Relationships among landslides, slope geometry, and river steepness

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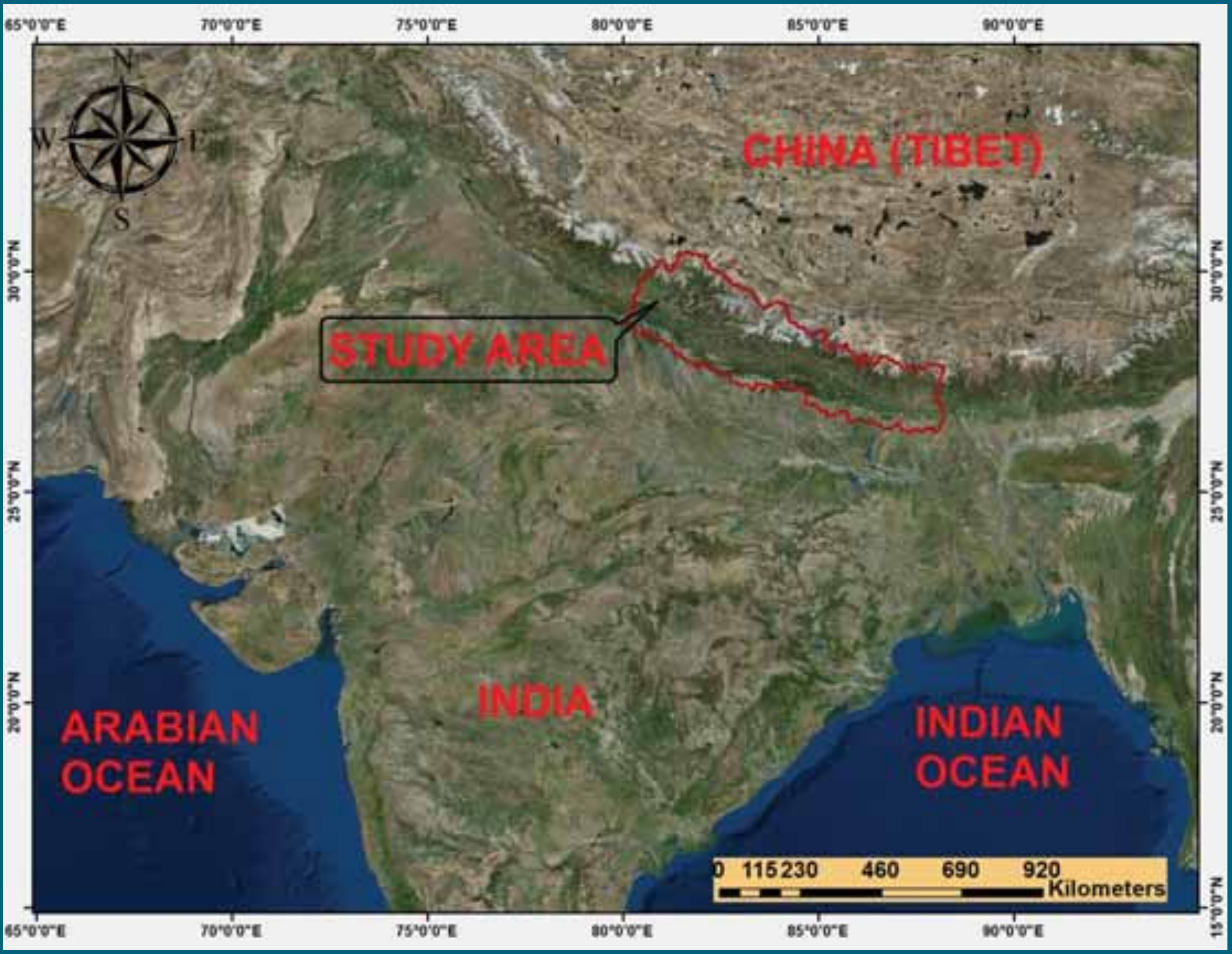
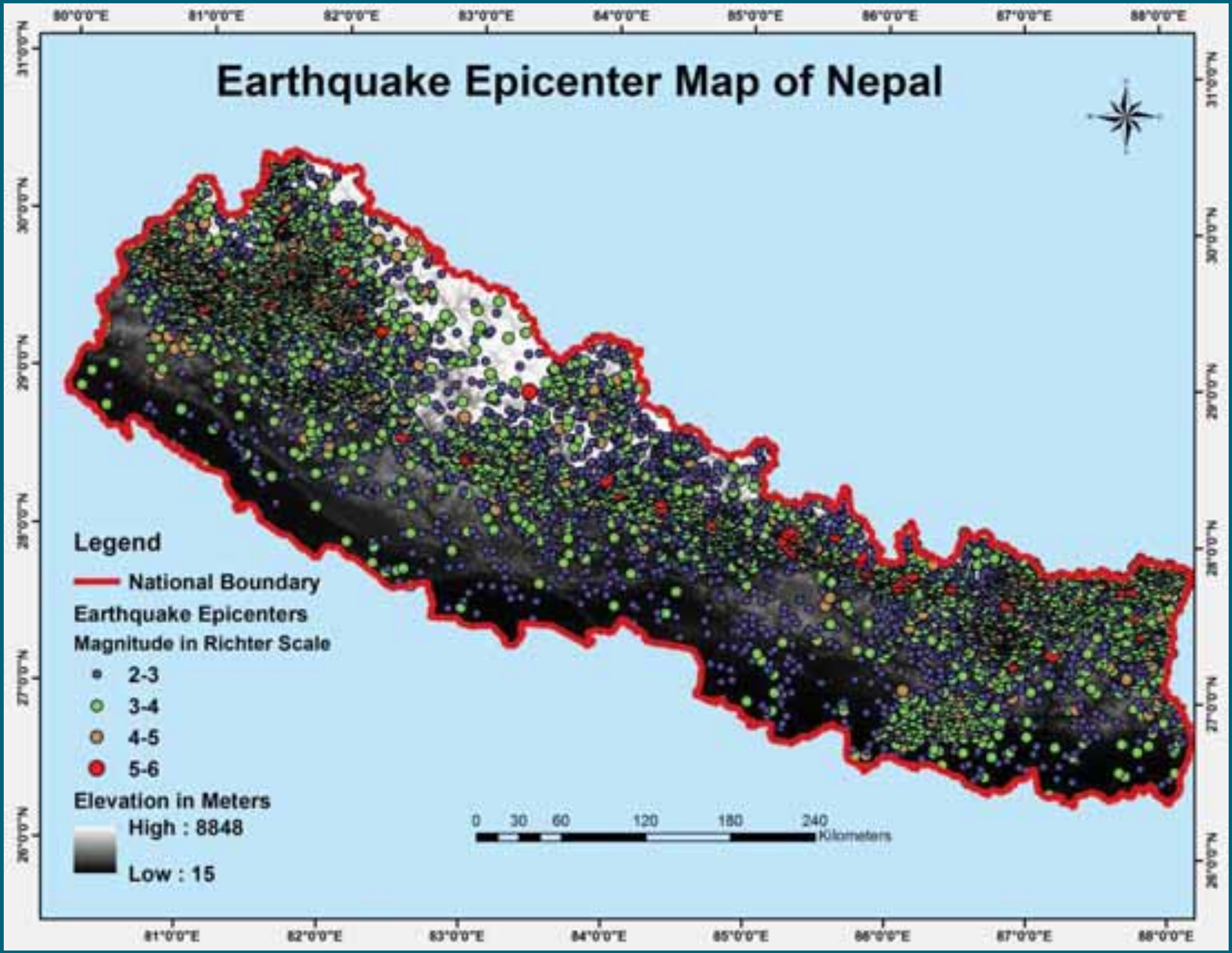
Introduction

- Landslide activity in Himalayan region is controlled by a complex interaction among geological structures, earthquakes, geomorphological, meteorological, and hydrological factors.
- **Landslides triggered by the 8 October 2005 Kashmir earthquake (Lewis et al., 2007).**
- **The catastrophic landslide of 16 July 2001 in Phata Byung area, Rudraprayag District, Garhwal Himalaya, India (Naithani et al., 2002).**
- **The relationship between geology and rock weathering on the rock instability along Mugling–Narayanghat road corridor, Central Nepal Himalaya (Regmi et al., 2013).**

