



**FLOOD RISK ASSESSMENT OF RIVER MAYANJA CATCHMENT THROUGH
INTEGRATING GEOGRAPHICAL INFORMATION SYSTEMS, ANALYTICAL
HIERARCHICAL PROCESS AND MACHINE LEARNING MODELLING**

BY

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DECLARATION

I, Deogratius Kemerwa, declare that this research thesis is original, except where referenced, and it has never been presented to any university or institution for any award.

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ABBREVIATION AND ACRONYMS

AHP	Analytical Hierarchy Process
AUC	Area Under the Curve
BFPA	Bootstrap Forest by Penalizing Attributes
CART	Classification and Regression Trees (CART)
CEC	Commission of European Communities
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CI	Consistency index
CNN	Convolutional Neural Network
CR	Consistency ratio
CSS	Constant Sum Scale
DEM	Digital Elevation Model
DFPA	Decision Forest by Penalizing Attributes
DMSP-OLS	Defense Meteorological Satellite Program Operational Line Scanner
DNNs	Deep Neural Networks
FAO	Food and Agriculture Organization
FHI	Flood Hazard Index
FPA	Forest by Penalizing Attributes
GBM	Gradient Boosting Machines
GBDT	Gradient Boosting Decision Tree
GDP	Gross Domestic Product
GDPPC	Gross Domestic Product Per Capita

GIS	Geographical Information Systems
GKMA	Greater Kampala Metropolitan Area
HEC-RAS	Hydrologic Engineering Center - River Analysis System
IDWI	Inverse Distance Weight Interpolation
InFRA	Index for Flood Risk Assessment
IPCC	Intergovernmental Panel on Climate Change
IFRC	International Federation of Red Cross and Red Crescent
LULC	Land Use Land Cover
MCDA	Multi-Criteria Decision Analysis
ML	Machine Learning
MLM	Machine Learning Models
MLP	Multi-Layer Perceptron
MWE	Ministry of Water and Environment
NFA	National Forest Authority
OpenLISEM	Open Limburg Soil Erosion Model
OSM	OpenStreetMap
RF	Random Forest
RI	Random index
ROC	Receiver Operating Characteristic
RS	Remote Sensing
SAR-1	Synthetic Aperture Radar 1
SDGs	Sustainable Development Goals
SRTM	Shuttle Radar Topographic Mission

SVM	Support Vector Machines
UBOS	Uganda Bureau of Statistics
UNMA	Uganda National Meteorological Authority
UTM	Universal Transverse Mercator
US\$	United States Dollar
XGBoost	Extreme Gradient Boosting
WBG	World Bank Group
WGS 84	World Geodetic System 1984

ABSTRACT

This study examines the flood hazards, exposure, and vulnerability in the River Mayanja Catchment. Geographic information systems (GIS) analysed hazards, vulnerability, and exposure data. Hazard factors included terrain from the digital elevation model (DEM), rainfall data, soil types, and land use. Vulnerability was assessed using socioeconomic indicators, such as per capita gross domestic product (GDP per capita) and household counts. Exposure factors included population density, building types, and proximity to infrastructure. The analytical hierarchy process (AHP) organised and weighted these datasets using pairwise comparisons. A weighted sum overlay of the hazard, vulnerability, and exposure maps produced a flood risk map. Machine learning models validated the map, including classification and regression trees (CART), Random Forests, gradient boosting machines (GBM) and logistic regression, with the ROC AUC metric confirming model performance.

The annual returns from 1981 to 2022 show significant fluctuations without a clear trend. The average return is 1,256 mm, with a minimum of 884 mm in 1983 and a maximum of 1,521 mm in 2019. Peaks over 1,500 mm occurred in 1997, 2019, and 2020, while troughs below 1,020 mm were noted in 1983 and 2009.

Return levels for 5 to 100-year return periods are modelled using normal, log-normal, Gumbel, Pearson III and log-Pearson III distributions. The Normal distribution predicts 150 mm at 5 years and 229 mm at 100 years. The Log-normal distribution estimates 149 mm and 366 mm for the same periods. The Pearson III distribution shows 148 mm at 5 years and 255 mm at 100 years, while the Log-Pearson III estimates 151 mm and 245 mm, respectively. The Gumbel distribution predicts 151 mm at 5 years and 294 mm at 100 years, offering the most conservative estimates for extreme events. Although rainfall estimates generally rise with longer return periods, model metrics (AIC, BIC, log-likelihood) indicate slight distribution variations. The Log-Pearson III is the best fit, with the lowest AIC (211,354) and BIC (211,384), and the highest log-likelihood (-105,674). Gumbel and Pearson III have similar AIC and BIC values, while Normal and Log-Normal are the worst fits with the highest AIC and BIC and the lowest log-likelihood.

Mapping of flooding extent and depth in the catchment area for return periods of 5, 15, 30, 50, 75, and 100 years. Longer return periods (75 to 100 years) are linked to deeper and more

widespread flooding. Shorter return periods (5 and 15 years) result in limited inundation, while moderate periods (30 and 50 years) indicate broader areas experiencing increased depths. The generated maps reveal that certain low-lying areas in Butambala, Luwero, Mityana, Mpigi, Nakaseke, and Wakiso regularly experience higher inundation making them vulnerable to severe flooding. Despite shorter return periods leading to minor flooding, they can last longer with greater depth, necessitating structural flood protection. In contrast, areas affected only by extreme events require zoning regulations, early warning systems, and disaster preparedness.

Key findings revealed that rainfall (32%), slope (20%), and elevation (15%) are the primary contributors to flood hazards, with moderate to high hazard zones accounting for 61% of the catchment. Population density (38%) and household numbers (25%) significantly affect flood exposure, impacting over 65% of the catchment. GDP per capita (43%) emerged as the primary vulnerability factor, with 75% of the region classified as moderately to very highly vulnerable. High and very high-risk areas comprise 60% of the catchment, underscoring the need for effective flood mitigation strategies. The Random Forest algorithm proved the most effective for validating the risk map, achieving an AUC of 0.87.

The study findings indicate that climate change influences the risk of flooding in the catchment area, highlighting the importance of addressing factors that influence economic resilience and emergency preparedness. Key focus areas include land-use planning, afforestation, improved drainage systems, and resilient infrastructure. The need for collaboration among policymakers and local stakeholders is stressed to implement effective flood management practices and enhance community resilience.

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