Rainfall-Induced Landslide Hazard Analysis Using TRIGRS Model: An Investigation of 2014 Malin Slide, Maharashtra, India

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November 24, 2022

Abstract

The Western Ghats region of India and its neighbouring areas are highly susceptible to rainfall-triggered landslides due to the regional geography, extreme rainfall, and anthropogenic intervention like excavation for construction activities etc. Every year in monsoon season, Maharashtra faces a massive loss of properties and life due to rainfall triggered landslides. In the monsoon of 2021, Pune and Konkan divisions in Maharashtra have witnessed severe rainfalls that triggered many landslides, which cause nearly 200 deaths and massive loss of properties. Thus, it is necessary to model an accurate early prediction system to mitigate such natural hazards. In this study, we have analyzed the efficiency of the transient rainfall infiltration and grid-based regional slope-stability (TRIGRS) model in predicting the location and timing of landslides. The case study selected for this analysis is a destructive rainfall-induced landslide triggered at Malin near Mumbai in July 2014, which resulted in 160 deaths, including the burial of an entire village under the debris. The TRIGRS is a widely applied model to analyze the effect of rainfall on pore water pressure fluctuations and related variation in factors of safety. It uses an infinite slope model to estimate the change in the factor of safety for every pixel. The model input data requires topographic properties (slope and elevation), soil layer thickness, material properties, initial water-table depth, and rainfall characteristics (intensity and duration). The preliminary analysis of rainfall data indicated that the study area was affected by 3-days intense rainfall prior to the landslide event. The TRIGRS model results show that the factor of safety of the Malin slope decreases with the increasing rainfall intensity and duration. The present study suggests that this model can also be used at large scale areas to prepare an active early warning system for landslide events. Keywords: Landslide; Rainfall; TRIGRS; Natural hazard; Maharastra

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Introduction

- **Rainfall-triggered landslides** are part of a natural process of hillslope erosion that can result in **catastrophic loss** of life and extensive property damage in mountainous, densely populated areas.
- The **Western Ghats region of India** and its neighbouring areas are highly **susceptible** to **rainfall-triggered landslides**.
- The primary **triggering factors** are **regional geography, extreme rainfall,** and **anthropogenic intervention**.
- In the **monsoon of 2021**, **Pune** and **Konkan divisions** in **Maharashtra** have witnessed severe rainfall-triggered landslides.
- Thus, it is necessary to model an accurate **early prediction** system to **mitigate** such **natural hazards**.

Objectives

- Application of the **Transient Rainfall Infiltration and Rrid-based Regional Slope-stability (TRIGRS)** model in predicting the **location** and **timing** of **landslides** in **Western Ghat India.**
- **Case study**: Destructive **rainfall-induced landslide** triggered at **Malin** near Mumbai in **July 2014**, which resulted in 160 deaths, including the burial of an entire village under the debris.
- **Qualitative analysis** of **efficiency** of **TRIGRS** model in predicting the location and timing of Malin 2014 landslide.

Study Area & Methodology

Fig-1 Location map of Malin Village.

Fig-2 Image of Malin Village before landslide event (Google Earth).

Fig-3 Image of Malin Village after landslide event (Google Earth).

