CATCHMENT HYDROLOGICAL RESPONSE TO CHANGING LAND SYSTEM IN KASHMIR HIMALAYA

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PRESENTATION OVERVIEW

- KASHMIR HIMALAYAS
  - UPPER INDUS SYSTEM
- DYNAMIC COMPONENTS
  - STREAM FLOW CHANGES
  - WETLANDS/LAKES
  - LAND SYSTEM CHANGES AND PROJECTIONS
  - CRYOSPHERE
  - CLIMATE CHANGE SCENARIO
- HYDROLOGICAL CHANGES W.R.T. LULC
- BMPs/SCENARIO MAPPING
- CONCLUSIONS


1 Indus River
2 Jehlum River
3 Chenab River
4 Ravi River
5 Beas River
6 Sultlej River
Federally Administered Northern Areas
North-West Frontier Province
Federally Administered Tribal Area
Pakistan-administered Kashmir
AFGHANISTAN
PAKISTAN
Baluchistan
Punjab
INDIA
Sindh
Arabian Sea
0mi 100 200 300
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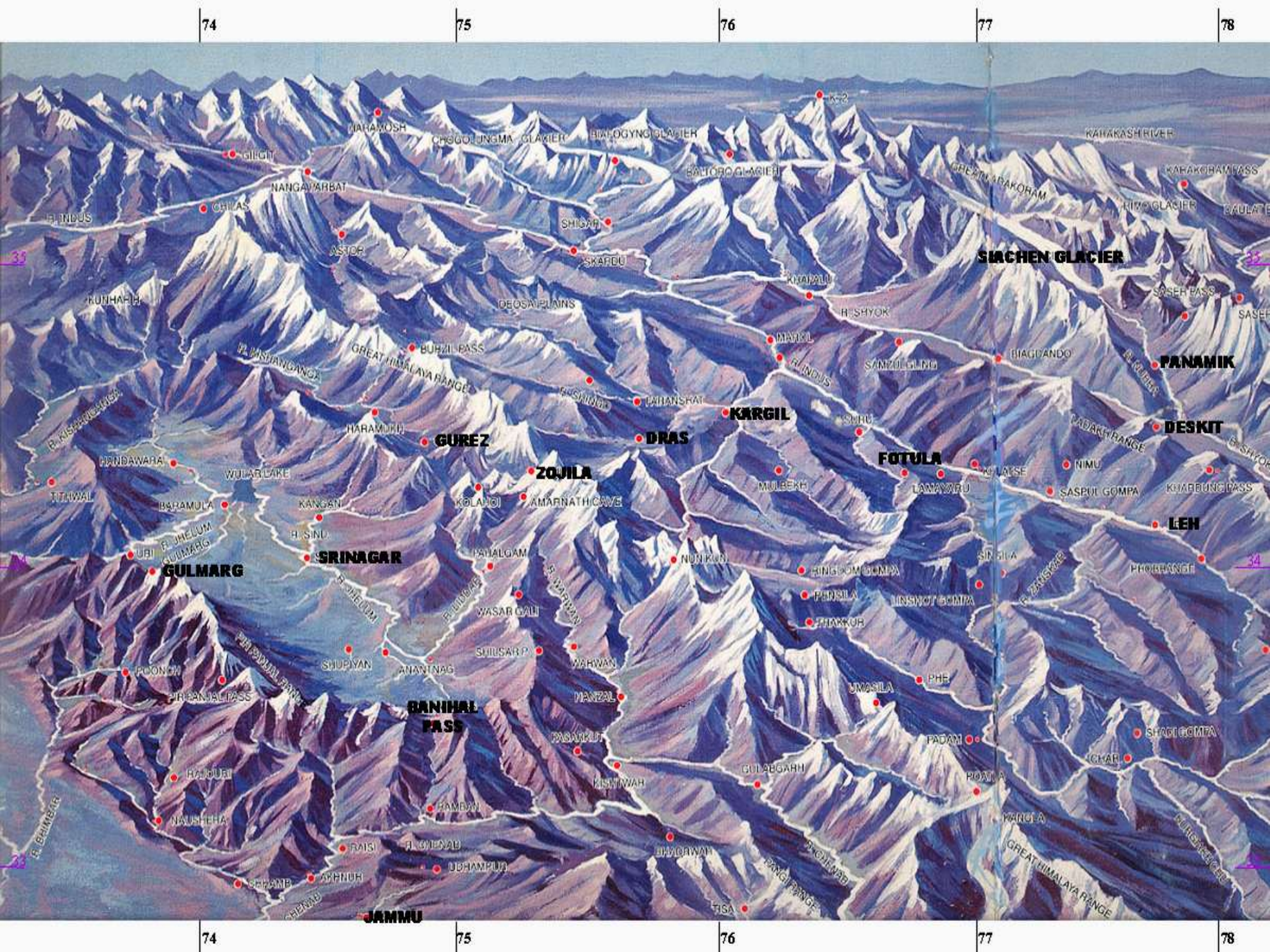
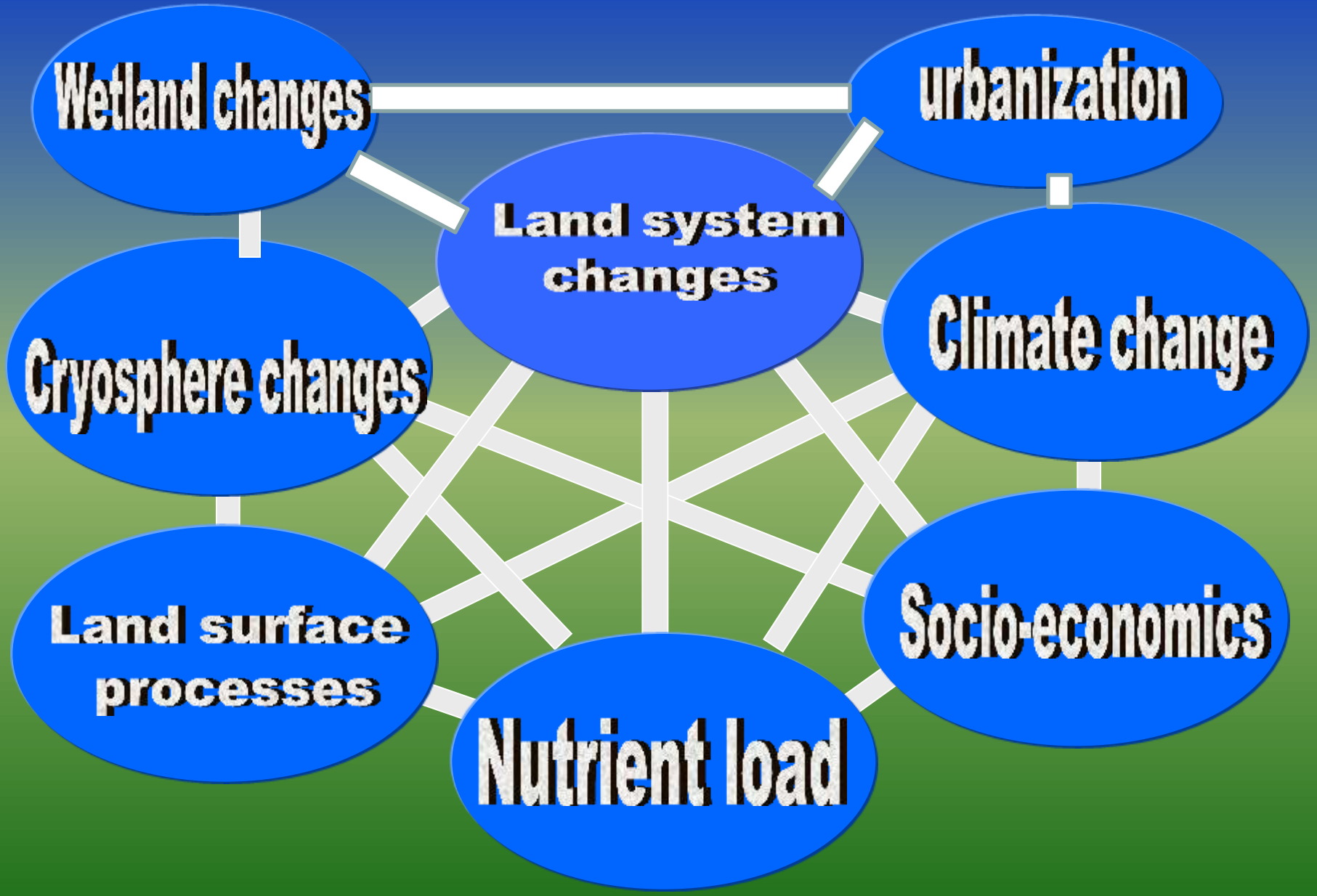
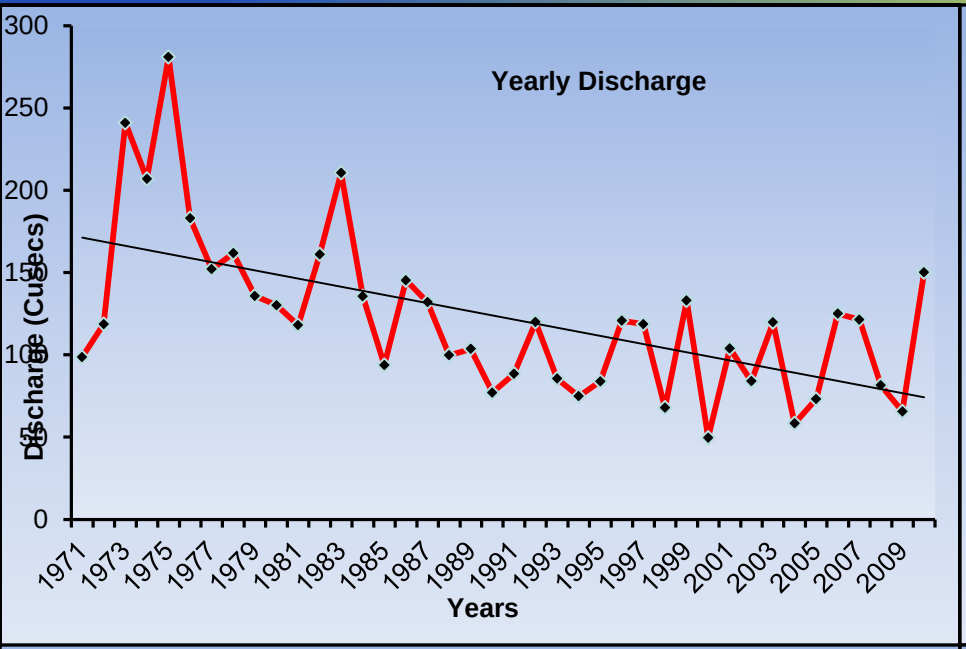


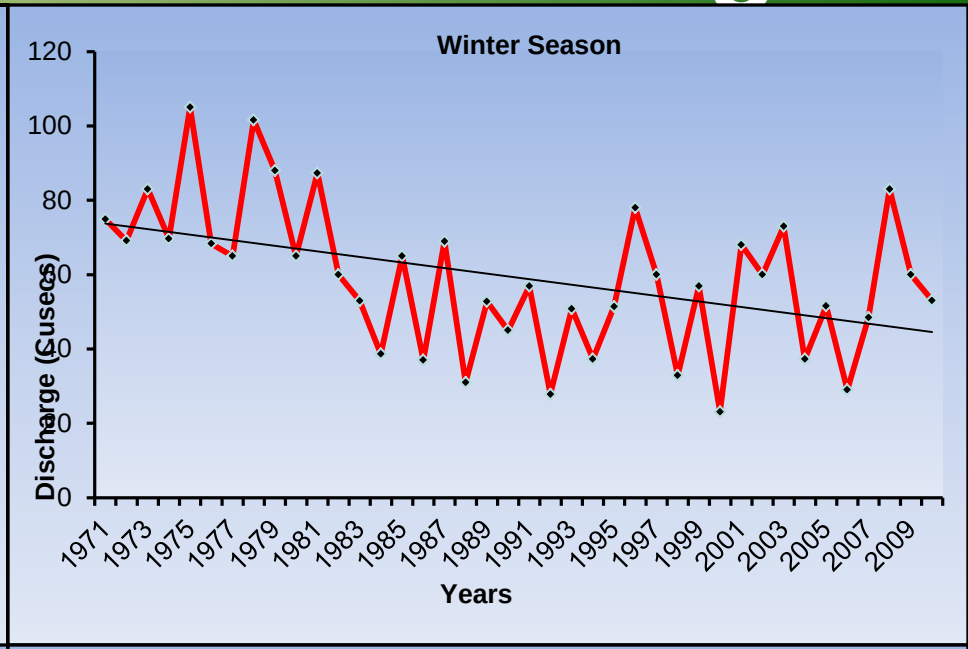
74
75
76
77
78
K-2
NANGA PARBAT
GILGIT
CHILAS
R. INDUS
ASTOR
SHIGAR
SKARDU
KHAPALU
R. SHYOK
DEOSAI PLAINS
BURZIL PASS
GREAT HIMALAYA RANGE
R. KISHANGANGA
SIACHEN GLACIER
KARAKASH RIVER
PANAMIK
DESKIT
LEH
KARGIL
DRAS
GUREZ
ZOJILA
FOTULA
HARAMUKH
HANDAWARA
WULAR LAKE
TITHWAL
BARAMULA
KANGAN
KOLAHOI
AMARNATH CAVE
MULBEKH
LAMAYURU
SASPUL GOMPA
KHARDUNG PASS
R. SIND
R. JHELUM
SRINAGAR
GULMARG
URI
PAHALGAM
NUN KUN
PENSILA
PHOBRANG
R. ZANSKAR
WASAR GALI
SHUPIYAN
ANANTNAG
POONCH
PIR PANJAL PASS
BANIHAL PASS
HANZAL
PADAM
CHAR
RAJOURI
NAUSHERA
KISHTWAR
GULABGARH
RAMBAN
R. CHENAB
RAISI
UDHAMPUR
BHADRWAH
AKHNUR
JAMMU
R. BHIMBAR
GREAT HIMALAYA RANGE

