region on the Loess Plateau of China. Agric. For. Meteorol. 131, 127–142.

Zhao, G.J., Mu, X.M., Tian, P., Wang, F., & Gao, P. (2012). The variation trend of streamflow and sediment flux in the middle reaches of Yellow River over the Past 60 years and the influencing Factors. Res. Sci., 34, 1070–1078.