# A comparative study using bivariate statistical method and knowledge-driven heuristic approach for the comparison of landslide susceptibility mapping in West Sikkim district of Sikkim Himalaya, India

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Outstanding Student & PhD candidate Presentation contest


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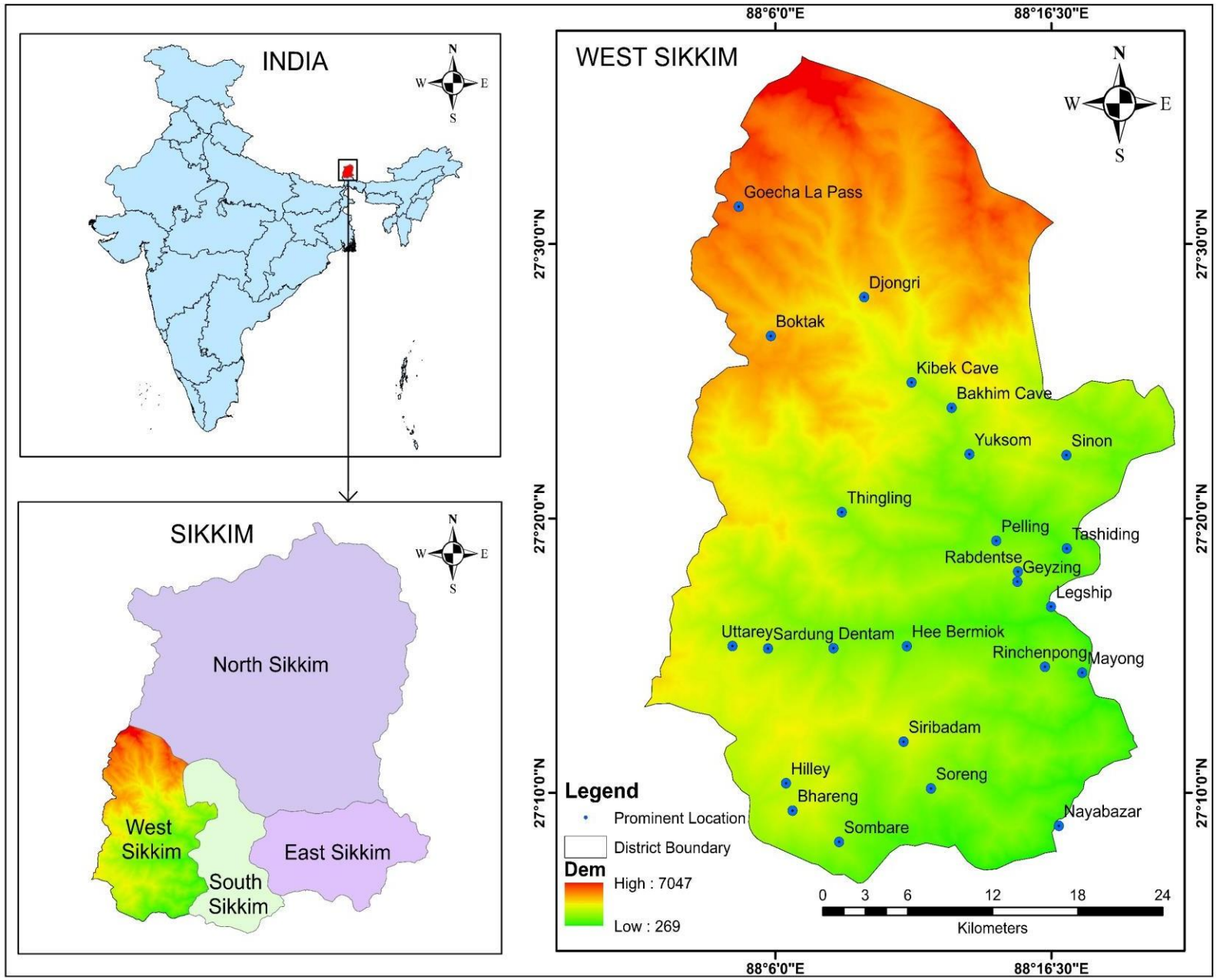
# INTRODUCTION

- Landslide is among the top 5 natural disasters in terms of death and property damages.
- Its susceptibility mapping is important in the landslide-prone zones.
- The present study deals with the comparison of probabilistic and heuristic methods in landslide susceptibility mapping.

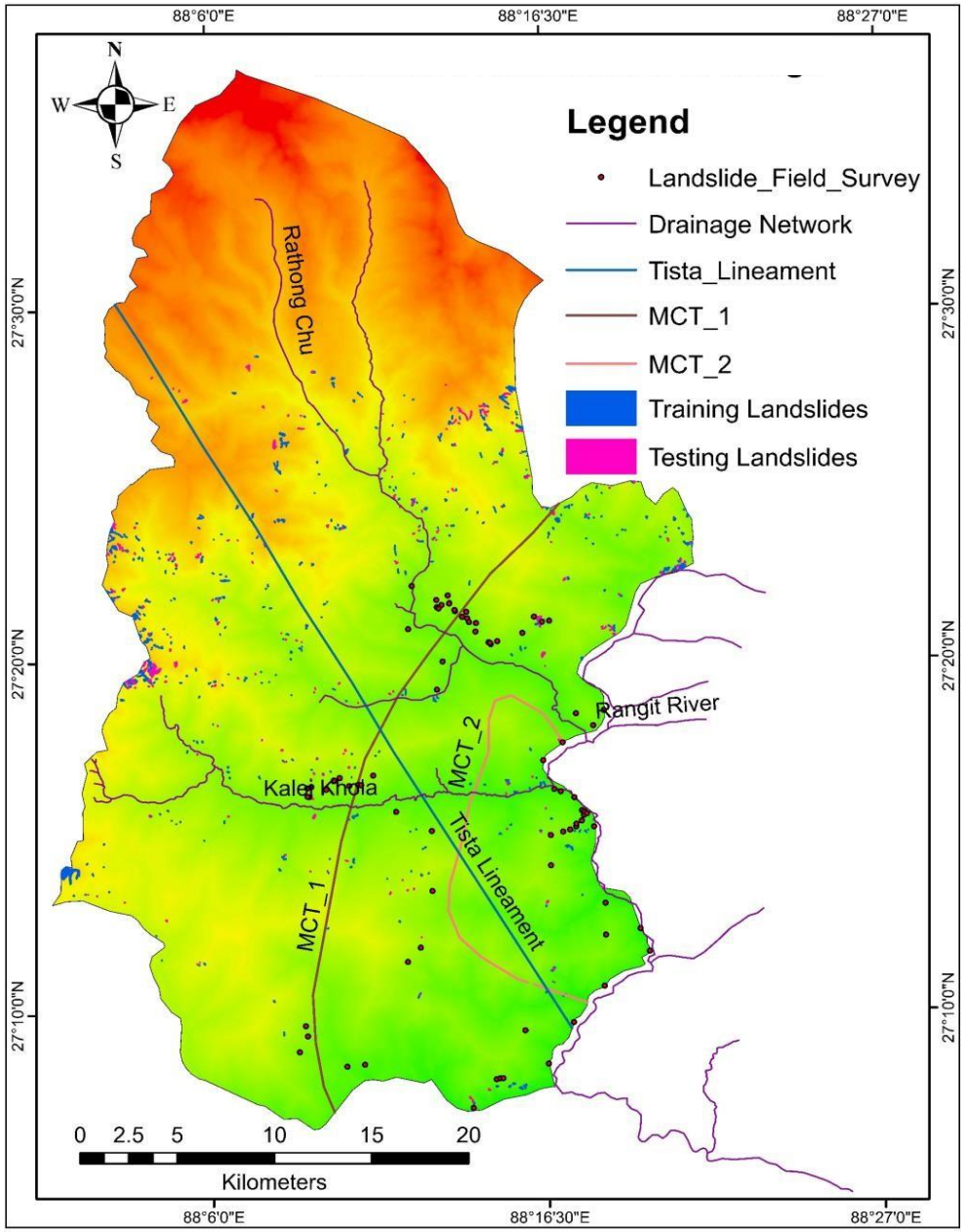
# STUDY AREA


INDIA
N
W
E
S
SIKKIM
North Sikkim
West Sikkim
East Sikkim
South Sikkim
WEST SIKKIM
88°6'0"E
88°16'30"E
27°30'0"N
27°20'0"N
27°10'0"N
Goecha La Pass
Djongri
Boktak
Kibek Cave
Bakhim Cave
Yuksom
Sinon
Thingling
Pelling
Tashiding
Rabdentse
Geyzing
Legship
Uttarey
Sardung
Dentam
Hee Bermiok
Rinchenpong
Mayong
Siribadam
Hilley
Soreng
Bhareng
Nayabazar
Sombare
Legend
Prominent Location
District Boundary
Dem
High : 7047
Low : 269
0 3 6 12 18 24
Kilometers

# DATA USED

| Data type | Source | Year | Spatial Resolution | Output extracted |
|---|---|---|---|---|
| **Satellite imagery** | Resourcesat - 2 (LISS IV - Mx) | 2019 | 5.8 m | landslide map, slope aspect, slope angle, slope curvature, drainage density, elevation, land use and land cover (LULC), normalized difference vegetation index (NDVI), geomorphology |
| | ALOS PALSAR | 2009 | 12.5 m | |
| **Google Earth image** | Google Earth Application | 2019 | ---- | landslide map, geomorphology, LULC |
| **Geological map** | Published by GSI | 2016 | ---- | lithology |
| **Field survey** | | 2017-2019 | ---- | field survey for landslide locations, the ground truth of LULC |
| **SRM data** | NBSS&LUP, India | 2000 | ---- | soil type |
| **Structural data** | Bhuvan portal, NRSC, India | 2019 | ---- | lineament density map |