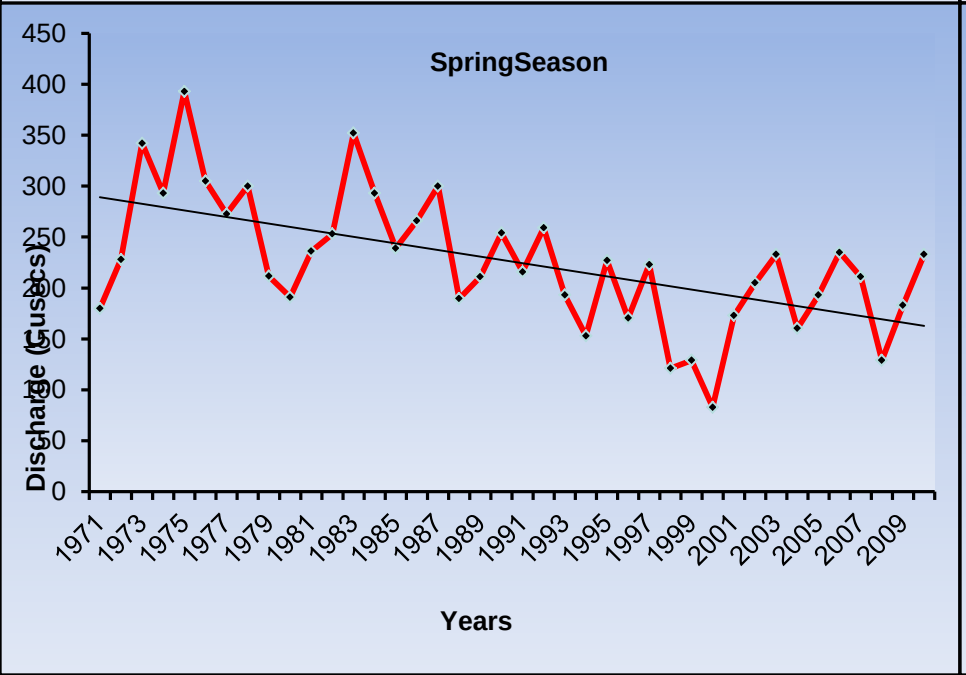
HYDROLOGIC SYSTEM LINKAGES

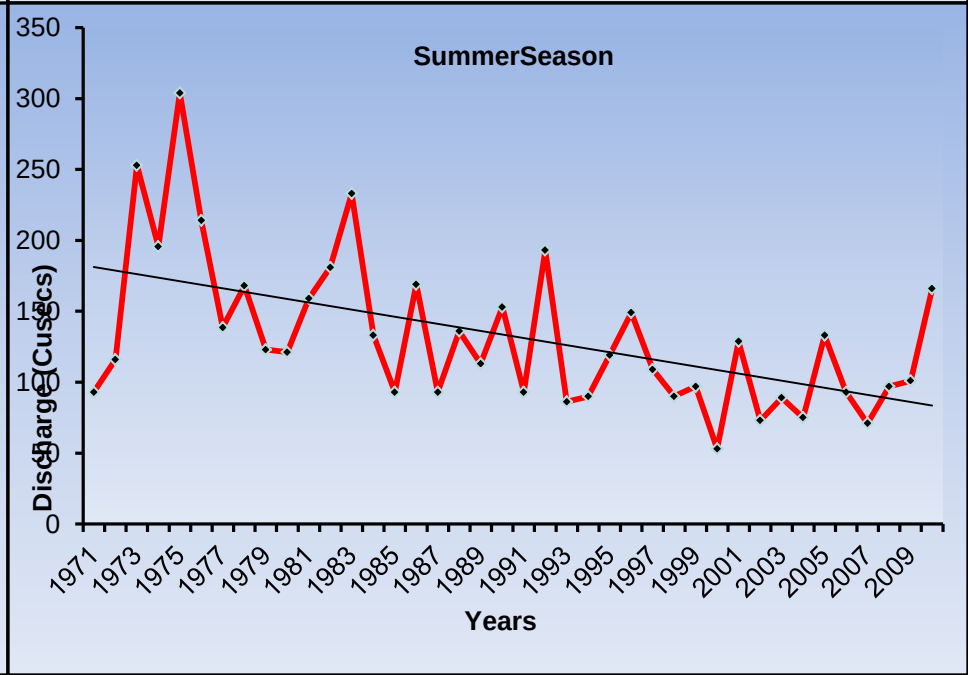


Observed Stream Flow Changes



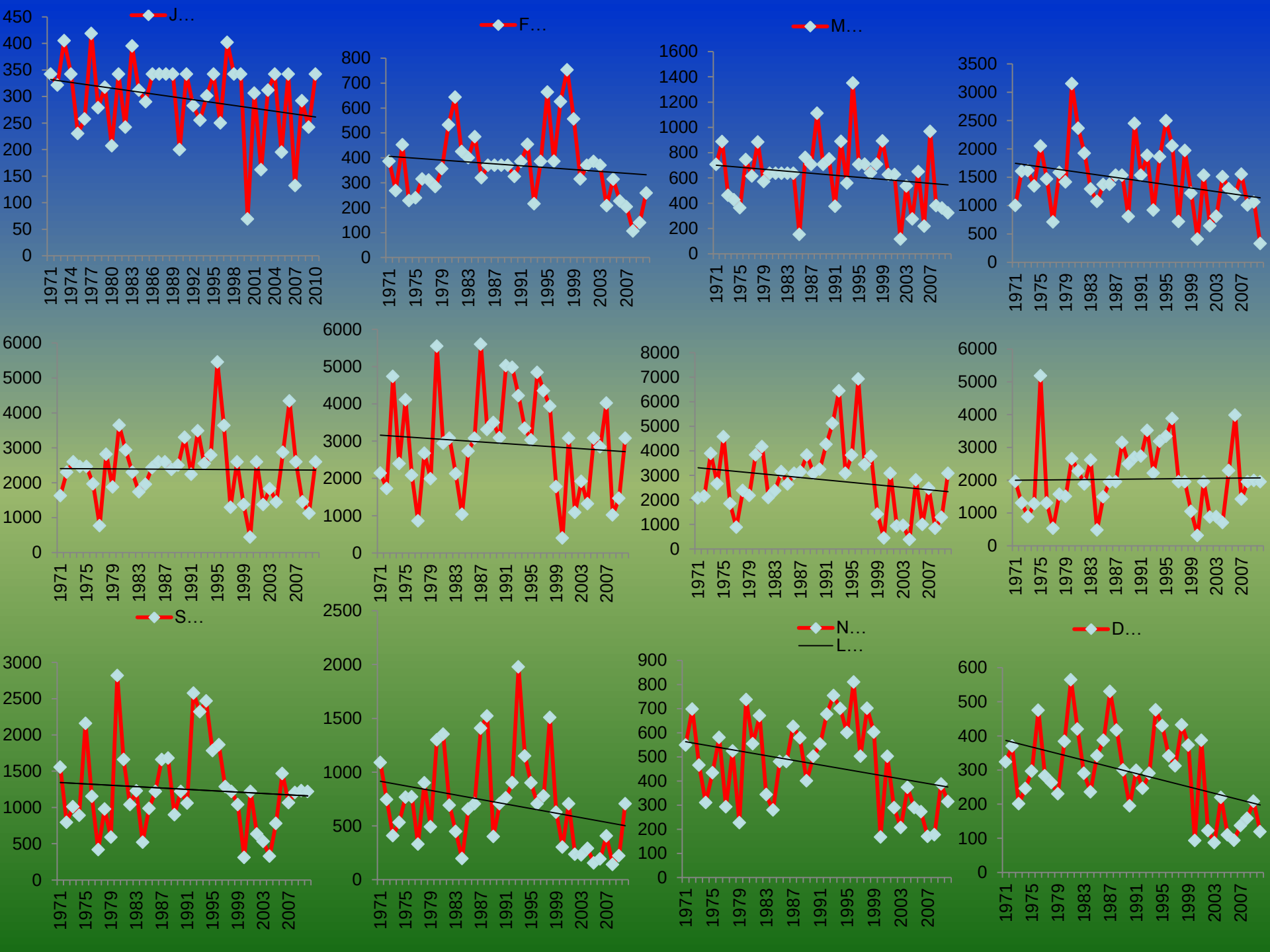




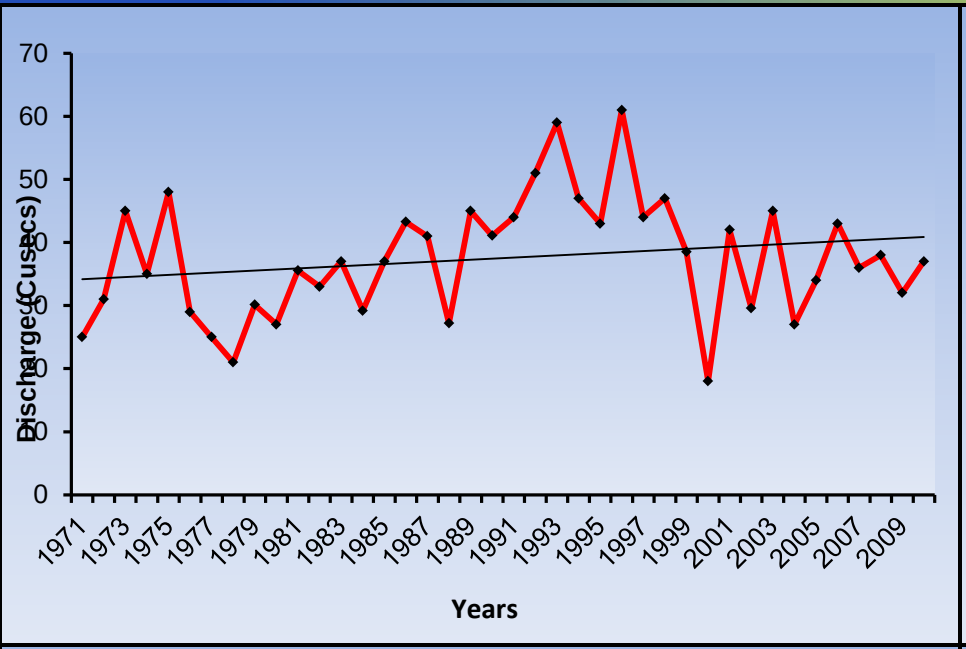


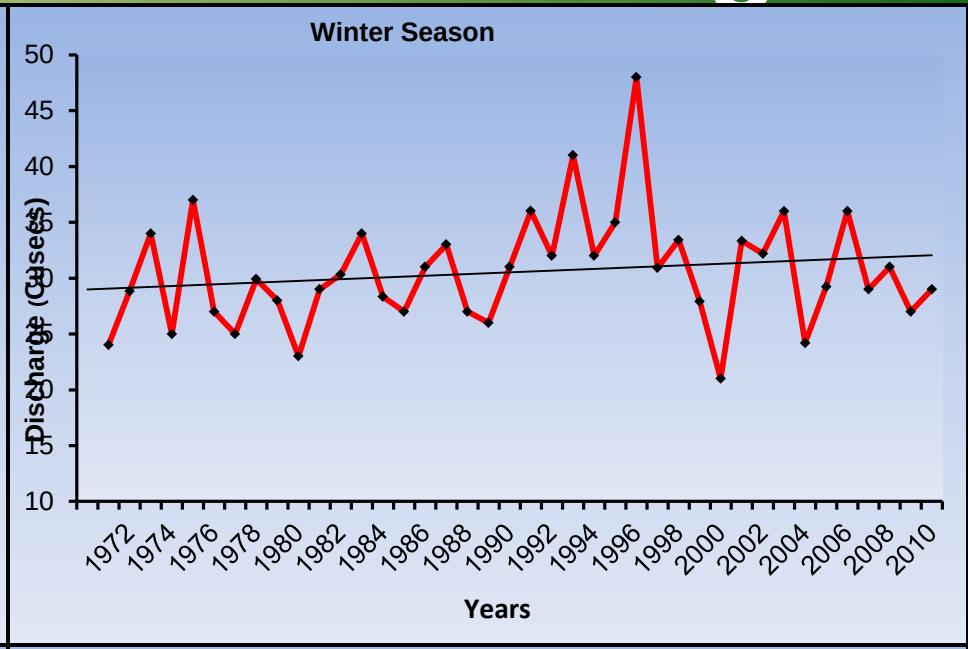
Name of the Test	DACHIGAM (yearly)				
	Test Static	a=0.1	a=0.5	a=0.01	Result
Mankendall	-3.787	1.645	1.96	2.576	S (0.01)
Spearman's Rho	-3.449	1.645	1.96	2.576	S (0.01)
Linear Regression	-4.468	1.687	2.025	2.713	S (0.01)

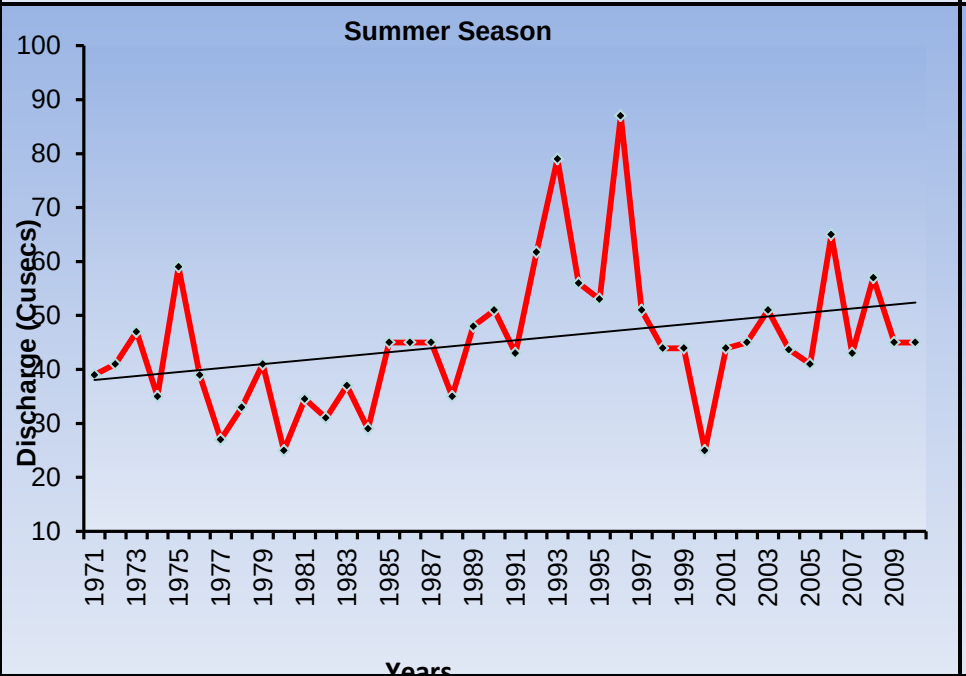
Test Type	DACHIGAM (Seasonal)					
	Season	Test statistic	a=0.1	a=0.05	a=0.01	Result
Mann-Kendall	Winter	-2.901	1.645	1.96	2.576	S (0.01)
	Spring	-3.577	1.645	1.96	2.576	S (0.01)
	Summer	-3.449	1.645	1.96	2.576	S (0.01)
Spearman's Rho	Winter	-2.698	1.645	1.96	2.576	S (0.01)
	Spring	-3.507	1.645	1.96	2.576	S (0.01)
	Summer	-3.231	1.645	1.96	2.576	S (0.01)
Linear Regression	Winter	-3.06	1.687	2.025	2.713	S (0.01)
	Spring	-4.402	1.687	2.025	2.713	S (0.01)

