Landslide Risk Management

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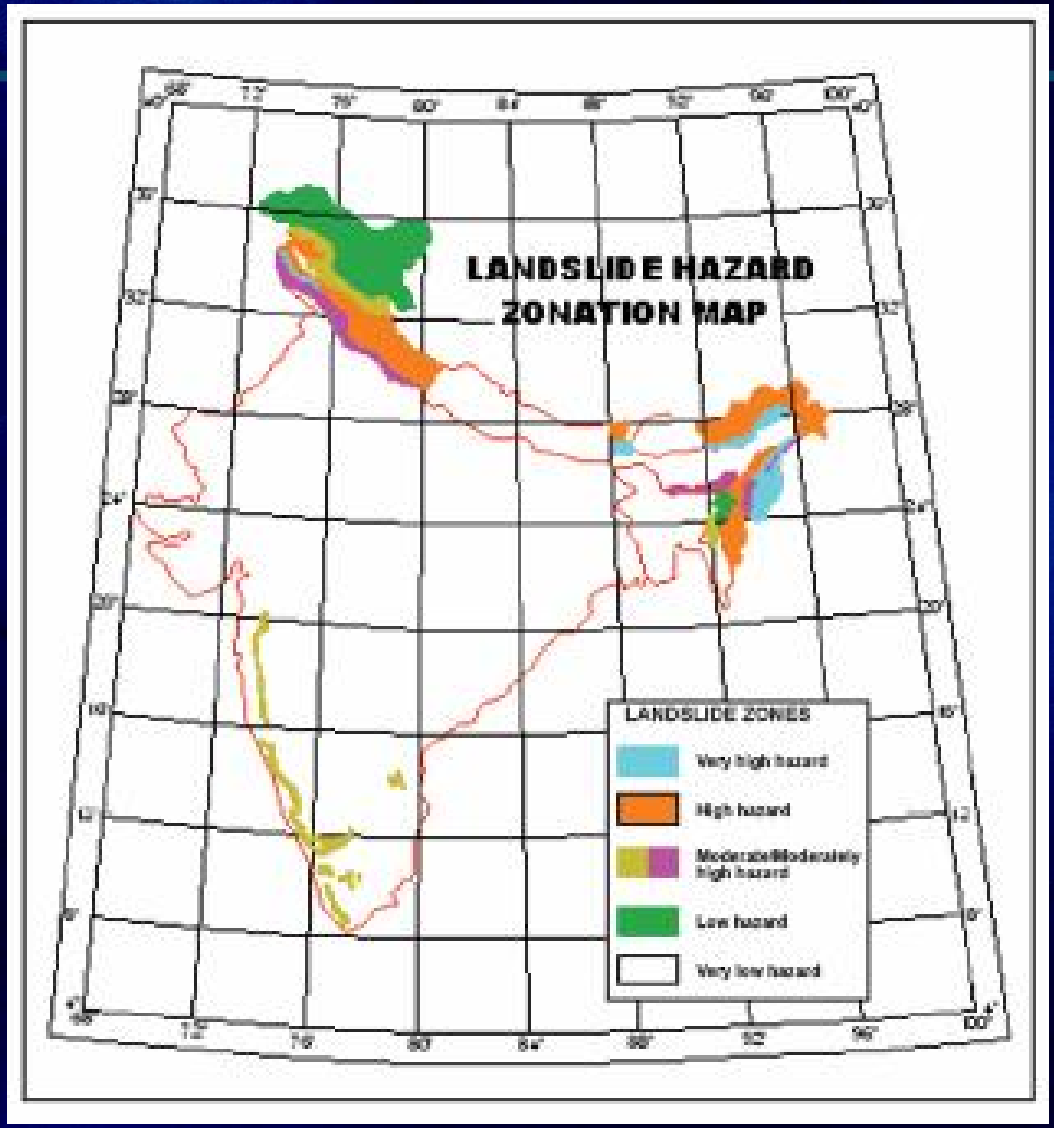
Landslide Hazard in India

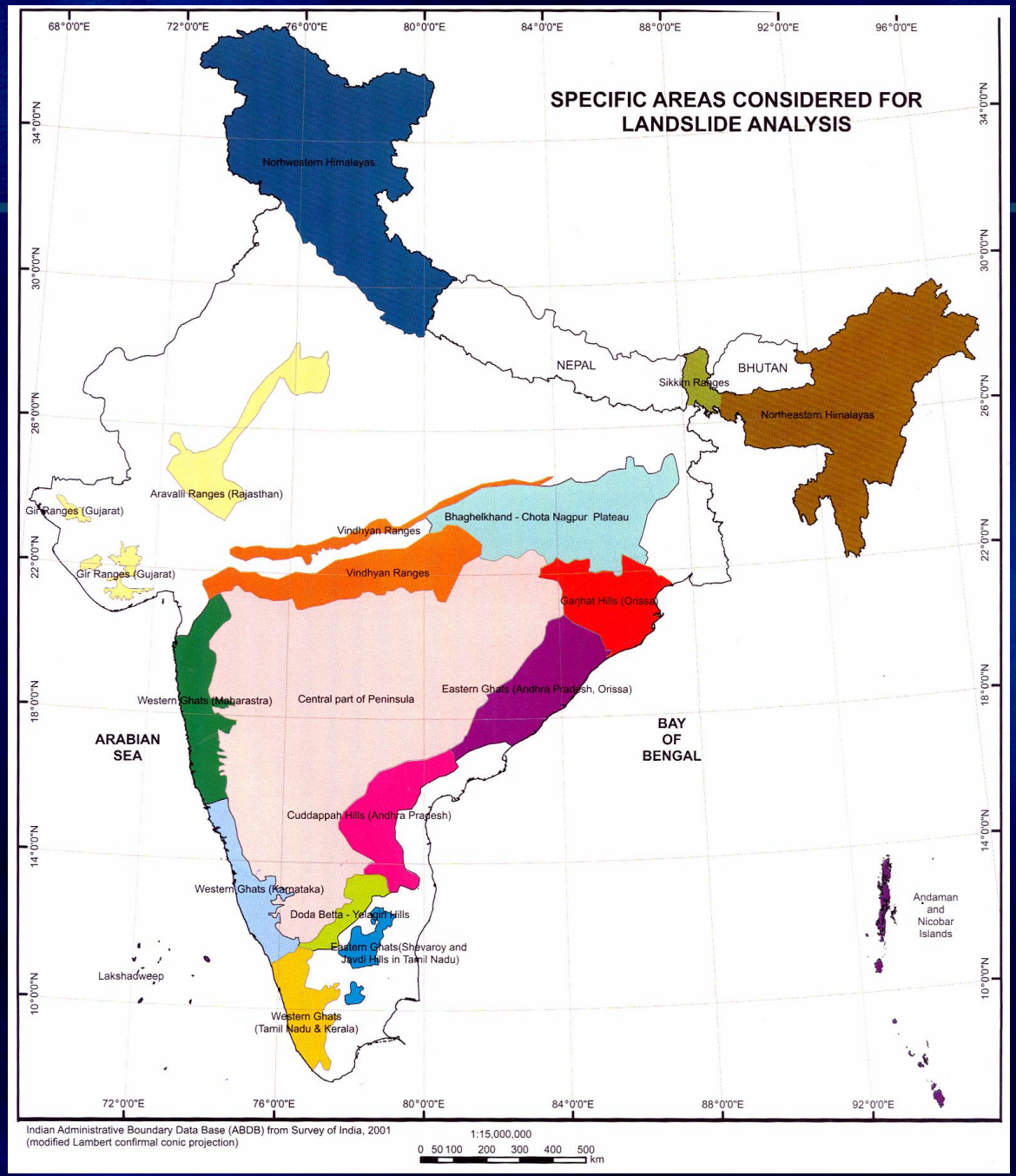
LANDSLIDE HAZARD ZONATION

Landslide Hazard Zonation (LHZ) simply means the division and preferably subdivision of a land surface into various zones according to the degrees of actual/ potential hazard caused by landslides and related phenomena



The earliest landslide studies in the country were carried out by the GSI.

This includes the study of the Nainital landslide by Sir R.D. Oldham in 1880 and C.S. Middlemiss in 1890.



SPECIFIC AREAS CONSIDERED FOR LANDSLIDE ANALYSIS

METHODOLOGY USED TO PRODUCE LANDSLIDE HAZARD ZONATION MAP OF INDIA

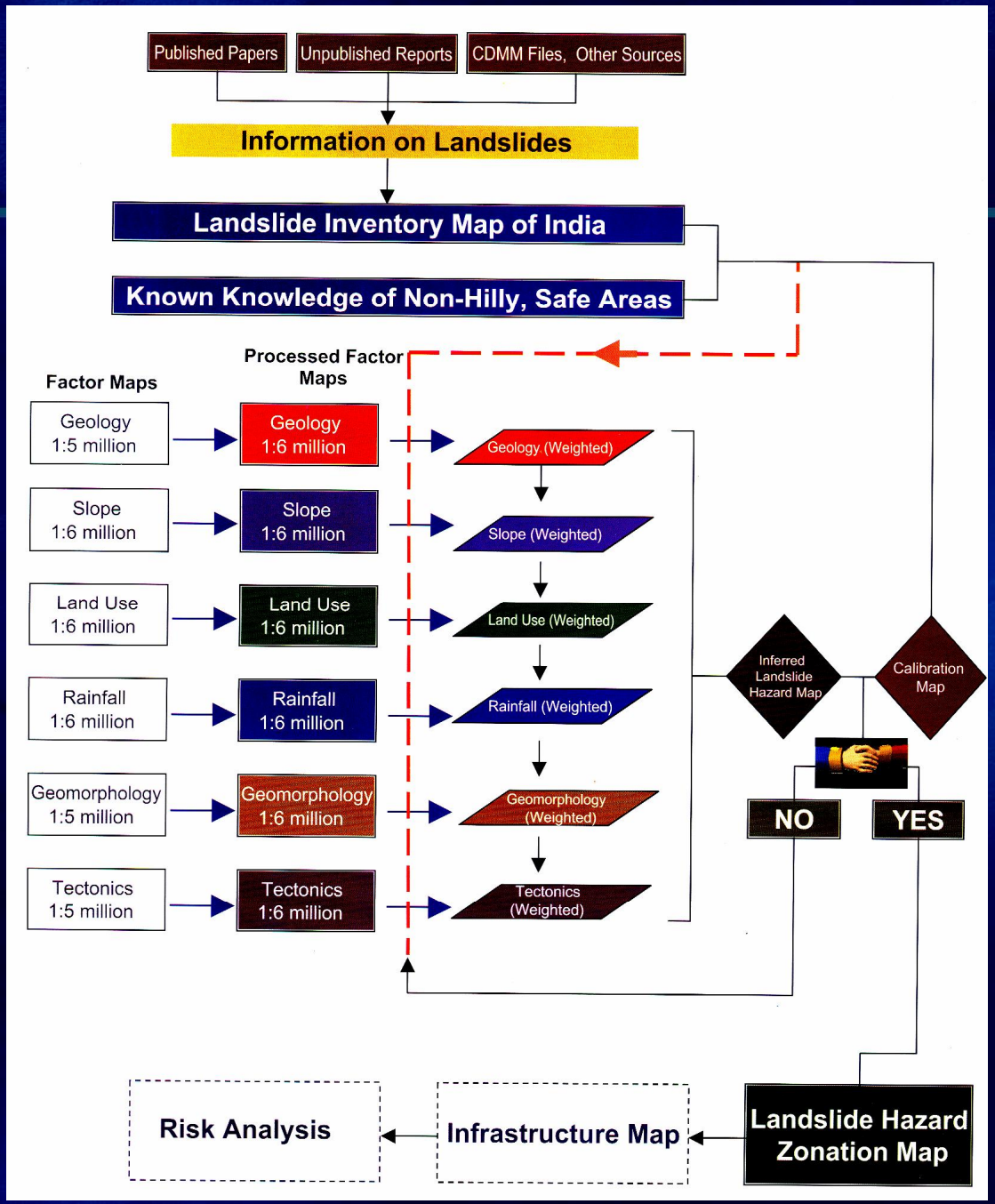


Table 3. Various Themes and their Labeled Units

(i) Slope

Unit No.	Slope Categories	Slope Angle
	Northwestern Himalayas & Peninsular India	
1	> 600 m/km	> 37°
2	300 - 600 m/km	37° - 17°
3	150 - 300 m/km	17° - 8°
4	80 - 150 m/km	8° - 4°
5	20 - 80 m/km	4° - 1°
6 - 11	10 - 20 m/km and less (elevation <100 m - >500 m above Mean Sea Level (MSL))	< 1°
	Northeastern Himalayas	
1	> 600 m/km	> 37°
2	300 - 600 m/km	37° - 17°
3	150 - 300 m/km	17° - 8°
4	20 - 80 m/km (elevation upto 100 m above MSL)	4° - 1°
5	20 - 80 m/km (elevation 100 m - 500 m above MSL)	4° - 1°
6	80 - 150 m/km	8° - 4°
7 - 12	10 - 20 m/km and less (elevation <100 m - >500 m above MSL)	< 1°
13	20 - 80 m/km (elevation over 500 m above MSL)	4° - 1°

