Landslide susceptibility mapping of earthquake affected districts of Nepal using logistic regression model

Consultative Workshop – Landslide Inventory, Risk Assessment and Mitigation in Nepal
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Background

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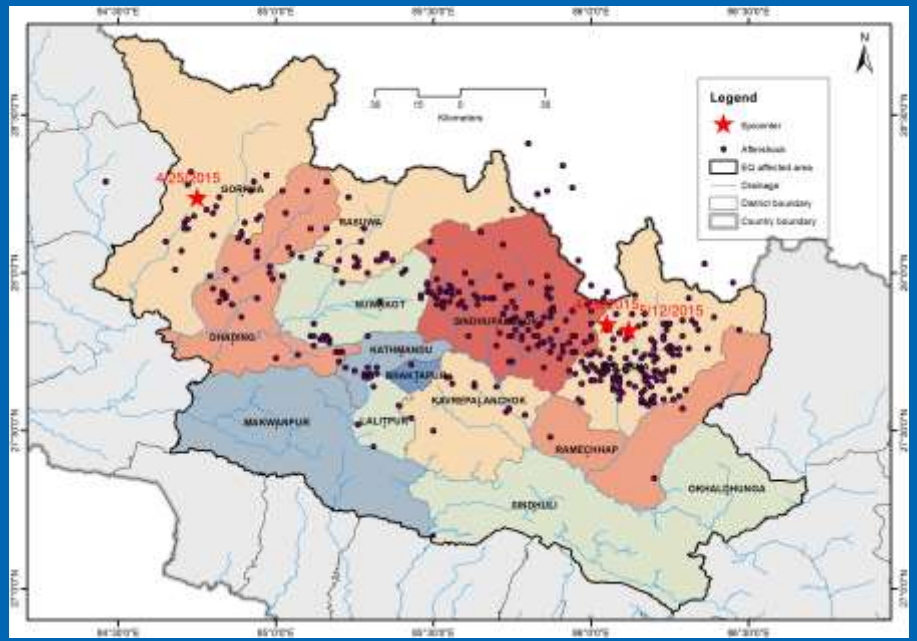
7.8 magnitude earthquake struck Nepal with epicenter at Barpak Village, Gorkha district on **April 25, 2015**.

Followed by strong aftershock of **6.9 local magnitude on 26 April** and **6.6 local magnitude on 12 May 2015** with epicenter in the border of Dolakha and Sindhupalchok districts
and many **aftershocks (395, >=4ml)**

Damages – Mainly in 14 districts of Nepal.

Casualties - death toll was 8671 until June 30 2015.



Landslide assessment

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This rapid assessment of landslides is based on satellite images received from NASA, DigitalGlobe, Indian Remote Sensing, Sentinel Asia, and Gaofen (China)

- A group of volunteers in ICIMOD
- ICIMOD staff
- Team of Chinese Academy of Sciences (CAS) from IMHE, ITP and CAREERI.
- ISRO

Landslide Susceptibility Mapping

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Give Coherent information on the spatial probability on where the landslides, or landslides scraps, might occur.

Likelihood of landslide occurring in an area with given local terrain information's.

Do not assessed the frequency or time of occurrence of the future landslide.

The Past and Present are the Keys to the Future.

The estimation of the possible future location of landslides is usually based on past and present landslides.

Data and Tools

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Past and Present Landslide map-
google earth images and Digital globe image downloaded from Hazard Data Distribution System (HDDS), USGS

Topographic Data –
Slope, Aspect, Curvature are generated from DEM
Drainage network
Road Network

Geology – provided by Prof Dr. Megh raj Dhital

Discontinuities / Faults/ Lineaments
Manually traced from geological map - DMG

PGA (Peak Ground Acceleration) – USGS

Land cover – ICIMOD mapped from Landsat images

TOOLS:

R – Programming
Regression analysis

ArcGIS v10.3
Data preparation, Calculation, interpretation and Final map outputs

Methodology

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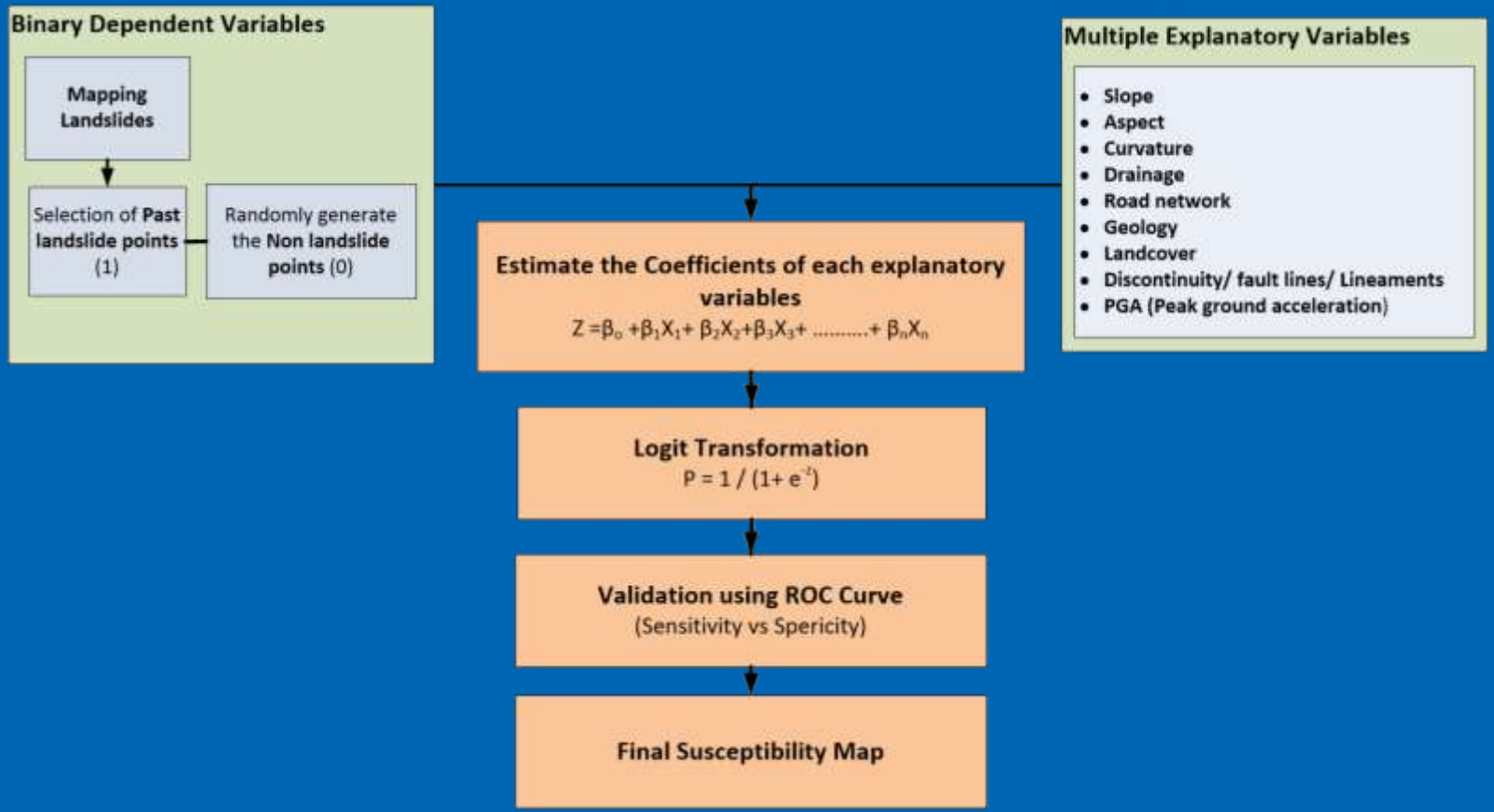

Logistic Regression

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Logistic regression is a type of generalized linear model (GLM)

It relates the probability of occurrences of landslides to predictors (Explanatory variables) $X_1, X_2, X_3, \ldots\ldots, X_n$

The Key is to transform the response variable:

$$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots\ldots\ldots\ldots + \beta_n x_n$$