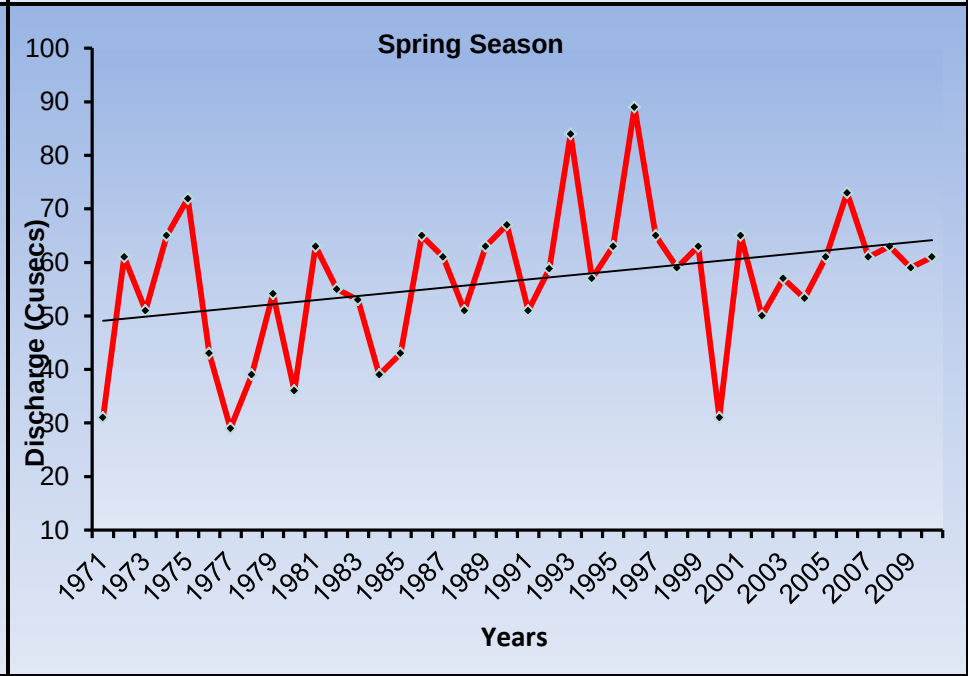

J…
F…
M…
S…
N…
L…
D…

Observed Stream Flow Changes





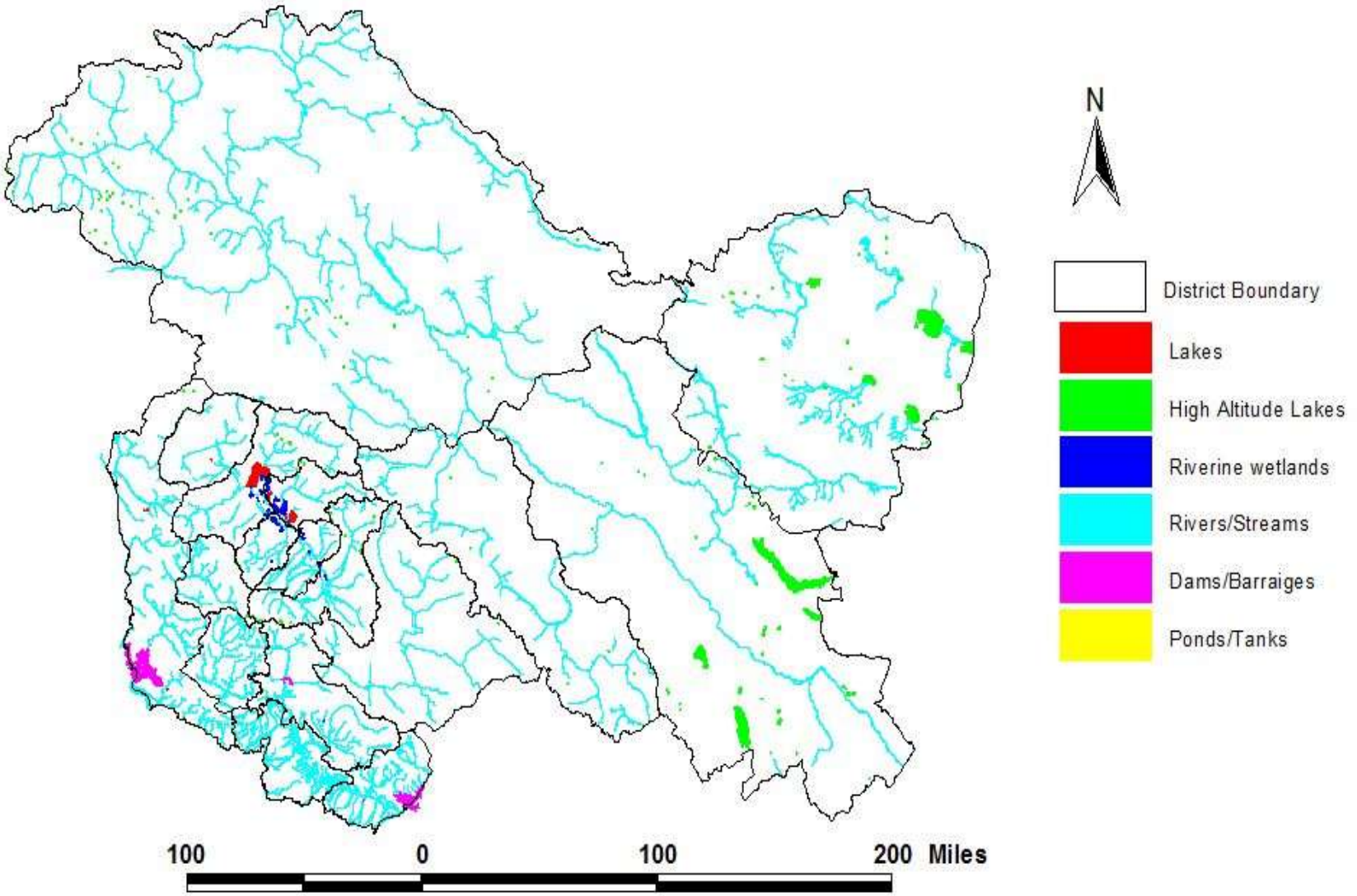




Name of the Test	DAKIL (yearly)				
	Test Static	a=0.1	a=0.5	a=0.1	Result
Mankendall	1.478	1.645	1.96	2.576	NS
Spearman’s Rho	1.544	1.645	1.96	2.576	NS
Linear Regression	1.337	1.687	2.025	2.713	NS

Test Type	DAKIL (seasonal)					
	Season	Test statistic	a=0.1	a=0.05	a=0.01	Result
Mann-Kendall	Winter	1.27	1.645	1.96	2.576	NS
	Spring	1.934	1.645	1.96	2.576	S(0.1)
	Summer	2.4	1.645	1.96	2.576	S(0.05)
Spearman's Rho	Winter	1.497	1.645	1.96	2.576	NS
	Spring	2.185	1.645	1.96	2.576	S(0.05)
	Summer	2.771	1.645	1.96	2.576	S(0.01)
Linear Regression	Winter	1.065	1.687	2.025	2.713	NS
	Spring	2.259	1.687	2.025	2.713	S(0.05)

Water Resource Map of UIB

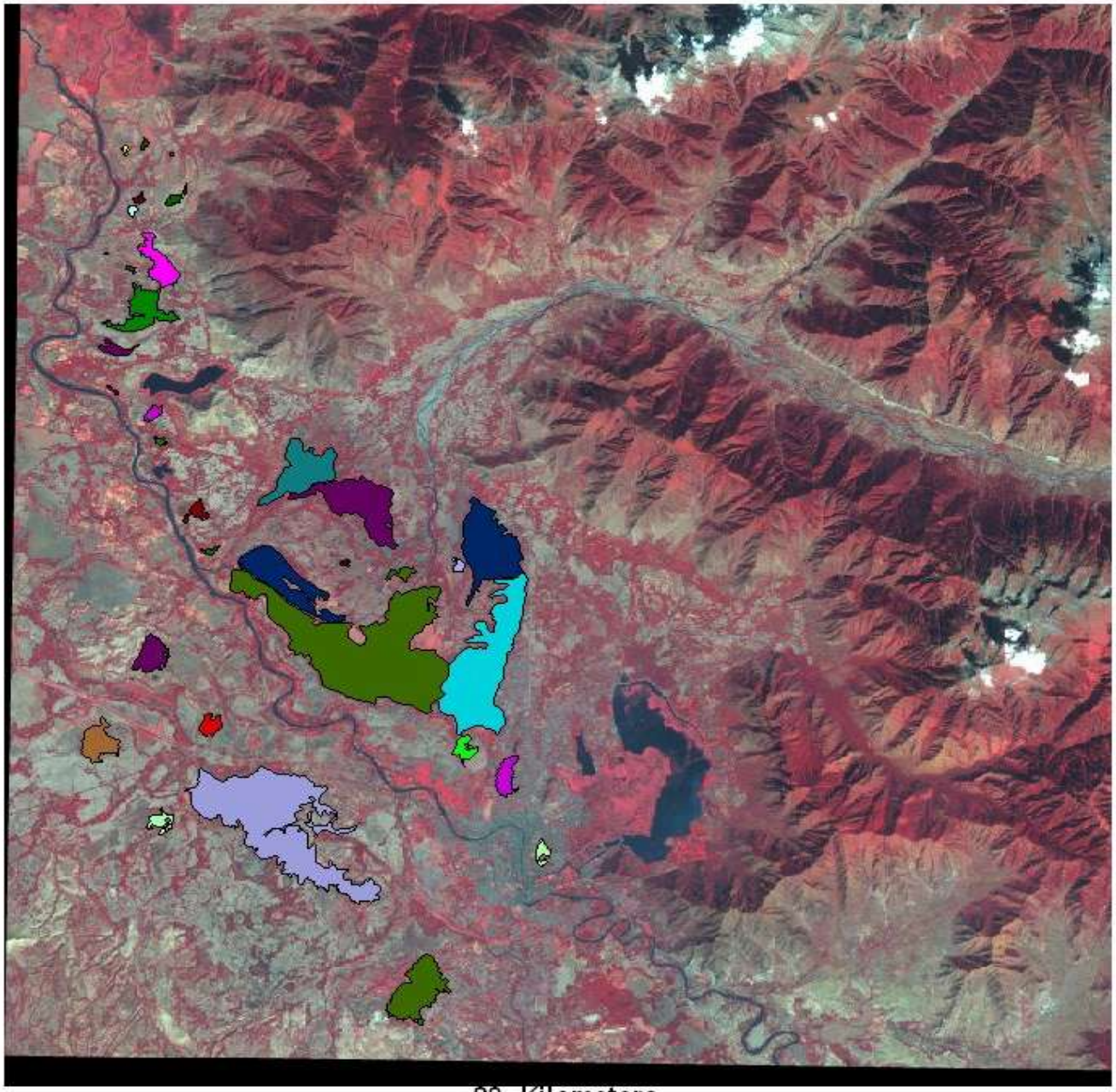


WATER RESOURCES

Area in ha

Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
				Post-monsoon Area	Pre-monsoon Area
Inland Wetlands - Natural					
Lakes/Ponds	36	13762	3.52	3371	6821
High altitude wetlands	1143	109170	27.88	105110	105072
Riverine wetlands	88	9594	2.45	153	1639
River/Stream	138	231597	59.16	170063	175550
Inland Wetlands -Man-made					
Reservoirs/Barrages	4	25132	6.42	23115	25121
Tanks/Ponds	2	6	0.00	6	6
Sub-Total	**1411**	**389261**	**99.43**	**301818**	**314209**
Wetlands (<2.25 ha)	2240	2240	0.57	-	-
Total	**3651**	**391501**	**100.00**	**301818**	**314209**

Wetland(2001)