# TECTONIC FRAMEWORK & DRAINAGE



# Methodology

## Frequency Ratio

$$\boldsymbol{FR} = \frac{\left(\frac{number\ of\ landslide\ pixels\ in\ each\ factor\ class}{total\ number\ of\ landslide\ pixels\ in\ the\ study\ area}\right)}{\left(\frac{\text{total number of pixels in each factor class}}{total\ number\ of pixels\ in\ the\ study\ area}\right)}$$

$$\boldsymbol{LSI} = \sum_{i}^{n}(FR)i \quad (i = 1,2, \dots \dots, n)$$

## Information Value

$$\mathbf{IV} = ln\left(\frac{landslide\ density\ within\ a\ factor\ class}{landslide\ density\ within\ the\ study\ area}\right)$$

$$\boldsymbol{LSI} = \sum_{i}^{n}(IV)i \quad (i = 1,2, \dots \dots, n)$$

## Analytic Hierarchy Process

$$\mathbf{CI} = \frac{(\boldsymbol{\lambda} max - n)}{(n-1)}$$

where $\boldsymbol{\lambda} max$= largest eigen value of the matrix, n= order of the matrix

$$\mathbf{CR} = \frac{CI}{RI}$$

where $RI$ = random index (average of consistency index)

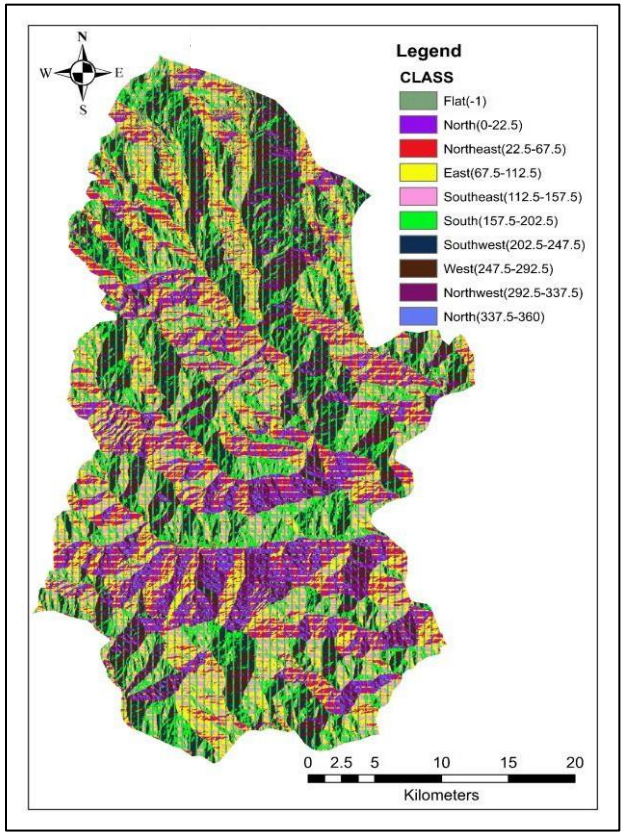
$$\boldsymbol{LSI} = \sum_{i}^{n}(cw * fw)i \quad (i = 1,2, \dots \dots, n)$$