A common transformation for z is logit transformation

$$P = \frac{1}{1 + e^{-z}}$$

Distribution of Landslides

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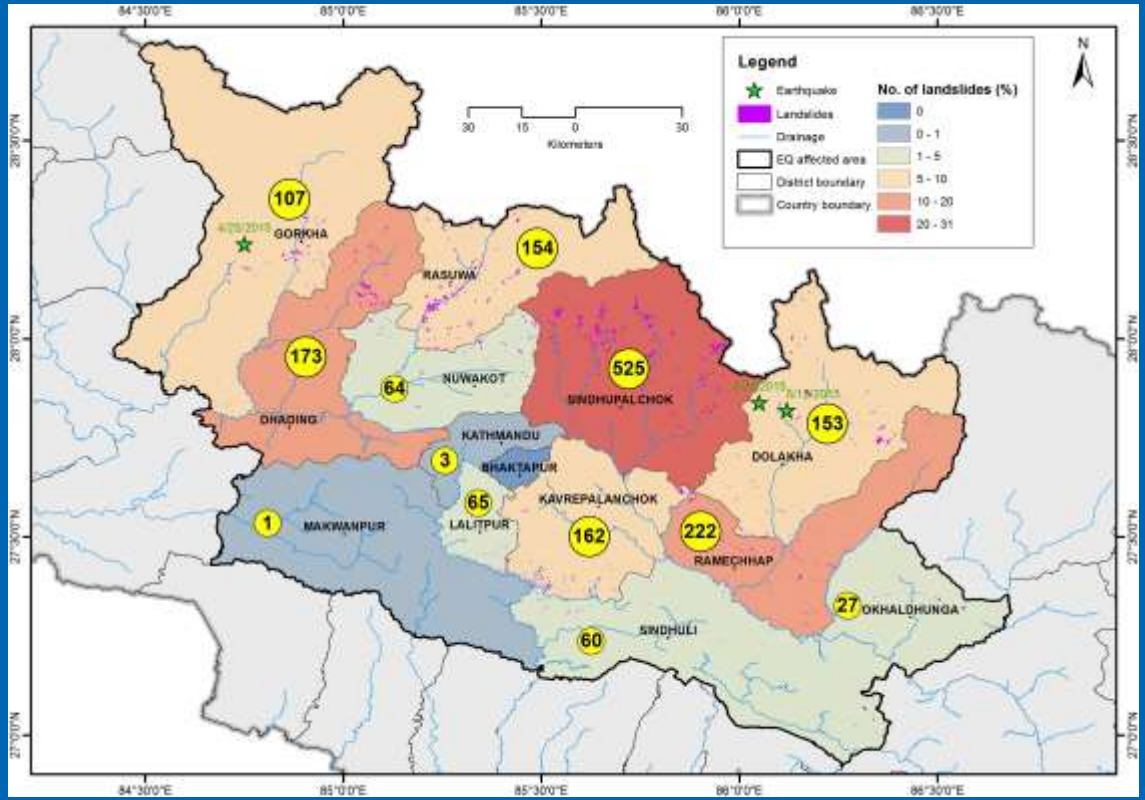

SN	District	Number	Area	N%
1	Gorkha	107	1.995	6.2
2	Dhading	173	1.713	10.1
3	Nuwakot	64	1.251	3.7
4	Rasuwa	154	6.375	9.0
5	Kathmandu	3	0.012	0.2
6	Lalitpur	65	0.085	3.8
7	Sindhupalchok	525	7.822	30.6
8	Kabhrepalanchok	162	1.115	9.4
9	Dolkha	153	3.074	8.9
10	Makawanpur	1	0.004	0.1
11	Sindhuli	60	0.496	3.5
12	Ramechap	222	0.71	12.9
13	Okhaldhunga	27	0.383	1.6
	Total	1716	25.035	100

