MODELLING OF 3D GEOLOGY AND LANDSLIDE HAZARD IN THE LESSER HIMALAYA, CENTRAL NEPAL

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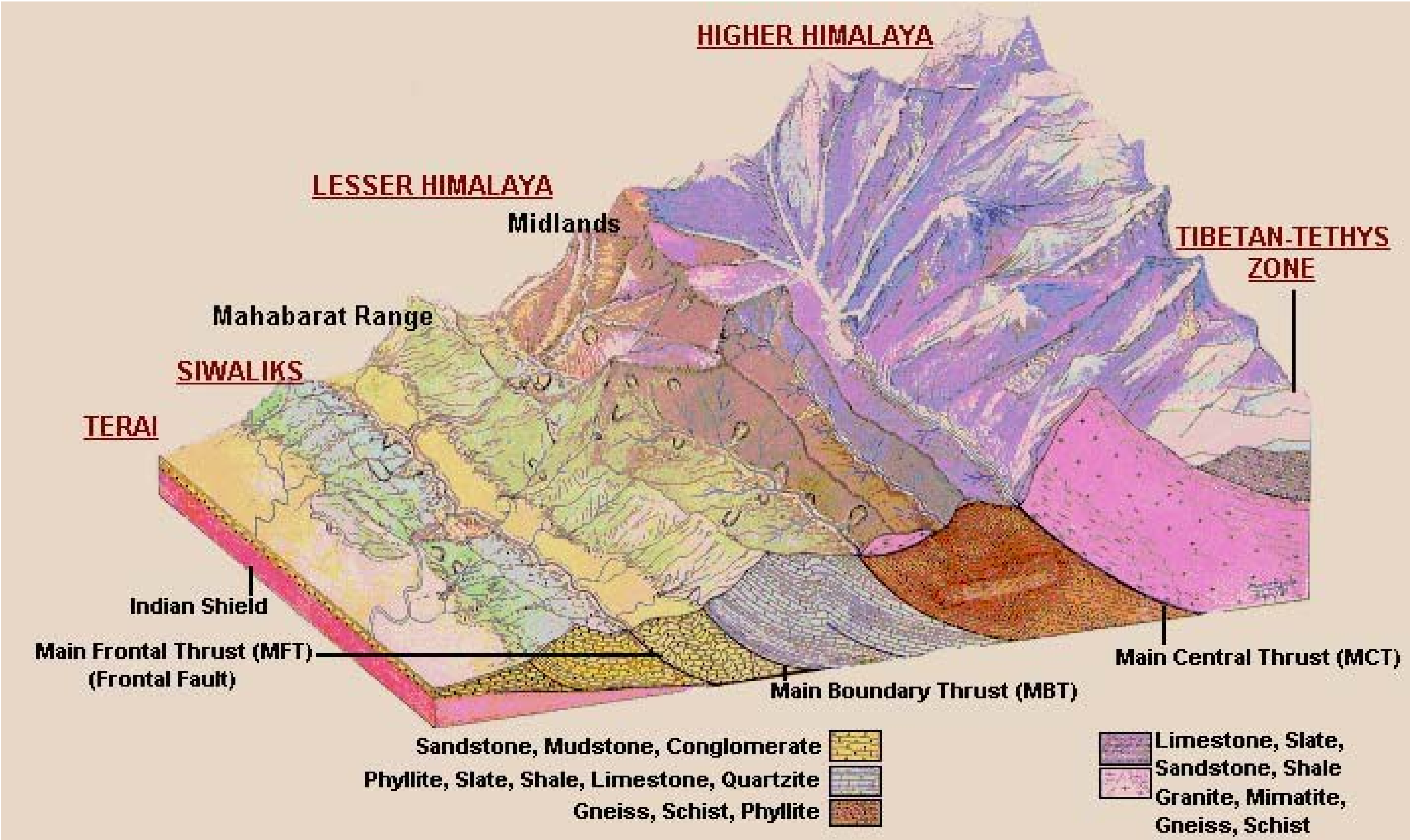
CONTENTS

- An brief overview of physiography, geology & landslide occurrence in the Nepal Himalaya
- 3D geological modelling of central Nepal
- Landslide hazard modelling of central Nepal
- Integration of model3D & landslide hazard/suceptibility
- Concluding remarks

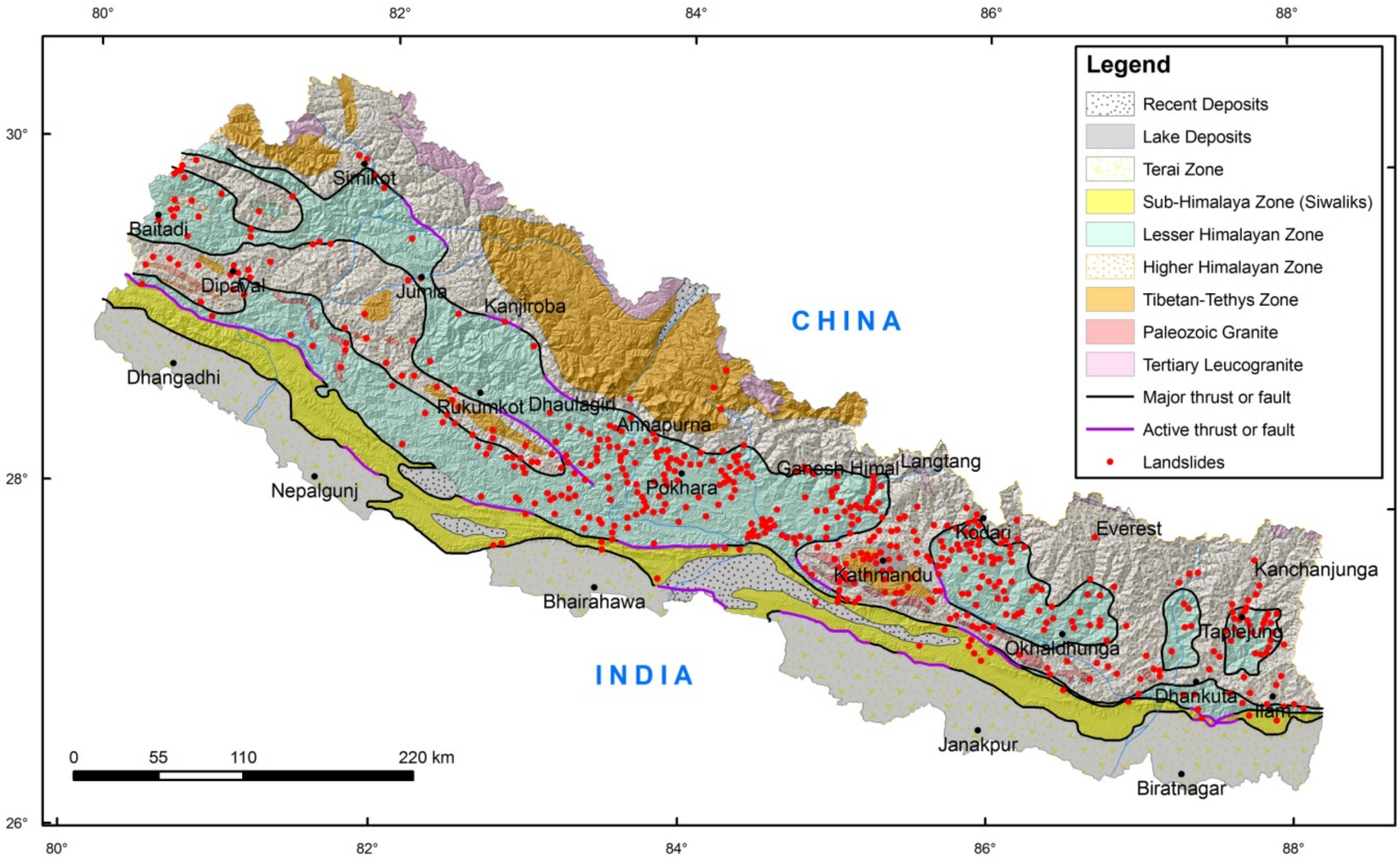
Physiography and geology of Nepal Himalaya