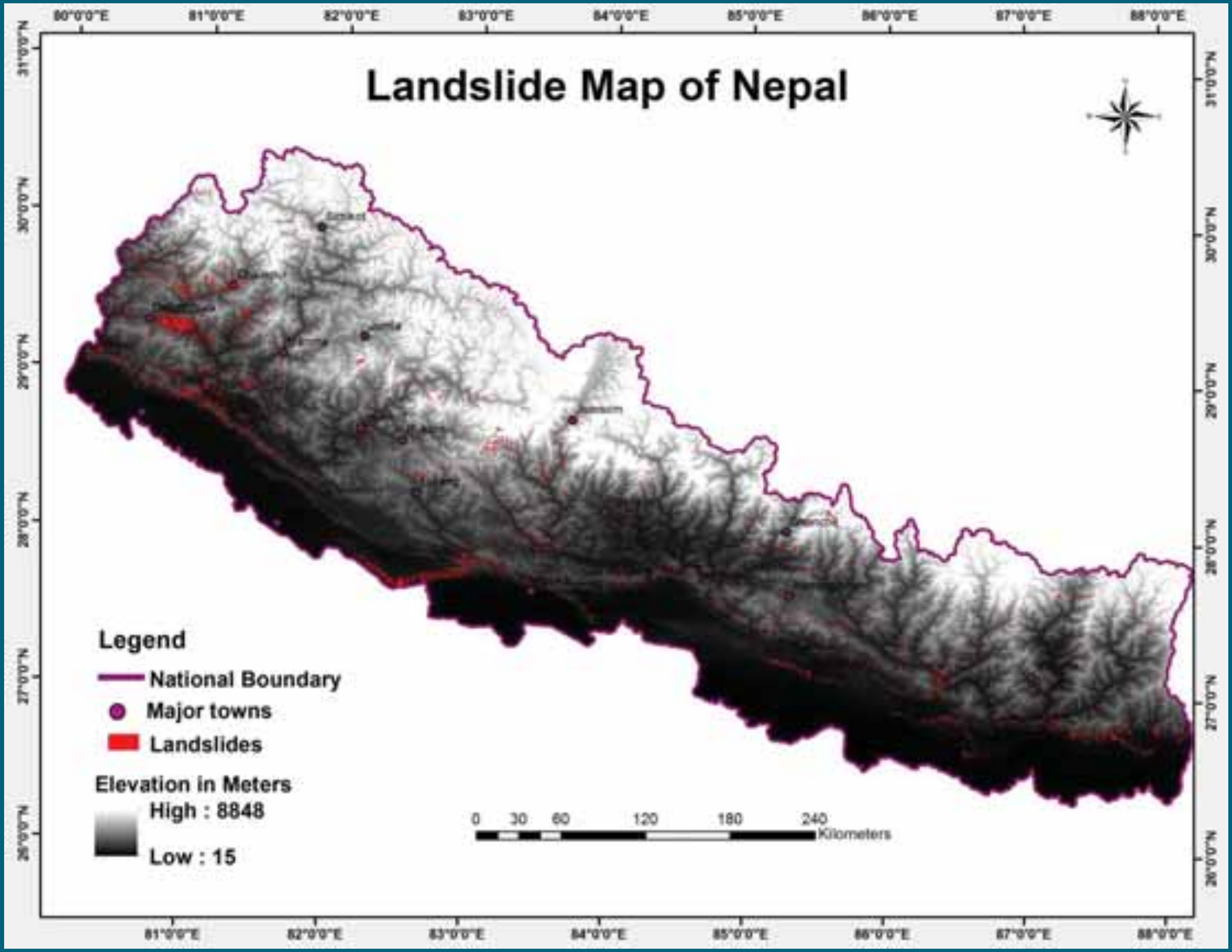
- The objective of this study is to understand the relationships of some of those factors with existing landslides in geologically, and geomorphologically, least explored far west Nepal using the following methods.
- Spatial analysis.
- Geometric alignment between topography and the geologic bedding planes.
- Fluvial knick zones.
- Quaternary dating of deformed terraces.



65°0'0"E
70°0'0"E
75°0'0"E
80°0'0"E
85°0'0"E
90°0'0"E
30°0'0"N
25°0'0"N
20°0'0"N
15°0'0"N
N
S
W
E
CHINA (TIBET)
STUDY AREA
INDIA
ARABIAN OCEAN
INDIAN OCEAN
0 115 230 460 690 920
Kilometers



Earthquake Epicenter Map of Nepal
Legend
National Boundary
Earthquake Epicenters
Magnitude in Richter Scale
2-3
3-4
4-5
5-6
Elevation in Meters
High : 8848
Low : 15
0 30 60 120 180 240
Kilometers
81°0'0"E
82°0'0"E
83°0'0"E
84°0'0"E
85°0'0"E
86°0'0"E
87°0'0"E
88°0'0"E



Landslide Map of Nepal
Legend
National Boundary
Major towns
Landslides
Elevation in Meters
High : 8848
Low : 15
0 30 60 120 180 240
Kilometers