where fw=weight of factor, cw= weight of class within each factor

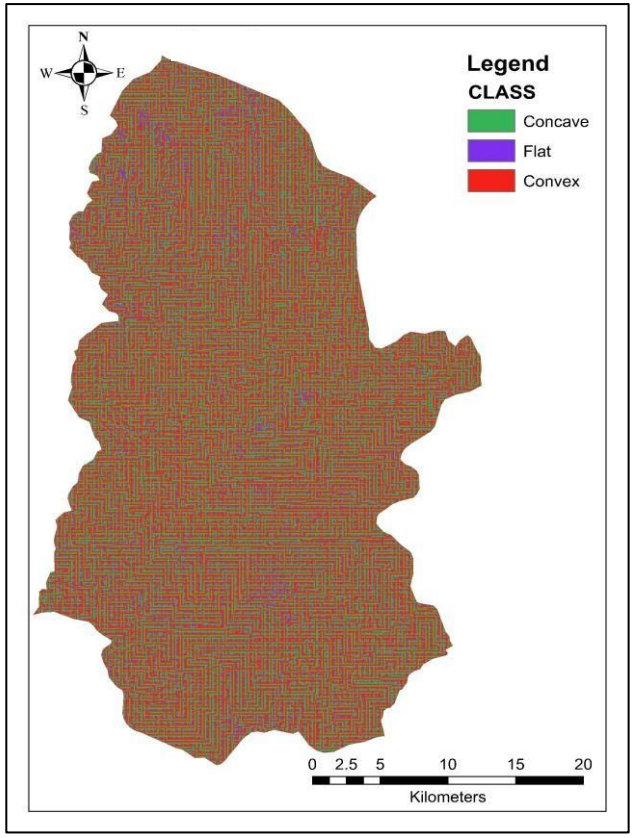
*LSI=landslide susceptibility index

# LANDSLIDE CONDITIONING FACTORS

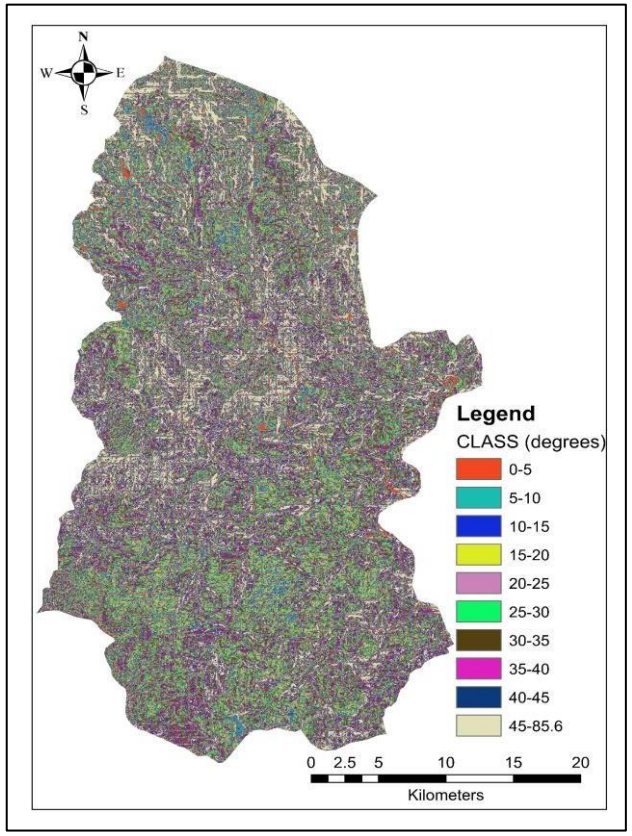
## SLOPE ASPECT



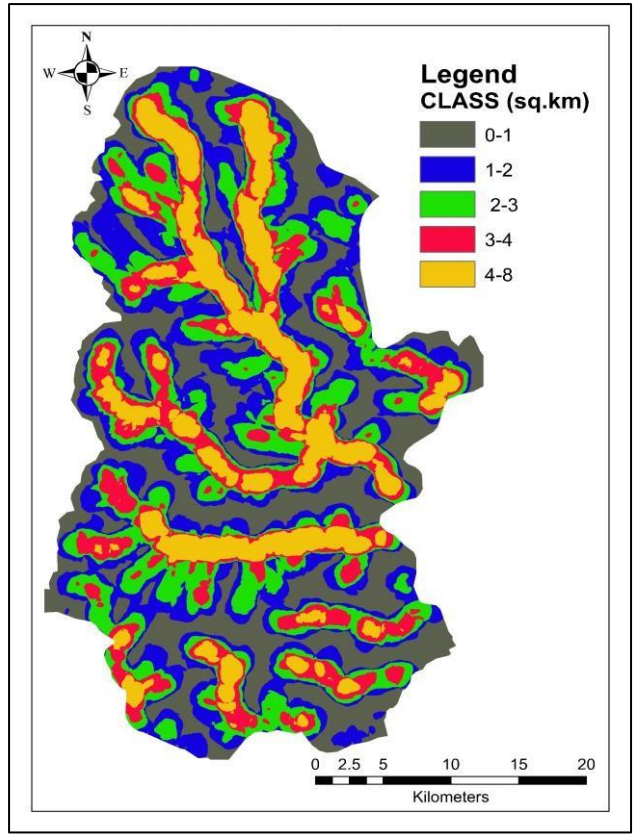

## SLOPE CURVATURE




## SLOPE GRADIENT

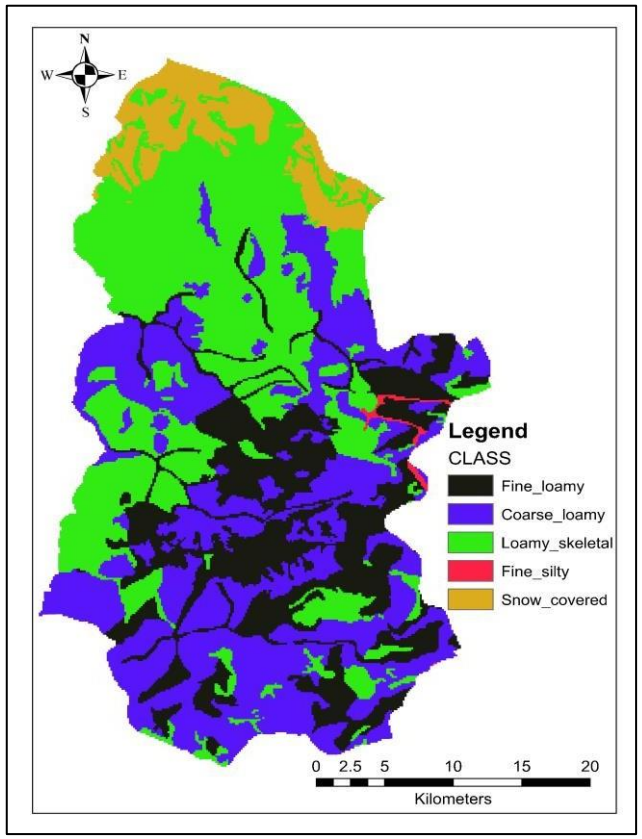



## DRAINAGE DENSITY

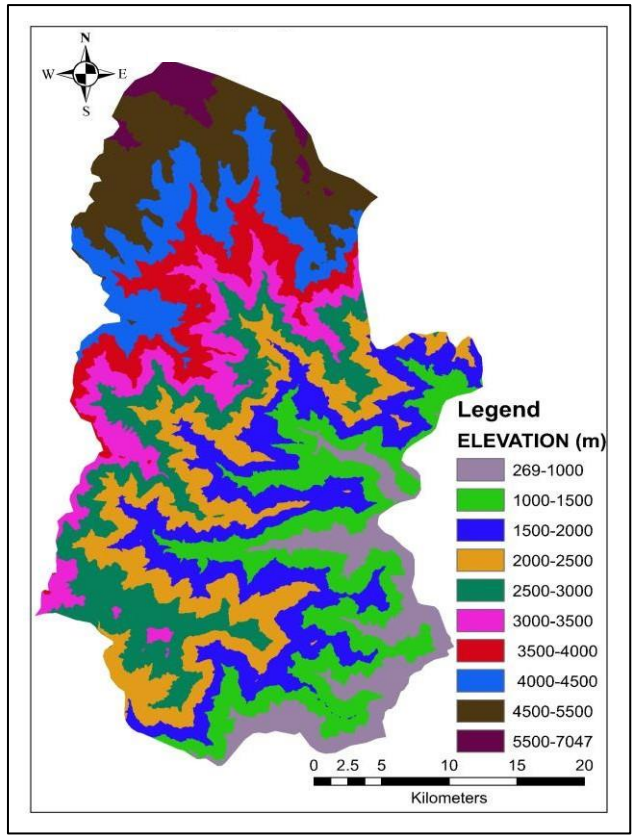


# LANDSLIDE CONDITIONING FACTORS

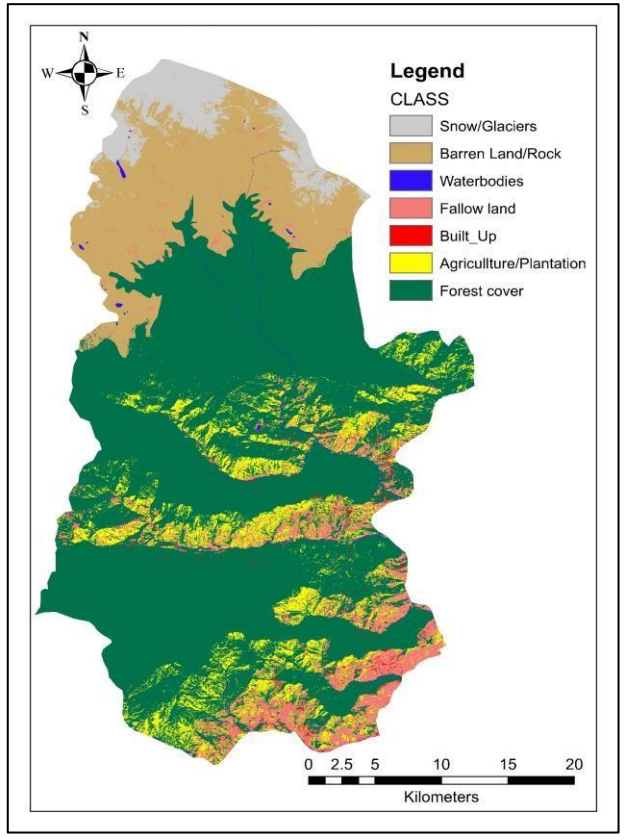