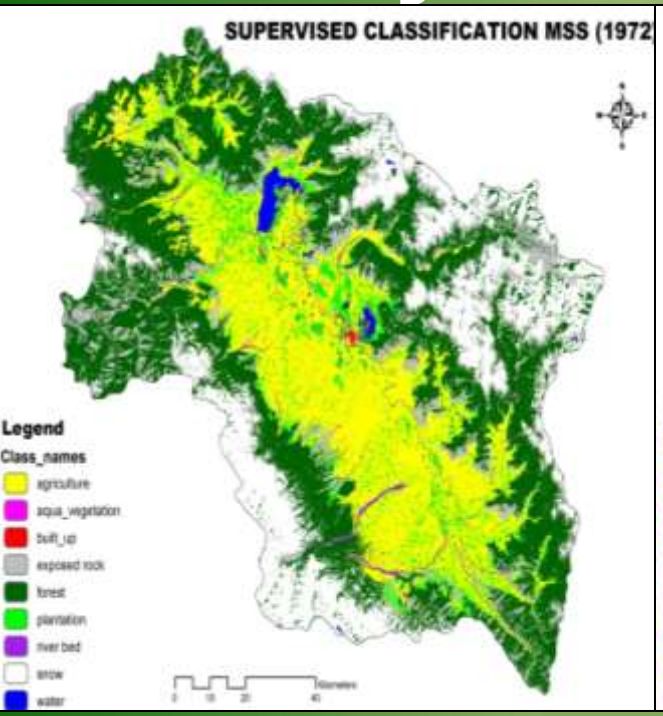


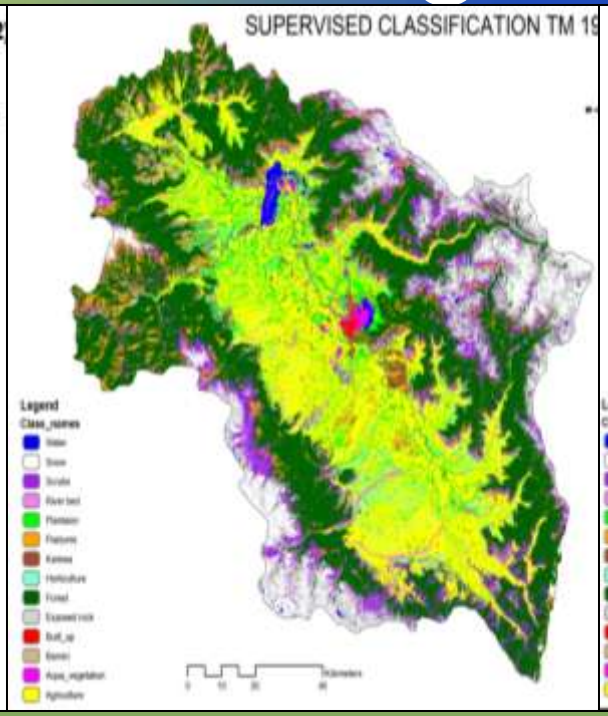
N

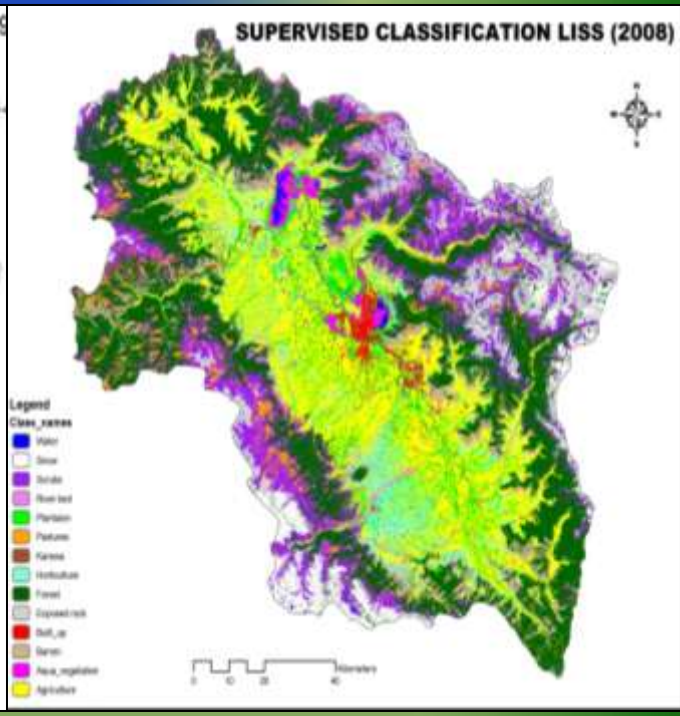
wetland(2001)
- ANCHAR
- BATAPUR
- BORIWAR SOLAPUR
- CHAK CHAND
- CHAKGUND
- CHANDARGAR
- GUND REHMAN
- HK_PRANG
- HOKAR SAR
- KHUSHAL SAR
- MIRGUND JILL
- NAMBALE NARAKUR
- NAMBALE SHALABUG
- NAMBLE SHALABUG
- NANDINARA
- NARANGBAD
- NAZ NAIK
- RAKH_I_ARAT
- RAKH_I_KUJAR
- RAKH_I_MALGAM
- RAKH_I_RABITAR
- RAKH_I_SALURA
- SADUNARA
- SHAH HAMDAN
- SHEKHPUR
- TENGPUR
- UK_AJAS CANAL
- UK_ASHAM
- UK_KUJAR
- UK_LOWIPURA
- UK_SUDARKOTE
- UK_YAKMANPUR
- UK_ZADIPURA
- ZINIPURA

0 20 Kilometers

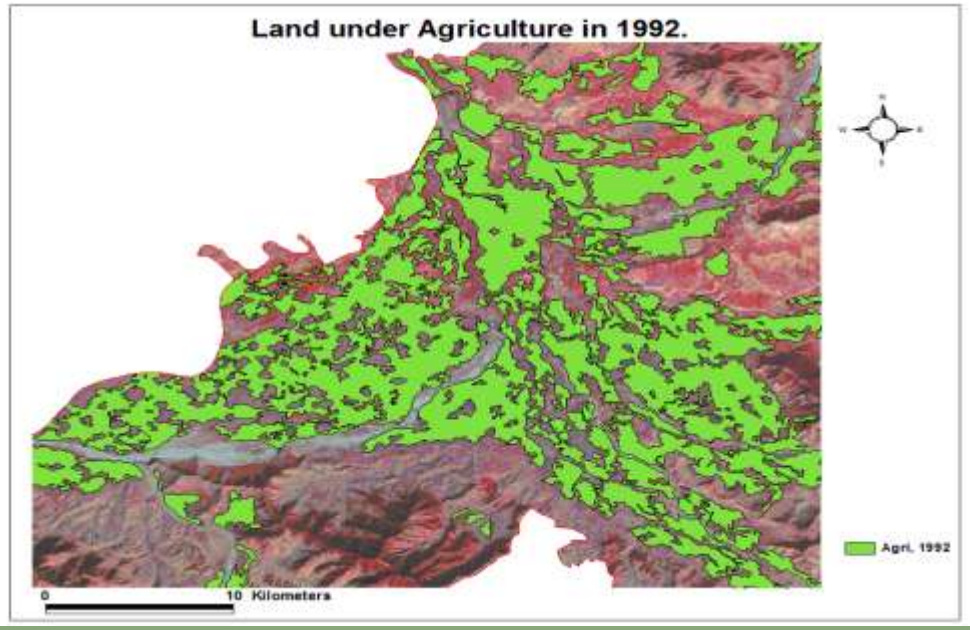
Land System Changes in Kashmir

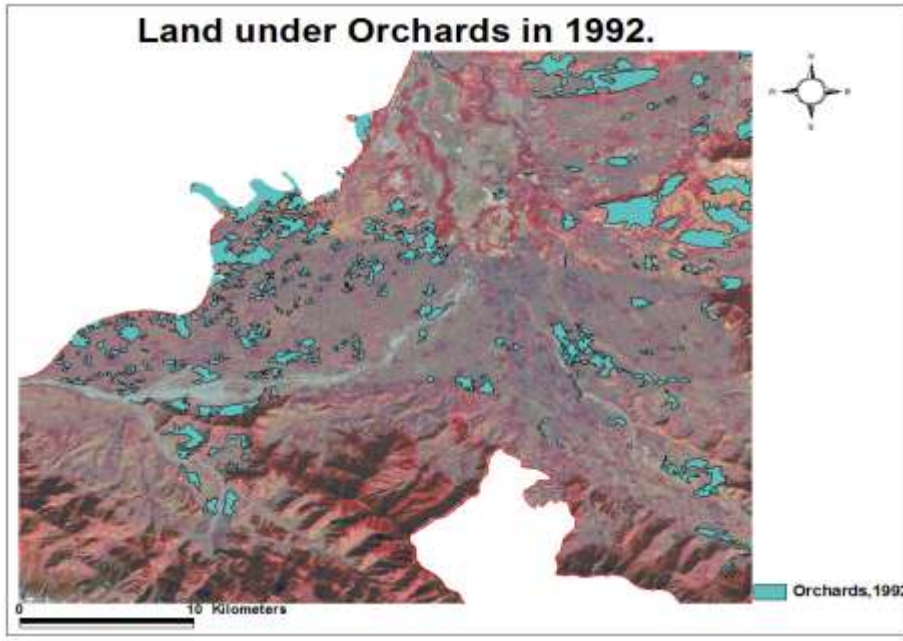


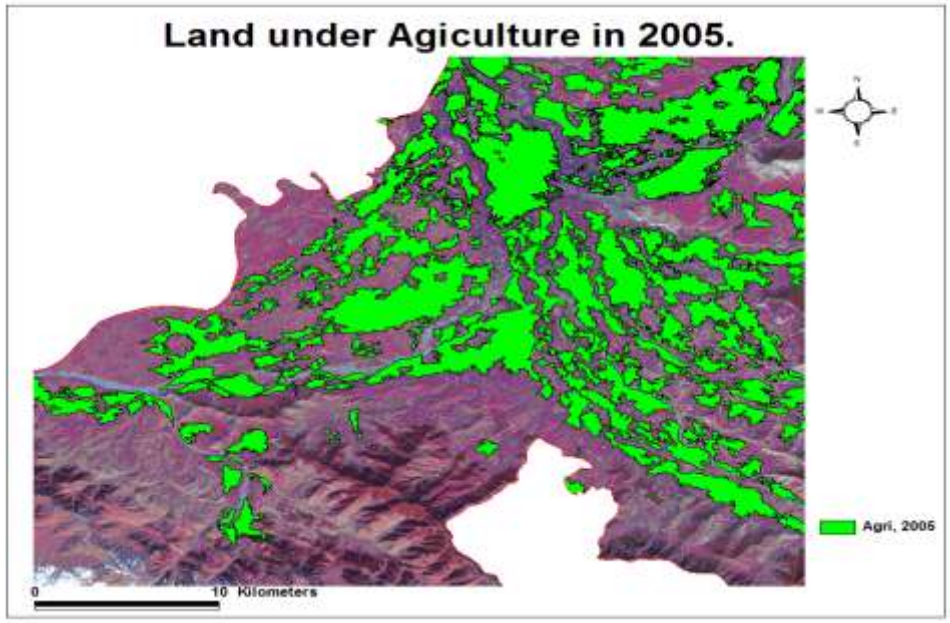


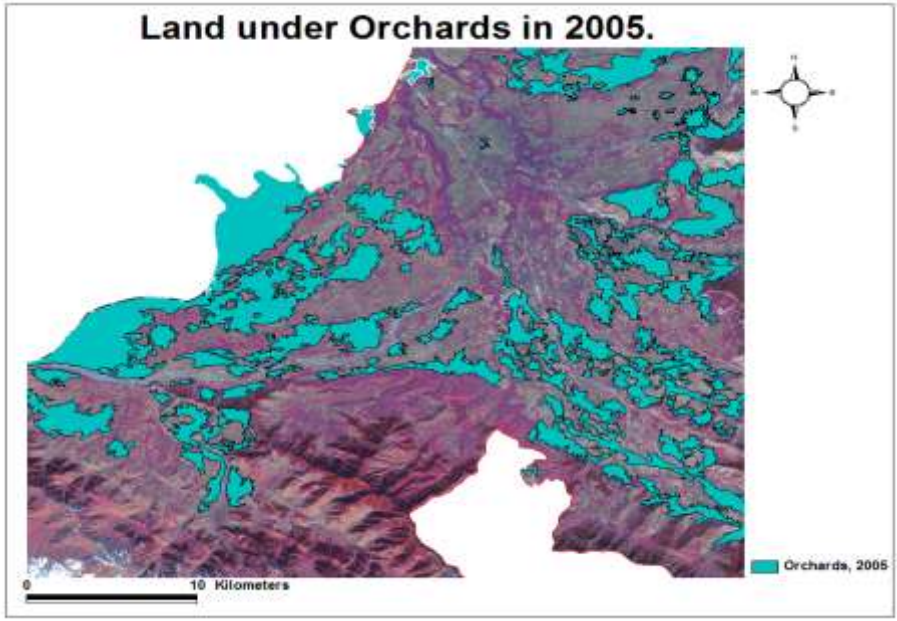


CLASS NAME	1972 AREA (HA)	1992 AREA (HA)	2008AREA (HA)
FOREST	485473.31	464798.36	391368.55
AGRICULTURE	337788.45	301094.00	269138.93
PLANTATION	92240.15	89443.34	85876.76
HORTICULTURE	17954.44	28858.26	71899.18
WATER	12795.11	11024.42	6827.09
RIVER BED	9899.81	9812.22	7512.82
AQUA_VEGETATION	3981.44	7503.56	11729.20
BUILT-UP	578.07	5914.96	21432.81

