

STUDY OF RAILFALL PATTERN AGAINST CYCLIC SLOPE MOVEMENT IN BHUTAN

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Introduction

The hazards and risks induced by slope failure and debris flow is a primary concern in mountainous regions around the globe. The slope disasters often cause casualties and infrastructures damages such as roads, bridges and buildings that has causative affect to providing services and business. The initiation of landslides is governed by various factors such as meteorology, geology, topography, vegetation cover and human activities. Among the factors, rainfall and geological conditions are probably the most important external and internal factors responsible for initiation of landslides⁽¹⁾. In recent times, erratic rainfall pattern due to climate change has further aggravated the risk of slope disasters and become life threatening issues in the hilly region. Bhutan as a part of Himalayan region, landslides has been prominent and devastating natural disasters. Most of the significant slope disaster mainly occur in cut slopes. The failures are mostly recurring, and it happens in rainy season during the month of June-September. Thus, it is claimed that rain induced slope failure is the most common geo-environmental hazard in Bhutan. However, there are limited scientific research performed in the past on Bhutan's condition to support the statement. The objective of this study is to explore the relationship between cyclic slope movement and rainfall pattern in Bhutan considering geology.

Data and Study Method

The scope of the research involves statistical analyses of slope movement with respect to rainfall intensity using Soil Water Index (SWI) and Parallel Tank model Index (PTI)⁽²⁾.

Slope Data

In this study, slope failure occurrence data are used from the record maintained with the Department of Surface Transport. A minimum of 14 representative slope failures out of 58 active slides are selected for the study.

Rainfall Data

The annual average rainfall of Bhutan was 2076.7 mm in 2020. The highest annual rainfall and 24-hour rainfall was

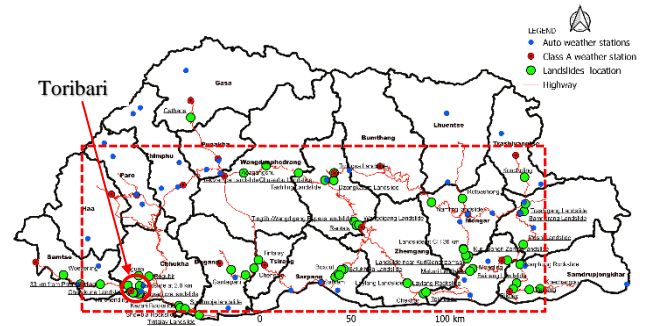


Fig. 1: Location of landslides and weather stations.

recorded at Bhur meteorological station in Sarpang, one of the southern districts in Bhutan with 7220.3 mm and 512.1 mm respectively⁽³⁾.

There are 92 rain gauge stations in Bhutan but only 20 stations (Figure 1) located in the District Headquarters, which are designated as class A stations have data available for daily rainfall of over 15 years (1980's to 2021). The meteorological stations in the country are recently upgraded to Real Time Automatic Weather Stations (AWS). The density of rain gauges is approximately one per 417 km². Due to the lack of rain gauge stations in the vicinity of slope failure sites, data from the nearest stations are used.

Soil Water Index (SWI) and Parallel Tank Index (PTI)

To derive relationship between recurrent slope movement and rainfall intensity, Soil Water Index (SWI) tank model is used. The SWI is a conceptual model to estimate the depth of remaining water in soil layers during a rainfall event as

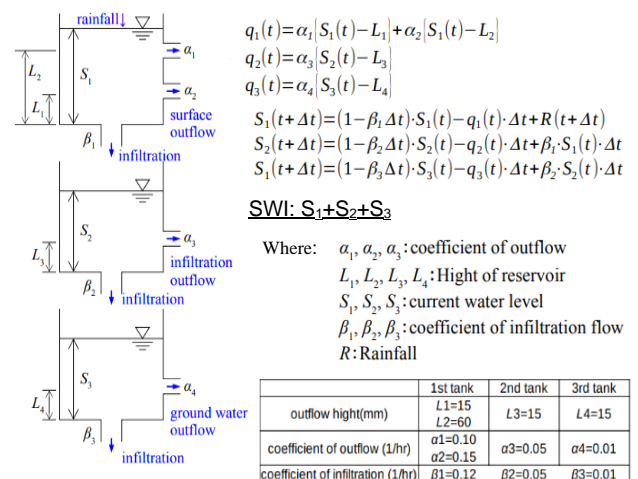


Fig. 2: Tank model simulating how rainwater flows out through soil (Source: JMA)

shown in Figure 2. SWI can well express for short period heavy rain, it is adapted by JMA for prediction of sediment disaster. Parallel tank model index (PTI) proposed by our lab is most suitable for long period light rain as it well express for time lag.

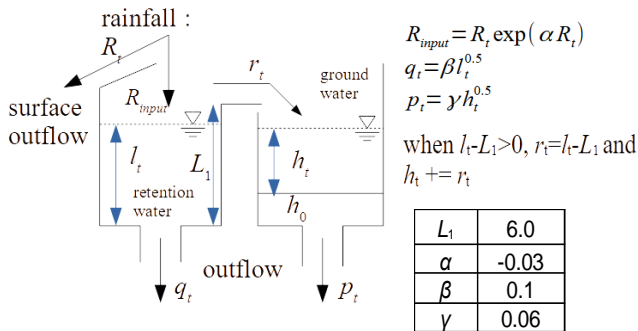


Fig. 4: Parallel Tank model setup

Discussion

Rainfall patterns that trigger landslides vary regionally depending upon geological conditions or lithology⁽⁴⁾ however, rainfall is well known as the primary factors of shallow landslides⁽⁵⁾. The geological condition influence differences in rainfall infiltration rates, on the initiation of landslides. Therefore, understanding the geological characteristics of a specific region and the influence of those characteristics on the probability of landslide occurrence provides useful insights into the landslide susceptibility of the region.