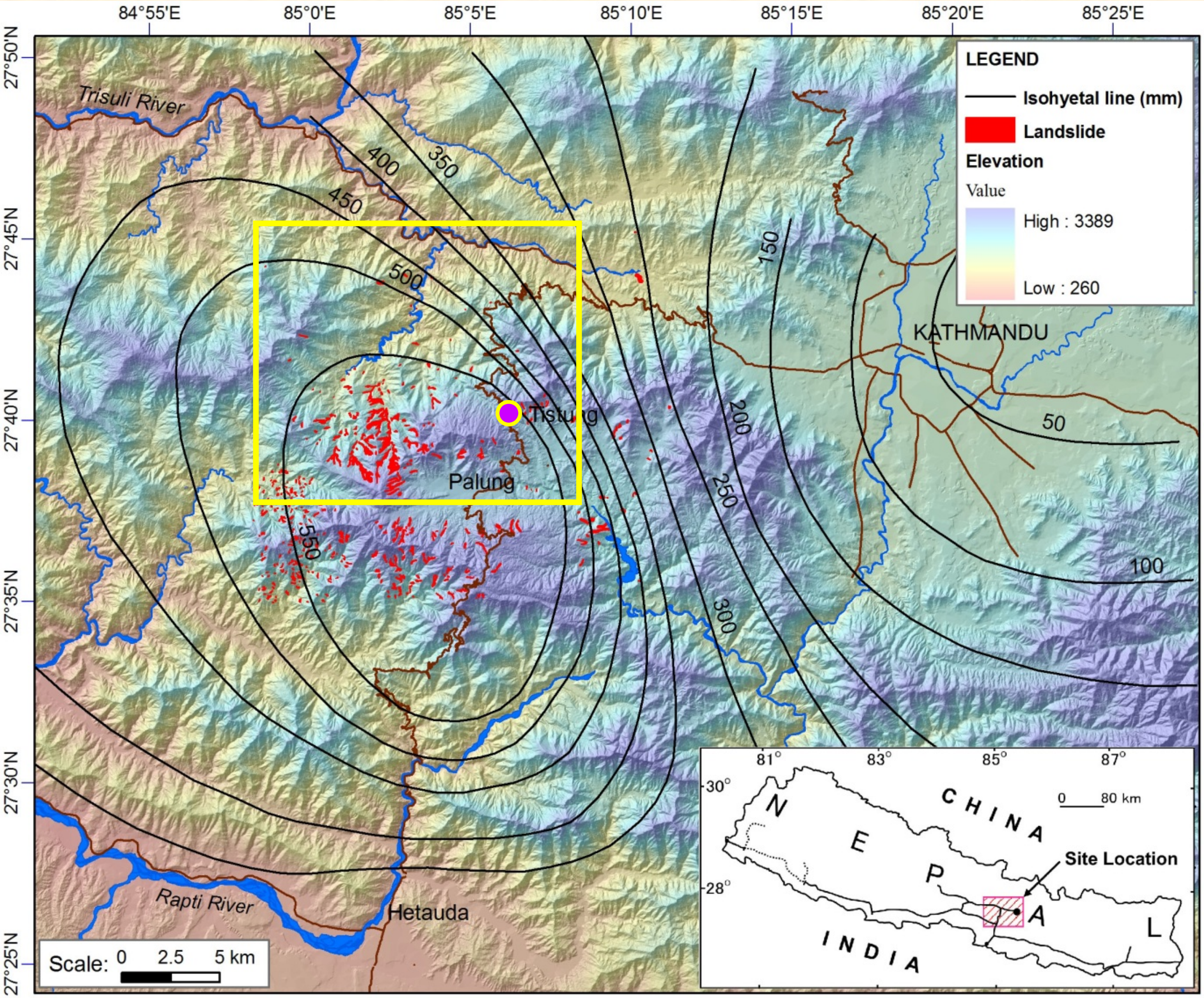
Nelson et al. 1980

Extreme vertical variation of topography with respect to geolocal subdivisions

Occurrence of landslides & tectonostratigraphy of Nepal Himalaya



Extreme weather event and landslide occurences (July 1993, central Nepal)



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Extreme weather event of 19–21 July 1993; rainfall measured at **Tistung**, central Nepal (source: Department of Soil Conservation & Watershed Management)