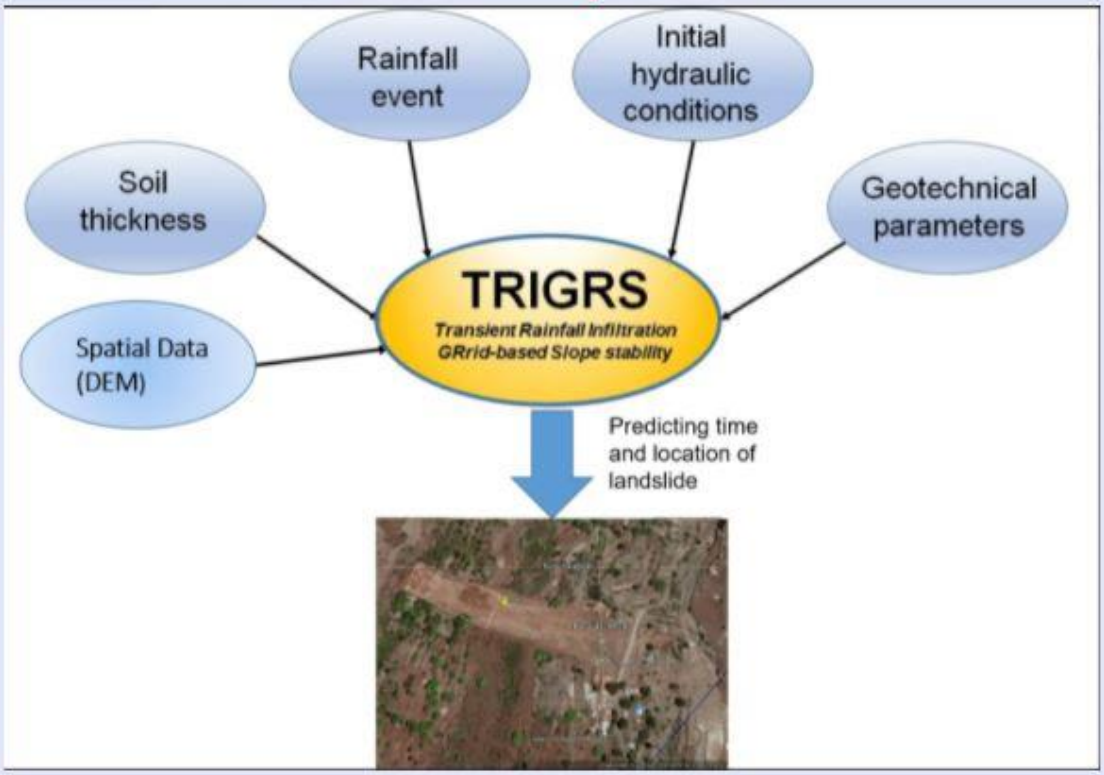
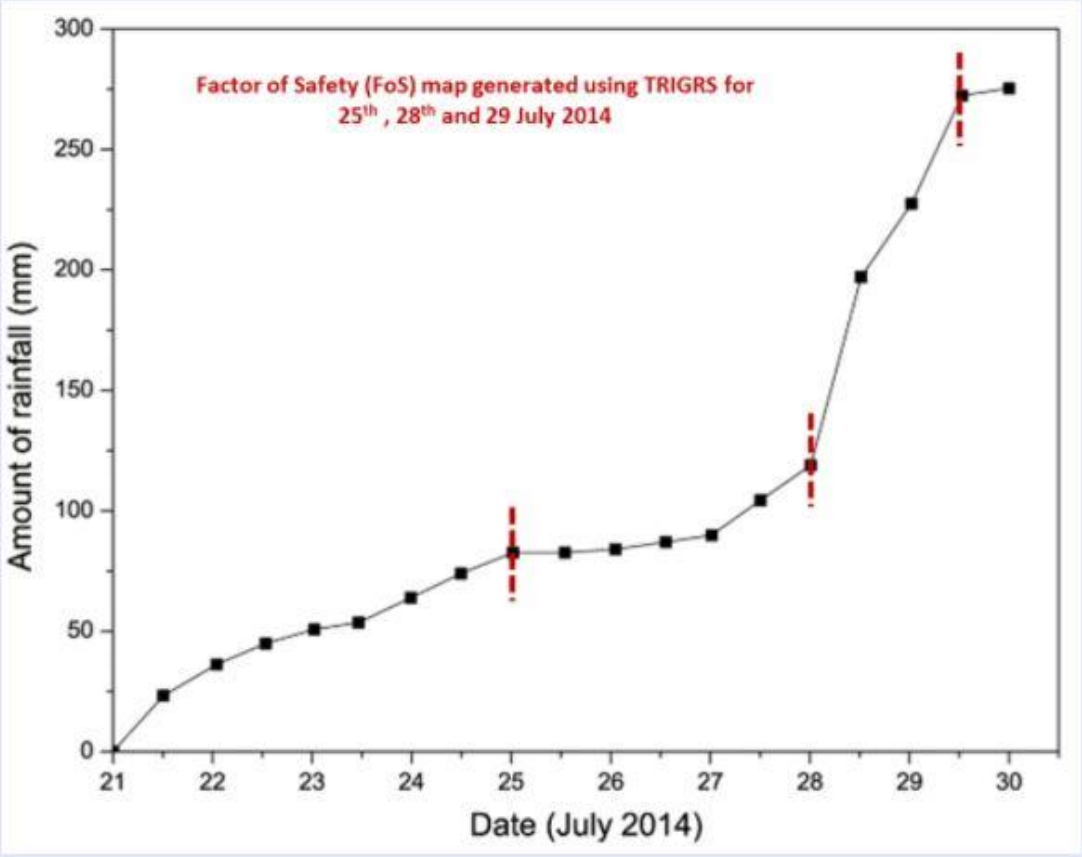


