AHP based landslide hazard assessment in a mountainous urban area of Dharamshala, Himachal Pradesh, India, using Remote Sensing technique

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About Arunachal GIS Info Solutions

- About: Govt. of Arunachal Pradesh proprietorship based firm
- Location: “Om Apartments”; “0” Point Tinali; Itanagar; Arunachal Pradesh. Post Box No: 294.
- Initiated in: 2012
- Nature of Work: Consultancy Services in the field of Remote Sensing, GIS, Surveying, & Information Technology.
- Staff Size: 1-15
- Projects handled so far: 3 (Ongoing) in collaboration with Department of Science and Technology; Govt. of Arunachal Pradesh & NEC GOI Shillong.
- Upcoming projects in fields: Geo-environmental Geoinformatics; Agriculture & Forestry; Urban & Regional Planning; Watershed Management.

Introduction

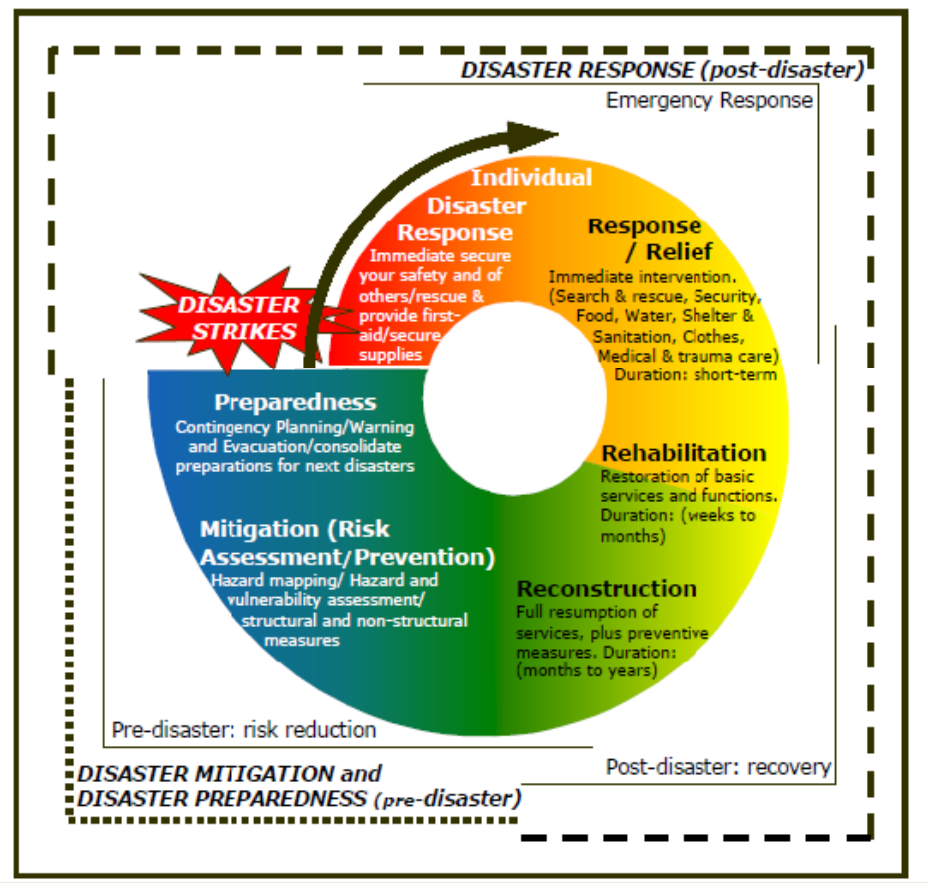
- Human Society and Natural environment is getting increasingly Vulnerable to natural Hazards and Disaster. In the last two decades, over 3 million people have been killed due to natural disasters in the world.

- There have been three times increase in losses in the past ten years compared to 1960's. Consequently, great increase in economic and human losses

- Himalayan belt has been so seismo-tectonically active, that there are frequent natural disasters and have become a part of everyday life, continually testing the resiliency of a resilient people.

- "*Nevertheless, we should be proud of the science-based progress that has recently been made in dealing with the inevitable risks that Himalayan region experiences……*. (Choudhury, 1999).

Introduction(contd....)



- Just a general study of the Landslide, Earthquake, Flood and allied hazard is of less impact, unless and until the susceptibility of a place to hazard, or the vulnerability of a society to hazard crops in.
- Thus the basic keywords are Susceptibility of a location to a hazard and Vulnerability of a society to Natural hazard .

Why I have selected Dharamshala for Study?

- The Mountainous Urban area of Dharamshala is highly susceptible to the natural hazards like landslides etc.

- Every year a large amount of property loss is sustained in the form of road damage, water supply disruptions, telephone transmission lines ,electric lines, forest, settlement areas and agricultural lands, recreational spots, commercial building. Sometimes such losses go undocumented.
- The massive landslides of 1967, 1976, 1978, 1997,1998,1999,2008,2010,etc have resulted in huge amount of property and catastrophic losses.

Research Hypothesis

A. The entire study area is under threat of landslide hazards.

B. The incidences of slope failures are more in the areas of high slopes.

C. The hydrological factors like infiltration, drainage density, and distance from stream, water movement etc directly influences landslide occurrences.

D. The population, built up area, urban sewerage etc have increased considerably over the last few decades, which further aggravates the situation.

E. The region is lacking from proper landslide hazard inventory and needs to be generated for effective disaster mitigation measures.

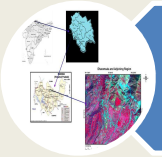
Research Questions?

- **The main Research Questions of the study includes-**

- ❑ What are the reasons of triggering landslides in the study area?
- ❑ What are the lithological, hydrological, morphological and tectonic conditions in which landslides are more likely to happen in the study area?
- ❑ Which are the areas susceptible to landslide?
- ❑ Apart from these, there area some subject specific questions.

OBJECTIVES OF THE STUDY

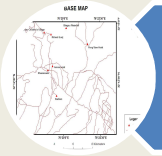
Geomorphological, Geological and Geo-Structural study of mountainous urban area of Dharamshala.



To understand and identify the major factor of landslide occurrences in Dharamsala.

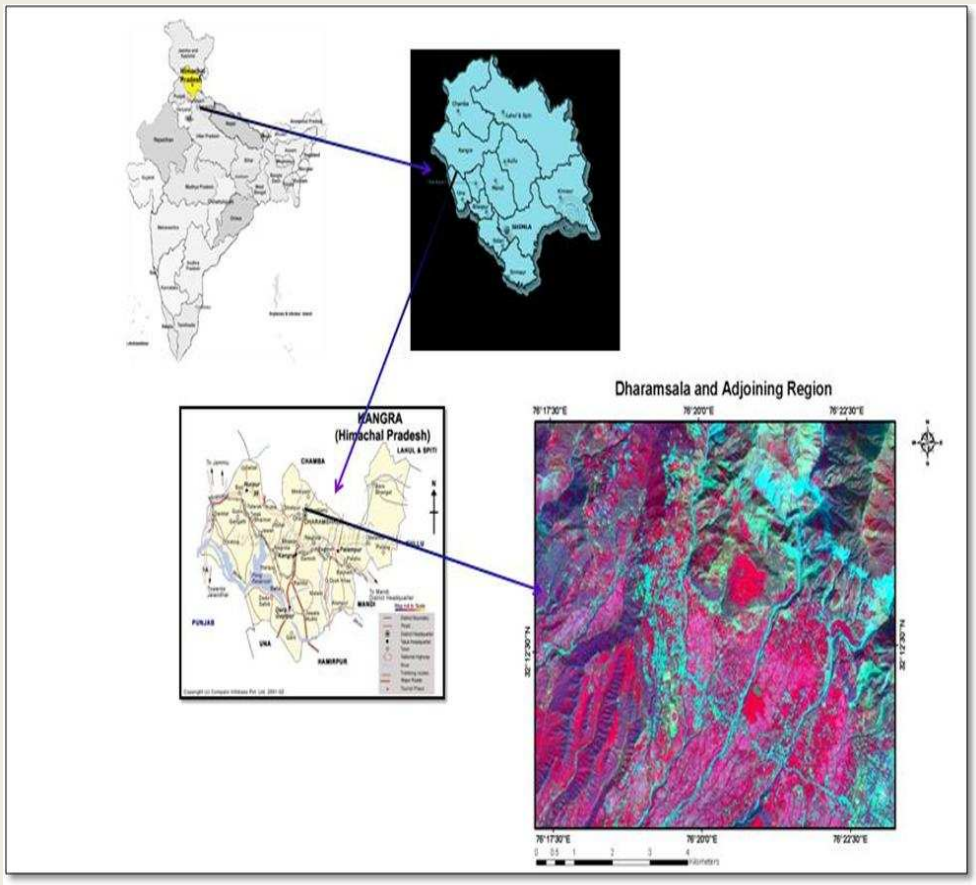
To identify and evaluate the expansion of built up land in the area.

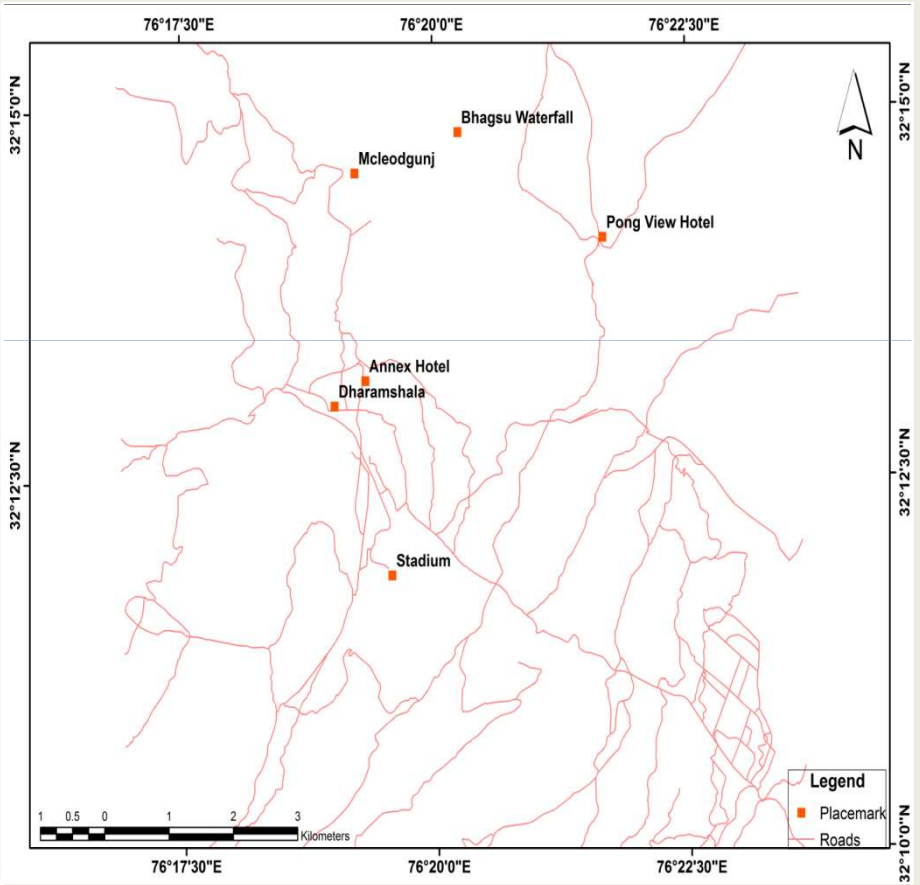
To identify and zonalise the study area into different landslide susceptibility zones and to estimate their hazard potential.



To generate the Settlement Density and urban expansion Inventory.

Do You Know this Place? This is Dharamshala,Himachal Pradesh





Review of Literature

- Akgun A, Bulut F (2007). GIS-based landslide susceptibility for Arsin- Yomra (Trabzon, North Turkey) region. Environmental Geology Online first.
- Akgun A, Dag S, Bulut F (2007). Landslide susceptibility mapping for a landslide-prone area (Findikli, NE of Turkey) by likelihood-frequency ratio and weighted linear combination models. Environmental Geology Online first.
- Bhandari, R.K. and Sreenivasulu, V. "Some New Instruments for Landslide Studies". Proceedings of the third International Symposium on Landslides, New Delhi, 1 (1980),343-348.
- Donati L, Turrini MC (2002). An objective method to rank the importance of the factors predisposing to landslides with the GIS methodology: application to an area of the Apennines (Valnerina; Perugia, Italy). Engr. Geol. 63, 277– 289.
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Review of Literature(contd…)

❖Esmali and H. Ahmadi, “Using GIS & RS in mass movements hazard zonation – A case study in Germichay watershed, Aderbil,Iran,” Proc. Map Asia 2003, Kuala Lumpur (Malaysia), 13-15 October, 2003.

❖V. Vapnik, The Nature of Statistical Learning Theory, 2nd ed. Springer-Verlag, New York (USA), 1995, pp 138-167.

❖Belousov, S. A. Verzakov, J. Von Frese, “Applicational aspects of support vector machines,” J. Chemom, vol. 16, pp 482-489, 2002.

