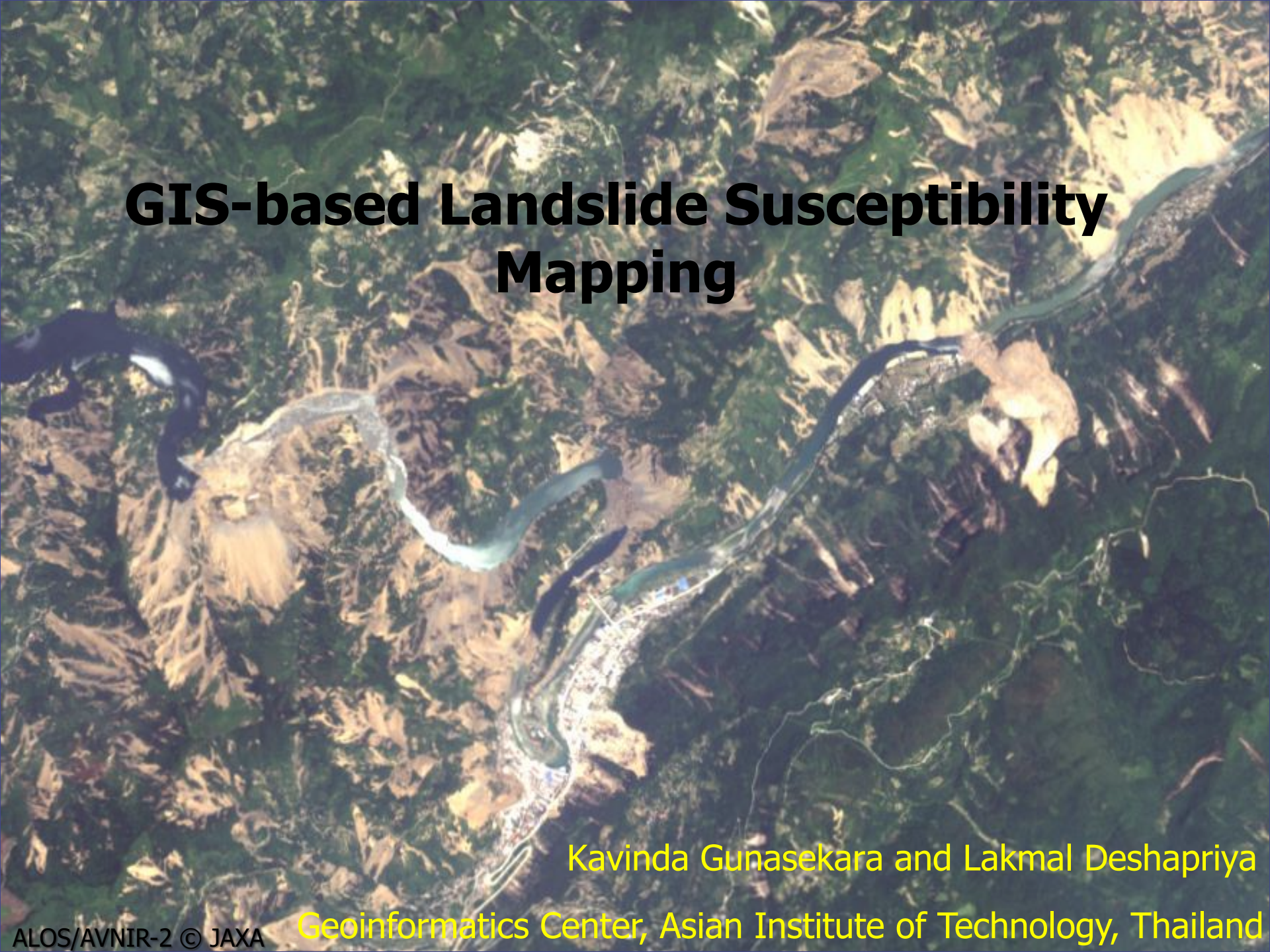


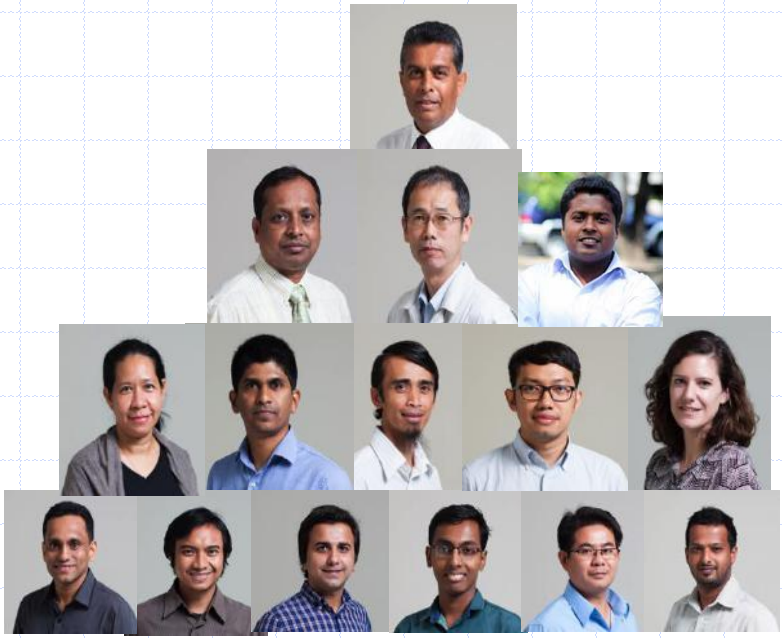
GIS-based Landslide Susceptibility Mapping

Kavinda Gunasekara and Lakmal Deshapriya

Geoinformatics Center, Asian Institute of Technology, Thailand

Geoinformatics Center
Established in 1999

Geoinformatics Center
Established in 1999 (Self Funded)

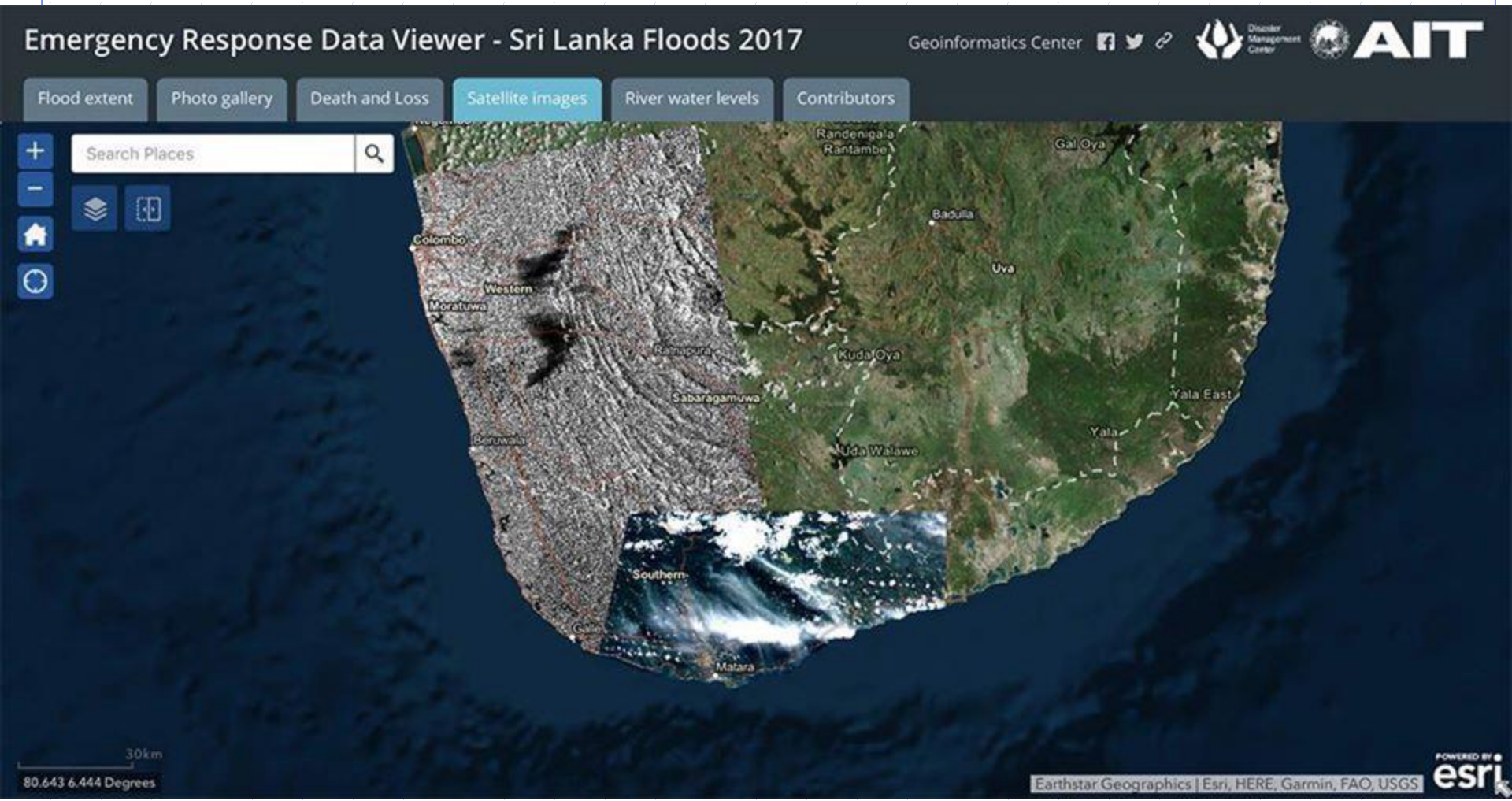


www.geoinfo.ait.ac.th

Activities of the GIC/AIT

- Projects and Consulting Works
- Training Programs, primarily in Asia and the Pacific
- QZSS GPS Monitoring Station and GNSS Research
- Emergency Disaster Response Mapping
  - Rapid Mapping Support for Sentinel Asia & IDC
  - Applied Research (DRR, Poverty, Environment, etc.)
- Exchange Programs: Students, Researchers, Experts ……
- Information Sharing and Publications: Journal, Conference, Reports, Manuals etc.

A Recent Disaster Response Activity



http://arcg.is/2r9Lw5m

Executed Landslide projects

- Sri Lanka
- Indonesia
- Philippines
- Pakistan
- Vietnam
- Lao PDR
- Thailand
- Tajikistan
- India

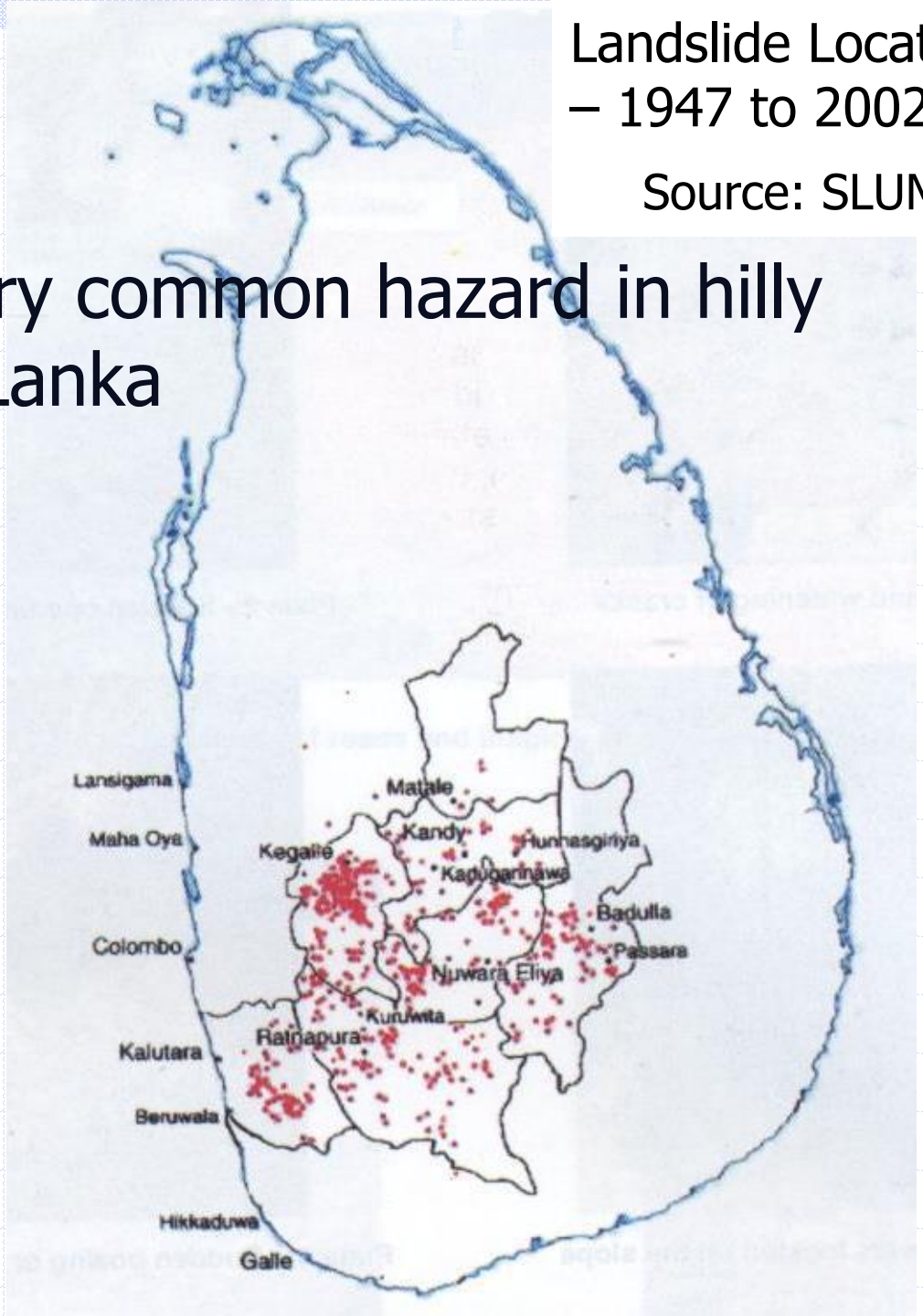
Presentation Content

- Landslide study in Sri Lanka using SINMAP (deterministic modeling)
- A ongoing Project: Statistical modeling

MODELLING OF RAIN TRIGGERED LANDSLIDE USING SINMAP: A CASE STUDY IN RATHNAPURA AREA, SRI LANKA

Introduction

- Landslide is very common hazard in hilly terrains in Sri Lanka



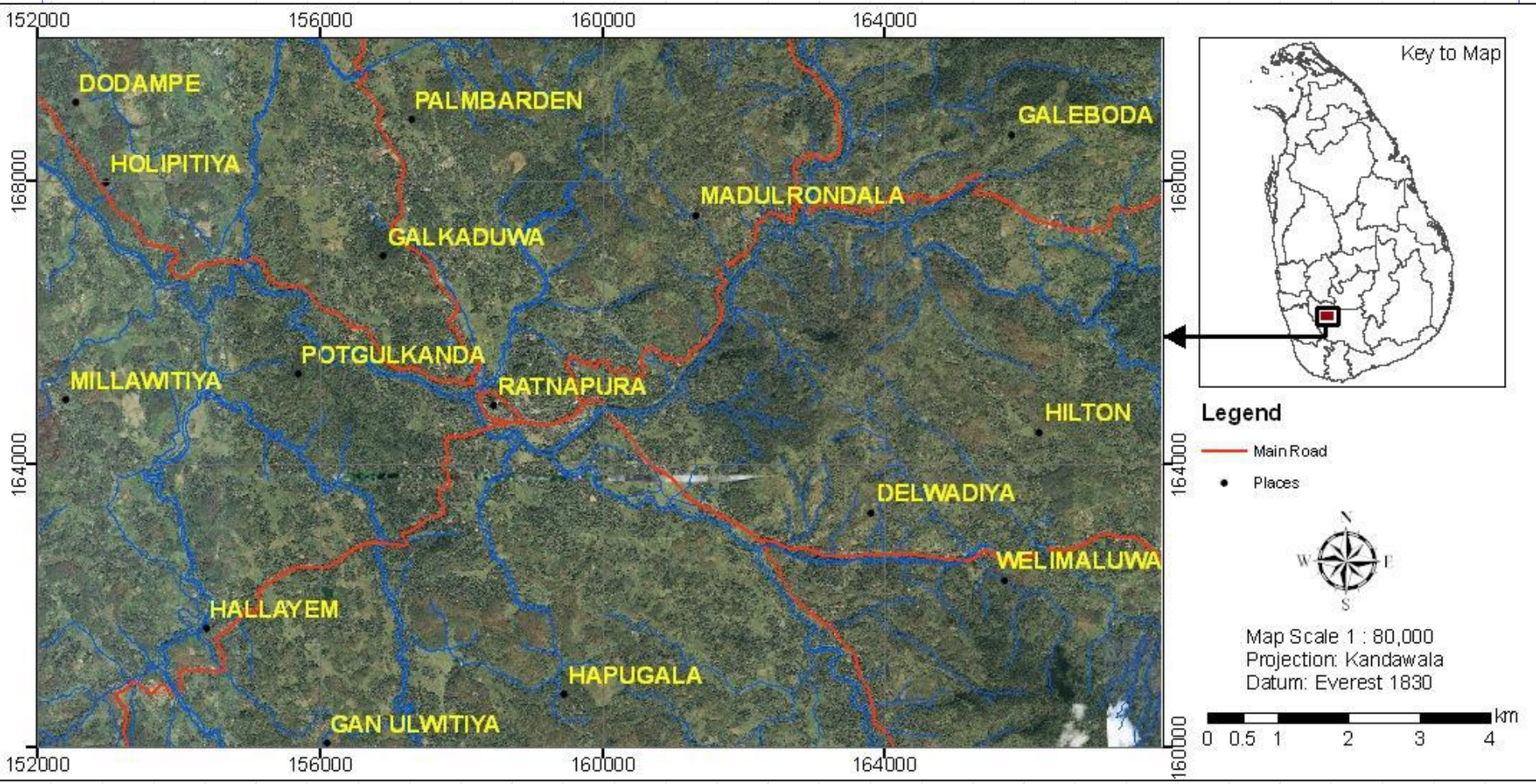
Introduction ... cond.