Number and area of Landslides

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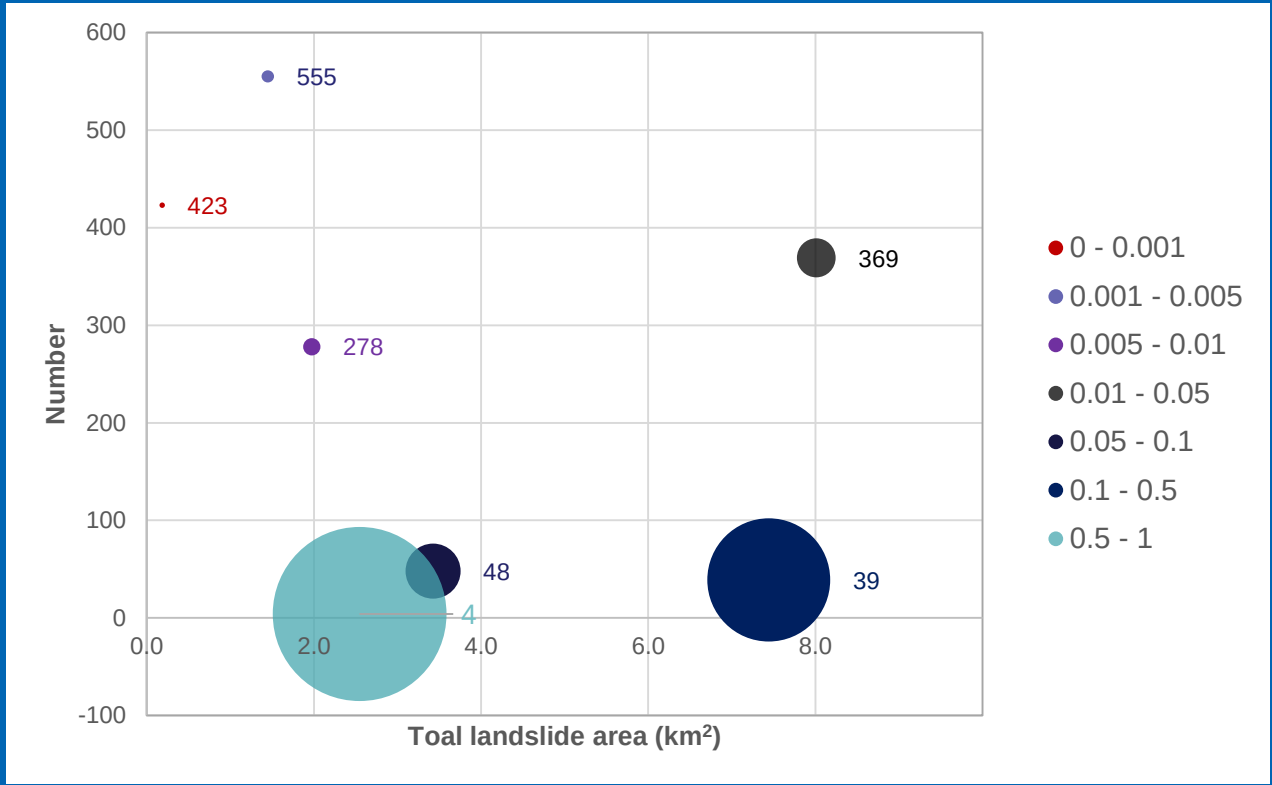
Smallest – 30m^2
Largest – 766800m^2

Area class (km^2)	Number	Area (km^2)
0 - 0.001	423	0.2
0.001 - 0.005	555	1.4
0.005 - 0.01	278	2.0
0.01 - 0.05	369	8.0
0.05 - 0.1	48	3.4
0.1 - 0.5	39	7.4
0.5 - 1	4	2.5
	1716	25.033



Slope and Elevation

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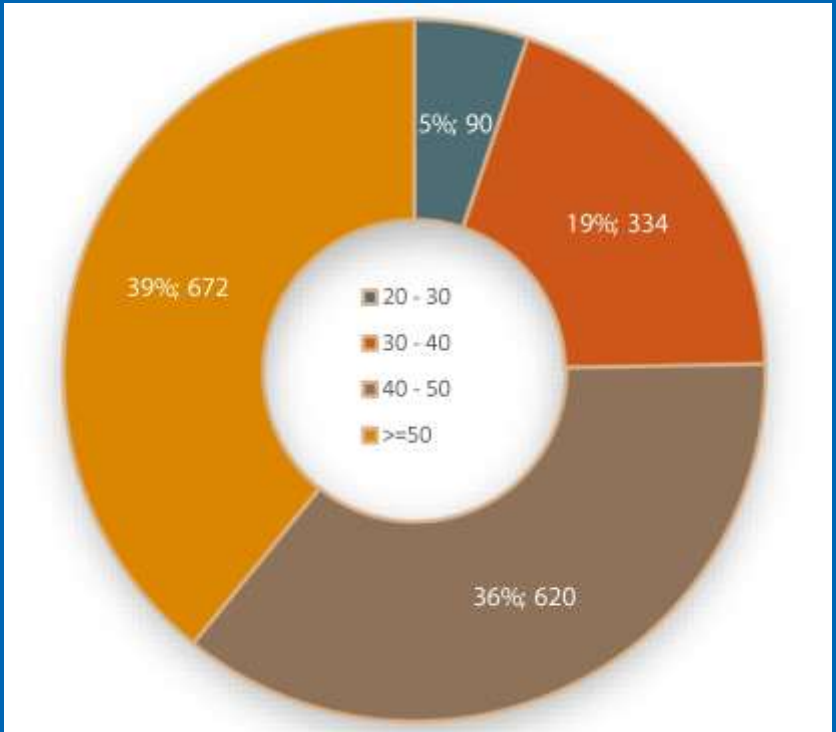
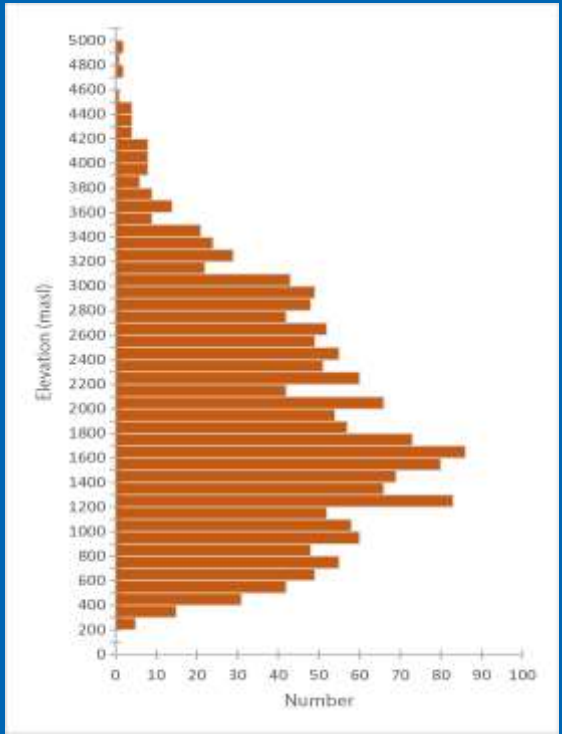