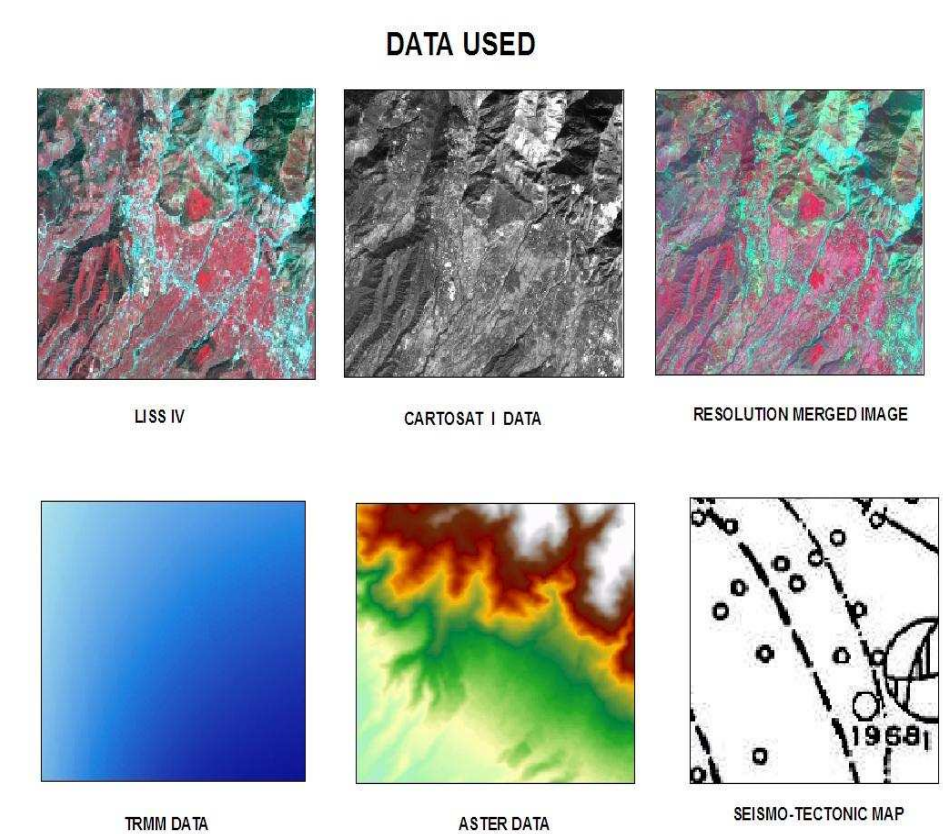
❖C. Van Westen et al, “Landslide hazard and risk zonation – Why is it still so difficult?”, Bull Eng Geol Environ, vol. 65, pp. 197-205, 2006.

❖V. Voženílek, “Landslide modeling for natural risk/hazard assessment with GIS,” Geographica, Acta Universitas Carolinae, vol. XXXV, pp. 145-155, 2000.

❖G. Ravi, Remote sensing Geology, Springer-Verlag, Berlin (Germany), 2002, pp. 429-583.

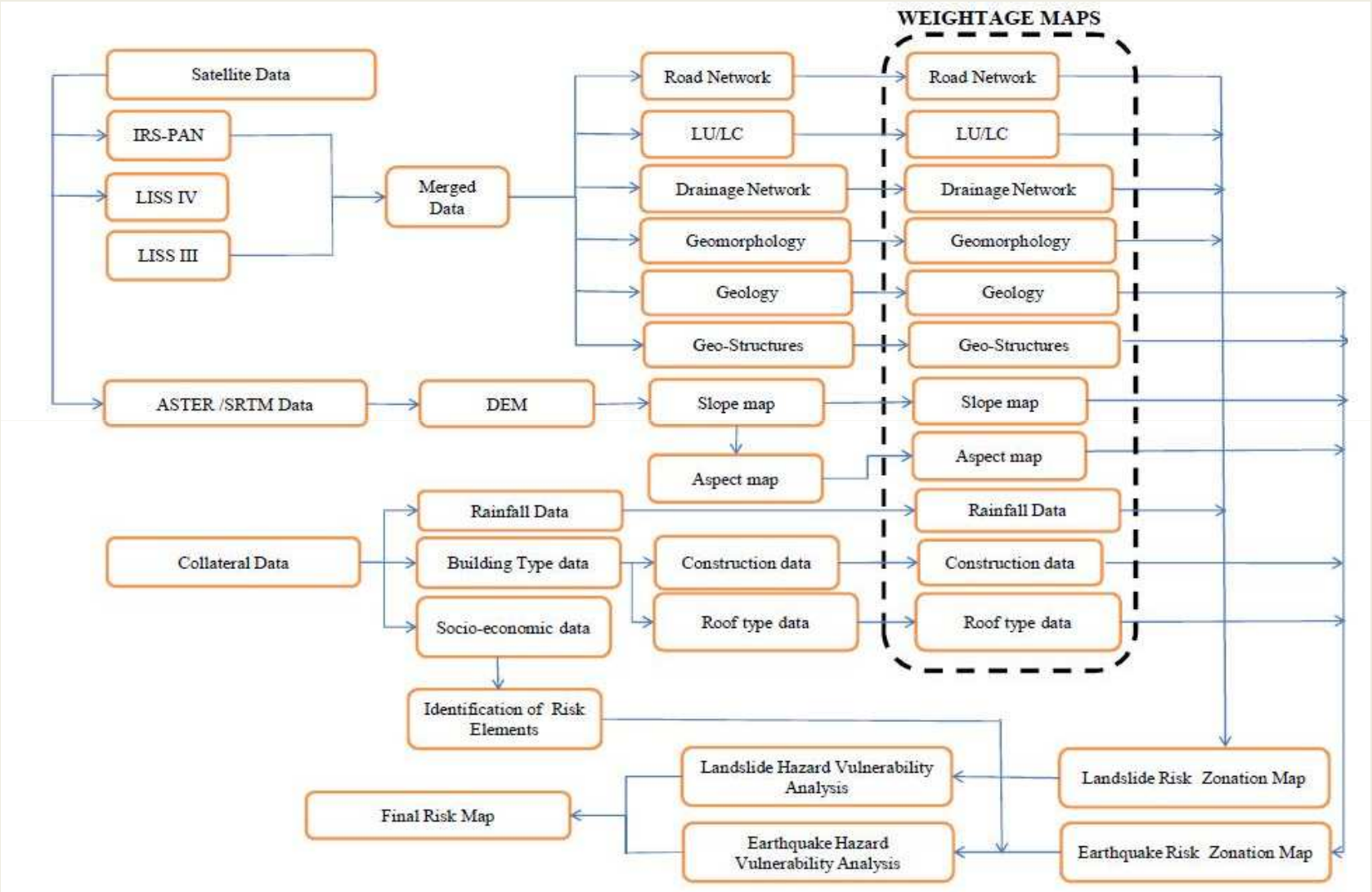
❖M. Marjanovi and B. Abolmasov, “AHP-driven multi-criteria analysis of landslide susceptibility on Fruška Gora Mountain,” unpublished

Software and Data Used

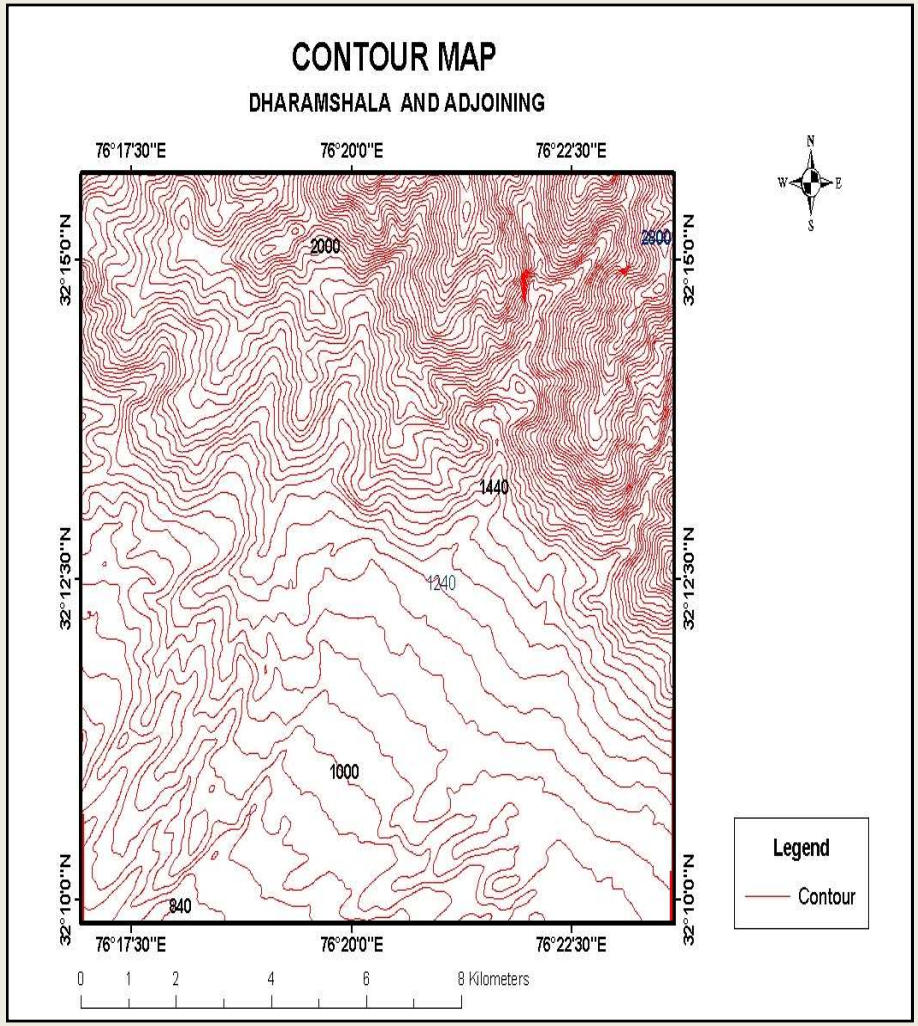


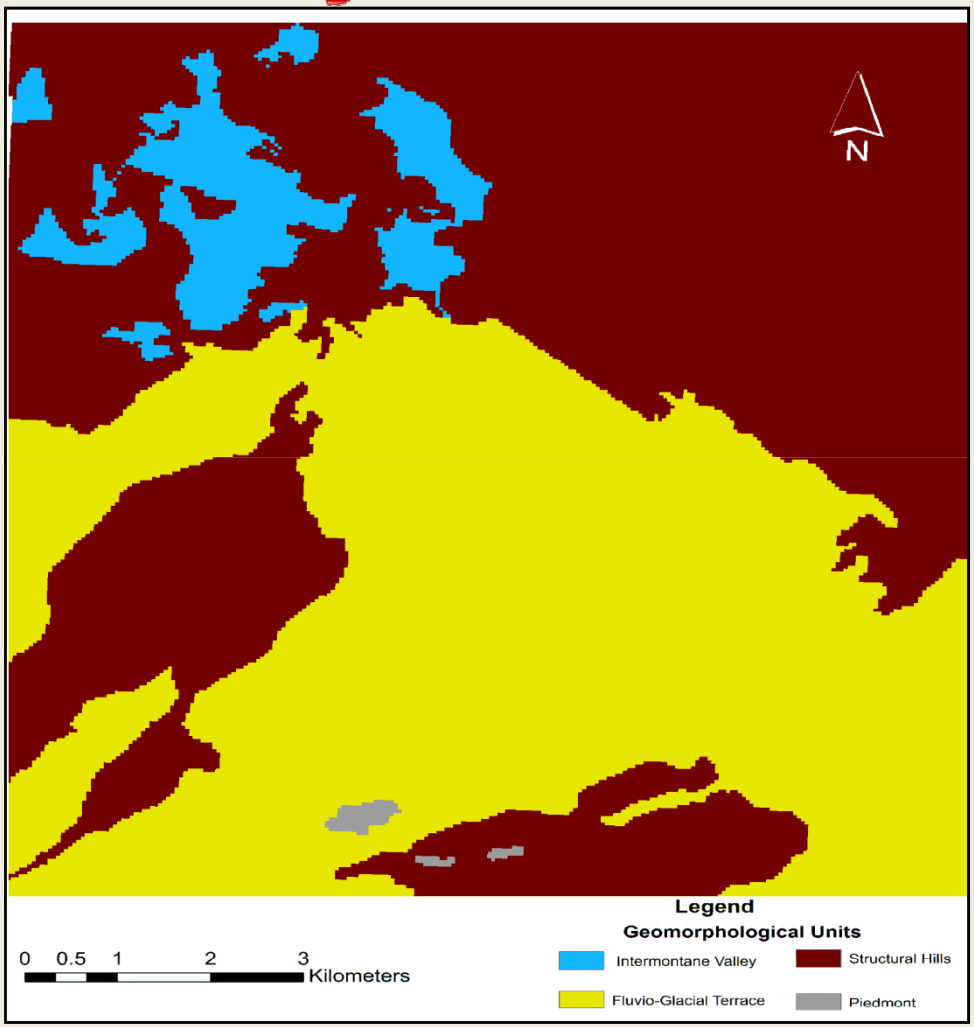
- Data Used:-
- LISS IV,CARTOSAT1,ASTER, Resolution Merged Image, Geological Map(GSI),Topographical Sheet(SOI), Soil Map(WIHG).
- Software Used:-
- ERDAS Imagine(9.3 version); Arc GIS(9.3 version); Arc Info; PCI Geometica.

