

Landslide Hazard Parameters

Landslide susceptibility map was prepared using Logistic Regression (LR) approach. The historical landslide data or inventory were used to develop a correlation between a dependent variable (Landslide) and the independent variables (predisposing or causative factors). The landslide inventory map was prepared from 2010 to 2022 from the Google Earth Pro image and field visit. A total of 224 points were defined as landslide areas within the basin where 70% of the total inventory was used as training data, and the rest were used as testing dataset for model validation. The landslide inventory was converted into point format, and the points were defined as 1. Moreover, 224 points were selected from the basin where landslide has not occurred, as non-landslide points, which was defined as 0. In this study, all the necessary dependent and independent variables were generated in ArcGIS 10.4.1, and then imported in R-studio. The dataset was exported to R-studio environment to build the Logistic Regression model using general linear model (glm()) function. The resulting susceptibility map was validated using training and testing data using Area Under Curve method.

Similarly, a landslide frequency map was prepared for the basin using landslide inventory of past 10 years. Grids of 500*500m cell size were generated, and landslide count in each grid was determined. The frequency map was integrated with the susceptibility map to generate a landslide hazard map, and classified as low, medium, and high.

Scenario1: Represents a landslide event occurring in today's existing infrastructure and urban environment

Scenario2: Represents a landslide event occurring in today's future infrastructure and urban environment

The landslide parameters were identified based on the observations and surveys summarised below.

Landslide 1

Type: Debris Flow

Location: 27°50'8.09"N, 82°45'45.30"E, 260.2m elevation at the base

Slope: 64 degrees

Occurrence: 2022 monsoon (local interview)

Deposition depth: 1.2m

Length= 26.7m

Depth= 0.6m

Breadth: 13.11m from the base

Volume= 210.02m³

Deposited materials: mud, debris, rocks of sizes up to 0.4m

Impacts: Temporary obstruction of the road



Landslide 2

Type: Debris Flow

Location: 27°50'7.70"N, 82°45'44.23"E, 253m elevation at the base

Slope: 62 degrees

Occurrence: 2022 monsoon; retaining structure built to manage the landslide (local interview)

Erosion depth: 0.4m

Deposition depth: 0.6m

Length= 16m

Depth= 1m

Breadth: 7.384m from the base

Volume= 118.144 m³

Deposited materials: mud, debris

Impacts: Temporary obstruction of the road



Landslide 3

Type: Translational slide

Location: 27°50'7.53"N, 82°45'42.10"E, 255m elevation at the base

Slope: 59 degrees

Occurrence: 2023 October; very recent (local interview)

Erosion depth: 1.4m

Deposition depth: 2.6m

Length= 20m

Depth= 1m

Breadth: 29.5m from the base

Volume= 590m³

Deposited materials: mud, debris, rocks of sizes up to 1.6m

Impacts: Temporary obstruction of the road; local people and police had to remove the fallen rocks



Landslide 4

Type: Debris Flow

Location: 27°50'0.07"N, 82°45'31.49"E, 279m elevation at the base

Slope: 64 degrees

Occurrence: 2019-2020

Erosion depth: 0.5m

Deposition depth: 0.8m

Length= 21m

Depth= 1m

Breadth: 26.7m from the base

Volume= 560.7m³

Deposited materials: mud, debris, rocks of sizes up to 0.6m

Impacts: Temporary obstruction of the road



Landslide 5

Type: Debris Flow

Location: 27°50'22.69"N, 82°45'17.54"E, 272m elevation at the base

Slope: 54 degrees

Occurrence: 2020 monsoon (local interview)

Erosion depth: 0.8m

Deposition depth: 1.1m

Length= 16m

Depth= 1.6m

Breadth: 7.31m from the base

Volume= 187.136m³

Deposited materials: mud, debris, rocks of sizes up to 0.25m

Impacts: No significant impacts



Landslide 7

Type: Debris Flow

Location: 27°50'22.55"N, 82°45'16.40"E, 261m elevation at the base

Slope: 60 degrees

Occurrence: 2019-2020 monsoon

Erosion depth: 0.6m

Deposition depth: 1m

Length= 28m

Depth= 1m

Breadth: 8.2m from the base

Volume= 229.6m³

Deposited materials: mud, debris, rocks of sizes up to 0.6m

Impacts: Temporary obstruction of the road



Landslide 8

Type: Debris Flow

Location: 27°51'55.64"N, 82°47'28.19"E, 256m elevation at the base

Slope: 62 degrees

Occurrence: 2023 monsoon, some days after Dashain; retaining structures built after the landslide (local interview)

Erosion depth: 1.8m

Deposition depth: NA

Length= 38m

Depth= 2.5m

Breadth: 29.72 m from the base

Volume= 2823.4m³

Deposited materials: mud, debris, rocks of sizes up to 0.15m

Impacts: Obstruction of the road (6-7 days)