## SOIL TYPE



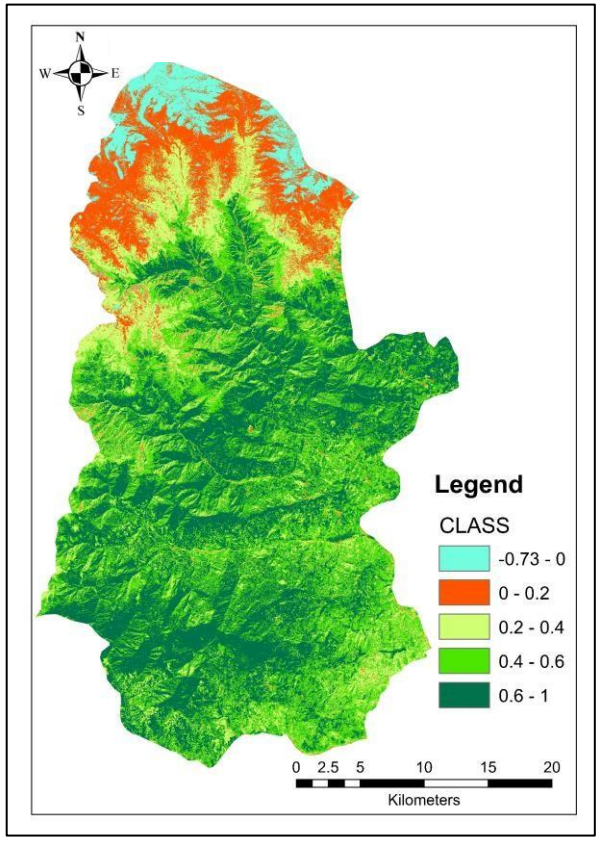

## ELEVATION




## LAND USE LAND COVER

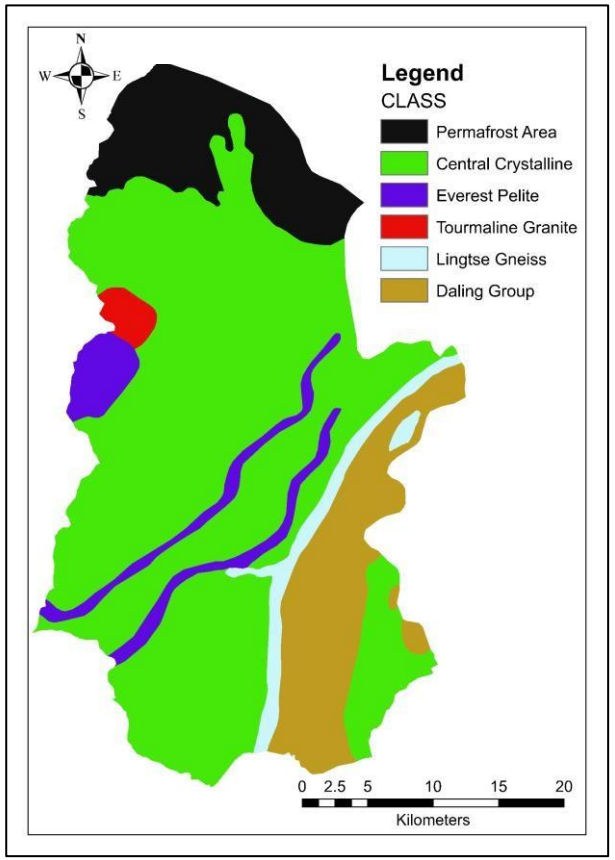



## NDVI

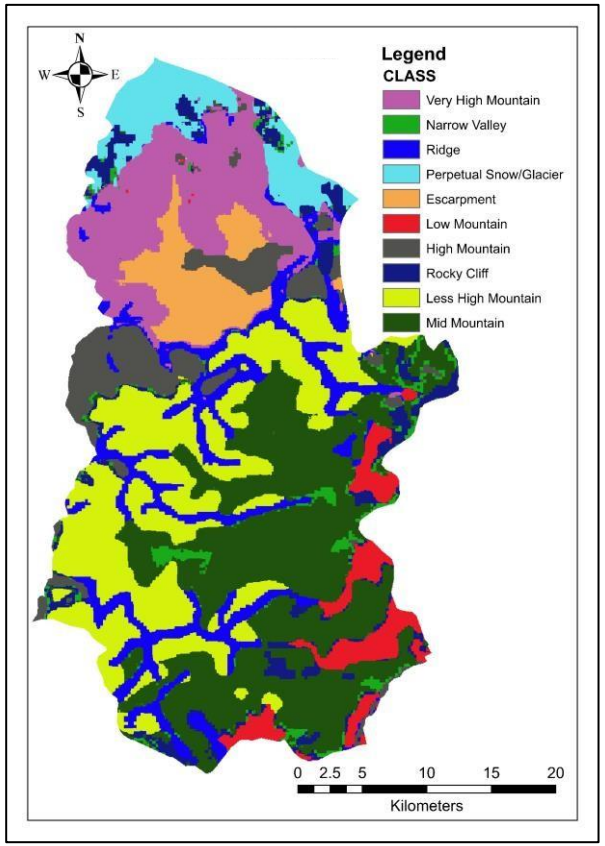


# LANDSLIDE CONDITIONING FACTORS

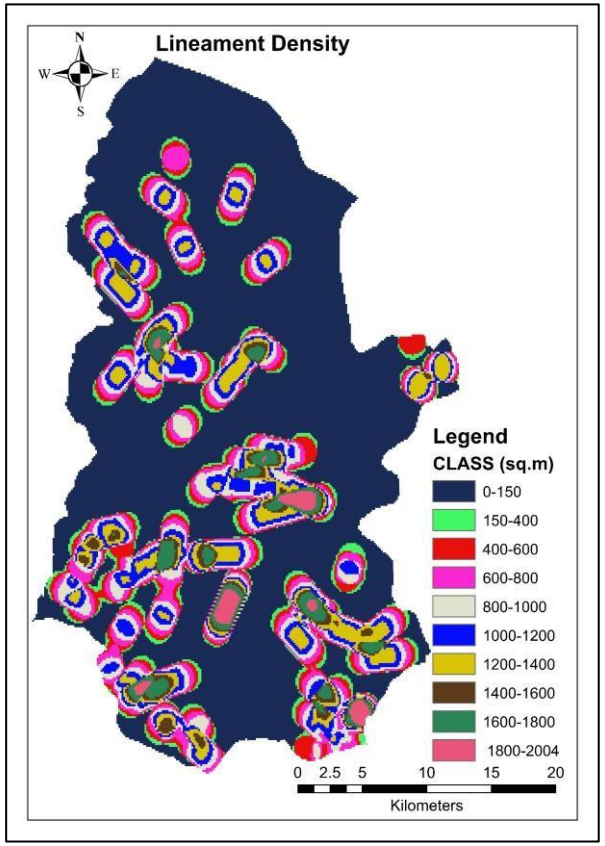
## LITHOLOGY



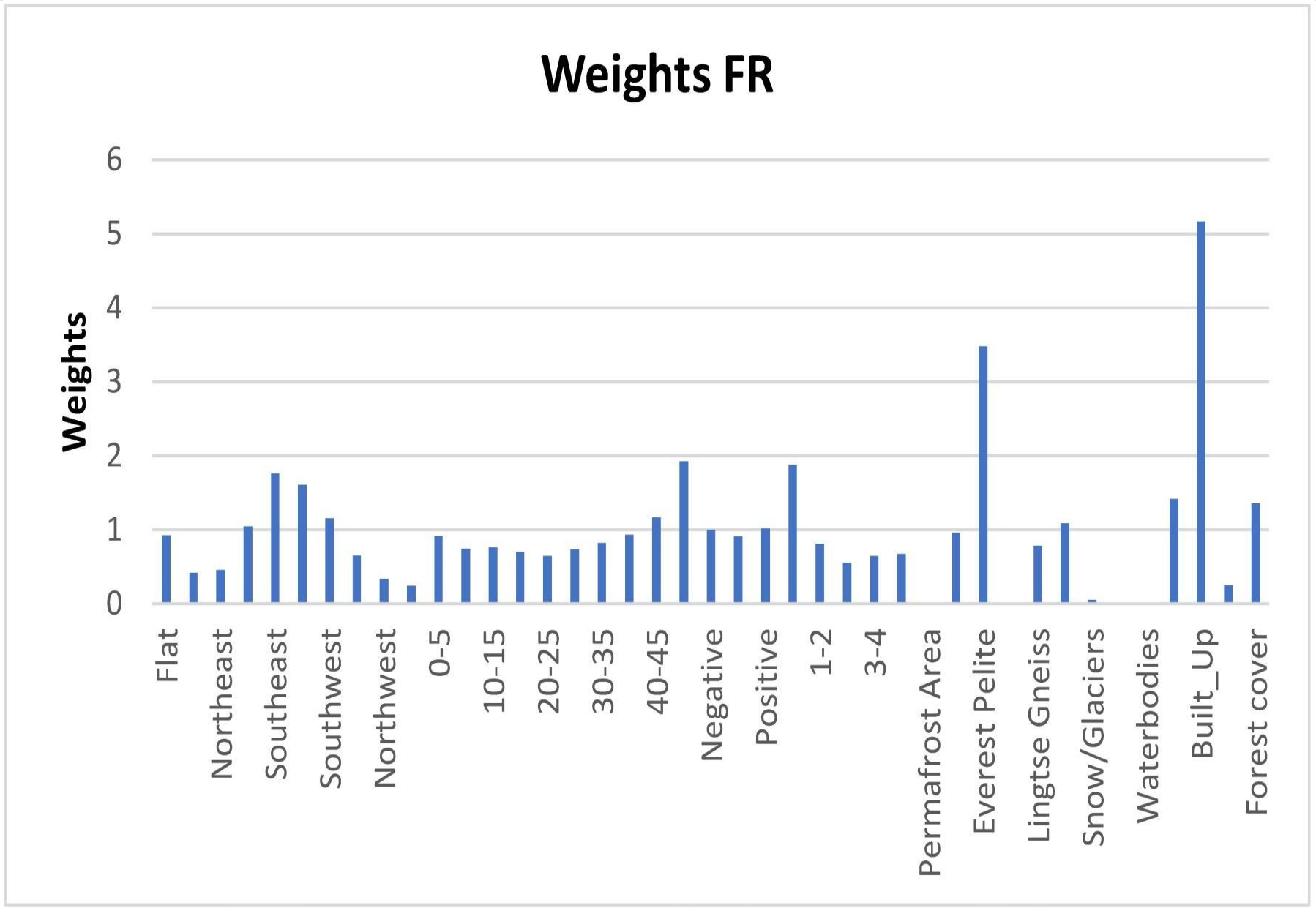

## GEOMORPHOLOGY

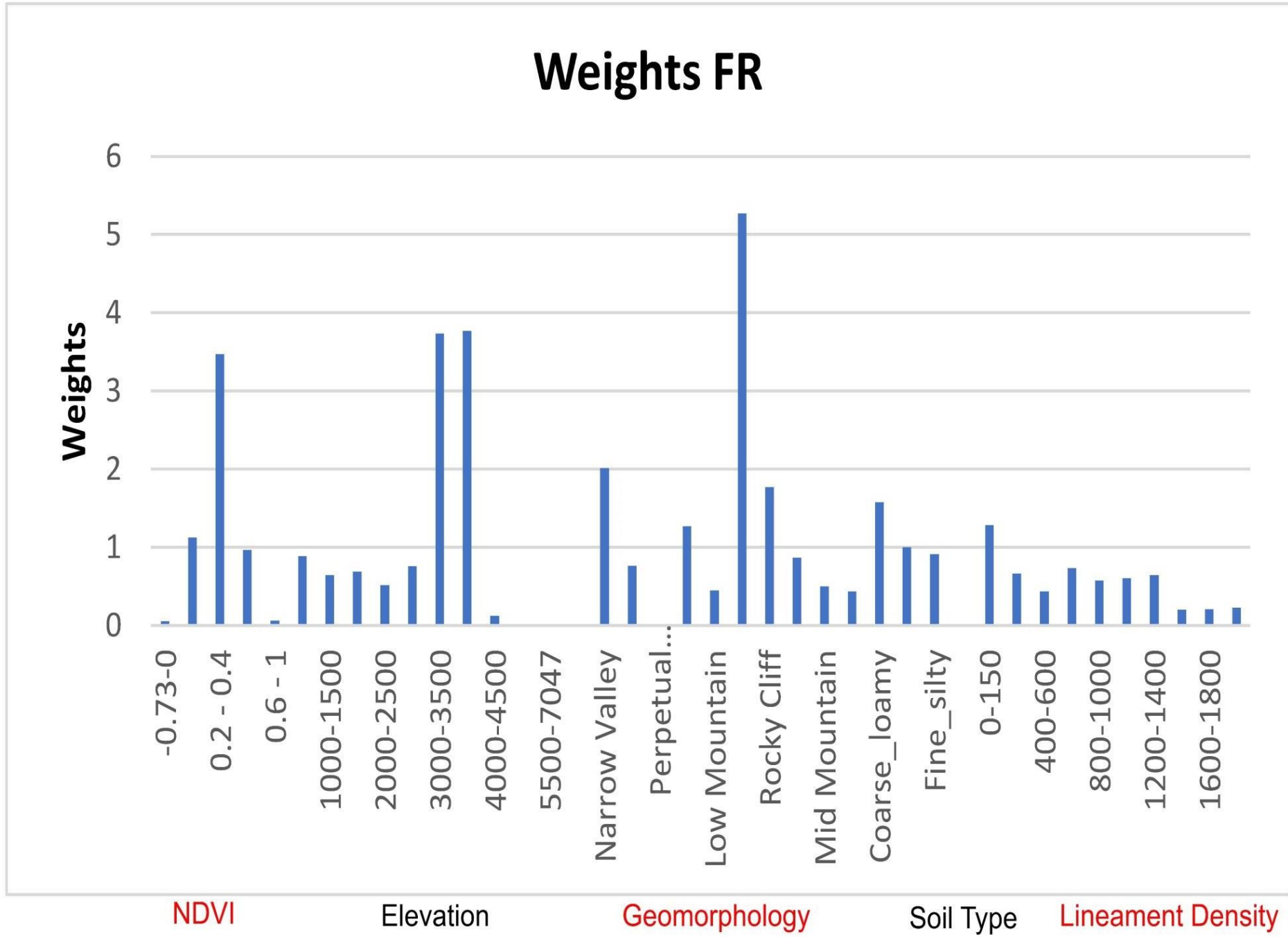


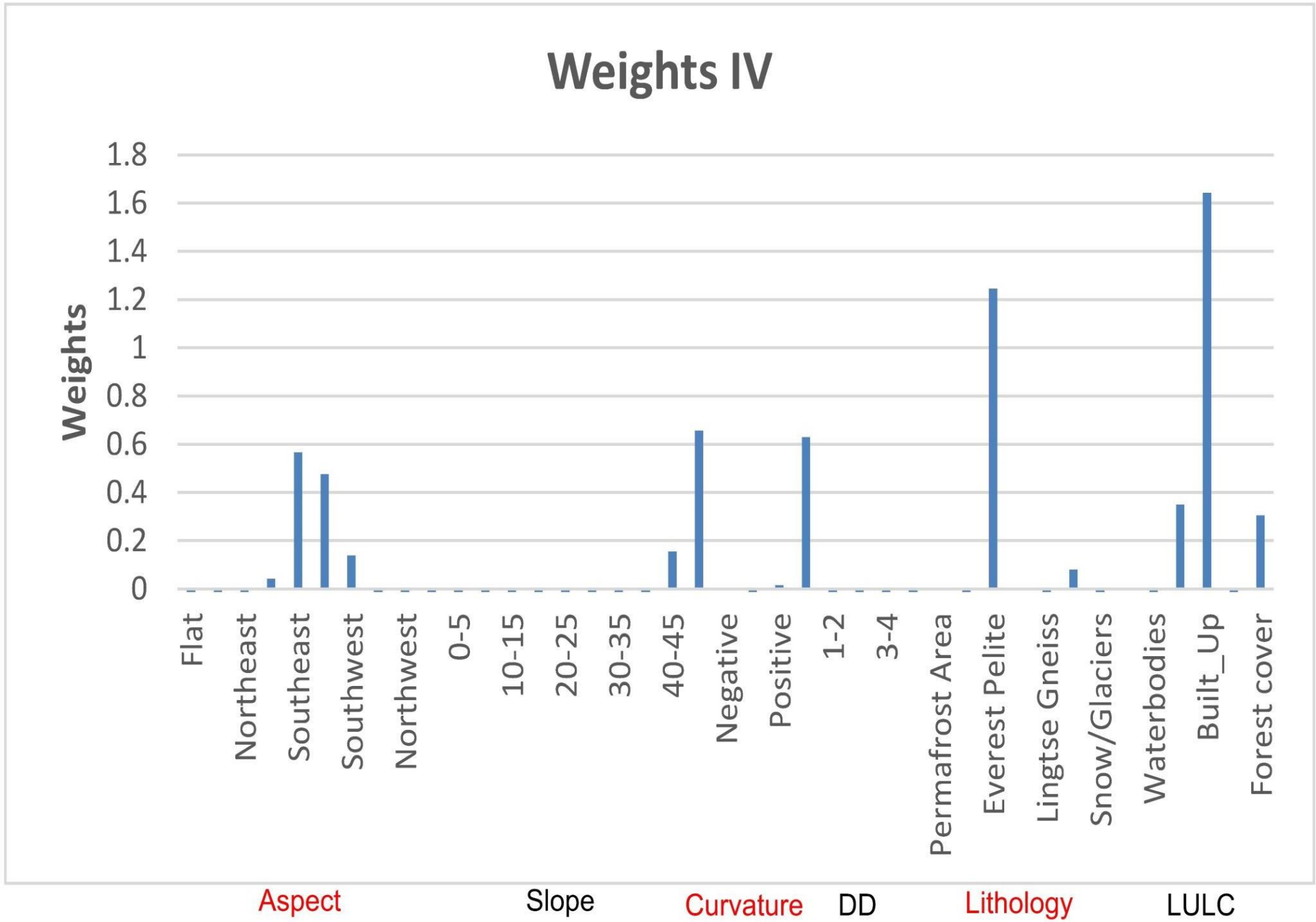

## LINEAMENT DENSITY

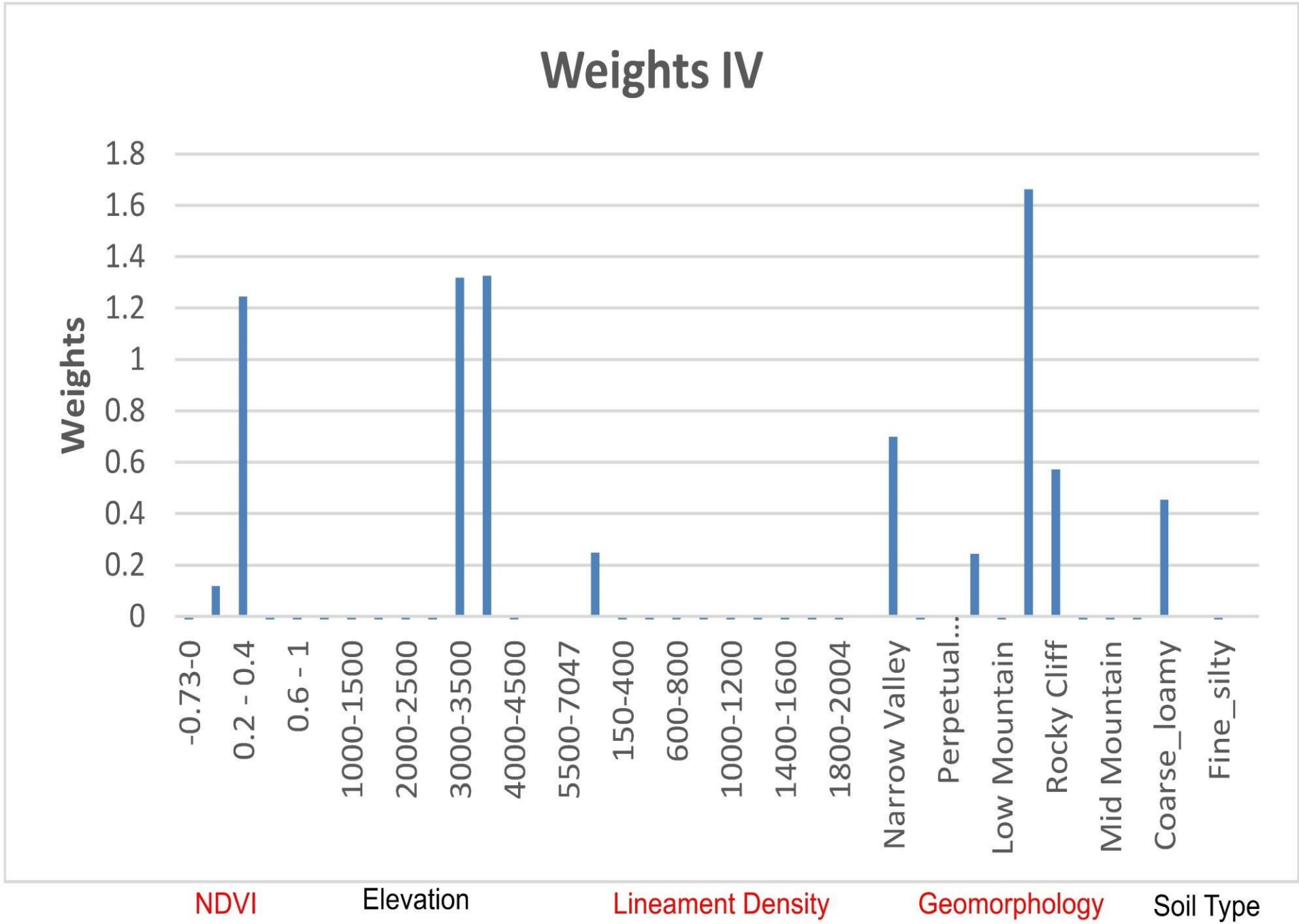