vi) Annual Rainfall

Unit No.	Rainfall (mm) Categories
1	0 – 100
2	100 – 200
3	200 – 300
4	300 – 400
5	400 – 500
6	500 – 600
7	600 – 700
8	700 – 800
9	800 – 1000
10	1000 – 1200
11	1200 – 1400
12	1400 – 1600

Unit No.	Rainfall (mm) Categories
13	1600 – 2000
14	2000 – 2400
15	2400 – 2800
16	2800 – 3200
17	3200 – 4000
18	4000 – 4400
19	4400 – 4800
20	4800 – 6000
21	6000 – 8000
22	8000 – 10,000
23	> 10,000

GIS ANALYSIS

WEIGHT AND RANK

Weight decides the preference or priority of the one theme over another in a grid based analysis. For example slope is assigned 10 and the less contributing themes are assigned lesser weights within ten-point scale.

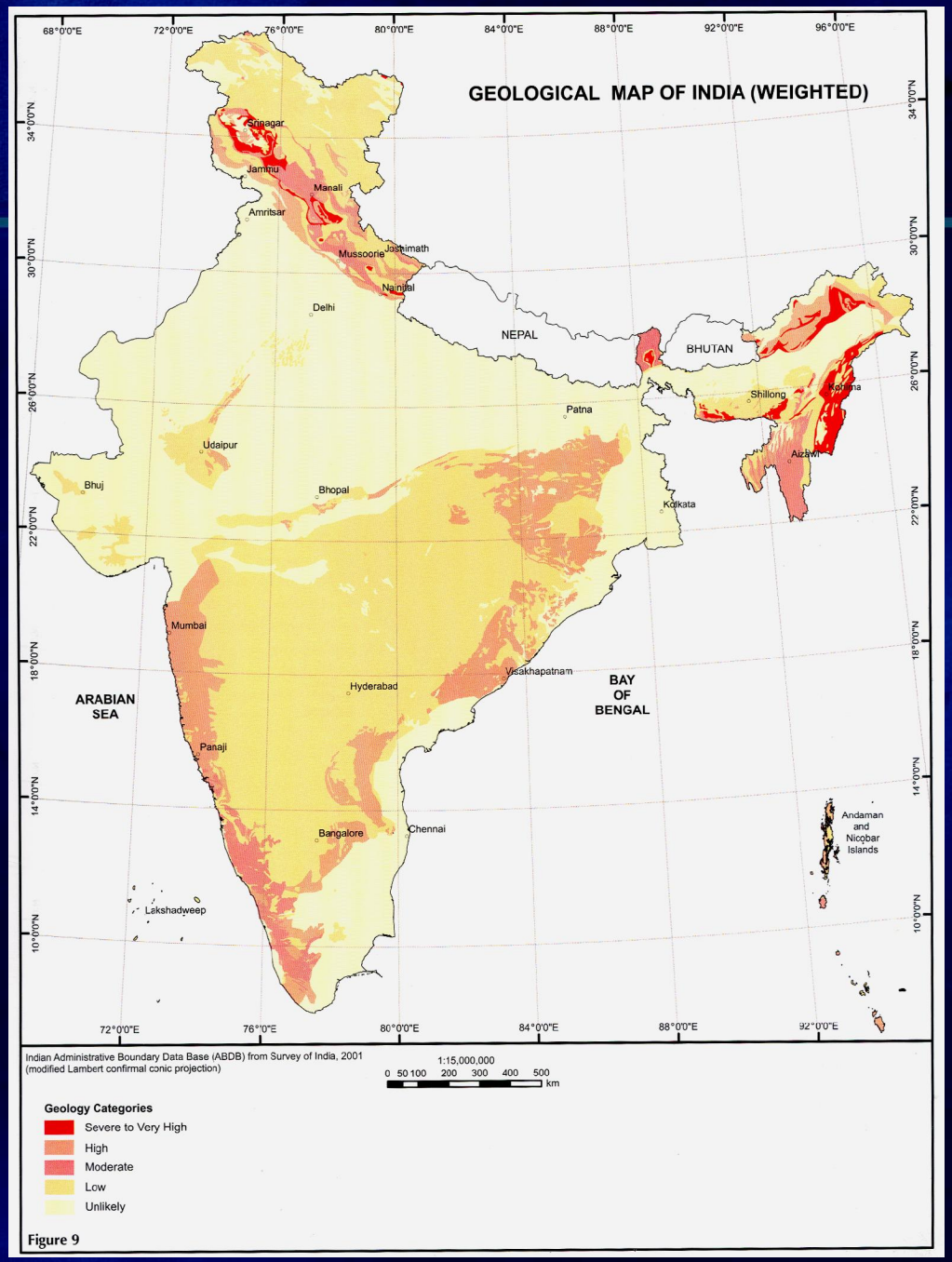
Rank decides the contribution of one unit over another within a theme. For example, high slope angle contributes more towards landslide susceptibility than low angle slopes.

A suitability scale ranging, in values from 1 to 5, was devised. The value of '1' was assigned to the lowest contributing unit in a particular theme and the highest contributing unit was assigned a value of '5'.

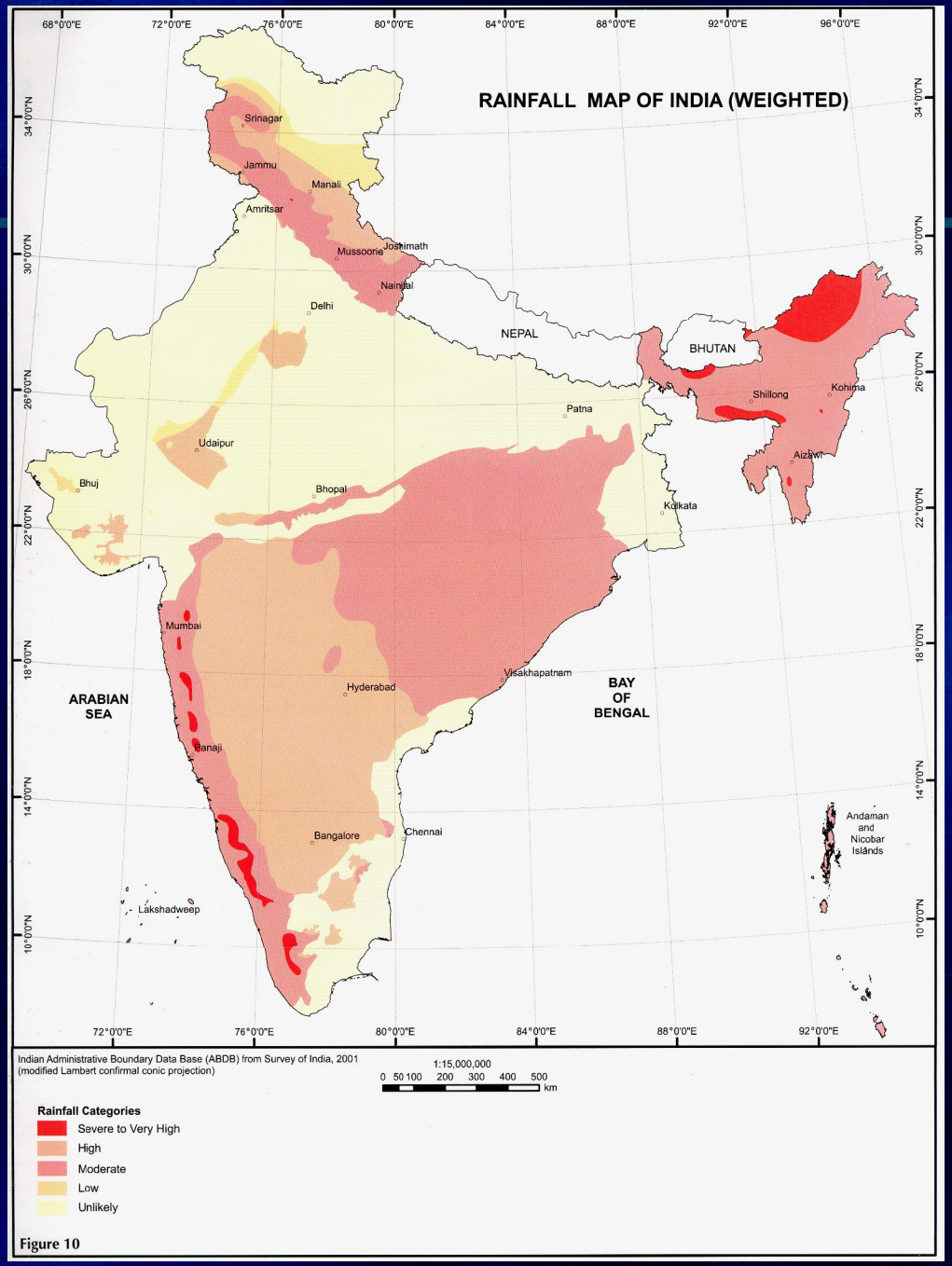
WEIGHT AND RANK

The weight values in a ten point scale and rank values from 1 to 5 help bring out the differences in contributions between the themes and between units within a theme during GIS analysis.

The rank and weightage values were also modified from region to region to achieve the best match between the reported landslide inventory of the region and the corresponding inferred landslide hazard zonation map.