Methodological Framework



Results and Analysis





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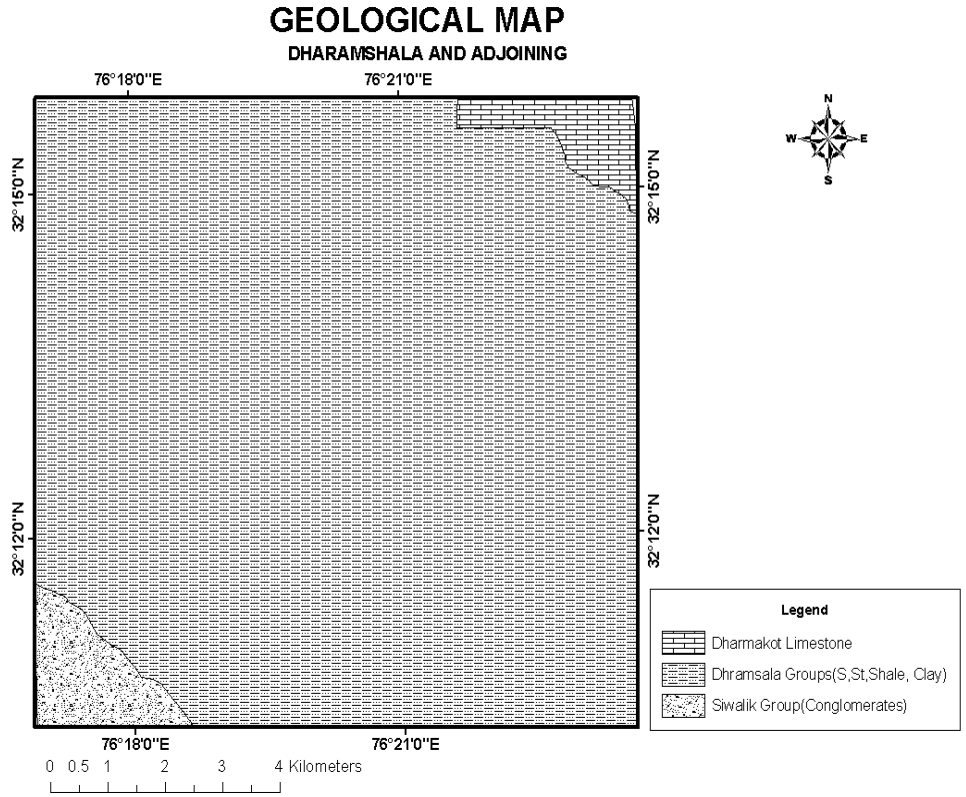
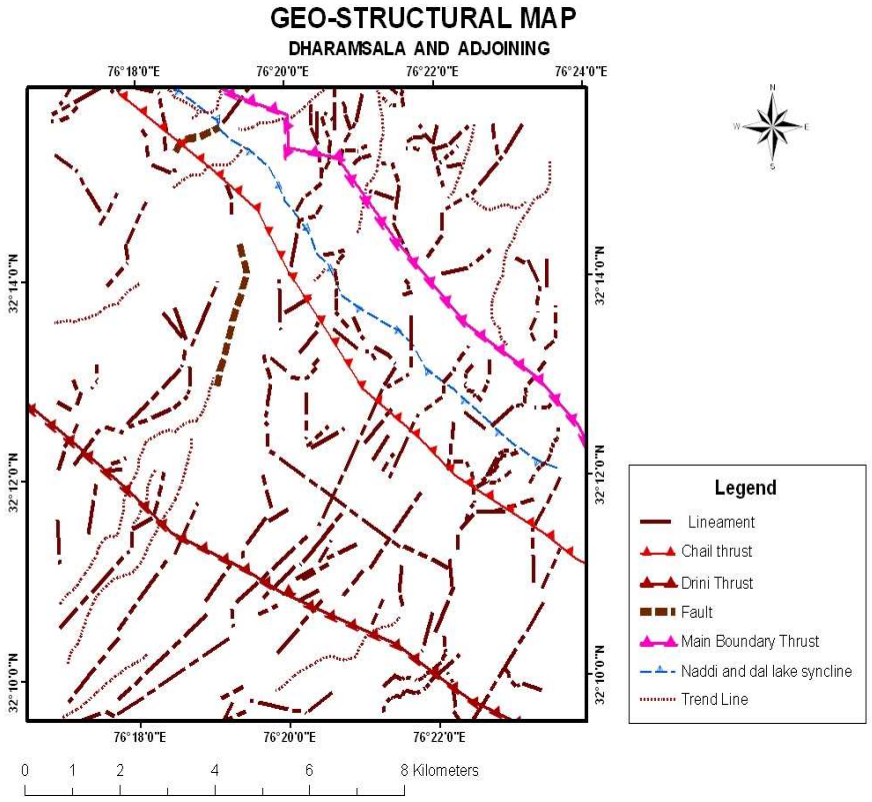
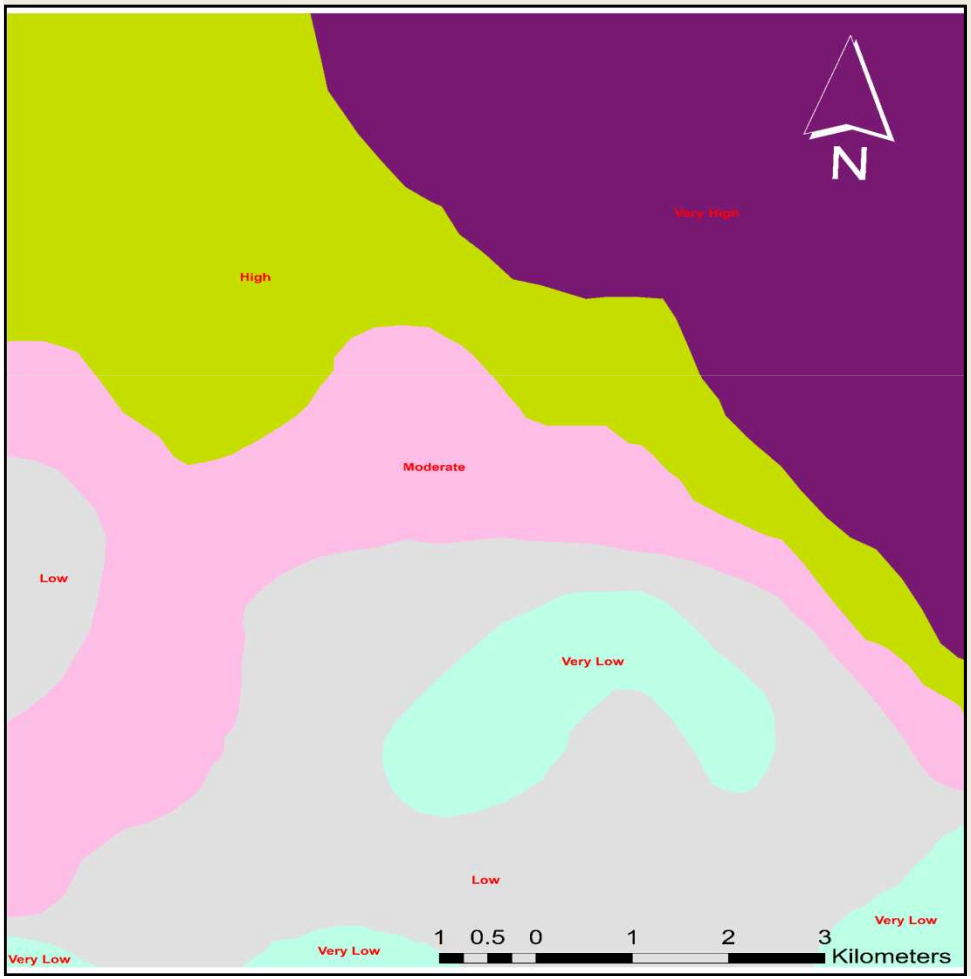
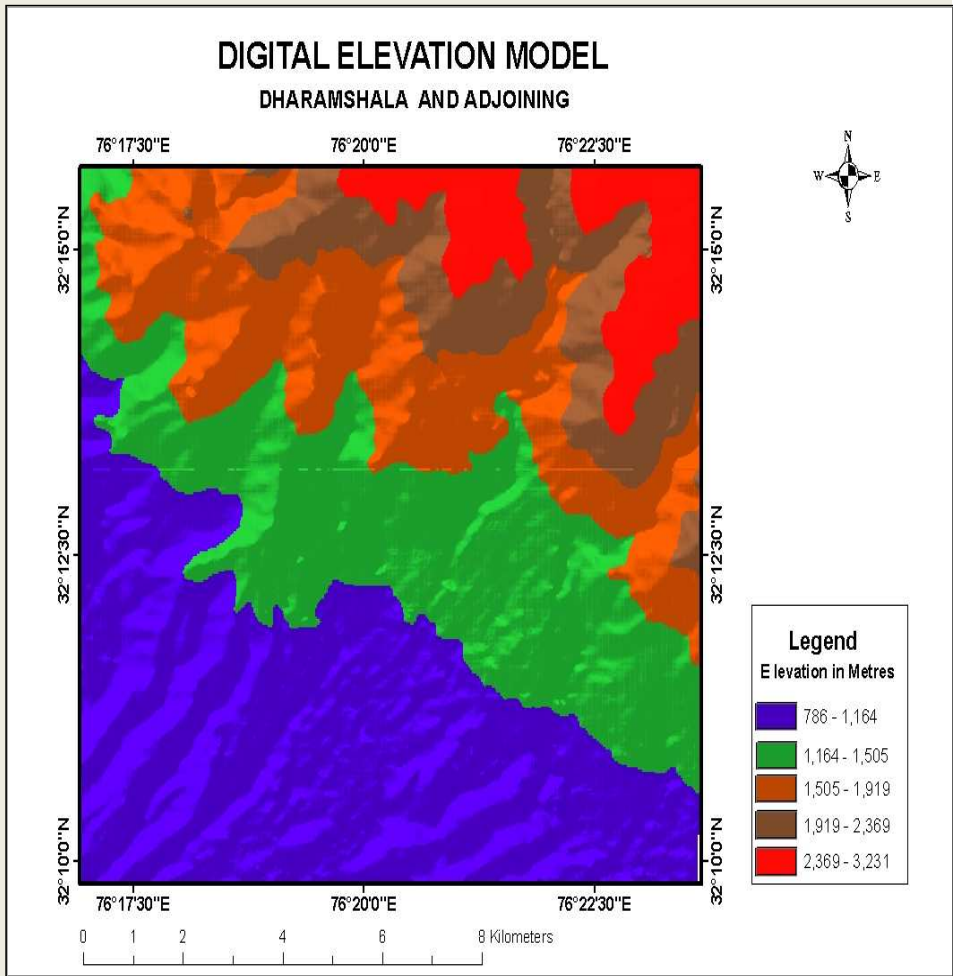

GEOLOGICAL MAP
DHARAMSHALA AND ADJOINING
76°18'0"E
76°21'0"E
32°15'0"N
32°12'0"N
N
W
E
S
Legend
Dharmakot Limestone
Dhramsala Groups(S,St,Shale, Clay)
Siwalik Group(Conglomerates)
0 0.5 1 2 3 4 Kilometers