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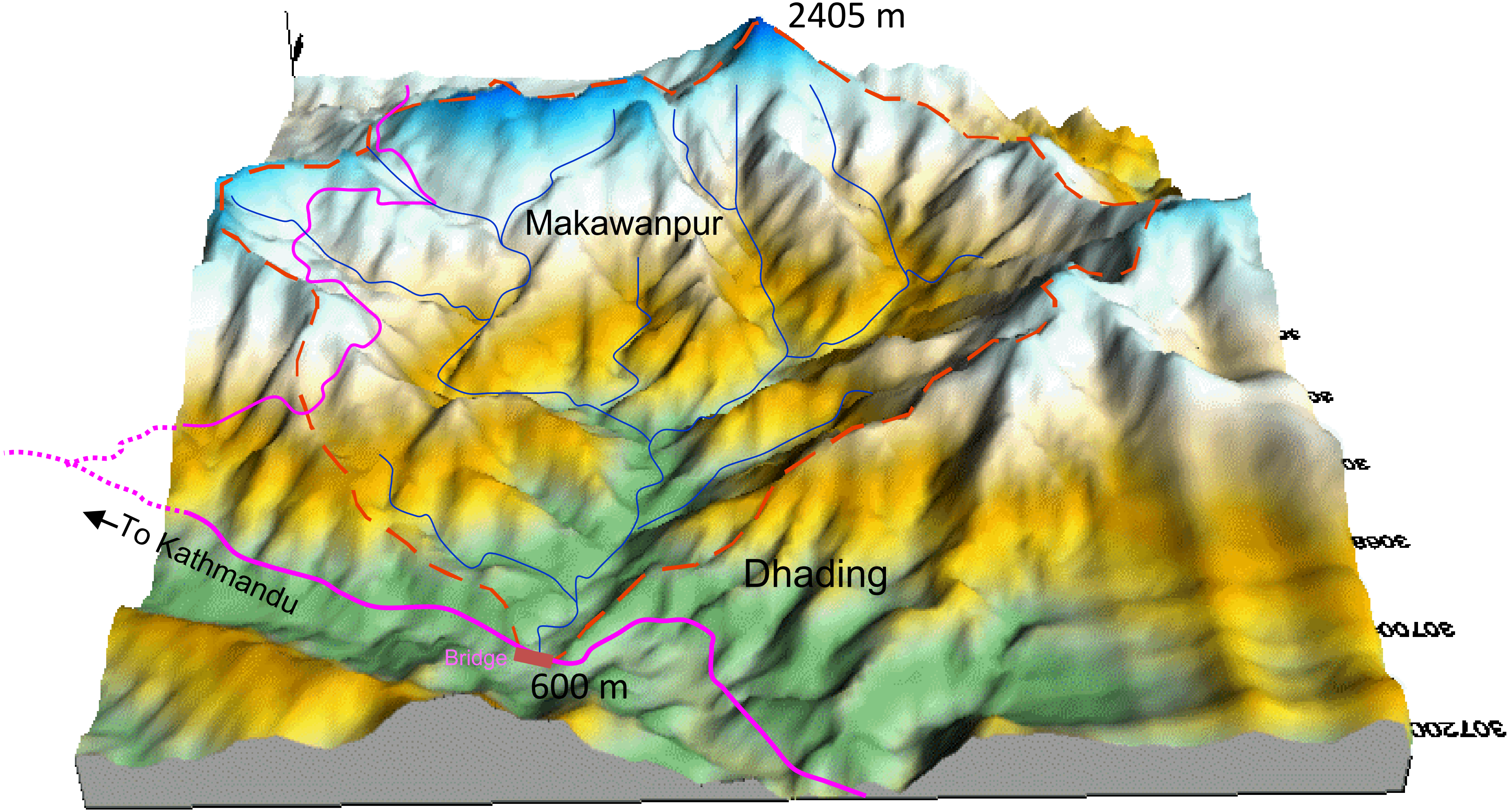
Modelling site (latitudes 27°37’ to 27°45’ N & longitudes 84°57’38” to 85°08’2” E)



Lesser Himalaya, central Nepal

19-21 July 1993 Cloudburst & landslide damages

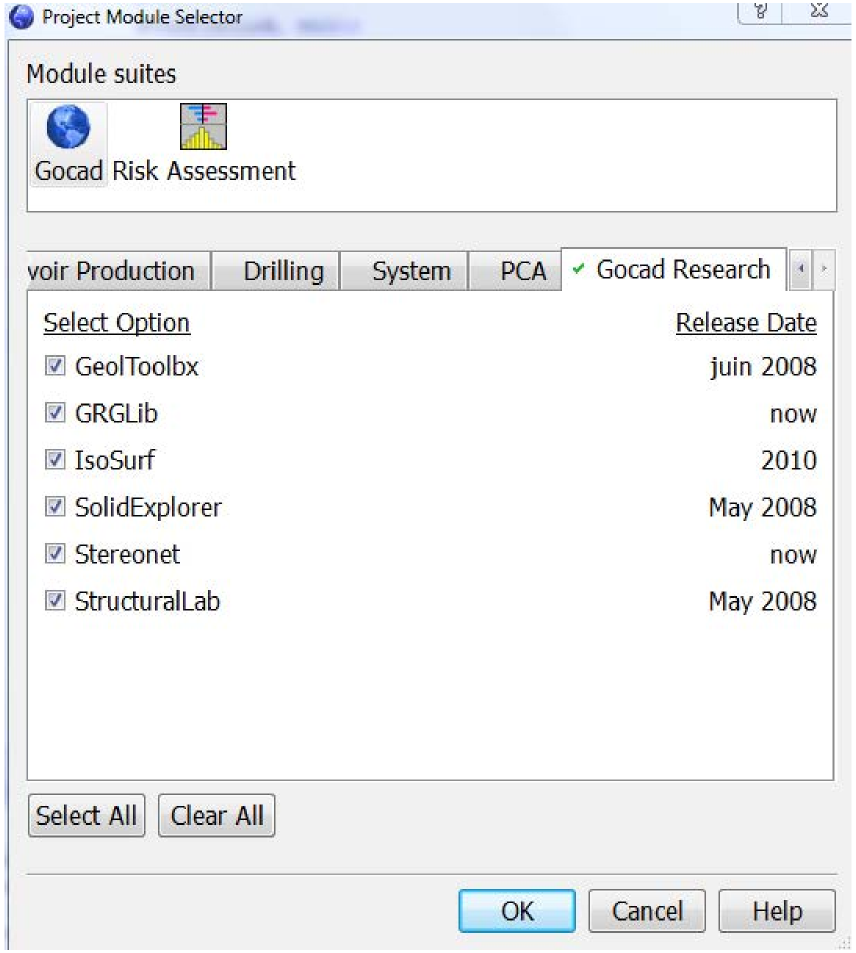
- Upstream extensive landslides
- Huge sediment transport along river course