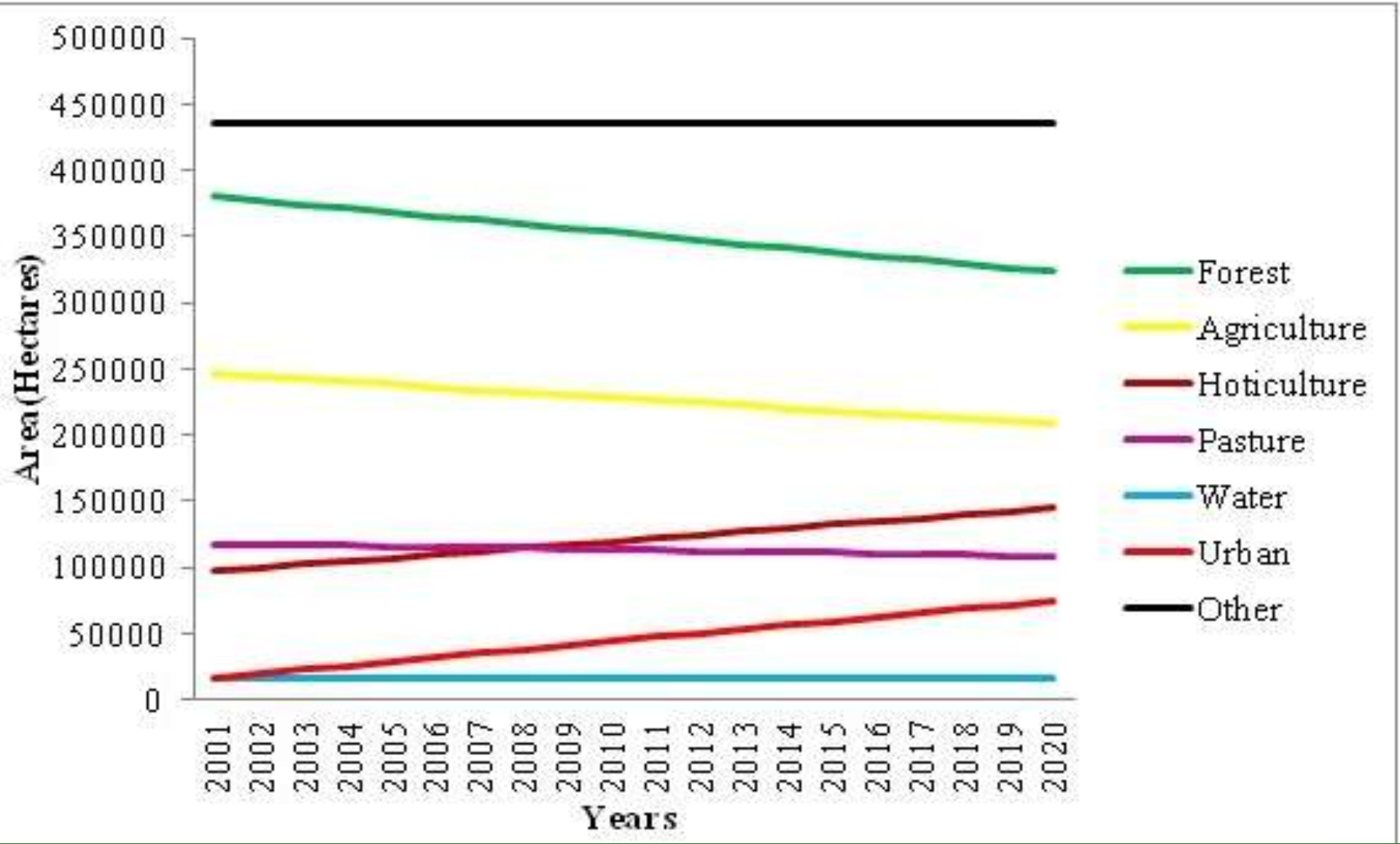

Land under Agriculture in 1992.
Agri, 1992
0
10 Kilometers


Land under Orchards in 1992.
Orchards,1992
0
10 Kilometers


Land under Agiculture in 2005.
Agri, 2005
0
10 Kilometers


Land under Orchards in 2005.
Orchards, 2005
0
10 Kilometers

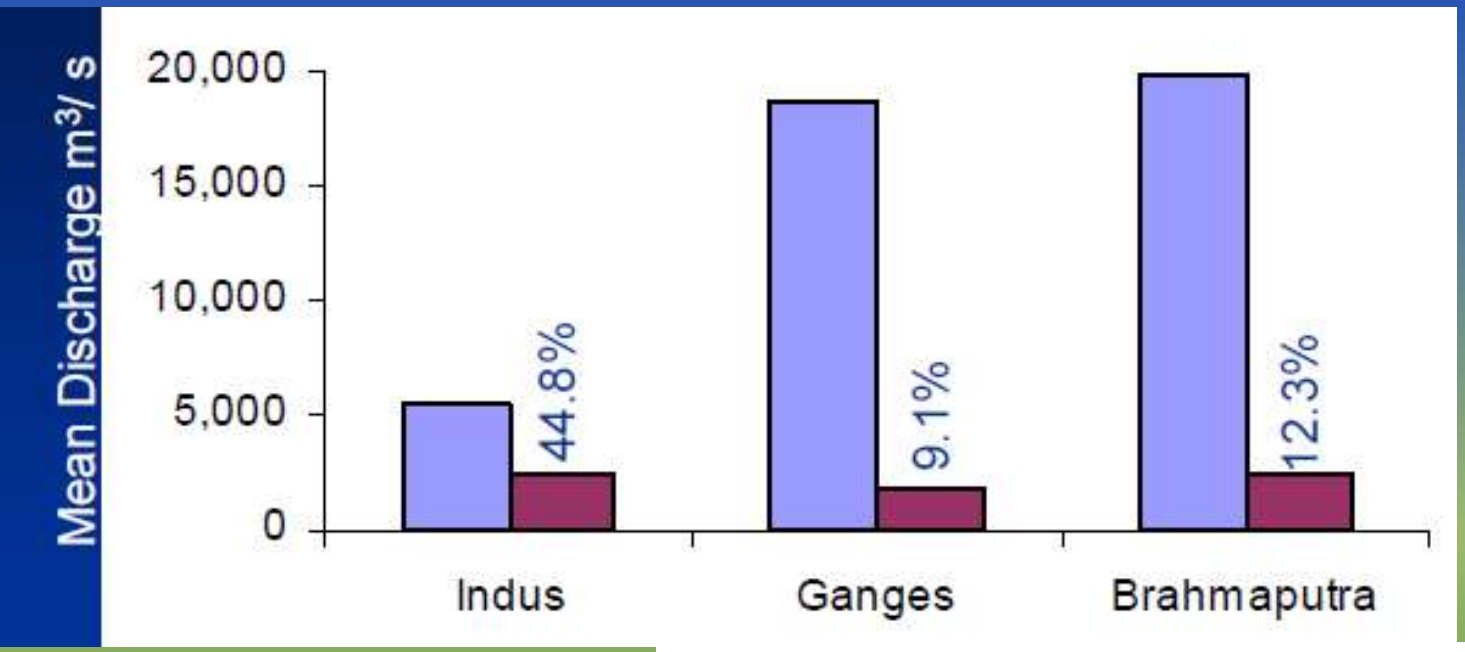
Land System Change Projections (2001-2020)

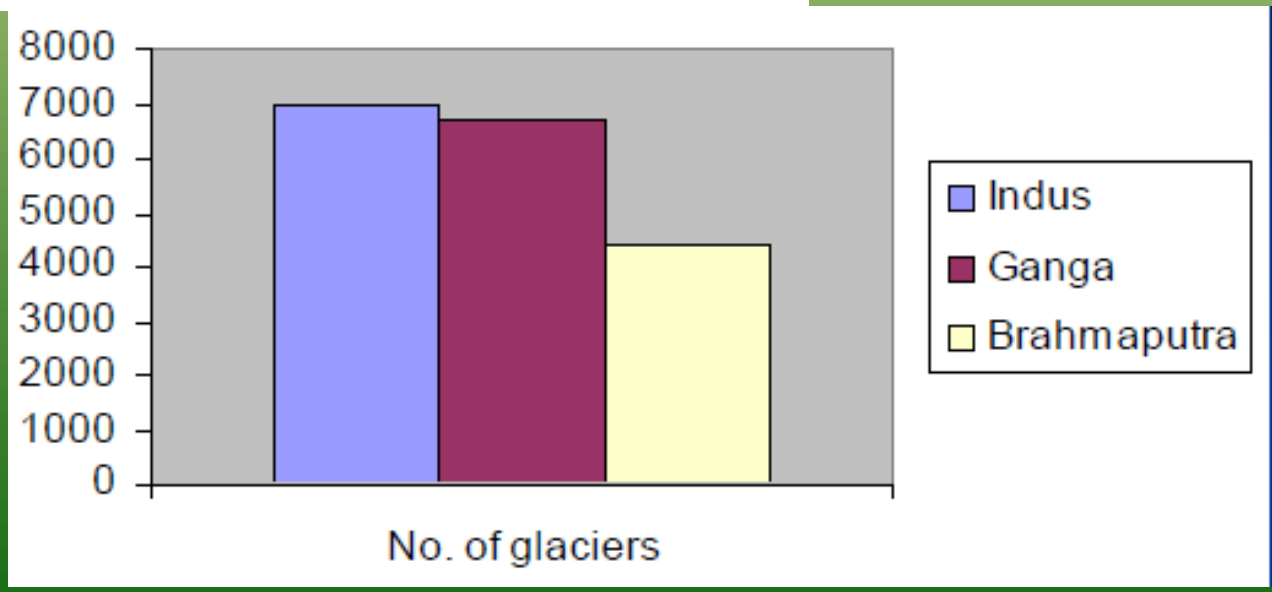


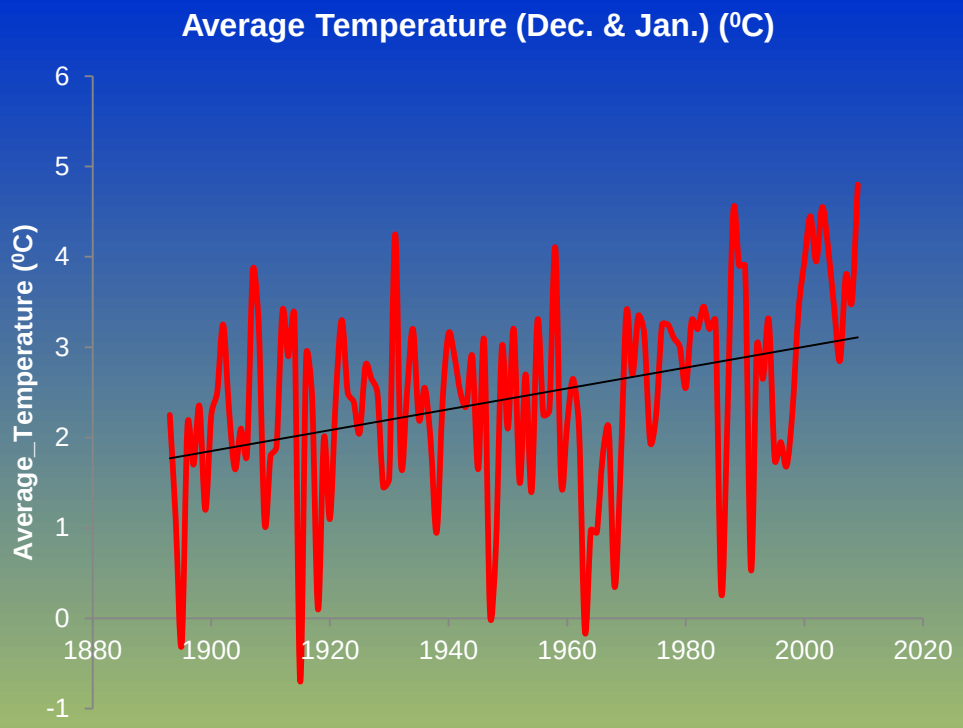
Changes in Kashmir Cryosphere

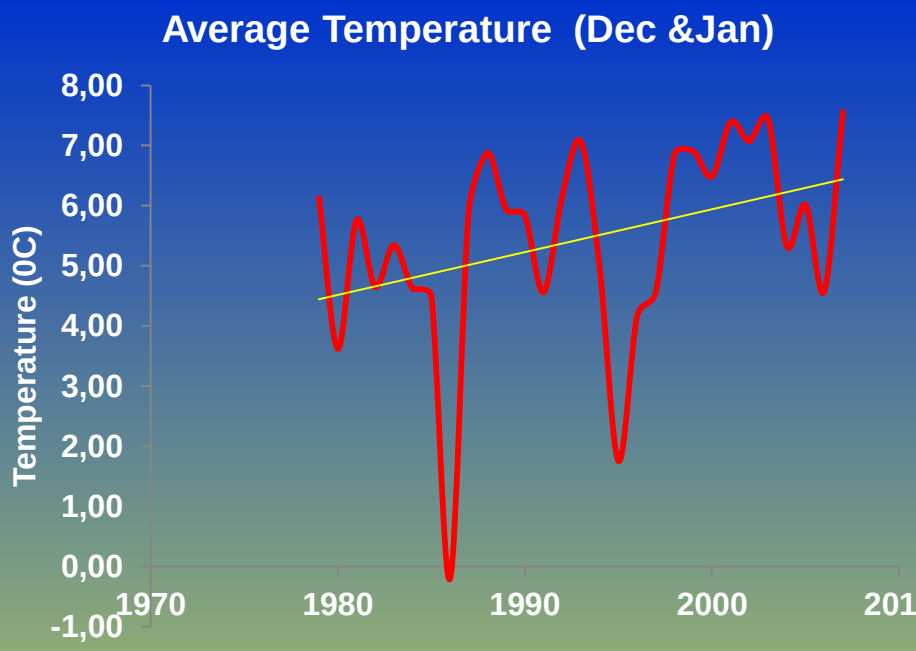
Total Glacier area in 1969 (sq. Km)	Total Glacier area 1992 (Sq. Km)	Total Glacier area 2001(sq. Km)	Total Glacier area 2010 (Sq. Km)
45.63	41.74	38.96	38.48