Landslide 9

Type: Debris Flow

Location: 27°52'42.10"N, 82°48'7.04"E, 273m elevation at the base

Slope: 62 degrees

Occurrence: 2023 monsoon (local interview)

Erosion depth: 0.6m

Deposition depth: NA

Length= 12m

Depth= 0.6m

Breadth: 11m from the base

Volume= 79.2m³

Deposited materials: primarily mud, debris

Impacts: No significant impacts



Landslide 10

Type: Debris Flow

Location: 27°51'29.03"N, 82°47'24.67"E, 294m elevation at the base

Slope: 55-60 degrees

Occurrence: 2023 monsoon, repeatedly occurs every year during extreme rainfall events (local interview)

Erosion depth: NA

Deposition depth: NA

Length= 42m

Depth= 0.6m

Breadth: 11.74 m from the base

Volume= 295.848m³

Deposited materials: mud, debris, rocks of sizes up to 0.1m

Impacts: Destroyed the retaining wall due to extreme rainfall event this year and last year



Landslide 11

Type: Translational slide

Location: 27°49'26.83"N, 82°45'16.46"E, 249m elevation at the base

Slope: 48 degrees

Occurrence: 2021-2022 monsoon (local interview)

Erosion depth: NA

Deposition depth: NA

Length= 49m

Depth= 0.6m

Breadth: 68m from the base

Volume= 1999.2m³

Deposited materials: NA; landslide managed by local community and police

Impacts: Road blocked for 1 whole day, disrupting traffic. Retaining structure built after the landslide which has managed the impacts



Landslide 12

Type: Debris Flow

Location: 27°49'41.93"N, 82°45'25.06"E, 253m elevation at the base

Slope: 65-70 degrees

Occurrence: 2022 monsoon (local interview)

Deposition depth: 2.5m

Length= 37m

Depth= 1.5m

Breadth: 8m from the base

Volume= 444m³

Deposited materials: mud, debris, rocks of sizes up to 0.4m

Impacts: Temporary obstruction of the road



Landslide 13

Type: Debris Flow

Location: 27°49'42.69"N, 82°45'22.12"E, 259m elevation at the base

Slope: 65-70 degrees

Occurrence: 2022 monsoon (local interview)

Deposition depth: 2.5m

Length= 29m

Depth= 1.5m

Breadth: 8.5m from the base

Volume= 369.75m³

Deposited materials: mud, debris, rocks of sizes up to 0.4m

Impacts: Temporary obstruction of the road



Landslide 14

Type: Debris Flow

Location: 27°49'42.16"N, 82°45'25.37"E, 259m elevation at the base

Slope: 65-70 degrees

Occurrence: 2023 monsoon; looks recent (local interview)

Deposition depth: 2.5m

Length= 29m

Depth= 1.5m

Breadth: 8.2m from the base

Volume= 356.7m³

Deposited materials: mud, debris, small rocks

Impacts: Temporary obstruction of the road



Landslide 15

Type: Debris Flow

Location: 27°49'42.73"N, 82°45'25.30"E, 270m elevation at the base

Slope: 62 degrees

Occurrence: 2022-2023 monsoon (estimated)

Deposition depth: 1.1m

Length= 36m

Depth= 1m

Breadth: 7m from the base

Volume= 252m³

Deposited materials: mud, debris, rocks of sizes up to 0.6m

Impacts: Temporary obstruction of the road



Landslide 16

Type: Rotational slide

Location: 27°50'36.23"N, 82°45'35.43"E, 297m elevation at the base

Slope: 65 degrees

Occurrence: 2022 monsoon (estimated)

Occurrence: 2022-2023 monsoon; condition exacerbated during 2023 rainfall (local interview)

Deposition depth: NA

Length= 142m

Depth= 2.5m

Breadth: 86m from the base

Volume= 30530m³

Deposited materials: mud, debris, rocks of sizes up to 1.2m

Impacts: Caused drinking water pipeline burst, extreme rainfall brought debris towards the houses



Landslide 17

Type: Translational slide

Location: 27°49'7.96"N, 82°45'29.28"E, 261m elevation at the base

Slope: 65-70 degrees

Occurrence: 2022 monsoon (local interview)

Deposition depth: 1.5m

Length= 30m

Depth= 1.2m

Breadth: 27m from the base

Volume= 972m³

Deposited materials: mud, debris, rocks up to size of 0.6m

Impacts: Temporary obstruction of the road; locals had to remove deposited rocks from the road



Landslide 18

Type: Translational slide

Location: 27°49'6.05"N, 82°45'32.19"E, 261m elevation at the base

Slope: 58 degrees

Occurrence: old landslide, condition worsens during every extreme rainfall events (local interview)

Deposition depth: 1.5m

Length= 32m

Depth= 0.9m

Breadth: 12m at the base

Volume= m³

Deposited materials: mud, debris, rocks up to size of 0.4m

Impacts: Temporary obstruction of the road; locals had to remove deposited rocks from the road; retaining structure built last year



