
FACULTY OF ENGINEERING AND TECHNOLOGY

**DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION
ENGINEERING**

MASTER OF SCIENCE IN IRRIGATION & DRAINAGE ENGINEERING

FINAL YEAR PROJECT

HYDRO-INFORMATICS FOR FLOOD RISK MODELLING AND ZONATION

A Case Study of the Kafu River Catchment

OMODING ABEL

BU/GS23/MID/15

SUPERVISORS: 1. Assoc. Prof. WATMON BITEK TITUS

2. Eng. OKIRYA MARTIN

Submitted as a final year project thesis to the Directorate of Graduate Studies, Research and Innovation in partial fulfillment for the award of a Masters Degree in Irrigation & Drainage Engineering at Busitema University.

ABSTRACT.

The researchers used hydro-informatics methods to model and map flood risks in the Kafu River catchment area. To improve flood preparedness, mitigation planning, and sustainable watershed management, the study focused on identifying and analysing the main causes of flooding, developing a comprehensive flood risk model, and ensuring its accuracy and reliability. A multidisciplinary approach was adopted to accomplish these goals. Historical river flow and rainfall data spanning 30 years (1993–2023) were collected and analysed to assess rainfall trends and flood recurrence intervals. The research integrated modelling techniques, geographic information systems, community surveys, and field-based data collection in a mixed-method approach. Hydrological modelling was performed using HEC-HMS software, with rainfall-runoff relationships developed through the SCS Unit Hydrograph method for direct runoff transformation and the SCS Curve Number method for loss estimation. Peak flows and related flood depths for five return periods were simulated by calibrating both the hydraulic model (HEC-RAS) and the hydrological model (HEC-HMS). Estimated peak discharges for the 10-, 50-, 100-, 200-, and 500-year return periods were 203.26 m³/s, 281.02 m³/s, 313.90 m³/s, 346.66 m³/s, and 389.87 m³/s, respectively, based on the Gumbel distribution. The maximum flood depths at the Kimengo cross-section near Kafu Bridge were 5.13 m, 6.34 m, 6.67 m, 7.13 m, and 7.46 m when these discharges were input into the HEC-RAS model. Statistical analyses, including the Chi-square test of independence and flood depth comparisons, confirmed the significant relationship between flood frequency and proximity to river channels. The model's ability to predict flood depths was validated by a strong correlation ($R^2 > 0.90$) between field data and simulated results. The study identified key factors contributing to flooding as land use changes—particularly deforestation and wetland encroachment—as well as heavy rainfall events and insufficient drainage infrastructure. Flood risk maps highlighted the areas surrounding the main Kafu River channel and its primary tributaries as most vulnerable to flooding. The findings demonstrated that combining GIS tools with hydrological and hydraulic models offers a strong framework for flood risk assessment and zoning. Overall, the developed model proved to be a valuable and reliable tool for flood risk management within the Kafu catchment area. To reduce flood impacts, it was recommended that local authorities and water resource managers prioritise flood-prone zones in future land use and infrastructure planning, employ GIS-based flood risk frameworks, and enhance community awareness.

Keywords: River Kafu catchment; inundation mapping; HEC-HMS; HEC-RAS; land-use change; hydrometeorological monitoring.

ACKNOWLEDGEMENT.

I give thanks to the Lord, for He is good, and His love endures forever. The fear of the Lord is the beginning of wisdom. I owe my deepest gratitude to my supervisors, Assoc. Prof. Watmon Bitek Titus and Eng. Okirya Martin, for their dedication and patience throughout this project. Without their valuable time and commitment, this project would not have been completed. Special thanks go to residents in the areas of Kimengo, Kitema, Kafu, and other stakeholders, especially the Ministry of Water and Environment, for providing me with results and datasets, and for always being there when I needed help. I must also appreciate my colleagues, Mr. Kusemererwa Joseph, Mr. Naleebi Isaac, Eng. Nuwamanya Goden, Mr. Omutojo Emmanuel, Mr. Emaru Andrew and the Collaborative MSc classmates. Irrigation and Drainage Engineering class of 2023, Busitema University, who were often there to assist. Lastly, my sincere appreciation goes to my wife, Mrs. Kemigisa Sheillah Omoding, and my family, for their friendship, generosity, love, and kindness. Above all, Almighty God, you are the master of everything. May You continue blessing us.