- Landslide is very common hazard in hilly terrains in Sri Lanka
- Landslide hazard analysis
  - Very costly and time consuming task
  - Requires large number of input parameters
  - Technical knowledge and techniques
- Solution……?
  - RS/GIS based slope stability models
  - GIS is a powerful tool for handling spatial data (topography, geology, rainfall, landuse)

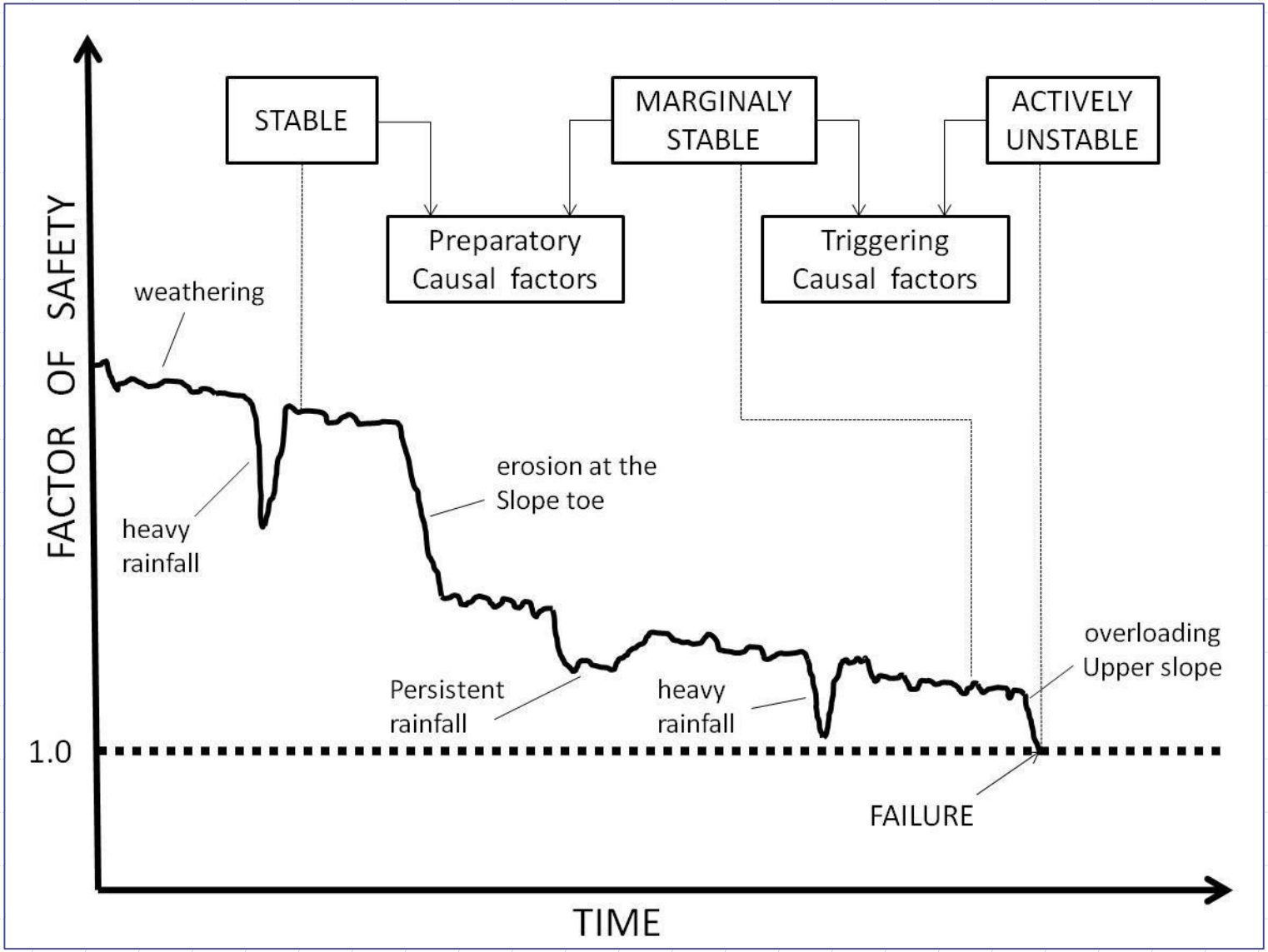
Objectives

- Main objective
  - Study the applicability of GIS based slope stability models
- Specific objectives
  - Landslide hazard map using SINMAP model
  - Comparison with existing NBRO's landslide hazard map
  - Rainfall scenarios with the object of arriving at rainfall threshold for steady state condition

Study area

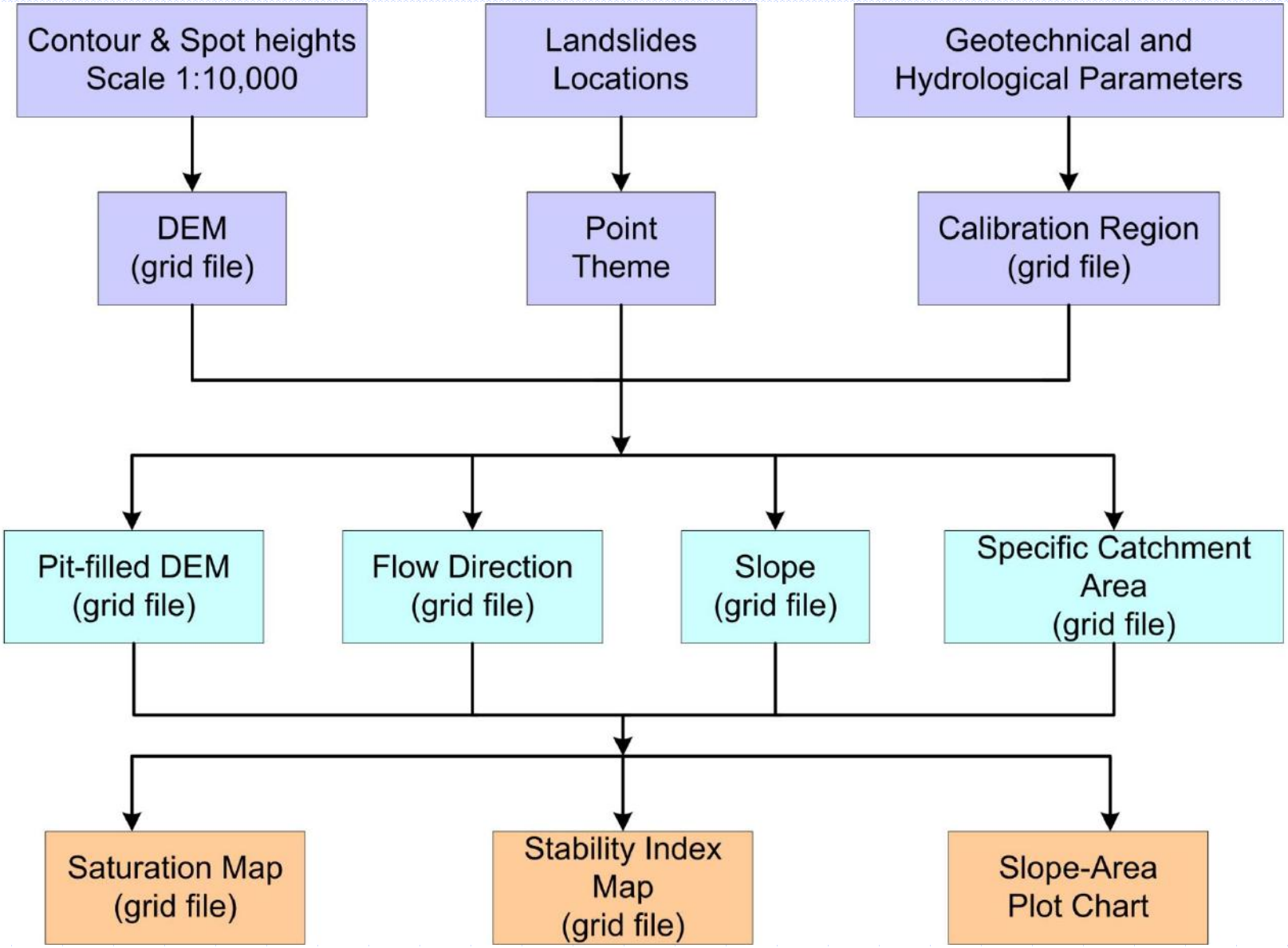

152000
156000
160000
164000
168000
164000
160000
DODAMPE
PALMBARDEN
GALEBODA
HOLIPITIYA
MADULRONDALA
GALKADUWA
POTGULKANDA
MILLAWITIYA
RATNAPURA
HILTON
DELWADIYA
WELIMALUWA
HALLAYEM
HAPUGALA
GAN ULWITIYA
Key to Map
Legend
Main Road
Places
N
W
E
S
Map Scale 1 : 80,000
Projection: Kandawala
Datum: Everest 1830
km
0 0.5 1 2 3 4

Causal Factors



Changes in the factor of safety with time (Popescu, 2005)

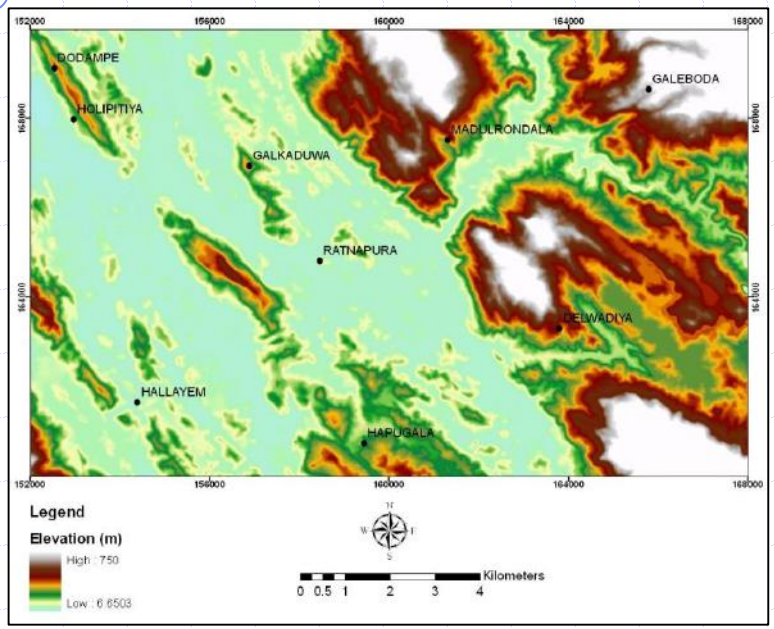
Flow chart - Stability INdex MAPping: SINMAP

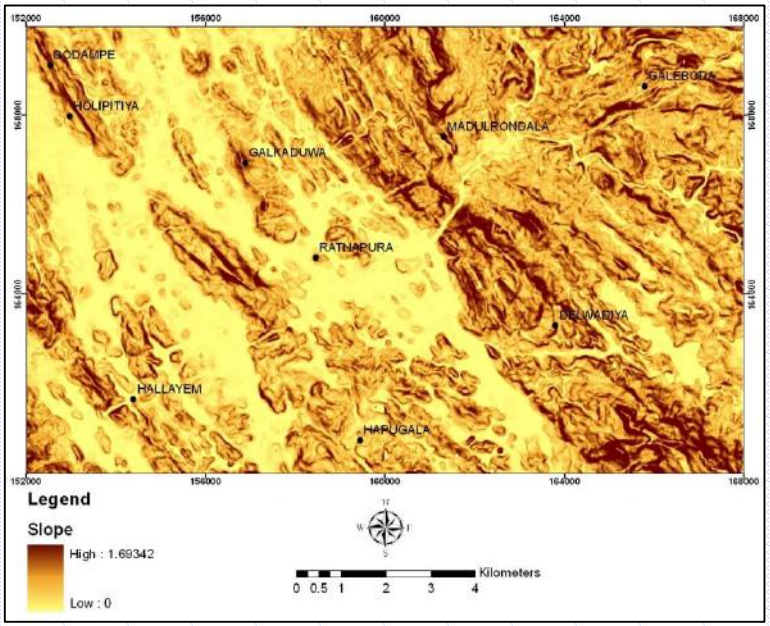


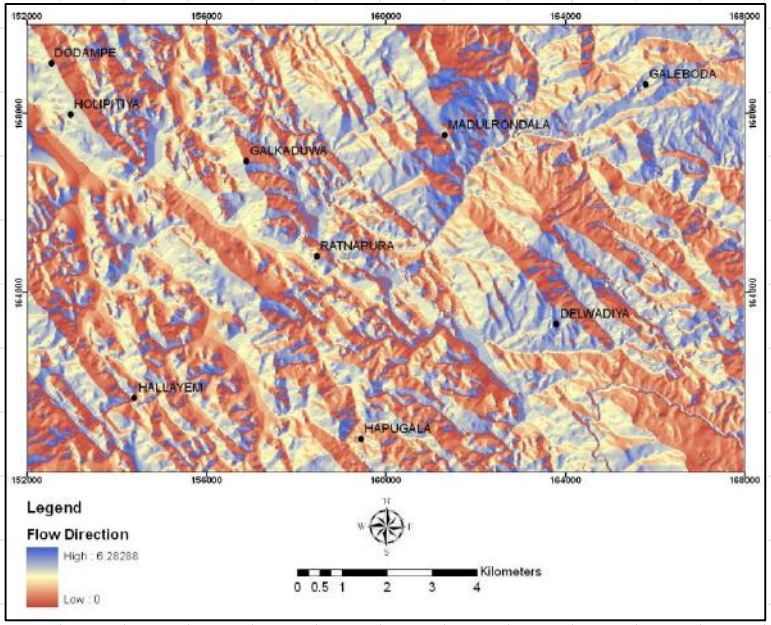
Parameterization of SINMAP model

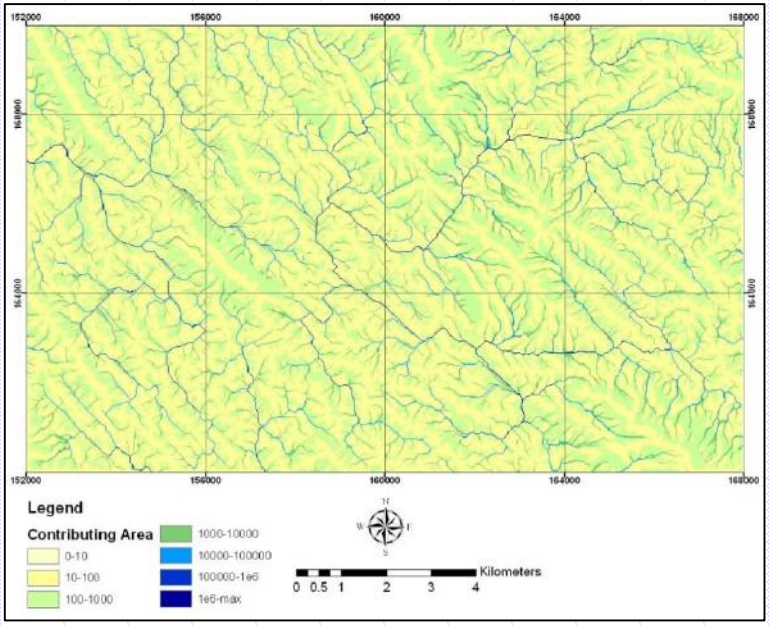
Region	Soil type	Soil depth (h)	Saturated Soil Density (kg/m^3)	Combined Cohesion		Dimensionless Cohesion		Friction Angle		Hydraulic Conductivity ks		Transmitivity T = ks * h		Recharge R		T/R	
				Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
		m	kg/m^3	Kpa	Kpa			deg	deg	m/sec	m/sec	m^2/day	m^2/day	mm/day	mm/day	m	m
1	Residual	1	1800	10	20	0.566	1.133	20.8	36	1.00E-06	1.00E-05	0.086	0.864	23	100	0.86	37.57
2	Residual	2	1800	10	20	0.283	0.566	20.8	36	1.00E-06	1.00E-05	0.173	1.728	23	100	1.73	75.13
3	Residual	8	1800	10	20	0.071	0.142	20.8	36	1.00E-06	1.00E-05	0.691	6.912	23	100	6.91	300.52
4	Coluvium	1	1750	2	12	0.116	0.699	20.8	36	1.00E-06	1.00E-05	0.086	0.864	23	100	0.86	37.57
5	Coluvium	3	1750	2	12	0.039	0.233	20.8	36	1.00E-06	1.00E-05	0.259	2.592	23	100	2.59	112.70
6	Coluvium	8	1750	2	12	0.015	0.087	20.8	36	1.00E-06	1.00E-05	0.691	6.912	23	100	6.91	300.52