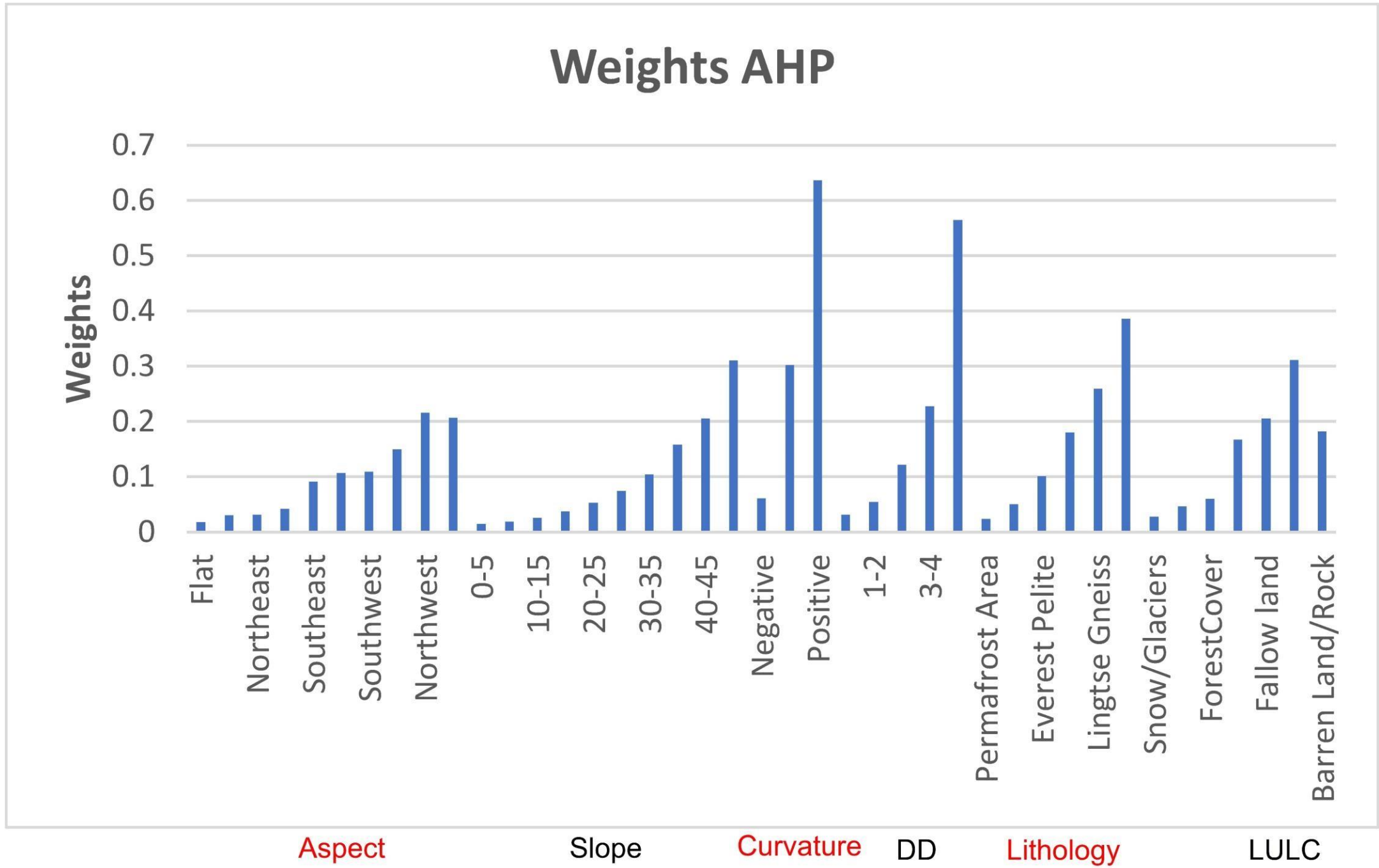
# RESULTS

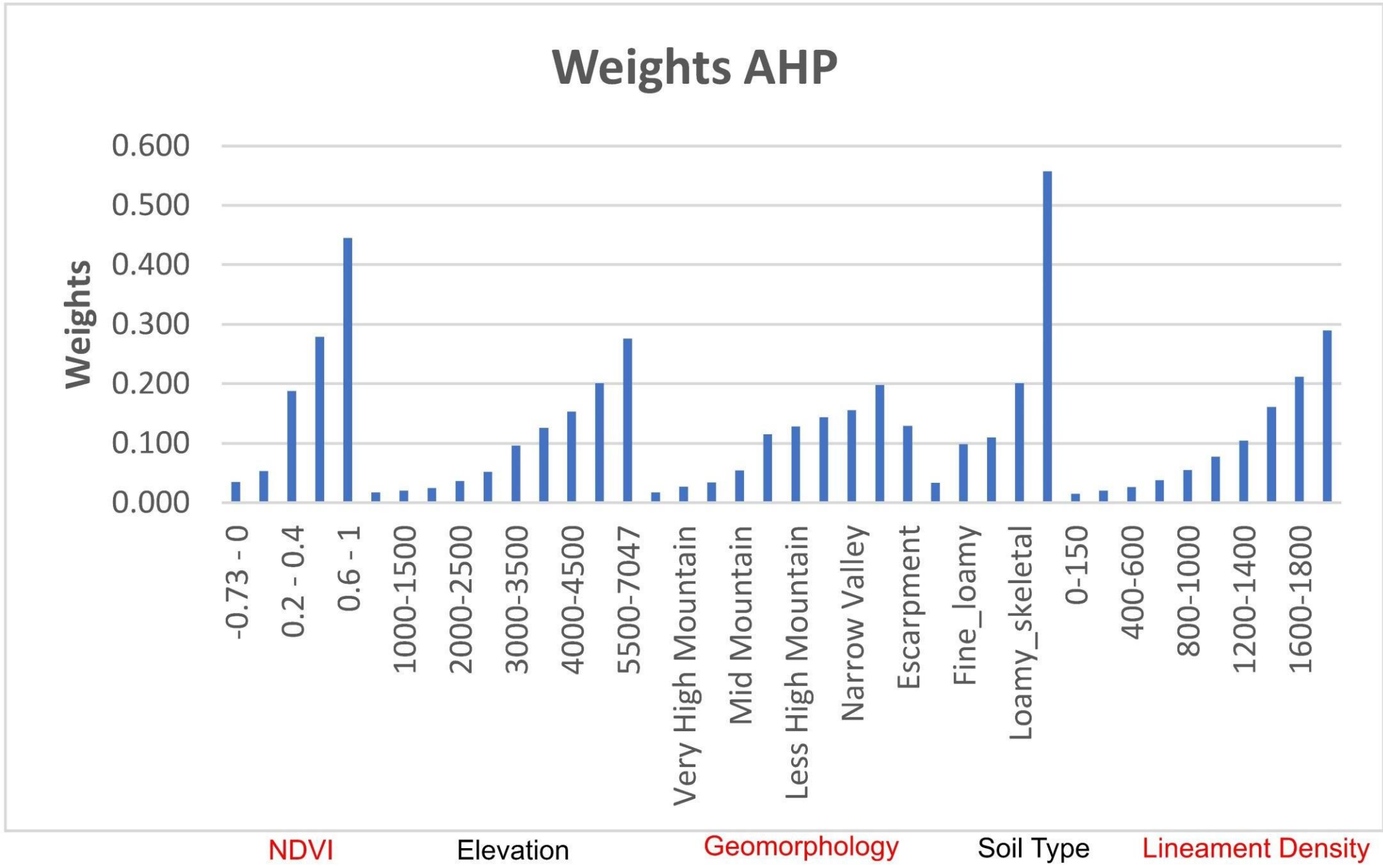

Weights FR
Weights
6
5
4
3
2
1
0
Flat
Northeast
Southeast
Southwest
Northwest
0-5
10-15
20-25
30-35
40-45
Negative
Positive
1-2
3-4
Permafrost Area
Everest Pelite
Lingtse Gneiss
Snow/Glaciers
Waterbodies
Built_Up
Forest cover
Aspect
Slope
Curvature
DD
Lithology
LULC


Weights FR
Weights
6
5
4
3
2
1
0
-0.73-0
0.2 - 0.4
0.6 - 1
1000-1500
2000-2500
3000-3500
4000-4500
5500-7047
Narrow Valley
Perpetual...
Low Mountain