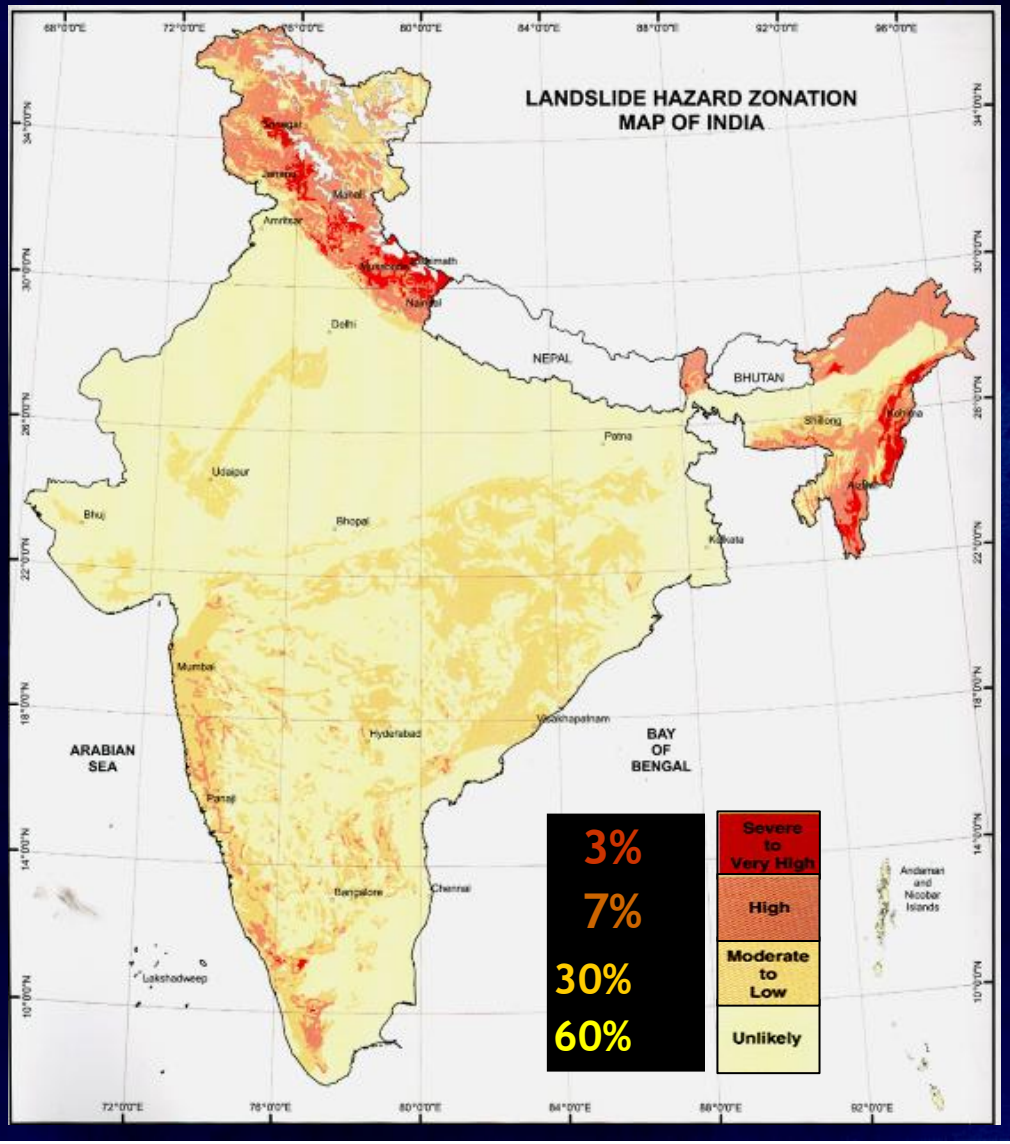


GEOLOGICAL MAP OF INDIA (WEIGHTED)



RAINFALL MAP OF INDIA (WEIGHTED)

Landslide Hazard Zonation Map of India



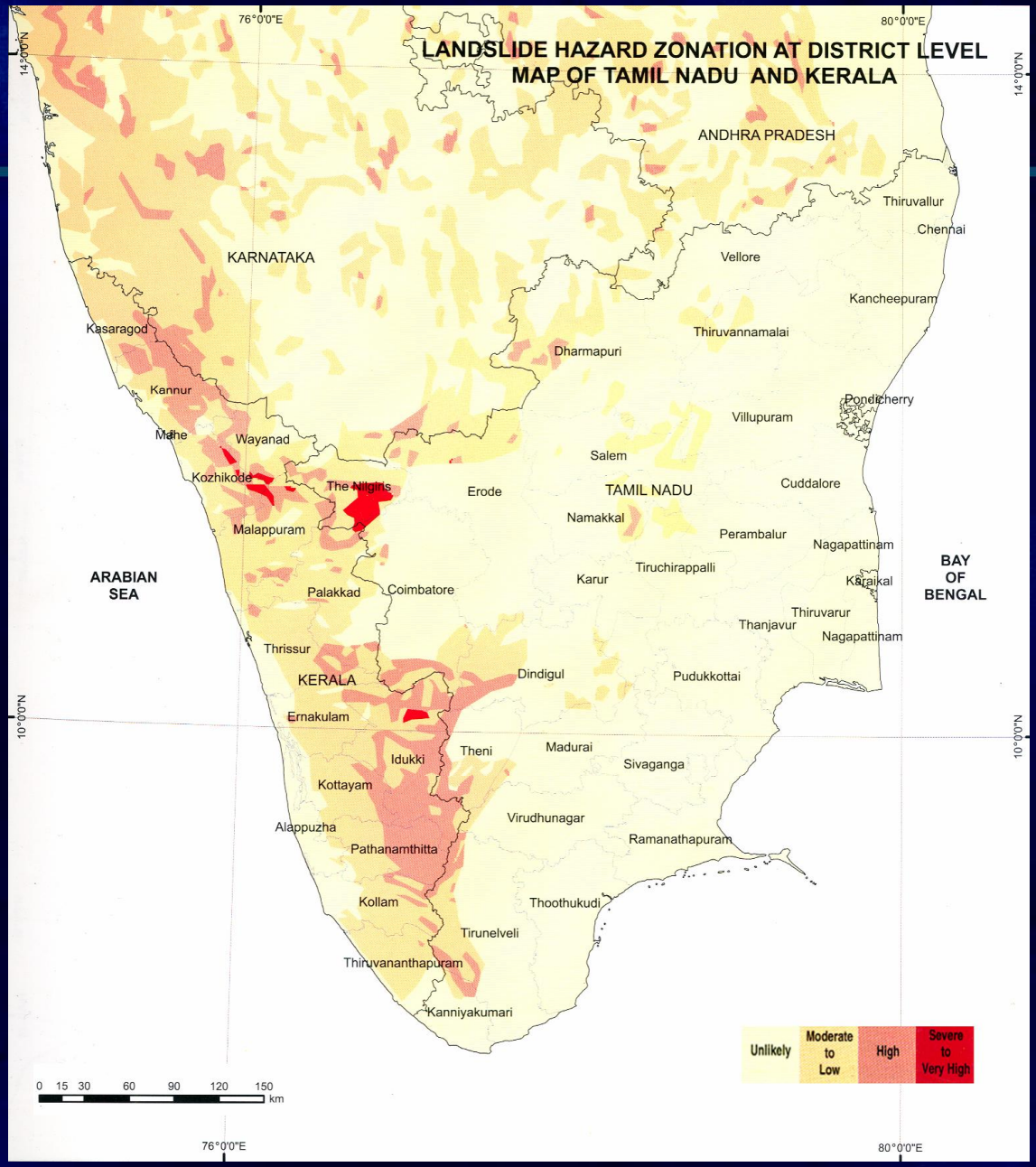
Landslide hazard zonal significance

Severe to Very High	The area is well known for the danger of landslides, and for the perennial threat to life and property. Restriction on all new constructions and adoption of improved land use and management practices deserve to be encouraged. Investments on landslide remediation measures, on public education and on early warning systems are strongly indicated.
High	This is a zone in which landslides have occurred in the past and are already to be expected in the future. New constructions in this zone should be strictly regulated and construction should be done only after proper site investigation and implementation of the appropriate remedial package. Before the new construction projects are cleared in this zone, environment impact assessment should be made mandatory.
Moderate to Low	Engineered and well-regulated new construction activities and well-planned agricultural practices could be permitted. All construction activities should, however be based on technically evaluated and certified plans by established institutions and authorized consultants.
Unlikely	No visible signs of slope instability are seen in this zone in the present state of knowledge. No blanket restriction needs to be imposed on various land use practices provided they conform to the prevailing building regulations and bye-laws. Location specific limitations may become necessary for high-density urban areas.

Agencies involved

- Geological Survey of India (GSI)
- Central Road Research Institute (CRRI)
- Central Building Research Institute (CBRI)
- Indian Institute of Technology, Roorkee (IIT-R)
- Wadia Institute of Himalayan Geology (WIHG)
- Department of Space (DoS)
- National Remote Sensing Centre (NRSC)
- Defence Terrain Research Laboratory (DTRL)
- Bureau of Indian Standards (BIS)
- some academic institutions, and individual experts.

Components of Landslide Disaster Management Process


LANDSLIDE HAZARD ZONATION AT DISTRICT LEVEL
MAP OF TAMIL NADU AND KERALA
76°0'0"E
80°0'0"E
14°0'0"N
10°0'0"N
ANDHRA PRADESH
KARNATAKA
TAMIL NADU
KERALA
ARABIAN SEA
BAY OF BENGAL
Thiruvallur
Chennai
Vellore
Kancheepuram
Thiruvannamalai
Dharmapuri
Kasaragod
Kannur
Mahe
Wayanad
Kozhikode
The Nilgiris
Erode
Villupuram
Pondicherry
Salem
Cuddalore
Namakkal
Perambalur
Nagapattinam
Malappuram
Tiruchirappalli
Karur
Karaikal
Palakkad
Coimbatore
Thiruvarur
Thanjavur
Nagapattinam
Thrissur
Dindigul
Pudukkottai
Ernakulam
Idukki
Theni
Madurai
Sivaganga
Kottayam
Virudhunagar
Alappuzha
Ramanathapuram
Pathanamthitta
Kollam
Thoothukudi
Tirunelveli
Thiruvananthapuram
Kanniyakumari
Unlikely
Moderate to Low
High
Severe to Very High
0 15 30 60 90 120 150
km

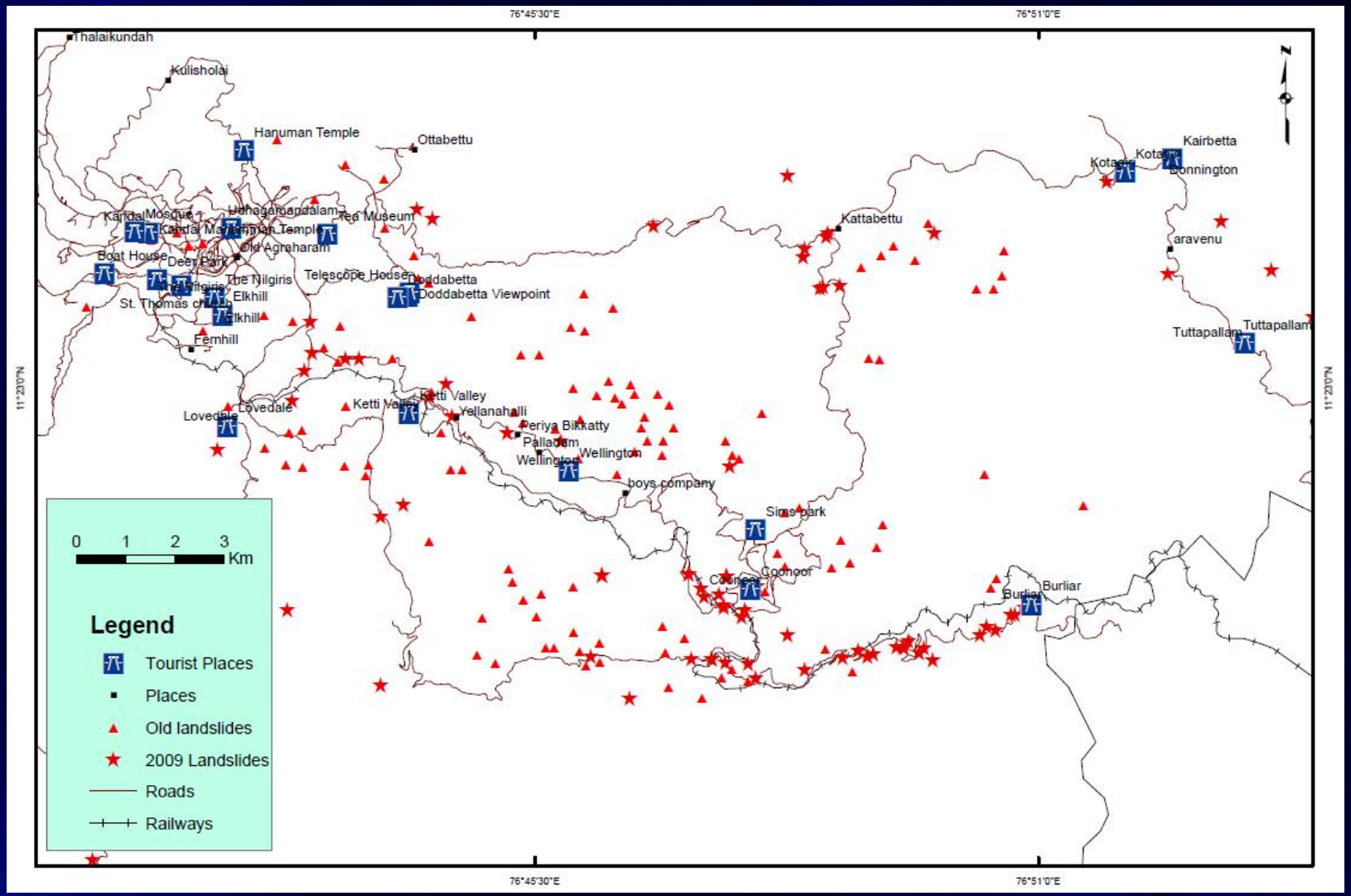
“You pay and talk for the mund”