Distribution in Slope Classes



Distribution at elevation

Logistic Regression

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Susceptibility

$$P = \frac{1}{1 + e^{-z}}$$

	Estimate	Std. Error	z - value	Pr(>|z|)
Intercept (β_0)	-2.935000	0.20710	-14.17	< 2.00E-16
Slope (β_1)	0.087960	0.00357	24.623	< 2.00E-16
Aspect (β_2)	-0.000417	0.00042	-1.002	0.31628800
Curvature (β_3)	-0.077070	0.02007	-3.84	0.00012300
River distance (β_4)	-0.000780	0.00016	-4.903	0.00000094
Road distance (β_5)	-0.000436	0.00007	-6.032	0.00000000
Geology (β_6)	0.002641	0.00078	3.392	0.00069500
Land cover (β_7)	-0.043380	0.01527	-2.841	0.00449100
PGA (β_8)	0.999400	0.18750	5.33	0.00000010
Discontinuity distance (β_9)	-0.000019	6.02E-06	-3.13	0.001746

Where,

P = estimated probability of landslide occurrence

$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots\ldots\ldots\ldots + \beta_n x_n$

β_0 = intercept of the model

β_i (i = 1, 2, 3, …n) = slope coefficient of the model

X_i (i = 1, 2, 3, … n) = independent variable

Landslide Susceptibility

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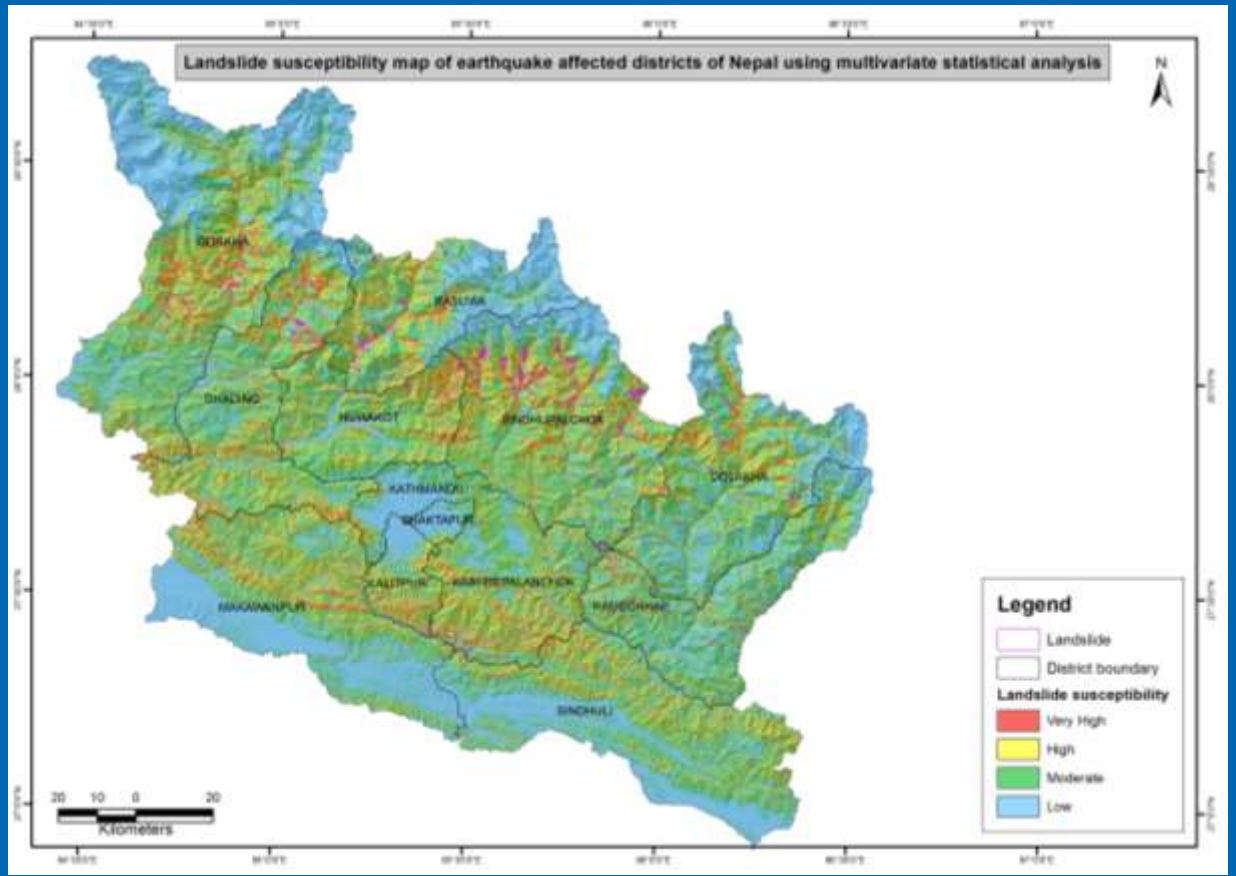

Susceptibility	Probability of Occurrence	Landslide Number	Percent(%)
Low	<0.25	25	1.46
Moderate	0.25 - 0.5	179	10.43
High	0.5 -0.75	446	**25.99**
Very High	> 0.75	1066	**62.12**
	Total	1716	100

About 88% of the landslide polygon fall on higher probability (P > 0.5).

Validation - ROC Curve

Receiver operating characteristics

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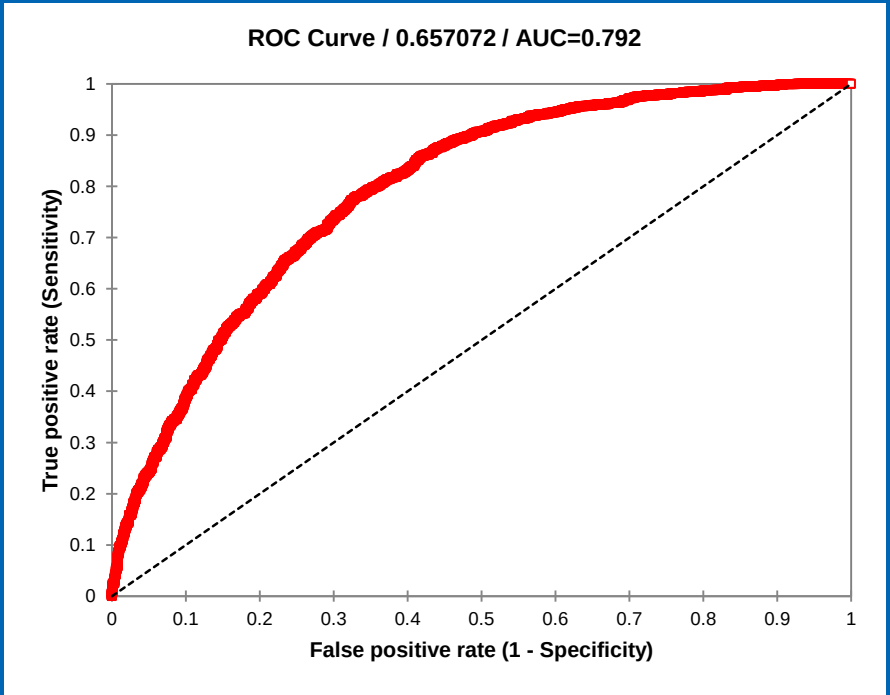
Since Area under curve (AUC) is 0.79, The susceptibility map is Good classified i.e. acceptable