DECLARATION.

I, **OMODING ABEL**, confirm to the best of my knowledge that this work is a result of my own efforts and has never been presented to any university or other institutions for any award or whatsoever.

Signature:

Date:

APPROVAL.

This research thesis is submitted to Busitema University, Department of Agricultural Mechanisation and Irrigation Engineering, with the approval of the following project supervisors;

PROF. WATMON BITEK TITUS,
Associate Professor
Faculty of Engineering and Technology.

Signature:

Date:

ENG. OKIRYA MARTIN,
Senior Lecturer
Faculty of Engineering and Technology.

Signature:

Date:

DEDICATION.

To my dear wife, Mrs. Kemigisa Sheillah Omoding

CONTENTS

ABSTRACT.....	i
ACKNOWLEDGEMENT.....	ii
DECLARATION.....	iii
APPROVAL.....	iv
DEDICATION.....	v
Contents	vi
LIST OF FIGURES.	ix
LIST OF TABLES.....	x
NOMENCLATURE	xi
1. CHAPTER ONE.....	2
1.1. Background.	2
1.2. Statement of the Problem.....	3
1.3. Objectives of the study.....	4
1.3.1. Main Objective/ Purpose of the study.	4
1.3.2. Specific objectives.	4
1.3.3. Research Questions.....	4
1.4. Scope of The Study.....	4
1.5. Significance of the Study.	5
1.6. Conceptual Framework.....	5
1.7. Structure of the Thesis.....	6
2. CHAPTER TWO.....	7
2.1. Origin of the name “Kafu.”.....	7
2.2. Types of floods.	7
2.2.1. Fluvial floods.	7
2.2.2. Flash floods.....	8
2.2.3. Coastal floods.	8
2.2.4. Pluvial floods.	8
2.2.5. Groundwater floods.	8
2.2.6. Urban floods.	9
2.2.7. Tsumani-induced floods.....	9
2.2.8. Snowmelt floods.	9
2.2.9. Ice jam floods.....	9
2.2.10. Dam break or levee failure floods.....	10
2.3. Assessing the main drivers of floods in the catchment.	10
2.3.1. Climate drivers.....	10

2.3.2.	Land use and land cover change.....	11
2.3.3.	Topographic and physiographic factors.	12
2.3.4.	Soil characteristics and infiltration capacity.	12
2.3.5.	Hydrological and channel related factors.....	12
2.3.6.	Infrastructure and drainage challenges.....	13
2.3.7.	Socio-economic and institutional factors.	13
2.4.	Developing a flood risk model for River Kafu catchment.....	13
2.4.1.	Finding the best flood probability distribution model.....	13
2.4.2.	Rainfall Runoff Modeling.	16
2.4.3.	Hydraulic Modeling.....	22
2.5.	Validating the generated flood risk model.....	24
2.5.1.	Field study analysis.....	24
2.5.2.	GIS analysis	26
3.	CHAPTER THREE.....	28
3.1.	Research Design	28
3.1.1.	Data Collection Process	28
3.1.2.	Instruments Used	29
3.2.	Study Area Description.....	30
3.3.	3.2 Dataset description.....	31
3.4.	Methodology for specific objective one: Assessing the primary drivers of floods in River Kafu catchment.....	31
3.4.1.	Questionnaire survey design and administration.	32
3.4.2.	Land use and land cover analysis.....	32
3.4.3.	Rainfall trend analysis.....	34
3.4.4.	Ranking the Causes of Flooding Using Analytical Hierarchy Process (AHP).	34
3.5.	3.4 Methodology for specific objective two: Generating a flood risk potential model for the River Kafu catchment.	35
3.5.1.	Determining the best flood probability distribution model.	35
3.5.2.	Hydrologic modeling.....	37
3.5.3.	Hydraulic modeling & flood plain mapping.....	39
3.6.	Methodology for specific objective three: Validating the generated suitability model for accuracy and reliability.	40
3.6.1.	Flood prone zoning using ArcGIS.	40
3.6.2.	On-field analysis.....	42
4.	CHAPTER FOUR.	43
4.	RESULTS ANALYSIS AND DISCUSSIONS.....	43