SINMAP Model execution results

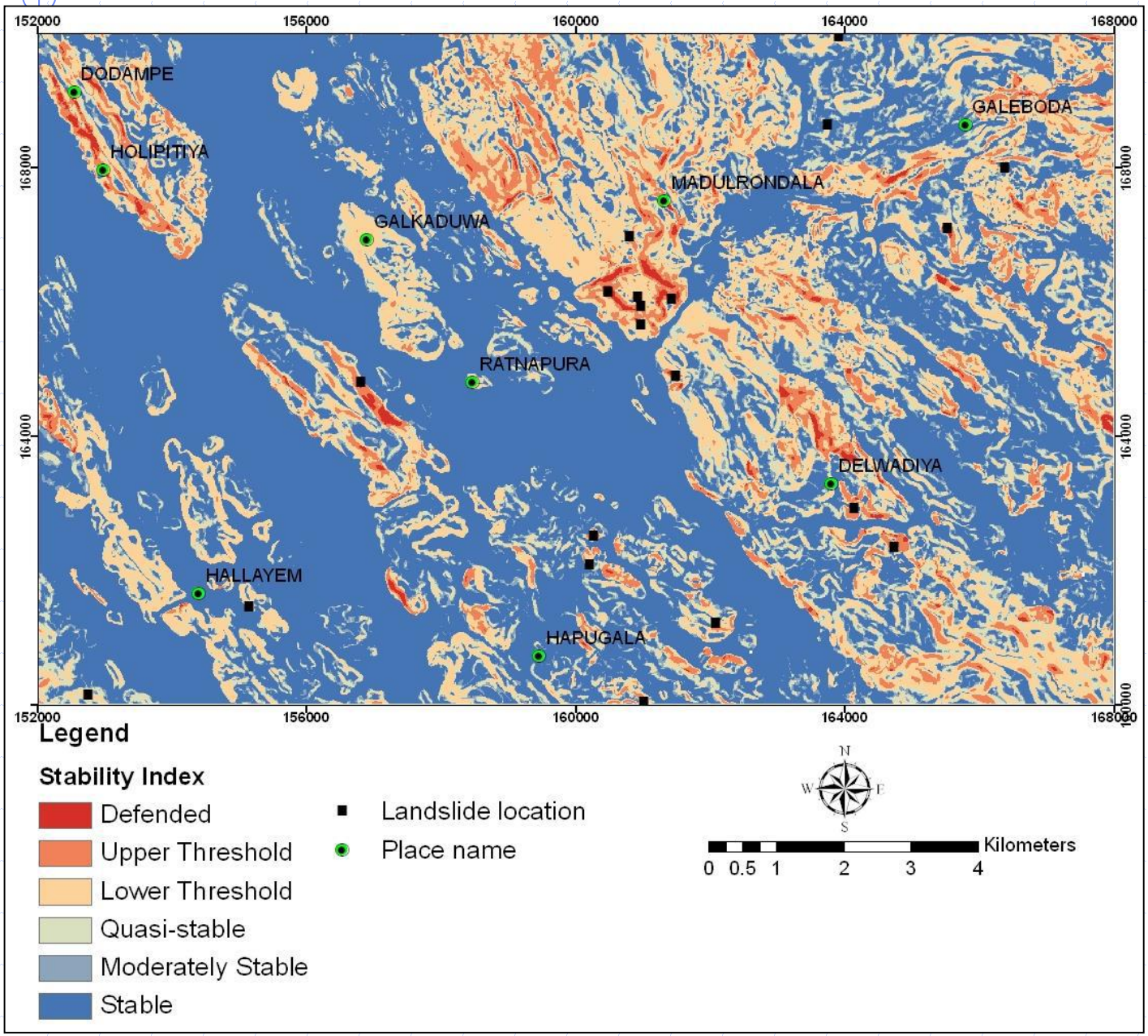






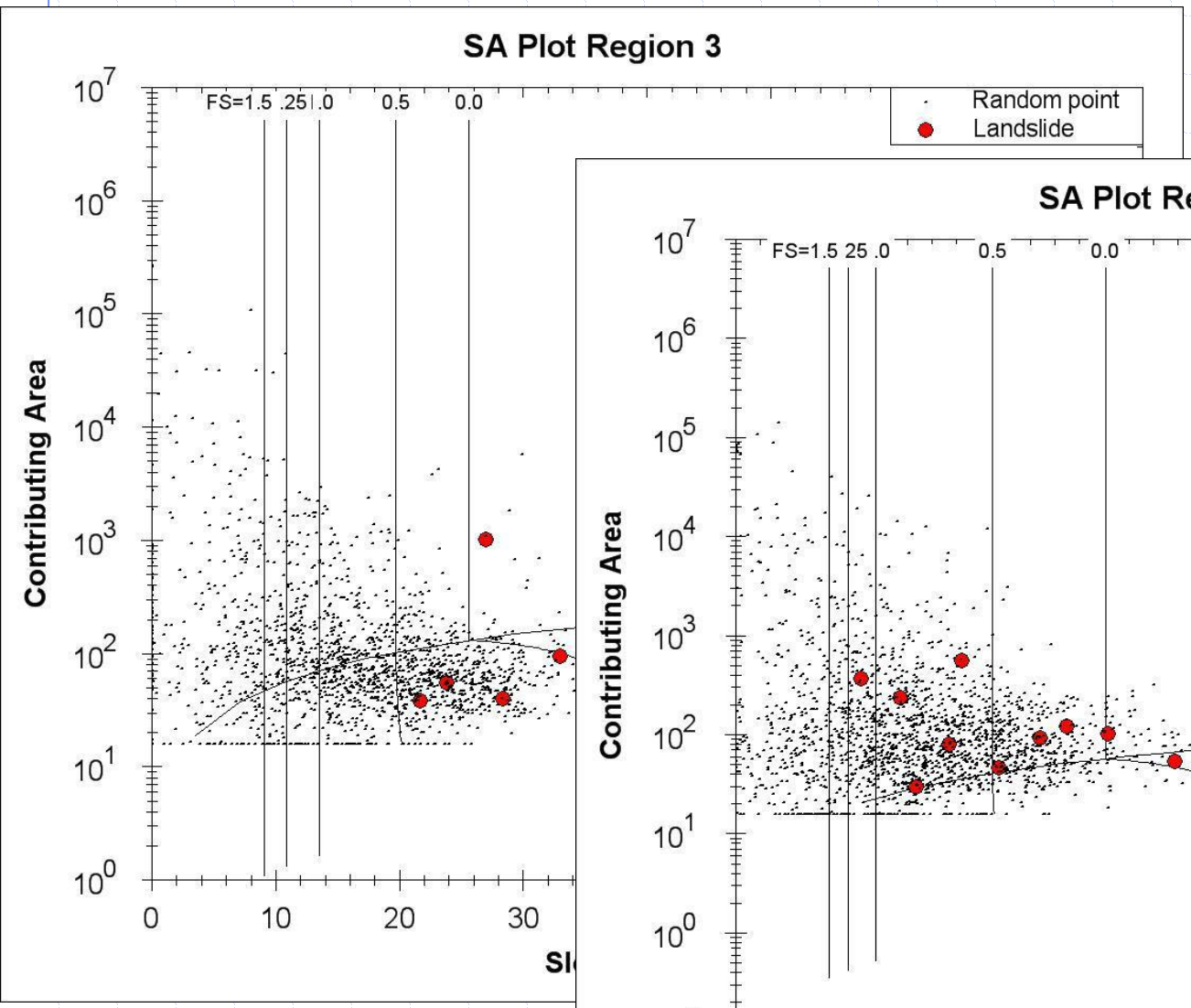


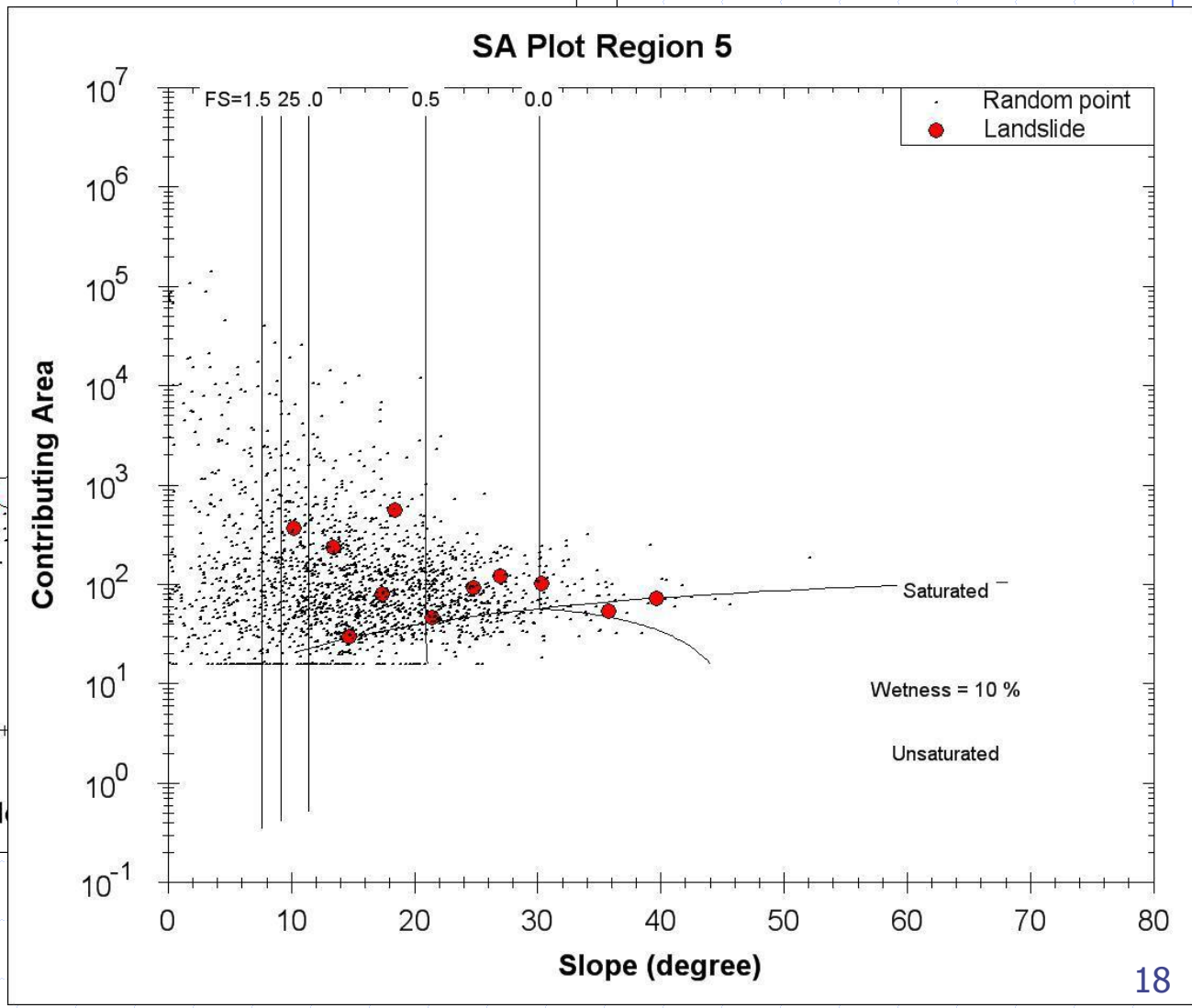
Stability Index map



Classification	Stability Index Values (SI)
Stable	SI > 1.5
Moderately Stable	1.25 < SI ≤ 1.5
Quasi-stable	1.0 < SI ≤ 1.25
Lower Threshold	0.5 < SI ≤ 1.0
Upper Threshold	0.0 < SI ≤ 0.5
Defended	SI = 0

Slope-area charts

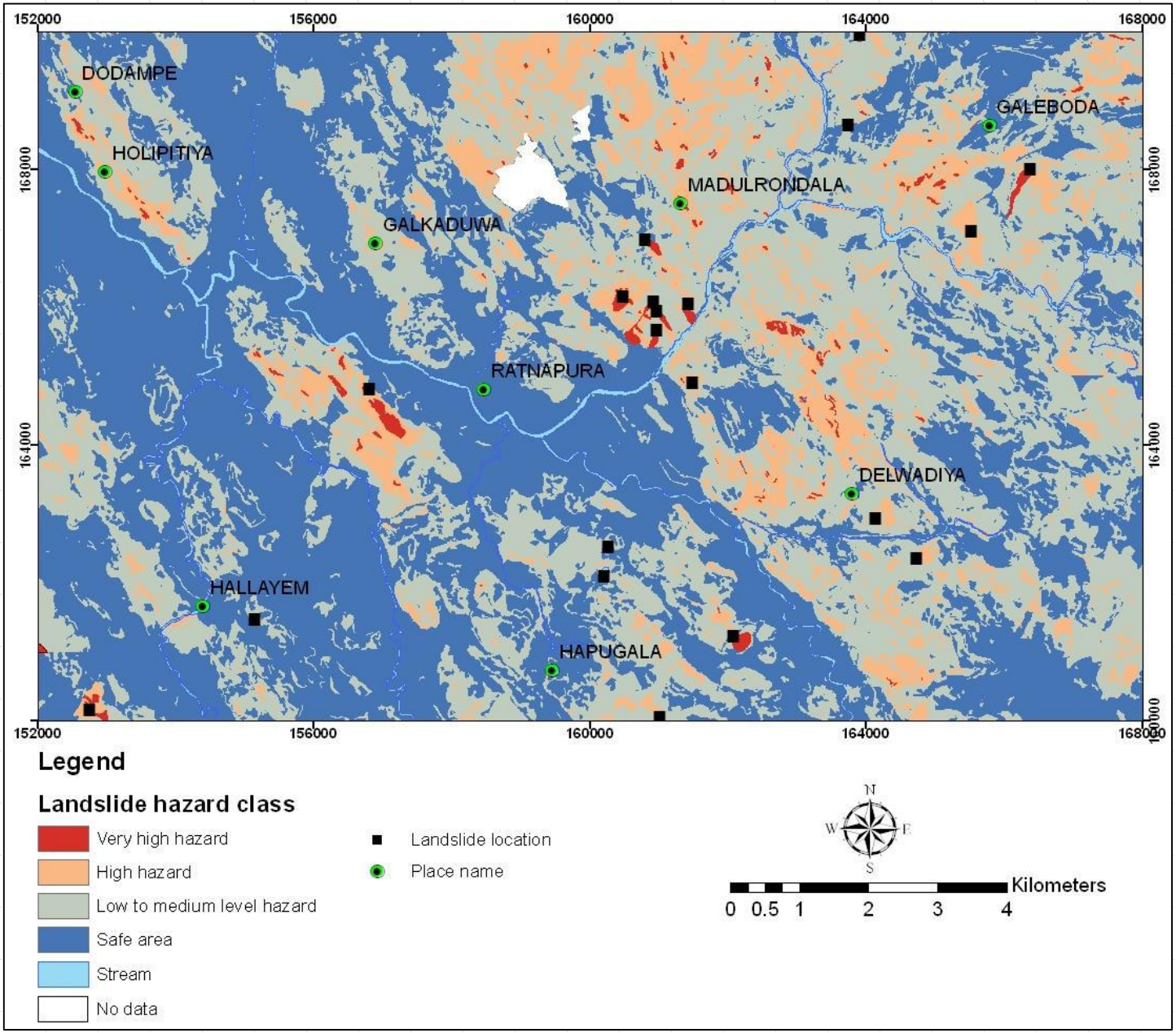




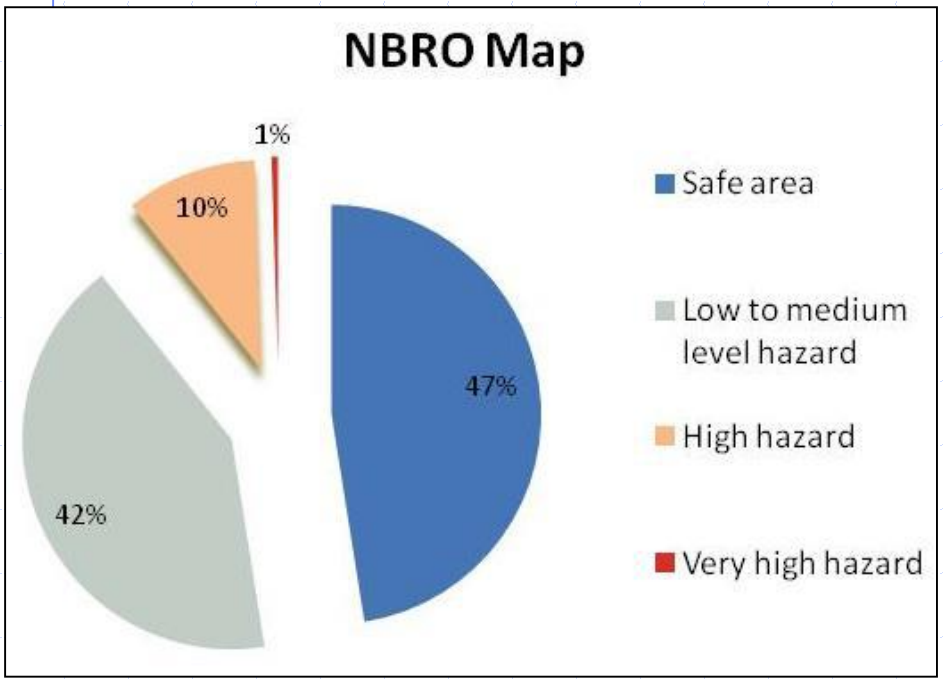
Landslides found in different stability classes