Failure of thin soils along the dip-slopes is the most occurrences

3D geological modelling: IMPLICIT APPROACH *(after Caumon et al. 2007)*

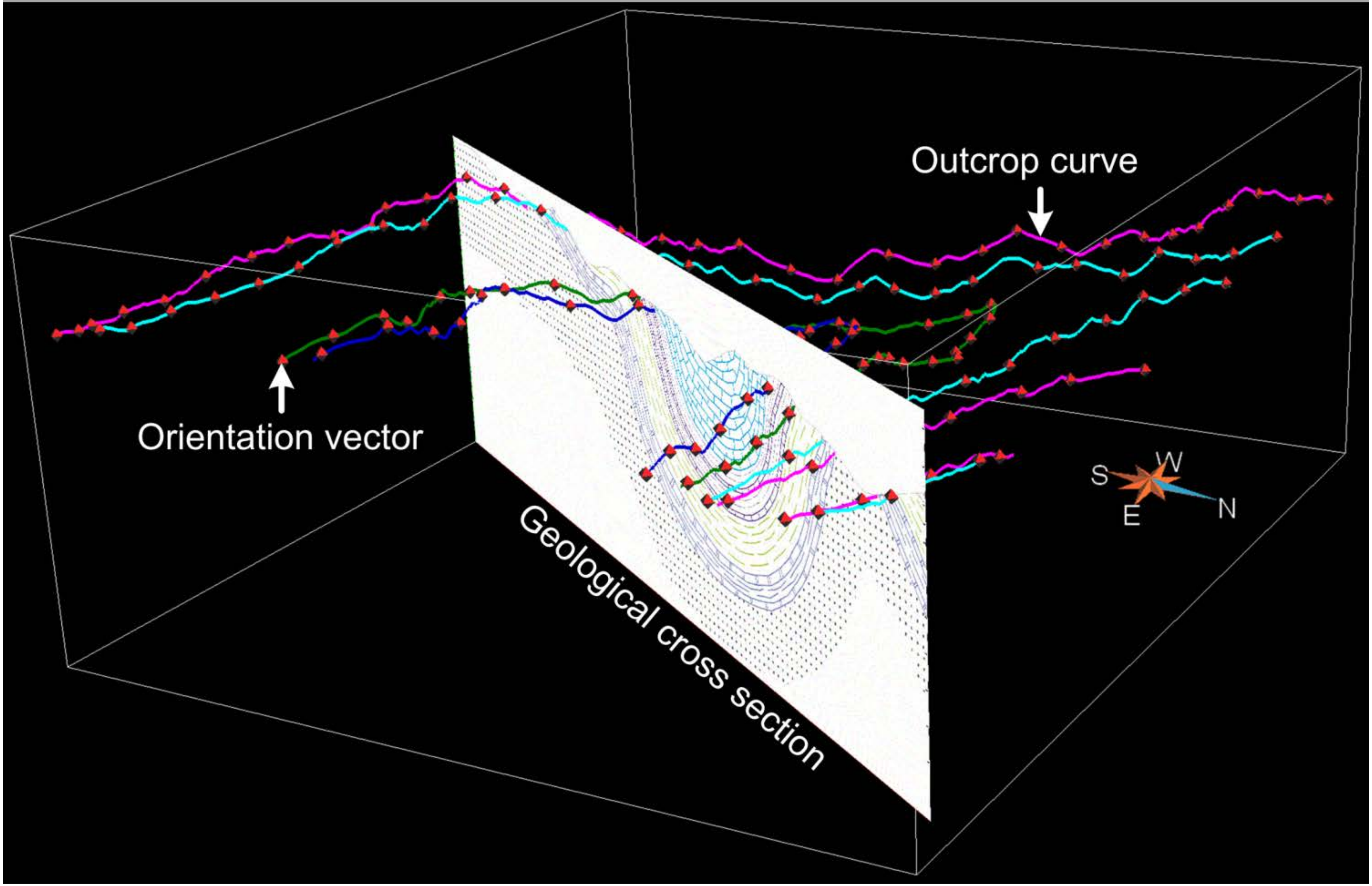
Using following GOCAD research plugins:

- GeolToolbx
- GRGLib
- IsoSurf
- SolidExplorer
- Stereonet
- StructuralLab



The coordinate system will be in meters, with Z positive upwards.

3D model configuration using GOCAD



Orientation vector (*v*)

$$v = \begin{bmatrix} \sin(\theta)\cdot\cos(\phi) \\ \cos(\theta)\cdot\cos(\phi) \\ \cos(\phi) \end{bmatrix}$$

