

Computational Mapping of Landslide Susceptibility Zones Using Satellite and Field Data

A Thesis submitted
in accordance with the requirements
for the degree of

Doctor of Philosophy

By

Sharad Kumar Gupta

Scholar No. D15015



School of Engineering
Indian Institute of Technology Mandi
Himachal Pradesh, India - 175075

“If a landslide comes as a surprise to the eyewitnesses, it would be more accurate to say that the observers failed to detect the phenomena which preceded the slide”

Karl von Terzaghi (1883-1963)

Dedicated to

My Tau Ji, My Parents, My Wife, My Brother, My Sisters

&

Three Cute Kids - Kanha, Guddan, and Aadu

Abstract

Landslides accounted for around 4.89% of the globally occurring natural disaster events during the last two decades. These are very prevalent in the Himalayan region, mainly due to varying lithology, changing weather, extreme precipitation, the density of drainage, tectonic activities, orography, topography, anthropogenic activities, and ongoing Seismicity. It is essential to identify such areas that are susceptible to landslides so that proper infrastructure management and development activities could be carried out. Thus, landslide susceptibility mapping (LSM) and its inventory preparation are important steps towards disaster management. LSM is the division of hill or mountainous areas into homogeneous spatial regions in accordance to their degrees of actual or potential susceptibility. It depends on various terrain attributes and subsurface properties called causative or conditioning factors and various triggering factors and their interrelations. Although several methods are in use for LSM around the globe, due to different landslide processes, no single method can efficiently identify, map and verify the susceptibility of a region.

Generally, the heuristic approach, where experts in the domain determine the weight of causative factors, is mostly applied in the Indian scenario. However, an expert-based approach induces subjectivity in susceptibility maps. This thesis presents a methodology for selecting the weights of causative factors in the preparation of susceptibility maps. The weights of the factors are determined based on the distribution of landslide and the intrinsic properties of data, which are used for LSM. Further, the selection of causative factors depends on the characteristics of the study area and spatial scale of analysis. To study the effect of scale and mapping units in LSM, the study area is divided into several sub-basins and micro-watersheds using grid-cells with geo-hydrological subdivisions (GCHU). This study recommends the use of sub-basin analysis as a representative of the susceptibility of a basin. The causative factors used in susceptibility mapping could be discrete (e.g., lithology) or continuous (e.g., slope gradient) in nature. A comparative analysis of susceptibility maps prepared using discrete and continuous factors is carried out. It is found that the factors represented by continuous data provide homogeneous susceptibility zone boundaries.

Furthermore, there are various approaches for LSM, namely distribution analysis, geomorphic or heuristic, statistical methods, deterministic approach, probabilistic approach, and distribution free or machine learning methods. The machine learning methods are widely used in LSM, but they require a large amount of training data. However, the landslides do not occur everywhere (there are also areas that are non-susceptible to landslides), and the number of landslide occurrences is limited in an area. This physical phenomenon creates an imbalance between landslide locations and non-landslide locations in the data. Hence, in this thesis the landslide susceptibility mapping is considered as an imbalanced learning problem. It is suggested to use informed under-sampling methods, namely Easy Ensemble and Balance Cascade, instead of random undersampling for balancing the data. Several methods, namely Fisher discriminant analysis, logistic regression, feed-forward neural network, cascade forward neural network, and support vector machine has been used for the preparation of landslide susceptibility maps in the thesis. Several accuracy measures such as precision, recall, receiver operating characteristics, f-score, geometric mean, and Heidke skill score are used to validate the susceptibility maps. The significance of the present work lies in the fact that it attempts to solve a few important issues such as subjectivity in weightage selection, subjectivity in selection of scale and study area, subjectivity in selection of factors, and finally problems associated with data imbalance in the general practice of landslide susceptibility mapping.

Keywords: Landslide susceptibility mapping; Scale dependency; Landslide causative factors; Data imbalance; Indian Himalayas

Declaration

I hereby declare that the entire work embodied in this Thesis is the result of investigations carried out by me in the **School of Engineering**, Indian Institute of Technology Mandi, under the supervision of **Dr. Dericks P. Shukla**, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgements have been made wherever the work described is based on finding of other investigators.

Mr. Sharad Kumar Gupta

Research Scholar

School of Engineering

IIT Mandi, 175005

Place: Mandi

Date: October 22, 2020

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Declaration by Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by **Mr. Sharad Kumar Gupta** (Scholar No: D15015), under my supervision in the **School of Engineering**, Indian Institute of Technology Mandi, and that no part of it has been submitted elsewhere for any Degree or Diploma.

Dr. Dericks P. Shukla
PhD Supervisor
Associate Professor
School of Engineering
IIT Mandi, 175005

Place: Mandi

Date: October 22, 2020

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Acknowledgements

Completion of the doctoral dissertation is indeed a long journey and therefore requires many helping hands. I am lucky to have plenty of them. To start with, I am thankful to Almighty God to enable me to complete my thesis.

First, I would like to express my gratitude to my parents, who make me what I am today. My parents' silent support, best wishes, and blessings have been the continuous source of inspiration and encouragement throughout my research program. The patience, sacrifices, and love my wife Shradha has shown during tough times are highly commendable. I really thank her so much. The understanding, endurance, and constant encouragement provided by my entire family can not be expressed in words.

Secondly, I want to thank my supervisor Dr. Dericks P. Shukla, for the guidance, support, discussions, and valuable help during the Ph.D. research work. I would like to express my sincere gratitude to him for patience, spending a significant amount of time, and paying great attention to my scientific and professional development. I will be forever indebted to him.

I want to express my sincere thanks to my doctoral committee members, Dr. Kala Venkata Uday, Dr. Deepak Swami, Dr. Surya Prakash Upadhyay, for their constant moral support, valuable suggestions, and encouragements during my research work. Furthermore, I would like to express my gratitude to Dr. Manoj Thakur, Dr. Rajeev Kumar (Ex-Chairperson SE), and Dr. Vishwanath Balakrishnan (Chairperson SE) for their valuable help and support.

Many thanks to my friends and colleagues, not only for help and support in my research work but more so for making my time in IIT Mandi fun and enjoyable, especially Abhay, Manushree, Naman Bartwal, Chanakya, Pankaj Sir, Nitu, Sneha, and Ankur for all lively discussions (both academic and non-academic), support and joyful moments. I am grateful to Naman Agarwal, Simran, Deepak, Tarun, and Ajeet for joyous moments in the later stage of my Ph.D.

Furthermore, I am truly thankful to the School of Engineering office staff, i.e., Mamta,

Chandan, and Sumeet Ji, for helping me throughout my Ph.D. and efficiently organize the Ph.D. viva-voce even in the unforeseen circumstances of Novel Corona Virus (COVID - 19) pandemic.

I am also grateful to the Indian and International examiners for a timely review of the thesis even during COVID - 19 pandemic and providing insightful comments that have shaped the thesis in great form.

Finally, I would like to thank all those who have directly and indirectly helped me through this work and made this work possible. Above all, I am thankful to Almighty for his divine blessings and the necessary courage and strength during difficult times.

Sharad Kumar Gupta

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