Methods

&

Results

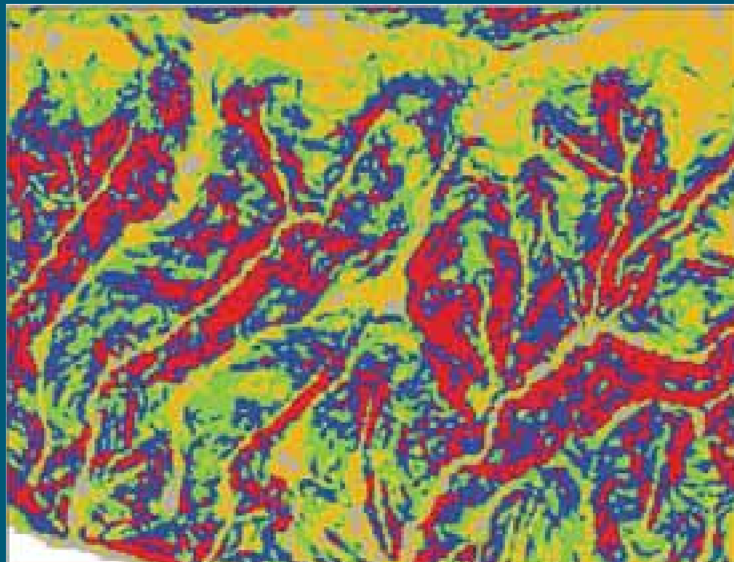
Landslide Inventory

Digital Topographical data

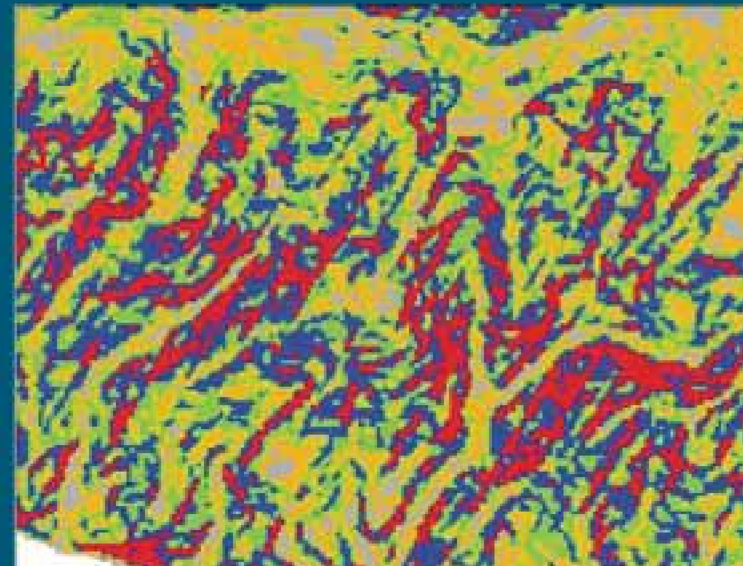
DEM from Digitized topo map

ASTER DEM

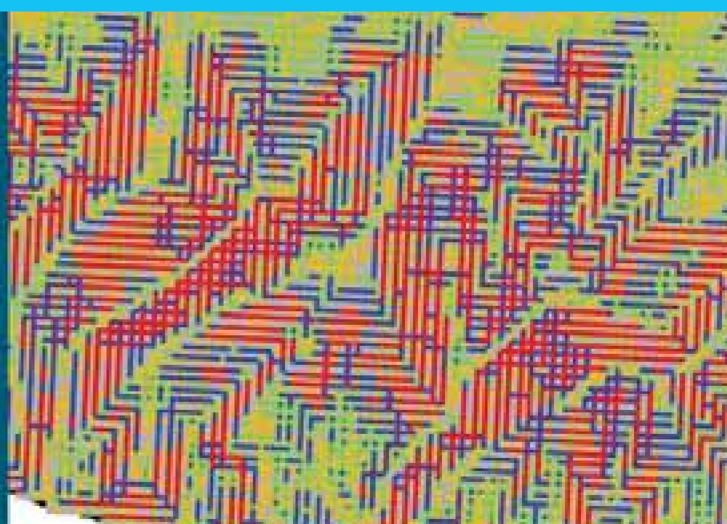
SRTM DEM



Slope map from digitized contours

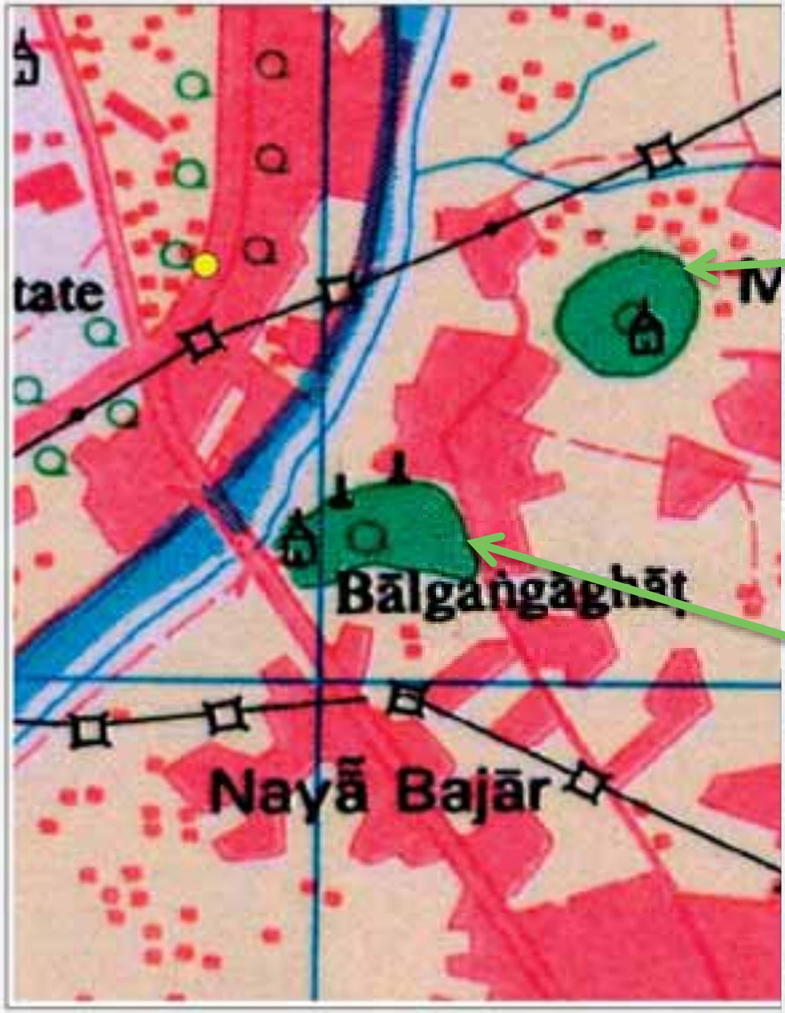


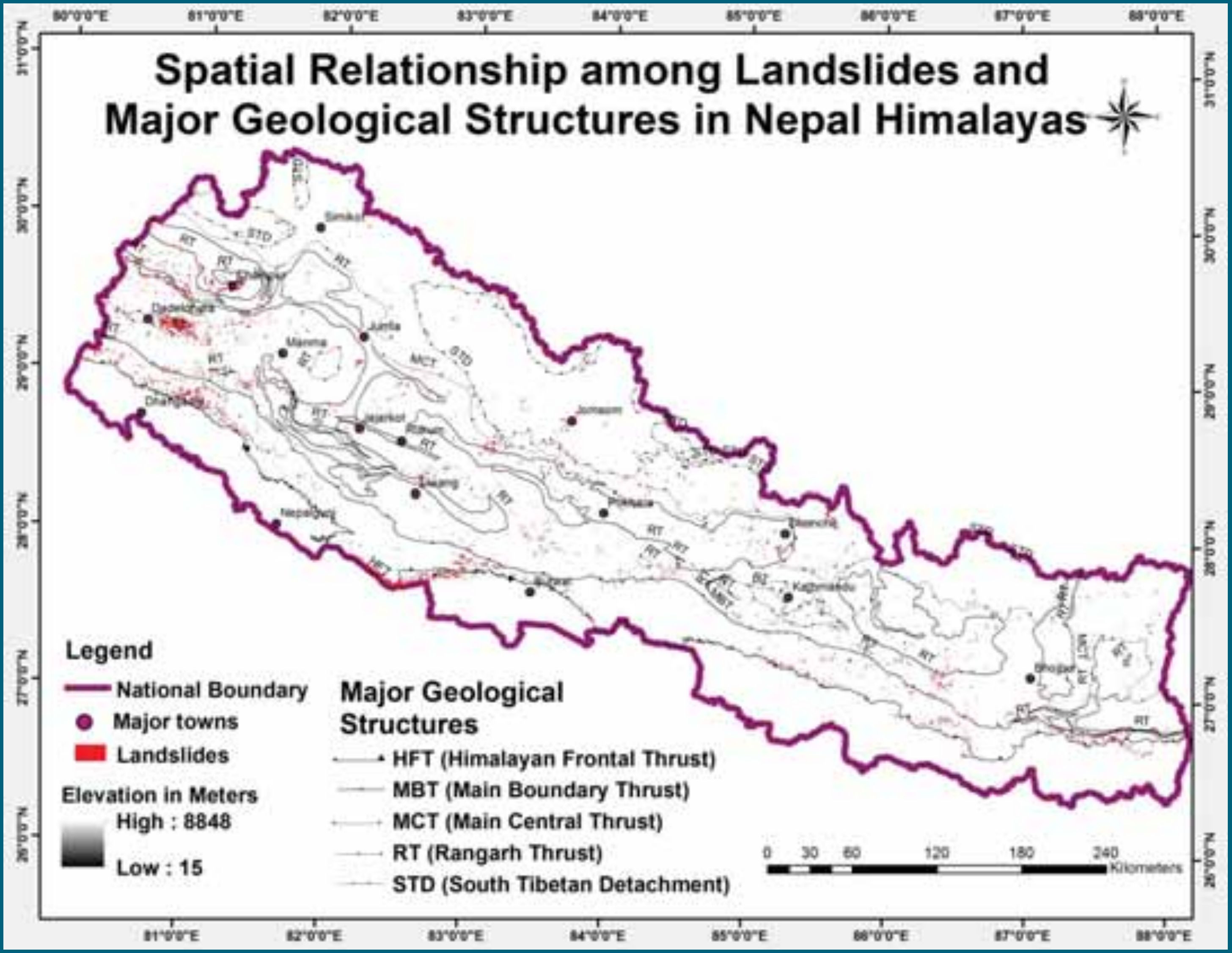
Slope map from ASTER DEM (29 mtrs)