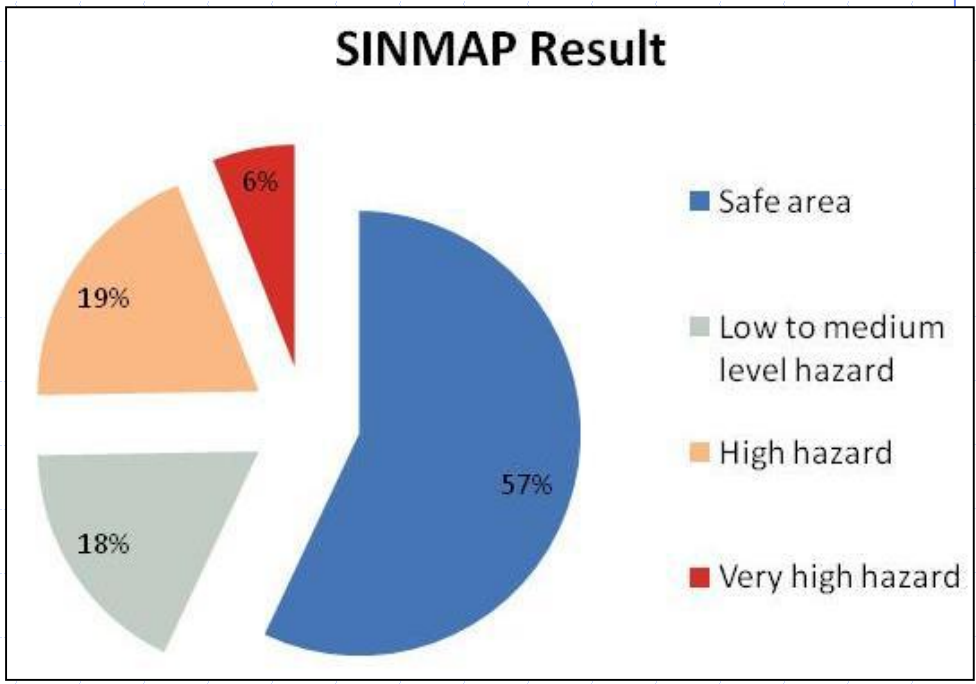
Region	Stable	Moderately Stable	Quasi Stable	Lower Threshold	Upper Threshold	Defended	Total number of Landslides in the region
1	0	0	0	0	0	0	0
2	0	0	1	2	0	0	3
3		0	0	0	4	1	5
4	0	0	0	1	0	0	1
5	0	0	1	4	3	3	11
6	0	0	0	0	0	0	0
Total landslides in the stability class	0	0	2	7	7	4	20
% landslides in the stability class	0%	0%	10%	35%	35%	20%	100%
General stability	0% Stable		10% Marginal	90% Unstable			

Existing NBRO's landslide hazard map

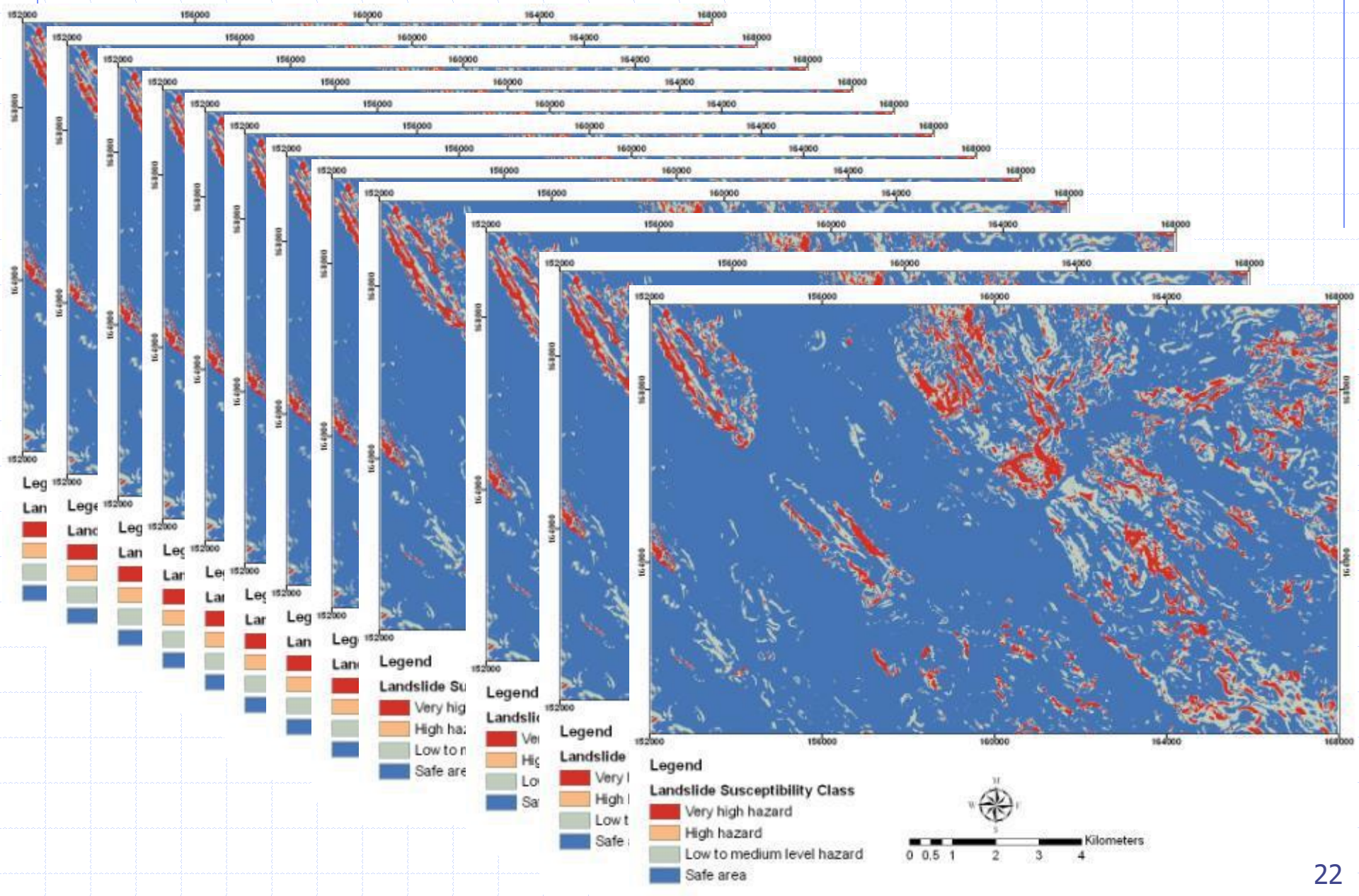


Comparison


NBRO Map
1%
10%
47%
42%
Safe area
Low to medium level hazard
High hazard
Very high hazard


SINMAP Result
6%
19%
57%
18%
Safe area
Low to medium level hazard
High hazard
Very high hazard

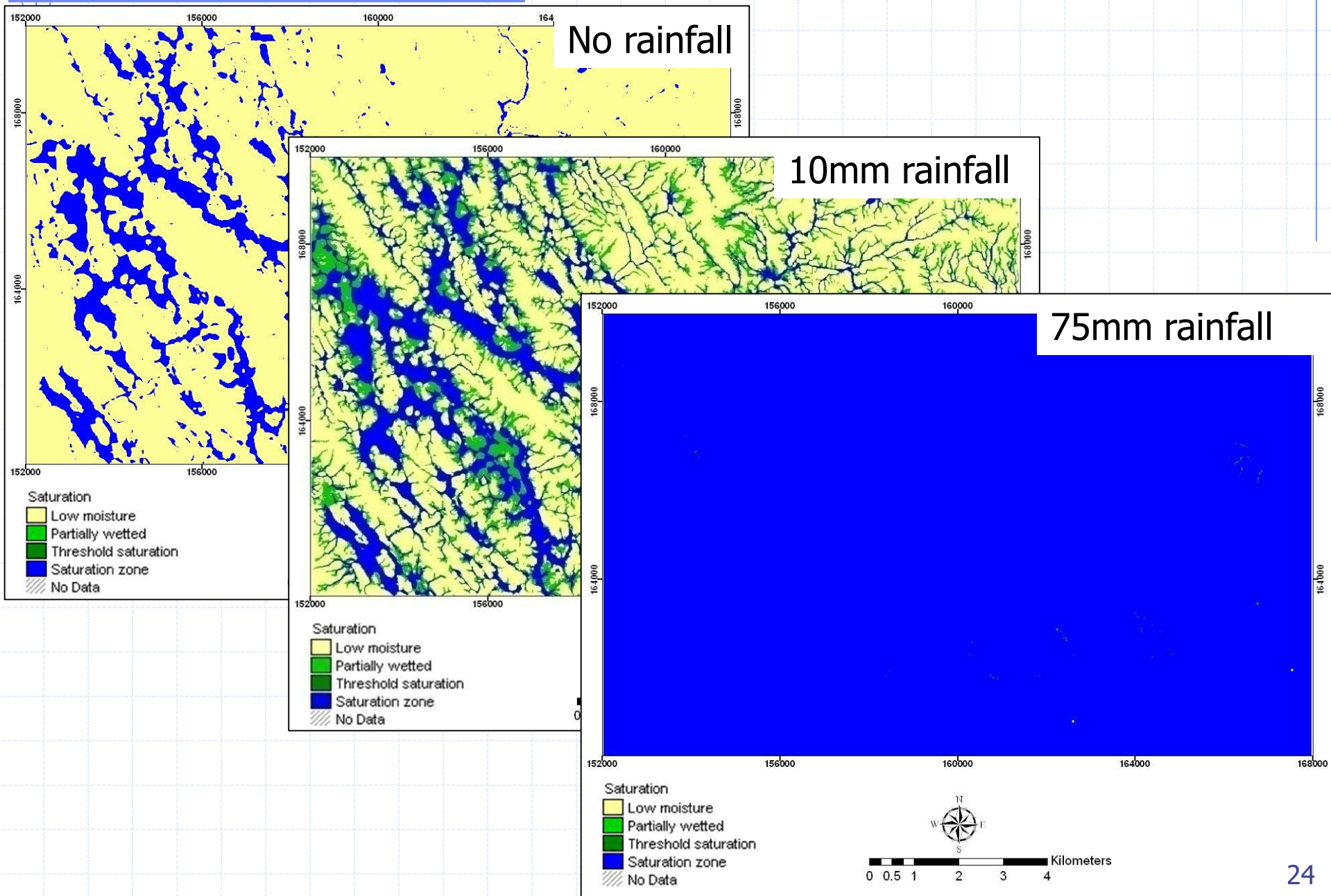
Scenario execution: 10, 20, 30, 40, 50, 60, 70, 80, 75, 100 and 345 mm rainfall



Number of pixels in hazard classes

	Rainfall (mm per day)										
Hazard Classes	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**~75**	**80**	**100**	**345**
Safe Area	503256	495161	493775	493642	493527	493485	493485	493485	493485	493485	493485
Low to medium level hazard	88637	89926	89842	89444	89428	89406	89362	89310	89310	89310	89310
Very high hazard	29843	36649	38119	38650	38782	38845	38889	38941	38941	38941	38941

Saturation maps



Conclusions and recommendations

- SINMAP is successfully utilized for delineating the landslide hazard zones in Rathnapura area
- 75mm daily rainfall was indentified as threshold value for fully saturation condition of the study area
- Comparison results show that, SINMAP model results give over estimation compared to the other hazard maps
- Both models predict the landslide initiation points only, landslide propagation need further investigation
- MapWindow GIS, SINMAP 2.0 for MapWindow are used for landslide hazard mapping at free of cost

Ongoing project

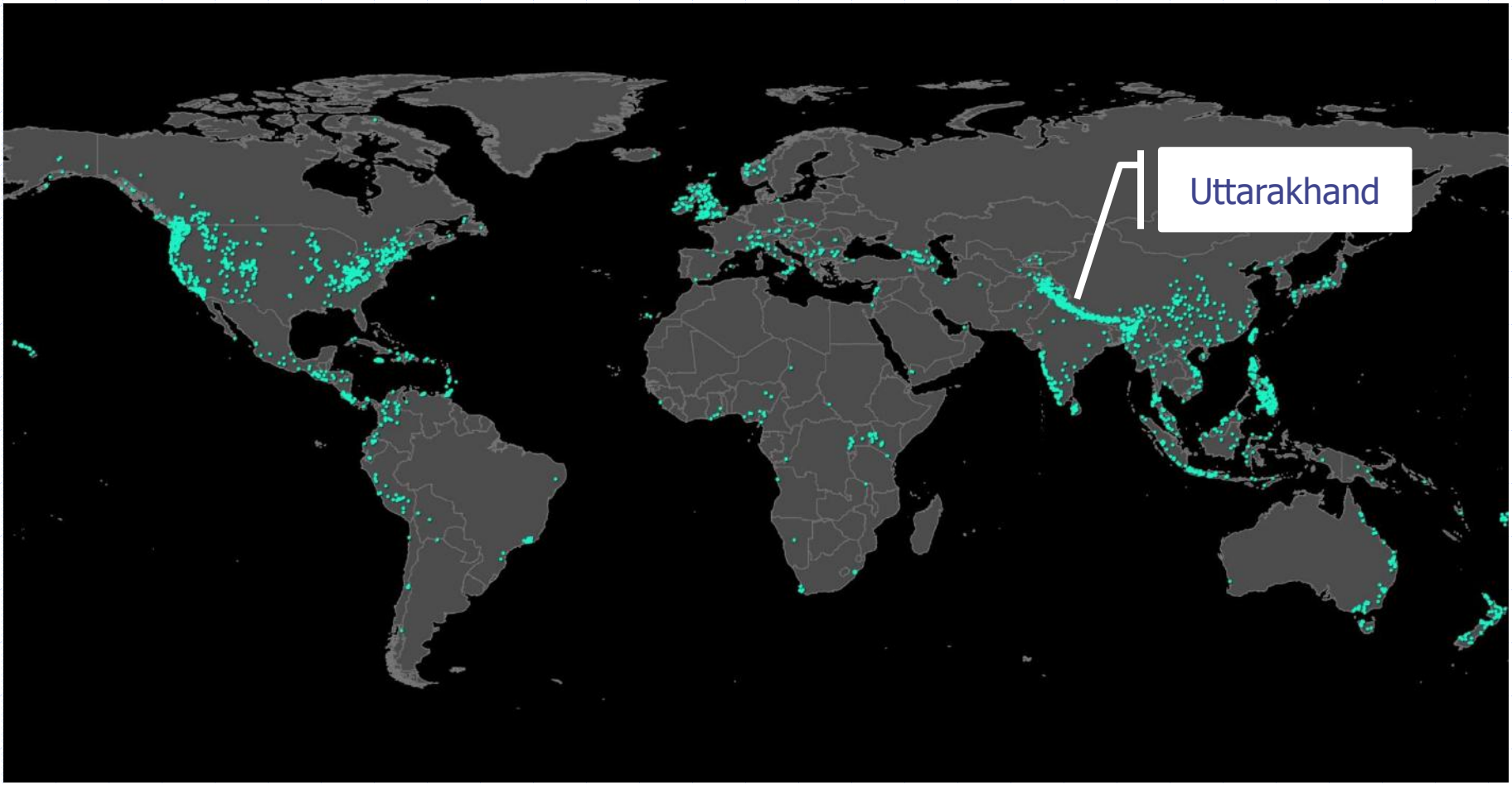
In collaboration with the Earth Observatory Singapore