	Frequency	%
Non landslide (0)	1960	50%
Landslide (1)	1960	50%
Prevalence	0.500	50%

	Condition Positive (1)	Condition Negative (0)
Predicted condition Positive	True Positive (TP)	False Positive (FP)
Predicted condition Negative	False Negative (FN)	True Negative (TN)

$$\textbf{Sensitivity} = \frac{True\ Positive\ (TP)}{True\ Positive\ (TP) + False\ Negative\ (FN)}$$

$$\textbf{Specificity} = \frac{True\ Negative\ (TN)}{False\ Positive\ (FP) + True\ Negative (TN)}$$

Validation

Slope vs Susceptibility

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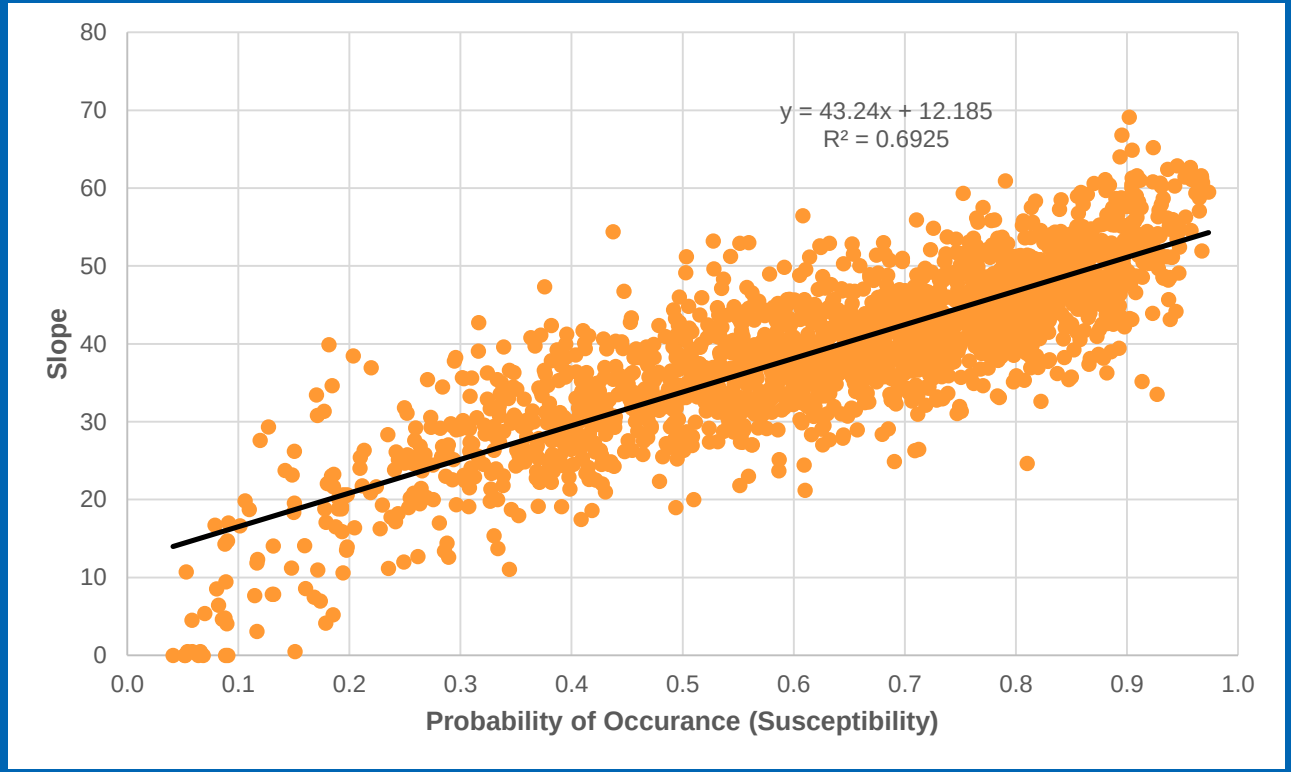