Ootacamund

Landslide Occurrences Since 1865 in Nilgiris

23rd October 1865	Worst Storm on record occurred around ooty and Coonoor. Coonoor Railway station was covered with water up to five feet deep. In Ooty Lake rose up to top of willow bound and threatened to breach it.
November 1891	Storm caused many landslips on the Coonoor Ghat, and did great damage to the Kotagiri - Metuppalayam road.
December 1902	21 inches of rain (three times the average amount) fell in that month in Coonoor, and at Kotagiri 24 inches (six times the average amount) was received, of which 8.45 inches fell in a single night.
4th October 1905	6.8 inches of rain fell at Coonoor in three hours
5th November 1978	323 MM of rain was recorded at ooty of which 243 MM was during the night-between 5.00 pm of 4th and 8.00 am.
November 1979 300 LS	Heavy rainfall started from 12th November 1979 and the highest rain fall was 114.5 MM at Kodanad. On 13th it was 149.4 MM at Coonoor and 169.9 MM at Kodanad. On the 15th night heavy landslide had occurred at Doddacombai. The rainfall recorded at Coonoor and Kodanad was 145.2 Mm and 142.2 MM respectively. On 19th there was heavy landslide of 100 yards in width and about 1.00 K.M. in length in Selas of Ketti Village of Coonoor Taluk resulting in filling up of a Valley of 30' - 50'. The heaviest rainfall of the day was 187.6 MM at Coonoor. On 20.11.1979 also, there was heavy rain of 102.2 MM at Coonoor and a heavy landslide at Selas in which a house was completely buried in the debris along with 2 women and 3 children. The rainfall recorded on that day at Kotagiri, Kodanad and Kundah was 90.4 MM, 99.8 MM and 78.0 MM respectively. There was heavy rainfall of 71.0 MM at Devala on 21st. On 28.11.79 also there was heavy rain of 144.2 MM at Coonoor.
25th October 1990	The North East Monsoon was heavy and there was a 'cloud burst'. More than 35 families were buried alive in a place called Geddai.
November 1993	There was another 'cloud burst' on 11-11-1993 in the upper reach of Marappalam of Coonoor Taluk, about 18 huts situated below the road and washing away Coonoor MTP ghat Road for about 1 ½ k.m. The Road traffic was suspended for more than a fort night. 12 persons lost their live and 15 persons missing. It is laid that 21 passengers were washed away with two buses.
11th December 1998	Due to continuous rain fall, one big boulder weighing about 20mtonnes fell an the Coonoor Mettupalayam main road and the road was closed for traffic , the rock was blasted and earth slips were removed and traffic was resumed from 14-12-98.
December 2001	Due to continuous rainfall, two massive land slides occurred near pudukadu on the coonoor-Mettupalayam high way damaging two bridges resulting in the complete closure of traffic. In addition a closer damage was also caused to the railway track between coonoor - Mettupalayam . Bridge no 55 near hill grove railway station was completely damaged and Bridge No 56 was also damaged.

Landslide Occurrences Since 1865 in Nilgiris



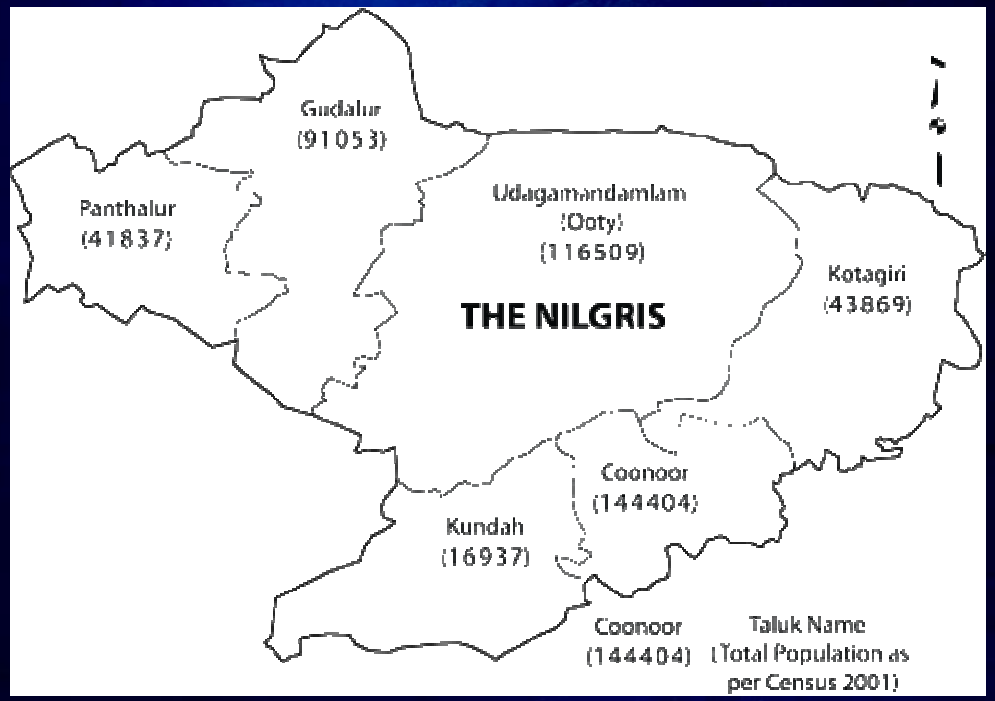
Population growth in Nilgiri District

Area : 2500Sq.km

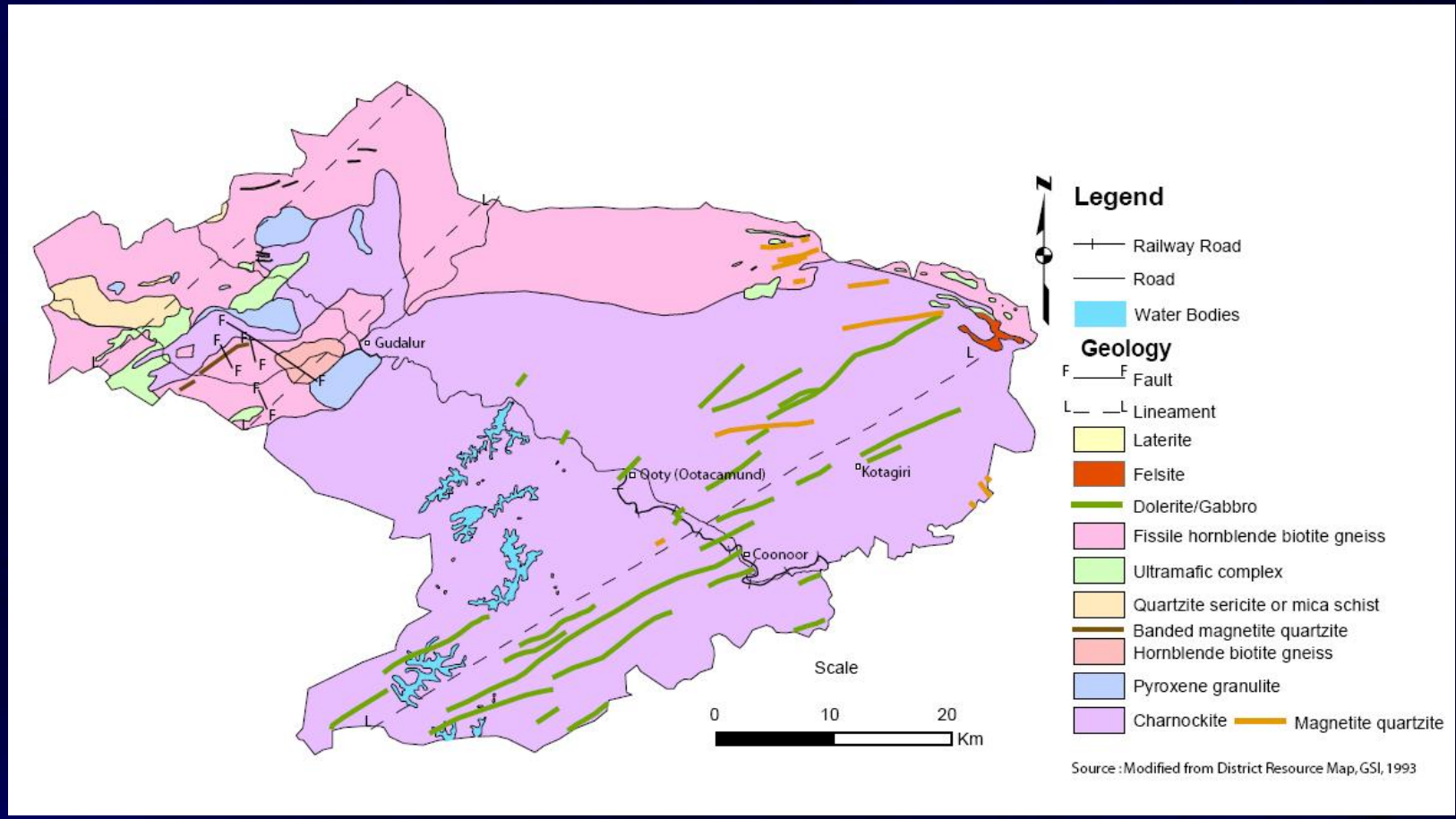
1901 **0.37 Lakhs**

Ootacamund	...	...	...	18596
Coonoor ...	...	...	...	8525
Wellington ...	...	...	...	4793
Kotagiri ...	...	...	...	5100