Disaster Risk Assessment of Uttarakhand

May 2016 – December 2017

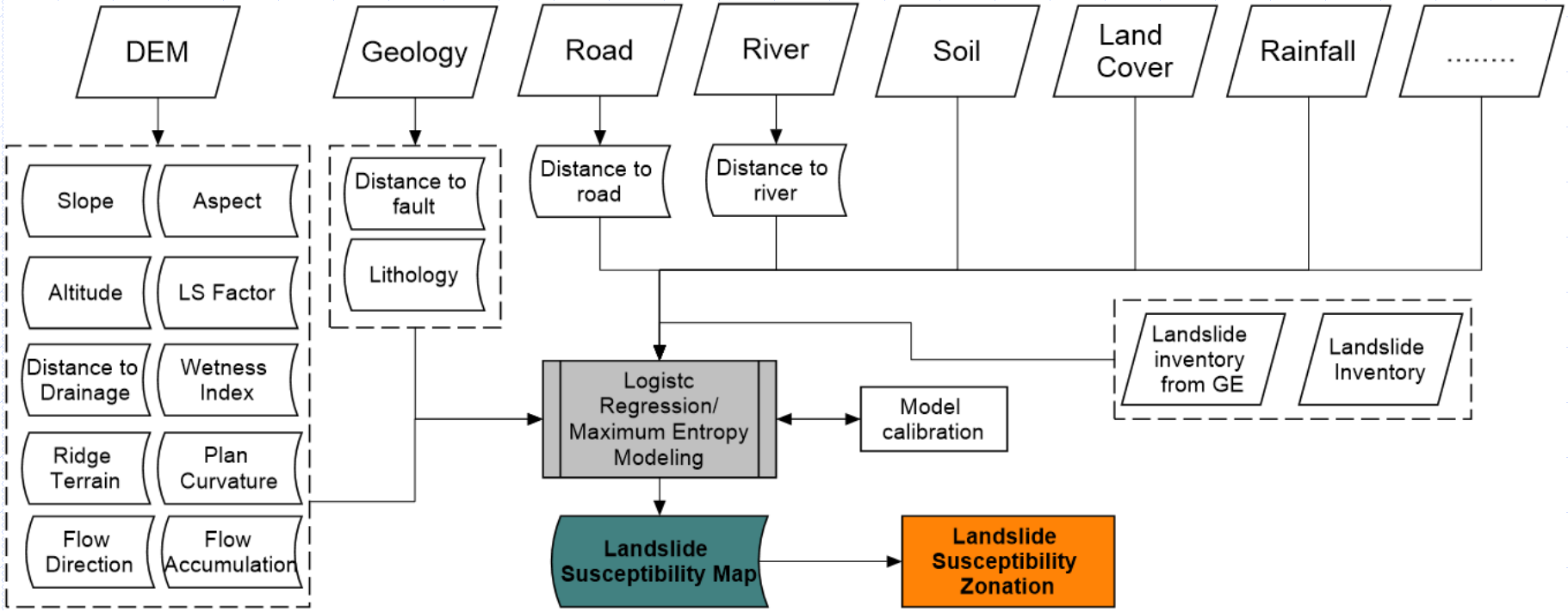
Funded by the World Bank and delivered for the Project Implementation Unit (TA & CBDRM), Uttarakhand Disaster Recovery Project (UDRP), Government of Uttarakhand.

High Prone Landslide areas in the World

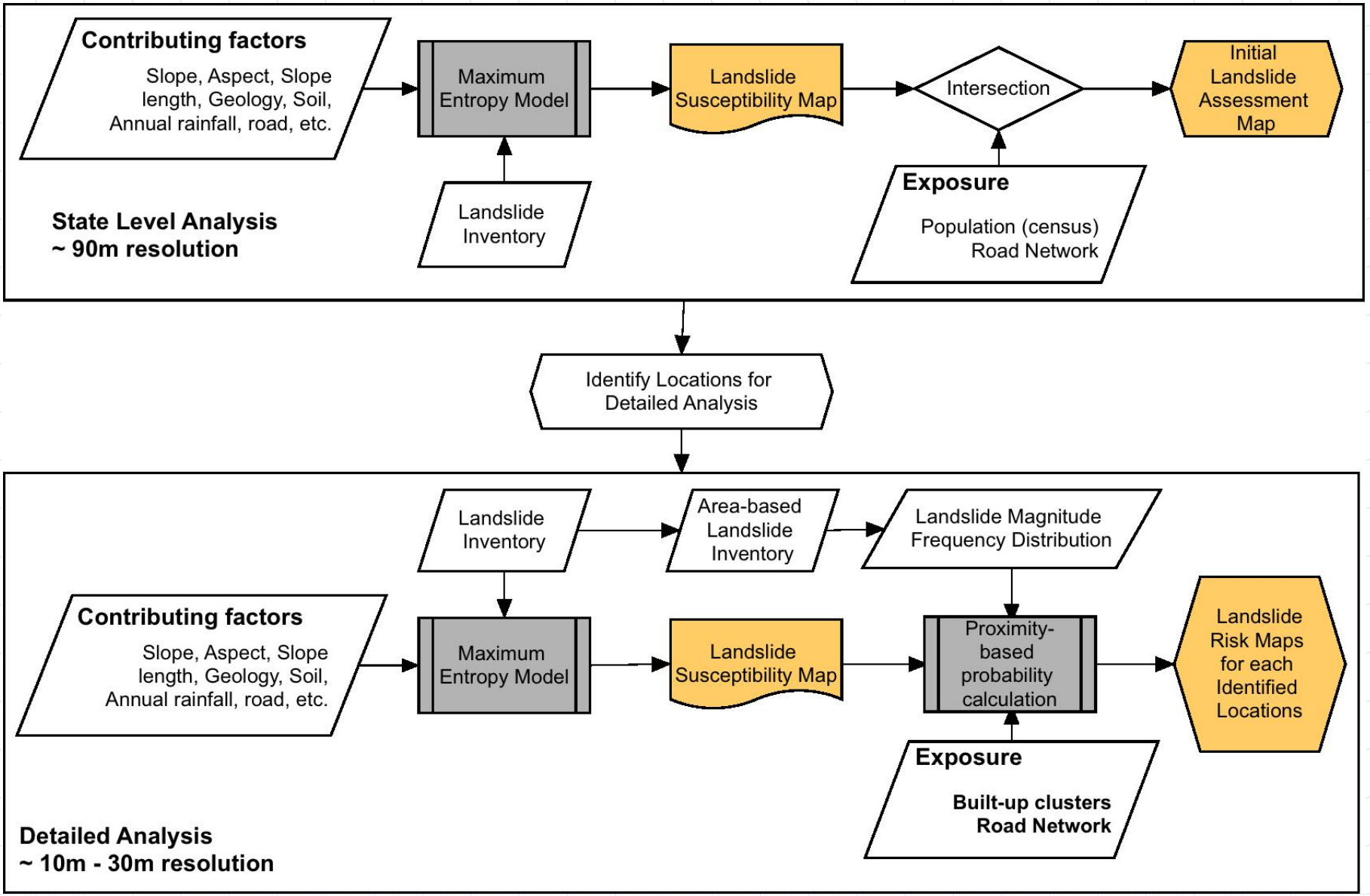


Source: https://www.nasa.gov/sites/default/files/thumbnails/image/landslide_locations.jpg

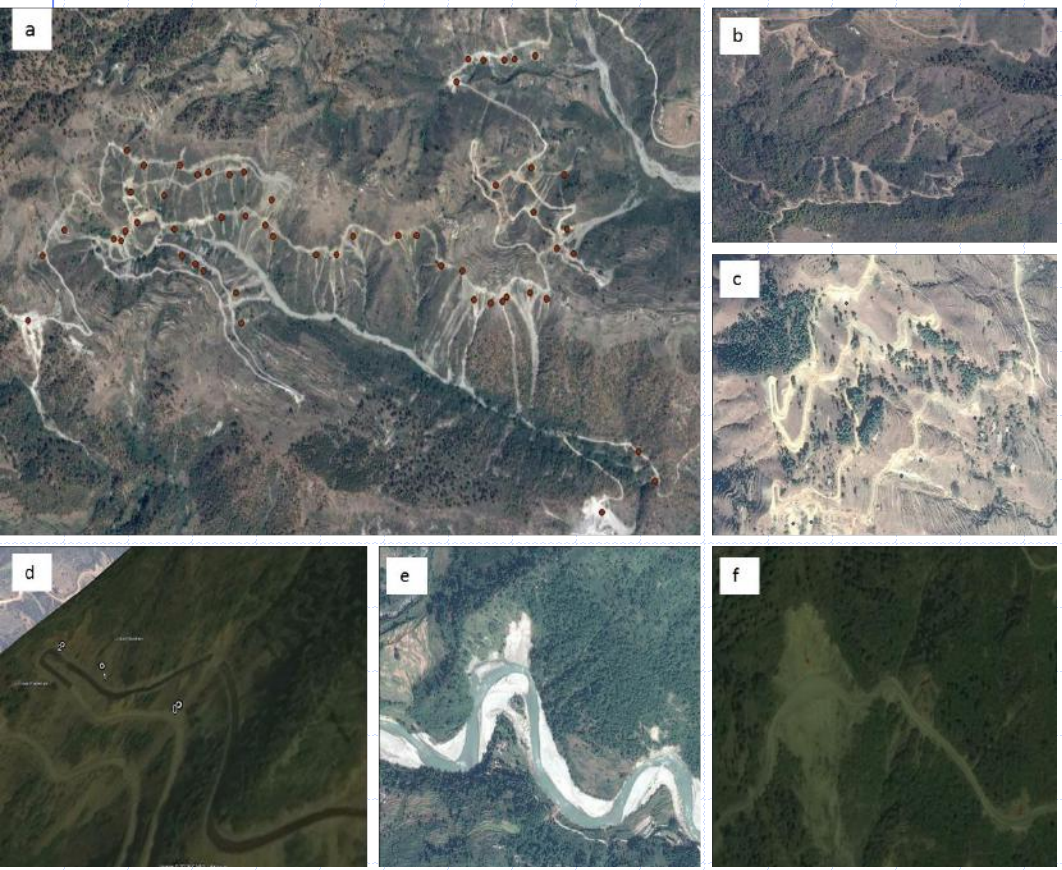
Landslide Susceptibility Mapping



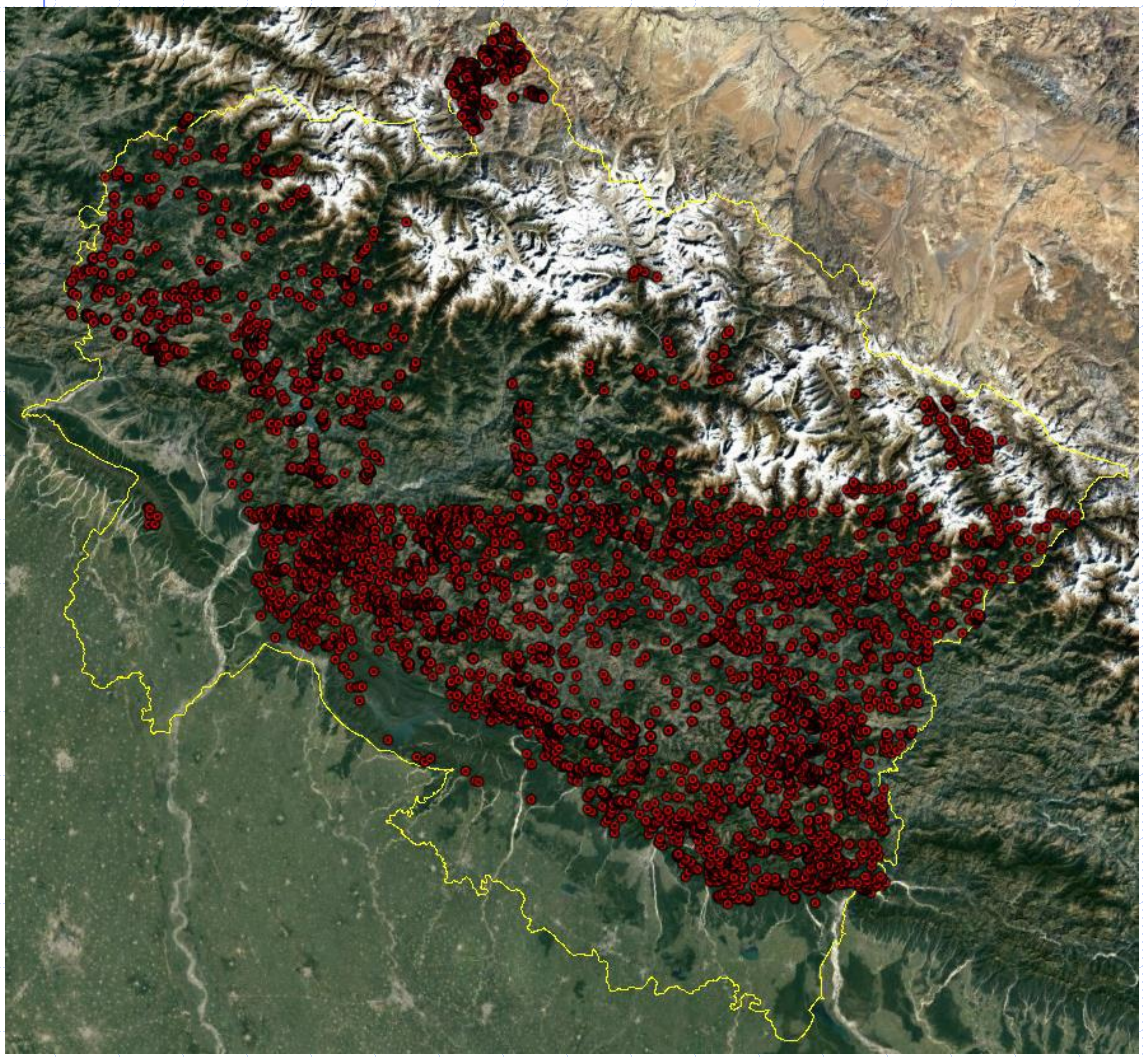
Overall methodology



Views of landslide scars in Google Earth



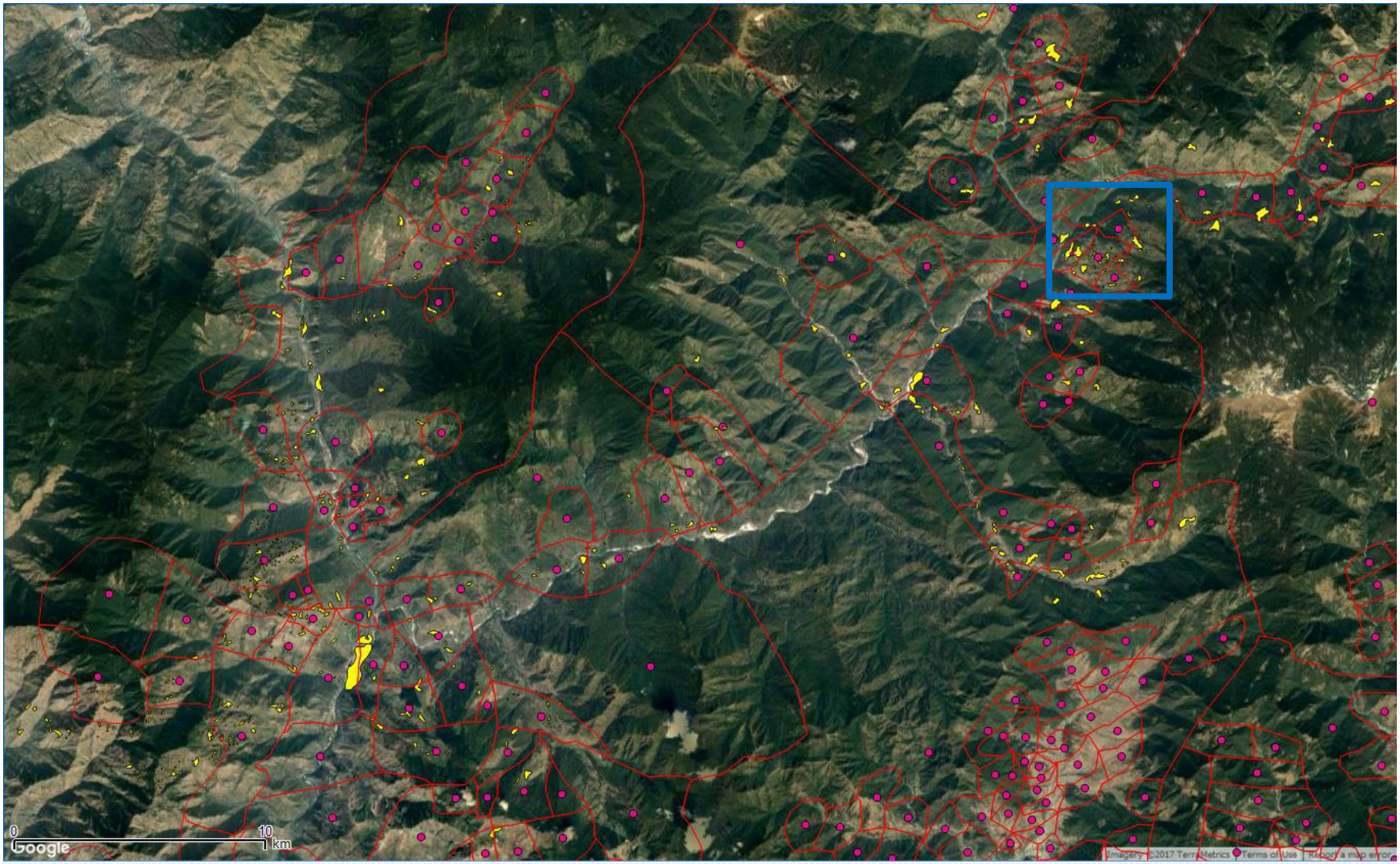
- Landslide inventory is the most important dataset for landslide hazard/ susceptibility mapping