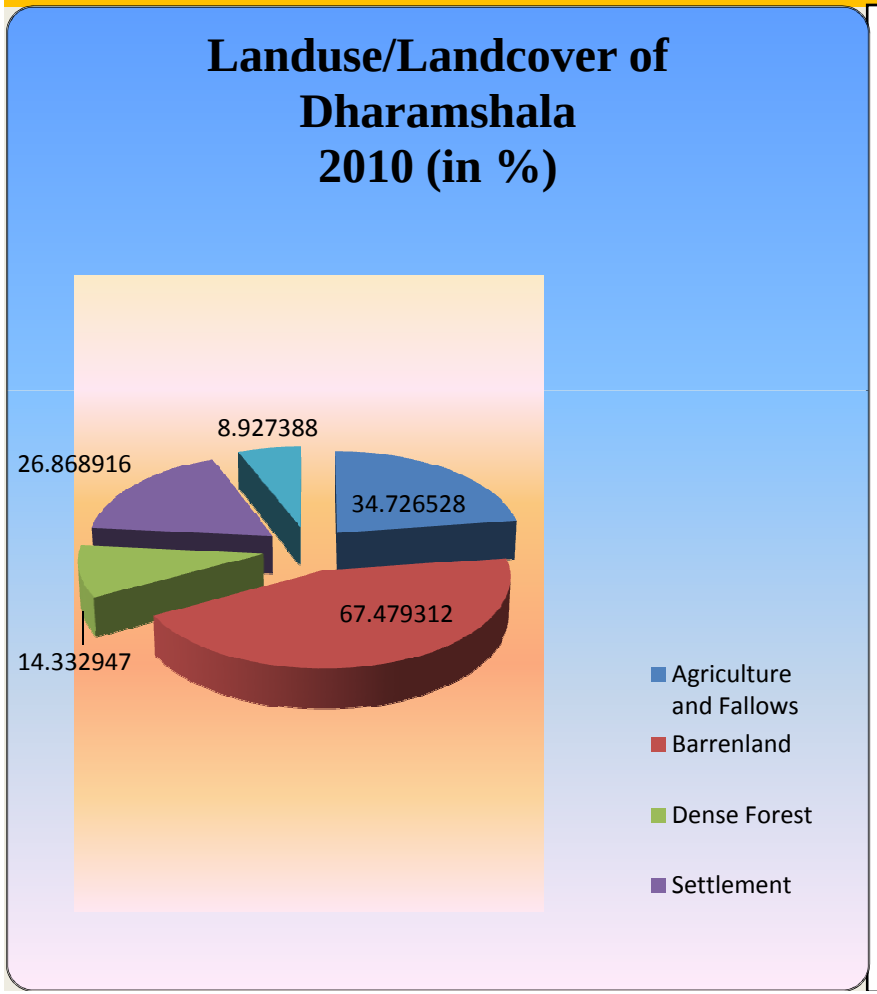

GEO-STRUCTURAL MAP
DHARAMSALA AND ADJOINING
76°18'0"E
76°20'0"E
76°22'0"E
76°24'0"E
32°14'0"N
32°12'0"N
32°10'0"N
Legend
Lineament
Chail thrust
Drini Thrust
Fault
Main Boundary Thrust
Naddi and dal lake syncline
Trend Line
0 1 2 4 6 8 Kilometers

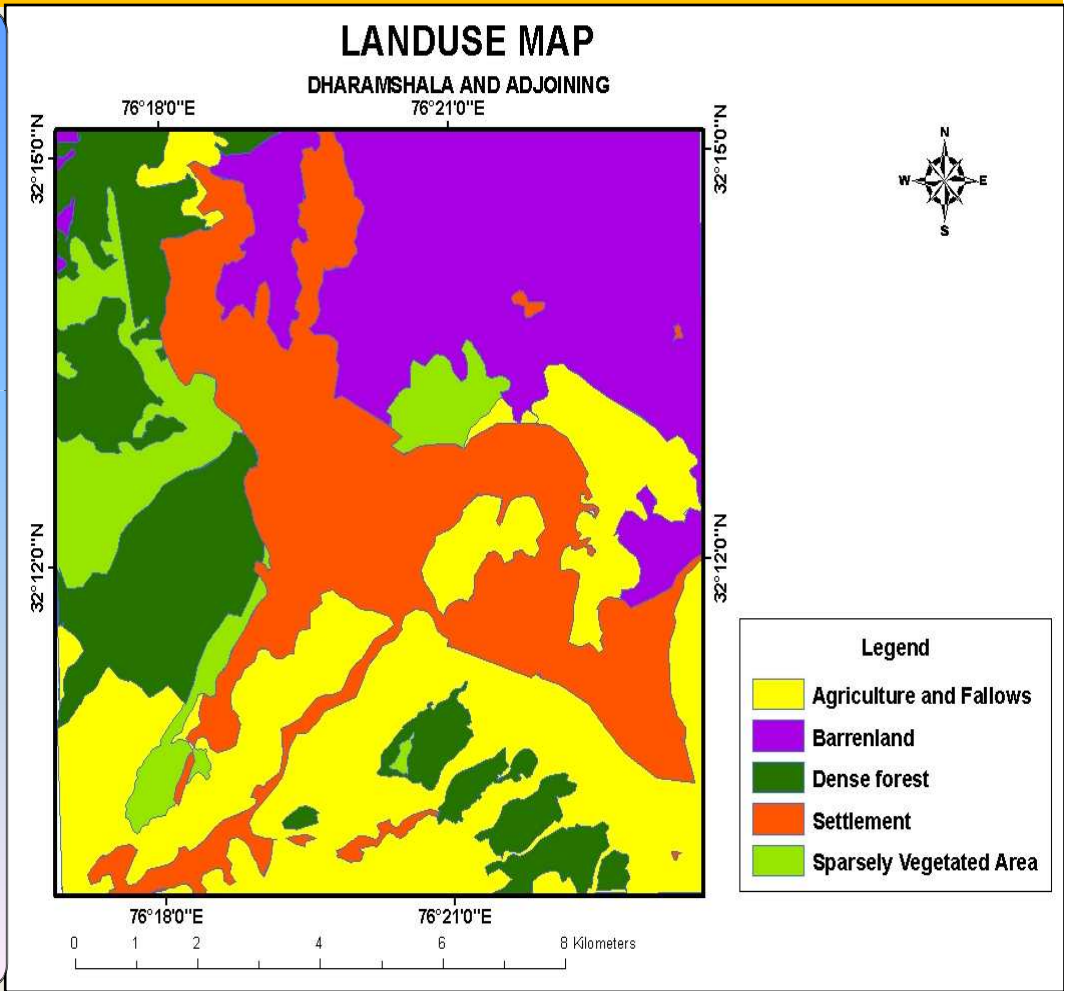
Slope and Elevation





Expansion of Urban Area





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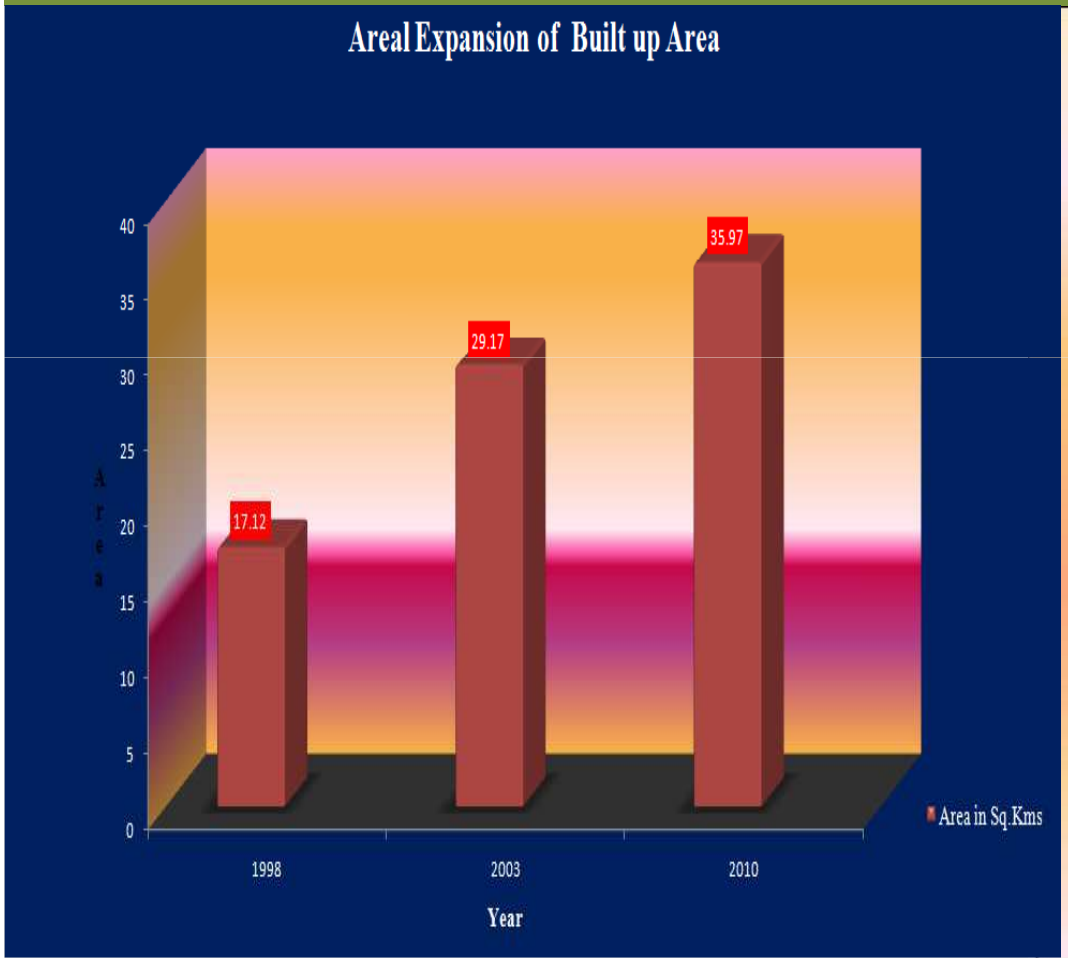
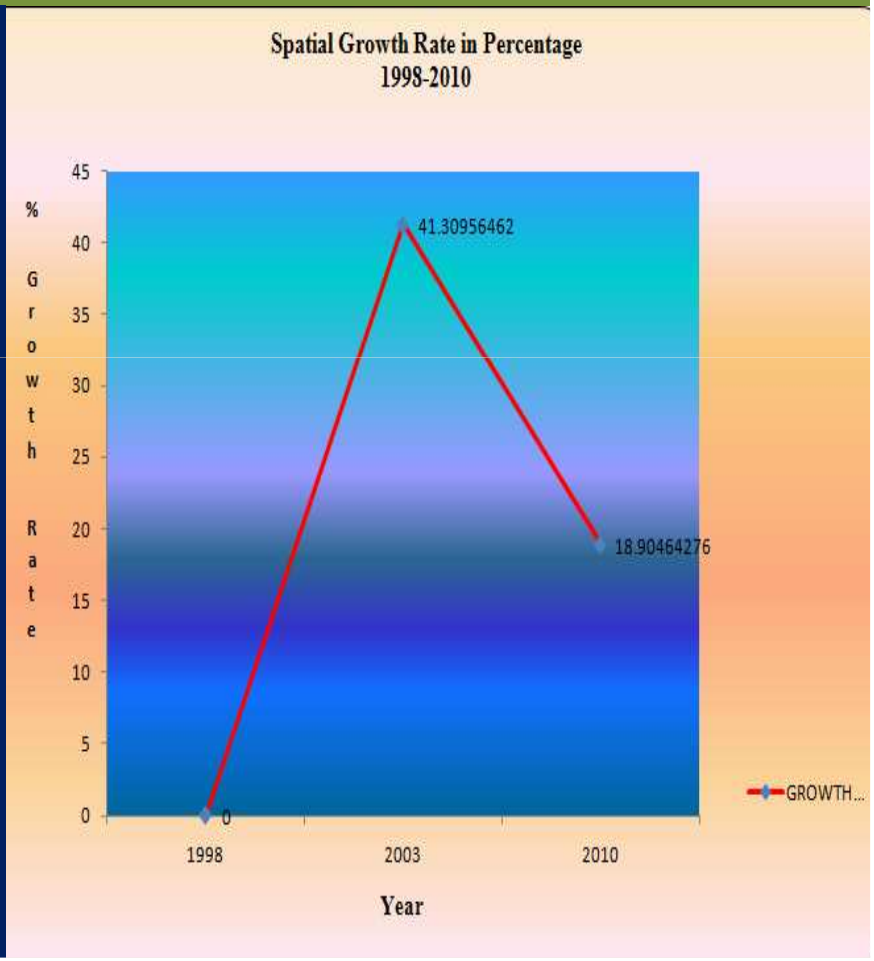
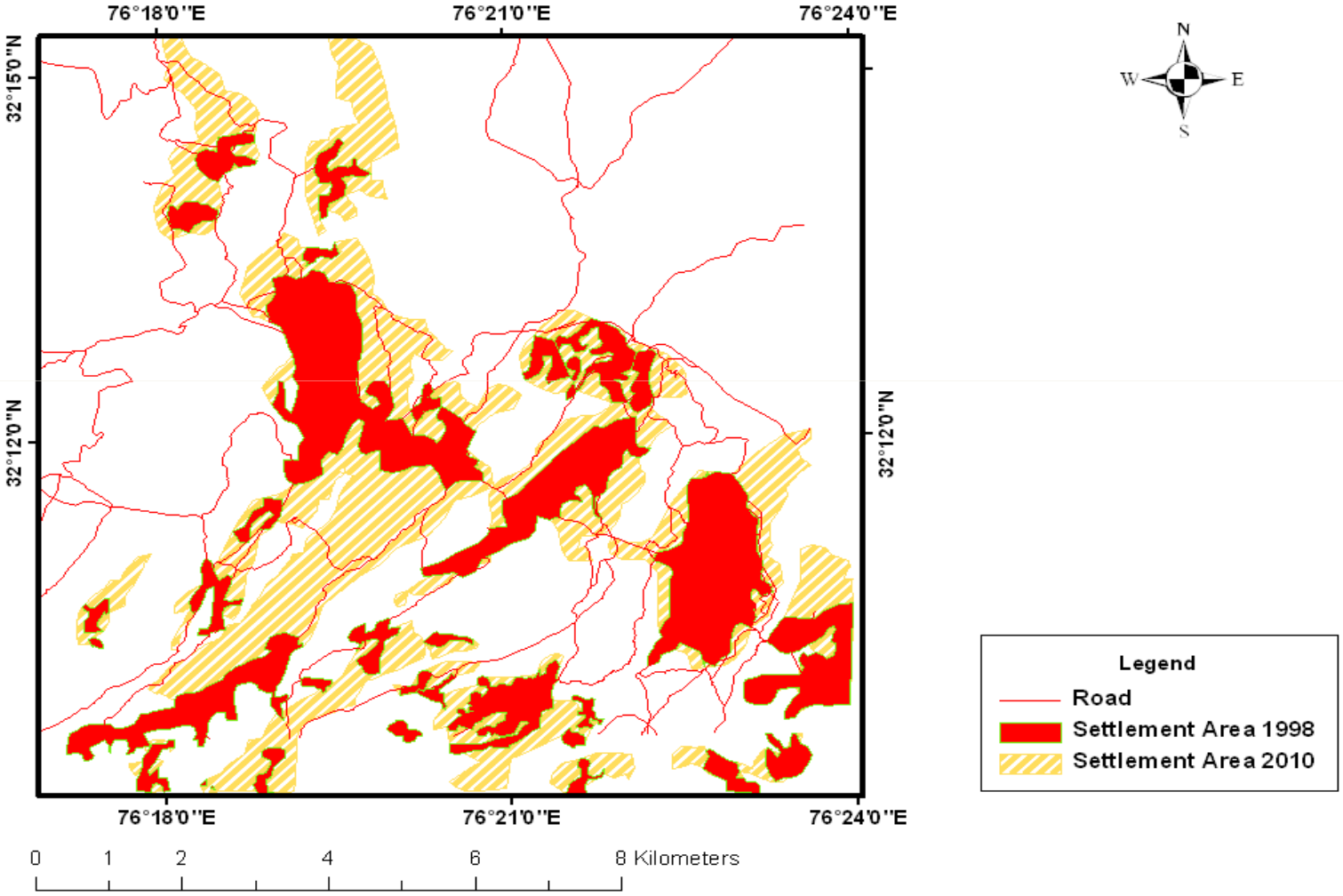