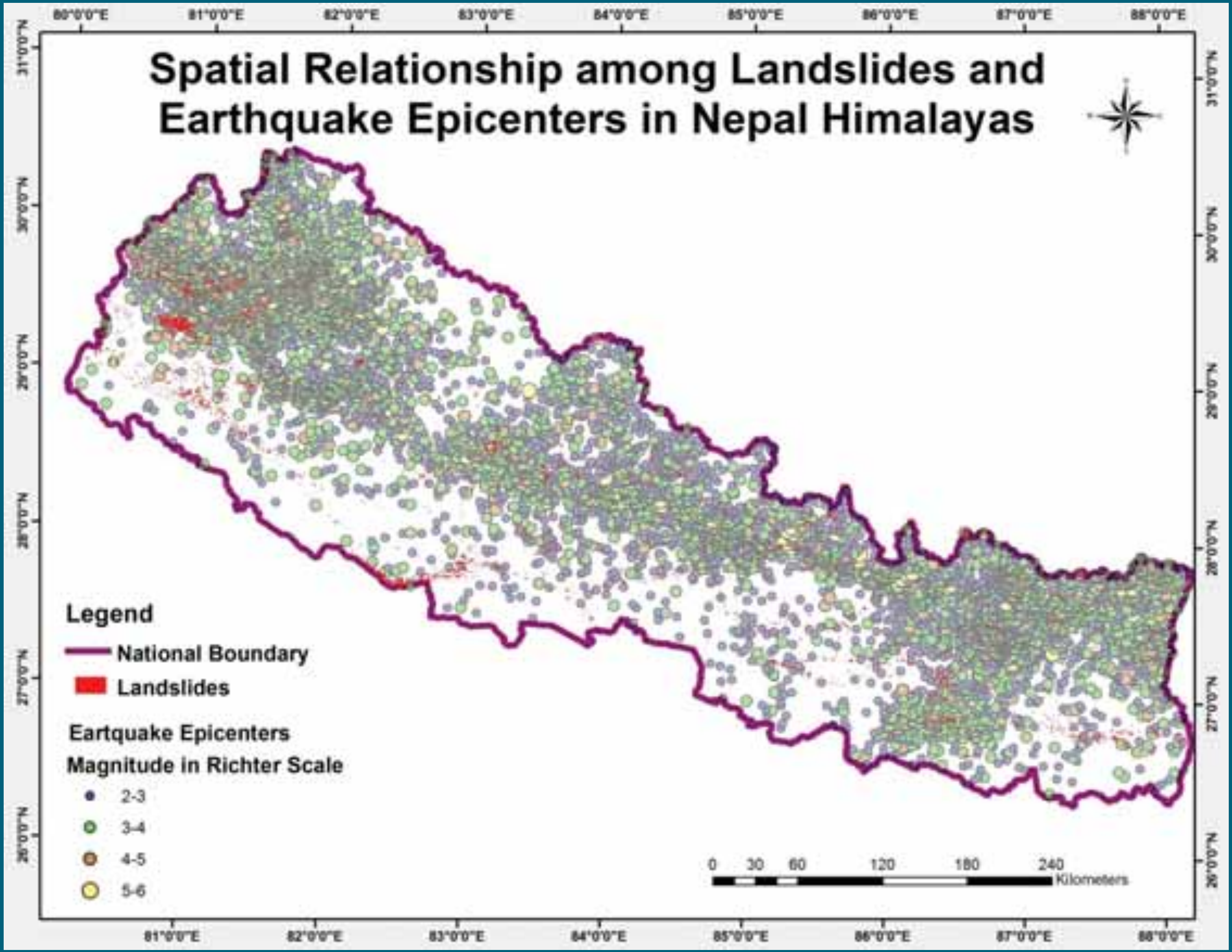


Slope map from SRTM DEM (3arc sec)

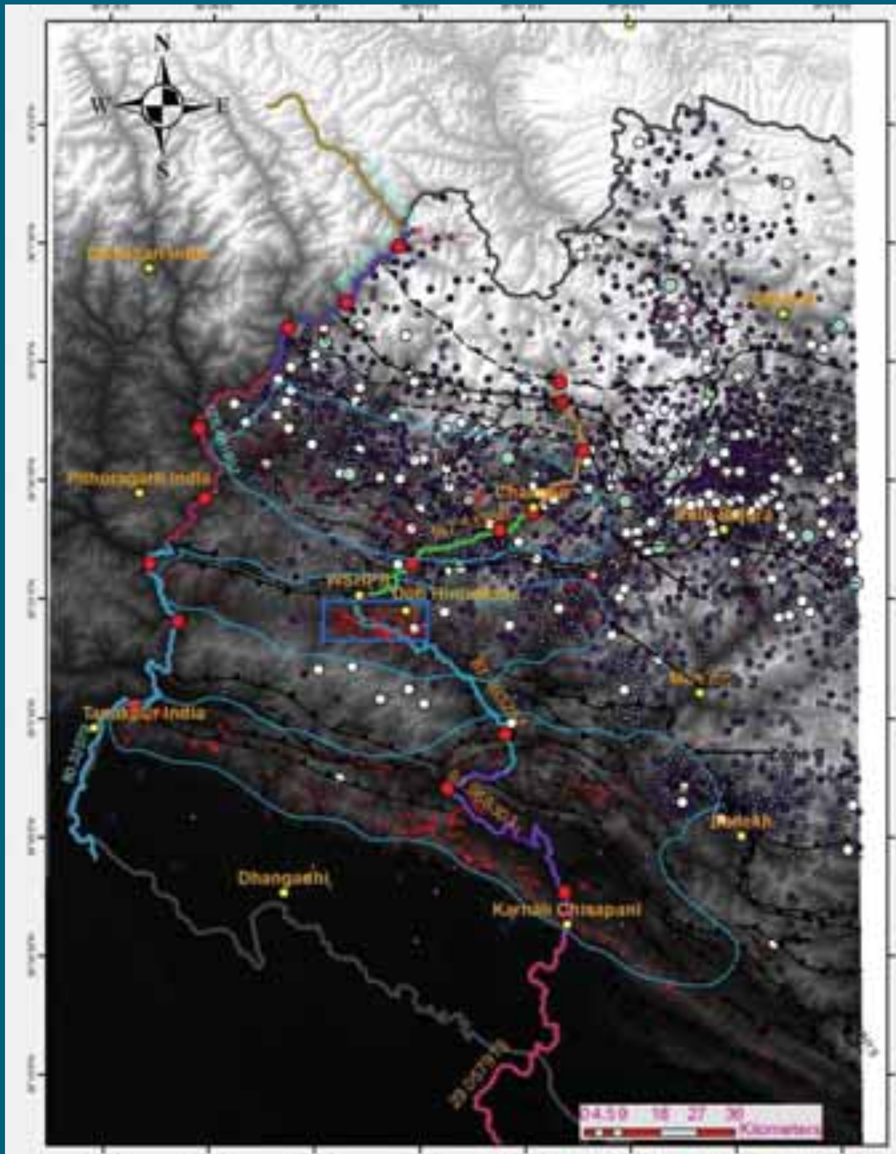
Spatial Analysis

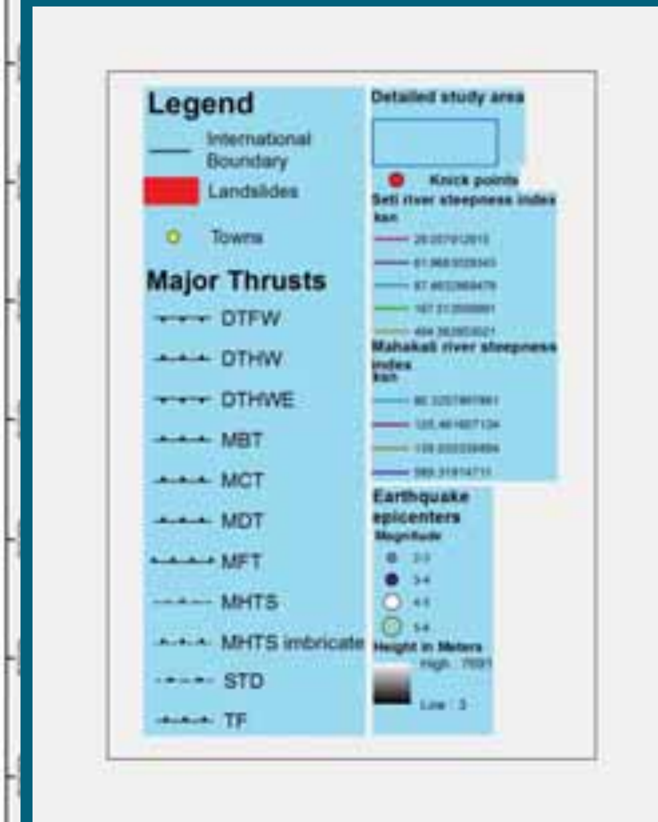

tate
Bālgaṅgaghāṭ
Nayā Bajār


Spatial Relationship among Landslides and
Major Geological Structures in Nepal Himalayas
Legend
National Boundary
Major towns
Landslides
Elevation in Meters
High : 8848
Low : 15
Major Geological Structures
HFT (Himalayan Frontal Thrust)
MBT (Main Boundary Thrust)
MCT (Main Central Thrust)
RT (Rangarh Thrust)
STD (South Tibetan Detachment)
0 30 60 120 180 240
Kilometers
81°0'0"E
82°0'0"E
83°0'0"E
84°0'0"E
85°0'0"E
86°0'0"E
87°0'0"E
88°0'0"E
Kathmandu
Pokhara
Jomsom
Jumla
Simikot
Nepalgunj
Butwal
Bhojpur
Dhangadhi
Dadeldhura
RT
MCT
STD
MBT



Spatial Relationship among Landslides and Earthquake Epicenters in Nepal Himalayas
Legend
National Boundary
Landslides
Eartquake Epicenters
Magnitude in Richter Scale
2-3
3-4
4-5
5-6
0 30 60 120 180 240 Kilometers
81°0'0"E
82°0'0"E
83°0'0"E
84°0'0"E
85°0'0"E
86°0'0"E
87°0'0"E
88°0'0"E


N
S
W
E
Pithoragarh India
Tanakpur India
Dhangadhi
Karnali Chisapani
Kilometers


Legend
International Boundary
Landslides
Towns
Major Thrusts
DTFW
DTHW
DTHWE
MBT
MCT
MDT
MFT
MHTS
MHTS imbricate
STD
TF
Detailed study area
Knick points
Seti river steepness index ksn
Mahakali river steepness index ksn
Earthquake epicenters
Magnitude
Height in Meters