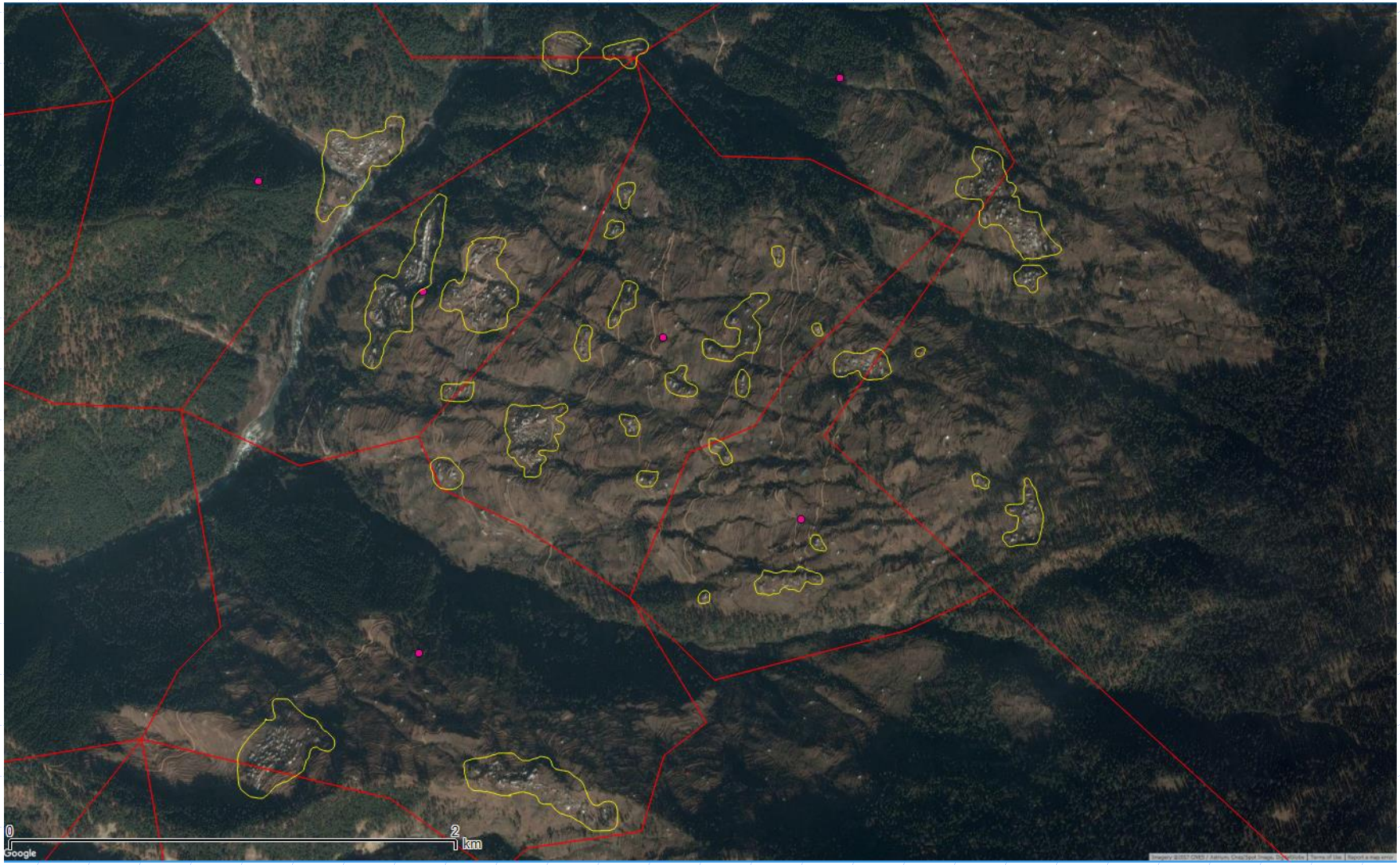


- The mapping is going on with the most recent images available in the Google Earth for whole Uttarakhand state
- Currently, around 7,200 landslides are identified
- Ongoing tasks
  - Mapping of landslide area
  - Mapping on past images on Google Earth too

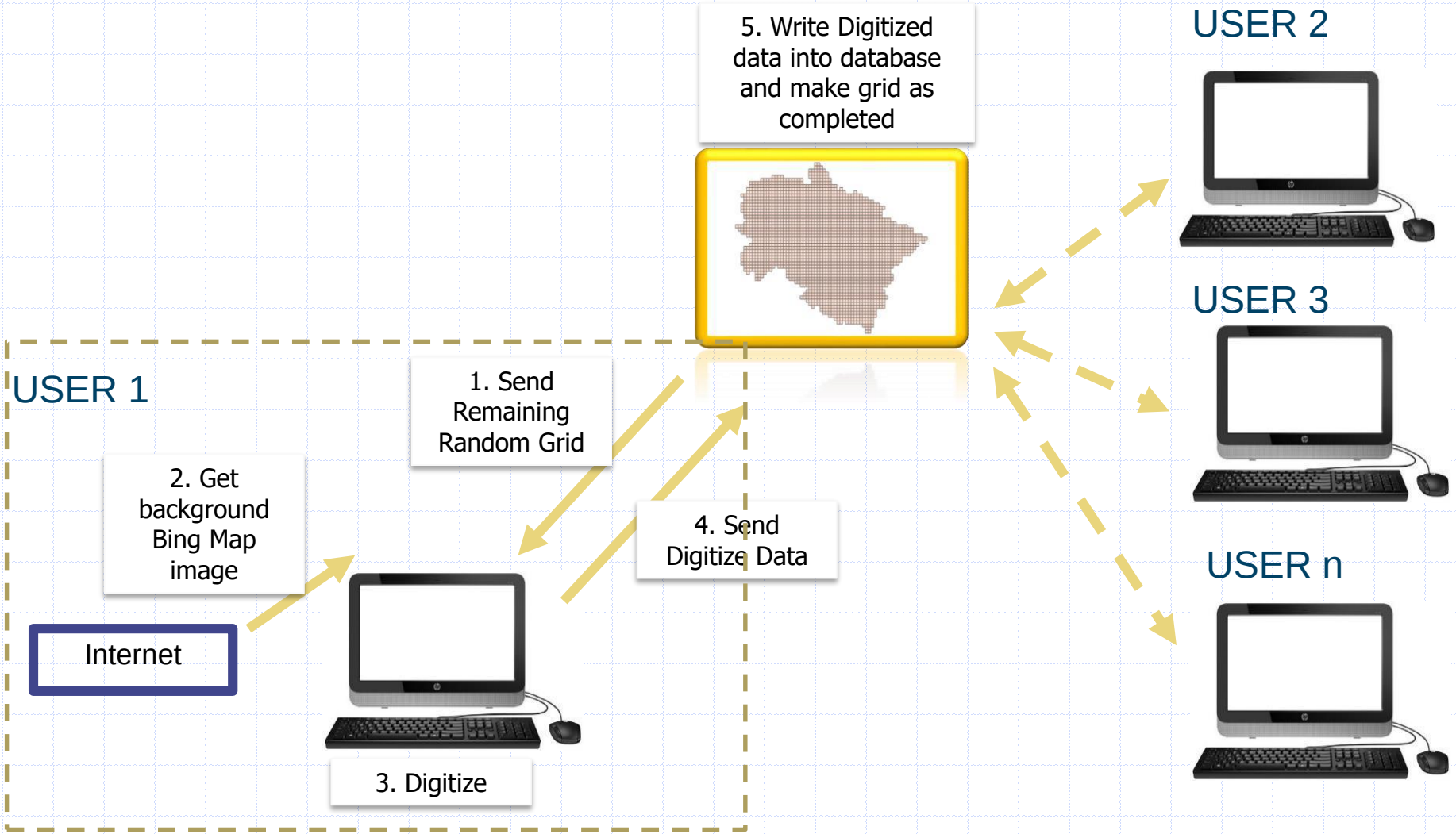
Innovative Crowdsourcing Approach For Determining Building Clusters