4.1. Identifying and analysing the primary drivers of flooding in the Kafu River catchment	43
4.1.1. Questionnaire results about people’s perceptions on floods.	43
4.1.2. Land use changes observed over the past 30 Years.....	46
4.1.3. Analysis of Rainfall trends.	47
4.1.4. Ranking the common causes of floods in the catchment.	47
4.2. Flood risk potential model results.	48
4.2.1. Flow hydrograph of River Kafu.	48
4.2.2. Flood frequency analysis of R. Kafu with its reaches sing three distributions.	49
4.2.3. Hydrological model results.....	53
4.2.4. 4.2.3.2 Simulated and observed hydrographs.	55
4.2.5. Optimization analysis of the Kafu HEC HMS model.....	55
4.3. Hydraulic model results.	56
4.3.1. Geometrical data model and its calibration.	56
4.3.2. Generated cross-sections at inflow and outflow hydrographs.	58
4.3.3. Flood hazard maps.....	58
4.4. Validation of the model.....	64
4.4.1. ArcGIS analysis.....	64
4.4.2. On-field analysis.....	68
4.4.3. Flood depths.	70
5. CHAPTER FIVE.....	72
5.1. Conclusions.....	Error! Bookmark not defined.
5.1.1. Assessing the primary drivers of floods in the catchment.....	72
5.1.2. Flood model generation.	72
5.1.3. Validation of the flood model.	73
5.2. Recommendations for further studies.....	73
5.2.1. Assessing the primary drivers of floods in the catchment.....	Error! Bookmark not defined.
5.2.2. Flood model generation.	Error! Bookmark not defined.
5.2.3. Validation the model.	Error! Bookmark not defined.
REFERENCES.....	75
APPENDICES.....	78

LIST OF FIGURES.

Figure 1.1: Conceptual framework.	6
Figure 2.1: Typical HEC-HMS representation of watershed runoff (USACE, 2000).	17
Figure 2.2: Elevation head, pressure head, and velocity head open channel flow.	23
Figure 2.3: Hydraulic cross-section for HEC-RAS parameters.	24
Figure 3.1: River Kafu catchment.	30
Figure 3.2: The Analytical Hierarchy Process.	41
Figure 4.1: Flood frequency from the questionnaire.	45
Figure 4.2: Suggested causes of floods.	45
Figure 4.3: Rainfall distribution over 30 years.	47
Figure 4.4: Flow hydrograph for River Kafu (1994 to 2023).	49
Figure 4.5: Normal, Log-Normal & Gumbel flood discharges for given return periods.	53
Figure 4.6: Basins delineated from Kafu catchment.	54
Figure 4.7: Inflow (Karongo, 2023) and outflow (Balyamuseny, 2023) hydrograph at Kafu gauge station.	55
Figure 4.8: Optimisation of the flow hydrograph.	56
Figure 4.9: Generated cross-sections from survey data.	57
Figure 4.10: Cross-section representing the main hydrograph along the two points.	57
Figure 4.11: Flood discharge for flow section at Balyamuseny (point 1 in Figure 4.10)	58
Figure 4.12: Flood discharge for flow section at Kafu (point 2 in Figure 4.10)	58
Figure 4.13: Flood discharge extents for 10-year return period.	59
Figure 4.14: Flood discharge extents for 50-year return period.	60
Figure 4.15: Flood discharge extents for 100-year return period.	61
Figure 4.16: Flood discharge extents for 200-year return period.	62
Figure 4.17: Flood discharge extents for 500-year return period.	63
Figure 4.18: Validated flood hazard map for Kafu catchment.	68
Figure 4.19: Scatter plot of GIS vs Field data	69
Figure 4.20: Comparison between field and model flood depths.	71

LIST OF TABLES.