Areal Expansion of Built up Area
40
35
30
25
20
15
10
5
0
A r e a
17.12
29.17
35.97
1998
2003
2010
Year
Area in Sq.Kms


Spatial Growth Rate in Percentage
1998-2010
45
40
35
30
25
20
15
10
5
0
% G r o w t h R a t e
41.30956462
18.90464276
0
1998
2003
2010
Year
GROWTH...

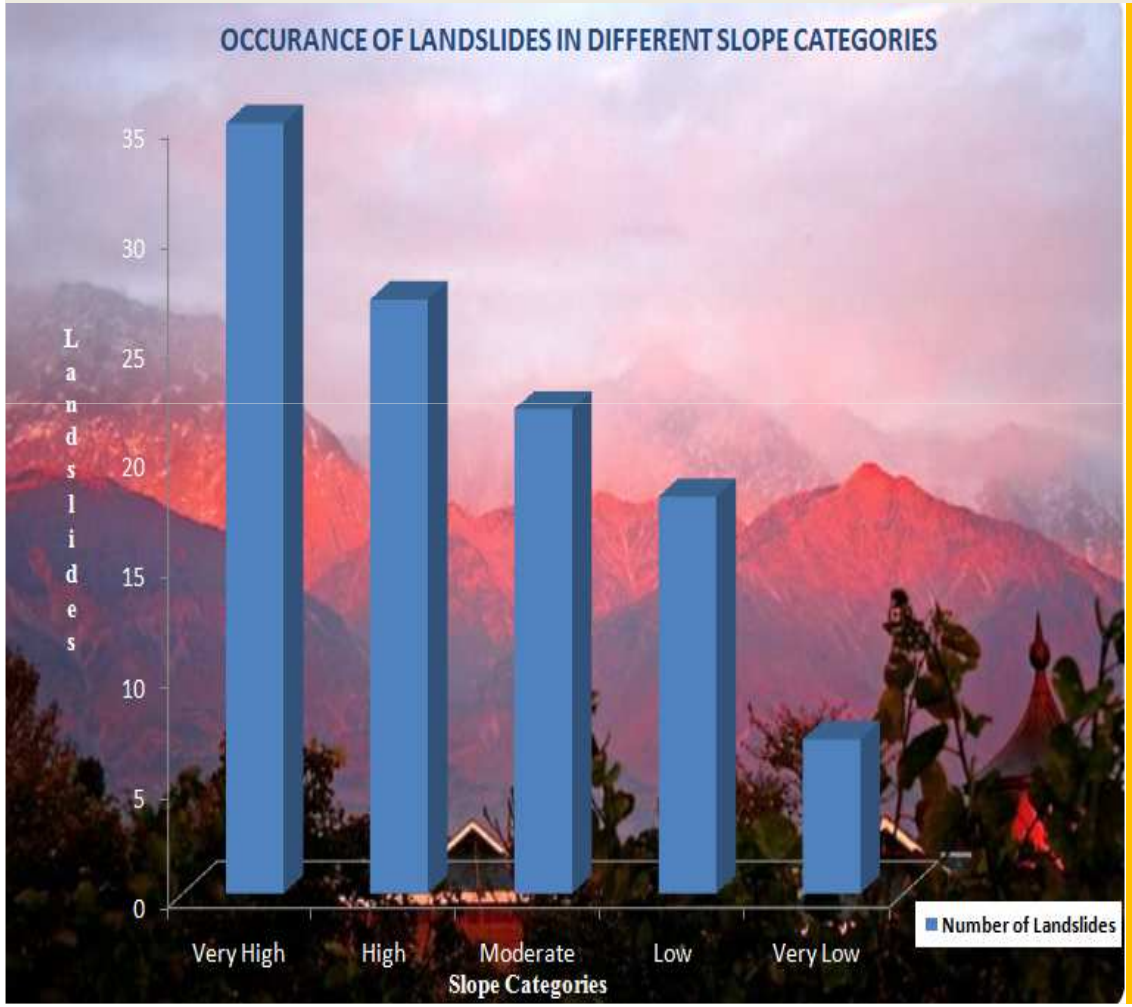
SETTLEMENT AREA EXPANSION MAP

DHARAMSALA AND ADJOINING

1998 - 2010



Major Landslide Triggering Factors



- **Slope**
- **Aspect**
- **Geology**
- **Geomorphology**
- **Landcover/Landuse**
- **Road**
- **Stream Density**
- **Stream**
- **Precipitation**
- **Lineament Density**
- Soil type

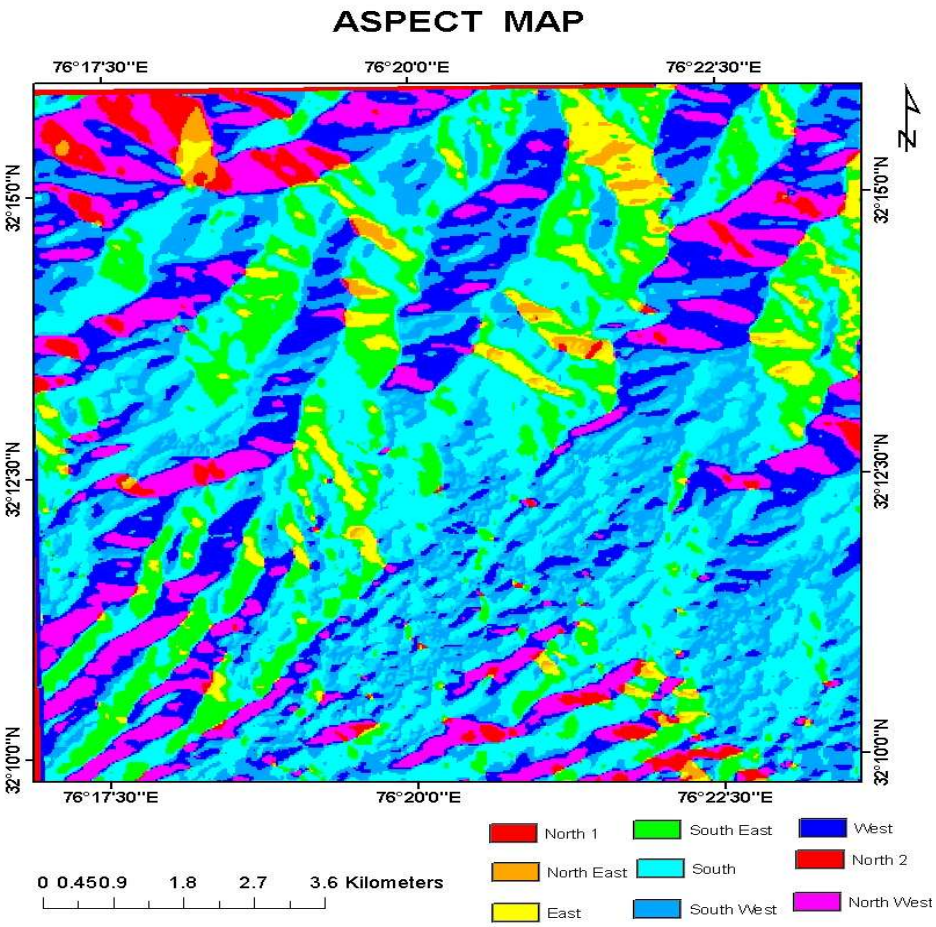
Influence of Slope and Aspect on landslide

Slope

Pair wise Comparison Matrix

	Very High	High	Moderate	Low	Very Low	Eigen Vector
Very High	1	3	5	7	9	0.51813
High	0.3333	1	3	5	7	0.261499
Moderate	0.2	0.3333	1	3	5	0.128976
Low	0.142857	0.2	0.3333	1	3	0.0633765
Very Low	0.1111	0.142857	0.2	0.03333	1	0.0333352

C.R.= 0.053; C.R= 0.0593688; Maximum Eigen Value = 5.23748



Triggering Factors(Contd...)

Aspect

Pairwise Comparison Matrix

	S	SE	SW	E	W	NW	NE	N	Weights(Eigen Vector)
S	1	3	5	7	7	9	9	9	0.394841
SE	0.3333	1	3	5	5	7	7	9	0.234781
SW	0.2	0.3333	1	3	5	5	7	7	0.146641
E	0.1428	0.2	0.3333	1	3	5	5	7	0.919859
W	0.1428	0.2	0.2	0.3333	1	3	3	5	0.0537326
NW	0.1111	0.1428	0.2	0.2	0.3333	1	3	5	0.0372363
NE	0.1111	0.1428	0.1428	0.2	0.3333	0.3333	1	3	0.0244878
N	0.1111	0.1111	0.1428	0.1428	0.2	0.2	0.3333	1	0.0162952

C.I.= 0.143228; Maximum Eigen Value= 9.0026

Pairwise Comparison Matrix

	Structural Hill	Inter montane Valley	Fluvio Glacial Terraces	Piedmont	Weights (Eigen Vector)
Structural Hill	1	3	5	7	0.565009
Inter montane Valley	0.3333	1	3	5	0.262201
Fluvio Glacial Terraces	0.2	0.3333	1	3	0.117504
Piedmont	0.1428	0.2	0.3333	1	0.0552855

C.I.= 0.0389941; Maximum Eigen Value = 4.11698

Major Factors(Contd.....)