Fig-4 Overall Methodology of the present Study.


Factor of Safety (FoS) map generated using TRIGRS for
25th , 28th and 29 July 2014
Amount of rainfall (mm)
0
50
100
150
200
250
300
21
22
23
24
25
26
27
28
29
30
Date (July 2014)

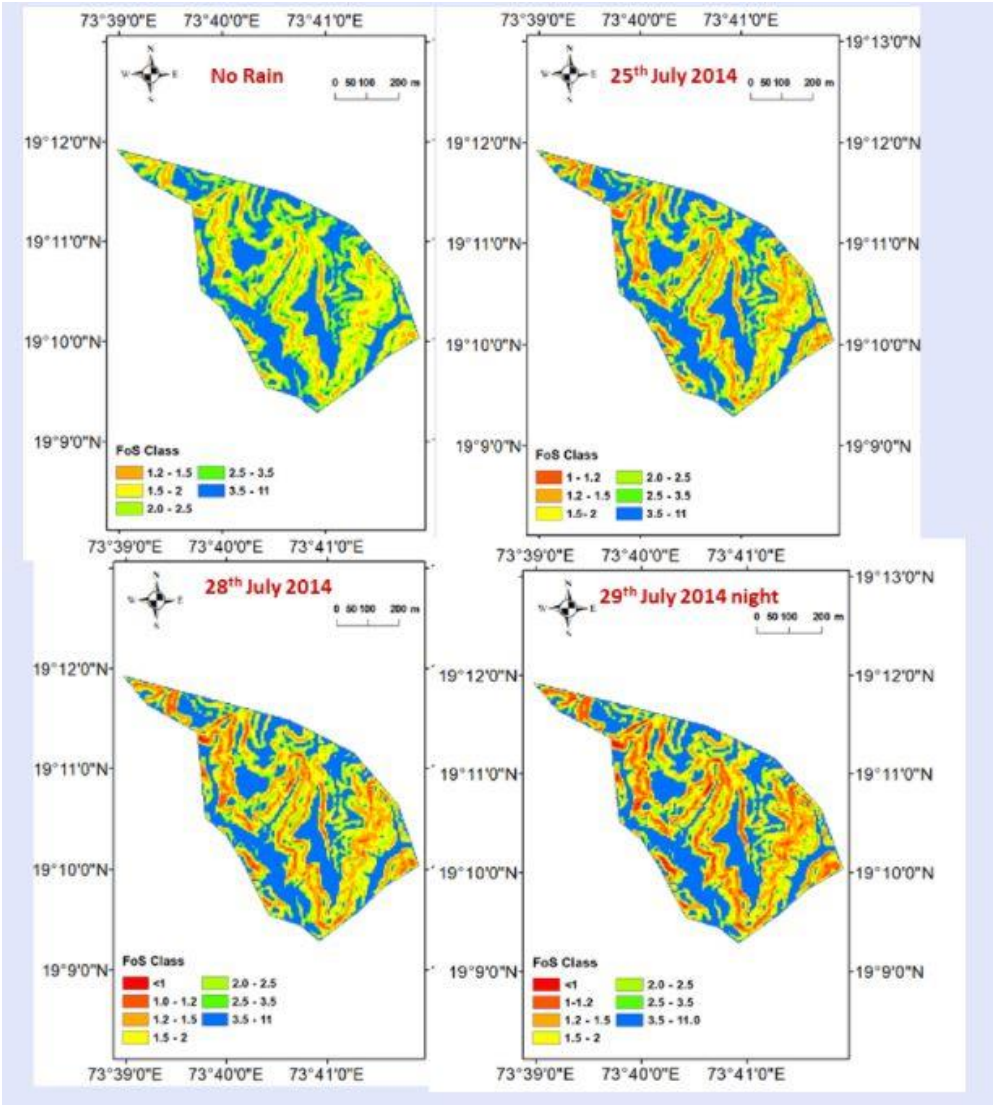


Fig-6 Variation of FoS of each pixel in the study area with rainfall obtained from TRIGRS model.

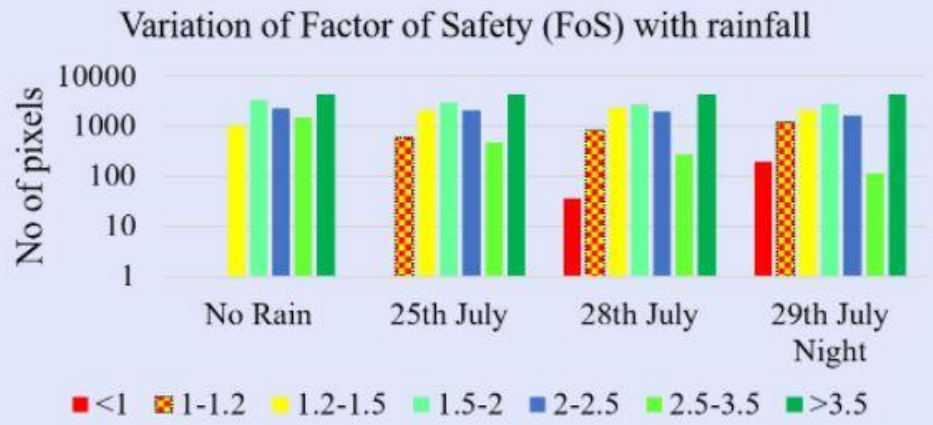


Fig-7 Variation of Factor of Safety (FoS) with rainfall.

Discussion

- The **geotechnical parameters of soil** are obtained from the earlier studies (**Meshram, S., 2016; Dey and Sengupta, 2018**).
- The **Factor of Safety (FoS)** map, generated using TRIGRS model in this present study suggests that the **Malin Village** and nearby area was **stable** (**FoS>1.2**) before rainfall.
- There were **no pixel values** having **FoS less than 1** till **25th July 2014**.
- However, **4.8%** of the considered area were having **FoS** between **1-1.2**.
- **FoS** of considered area **decreased significantly** after **3-day high-intensity rainfall** and around **11%** of the area became **highly unstable** (**FoS <1.2**) prior to the actual landslide event.

Conclusion

- The considered model in this study, i.e. TRIGRS model can predict the **slope unitability** of the Maline landslide triggered due to rainfall.
- The present study shows that the model efficiency is limited to the **quality of the Digital Elevation Model (DEM), geotechnical data of soil, and rainfall data** which can further improve the prediction of the location and timing of landslides.