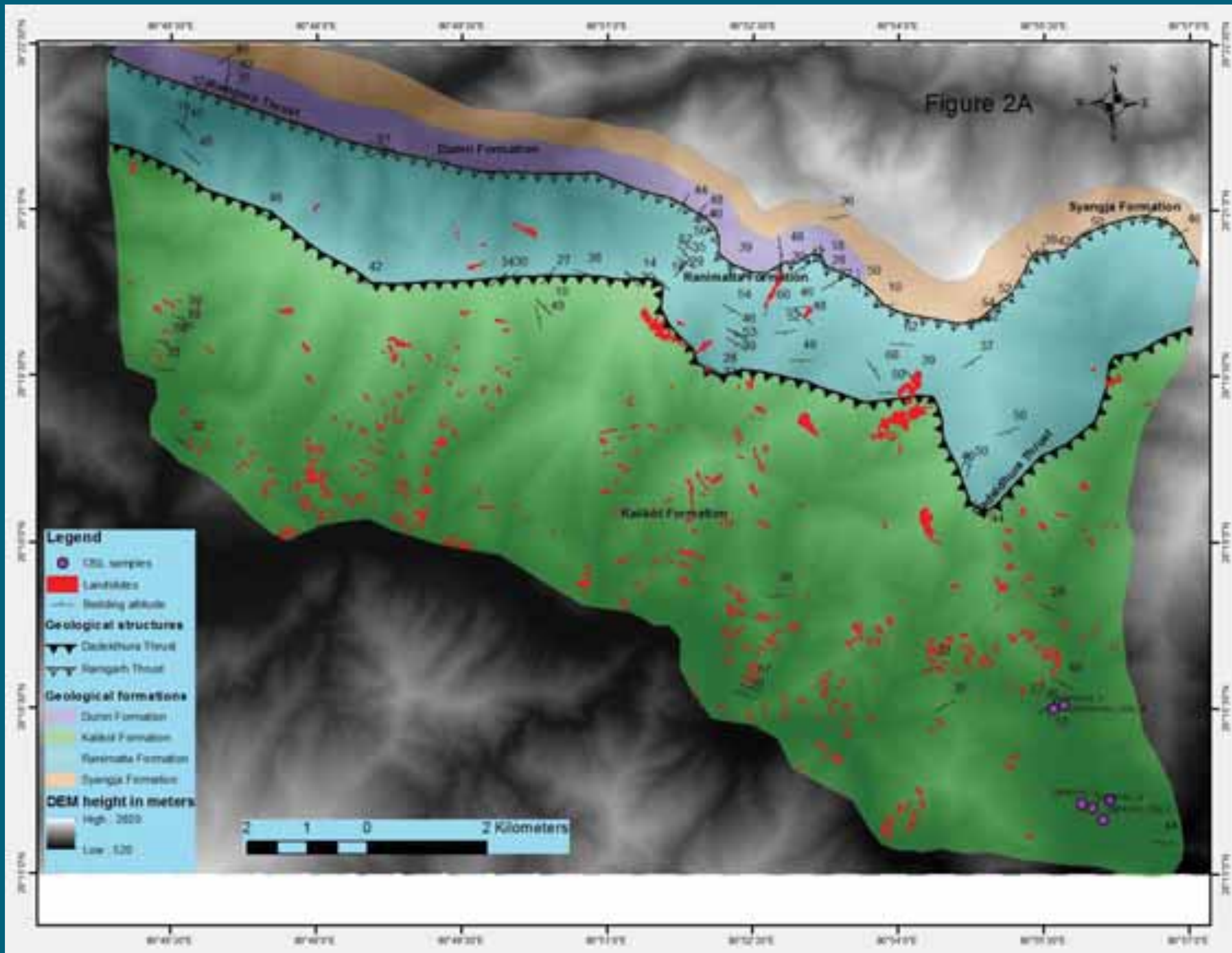
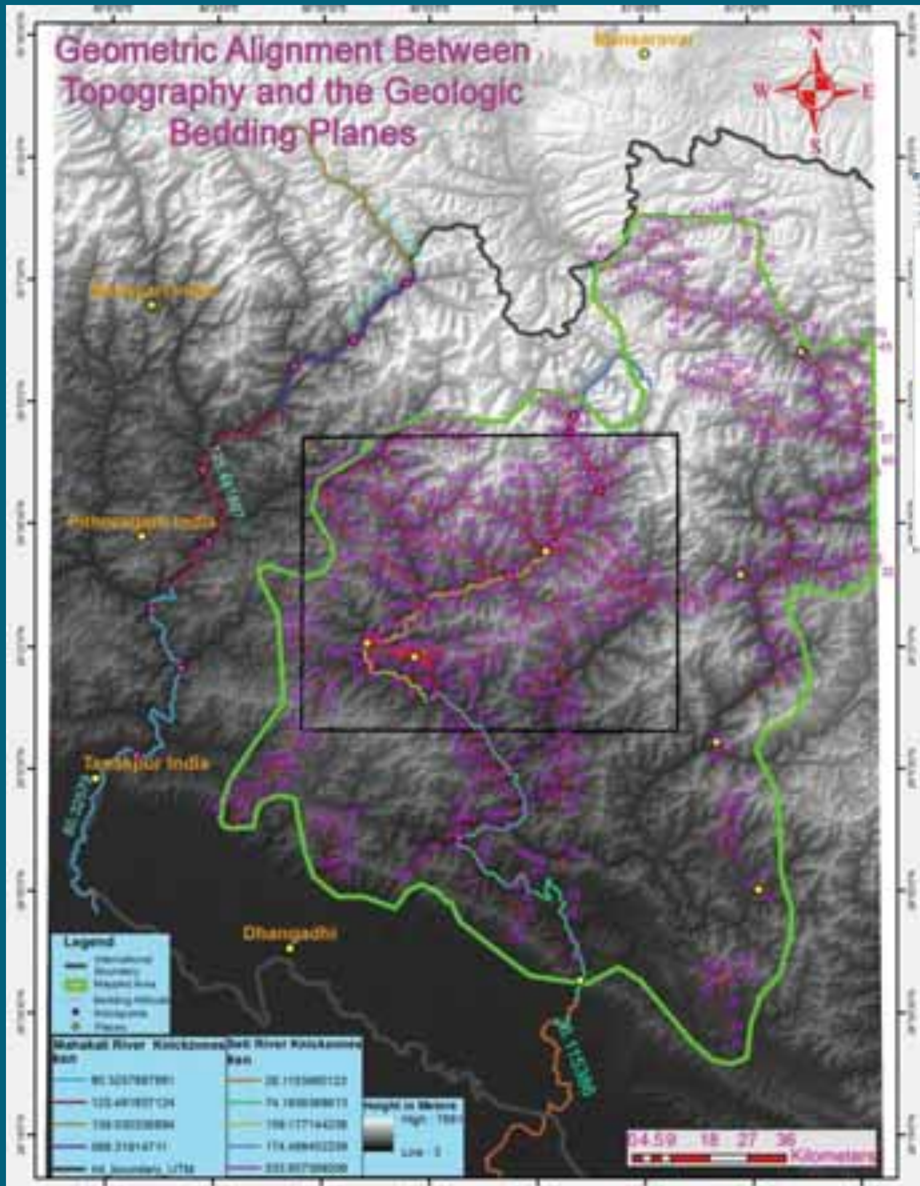
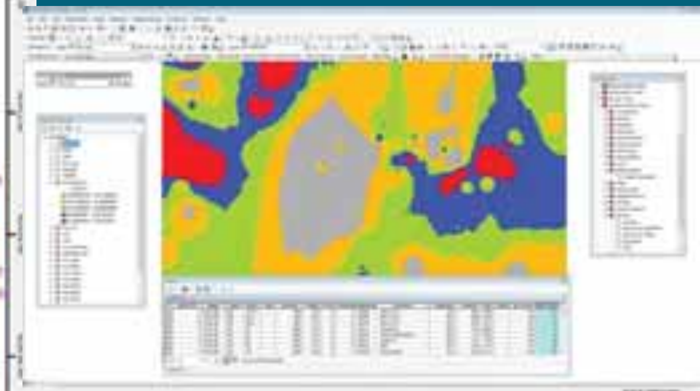


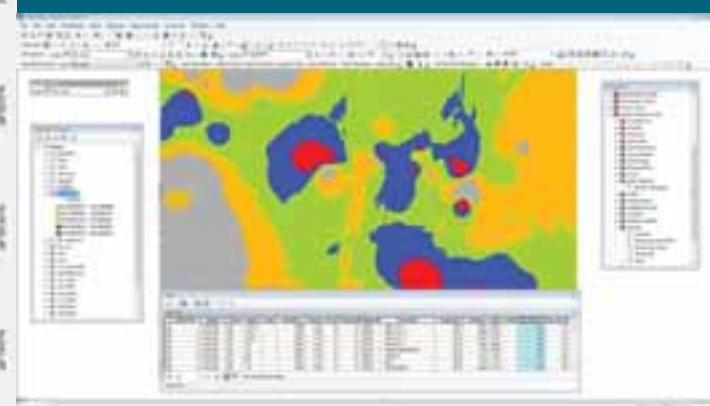
Figure 2A
Legend
Geological structures
Geological formations
DEM height in meters
Dumri Formation
Syangja Formation
Ranimatta Formation
Kalikot Formation
2 1 0 2 Kilometers



