ASSESSMENT OF DEFORESTATION AND LAND COVER CHANGE IMPACTS ON FLOOD PEAK DISCHARGE IN MADURU OYA BASIN, SRI LANKA

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Degree of Master of Science

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Department of Civil Engineering

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ABSTRACT

Assessment of Deforestation and Land Cover Change Impacts on Flood Peak Discharge in Maduru Oya Basin, Sri Lanka

Population growth raises demand and competition for water resources and food stocks while it changes the landuse types by anthropogenic activities to adopt applicable measures for supplying water for domestic, agricultural, and industrial purposes. These changes alter the hydrological response of the river basins and can impose the communities to severe environmental risks like floods and landslides. Therefore, understanding of landuse change is crucial to study river basins' behavior and take mitigatory measures. The study presented here quantifies and analyzes the historical deforestation and landuse/landcover (LULC) change impacts on flood peak discharge of the Maduru Oya river basin, Sri Lanka using Hydrologic Engineering Centre-Hydrologic Modeling System (HEC-HMS) and remote sensing techniques. The Landsat Multispectral Scanner (MSS), Thematic Mapper (TM), and Operational Land Imager-thermal Infrared Sensor (OLI-TIRS) images are acquired in 1976, 1994, 2009, 2021 and classified using maximum likelihood algorithm of supervised classification.

The analysis of LULC change revealed that LU change was faster and in high magnitude from 1976 to 1994 compared to the remaining period to 2021. The LULC change quantification by analyzing each scenario revealed a 24.9% deforestation while a 2.2%, 9.8%, 8.4%, and 4.5% increase in homestead/garden, paddy, scrubland, and water body between 1976 to 1994, respectively. The deforestation further continued to a rate of 4.1% and a 2.0% decrease in water bodies was also found in 2009 while homestead/garden, paddy, and scrubland continued to increase by 3.5%, 1.4%, and 1.5% compared to 1994 landuse scenario, respectively. In contrast, the 2021 landuse scenario indicated a 7.6% decrease in scrubland while 3.6%, 0.5%, 1.5%, and 1.8% increase in forests, homestead/garden, paddy, and water bodies. The classified images were subjected to accuracy assessment. The overall accuracy of 82%, 84%, 88%, and 91% are found for 1976, 1994, 2009, and 2021 LU scenarios while having kappa coefficients of 0.78, 0.80, 0.85, and 0.89 for respective years. The Normalized Difference Vegetation Index (NDVI) assessment of scenarios corresponds to the landuse classified images.

An event-based HEC-HMS model is used to simulate the flood events in the Welikanda catchment of the Maduru Oya river basin. The model is calibrated and validated using the 1976 landuse and then the subsequent landuses are applied to study LU change impact on flood peak discharge. For model performance evaluation, the Nash-Sutcliffe, RMSE Observations Standard Deviation Ratio (RSR) Percent Bias (PBIAS), and the Coefficient of determination (R^2) were exploited. The average NSE, RSR, PBIAS, and R^2 values of 0.92, 0.25, 17.60, and 0.94 achieved in calibration and 0.73, 0.50, -3.03, and 0.78 are found in the validation which all can be rated very good performance except for PBIAS as satisfactory in calibration and NSE as good in the validation. The land cover change resulted in an increase (22.3%) in flood peak from 842 m^3/s in 1976 to 1,030 m^3/s in 2021. As a result of the landcover changes, the volume is also increased (42.3%) from 178.16 MCM in 1976 to 253.52 MCM in 2021. This study provides useful information for land and water managers, forests conservation units, and hydrologist to understand the LULC change impacts on floods and paves the way for broad LU and hydrological studies in Sri Lanka which are rarely conducted. The same approach can be applied in different parts of Sri Lanka which are exposed to severe LU changes.

Keywords: Data Scarcity, Forests, HEC-HMS, Hydrological Modeling, Satellite Observations, Water Cycle

DEDICATION

I would like to dedicate this study to my first teachers - my father and mother, in whom the existence gets a meaning, who have always stood up like the mountains against the challenges of life and have supported their children. When they were hardly surviving, they bought books and pens for their children to read, write and learn. It is with them that I feel big like the sky to spread the shade of kindness, smile, and supporting others. I owe them whatever I have in my life.

I also would like to dedicate this study to my family members, my brothers, and sisters who never spared to give me a hand when I was facing difficult times in my life.

I would like to honor the memory of my beloved late professor Ibrahim Najaf and my bachelor's degree supervisor Dr. Mohammad Hadi Asadi who have shaped my engineering life and dedicate this work to them.

Lastly, I would like to dedicate this work to my sweet homeland - Afghanistan in which I have grown up and do not know when to see it again, and Sri Lanka - my second homeland, the country that I have lived a life in so far.

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LIST OF ABBREVIATIONS

AMP	Accelerated Mahaweli Program
ANN	Artificial Neural Networks
C3S	Copernicus Climate Change Service
CN	Curve Number
DEM	Digital Elevation Model
DS	Direct Sampling
ECMWF	European Centre for Medium-Range Weather Forecasts
EDA	Exploratory Data Analysis
EDASM	European Digital Archive of Soil Maps
ERA 40	40-yr European Centre for Medium-Range Weather Forecasts Re-analysis
ERA5	Fifth Generation of Atmospheric Reanalysis of the Global Climate
ERA-Interim	ERA-Interim Represents a Third Generation Reanalysis
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization
FFPO	Fauna and Flora Protection Ordinance
GFDS	Global Flood Detection System
GIS	Geographical Information System
GSFC	Goddard Space Flight Center
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HRES	High-Resolution Forecast
LULC	Landuse/Landcover

MDP	Mahaweli Development Program
MERRA	Modern Era Retrospective-Analysis for Research and Applications
MI	Multiple Imputation
MLC	Maximum Likelihood Classifier
MLP	Multilayer Perceptron
MNN	Multivariate Nearest-Neighbor
MNP	Maduru Oya National Park
MSL	Mean Sea Level
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration.
NCEP	National Centers for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared Reflactance
NSE	Nash-Sutcliffe Simulation Efficiency
OLI	Operational Land Imager
PBIAS	Percentage Bias
PRF	Peak Rate Factor
R^2	Coefficient of Determination
RED	Red Reflectance
REGEM	Regularized Expectation–Maximization Algorithm
RSR	Root Mean Square Error Observations Standard Deviation Ratio
SCS	Soil Conservation Service
SOM	Self-organizing Map
SRTM	Shuttle Radar Topography Mission

Tc	Time of Concentration
TM	Thematic Mapper
UH	Unit Hydrograph
UN-REDD	United Nations-Reducing Emissions from Deforestation aAnd Degradation
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey