

Long term land use change affects soil erosion in the Nepal Himalayas

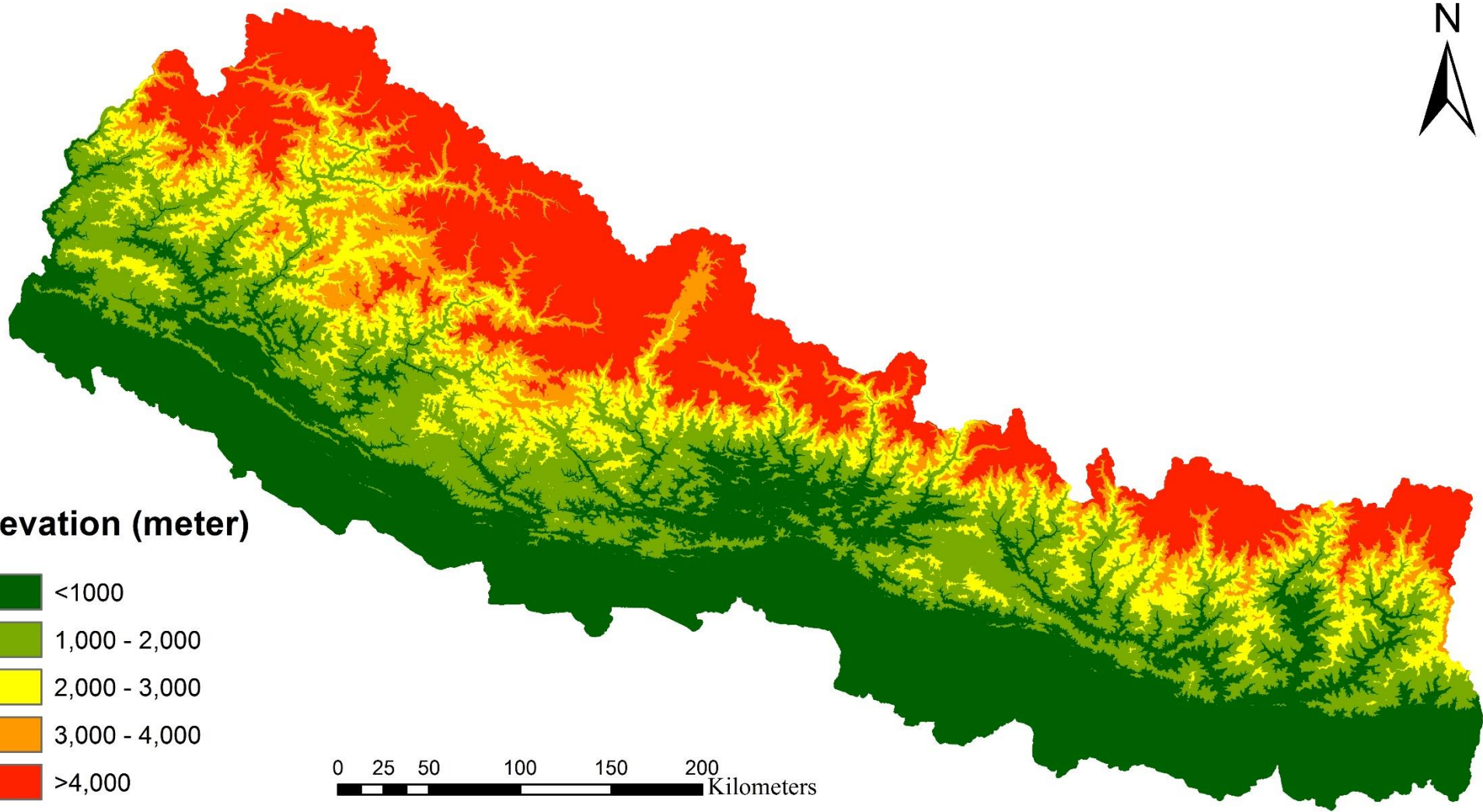
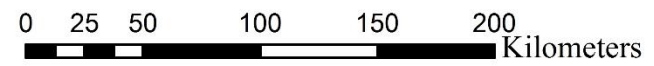
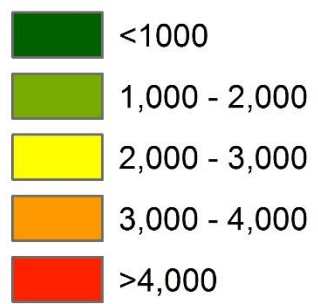
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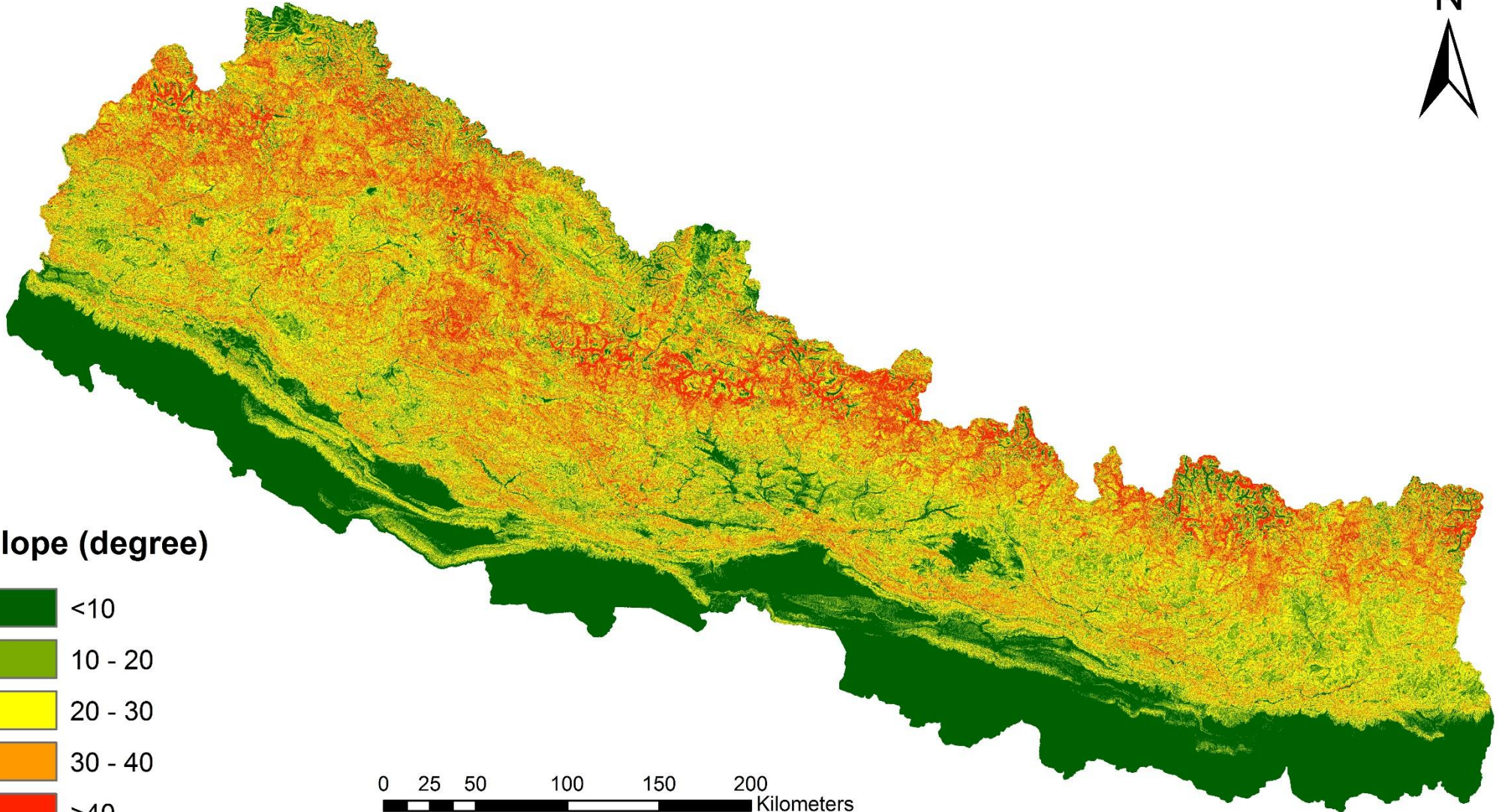
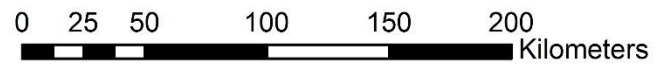
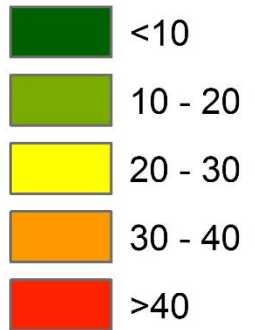
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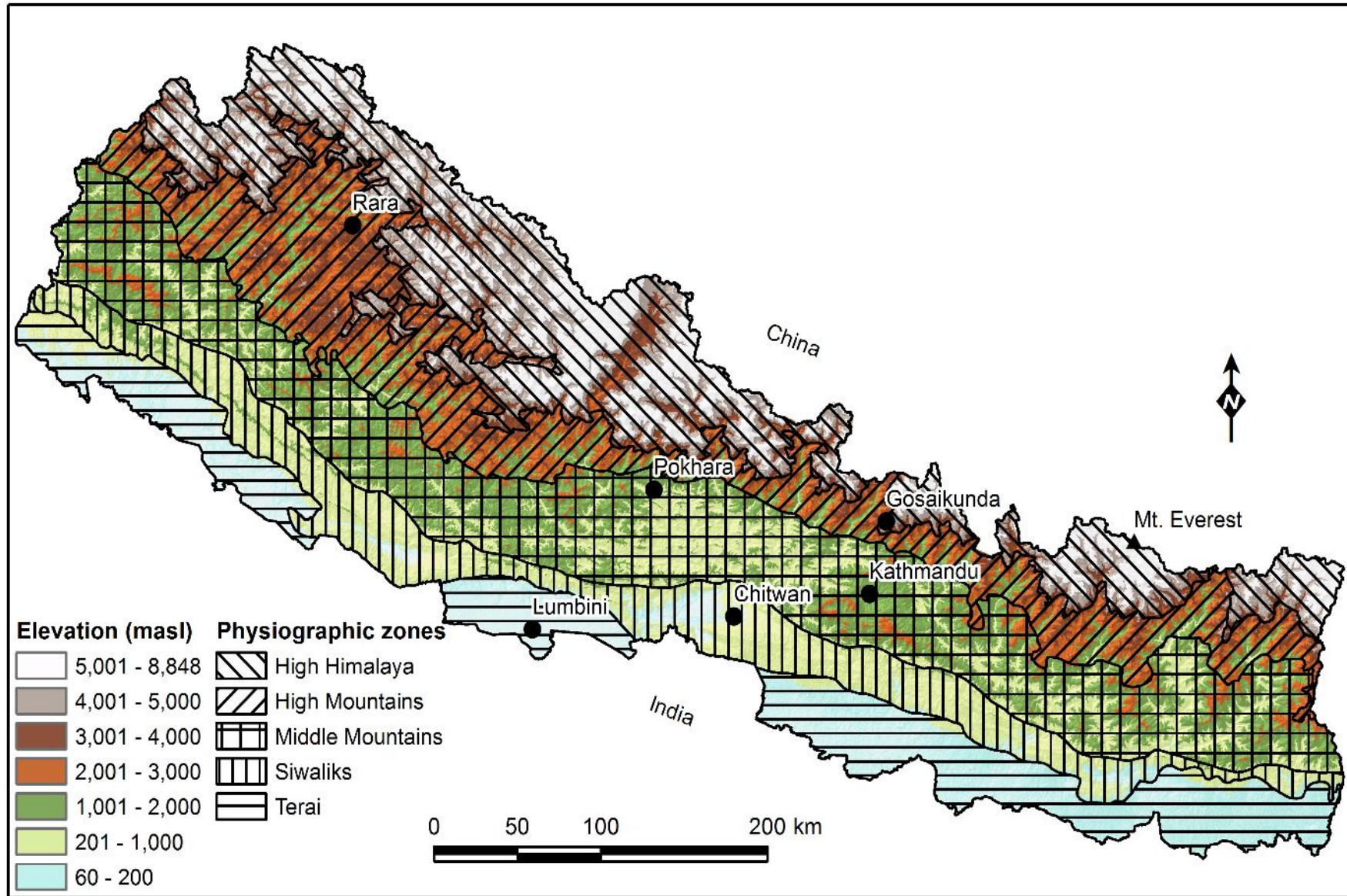
Elevation (meter)





Slope (degree)





Source: Survey Department, Ministry of Land Management, Cooperatives and Poverty Alleviation, <http://dos.gov.np/>

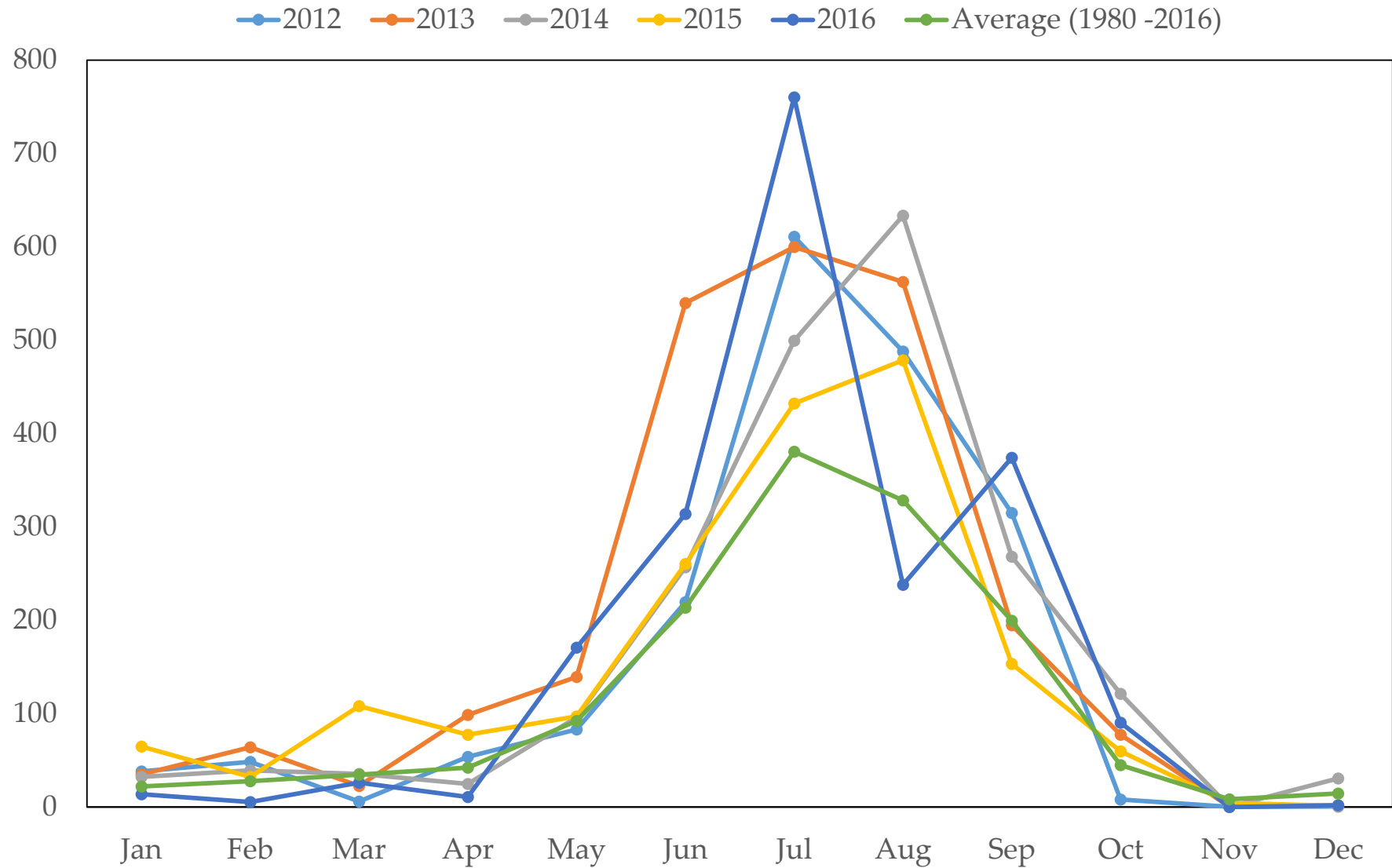
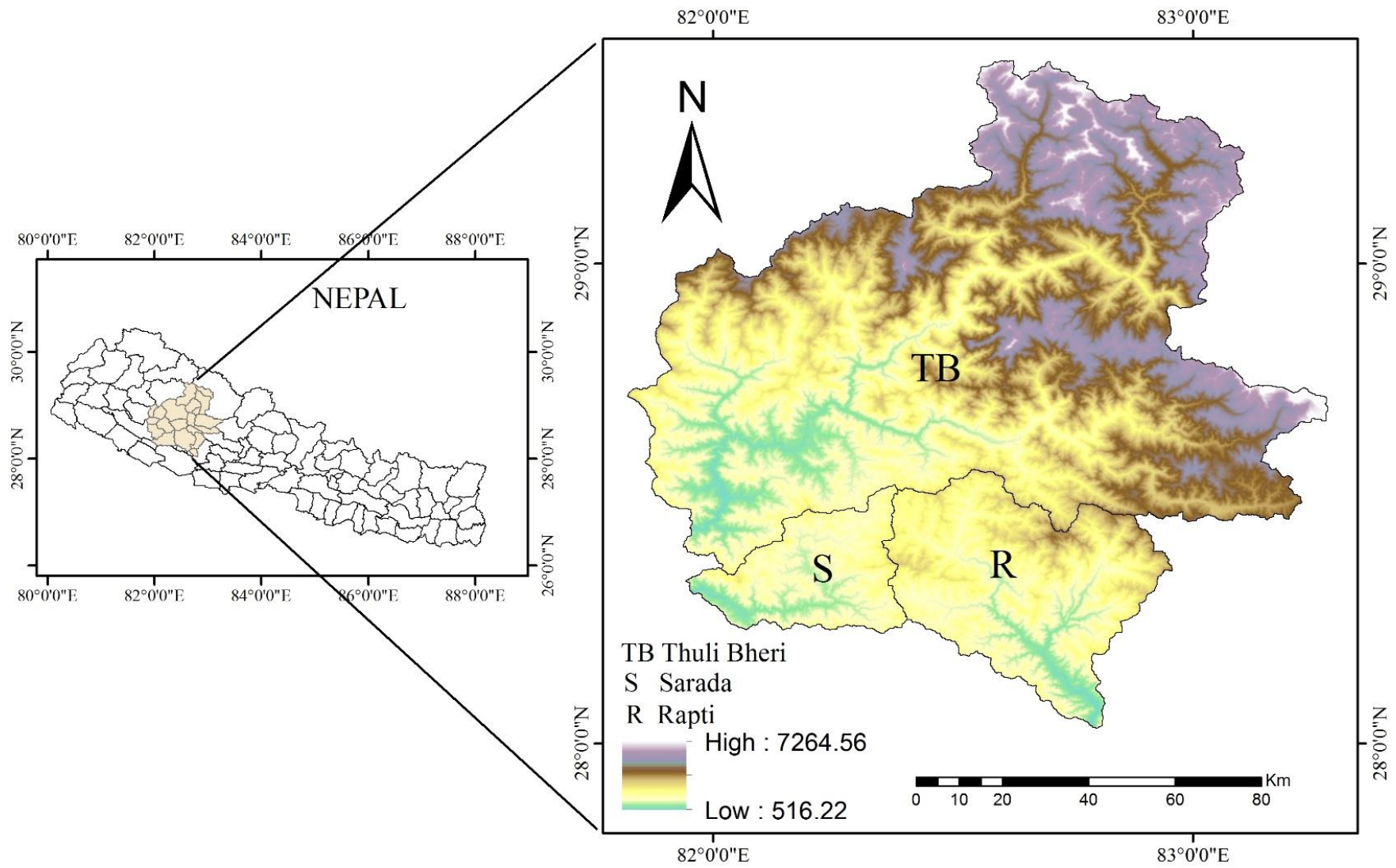


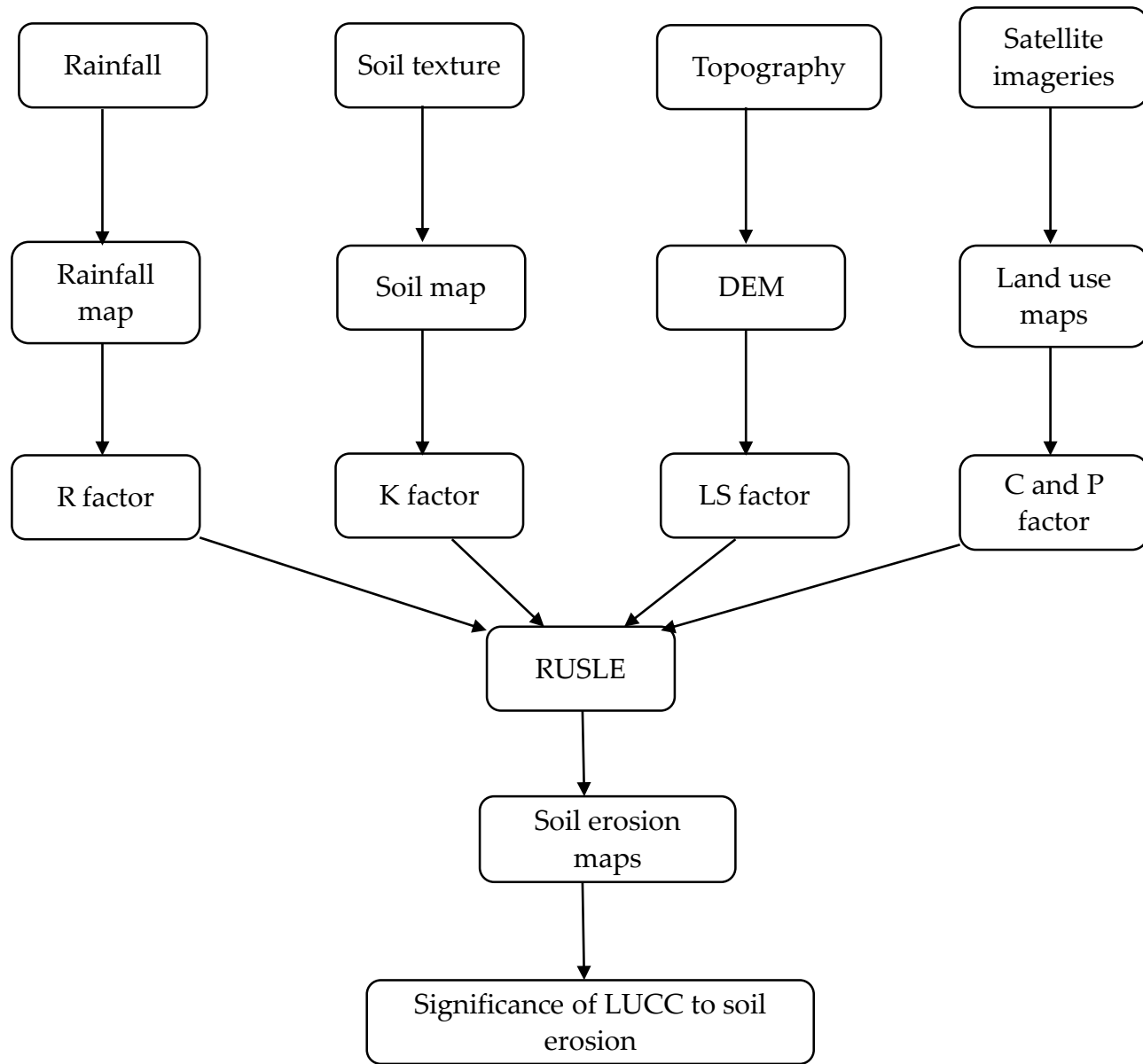
Fig: Mean monthly rainfall in Western Nepal for the years 2012 - 2016 and the average for 1980 – 2016



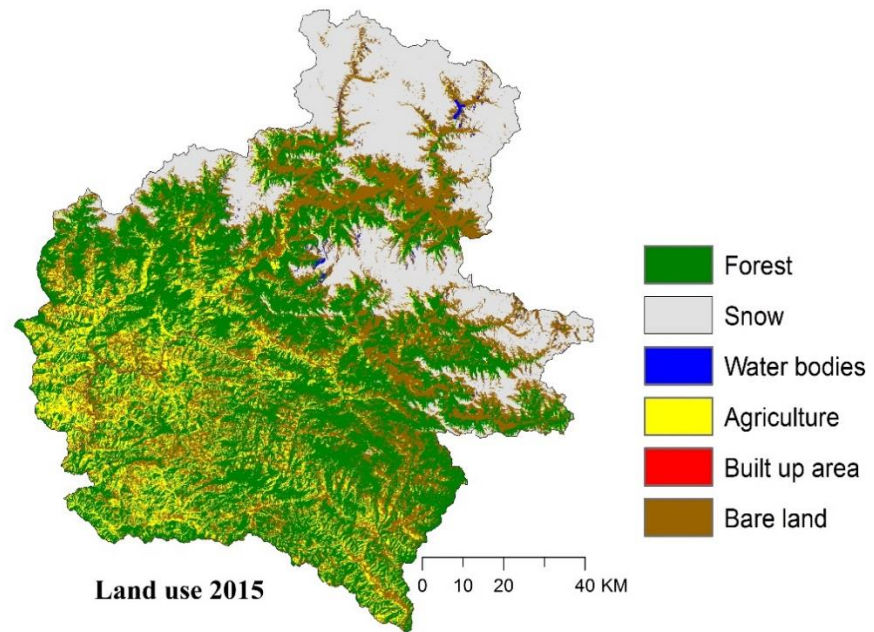
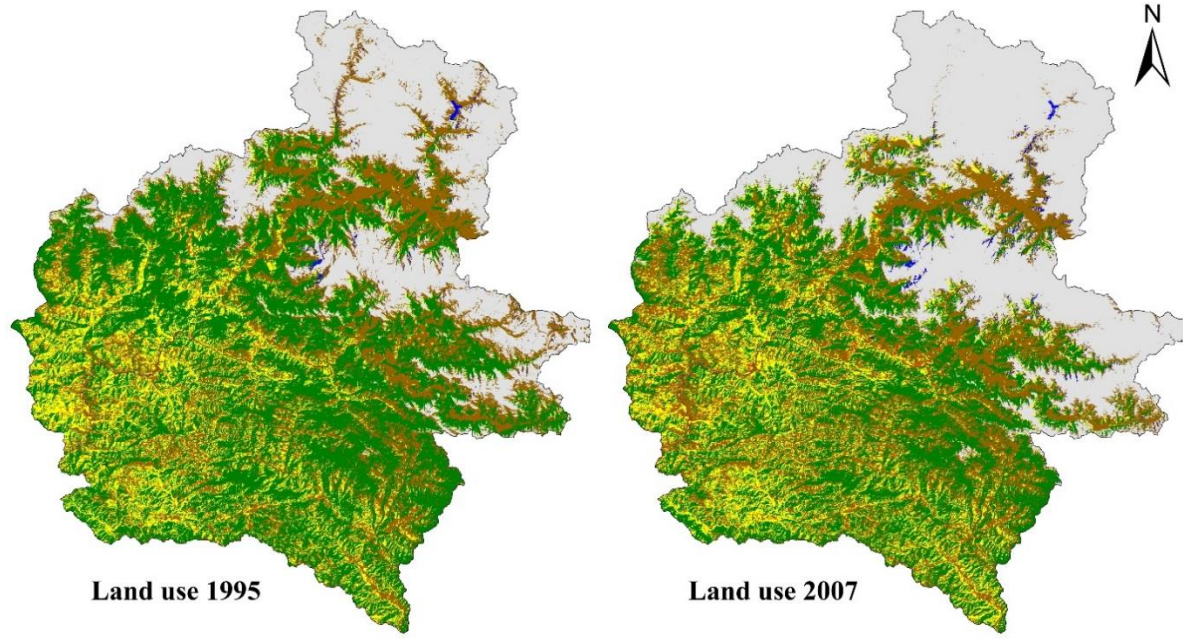
Study area with the DEM

Location and coverage of the study area

River basin	Elevation (m)	Location (^o)	Slope range (^o)	Physiographic region	Climate	Area (Sq. km)
Sarada	521 – 2,776	81°56'33" – 82°24'13" E 28°13'45" – 28°32'21" N	0 – 65.06	Terai Plains, Siwalik Hills, Middle Mountains and High Mountains	Humid tropical, moist subtropical, temperate and cool to sub-alpine	872
Rapti	516 – 3,597	82°21'4" – 82°57'22" E 28°1'51" – 28°34'18" N	0 – 71.86	Terai Plains, Siwalik Hills, Middle Mountains and High Mountains	Humid tropical, moist subtropical, temperate and cool to sub-alpine	1,972
Thuli Bheri	523 – 7,264	81°49'17" – 83°16'49" E 28°21'5" - 29°25'20" N	0 – 77.43	Terai Plains, Siwalik Hills, Middle Mountains, High Mountains and High Himalayas	Humid tropical, moist subtropical, temperate, cool to sub-alpine and alpine to arctic	9,338



Factor	Input	Source	Equations employed
R	Precipitation data (2006-2016)	Department of Hydrology and Meteorology, Kathmandu, Nepal	$R = 38.5 + 0.35 r$ (where r is annual rainfall in mm) (Harper 1987)
K	Soil texture and SOM values from laboratory analysis	Field work	Literature review
LS	DEM (20 m)	Nepal Agricultural Research Council, Kathmandu, Nepal	$L = (Cell\ size/22.13)^m$, where m ranges from 0.2 and 0.5. (Wischmeier and Smith 1978) $S = 0.0138 + 0.0097 s + 0.00138 s^2$ where s = slope in % (Šurda et al., 2007)
C	Land use map from Landsat 8 OLI	USGS Earth Explorer	Literature review
P	Land use map from Landsat 8 OLI	USGS Earth Explorer	Literature review

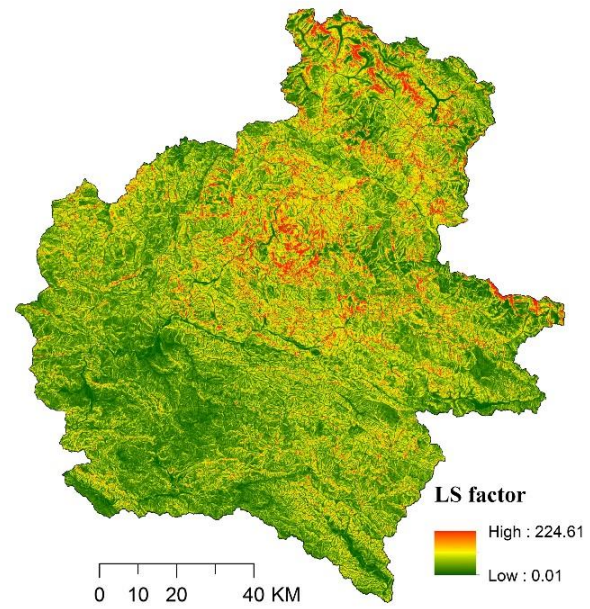
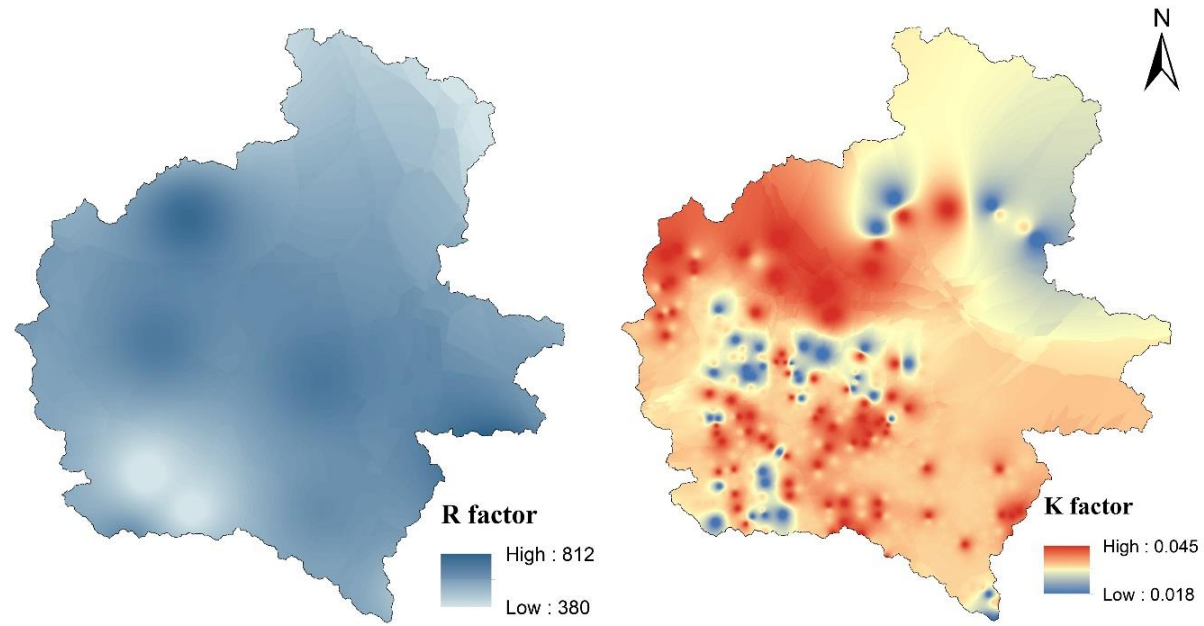


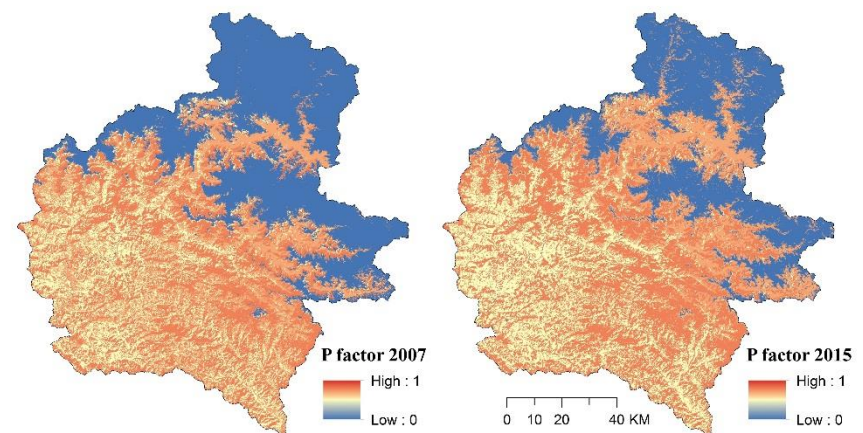
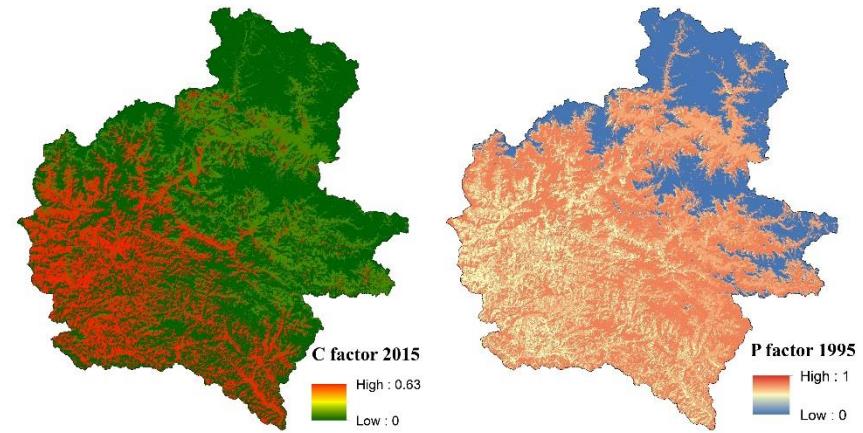
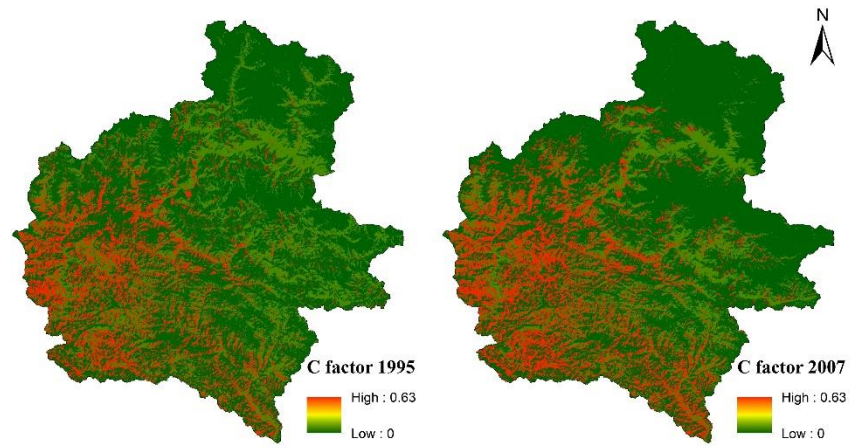
Distribution and percent change in LULC through the years 1995, 2007 and 2015

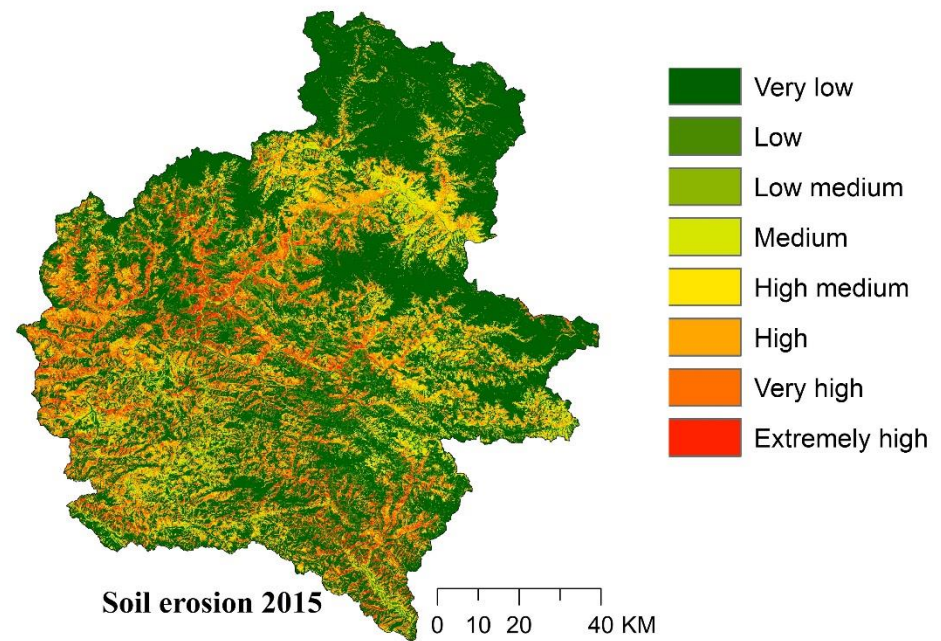
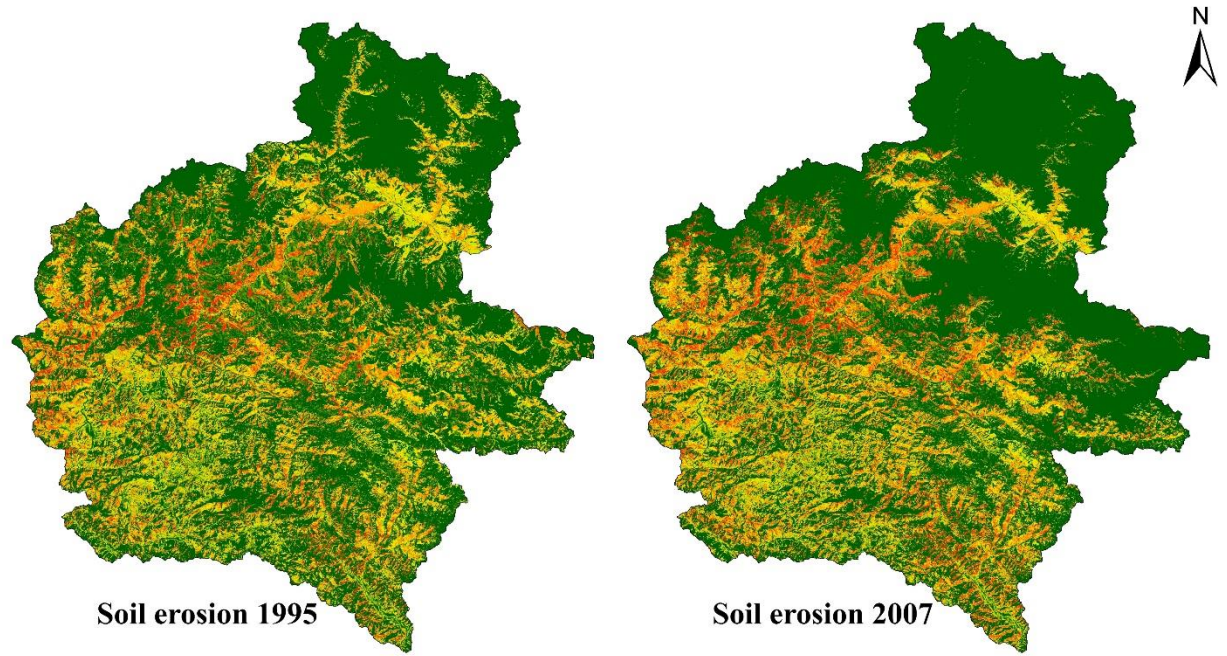
LULC	Area						Percent change in area		
	1995		2007		2015		1995 – 2007	2007 – 2015	1995 – 2015
	Area (sq. km)	(%)	Area (sq. km)	(%)	Area (sq. km)	(%)			
Agriculture	1780.78	14.61	2178.56	17.89	2722.3	22.35	22.33	24.95	52.87
Bare land	2994.56	24.59	2504.96	20.56	2311.5	18.97	-16.34	-7.72	-22.81
Built up area	0.2	0.001	7.1	0.05	16.1	0.13	3450	126.76	7950
Forest	4695.26	38.54	3518.04	28.88	4170.76	34.24	-25.07	18.55	-11.17
Snow	2673.3	21.95	3942.44	32.37	2946.44	24.19	47.47	-25.26	10.21
Water bodies	38.2	0.31	31.2	0.25	15.2	0.12	-18.32	-51.28	-60.21