Table 1: Landslide occurrence record at Toribari

Sl. No	Disaster Location	Causes	Occurance Date	Occurance time	Rain data	Max Rain (mm)
1	Toribari 2.6km	Landslide	11-05-2019	7:45 PM	Exist	24.5
2	Toribari 2.6km	Landslide	25-06-2019	2:00 AM	Exist	10.5
3	Toribari 2.6km	Landslide	26-06-2019	2:00 AM	No	
4	Toribari 2.6km	Landslide	10-07-2019	8:00 PM	No	
5	Toribari 2.6km	Landslide	12-07-2019	6:00 AM	No	
6	Toribari 2.6km	Landslide	13-07-2019	12:00 PM	No	
7	Toribari 2.6km	Landslide	15-07-2019	8:00 PM	No	
8	Toribari 2.6km	Landslide	23-07-2019	10:00 PM	No	
9	Toribari 2.6km	Landslide	25-07-2019	2:00 AM	No	
10	Toribari 2.6km	Landslide	26-07-2019	10:00 PM	No	
11	Toribari 2.6km	Landslide	12-09-2019	3:00 PM	Exist	1.75
12	Toribari 2.6km	Debris Flow	16-09-2019	10:00 PM	Exist	18.5
13	Toribari 2.6km	Landslide	10-10-2019	10:30 PM	Exist	11.25
14	Toribari 2.6km	debris flow	29-06-2020	7:00PM	No	
15	Toribari 2.6km	Mud flow	05-07-2020	7:17 AM	No	
16	Toribari 2.6km	Flooding	01-08-2020	7:00 AM	No	
17	Toribari 2.6km	Scouring	04-08-2020	7:00 AM	No	
18	Toribari 2.6km	land slide	07-06-2021	7:46 AM	Exist	22.2
19	Toribari 2.6km	landslide	08-06-2021	7:54 AM	Exist	5.2
20	Toribari 2.6km	Flooding	09-06-2021	3:14 PM	Exist	18.6
21	Toribari 2.6km	landslide	29-06-2021	5:47 PM	Exist	14.6
22	Toribari 2.6km	landslide	30-06-2021	8:25 AM	Exist	2.6
23	Toribari 2.6km	land slide	20-08-2021	7:40 AM	No	
24	Toribari 2.6km	land slide	21-08-2021	8:30 AM	No	
25	Toribari 2.6km	Debries flow	23-08-2021	8:08 AM	No	
26	Toribari 2.6km	Debries flow	25-08-2021	8:00 AM	No	

A total of 26 recurring landslide recorded over the span of 3 years at Toribari as shown in table 1. Recurring occurrence of the slope failures are plotted with corresponding to rainfall intensity and PTI as shown in

figure 5. There are incidences of slope failure even at low rainfall intensity or without rainfall. The geology of Bhutan mainly consists of sedimentary and metamorphic rock. Geology of the study area consist of phyllite interbedded with highly weathered conglomeratic quartzite. There are several tectonic fault zones passing across southern belt of geographical area of Bhutan.

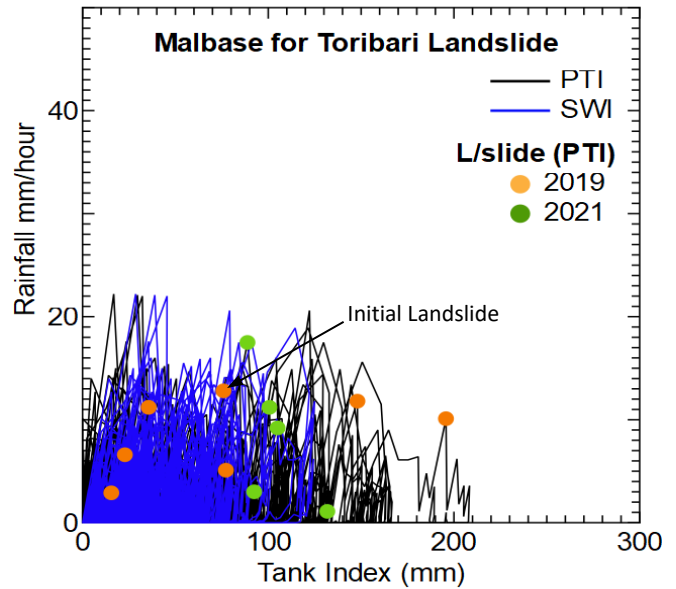


Fig. 5: PTI can express initial landslide of the rainy

Conclusion

The preliminary findings on relationship between recurrent slope movement and rainfall pattern reveled that low intensity short period precipitation induced slope failure in a road cut slope at fragile geological slope condition.

The findings of study shall be obtained towards the end of 2023 since, this research is ongoing study as the part of graduate program.

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