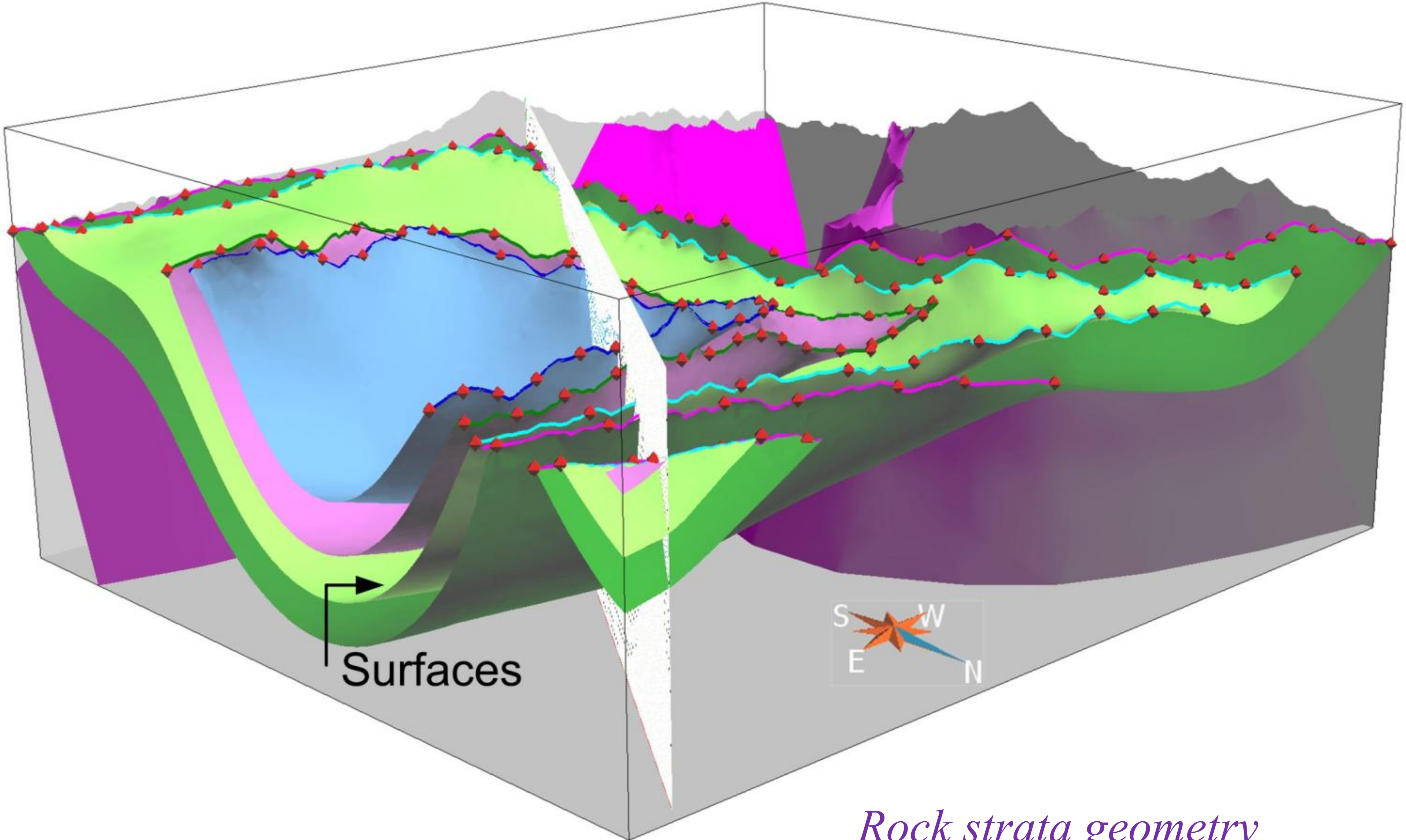
where, dip direction ϑ (azimuth) and dip ϕ angles

DSI (Mallet 2002)

$$R^*(\varphi) = \sum_{\alpha\in\Omega} \mu(\alpha)\cdot R(\varphi|\alpha) + (\phi\cdot\varpi)\cdot \sum_{c\in C\approx} \varpi_c \cdot \rho(\varphi|c)$$

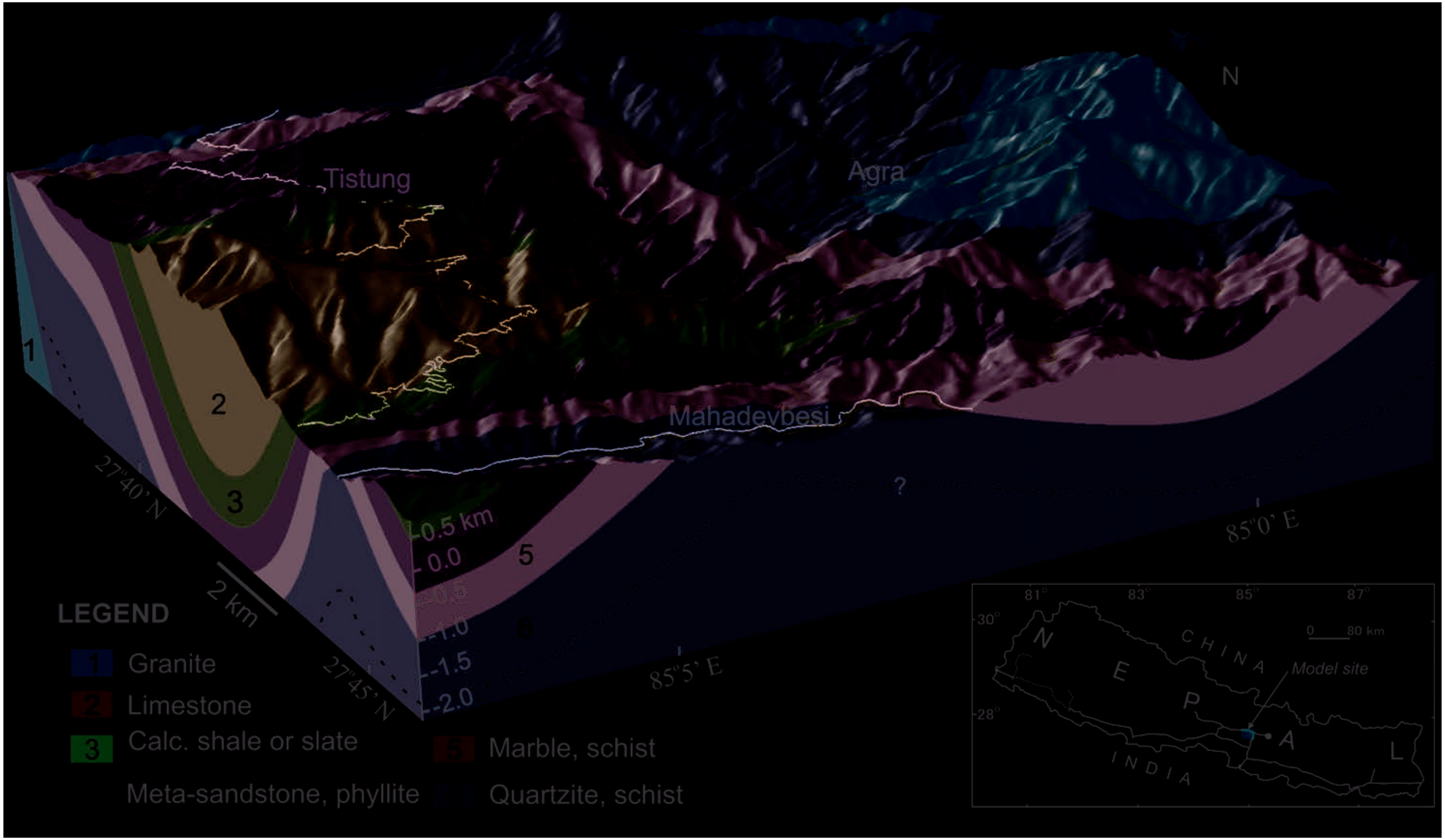
where, $R(\varphi|\alpha)$ is the local roughness at node α, $\rho(\varphi|c)$ is a constraint defined for node α, μ is a stiffness coefficient, and ϖ_c, $\phi.\varpi$ are weight coefficients

Computed stratigraphic surfaces for Model3D



Rock strata geometry

3D geological model of Lesser Himalaya, central Nepal



Landslide hazard modelling using LR

If the probability of presence (1) of a phenomenon is Pa, then Pb represents the absence (0).