Land use change matrix of the study area (1995 – 2007 and 2007 – 2015)

2007	1995						
	Agriculture	Bare land	Built up area	Forest	Snow	Water bodies	Total
Agriculture	1312.62	326.42	0	538.82	0.6	0.1	2178.56
Bare land	236.12	1819.62	0	443.62	1.1	4.5	2504.96
Built up area	1.4	4.7	0.2	0.8	0	0	7.1
Forest	116.32	59.2	0	3340.82	0.9	0.8	3518.04
Snow	114.22	780.12	0	354.5	2670.4	23.2	3942.44
Water bodies	0.1	4.5	0	16.7	0.3	9.6	31.2
Total	1780.78	2994.56	0.2	4695.26	2673.3	38.2	12182.3
2015	2007						
	Agriculture	Bare land	Built up area	Forest	Snow	Water bodies	Total
Agriculture	1633.06	829.2	5	179.14	75.8	0.1	2722.3
Bare land	71.9	1333.7	1.4	64.1	831.9	8.5	2311.5
Built up area	2.1	3	0.1	0.1	10.8	0	16.1
Forest	471.1	334.56	0.6	3268.8	88.4	7.3	4170.76
Snow	0.2	2.2	0	3.9	2934.14	6	2946.44
Water bodies	0.2	2.3	0	2	1.4	9.3	15.2
Total	2178.56	2504.96	7.1	3518.04	3942.44	31.2	12182.3







Soil erosion classes and severity in the study area through the years 1995, 2007 and 2015

Soil loss (t/ha/year)	Erosion severity	1995		2007		2015	
		Area (sq km)	%	Area (sq km)	%	Area (sq km)	%
0 – 0.5	Very low	6761.12	55.49	7169.28	58.85	6563.82	53.88
0.5 – 1	Low	808.87	6.64	600.24	4.93	666.12	5.47
1 – 2	Low medium	337.17	2.77	267.54	2.19	228.57	1.87
2 – 5	Medium	825.17	6.77	700.68	5.76	614.81	5.04
5 – 10	High medium	1115.09	9.16	955.96	7.85	1064.21	8.73
10 – 20	High	1148.61	9.43	1080.34	8.87	1366.05	11.22
20 – 50	Very high	876.53	7.19	1003.35	8.23	1255.39	10.32
> 50	Extremely high	309.74	2.55	404.91	3.32	423.33	3.47

Variation of soil loss with physiographic zones

Physiographic zones	Total area		Mean erosion (t/ha/year)		
	Sq km	%	1995	2007	2015
Terai Plains (516 – 700 m)	98.77	0.81	3.17	3.76	5.45
Siwalik Hills (700 -1500 m)	2535.29	20.81	9.67	11.26	13.55
Middle Mountains (1500 – 2700 m)	4281.48	35.14	8.52	10.51	11.07
High Mountains (2700 – 4000 m)	2909.19	23.89	5.42	5.04	6.16
High Himalayas (4000 – 7264 m)	2357.57	19.35	1.28	0.07	0.77

Variation of soil loss with LULC

Land use	1995				2007				2015			
	Area (Sq km)	Mean erosion rate (t/ha/year)	Total soil loss (t/year)	Contribution (%)	Area (Sq km)	Mean erosion rate (t/ha/year)	Total soil loss (t/year)	Contribution (%)	Area (Sq km)	Mean erosion rate (t/ha/year)	Total soil loss (t/year)	Contribution (%)
Agriculture	1780.78	29.65	52800.12	65.95	2178.56	28.76	62655.38	70.55	2722.3	29.39	80008.39	76.36
Bare land	2994.56	8.62	25813.10	32.24	2504.96	9.97	24974.45	28.13	2311.5	10.07	23276.81	22.22
Built up area	0.2	0.04	0.008	0.0001	7.1	12.93	91.80	0.1	16.1	12.7	204.47	0.19
Forest	4695.26	0.31	1455.53	1.81	3518.04	0.31	1090.59	1.22	4170.76	0.31	1292.93	1.23
Snow	2673.3	0	0	0	3942.44	0	0	0	2946.44	0	0	0
Water bodies	38.2	0	0	0	31.2	0	0	0	15.2	0	0	0
Total	12182.3	5.92	80068.75	100	12182.3	6.66	88812.22	100	12182.3	7.79	104779.60	100

THANK YOU

Soil texture	K factor
Clay, clay loam, loam, sandy clay loam, silty clay	0.035
Loamy sand, sand	0.007
Sandy loam	0.018
Silty clay loam, silty loam	0.045

LULC	C value	P value
Agriculture	0.63	0.5
Bare land	0.09	0.7
Built up area	0.09	1
Forest	0.003	0.8
Snow	0	0
Water bodies	0	0