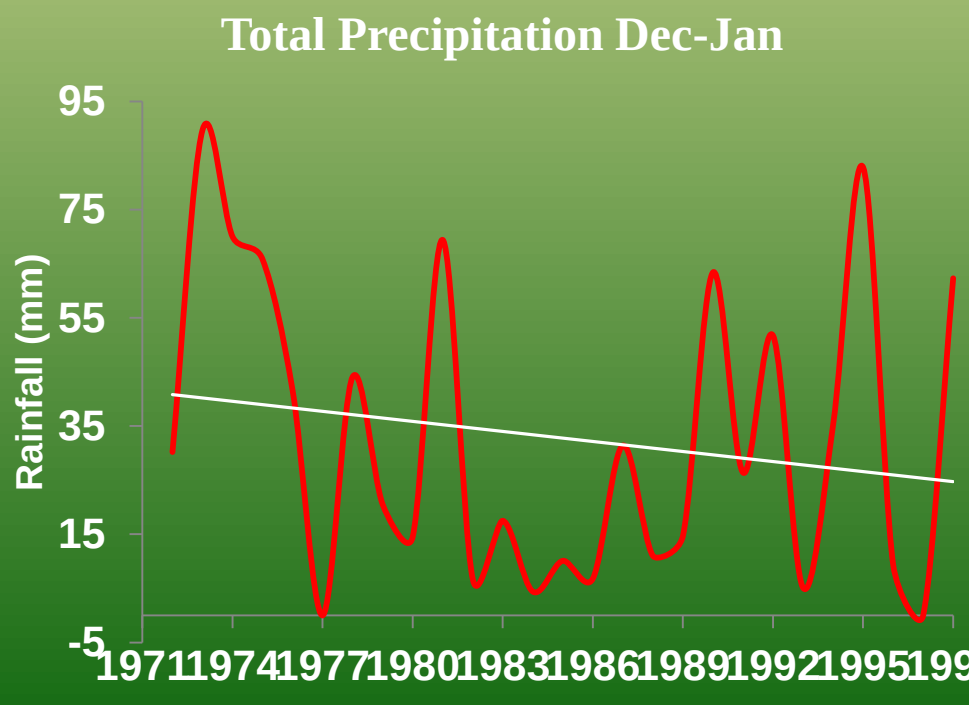
Water Tower of Asia

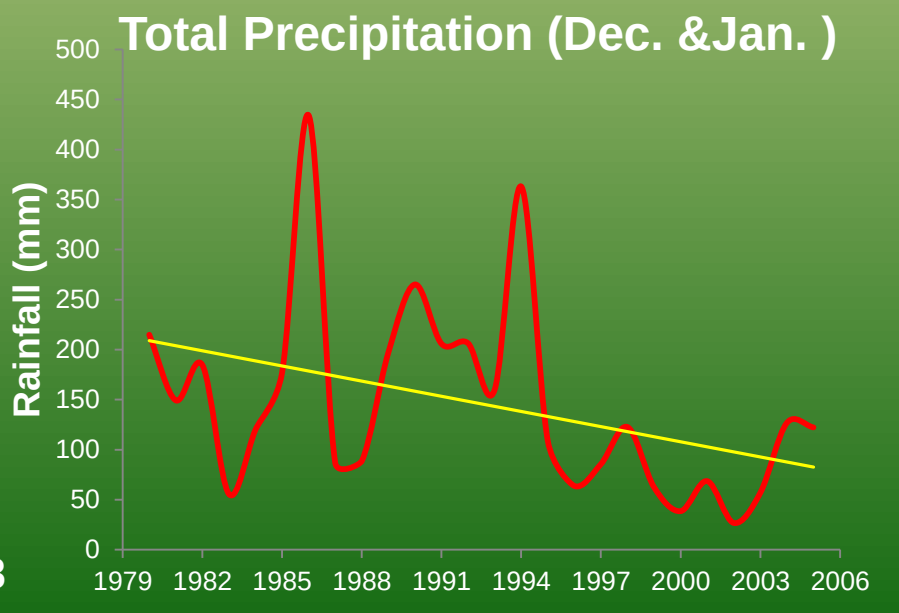




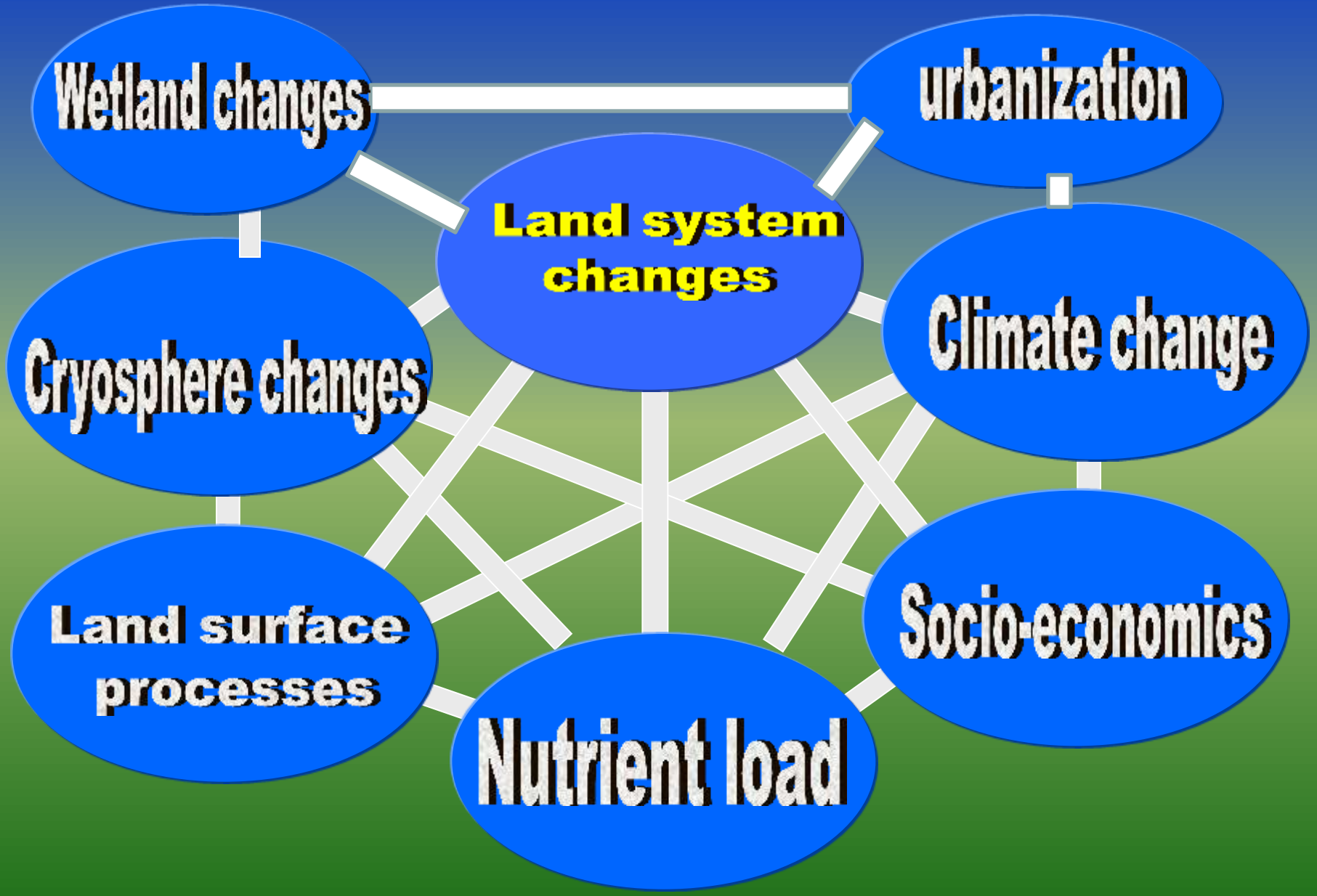

Average Temperature (Dec. & Jan.) (⁰C)
Average_Temperature (⁰C)
6
5
4
3
2
1
0
-1
1880
1900
1920
1940
1960
1980
2000
2020


Average Temperature (Dec &Jan)
Temperature (0C)
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
-1,00
1970
1980
1990
2000
201


Total Precipitation Dec-Jan
Rainfall (mm)
95
75
55
35
15
-5
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998

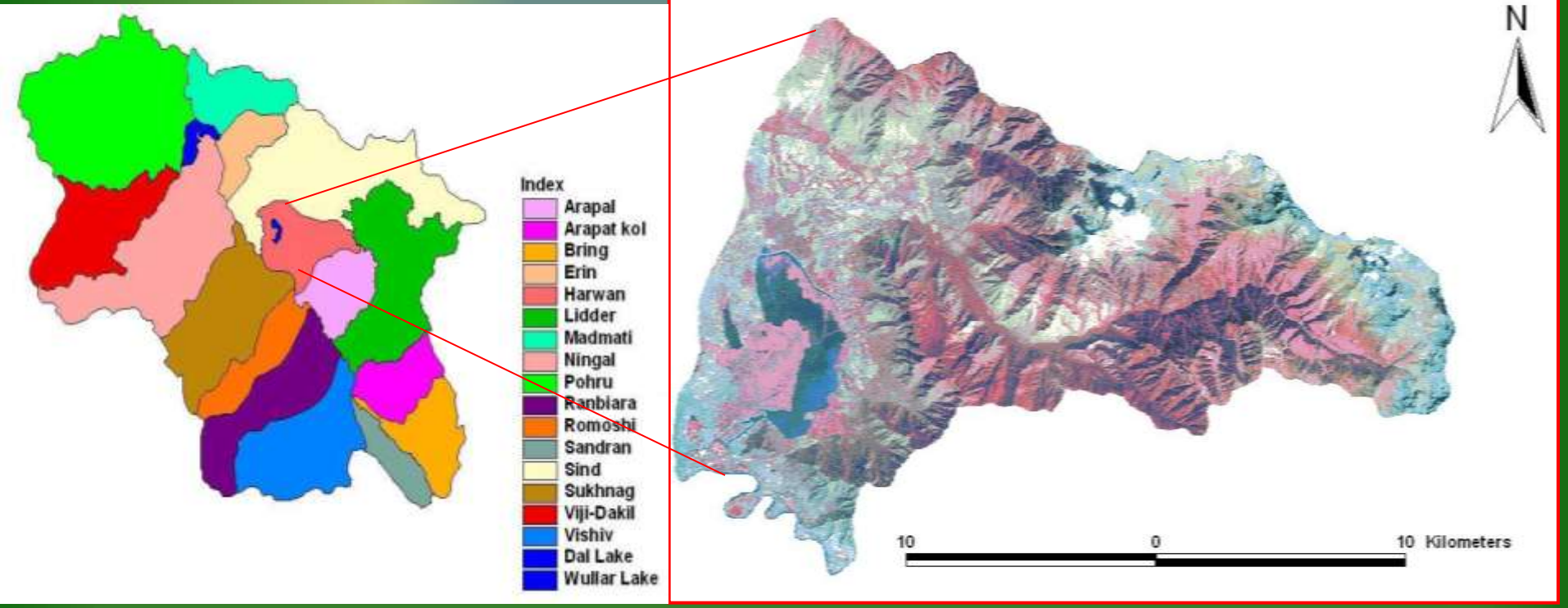

Total Precipitation (Dec. &Jan.)
Rainfall (mm)
500
450
400
350
300
250
200
150
100
50
0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006