Rocky Cliff
Mid Mountain
Coarse_loamy
Fine_silty
0-150
400-600
800-1000
1200-1400
1600-1800
NDVI
Elevation
Geomorphology
Soil Type
Lineament Density

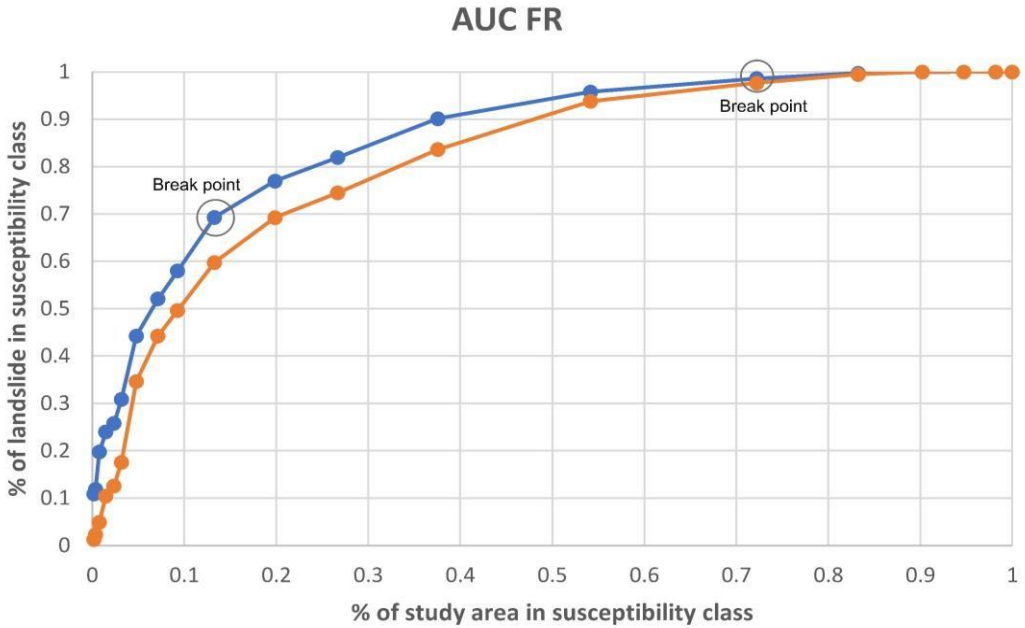

Weights IV
Weights
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flat
Northeast
Southeast
Southwest
Northwest
0-5
10-15
20-25
30-35
40-45
Negative
Positive
1-2
3-4
Permafrost Area
Everest Pelite
Lingtse Gneiss
Snow/Glaciers
Waterbodies
Built_Up
Forest cover
Aspect
Slope
Curvature
DD
Lithology
LULC