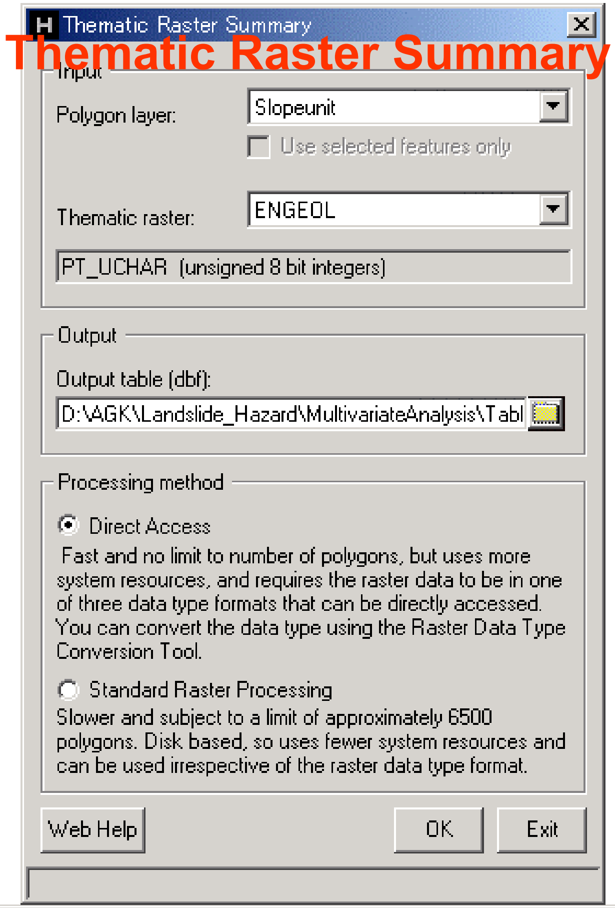
(i. e. Pa + Pb = 1)

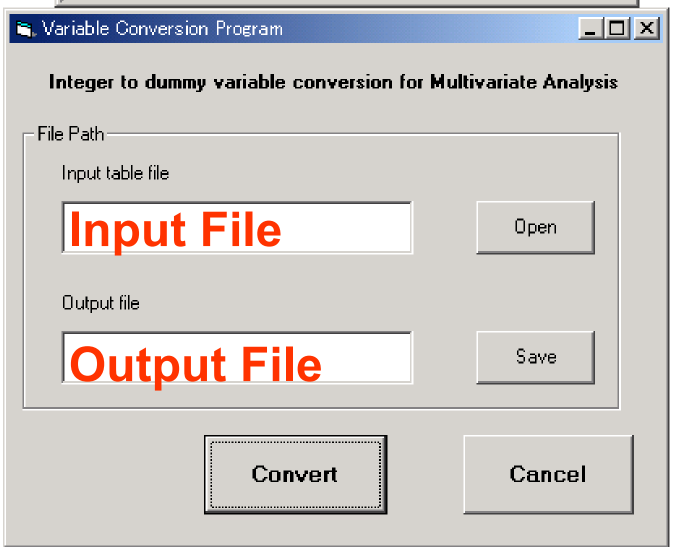
$$P(Y) = \frac{1}{1 + e^{-Z}}$$

Where P(Y) is the probability of an event occurring.

Z = b0 + b1A1+ ……….. +bnAn

Where, bi (i=0,1, ……,n) is coefficient estimated from sample data, and Ai (i=1,2, …..,n) is independent variables (i.e. landslide related physical parameters)





Integer variable matrix

0	541	4	0	0	0	0
1	349	677	0	0	0	0
2	0	535	0	0	0	0
3	0	574	0	0	0	0
4	0	375	0	0	0	0
5	75	579	0	0	0	0
6	0	341	0	0	0	0
7	0	292	0	0	0	0
8	0	25	0	0	0	0
9	0	190	0	0	0	0
10	0	452	0	0	0	0
11	0	196	0	0	0	0
12	0	889	0	0	0	0
13	0	662	0	0	0	0

Dummy variable matrix

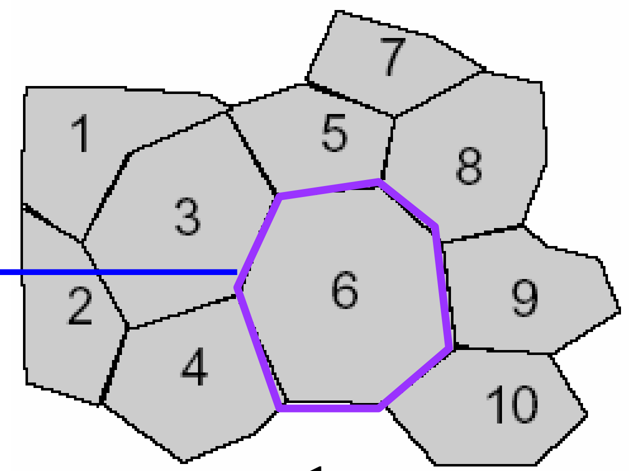
0	1	1	0	0	0	0
1	1	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	1	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0
1	0	1	0	0	0	0

Logistic Regression Coefficients

Variables	Coef.	Variables	Coef.
Slope angle		***Slope complexity***	
<15°	-0.217	Granite slope (GS)	-1.662
15°-25°	0.074	Oblique slope (OS)	-0.349
25°-35°	0.778	Dip-slope ≥ slope (DS-EL)	1.357
35°-45°	0.417	Dip-slope > slope (DS-G)	-0.023
>45°	-0.145	Counter dip-slope (CDS)	-0.163
Slope aspect		Fractured zone (FZ)	-1.030
Flat	-0.385	***Land use***	
North (N)	0.117	Forest (Fo)	1.536
North East (NE)	0.253	Shrub land (SrL)	-0.124
East (E)	0.590	Grassland (GrL)	0.880
South East (SE)	-0.177	Cultivated land (CuL)	0.657
South (S)	0.195	Barren land (BaL)	2.845
South West (SW)	-0.348	Constant	-3.640
West (W)	-0.027		
North West (NW)	0.333		
Engineering geology			
Thin soil [1-3 m] (TnSl)	-0.203		
Thick soil [>3 m] (TkSl)	-0.272		
Colluvium (Clv)	-0.876		
Alluvium (Alv)	0.240		
High Rock Mass Strength (HRMS)	-0.868		
Medium Rock Mass Strength (MRMS)	0.222		
Low Rock Mass Strength (LRMS)	1.420		