HYDROLOGIC STYTEM LINKAGES

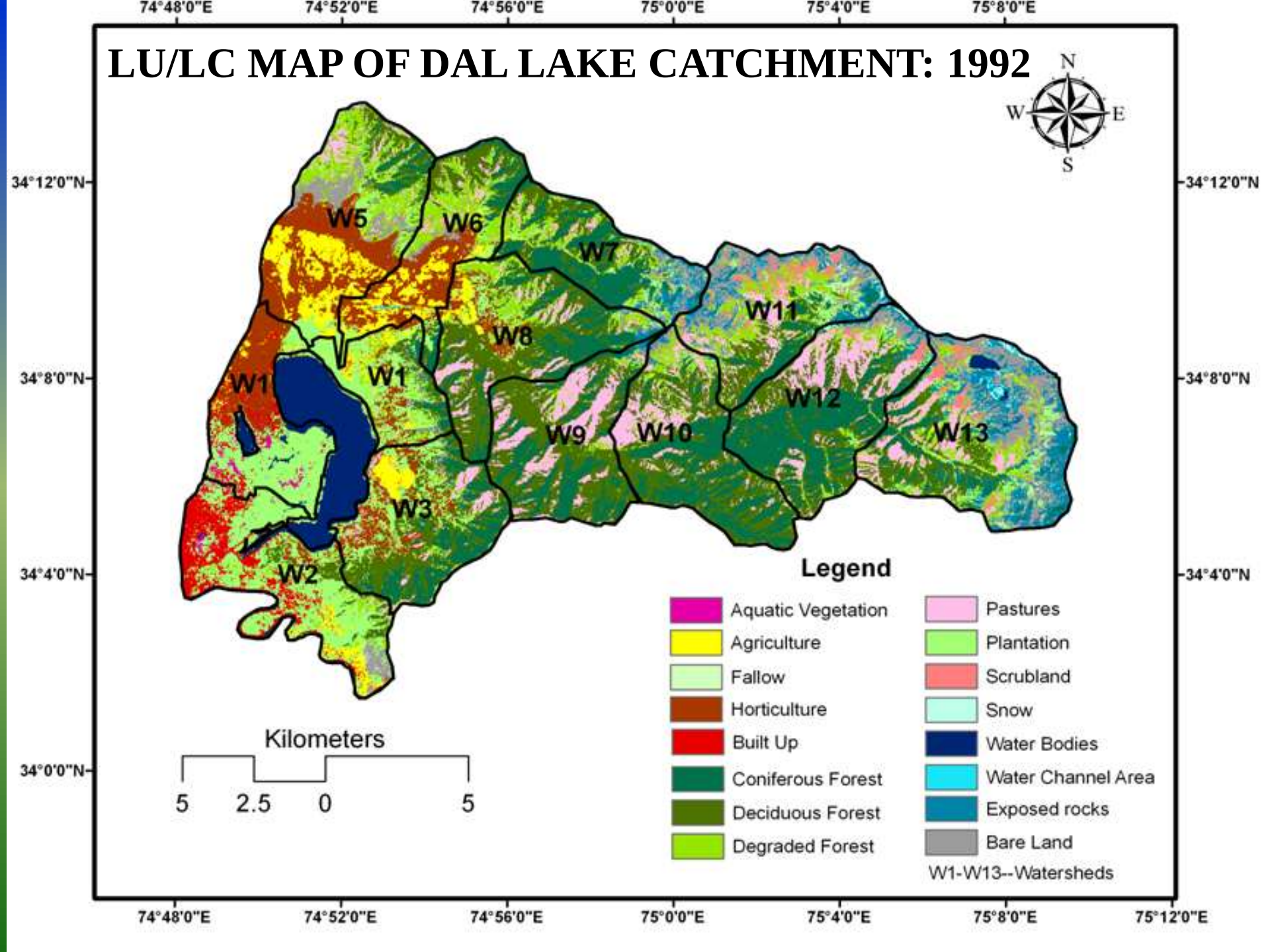


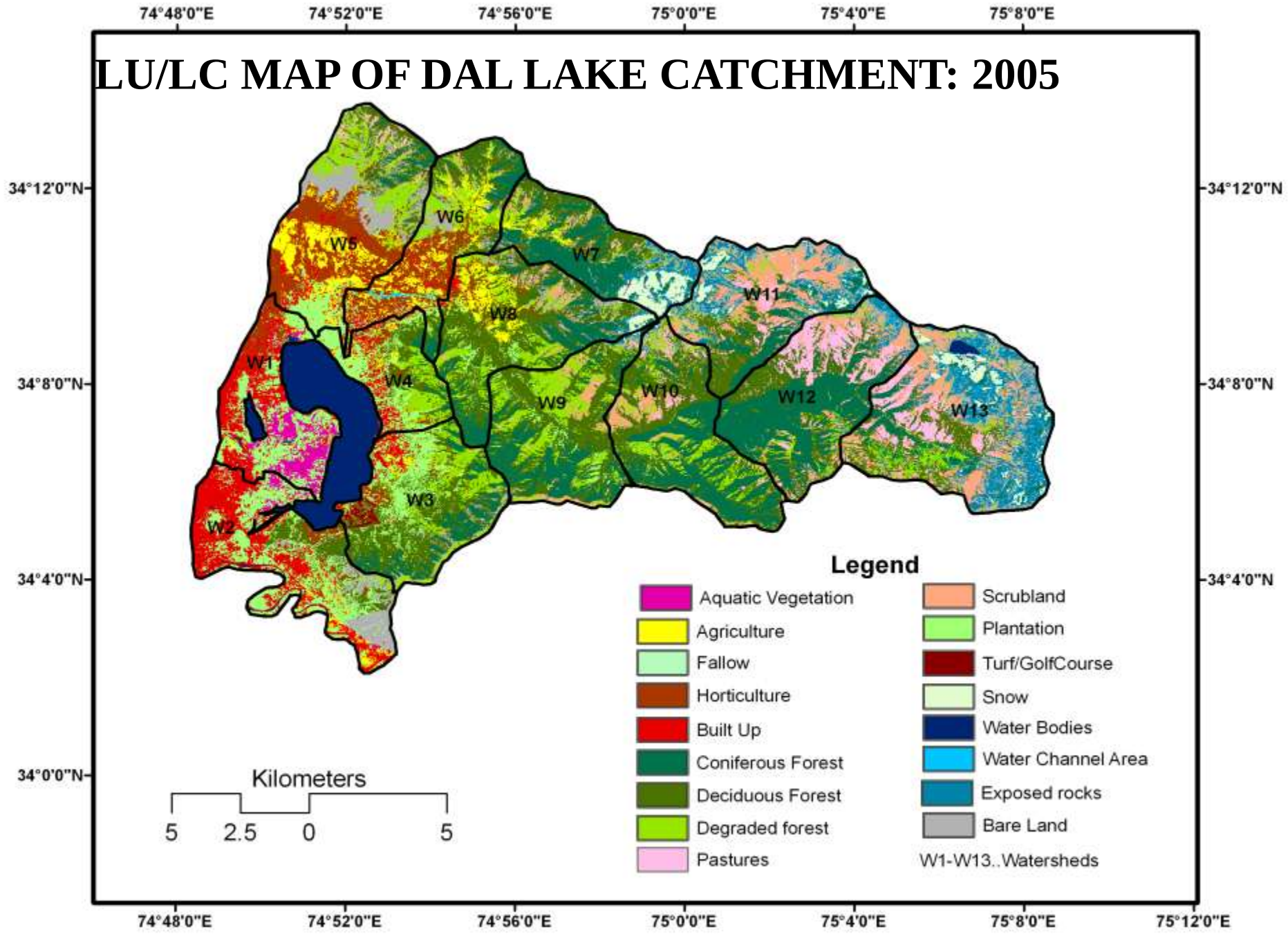
CATCHMENT SCALE STUDIES

The study area is the Dal Lake Catchment highly urbanized and situated in Srinagar city (KASHMIR HIMALAYAS) having an area of 337 km².



Location of Dal Lake Catchment


LU/LC MAP OF DAL LAKE CATCHMENT: 1992
N
W
E
S
74°48'0"E
74°52'0"E
74°56'0"E
75°0'0"E
75°4'0"E
75°8'0"E
75°12'0"E
34°12'0"N
34°8'0"N
34°4'0"N
34°0'0"N
W1
W2
W3
W5
W6
W7
W8
W9
W10
W11
W12
W13
Kilometers
5 2.5 0 5
Legend
Aquatic Vegetation
Agriculture
Fallow
Horticulture
Built Up
Coniferous Forest
Deciduous Forest
Degraded Forest
Pastures
Plantation
Scrubland
Snow
Water Bodies
Water Channel Area
Exposed rocks
Bare Land
W1-W13--Watersheds


LU/LC MAP OF DAL LAKE CATCHMENT: 2005
74°48'0"E
74°52'0"E
74°56'0"E
75°0'0"E
75°4'0"E
75°8'0"E
75°12'0"E
34°12'0"N
34°8'0"N
34°4'0"N
34°0'0"N
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
W12
W13
Legend
Aquatic Vegetation
Agriculture
Fallow
Horticulture
Built Up
Coniferous Forest
Deciduous Forest
Degraded forest
Pastures
Scrubland
Plantation
Turf/GolfCourse
Snow
Water Bodies
Water Channel Area
Exposed rocks
Bare Land
W1-W13..Watersheds
Kilometers
5 2.5 0 5

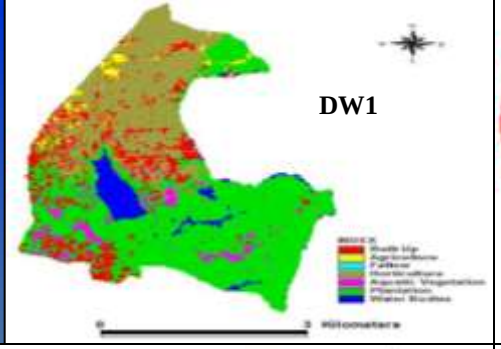
Area change in LULC from 1992 to 2005

S. No.	Class Name	Area (Km^2)		Area change	% change
		1992	2005		
1	Built up	9.31	21.39	+12.08	3.58
2	Agriculture	14.71	12.87	-1.84	0.54
3	Fallow	0.08	0.004	-0.076	0.02
4	Horticulture	26.91	19.34	-7.57	2.24
5	Coniferous Forest	51.87	46.2	-5.67	1.68
6	Deciduous Forest	76.49	74.69	-1.8	0.53
7	Sparse Forest	19.76	18.8	-0.96	0.28
8	Grasslands	33.31	25.42	-7.89	2.34
9	Scrubland	3.68	15.65	+11.97	3.55
10	Plantation	47.9	35.00	-12.9	3.82
11	Aquatic Vegetation	1.03	4.50	+3.47	1.02
12	Bare Land	20.82	25.26	+4.44	1.31
13	Bare Exposed Rocks	14.09	15.7	+1.61	0.47
14	Water Bodies	14.8	13.89	-0.91	0.27
15	Water Channel Area	1.24	1.30	+0.06	0.01
16	Snow	1.05	6.50	+5.45	1.61
17	Golf course/Turf	0.00	0.51	+0.51	15.37
Total		337	337		

c	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
Built up	9	8	8	88.89	100.00
Agriculture	5	8	5	100.00	62.50
Agriculture Fallow	2	5	2	60.00	40.00
Horticulture	13	11	11	84.62	100.00
Coniferous Forest	21	24	20	95.24	83.33
Deciduous Forest	41	35	31	75.61	88.57
Sparse Forest	14	13	10	71.43	76.92
Grasslands	8	10	5	62.50	50.00
Scrubland	2	2	1	50.00	50.00
Plantation	15	18	14	93.33	77.78
Aquatic Vegetation	3	3	3	100.00	100.00
Barren	8	10	4	40.00	30.00
Bare Exposed Rocks	4	4	3	75.00	75.00
Water	4	4	4	100.00	100.00
Water Channel Area	2	5	2	40.00	20.00
Snow	2	2	2	100.00	100.00
Totals	308	308	283		
Overall Accuracy = 89.67% %					

KAPPA (K^) STATISTICS	
OVERALL KAPPA STATISTICS = 0.8541	
KAPPA FOR EACH CATEGORY	
Class Name	Kappa
Built up	1
Agriculture	0.6186
Agric. Fallow	0.3213
Horticulture	1
Coniferous Forest	0.8208
Deciduous Forest	0.8676
Sparse Forest	0.7579
Grasslands	0.4863
Scrubland	0.4966
Plantation	0.7661
Aquatic Vegetation	0.463
Barren	0.3836
Bare Exp. Rocks	0.7466
Water	1
Water Channel	0.658
Snow	0.333

KAPPA (K^) STATISTICS	
OVERALL KAPPA STATISTICS= 0.91314	
KAPPA FOR EACH CATEGOR	
Class Name	Kappa
Built up	0.8851
Agriculture	0.8305
Agricultural Fallow	0.3213
Horticulture	1
Coniferous Forest	0.9094
Deciduous Forest	0.8304
Sparse Forest	0.8851
Grasslands	1
Scrubland	0.8305
Plantation	0.7902
Aquatic Vegetation	0.6644
Barren	.9126
Bare Exposed Rocks	.6610
Water	1
Water Channel Area	0.658
Snow	.6644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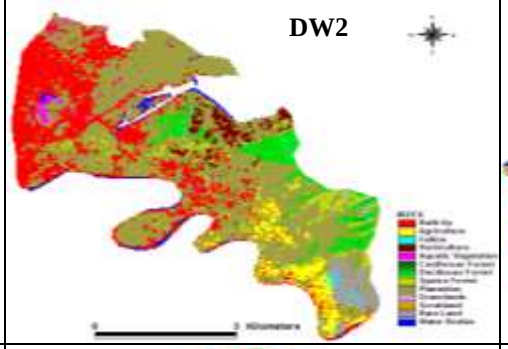
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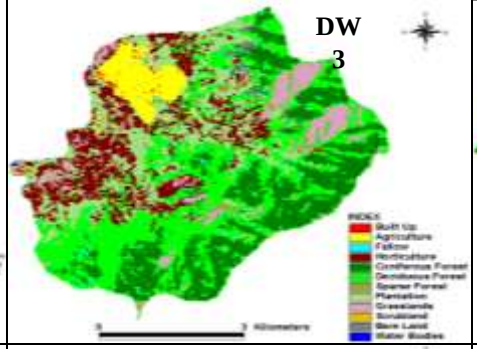
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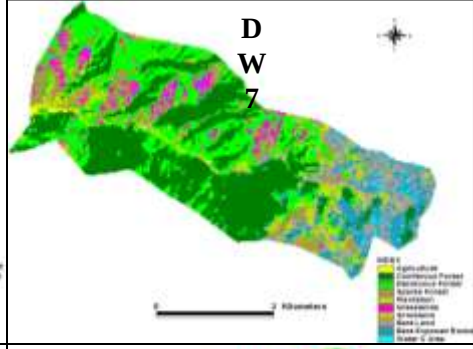
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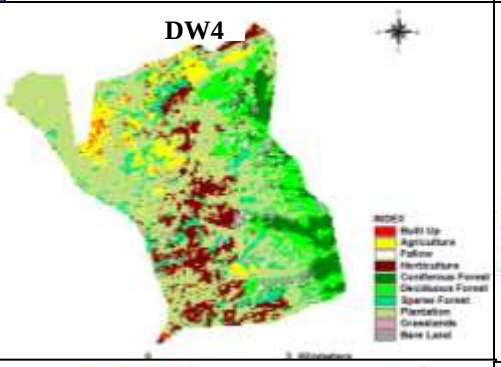
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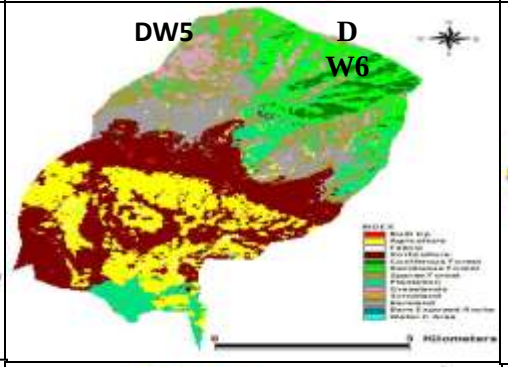
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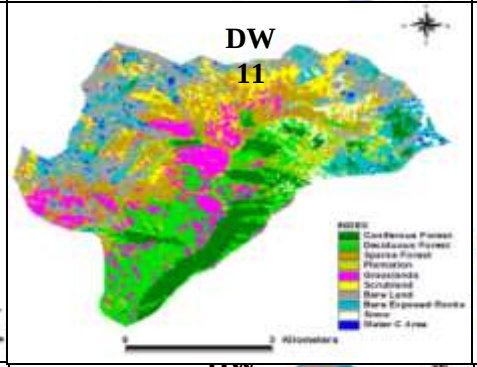
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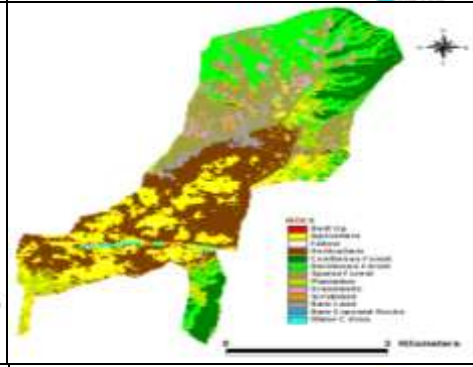