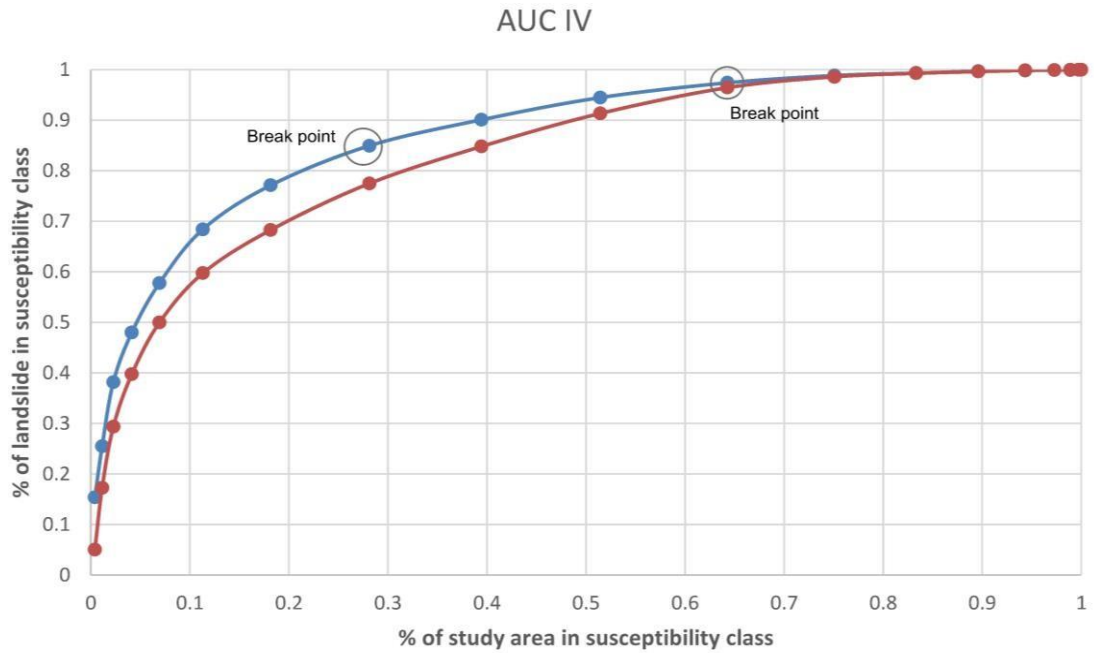

Weights IV
Weights
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.73-0
0.2 - 0.4
0.6 - 1
1000-1500
2000-2500
3000-3500
4000-4500
5500-7047
150-400
600-800
1000-1200
1400-1600
1800-2004
Narrow Valley
Perpetual...
Low Mountain
Rocky Cliff
Mid Mountain
Coarse_loamy
Fine_silty
NDVI
Elevation
Lineament Density
Geomorphology
Soil Type

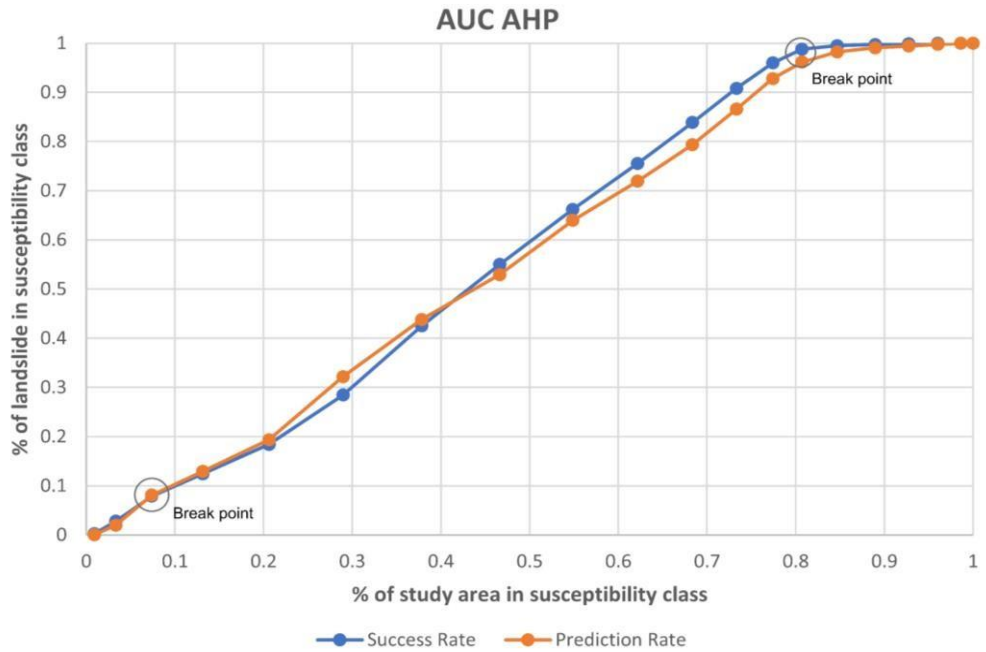

Weights AHP
Weights
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flat
Northeast
Southeast
Southwest
Northwest
0-5
10-15
20-25
30-35
40-45
Negative
Positive
1-2
3-4
Permafrost Area
Everest Pelite
Lingtse Gneiss
Snow/Glaciers
ForestCover
Fallow land
Barren Land/Rock
Aspect
Slope
Curvature
DD
Lithology
LULC


Weights AHP
Weights
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-0.73 - 0
0.2 - 0.4
0.6 - 1
1000-1500
2000-2500
3000-3500
4000-4500
5500-7047
Very High Mountain
Mid Mountain
Less High Mountain
Narrow Valley
Escarpment
Fine_loamy
Loamy_skeletal
0-150
400-600
800-1000
1200-1400
1600-1800
NDVI
Elevation
Geomorphology
Soil Type
Lineament Density

