INTEGRATION OF RADAR AND OPTICAL REMOTE SENSING FOR LANDSLIDE INVESTIGATION – CASE STUDY OF KOSLANDA AREA IN SRI LANKA

Ahangama Kankanamge Rasika Nishamanie Ranasinghe

(118027 L)

Degree of Doctor of Philosophy

Department of Civil Engineering

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Declaration

I declare that this is my own work and this thesis does not incorporate, without acknowledgement, any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Name of the Supervisor: Prof. U. G. A. Puswewala

Signature of the Supervisor: Date:

Name of the Supervisor: Dr. T. L. Dammalage

Signature of the Supervisor: Date:

Abstract

Koslanda, in Sri Lanka is an area that remains in the memories of people due to frequently occurring landslides as the area is made vulnerable by both climatic and geomorphological settings. Additionally, the aftermath of the landslide, i.e. the debris flow, causes more damages when compared to the landslide itself. As such, this study focuses on the integration of radar and optical remote sensing for landslide investigation with inclusion of debris flow. The significance of the data types derived from radar and optical images are examined in terms of sensor characteristics and spectral information.

Radar and optical images before and after the event, geometrically registered and radiometrically normalized, are used to delineate the landslide area by different change detection techniques. Detected landslide areas are compared with the area determined by GPS field surveying. At the comparison stage, landslide detection capacity of the optical images was 76% while it was 86% with the radar images. This is mainly due to inherent nature of radar being able to collect data under any climatic condition.

The Information Value method uses bivariate analysis without radar induced factors (BiNR), and bivariate analysis with radar induced factors (BiWR), while the Multi Criteria Decision Analysis based on AHP uses multivariate analysis without radar induced factors (MNR), and multivariate analysis with radar induced factors (MWR). When utilizing the multivariate method, an increase in the area showing high and moderate susceptibility to landslides was observed as 5% and 3% from the total area, respectively. With the inclusion of radar induced factors (surface roughness, near surface soil moisture from delta index, and forest biomass), high and very low susceptible regions to landslide increased by 7% and 4% when using the bivariate method, while it was 3% for both cases when using the multivariate method. Landslide prediction analysis is enhanced by incorporating debris flow analysis with DEM derived factors, as appropriate for a country like Sri Lanka, where data scarcity of acceptable accuracy is high for smaller scale studies.

Key Words – Radar, Optical, Landslide, Prediction, Debris

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Ahangama Kankanamge Rasika Nishamanie Ranasinghe

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LIST OF ABBREVIATIONS

AHP – Analytic Hierarchy Process

ALOS - Advanced Land Observation Satellite

ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer

AUC - Area Under Curve

AVNIR-2 - Advanced Visible and Near Infrared Radiometer type 2

CI – Consistency Index

CR - Consistency Ratio

CVA - Change Vector Analysis

DEM - Digital Elevation Model

DFR - Debris Flow Regions

DGPS - Differential Global Positioning System

DI – Delta Index

DInSAR – Differential Interferometric SAR

DLR - German Aerospace Center

DMC – Disaster Management Center

DN - Digital Numbers

DT - Decision Tree

EEC - Enhanced Ellipsoid Corrected

EM-DAT - Emergency events data base

ENVISAT – Environmental Satellite

EO - Earth Observation

ERDAS - Earth Resource Data Analysis System

ERTS - Earth Resources Technology Satellite

ERS - European Remote Sensing

ESA - European Space Agency

EW - Extra Wide swath

FR - Frequency Ratio

GCP - Ground Control Points

GEC - Geocoded Ellipsoid Corrected

GIS – Geographical Information System

GPS – Global Positioning Systems

GRD - Ground Range Detected

GSMB - Geological Survey Mines Bureau

IDW - Inverse Distance Weighting

InfoVal - Information value

InSAR - Interferometric SAR

IRS – Indian Remote Sensing

IW - Interferometric Wide swath

JICA - Japan International Co-operation Agency

LST – Land Surface Temperature

MCDA – Multi Criteria Decision Analysis

MGD - Multi look Ground range Detected

MSL – Mean Sea Level

NBRO - National Building Research Organization

NDVI - Normalized Difference Vegetation Index

NIR - Near Infrared

OCN – Ocean

OLI - Operational Land Imager

PALSAR - Phased Array type L-band Synthetic Aperture Radar

PCA – Principle Component Analysis

PRISM - Panchromatic Remote-sensing Instrument for Stereo Mapping

RDFD - Relative Debris Flow Density

RFD - Relative Failure Density

ROC - Receiver Operating Characteristics

SAFE - Standard Archive Format for Europe

SAR - Synthetic Aperture Radar

SI - Statistical Index

SM - Strip Map

SMI – Soil Moisture Index

SPI - Stream Power Index

SRTM - Shuttle Radar Topographic Mission

SSC - Single look Slant range Complex

SVM - Support Vector Machine

T - Temperature

TauDEM - Terrain analysis using DEM

TFSI - Terrain Failure Susceptibility Index

TIRS - Thermal Infrared Sensor

TM - Thematic Mapper

TOA - Top-Of-Atmosphere

TWI - Topographical Wetness Index

UDA – Urban Development Authority

WOE - Weight of Evidence