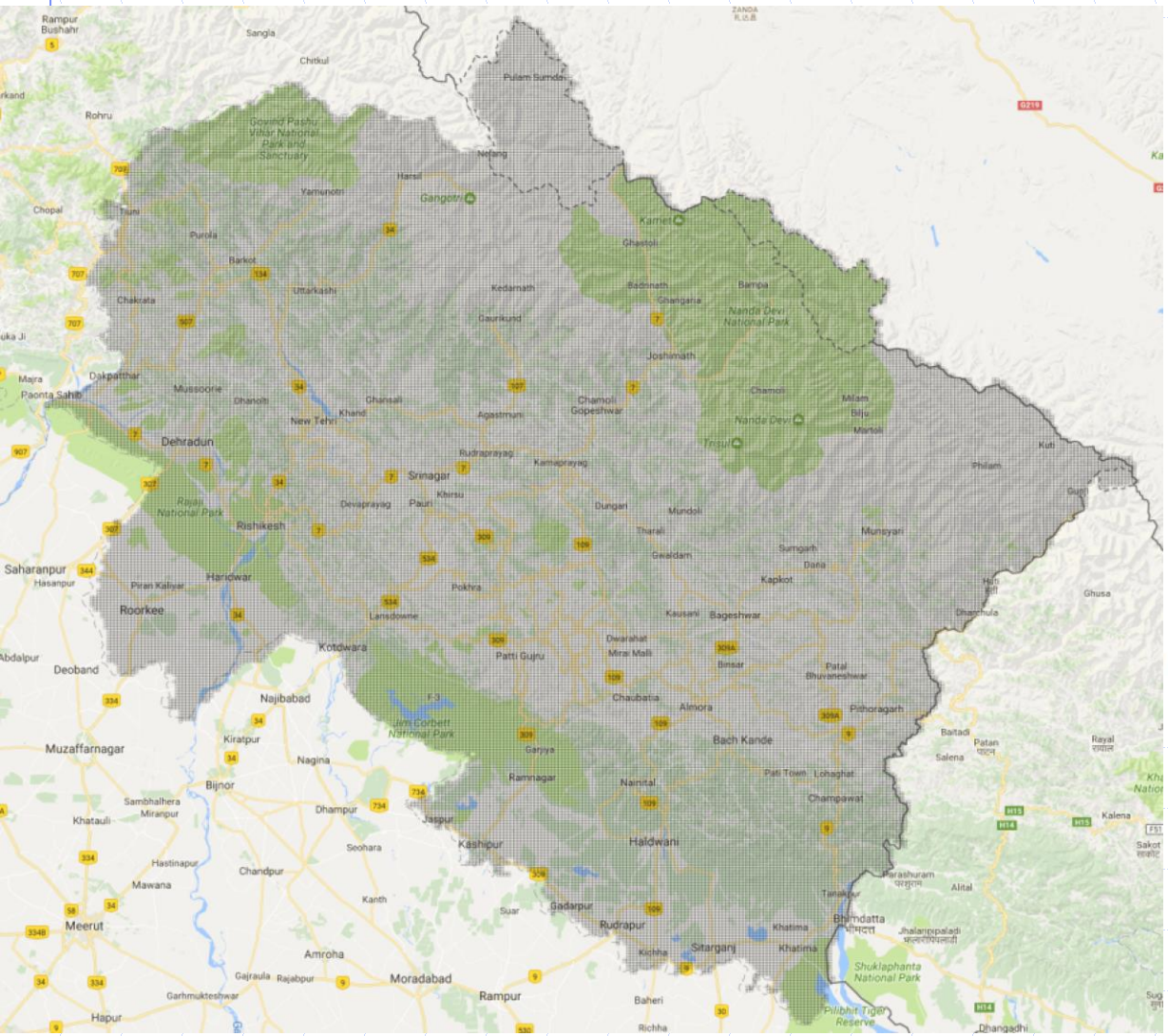
Why

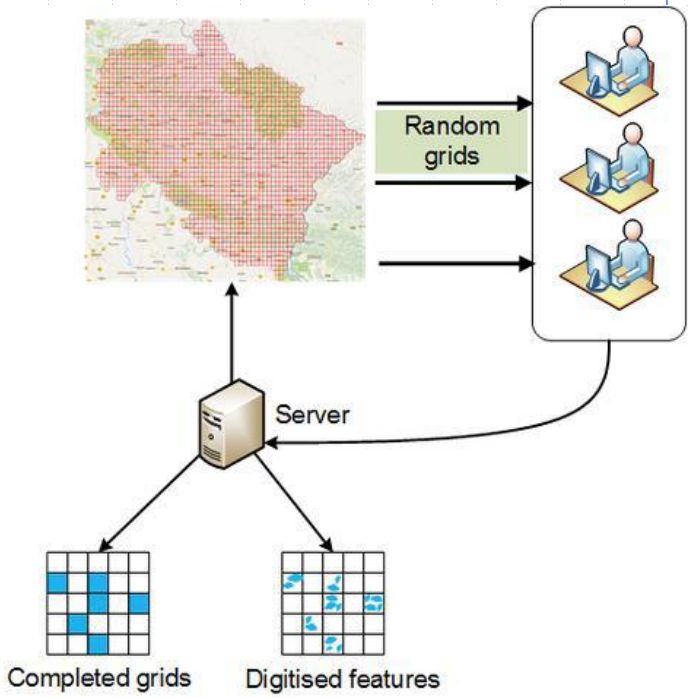



0
2
km
Google

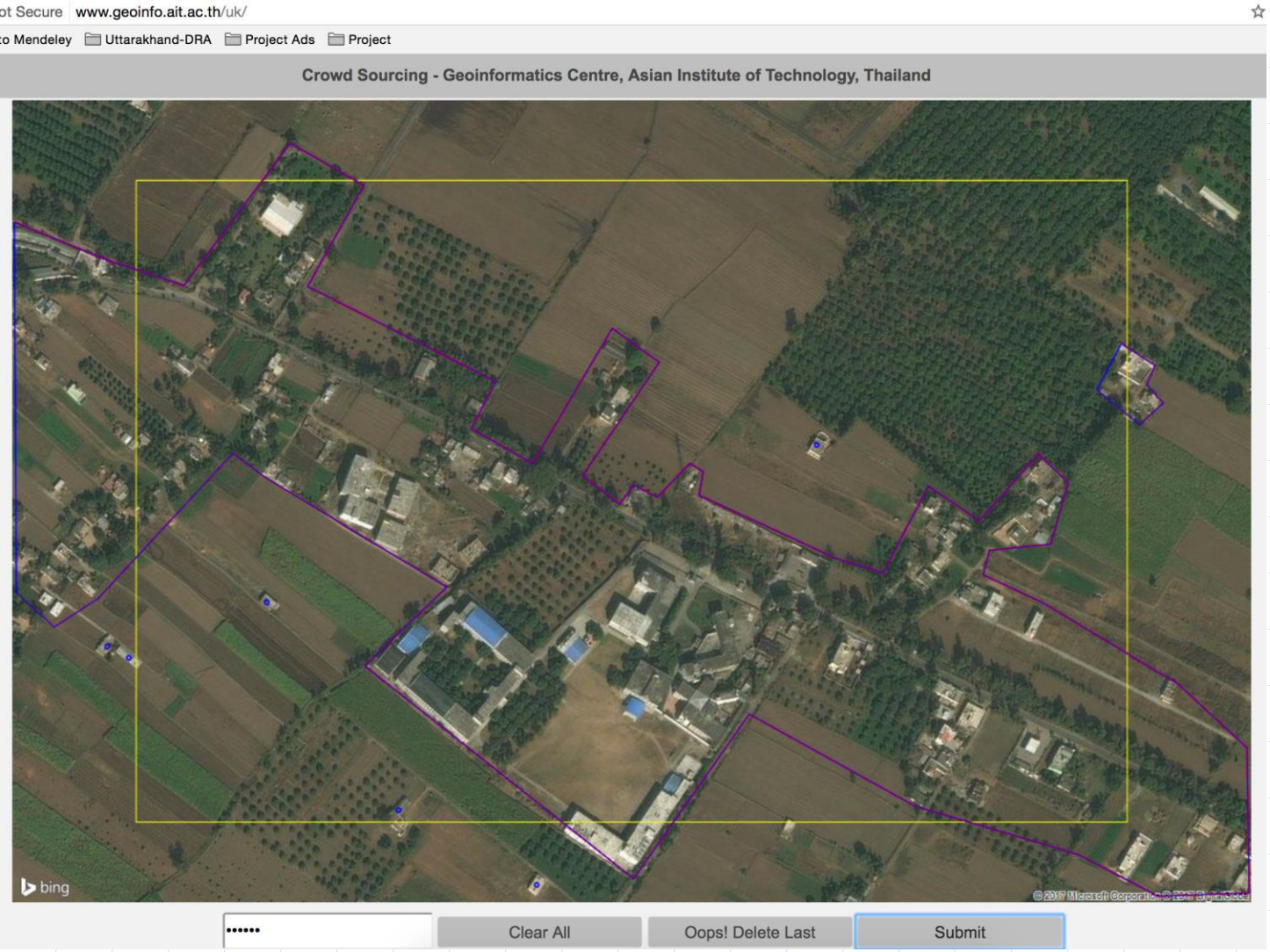
Crowdsourcing approach



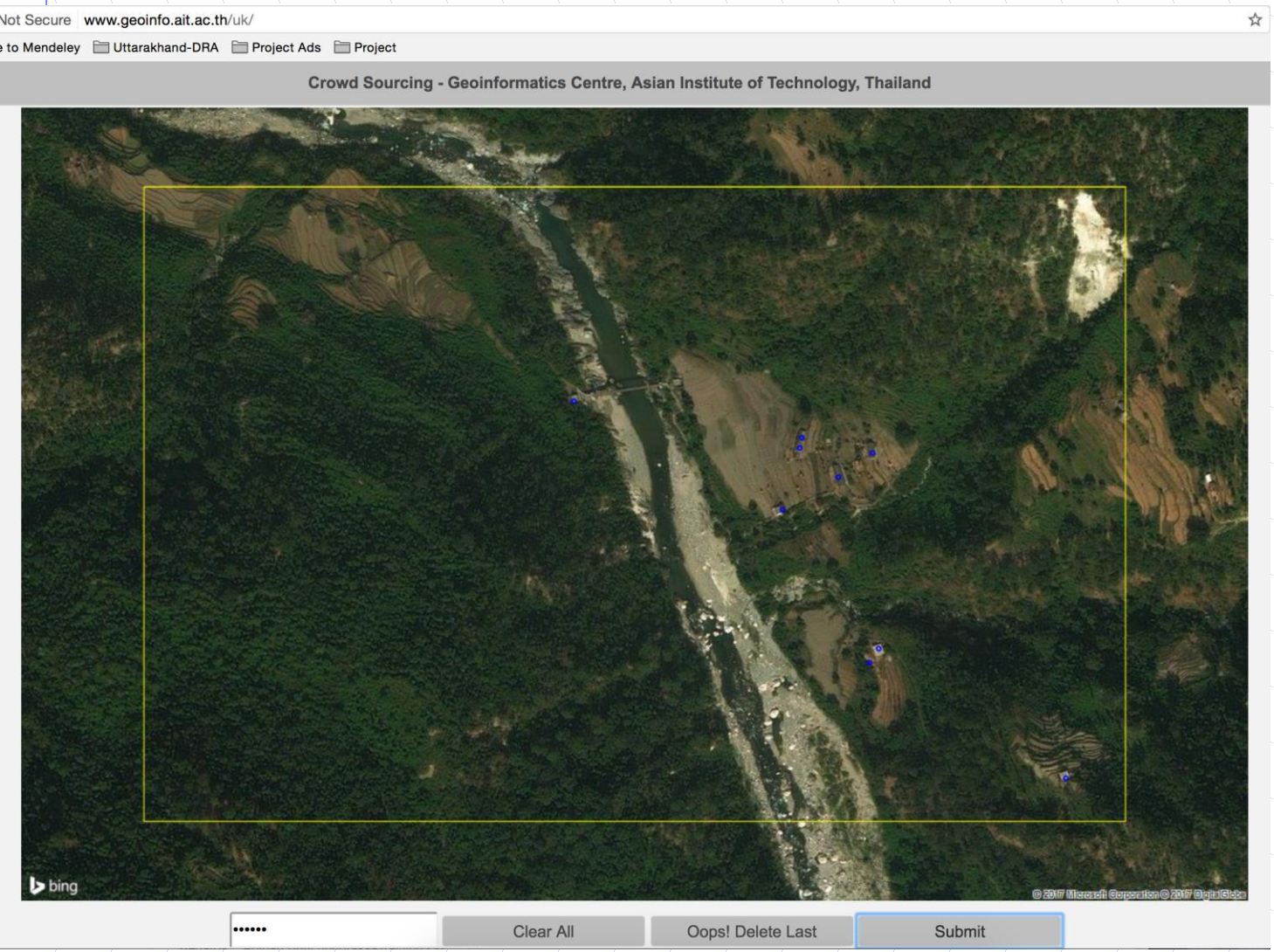




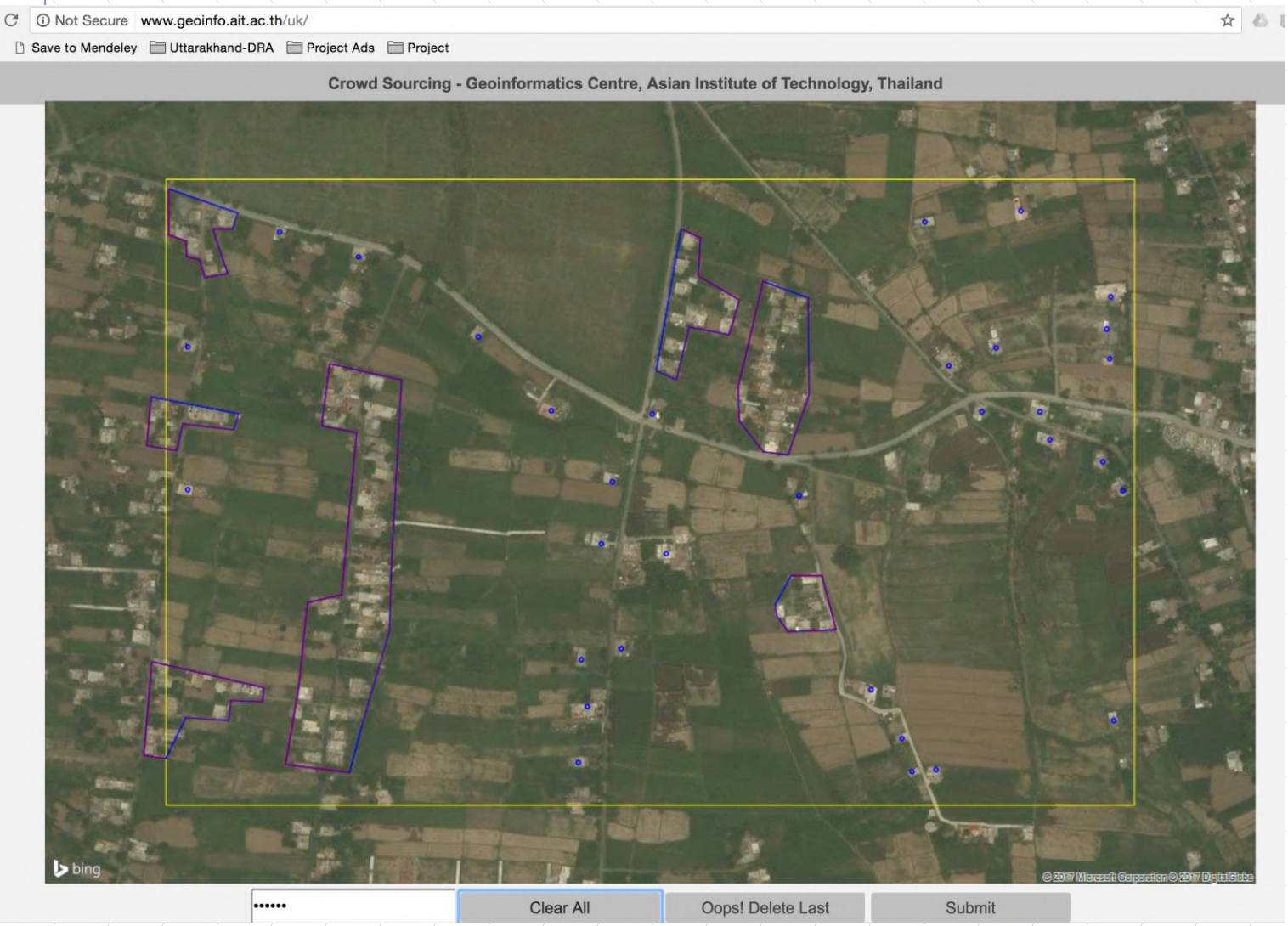
Number of Grids: 75563
Grid size: 1.2km * 0.8 km



Notes:
Level of this details would be enough



Notes:
All the buildings near the river and mountainous area need to be digitized

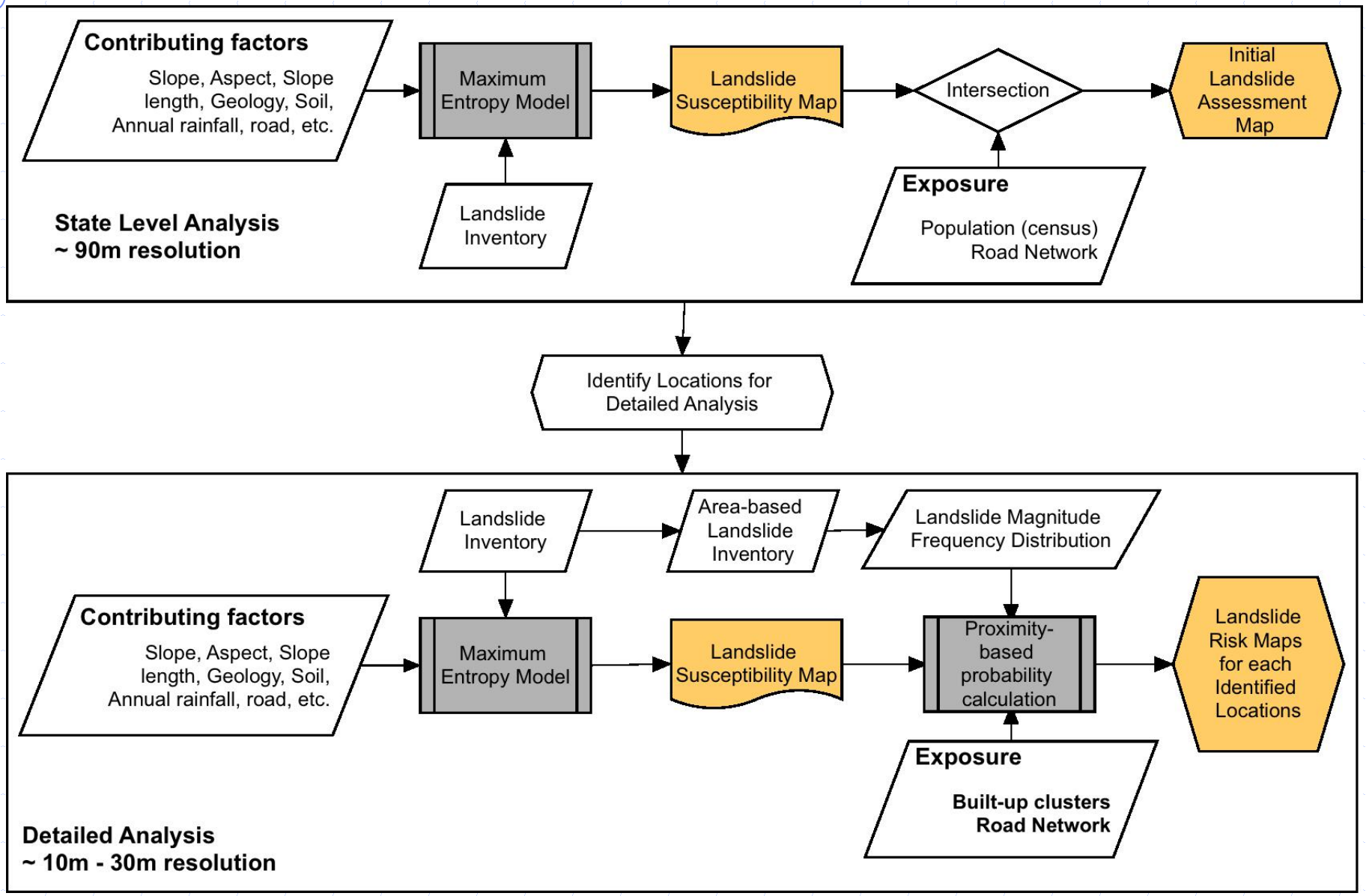


Notes:
Hope you can understand level of details we expect to be digitized

Monitoring and Quality Control

Continuously monitoring the quality of the work and communicating with crowdsourcing people

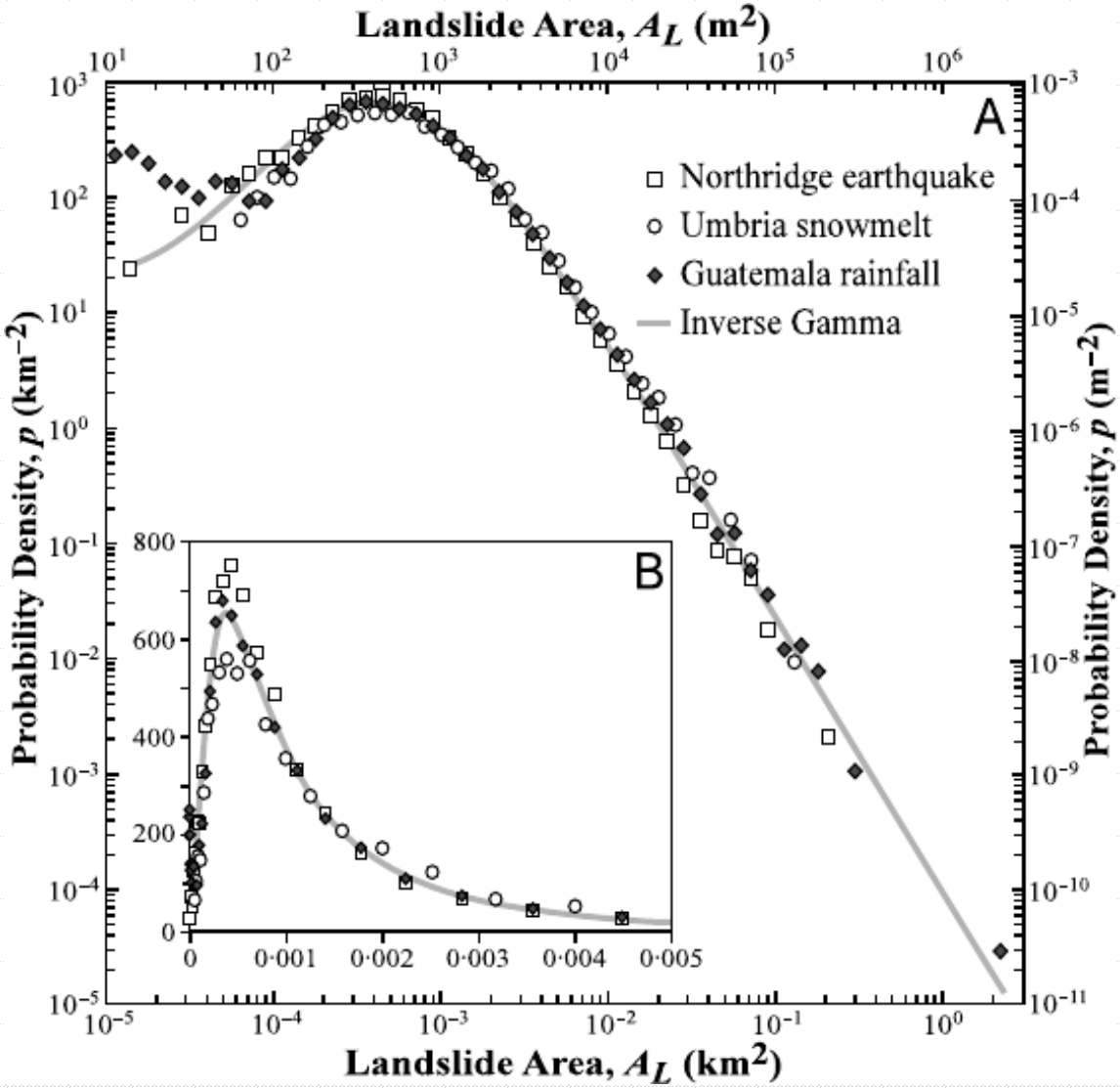
Overall Methodology



Association of Landslide Magnitude (Area)