Dip amount layer (IDW interpolation)



Dip direction layer (IDW interpolation)



Topography, Geological Structures, and Landslides

Ross K. Meentemeyer, Aaron Moody 1999

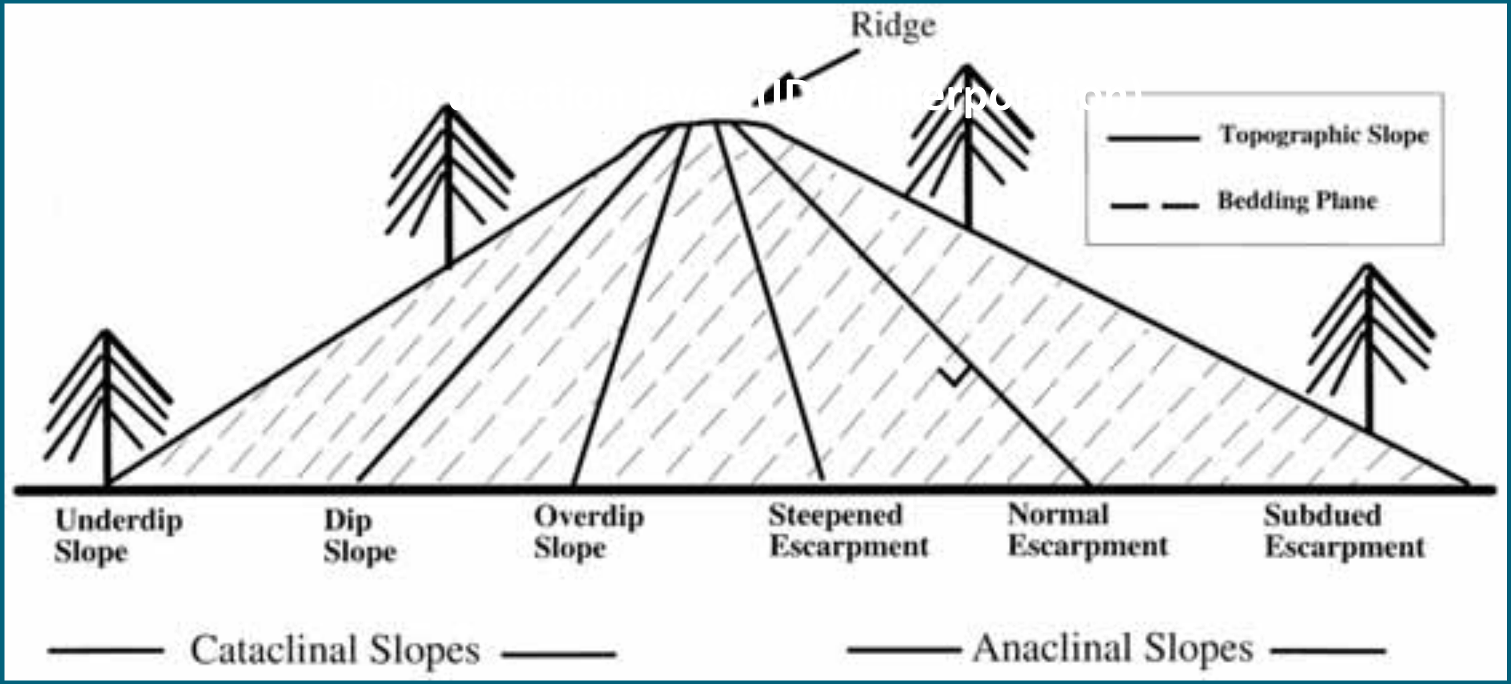
$TOBIA = \cos\theta \cos S + \sin\theta \sin S \cos(\alpha - A)$

θ = Bedding dip amount $0\text{-}90^0$

S = Slope $0\text{-}90^0$

A = Slope aspect $0\text{-}360^0$

α = Bedding dip direction $0\text{-}360^0$



Gamini JAYATHISSA, Dietrich SCHRÖDER and Edwin FECKER 2009

Deviation angle (θ) layer

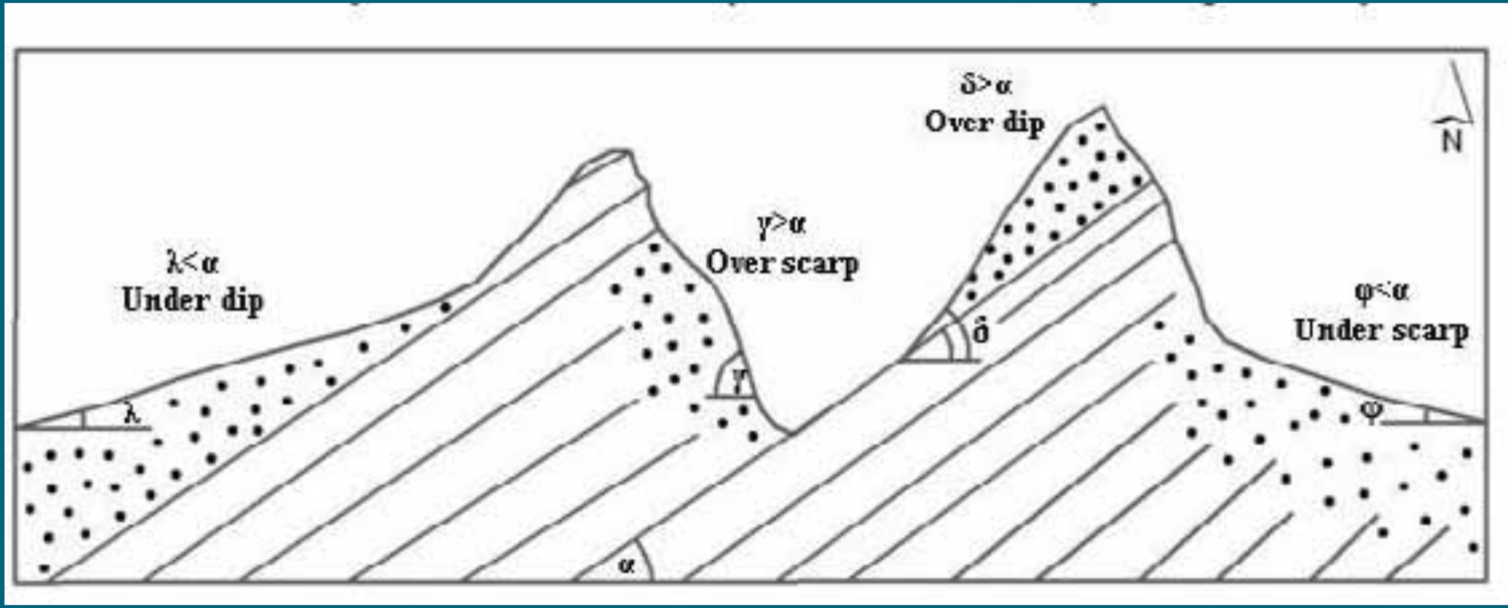
con(abs([Aspect] - [DipDir]) < 180, abs([Aspect] - [DipDir), 360 - abs([Aspect] - [DipDir]))