Results

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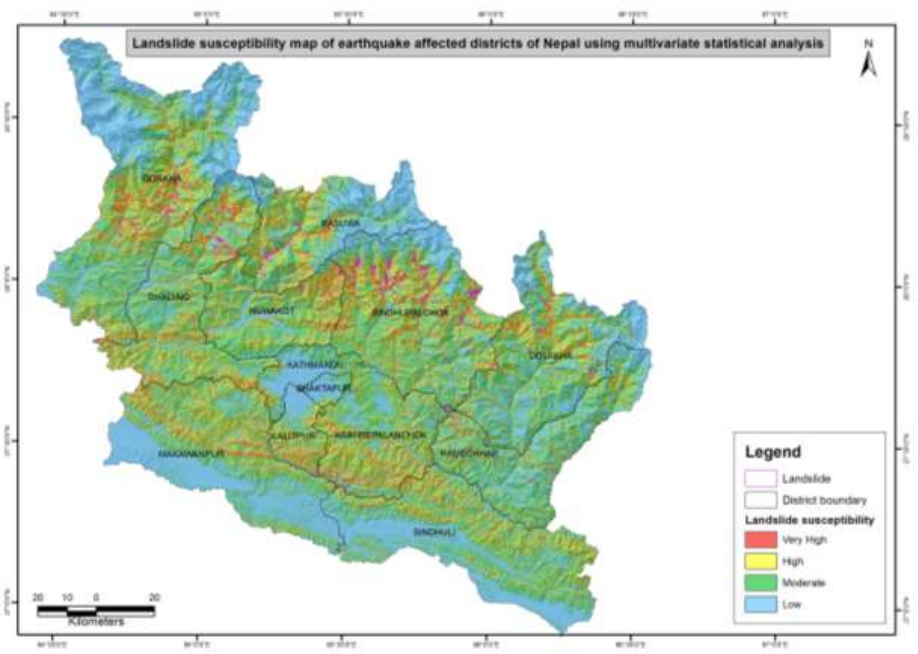

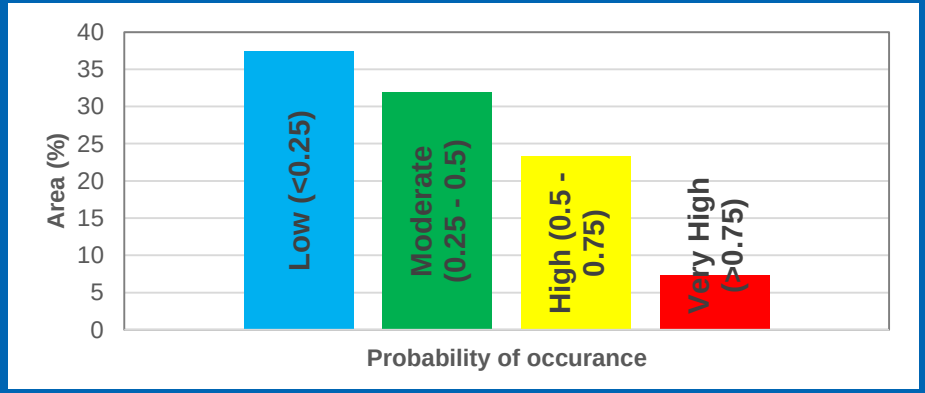

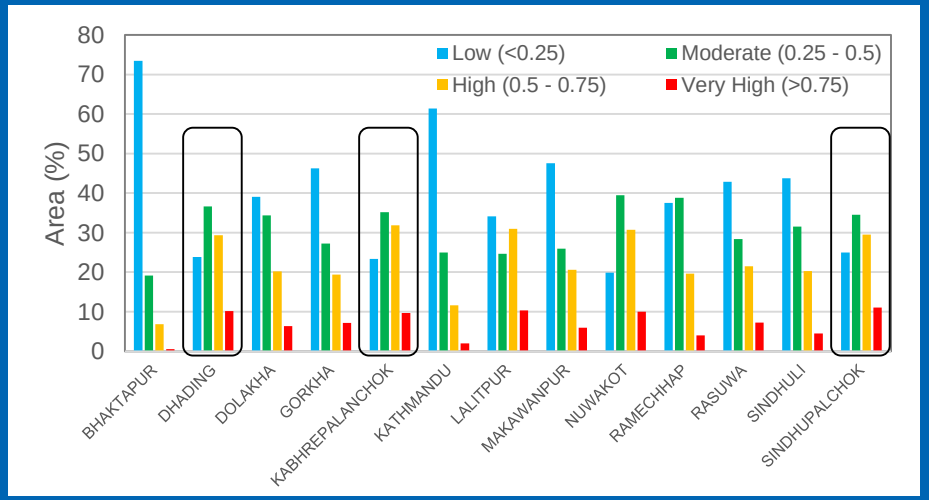

THANK YOU