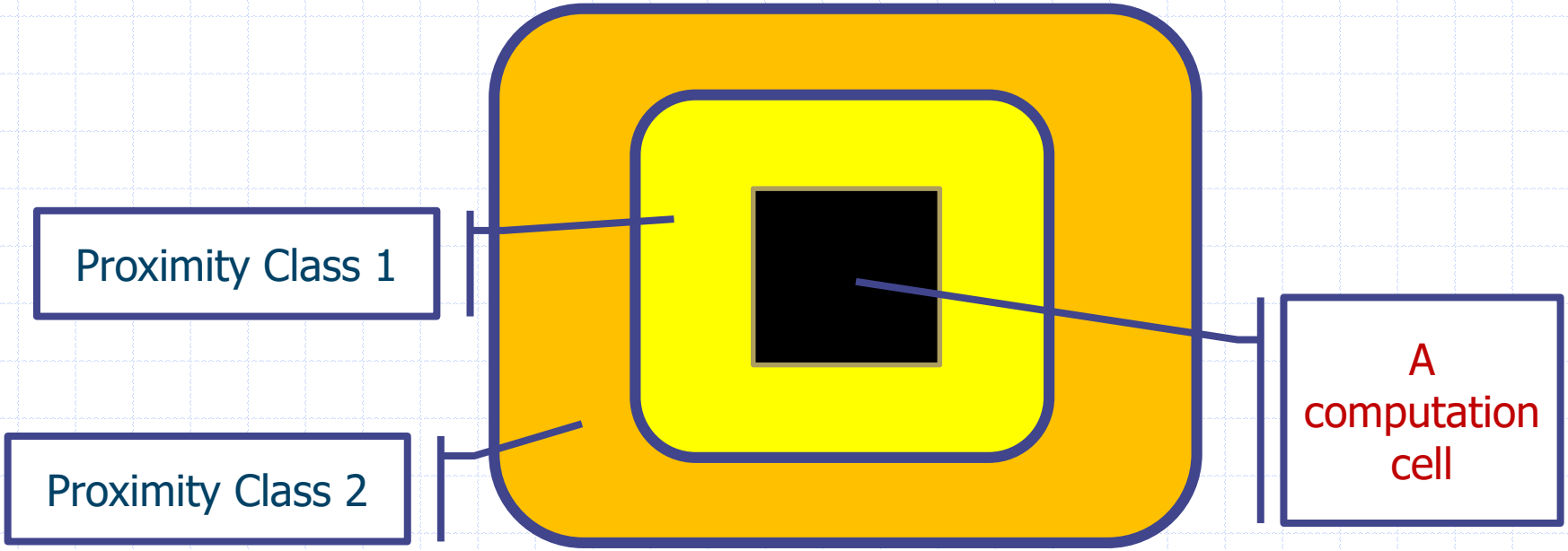
- In order to assess the landslide risk to settlement/road, magnitude of landslide is an important factor
- Landslide Magnitude-Frequency distribution follows a Gamma Distribution
- So, we will assess the proximity of the settlement/road to landslide susceptibility and determine the Landslide Magnitude-Frequency distribution

Association of Landslide Magnitude (Area)



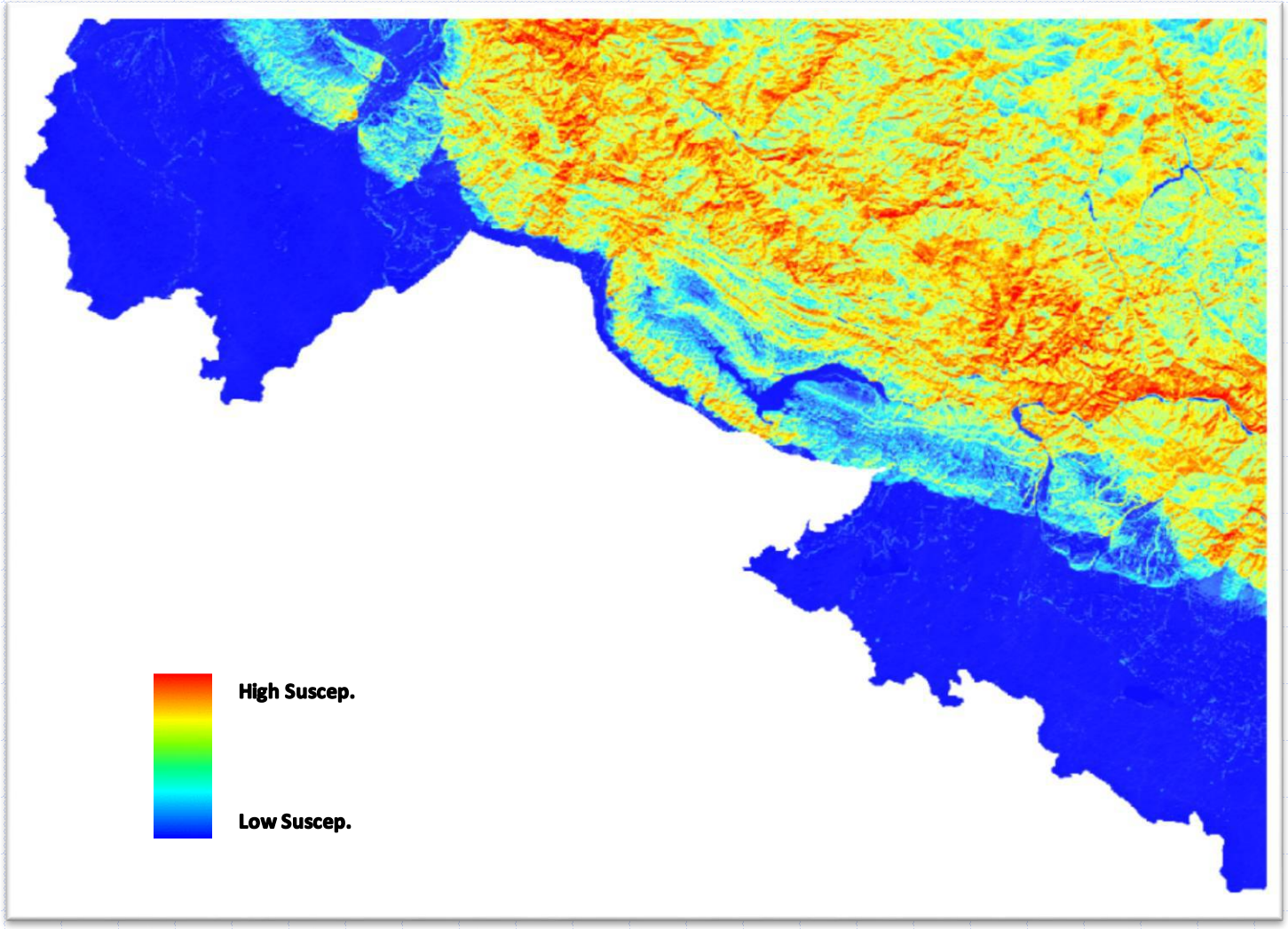
Source:
https://www.researchgate.net/profile/Bruce_Malamud/publication/241388019/viewer/AS:99596793548809@1400757135555/background/7.png

Assessment of Landslide Probability



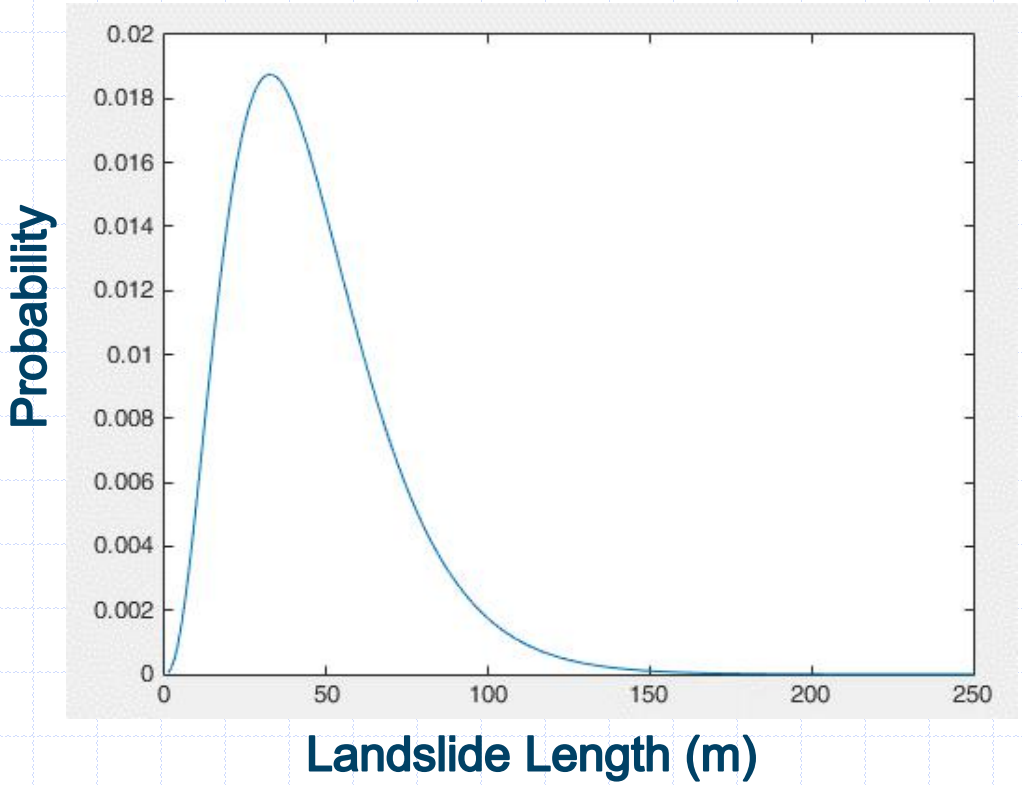
$$Landslide\ probability\ of\ a\ cell = \sum_{i=1}^{n} (Average\ Susceptibility\ of\ Proximity\ Class\ \times$$

Preliminary results: part of susceptibility map

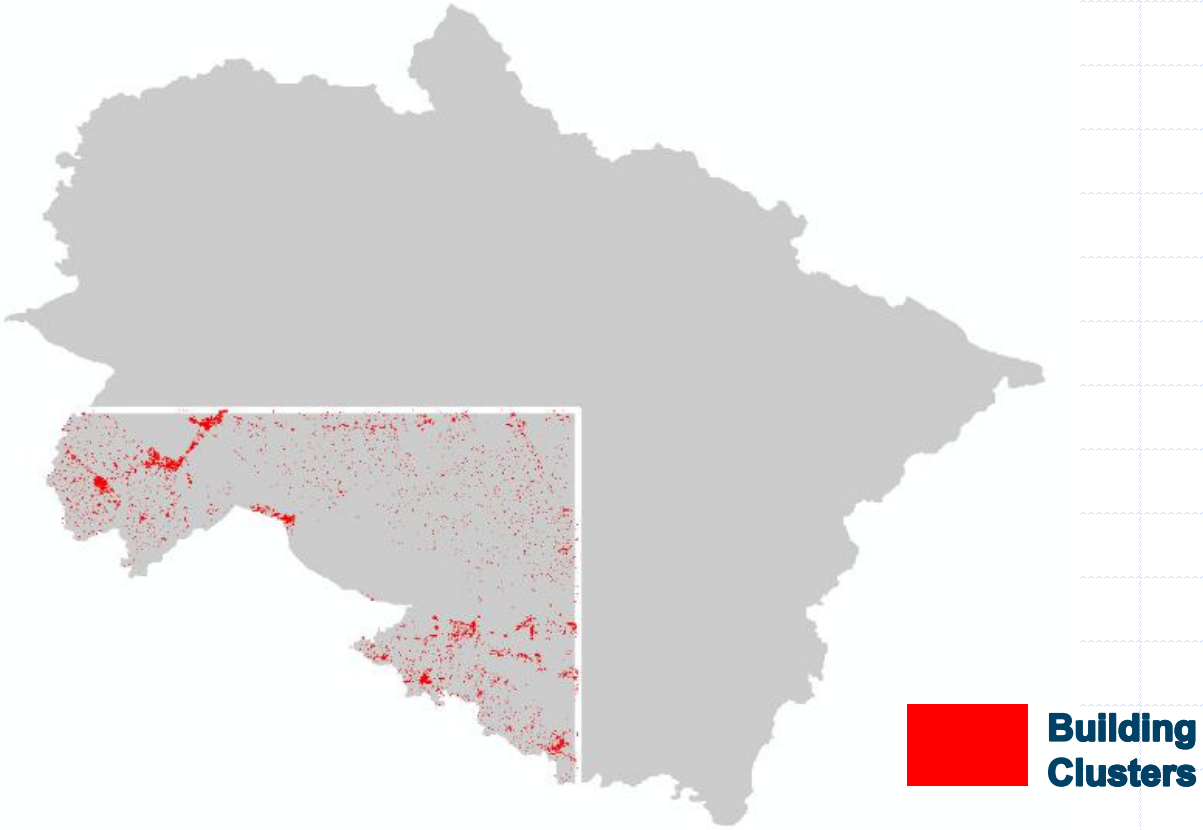


Landslide Magnitude-Frequency distribution

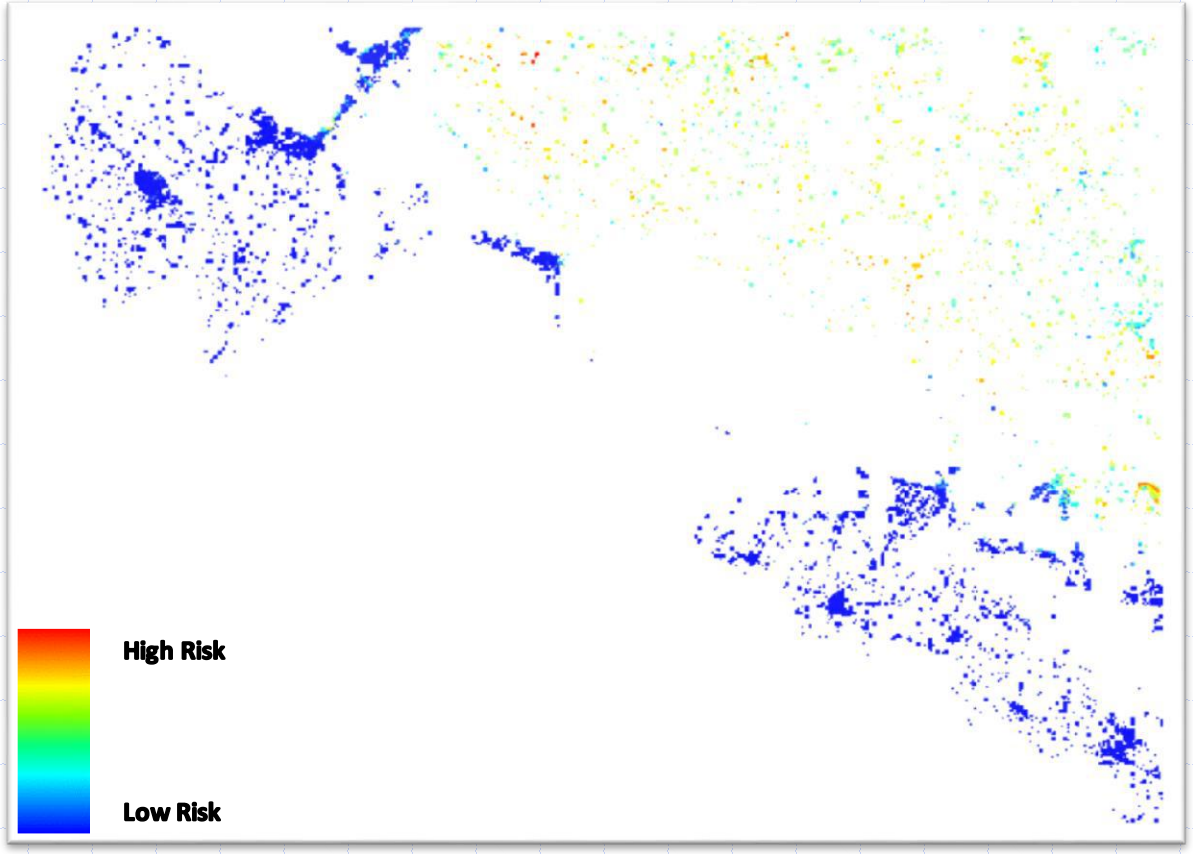
- Developed based on the one GSI report



Preliminary results: Building clusters



Preliminary results: Landslide risk map



THANK YOU