Geology

Pairwise Comparison Matrix

	Dharamsala Group	Dharamsala Limestone	Siwalik Group	Eigen Vector
Dharamsala Group	1	7	9	0.785391
Dharasala Limestone	0.142857	1	3	0.148815
Siwalik Group	0.1111	0.3333	1	0.0657937

Maximum Eigen Value = 3.0803; C.I.= 0.0401499; C.R= 0.06922

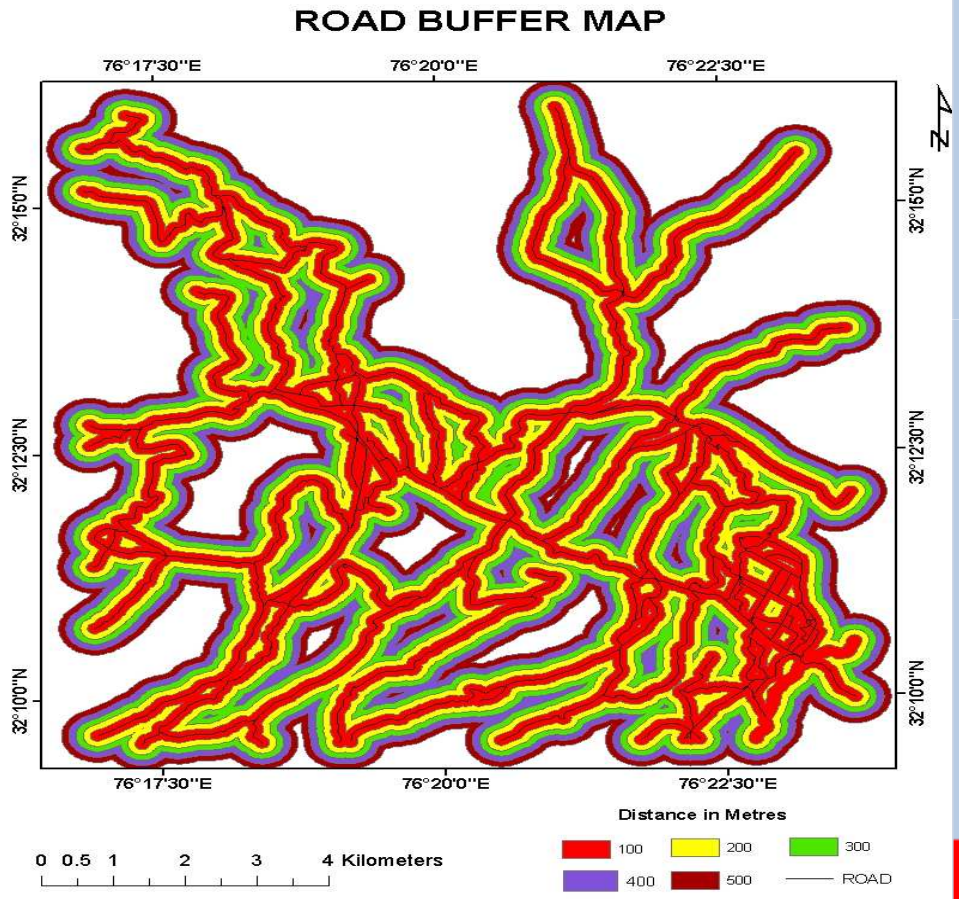
Landuse Landcover

Pairwise Comparison Matrix

	Barrenland	Settlement	Agriculture and Fallows	Sparse Vegetation	Dense Forest	Eigen Vector
Barrenland	1	3	5	7	9	0.512813
Settlement	0.333333	1	3	5	7	0.261499
Agricultural land and Fallows	0.2	0.33333	1	3	5	0.128976
Sparse Vegetation	0.142857	0.2	0.333333	1	3	0.0633765
Dense Forest	0.111111	0.142857	0.2	0.333333	1	0.033335

Maximum Eigen Value= 5.23748; C.I.= 0.0593688; C.R= 0.05

Influence of Road



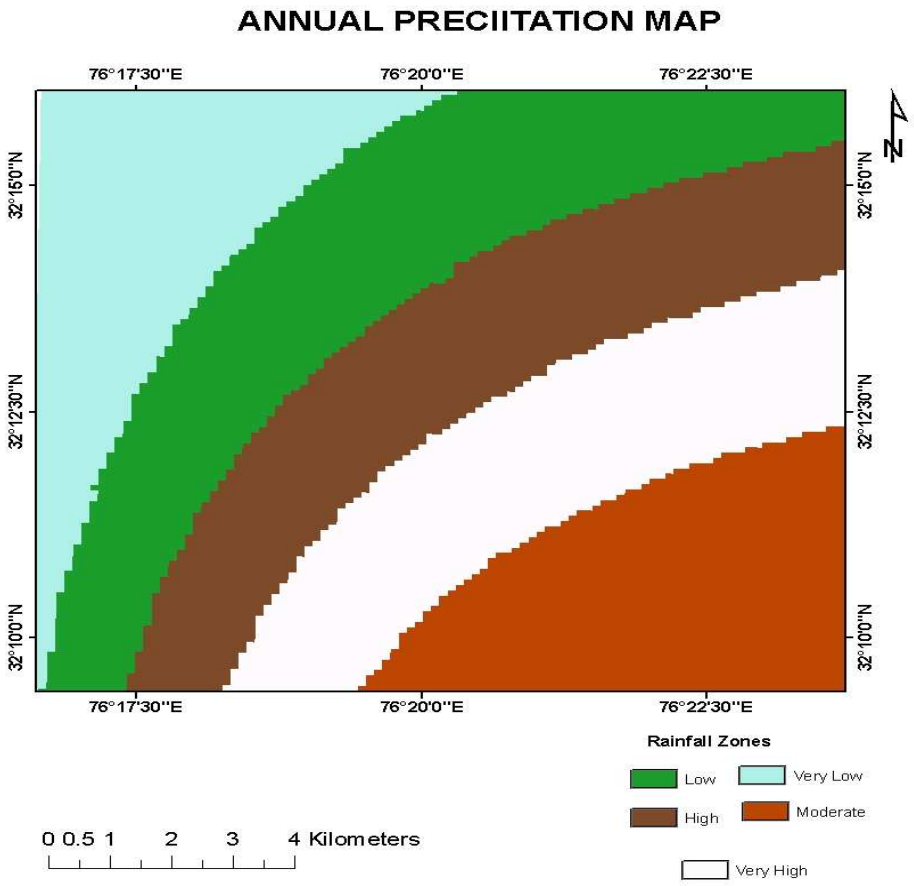
Distance from Road

Pairwise Comparison Matrix

	100 mts	200 mts	300 mts	400 mts	500mts	Eigen Vector
100 mts	1	3	5	7	9	0.512813
200 mts	0.333333	1	3	5	7	0.261499
300 mts	0.2	0.333333	3	5	7	0.128976
400 mts	0.142857	0.2	0.33333	1	3	0.0633765
500mts	0.111111	0.142857	0.2	0.3333	1	0.0333352

Maximum Eigen Value= 5.23748; C.I.= 0.0593688; C.R.= 0.0534

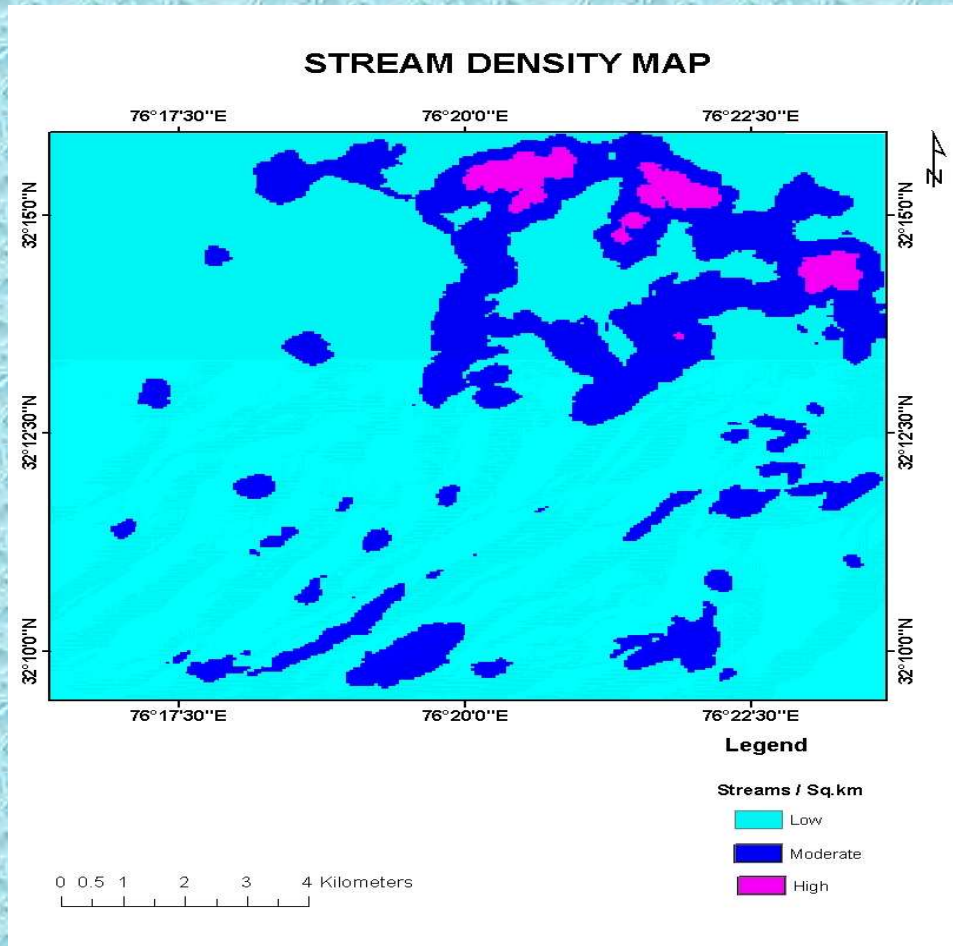
Precipitation-Landslide Relation

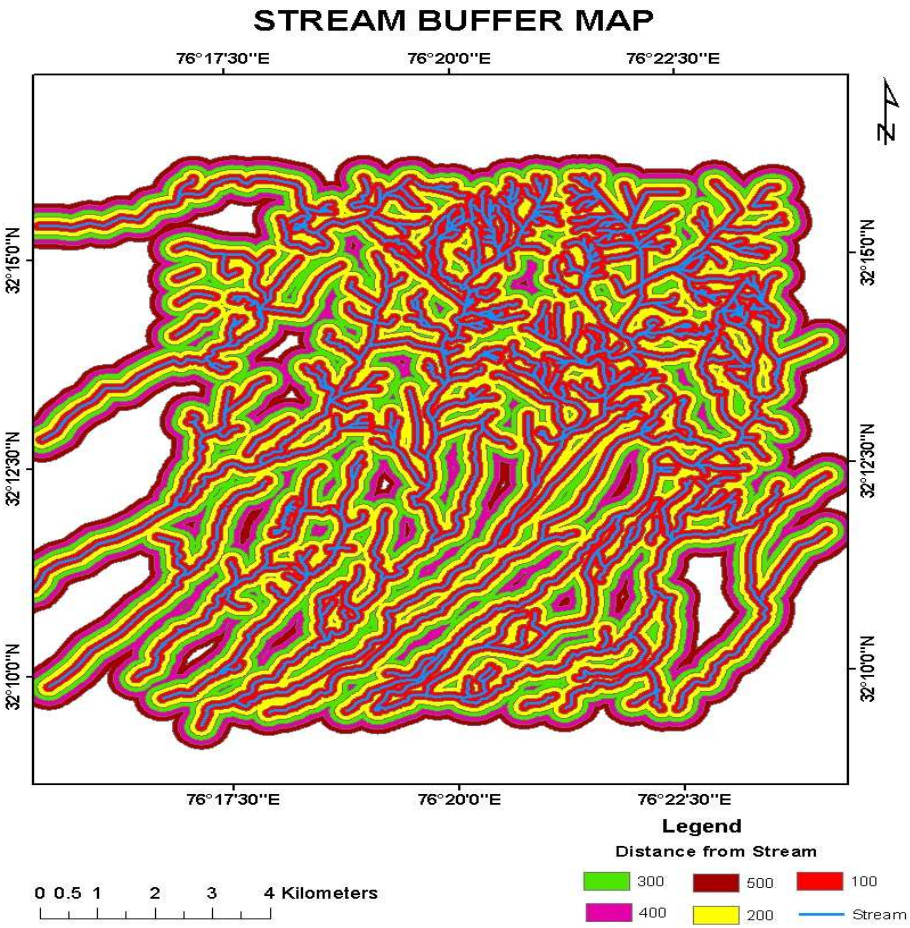


Rainfall						
Pairwise Comparison Matrix						
	High	Moderate	Very high	Low	Very Low	Eigen Values
High	1	3	5	7	9	0.512813
Moderate	0.33	1	3	5	7	0.261499
Very High	0.2	0.33333	1	3	5	0.128976
Low	0.14	0.2	0.33	1	3	0.0633765
Very Low	0.11	0.14	0.2	0.33	1	0.0333352

C.I.=0.0593688 ; C.R.= 0.053007

Hydrology-landslide relation

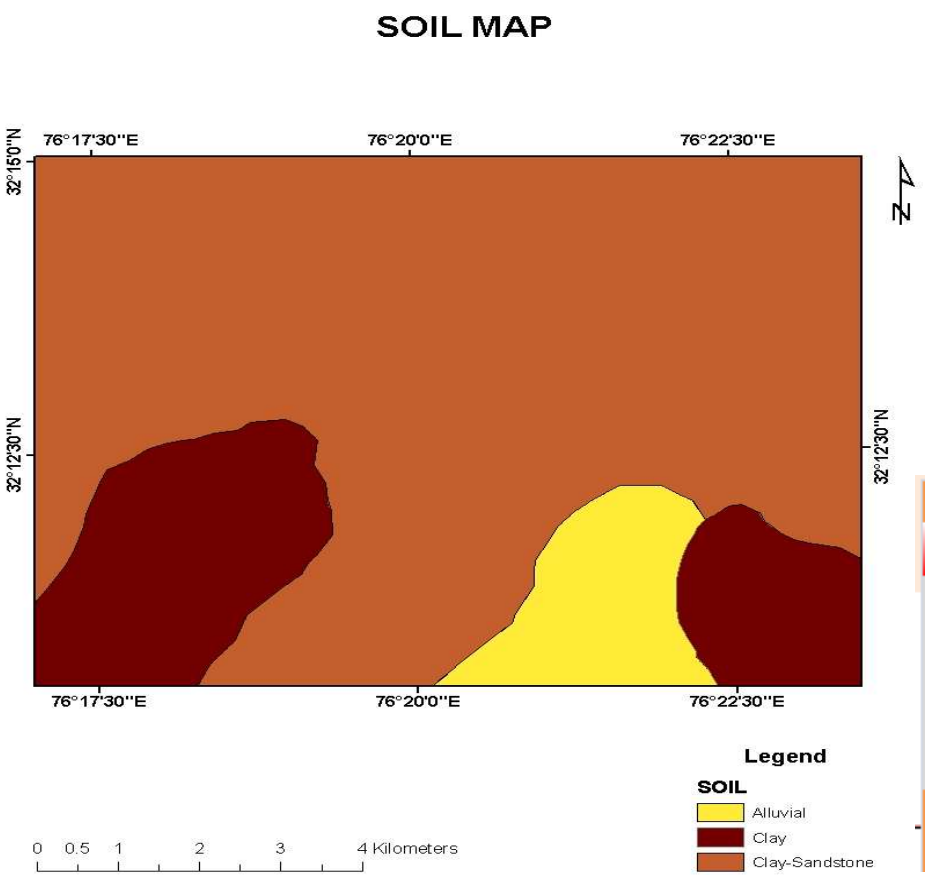




Distance from Stream Side						
Pairwise Comparison Matrix						
	100 mts	200 mts	300mts	400mts	500 mts	Eigen Vector
100 mts	1	3	5	7	9	0.512813
200 mts	0.3333	1	3	5	7	0.261499
300 mts	0.2	0.3333	1	3	5	0.128976
400 mts	0.1428	0.2	0.3333	1	3	0.063376
500 mts	0.1111	0.142857	0.2	0.3333	1	0.033352
Maximum Eigen Value= 5.23748; C.I.= 0.0593688; C.R.= 0.053						

