DEVELOPMENT OF A RAINFALL-RUNOFF-INUNDATION MODEL AND FLOOD MONITORING SYSTEM BASED ON SATELLITE IMAGERY FOR KALU GANGA BASIN, SRI LANKA

Tina Sultana

208363F

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa
Sri Lanka

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Supervised by

Prof. R. L. H. L. Rajapakse

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ABSTRACT

Development of a Rainfall-Runoff-Inundation Model and Flood Monitoring System based on Satellite Imagery for Kalu Ganga Basin, Sri Lanka

Floods are getting severe due to climate change and anthropogenic activities which need immediate response to lower the risk and decrease the human and financial losses. Flood inundation mapping for flood risk preparedness using satellite data has been widely used in many recent studies. However, satellite imageries may contain some uncertainties. Therefore, flood inundation maps from satellite data need to be verified with flood inundation maps generated by hydrological models from observed data for accurate estimation of flood risk. Although satellite-generated flood maps are widely used to determine the inundation extent, there are certain challenges to their use such as inaccessibility of imagery due to satellite orbit or cloud cover, which hampers accurate measurement of inundation risk.

In this study, the rainfall-runoff inundation (RRI) model for the Kalu Ganga basin was developed, and its applicability to evaluate the discharge and flood inundation areas was discussed. The RRI model could estimate discharge, water levels, and inundation areas simultaneously based on two-dimensional diffusion wave equations. The results and statistical analysis indicate that the RRI model could efficiently estimate extreme flood events. For model calibration, the R^2 value ranges from 0.72-0.80 and for model validation, the R^2 value ranges from 0.75-0.90, which shows good performance of the model.

The simulated inundation extents were verified and compared with Sentinel 1A SAR (Synthetic Aperture Radar) satellite imagery data for 2016 and 2017 flood events. Sentinel 1A, GRD-IW (Ground Range Detected - Interferometric Wide swath) mode of VV co-polarization, with a spatial resolution of 20 m was acquired and pre-processed using the Sentinel Application Platform (SNAP) software toolbox. The pre-processed images were corrected, and maximum likelihood supervised classification was performed to produce the flood inundation maps of the study area. The actual flooded area from RRI is found to be 291.97 km^2 and that from satellite image is found to be 201.7 km^2 for the 2016 flood event. For the 2017 flood event, the actual flooded area from RRI is found to be 371.14 km^2 and that from satellite image is found to be 297.42 km^2. Hence, the flooded area difference was found to be 35.54 % for 2016 and 22.13 % for 2017 flood events from the total area selected from the model. Most of the floodplains from the RRI model and satellite images were along the main river in the basin, including the city of Ratnapura (upstream), the city of Kalutara (downstream), and the areas in between. These results with an accuracy level of ~25 % - 30 % are deemed to be within an acceptable range for emergency evacuation and rapid flood damage assessment purposes. Future studies should further investigate and validate the flood inundation mapping ability of Sentinel 1A SAR using ground-based reference flood maps or other satellite data. This study reveals that satellite imagery can be one of the most cost-effective ways to capture the flood disaster footprints, identify flood-prone areas, and understand the flooding problem in a better way. This methodology can be effectively used for disaster risk management, where the time factor is very critical.

Keywords: Catchment hydrology, Extreme events, River discharge, SAR, Sentinel 1A

DEDICATION

I would like to dedicate this work to my parents and my brother who always supported me, encouraged, and guided me throughout my life.

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LIST OF ABBREVIATIONS

AMSR	Advanced Microwave Scanning Radiometer
ALOS	Advanced Land Observing Satellite
APHRODITE	Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation
ASAR	Advanced Synthetic Aperture Radar
ASTER	Advanced Space-borne Thermal Emission and Reflection
AVHRR	Advanced Very High Resolution Radiometer
AVNIR	Advanced Visible and Near Infrared Radiometer
DEM	Digital Elevation Model
ENVISAT	Environmental Satellite
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
EW	Extra Wide Swath
FBD	Fine Beam Dual
GIS	Geographic Information System
GPCC	Global Precipitation Climatology Centre
GSMaP (RNL)	Global Satellite Mapping of Precipitation Reanalysis Product
GRD	Ground Range Detected
IR	Infra-red Wave

IW	Interferometric Wide Swath
MERIS	Medium Resolution Imaging Spectrometer
MLSWI	Modified Land Surface Water Index
MODIS	Moderate Resolution Imaging Spectro-Radiometer
MSE	Mean Square Error
MSI	Multi Spectral Imaging Mission
NIR	Near Infra-red Wave
NDVI	Normalized Differential Vegetation Index
NDWI	Normalized Differential Water Index
NOAA	National Oceanic and Atmospheric Administration
NSE	Nash Sutcliffe Efficiency
LSWI	Land Surface Water Index
LULC	Land-Use Land Cover
PALSAR	Phased Array Type L-Band Synthetic Aperture Radar
PERSIANN-CDR	Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks- Climate Data Record
RADARSAT	Radar Satellite
RGB	Red Green Blue
RMSE	Root Mean Square Error
RRI	Rainfall-runoff-inundation
SAR	Synthetic Aperture Radar

SM	Strip-map Mode
SNAP	Sentinel Application Platform
SLC	Single Look Complex
SRTM	Shuttle Radar Topography Mission
SWIR	Short Wave Infra-red
TRMM	Tropical Rainfall Measuring Mission
VH	Vertical Transmit- Horizontal Receive
VV	Vertical Transmit- Vertical Receive
WV	Wave Mode