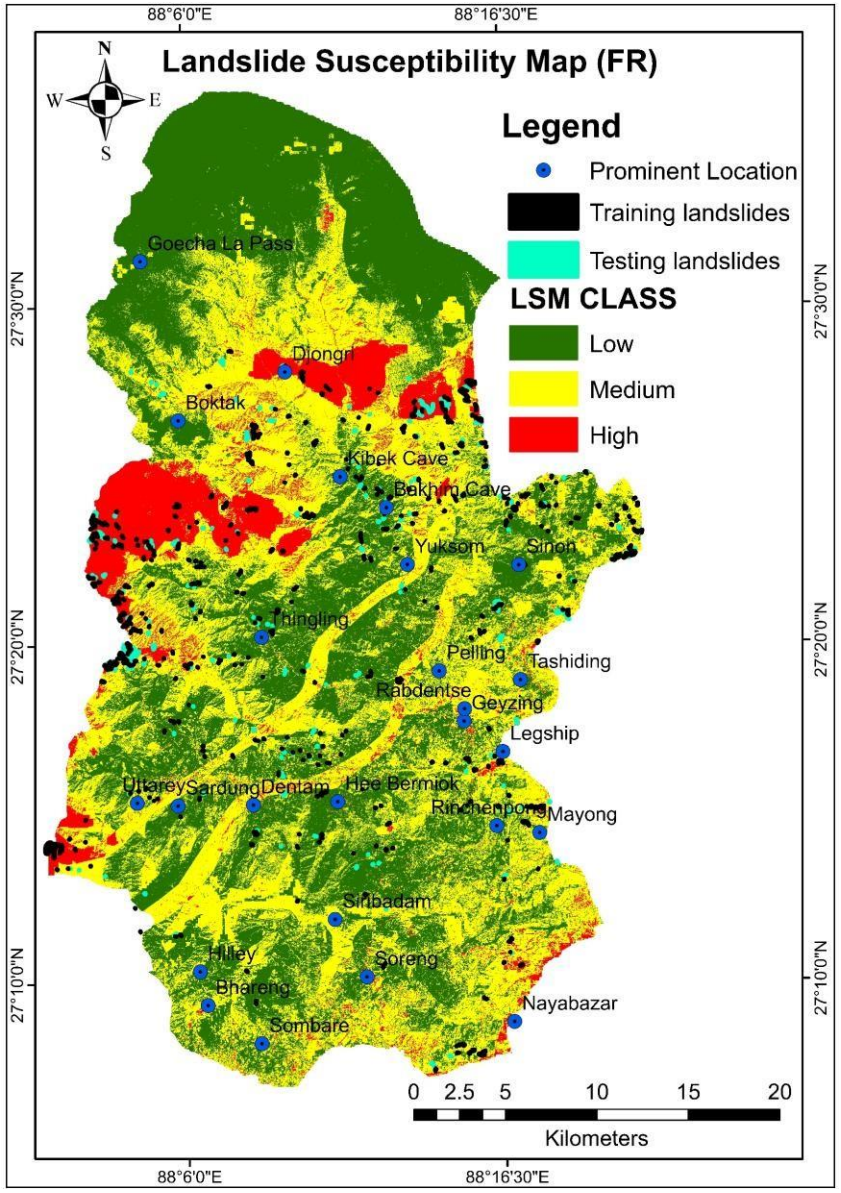
# Success & Prediction Rate Curve

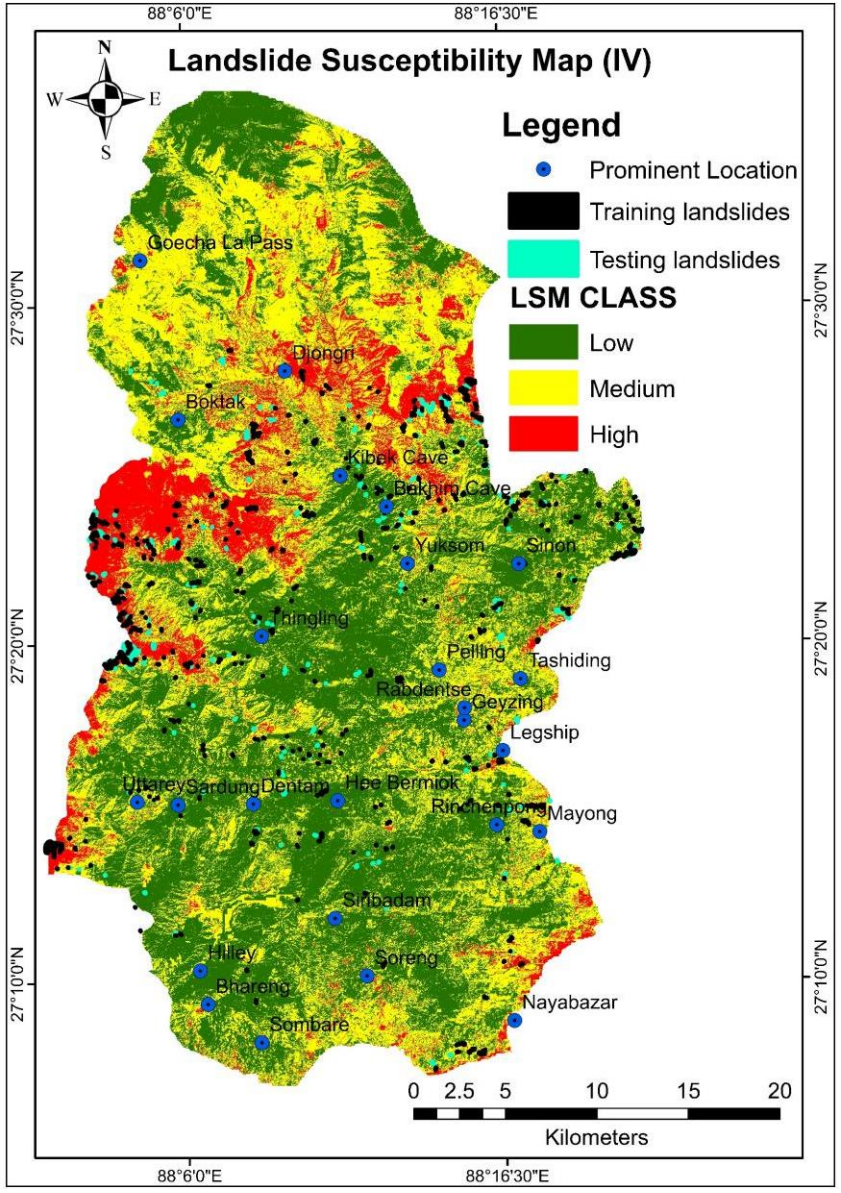


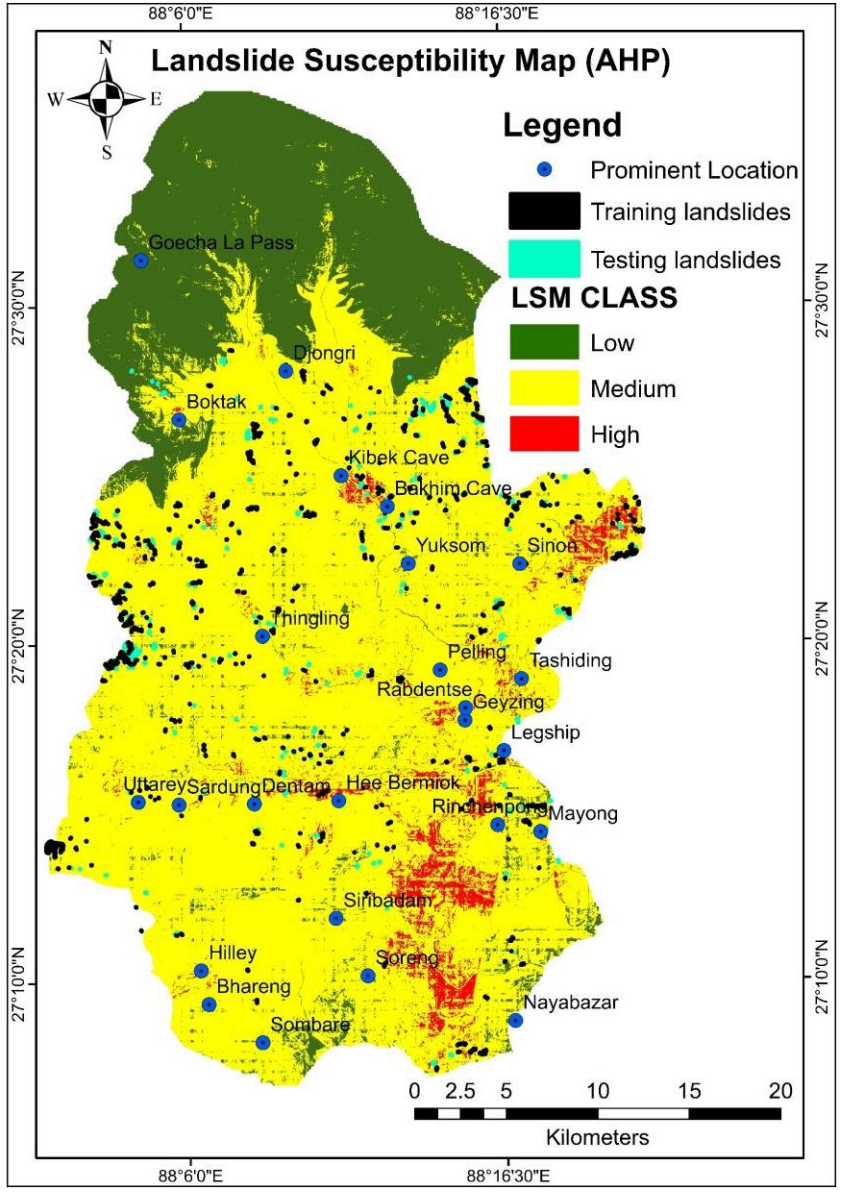



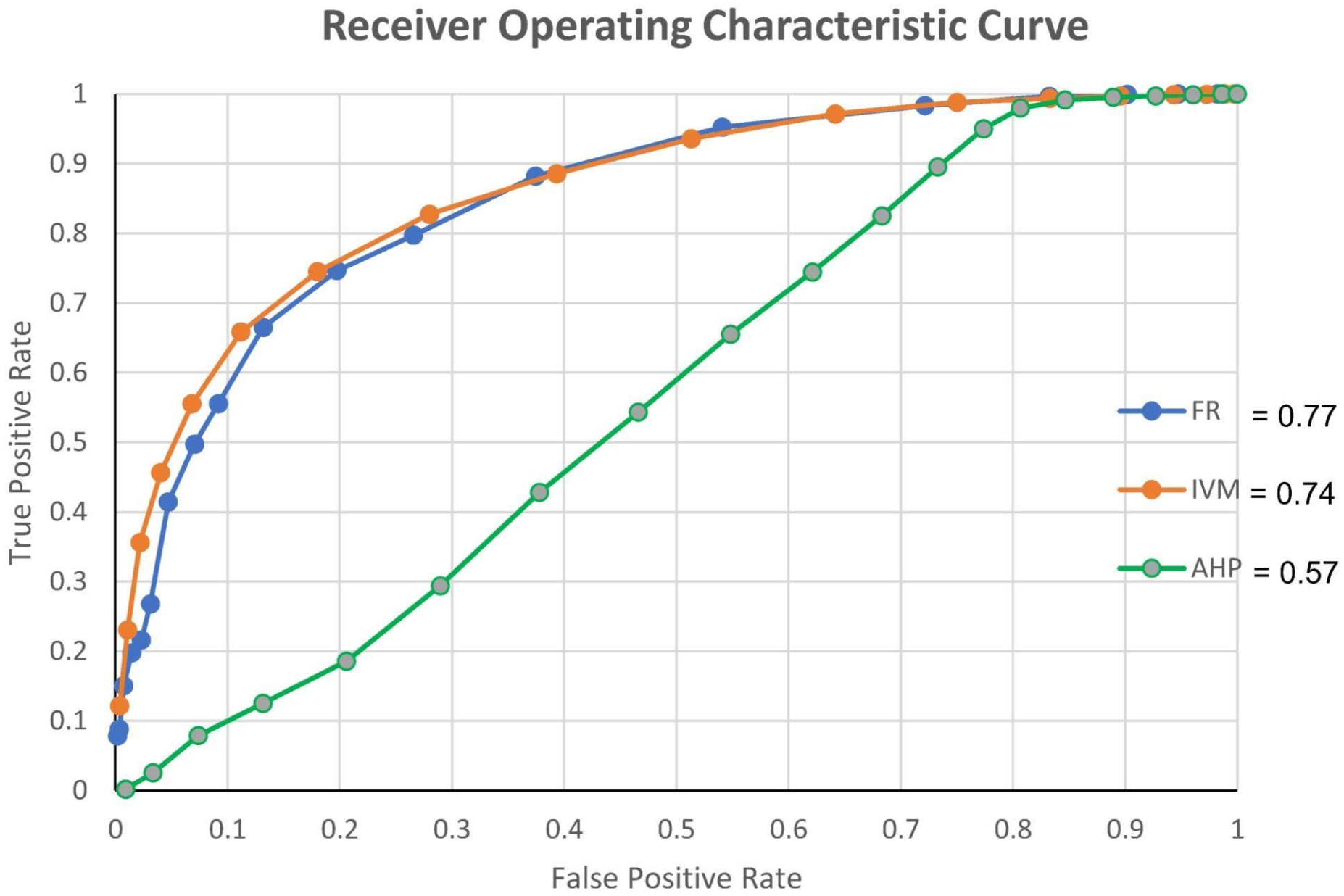
# Landslide Susceptibility Map



# Validation


Receiver Operating Characteristic Curve
True Positive Rate
False Positive Rate
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
FR = 0.77
IVM = 0.74
AHP = 0.57

# CONCLUSIONS

- ✓In the current study, all the three methods used for the preparation of LSM fits the acceptable considerable value.
- ✓From this study we can comment that the statistical method gives the best result in comparison to the knowledge-driven method.
- ✓Landslide susceptibility mapping is helpful for the planners and the decision-makers for the initiation of any developmental activities in the hilly terrains.
- ✓However, more causative factors and landslide samples can be added for the future study to get more accuracy.

# Acknowledgements

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Thank You