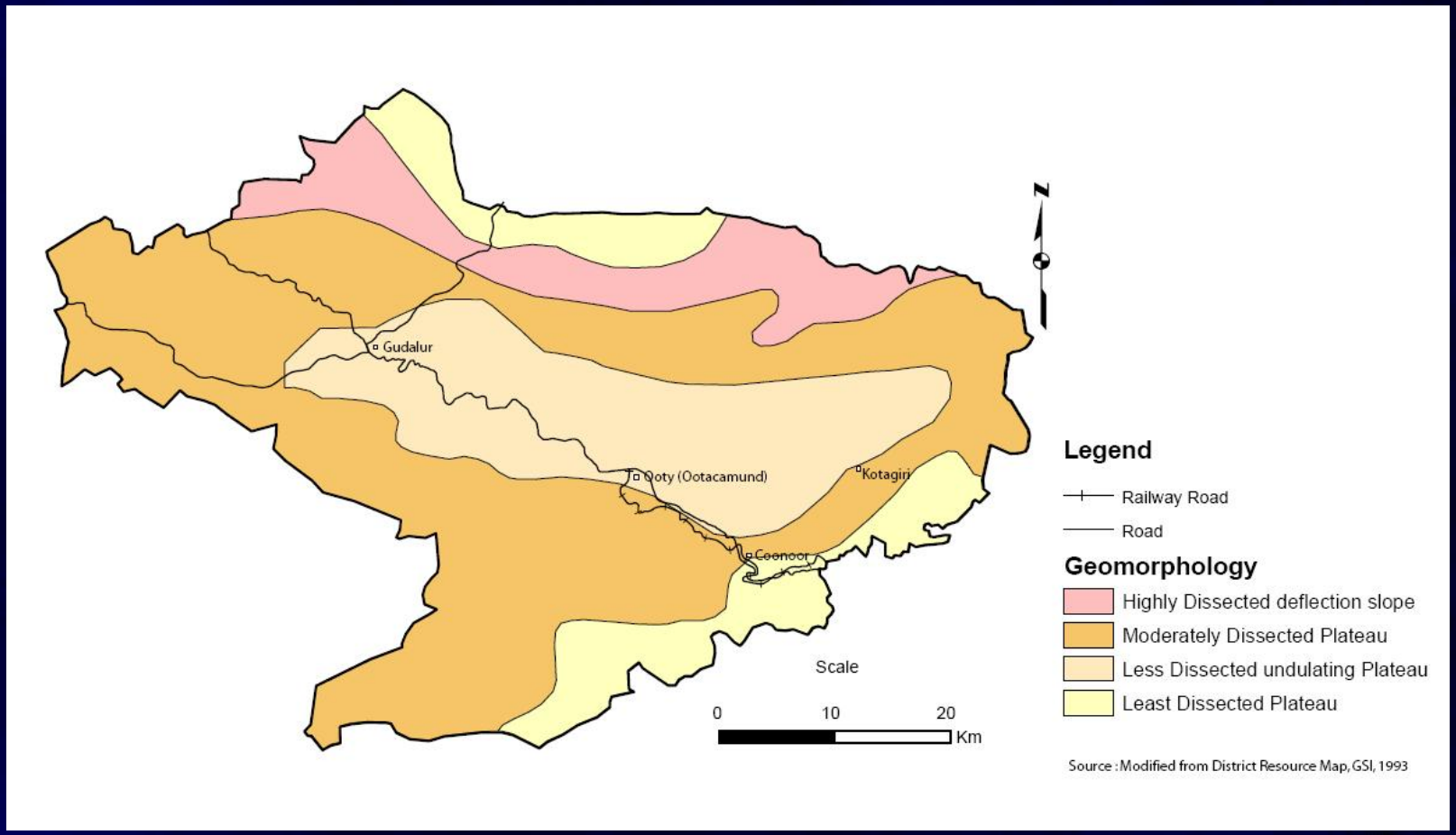
2001 **7.62 Lakhs**



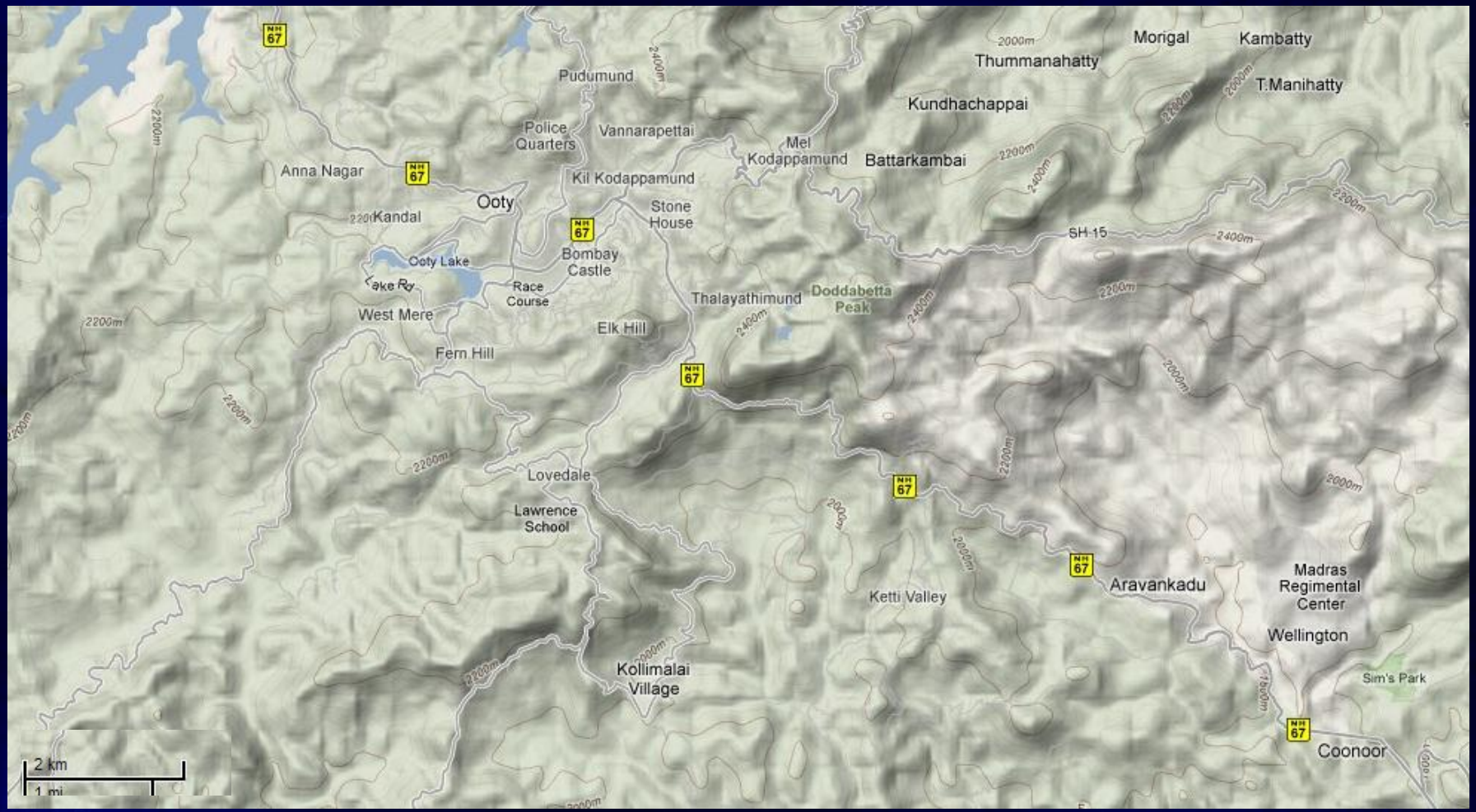
Geological Map



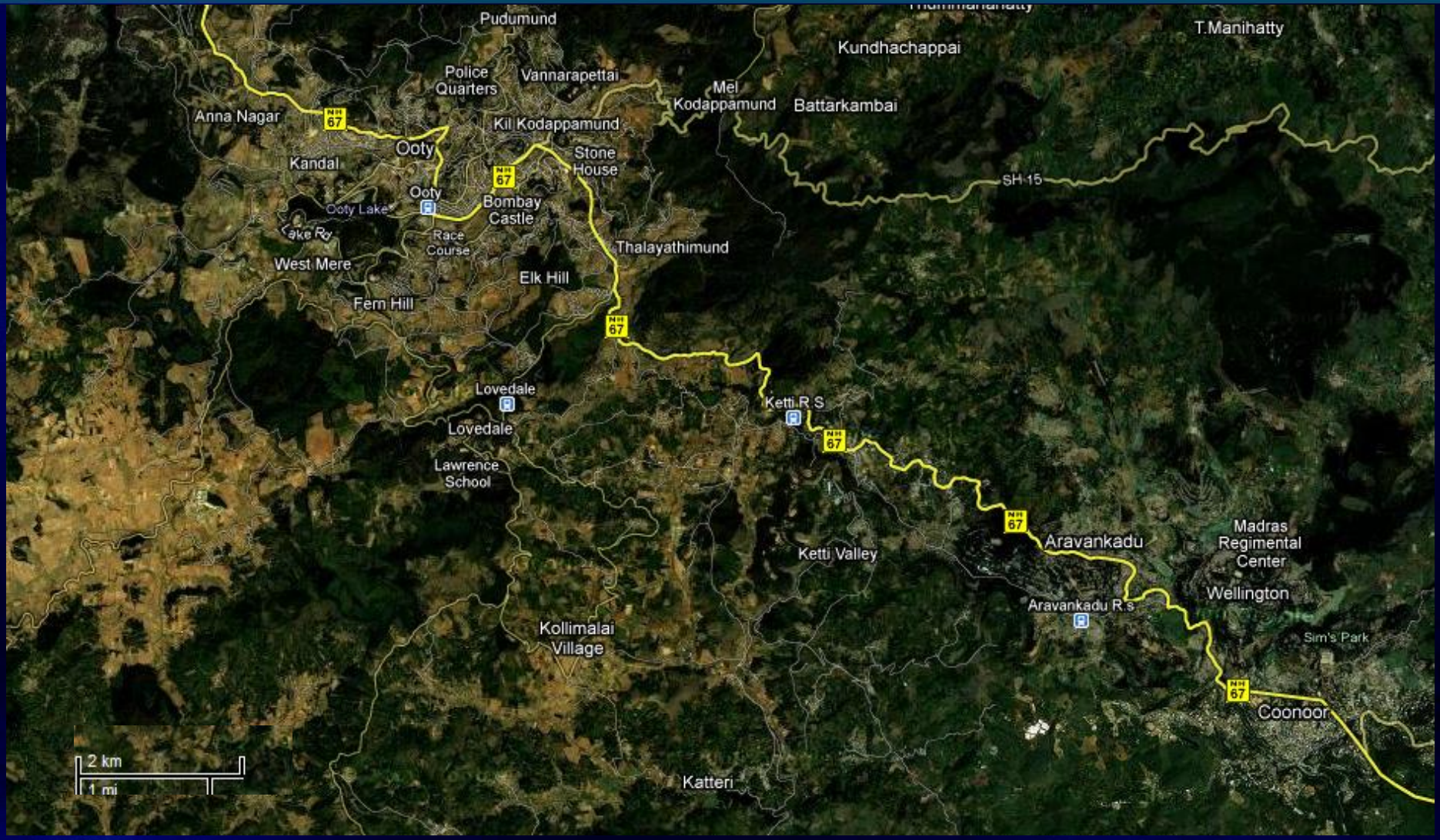
Geomorphological Map



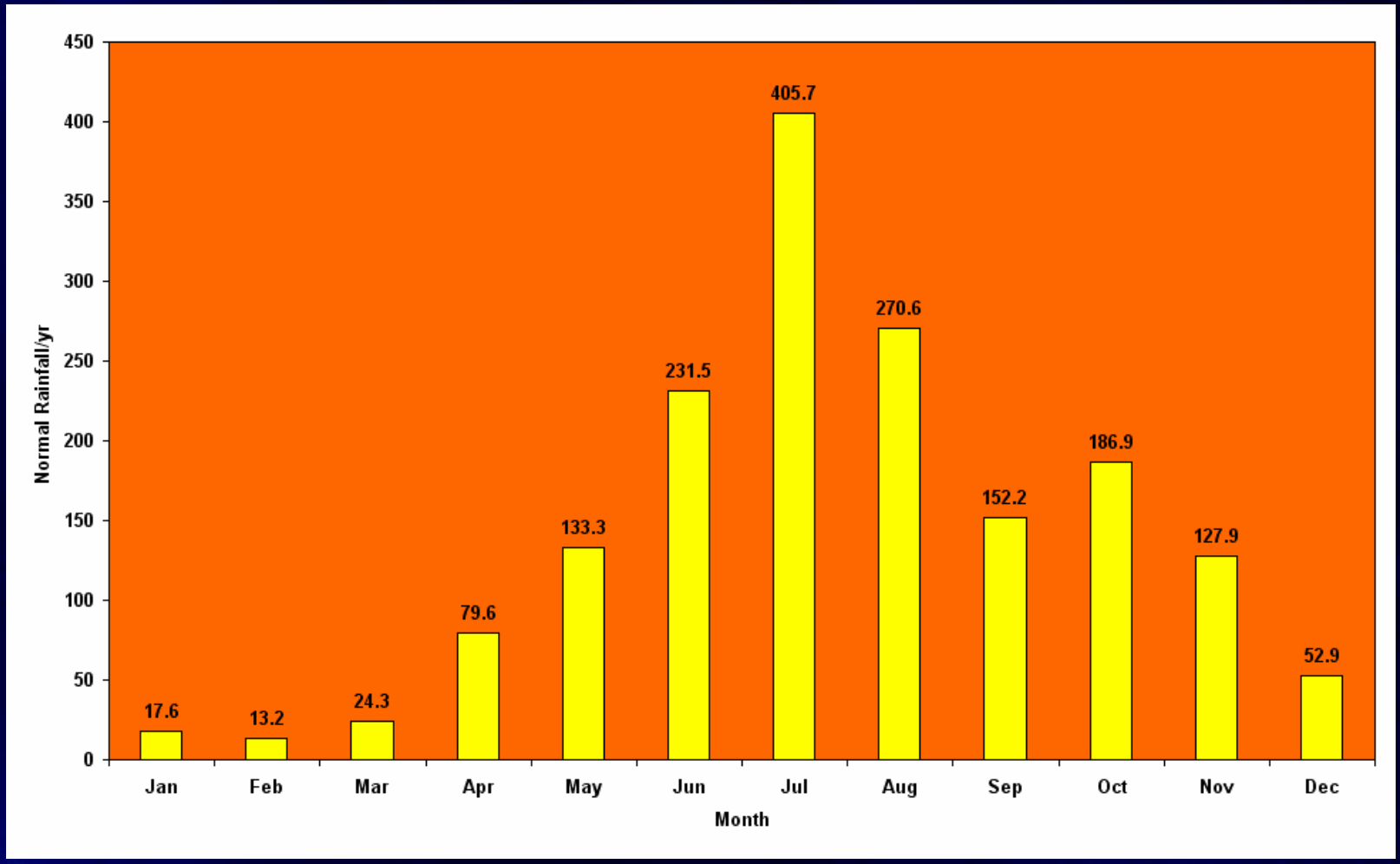
Topography - Coonoor to Ooty



Aerial view of Coonoor to Ooty



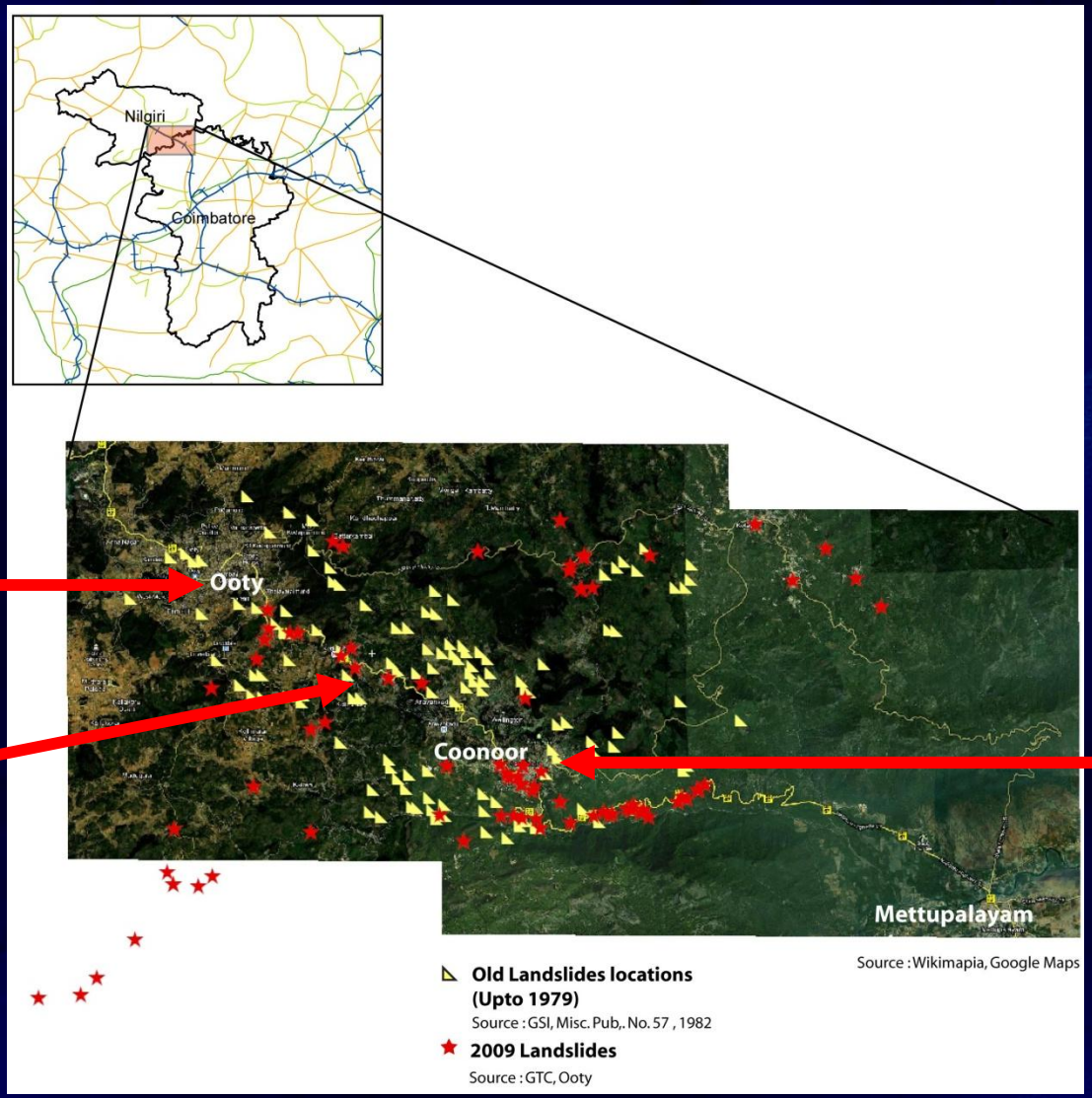
Monthly Normal Rainfall in Nilgiri District



November 2009 Landslides

- Heavy rains triggered a series of landslides in Ooty, Coonoor and Kotagiri regions of the Nilgiris
- Killed 42 people within 48 hours. Total Deaths 80.
- Estimated loss about 300 Crores