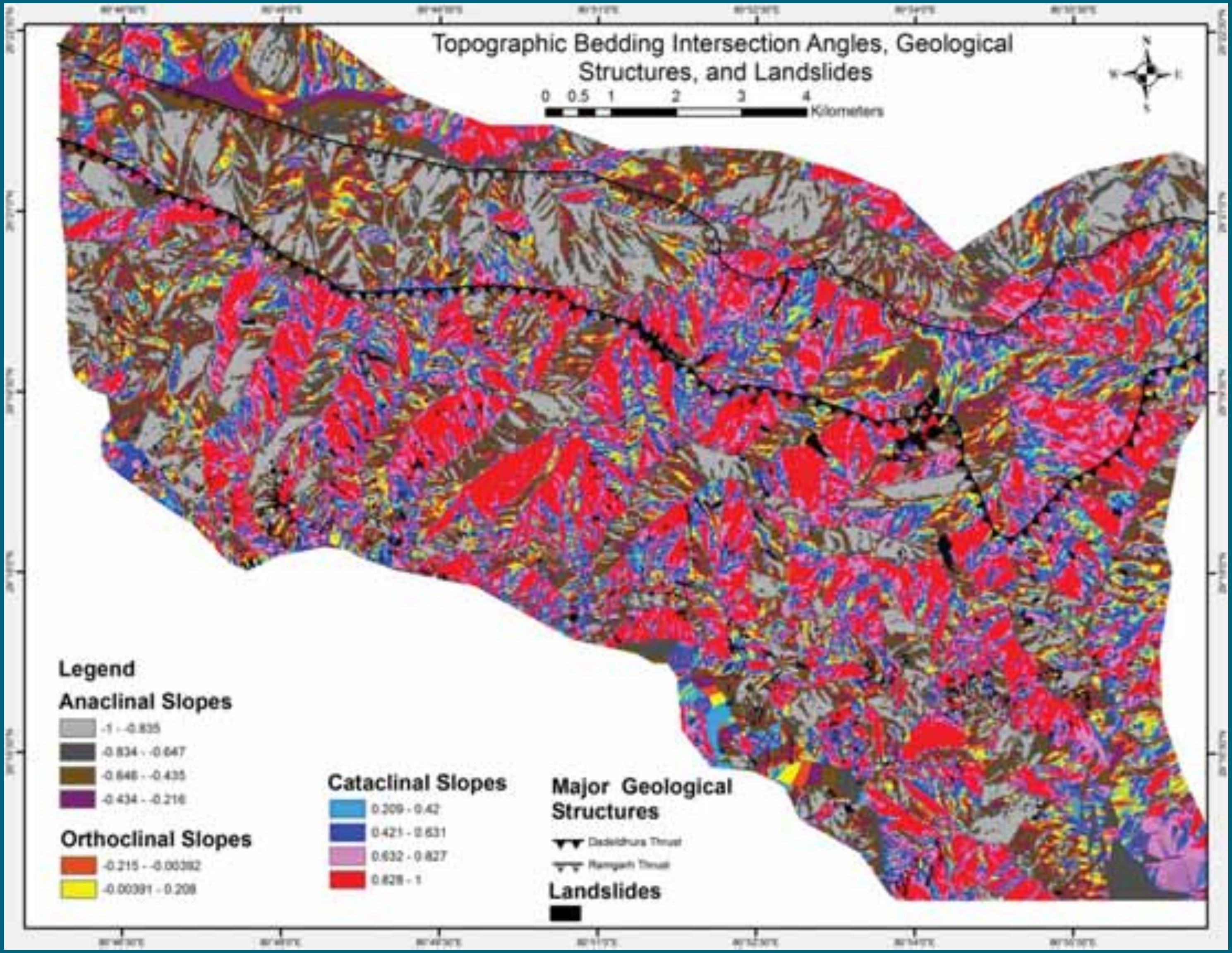
Apparent dip (β) Layer

β = tan-{(tanα) * (cosθ)}

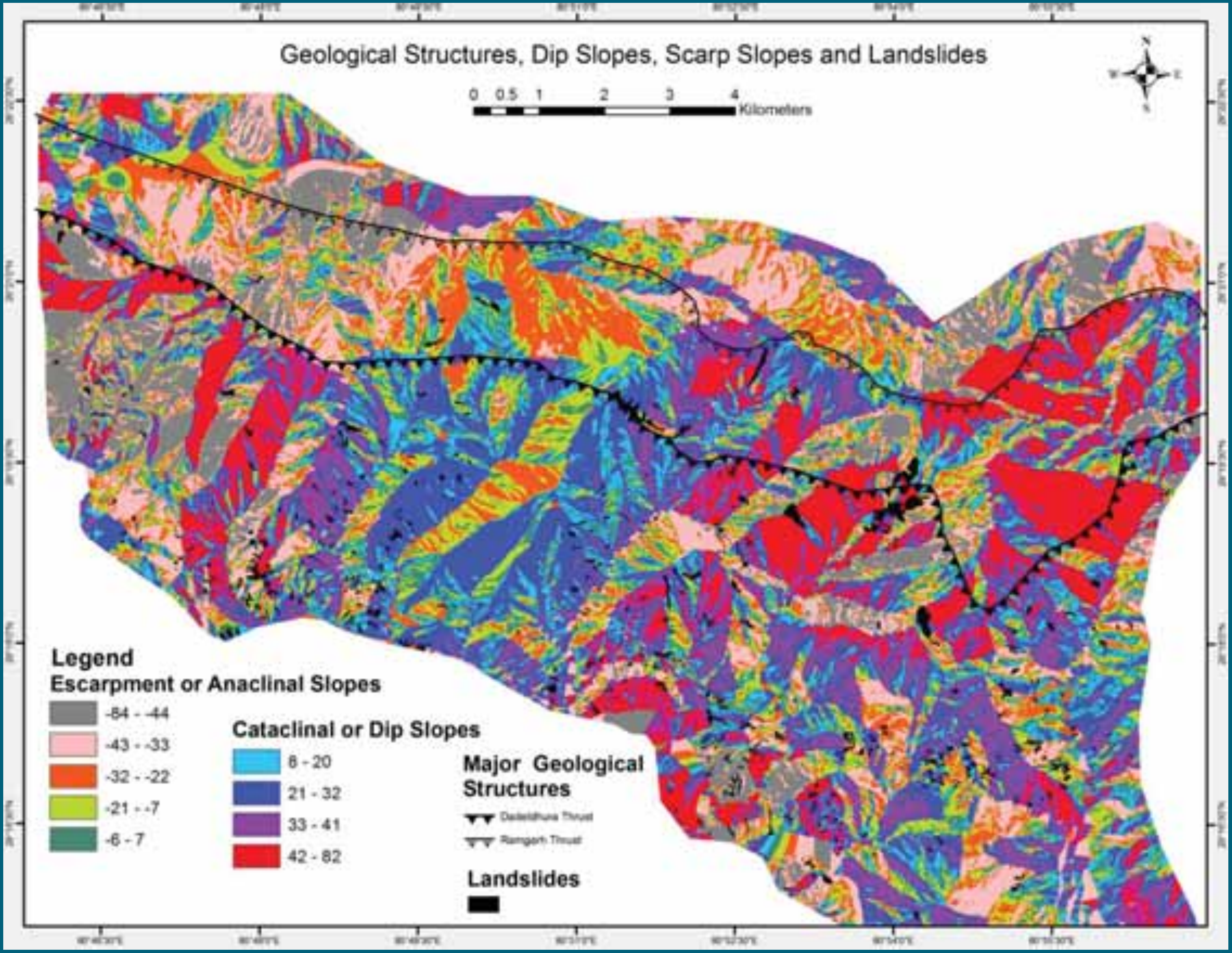
θ = Deviation angle layer

α = Dip angle layer

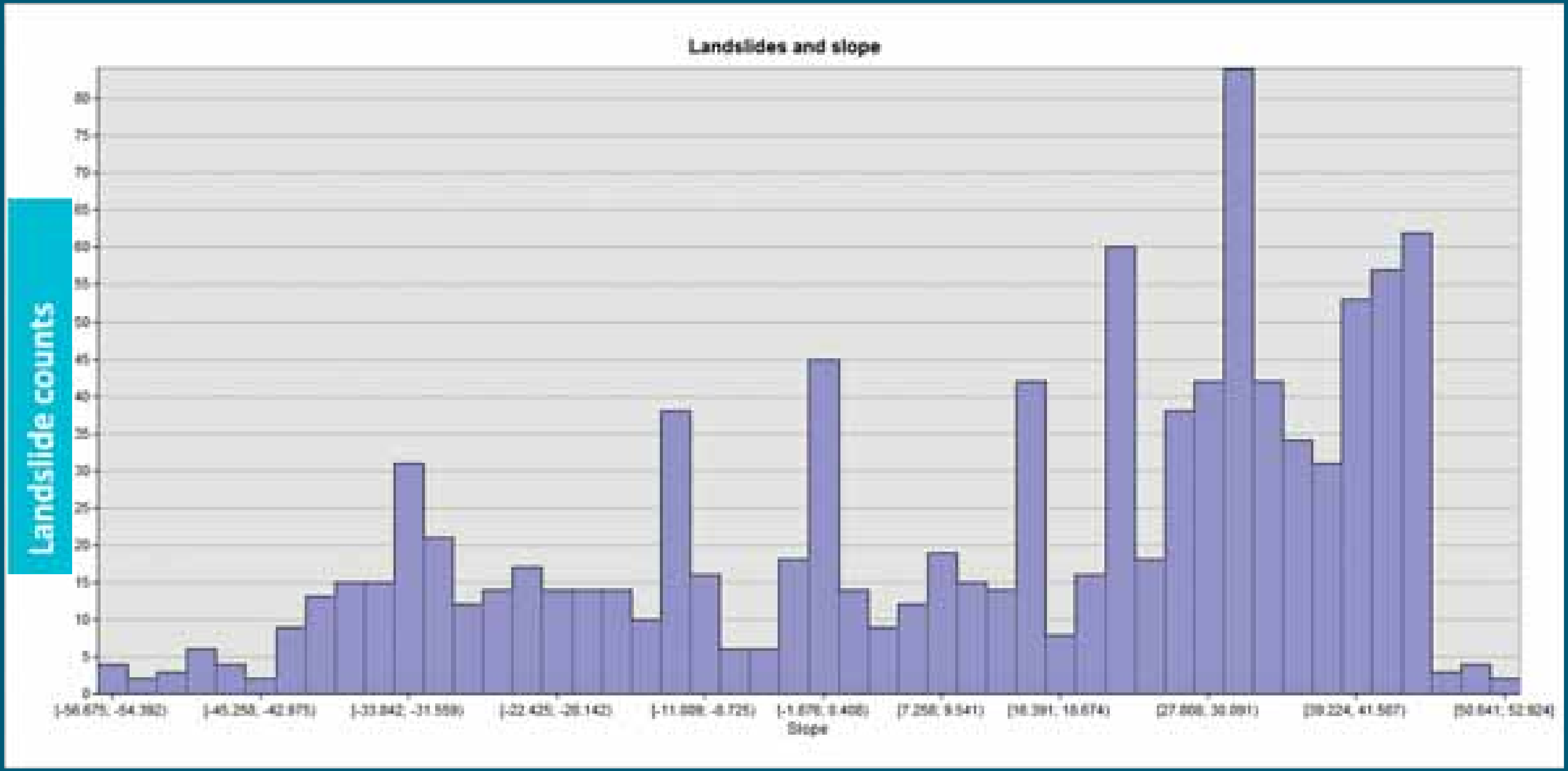




Topographic Bedding Intersection Angles, Geological Structures, and Landslides
0 0.5 1 2 3 4 Kilometers
Legend
Anaclinal Slopes
-1 - -0.835
-0.834 - -0.647
-0.646 - -0.435
-0.434 - -0.216
Orthoclinal Slopes
-0.215 - -0.00392
-0.00391 - 0.208
Cataclinal Slopes
0.209 - 0.42
0.421 - 0.631
0.632 - 0.827
0.828 - 1
Major Geological Structures
Dadeldhura Thrust
Ramgarh Thrust
Landslides


Geological Structures, Dip Slopes, Scarp Slopes and Landslides
0 0.5 1 2 3 4
Kilometers
N
W
E
S
Legend
Escarpment or Anaclinal Slopes
-84 - -44
-43 - -33
-32 - -22
-21 - -7
-6 - 7
Cataclinal or Dip Slopes
8 - 20
21 - 32
33 - 41
42 - 82
Major Geological Structures
Dadeldhura Thrust
Ramgarh Thrust
Landslides

Histogram represents the strong correlation among threshold cataclinal slopes and landslides



-55 -45 -33 -22 -11 0 10 19 30 41 52

Anaclinal slopes | Cataclinal slopes

Fluvial Knick zones, Landslides, and Geological Structures

Snyder et al., 2000; Kirby and Whipple, 2001; Wobus et al., 2006a; Garzanti et al., 2007

According to above authors the geometry of river longitudinal profiles can be characterized by power law function of drainage area and channel gradient as expressed in the following equation:

$S = K_s A^{-\theta}$

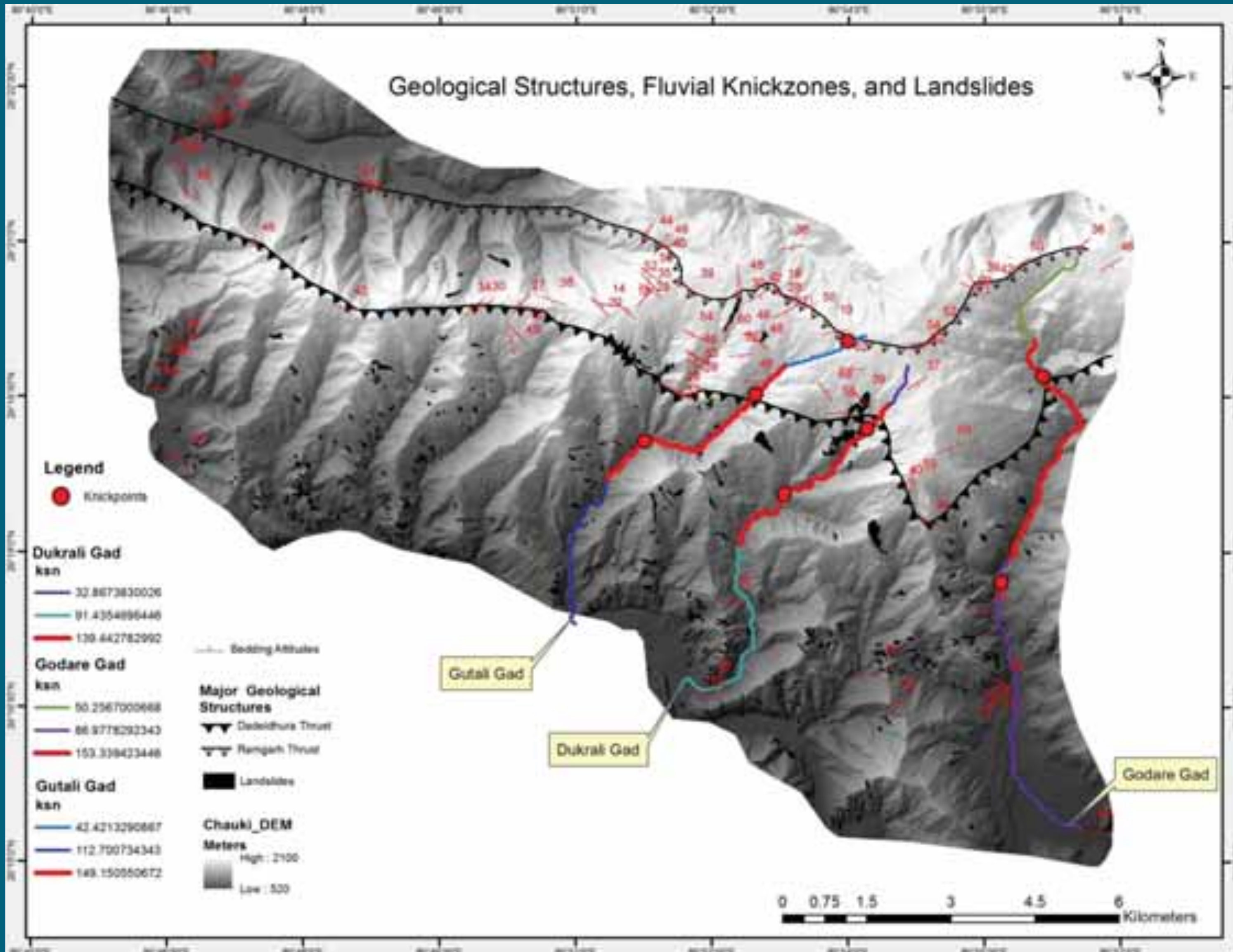
S= Local Channel Slope