Table 2.1: Probability distribution parameters in relation to sample moments.	14
Table 3.1: Instruments used in the study.	29
Table 3.2: Description of the dataset used in the study.	31
Table 3.3: Plotting positions for three PDFs.	36
Table 3.4: Calculating the Standard Normal Variate for three PDFs.	36
Table 3.5: Kafu catchment basin model parameters.	37
Table 3.6: Criteria used in validating the flood risk model.	40
Table 4.1: Summary of questionnaire responses from 100 people.	43
Table 4.2: Mayanja reach flood discharge computation using Normal distribution.	49
Table 4.3: Mayanja reach flood discharge computation using Log-Normal distribution.	50
Table 4.4: Mayanja reach flood discharge computation using Gumbel distribution.	50
Table 4.5: Lugogo reach flood discharge computation using Normal distribution.	50
Table 4.6: Lugogo reach flood discharge computation using Log-Normal distribution.	51
Table 4.7: Lugogo reach flood discharge computation using Gumbel distribution.	51
Table 4.8: Kafu flood discharge computation using Normal distribution.	52
Table 4.9: Kafu flood discharge computation using Log-Normal distribution.	52
Table 4.10: Kafu flood discharge computation using Gumbel distribution.	52
Table 4.11: Areas, flow paths lengths, slope, relief and drainage density of sub-basins.	54
Table 4.12: Pairwise comparison matrix.	67
Table 4.13: Normalized pairwise comparison matrix.	67
Table 4.14: Elevation data for different locations.	68
Table 4.15: Interview results from three districts.	69
Table 4.16: Calculation for the Chi-square statistic value.	70
Table 4.17: Data for flood depths from field and model.	70
Appendix 1: Structured questionnaire for Kafu flood catchment.	78

NOMENCLATURE

AHP	: Analytical Hierarchy Process
CN	: Curve Number
DEM	: Digital Elevation Model
FoS	: Factor of Safety
GIS	: Geographic Information System
HEC-HMS	: Hydrologic Engineering Center – Hydrologic Modeling System
HEC-RAS	: Hydrologic Engineering Center – River Analysis System
HSG	: Hydrologic Soil Group
PDF	: Probability Distribution Function
RS	: River Station
SCS	: Soil Conservation Service
SPSS	: Statistical Package for the Social Sciences
USACE	: United States Army Corps of Engineers
SDGs	

REFERENCES.

- Abdelkareem, M., & Mansour, A. M. (2023). Risk assessment and management of vulnerable areas to flash flood hazards in arid regions using remote sensing and GIS - based knowledge - driven techniques. *Natural Hazards*, 117(3), 2269–2295. <https://doi.org/10.1007/s11069-023-05942-x>
- Abdinour, S., & Jayanta, O. (2023). GIS - based flood risk assessment using multi - criteria decision analysis of Shebelle River Basin in southern Somalia. *SN Applied Sciences*, January. <https://doi.org/10.1007/s42452-023-05360-5>
- Agnihotri, A. I. P. P. G. (2020). *Application of new HEC - RAS version 5 for 1D hydrodynamic flood modeling with special reference through geospatial techniques : a case of River Purna at Navsari , Gujarat , India. 0123456789.*
- Ahmad, N., Yi, X., Tayyab, M., Zafar, M. H., & Akhtar, N. (2024). Water resource management and flood mitigation: hybrid decomposition EMD-ANN model study under climate change. *Sustainable Water Resources Management*, 10(2). <https://doi.org/10.1007/s40899-024-01048-9>
- Bayazıt, Y., Bakış, R., & Koç, C. (2021). A study on transformation of multi-purpose dams into pumped storage hydroelectric power plants by using GIS model. *International Journal of Green Energy*, 18(3), 308–318. <https://doi.org/10.1080/15435075.2020.1865362>
- Efraimidou, E., & Spiliotis, M. (2024). A GIS-Based Flood Risk Assessment Using the Decision-Making Trial and Evaluation Laboratory. In *Environmental Processes*. Springer International Publishing. <https://doi.org/10.1007/s40710-024-00683-w>
- Green, J., Haigh, I. D., Quinn, N., Neal, J., Wahl, T., Wood, M., Eilander, D., De Ruiter, M., Ward, P., & Camus, P. (2025). Review article: A comprehensive review of compound flooding literature with a focus on coastal and estuarine regions. *Natural Hazards and Earth System Sciences*, 25(2), 747–816. <https://doi.org/10.5194/nhess-25-747-2025>
- Hagos, Y. G., Andualem, T. G., Yibeltal, M., & Mengie, M. A. (2022). Flood hazard assessment and mapping using GIS integrated with multi - criteria decision analysis in upper Awash River basin ,. *Applied Water Science*, 12(7), 1–18. <https://doi.org/10.1007/s13201-022-01674-8>