Spatial Distribution - November 2009 Landslides

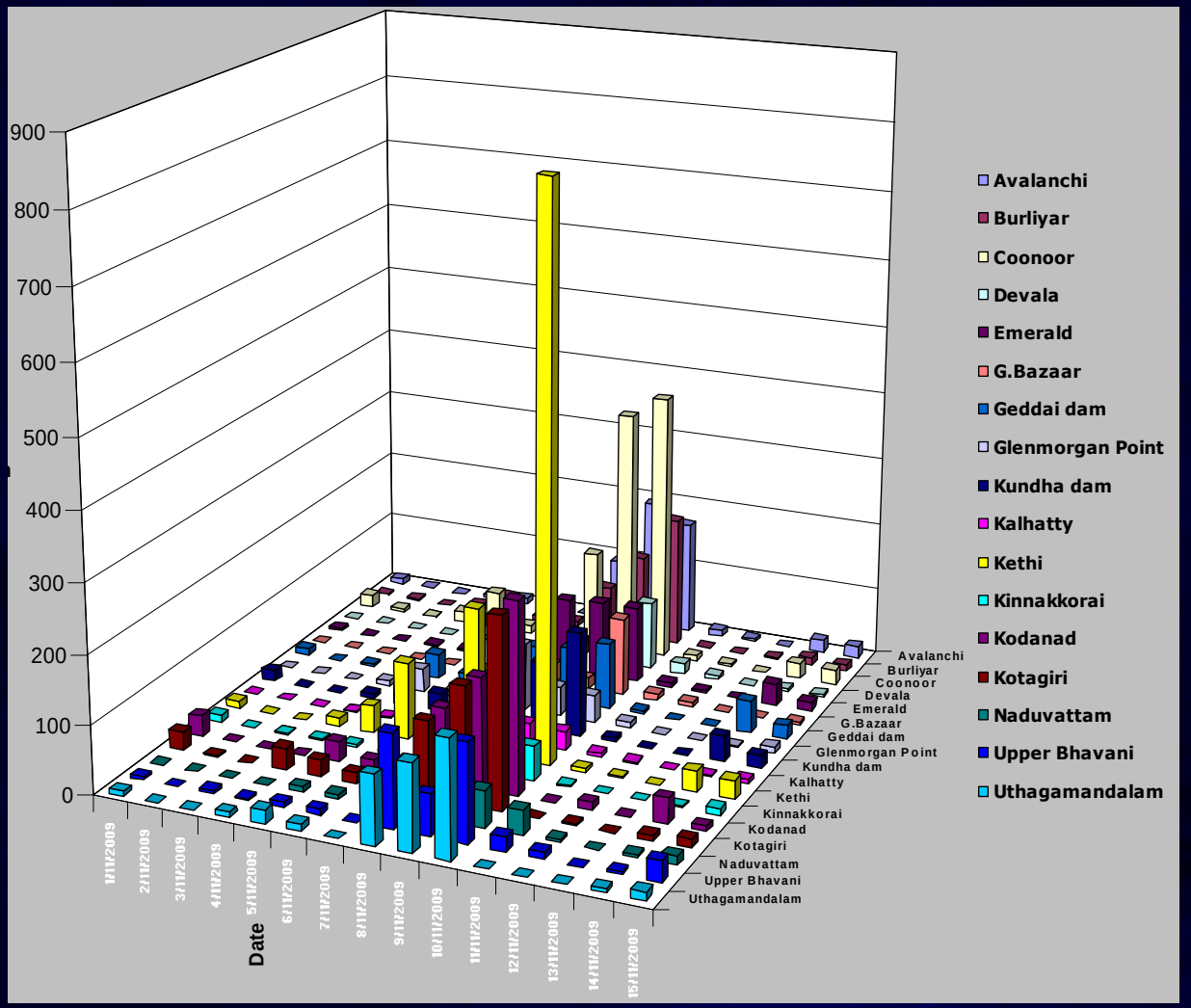


RF: 19cm

RF: 82cm

RF: 31cm

Daily Rainfall from 01 - 15 November 2009



November 2009 Landslides Lessons Learned

- Many slides have taken place in areas of intense cultural activity.
- agricultural operations,
- construction of buildings and roads
- removal of earth and rock
- levelling of slopes
- deforestation and
- blocking of natural drainage.

November 2009 Landslides Lessons Learned

Considering all these evidences the following factors appear to have been involved, singly or in combination, in inducing the landslides.