Probability calculation using logistic regression

For example:



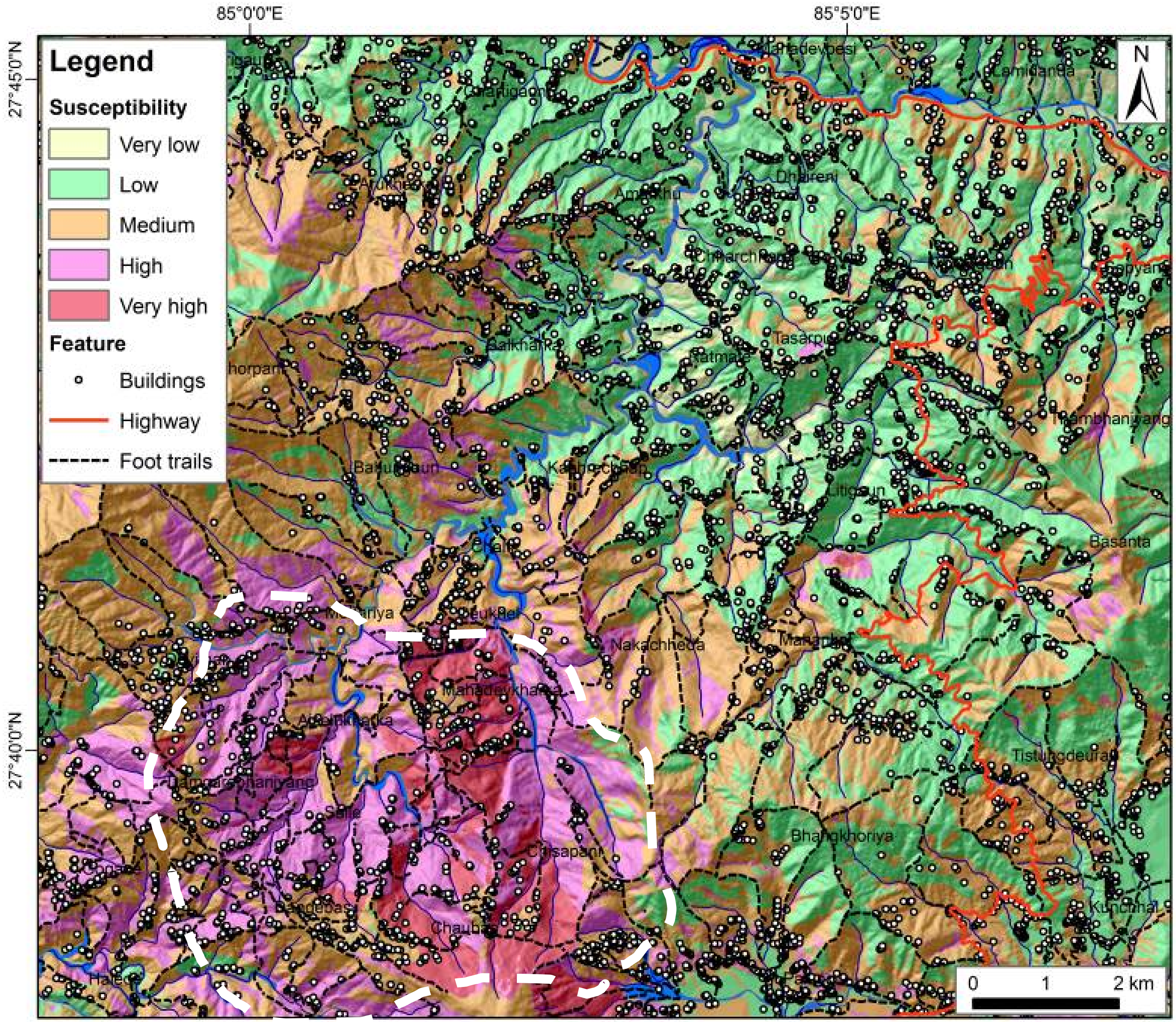
$$p(Y) = \frac{1}{1 + e^{-(\beta o + \beta 1 quartzite + \beta 2 Forest + \beta 3 Slope(15-25) + \beta 4 AspectNW)}}$$