K_s=Local Steepness Index

A= Upstream drainage area

θ= Concavity Index

Using our own digitized spatially corrected 20 Meter DTM we have calculated the k_{sn} and θ using an ArcGIS stream profiler toolbar and Matlab scripts acquired from http://www.geomorphtools.org (K. Whipple et al., New tools for quantitative geomorphology: Extraction and interpretation of stream profiles from digital topographic data, 2007,http://www.geomorphtools.org/Tools/StPro/Tutorials/StPro_UserGuidees_Final.pdf, hereinafter referred to asWhipple et al., online report, 2007).


Geological Structures, Fluvial Knickzones, and Landslides
Legend
Knickpoints
Dukrali Gad
ksn
32.8673830026
91.4354896446
139.442782992
Godare Gad
ksn
50.2567000668
86.9778292343
153.339423446
Gutali Gad
ksn
42.4213290867
112.700734343
149.150550672
Bedding Attitudes
Major Geological Structures
Dadeldhura Thrust
Ramgarh Thrust
Landslides
Chauki_DEM
Meters
High : 2100
Low : 520
Gutali Gad
Dukrali Gad
Godare Gad
0 0.75 1.5 3 4.5 6
Kilometers

Conclusion

Gamini JAYATHISSA, Dietrich SCHRÖDER and Edwin FECKER 2009

Conclusion continued

- Landslide is the result of a balance between driving forces and resisting forces. To date Nepal (a least developed country in Asia) does not have a database that allows planners and policy makers to understand this relationship to save lives and property.
- Our team at university of Arizona is trying to help Nepal by developing a GIS based, geological, geomorphological, and topographical database to understand the above relationship.