- Mojaddadi, H., Pradhan, B., Nampak, H., Ahmad, N., & Halim, A. (2017). *Ensemble machine-learning-based geospatial approach for flood risk assessment using multi- sensor remote-sensing data and GIS*. 5705. <https://doi.org/10.1080/19475705.2017.1294113>
- Mujambere, D. (2022). *A Theological-Ethical Response to the Groaning of the Creation and Environmental Crises in Uganda, the Case of Kampala, and its Surroundings*.
- Mukhtar, M. A., Shangguan, D., Ding, Y., Anjum, M. N., Banerjee, A., Butt, A. Q., & He, B. B. (2024). *Integrated flood risk assessment in Hunza-Nagar , Pakistan : unifying big climate data analytics and multi-criteria decision-making with GIS*. February, 1–18. <https://doi.org/10.3389/fenvs.2024.1337081>
- Nagamani, K., Mishra, A. K., Meer, M. S., & Das, J. (2024). Understanding flash flooding in the Himalayan Region: a case study. *Scientific Reports*, 14(1), 1–16. <https://doi.org/10.1038/s41598-024-53535-w>
- Narendr, A., Vinay, S., Aithal, B. H., & Das, S. (2022). Multi-dimensional parametric coastal flood risk assessment at a regional scale using GIS Multi - dimensional parametric coastal flood risk assessment at a regional scale using GIS. *Environment, Development and Sustainability*, July. <https://doi.org/10.1007/s10668-021-01839-6>
- Shams, Z., Tasnuva, R., & Sarker, S. (2022). *National-Scale Flood Risk Assessment Using GIS and Remote Sensing- Based Hybridized Deep Neural Network and Fuzzy Analytic Hierarchy Process Models : A Case of Bangladesh National-Scale Flood Risk Assessment Using GIS and Remote Sensing- Based Hybridized Deep Neural Network and Fuzzy Analytic Hierarchy Process : A Case of Bangladesh*. 37, 12119–12148.
- Stein, J. (2019). *Jeepo*, 8(2), 13-25. 8(2), 13–25.
- Uganda National Planning Authority. (2020). Third National Development Plan (NDPIII) 2020/21-2024/25. *Uganda Vision 2040, Third*, 341.
- UN. (2015). *Sustainable Development Goals*.
- Water, L., Engineering, P. H., & Engineering, C. (2022). *CITY-SCALE MODELLING OF FACTORS AFFECTING URBAN PLUVIAL FLOOD HAZARD IN RAPIDLY DEVELOPING CITIES USING GLOBAL DATA* Victor Olajubu. July, 1–213.
- Yavuz, F. (2016). *AHP and GIS based land suitability analysis for Cihanbeyli (Turkey) County*. <https://doi.org/10.1007/s12665-016-5558-9>

- Zhran, M., Ghanem, K., Tariq, A., Alshehri, F., Jin, S., & Das, J. (2024). Exploring a GIS - based analytic hierarchy process for spatial flood risk assessment in Egypt : a case study of the Damietta branch. *Environmental Sciences Europe*. <https://doi.org/10.1186/s12302-024-01001-9>
- Zhu, Y., Burlando, P., Tan, P. Y., Blagojevic, J., & Fatichi, S. (2024). Investigating the influence of urban morphology on pluvial flooding: Insights from urban catchments in England (UK). *Science of the Total Environment*, 953(September), 176139. <https://doi.org/10.1016/j.scitotenv.2024.176139>