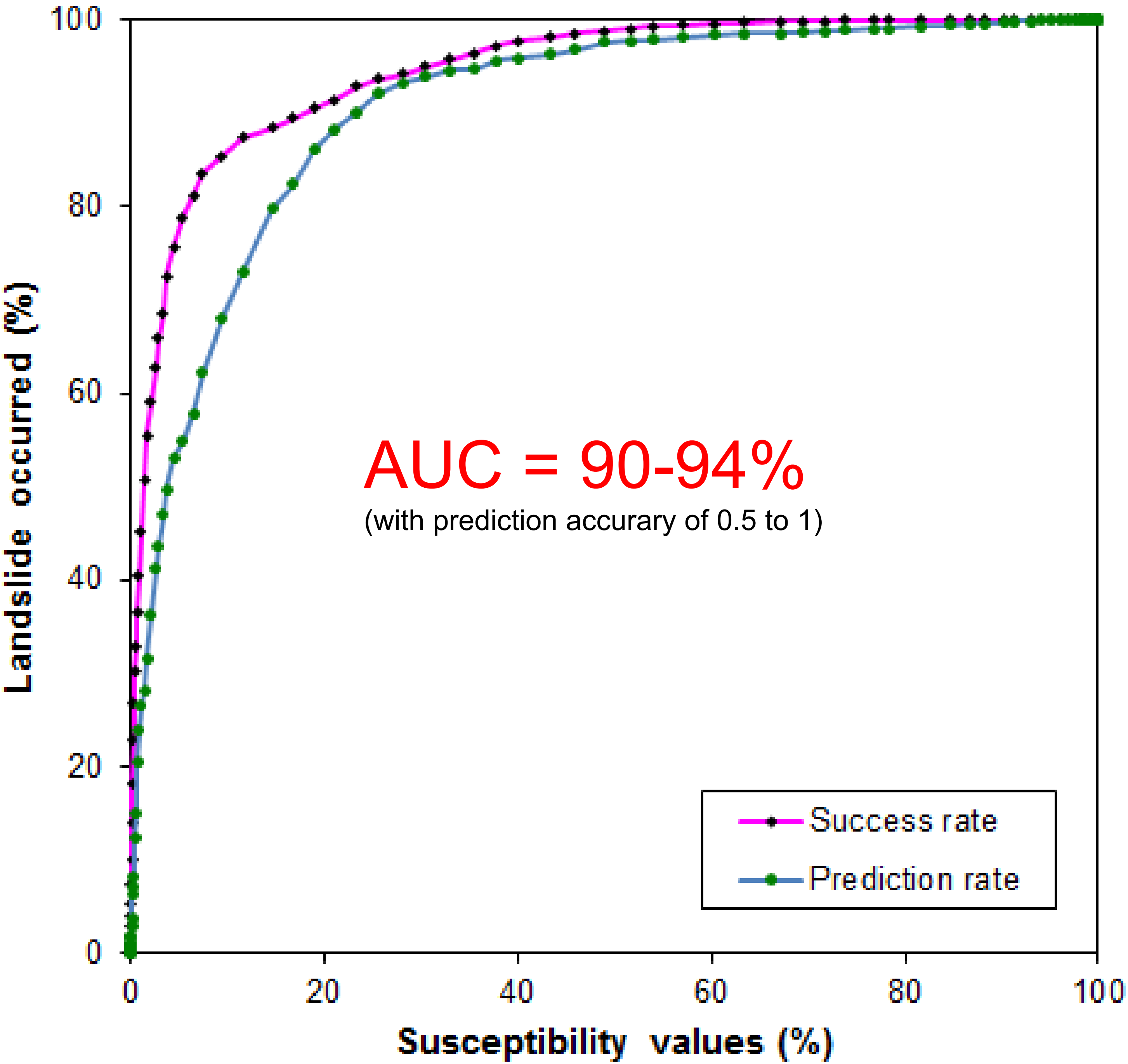
Intercept

Regression value

Present = 1
Absent = 0

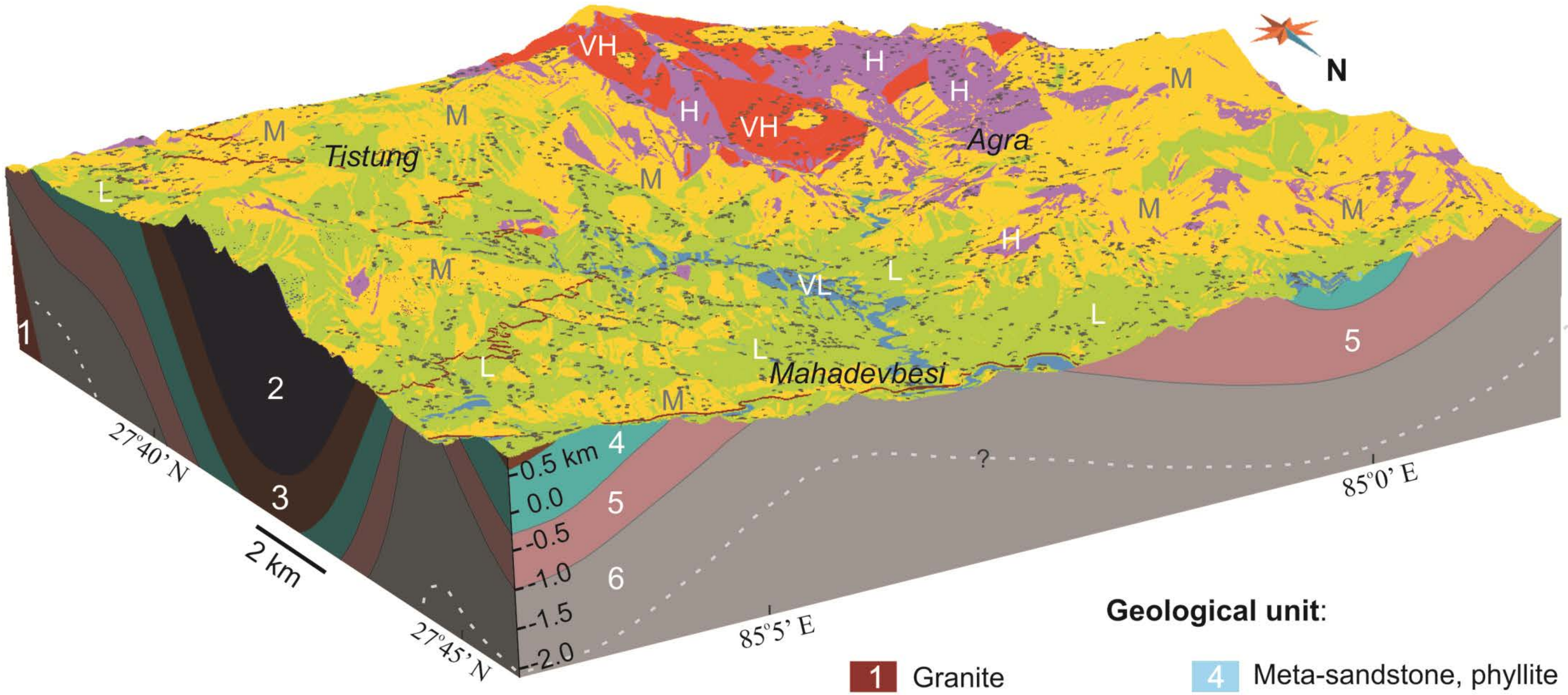
Predicted Landslide Hazard/suceptibility Map





Landslide occurred (%)
0
20
40
60
80
100
0
20
40
60
80
100
Susceptibility values (%)
AUC = 90-94%
(with prediction accurary of 0.5 to 1)
Success rate
Prediction rate

Integration of 3D geomodel & Landslide hazard/suceptibility



Geological unit:

1 Granite
2 Limestone
3 Calc. shale or slate
4 Meta-sandstone, phyllite
5 Marble, schist
6 Quartzite, schist

Landslide hazard:

VH Very High | H High | M Medium | L Low | VL Very Low

Feature: Road · Buidlings

CONCLUDING REMARKS

- Implicit approach of **"sparse data"** modelling quite illustrative to compute geologic-boundary surfaces.
- **Statistical modelling** of landslide hazard is particularly suited in regional terrain of central Nepal.
- **3D geomodel and landslide hazard** has provided interactive evaluation of integrated scenarios.


Thank you very much !!!