- Water (Heavy rainfall)
- Toe Removal
- Increase of Head Load

Lovedale Road view from Coonoor Road 10.11.2009

Increase of Head Load

Toe Removal

Water

Closer View

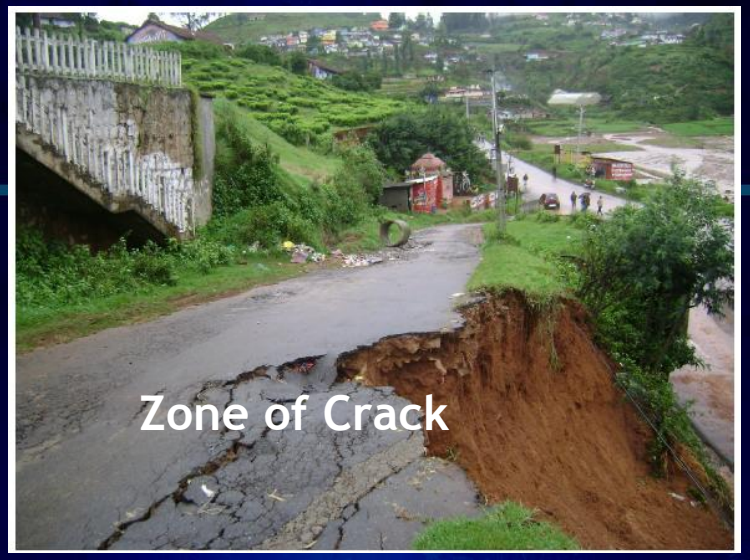
Closer View

Closer View

Lovedale Road View from Coonoor Road Landslide Scenario

10.11.2009

28.11.2009



Lovedale Road at Thalayattu Mandu on 10.11.09 top and bottom side showing the Zone of Crack and Zone of Failure

Houses built in the Stream Channel – Severe Damage at Naduhatti

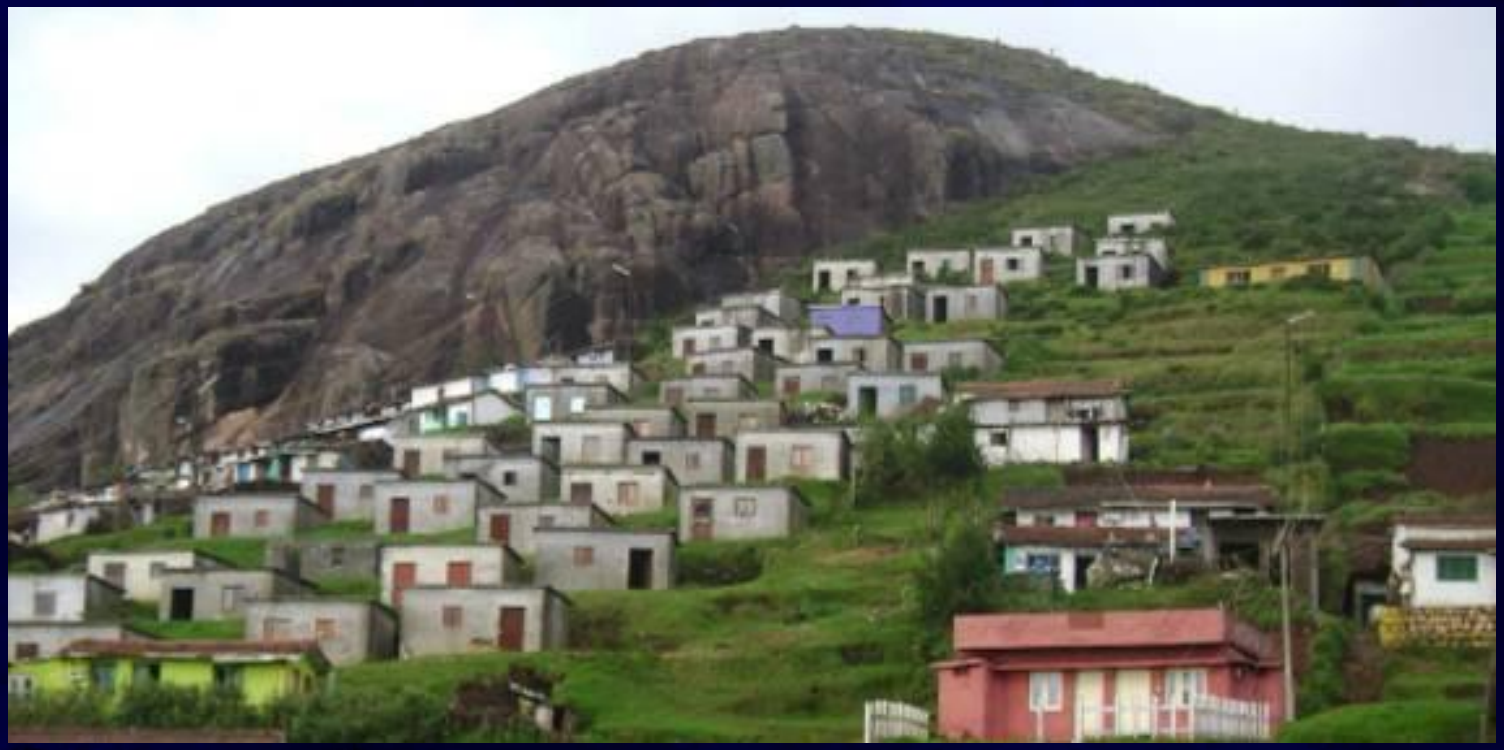
Debris covered at Naduhatti

Severely Damaged Road - Ooty Coonoor Road near Thalayattu Mund Junction.

Ooty Coonoor NH. 2 kms from Valley View point.
No way beyond this point.

Near Sagar Holiday Resorts, Valley View.

Unplanned colonization



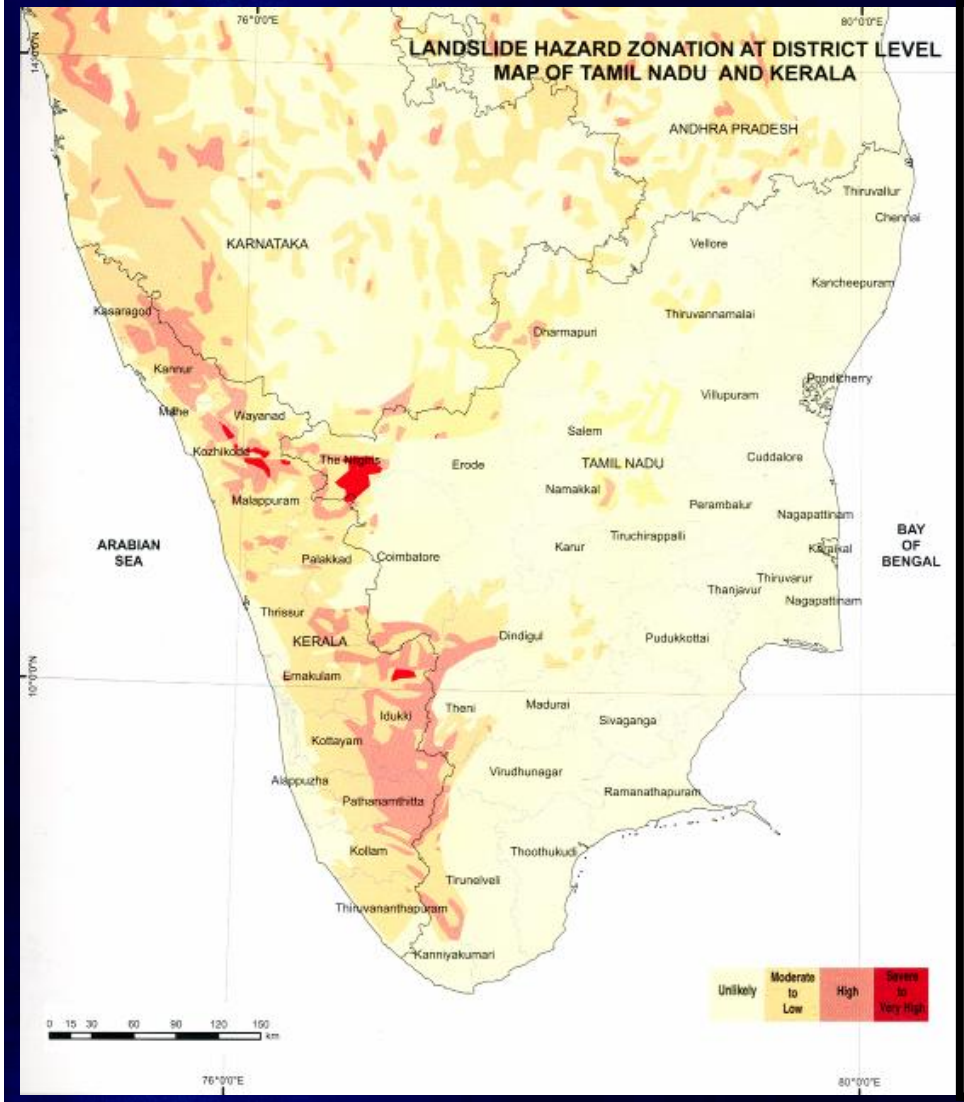
Lessons for the Planners and public

2009 landslides

Severe to High Landslide Areas identified by GSI in 1982

Landslide hazard zonal significance

(BMTPC, Landslide Hazard Zonation Atlas of India 2003)



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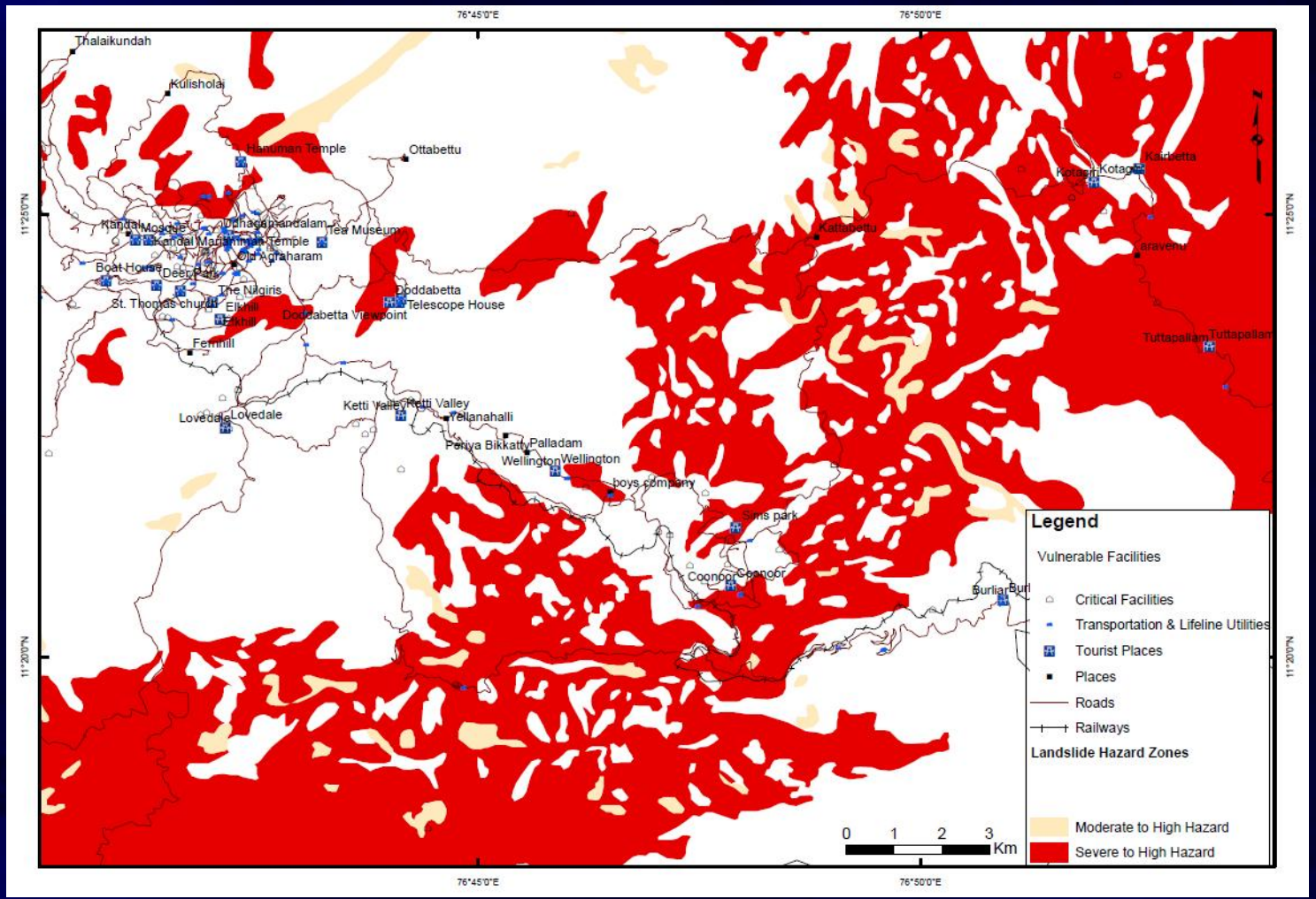
Vulnerability



Critical Facilities

1. **Essential facilities**

   hospitals, medical clinics, schools/educational institutions, fire stations, police stations and emergency operations facilities

2. **High potential loss facilities**

   dams, levees, military installations, nuclear power plants and hazardous material sites

Lifeline Inventory

1. Transportation

   highways, railways, bus, ports, ferry and airports

2. Lifeline Utility

   potable water, wastewater, natural gas, crude & refined oil, electric power and communications.

