DEVELOPMENT OF LANDSLIDE DISASTER RISK INDEX (DRI) BASED ON GEOSPATIAL ANALYSES: A CASE STUDY FROM KEGALLE DISTRICT, SRI LANKA

Elibichchiralalage Nimala Chinthake Perera

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By

Elibichchiralalage Nimala Chinthake Perera

Thesis submitted to the University of Sri Jayewardenepura award of the Degree of Doctor of Philosophy on 2019

DECLARATION OF THE CANDIDATE

I do hereby declare that the work reported in this thesis was exclusively carried out by me under the supervision of Dr DT Jayawardana, Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Dr Pathmakumara Jayasingha, Senior Scientist Landslide Research and Risk Management Division, National Building Research Organization (NBRO) of Sri Lanka and Mr RMS Bandara, Director, Landslide Research and Risk Management Division, National Building Research Organization of Sri Lanka. It describes the results of my own independent research except where due reference has been made in the text. No part of this project thesis has been submitted earlier or concurrently for the same or any other degree.

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DECLARATION OF THE SUPERVISORS

This is to certify that this thesis is based on the work carried by Mr Elibichchiralalage Nimala Chinthake Perera under our supervision. The thesis has been prepared according to the format stipulated and is of an acceptable standard.

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LIST OF ABBREVIATIONS

NBRO	National Building Research Organization
GSMB	Geological Survey and Mines Bureau
DMC	Disaster Management Center
LHZ	Landslide Hazard Zonation
DRM	Disaster Risk Management
UNDP	United Nations Development Program
GSSL	Geological Society of Sri Lanka
JICA	Japan International Cooperation Agency
HC	Highland Complex
VC	Vijayan Complex
WC	Wanni Complex
DSD	Divisional Secretariat Division
DRI	Disaster Risk Index
GIS	Geographical information system
GDP	Gross Domestic Product
HPI	Human Poverty Index
AHP	Analytic Hierarchy Process
PCA	Principal Component Analysis
FA	Factor Analysis
RS	Remote Sensing
DRR	Disaster Risk Reduction
KHG	Kandyan Home Garden
GND	Grama Niladari Division
GPS	Global Positioning System

GLONASS	Global Navigation Satellite System
SPSS	Statistical Package for Social Sciences
SAR	Synthetic Aperture Radar
ID	Intensity-Duration
SMEM	Multi-Criteria Evaluation Model
AHP	Analytic Hierarchy Process
CR	Consistency Ratio
CI	Consistency Index
IDW	Inverse Distance Weighting

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ABSTRACT

Landslides are the most far-flung natural hazards, causing loss of thousands of lives and billions of dollars annually worldwide. In Sri Lanka, during the last few decades' landslides occurred with increasing frequency. Approximately 20,000 Km^2 (30.7%) land area from 13 districts of the country susceptible to landslides. This study mainly focused to develop a methodology for the generation of a landslide disaster risk index (DRI) by quantifying associated uncertainties; hazard, vulnerability, and exposure using the geospatial model for Kegalle District, Sri Lanka. In Sri Lanka, previous studies have not focused on establishing a relationship between intensity and duration of rainfall. Therefore, in the initial phase of the experimental design, a rainfall intensity-duration (I-D) models were developed for Badulla and Kegalle Districts to establish rainfall thresholds for landslides. Also, the study extended to assess the impact of land cover/use change on the frequency of the occurrence of the landslide by using multi-temporal optical (Landsat-8) and synthetic aperture radar (SAR, Sentinel-1) images 1988, 1997, and 2017 for hazard assessment. Then the landslide hazard assessment was conducted based on conditioning factors. These causative factors were weighted and modeled to define hazardous zones by the geographical information system (GIS) based spatial multi-criteria evaluation (SMCE). Then questionnaire survey was conducted with 420 sample to obtained social conditions for landslide vulnerability. Landslide

vulnerability was assessed combining physical and social indicators and Entropy method was used to determine the weights for indicators. Next spatial distribution of exposure to landslides were assessed and mapped. Finally, landslide Disaster Risk Index (DRI) was developed as a function Hazard, Vulnerability and Exposure. Developed DRI was used to map the spatial distribution of landslide risk with 100×100m spatial resolution. The finding of this study confirms the increase in the frequency, severity, and spatial distribution of landslides in Kegalle. Rainfall I-D threshold for trigger a landslide in Kegalle District modeled as; $I = 58.35D^{-0.114}$ $(5 \leq D \leq 14\ h)$. The developed landslide hazard map shows a 90% level prediction accuracy compared to previous landslides. According to landslide hazard zonation map, 13% (214 Km^2) of the entire area is found to be of high landslide susceptibility zone. According to landslide vulnerability model, 14.6 % (247 Km^2) of the entire area is found to be the highest vulnerable zone for a landslide. Correlation analysis revealed that vulnerability and hazard could significantly (0.00 <0.05) contribute to risk but contribution of exposure was insignificant. Records of previous landslides confirmed the validity of developed landslide DRI. According to the spatial distribution of landslide risk, the study area demonstrates notable regional specifications. Besides, the spatial distribution of risk has shown a close relationship with rural and urban settlements. According to the record of the impact of a historic landslide that occurred in the study area, the developed DRI can sufficiently reflect the level and distribution of landslide risk. The developed method should be useful to decision makers spatial planning and civil protection. The DRI can be significantly improved, and its reliability can be increased by adding more parameters with high resolution and accuracy.

Keywords: Landslides, Hazard, Vulnerability, Risk index, Entropy Method