Stream Density				
Pairwise Comparison Matrix				
	High	Medium	Low	Eigen Vector
High	1	3	7	0.649118
Medium	0.33333	1	5	0.278955
Low	0.14286	0.2	1	0.0719274
C.I.= 0.0324438; C.R.= 0.055937				

Soil texture-Landslide Relation



Soil

Pairwise Comparison Matrix

	Clay sandstone	Alluvium	Clay	Eigen Vector
Clay Sandstone	1	5	7	0.730645
Alluvium	0.2	1	3	0.188394
Clay	0.142857	0.3333	1	0.0809612

C.I.= 0.0324438; C.R= 0.06

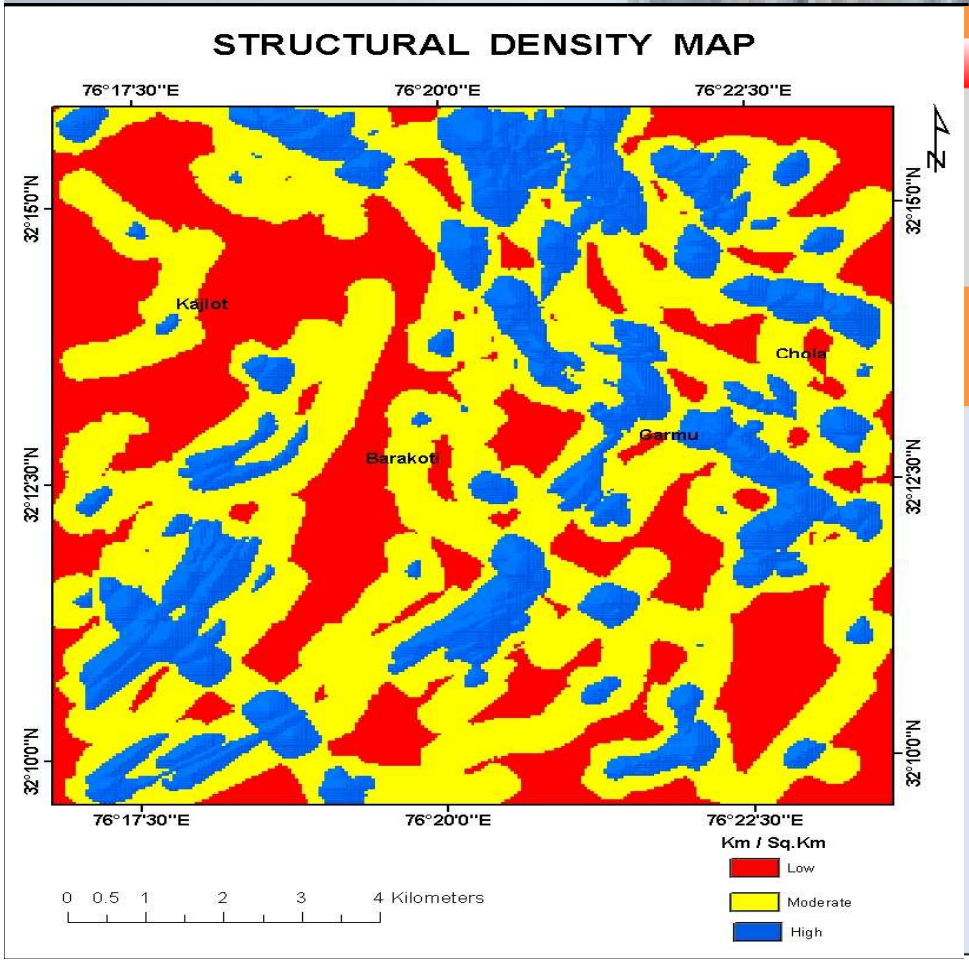
Structural Density

Pairwise Comparison Matrix

	High	Moderate	Low	Eigen Vector
High	1	3	9	0.655355
Moderate	0.333333	1	7	0.289744
Low	0.111111	0.142857	1	0.0549004

Maximum Eigen Value=3.0803: C.I.=0.0401: C.R.= 0.06922

LINEAMENT DENSITY-LANDSLIDE RELATION



Structural Density

Pairwise Comparison Matrix

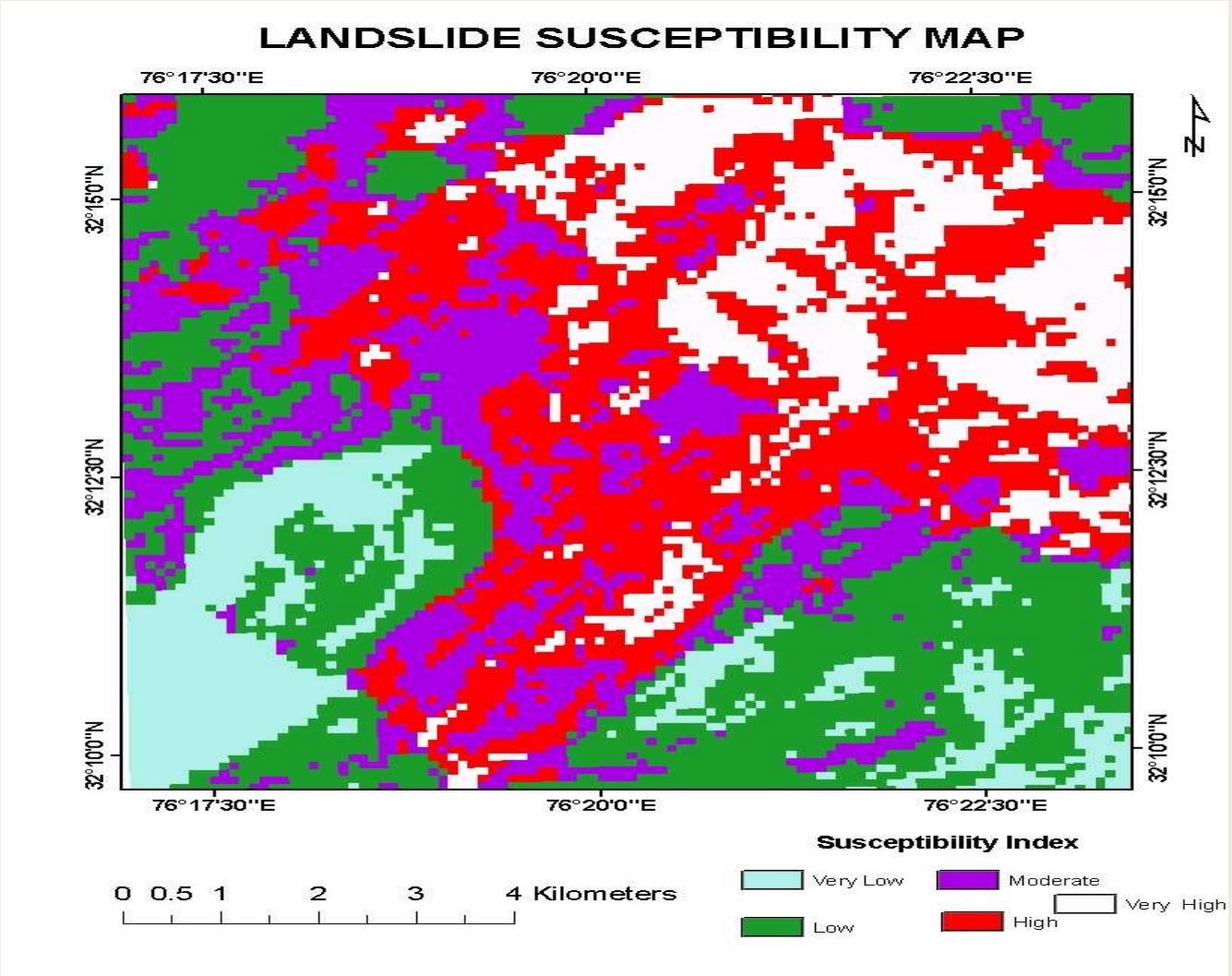
	High	Moderate	Low	Eigen Vector
High	1	3	9	0.655355
Moderate	0.333333	1	7	0.289744
Low	0.111111	0.142857	1	0.0549004

Maximum Eigen Value=3.0803; C.I.=0.0401; C.R.= 0.06922

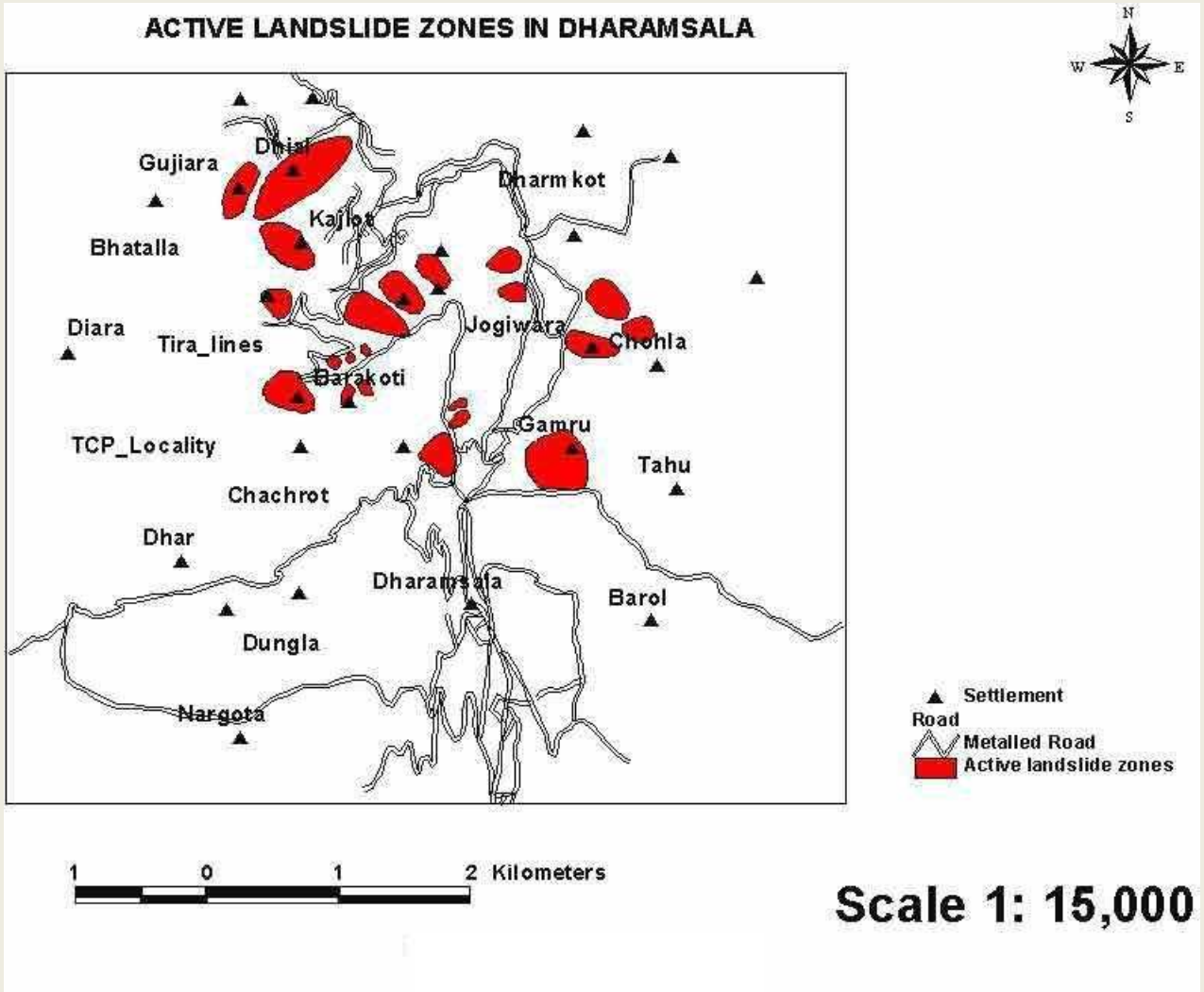
	Slope	Aspect	Geology	Geom	Hydro	LU/LC	Geos	Soil	weighted values(eigen vector)
Slope	1	3	5	7	5	5	5	7	0.363798
Aspect	0.33	1	3	7	5	5	3	5	0.224891
Geology	0.2	0.33	1	5	3	3	0.33	3	0.992673
Geom	0.14	0.14	0.2	1	0.2	0.33	0.2	0.33	0.0221563
Hydro	0.2	0.2	0.33	5	1	3	0.33	3	0.072048
LU/LC	0.2	0.2	0.33	3	0.33	1	0.33	3	0.0502096
Geos	0.2	0.33	3	5	3	3	1	3	0.131707
Soil	0.14	0.2	0.33	3	0.33	0.33	0.33	1	0.03592228