Vulnerability

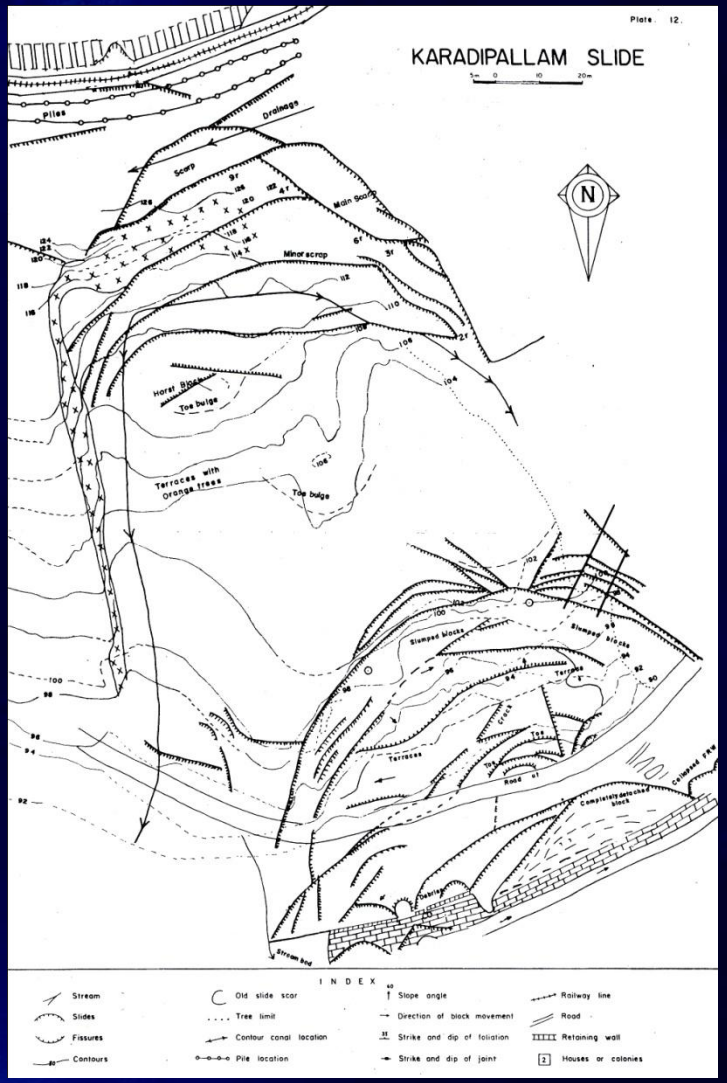
Sl.No	Facilities	Total	Falls Under High to Moderate Hazard Areas	Percentage
1	Essential	114	24	21%
2	Lifeline	96	7	7.3%
3	Transportation	20	6	30%
4	Village/Towns	42	7	16.7%

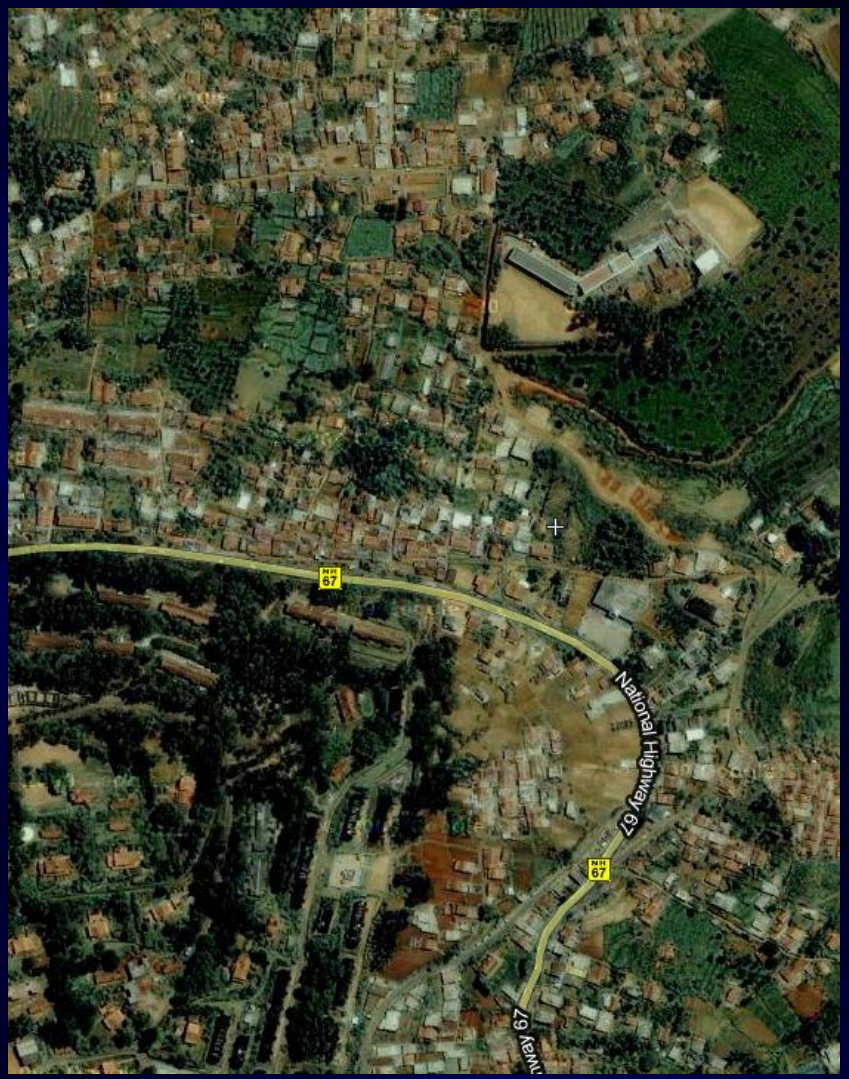
Dangerous Slopes

Blocking the Natural Draines

We Don’t Bother

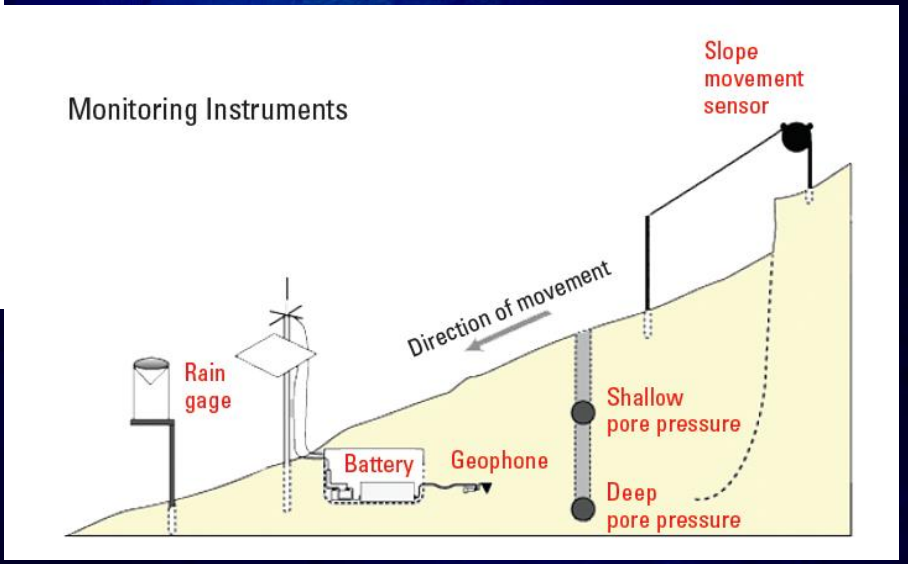
Understanding the Past and Present





Monitoring

Additional rain gauge stations may be installed in close interval and monitor the intense rainfall as well as the existing unstable slopes.



Recommendations

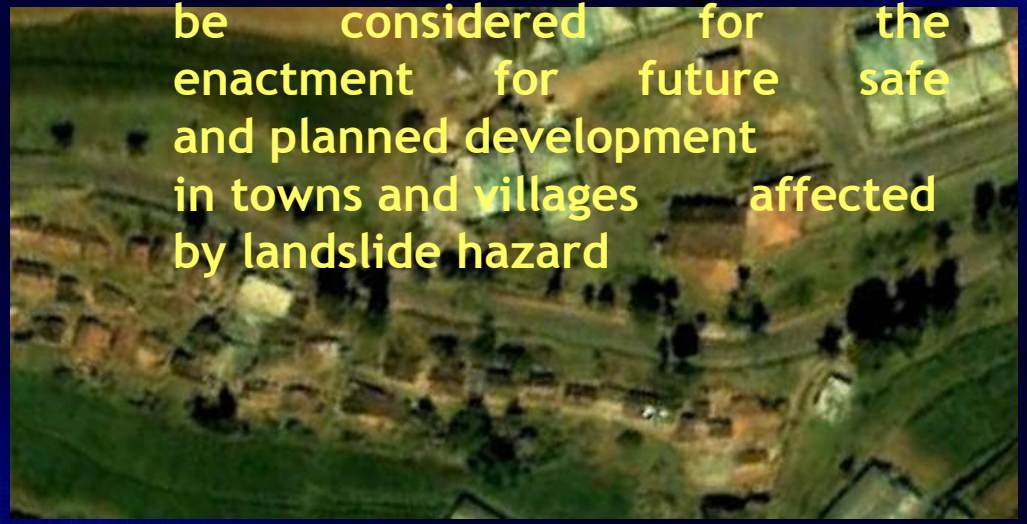
One of the most difficult problems concerning landslide hazards in place like Nilgiris is dealing with existing urban areas where buildings are constructed on or close to a landslide.

- avoid further development in high-risk landslide prone areas, limit existing-use rights to rebuild, and limit the use of buildings.

- avoid further development and use of buildings (building type) is consistent with the level of risk posed and the district plan maps clearly show landslide hazard zones.

Recommendations

- A detailed large scale risk map is required for further planning.
- Town planning bye-laws needs to be developed, which will translate and codify landslide concerns into village development.
- Appropriate legislation may be considered for the enactment for future safe and planned development in towns and villages affected by landslide hazard



Destination- Disaster Free India