Maximum Eigen Value =8.82684, C.I. = 0.118119, C.R. = 0.08377

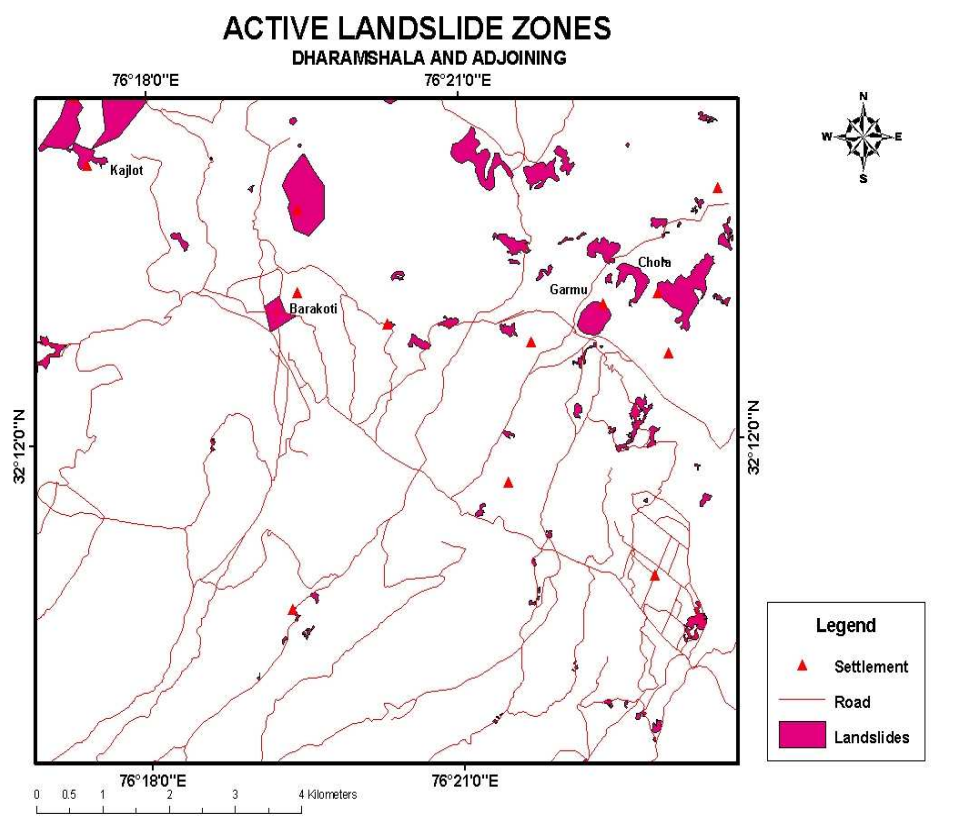
LANDSLIDE SUSCEPTIBILITY



Validation of Landslide Susceptibility(2009) {*after WIHG*}



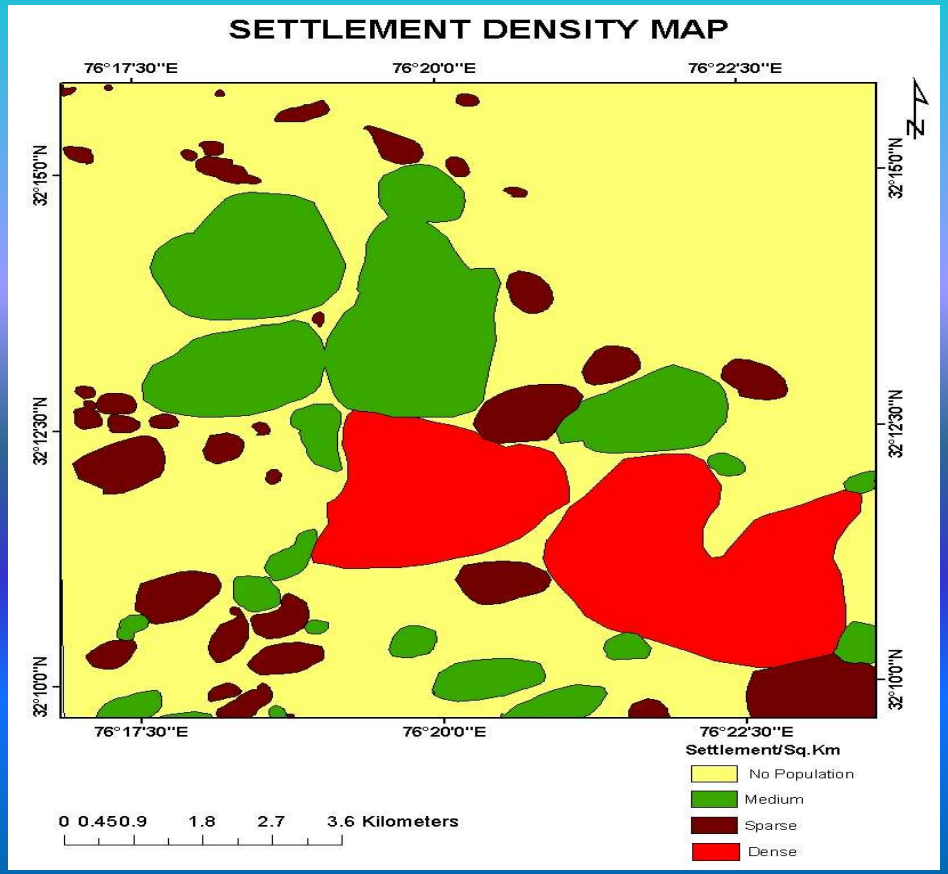
Validation of Landslide Susceptibility



- **The landslide susceptibility analysis result was validated using known landslide locations. Validation was performed by comparing the known landslide location data with the landslide susceptibility map.**

- **The Landslide zone occupies 2.6 Sq.Km of the area under investigation and the ground truthing has proved 82.16% of the assumptions to be true.**

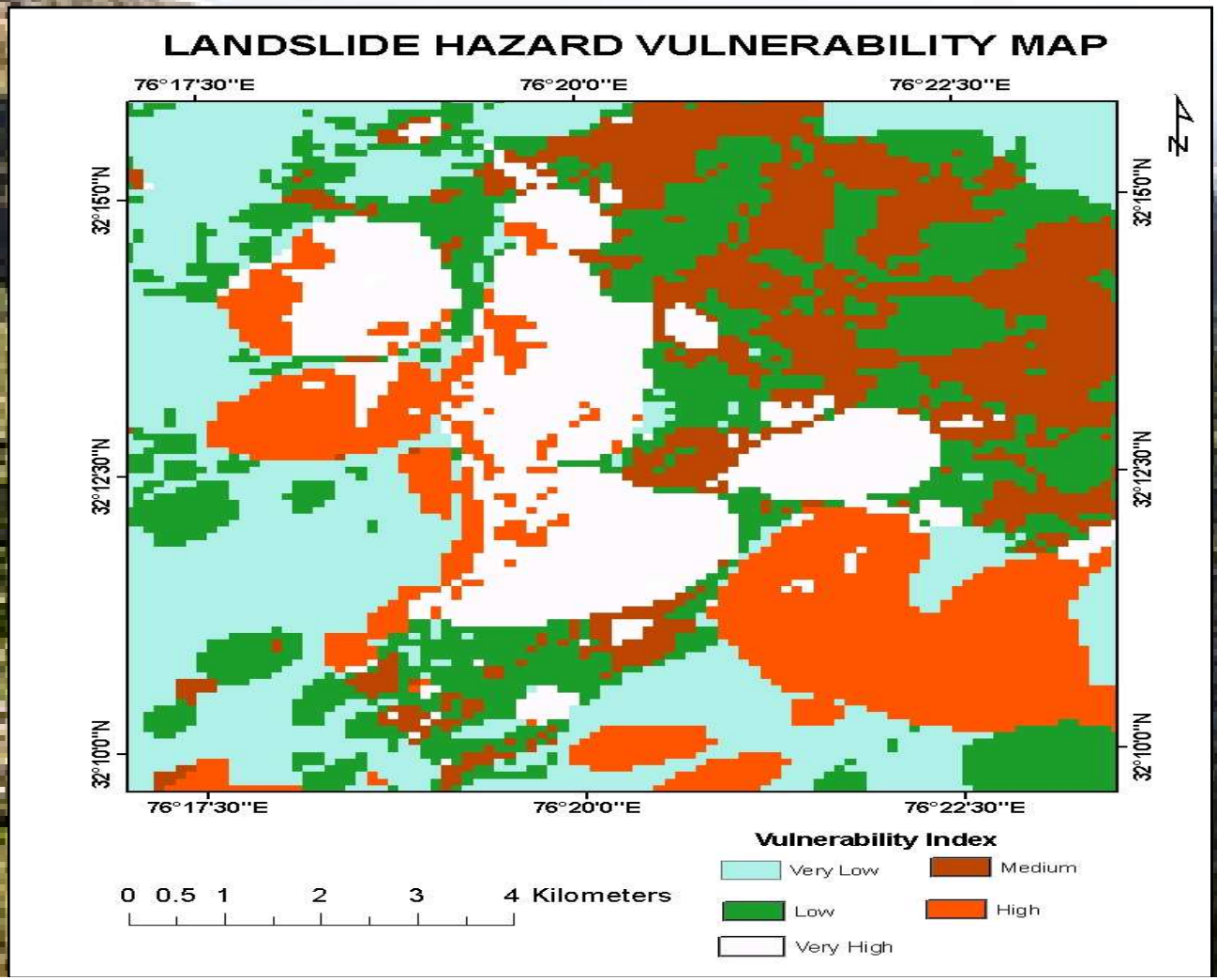
Settlement Density and its role in determining landslide vulnerability



Settlement Density					
Pairwise Comparison Matrix					
	Dense	Medium	Sparse	No Population	Eigen Value
Dense	1	3	5	7	0.566008
Medium	0.33	1	3	7	0.267418
Sparse	0.2	0.33	1	5	0.126698
No Population	0.11	0.14	0.2	1	0.0398755

Maximum Eigen Value= 4.17067; C.I= 0.568895; C.R= 0.06321

LANDSLIDE VULNERABILITY



Conclusions and Recommendations

1) The landslide susceptibility shows that a good section of settlement area is under landslide threat. Landslides may be controlled by one or any combination of four principle measures: modification of slope geometry, drainage, retaining structures and internal slope reinforcement.

2) Study enabled to generate a landslide risk map that provides information concerning the selection of the proper location for the construction of infrastructure vital during a crises situation

Contd….

3) Additionally, the risk map can be used, from the public protection services, for the definition of the proper concentration points' distribution in order to cover correctly the high risk sections.

- **Recommendations (General)**
- **Recommendations(Area Specific)**

1. ***Special attention*** *needs to be drawn in laying down a proper sewerage disposal* system in the Mc Leod Gunj, Army Cantt. Area, Tibetian Library complex, Dharamsala Township, including Mant Panchayet.
2. ***Adequate and well planned drainage*** system is a requirement as well as a long term measure. It should consist of each hill side catch water drains and culverts along and across the contour lines.

3. Local *residents* need to channelize their daily water disposal in a proper way so that it should not seep into the body of slide zone or base slopes.

4. Special care needs to be undertaken to stop construction on the NE face of Mc Leod Gunj, and in the areas of Librarian Complex area.

5. All natural drains needs to be cleared before every monsoon, because chocking of drains creates pools/ponds increasing infiltration.

Future Scope of Work

The landslide risk map generated needs to be integrated with the different landuse landcover classes and the vulnerability analysis needs to be performed by integrating the socio-economic data. Special attention needs to be drawn to the areas of high landslide susceptible areas and every activity starting from residential to commercial, academic to institutional activities needs to done accordingly. Efforts should be undertaken to reduce the load of settlement in the zones of high and very high landslide susceptibility. Afforestation and programme to protect the existing vegetation cover on the hill slopes needs to be undertaken in order to resist high rate of erosion and high propensity of sliding.

On the other hand, speaking in terms of research methodology, more research is needed on the optimal ways for generating landslide inventories, in particular to design different inventory systems based either on local reports or on periodical surveys. The result can be validated using other techniques and DSS.

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Thanks for your attention