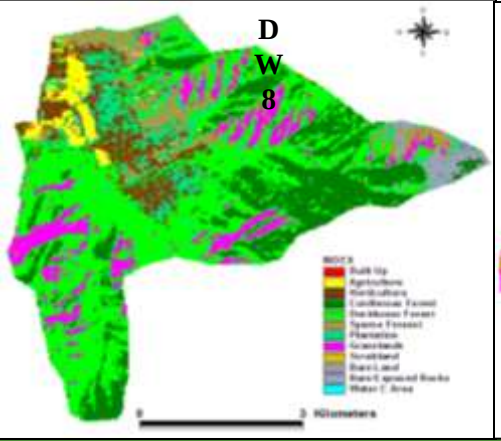
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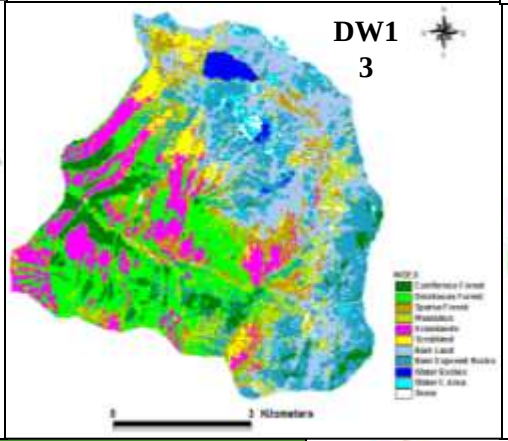
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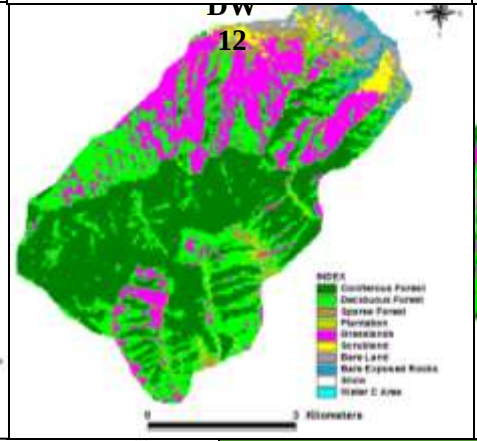
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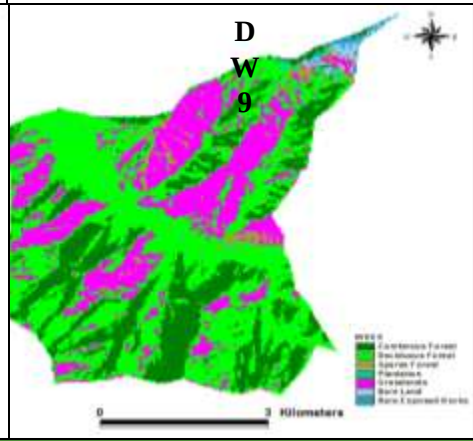
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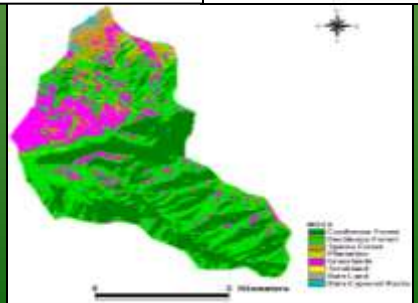
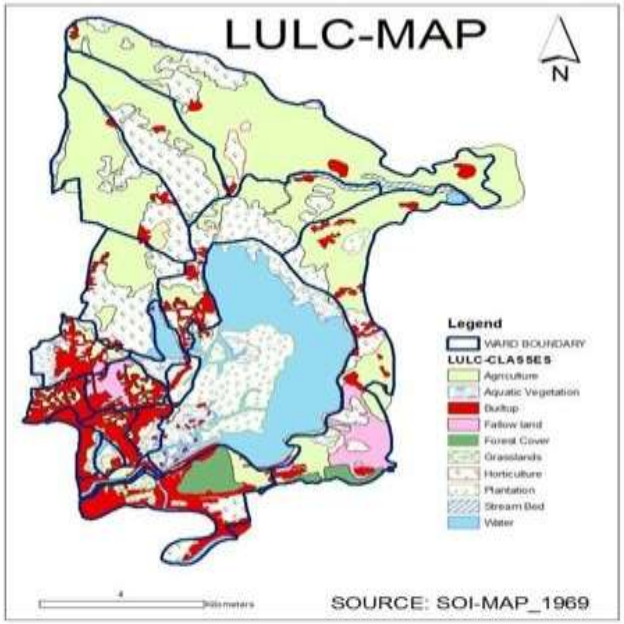
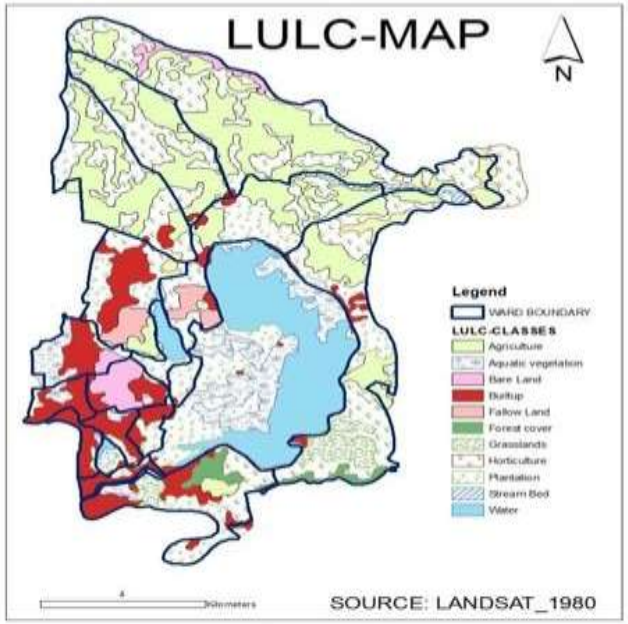
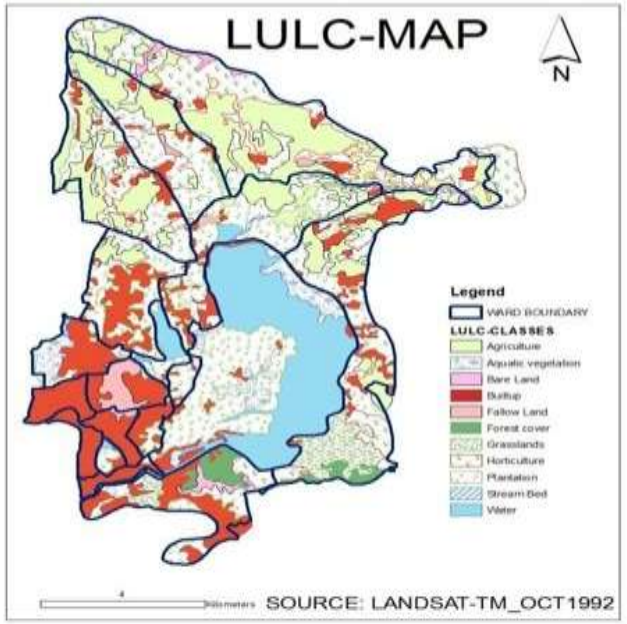
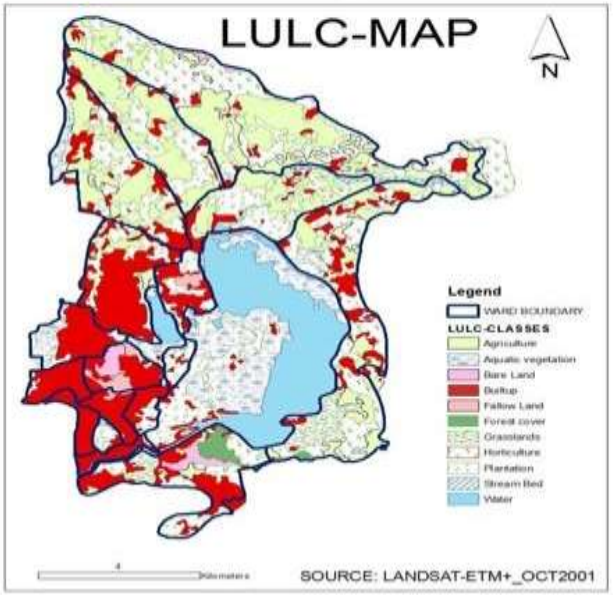


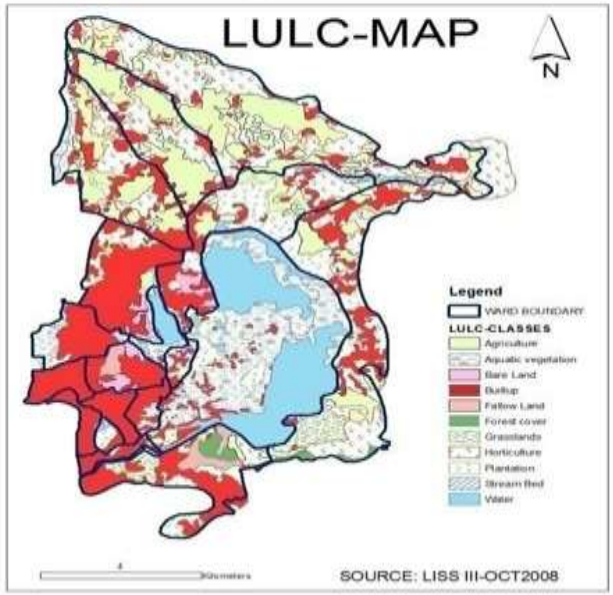
DAL LAKE ENVIRONS





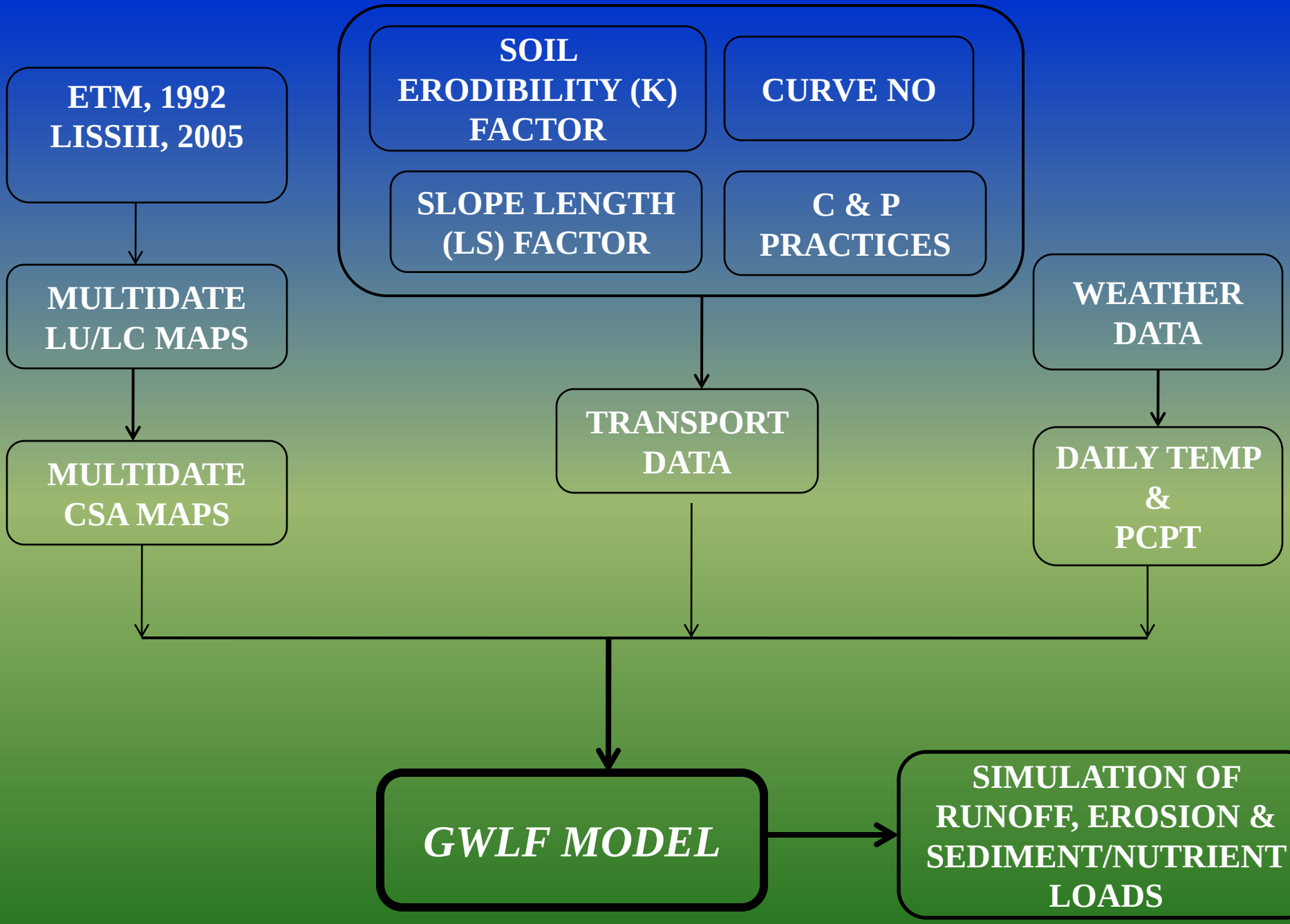






LULC CHANGES AROUND DAL LAKE (1969-2008)

CLASS NAME	*Area (hectares)*					
	1969	*1980*	*1992*	*2001*	*2008*	*Area change (1969-2008)*
Agriculture	4350.52	2717.17	2141.96	2242.43	1936.26	-2414.26
Aquatic veg	510.53	777.07	335.51	931.20	1226.82	716.29
Bare Land		260.00	96.33	126.47	147.53	-147.53
Builtup	1306.80	1184.81	2023.12	2374.21	3020.68	1713.89
Fallow Land	333.18	174.73	172.57	89.29	134.80	-198.38
Forest	208.46	145.55	137.70	89.81	86.77	-121.69
Grasslands	58.05	253.93	334.11	237.62	214.02	155.97
Horticulture	1737.21	2406.59	1498.72	1977.04	2109.72	372.51
Plantation	1004.90	1807.14	2878.91	1680.95	1044.42	39.52
Stream Bed	72.00	50.97	46.18	50.63	42.30	-29.69
Water	1455.75	1259.41	1332.27	1237.74	1074.05	-381.70



QUANTIFING THE HYDROLOGICAL PROCESSES

Hydrological Model

$$Q_{kt} = \frac{(R_t + M_t - 0.2DS_{kt})^2}{R_t + M_t + 0.8DS_{kt}}$$

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4$$

$$X_{kt} = 0.132 * RE_t * K_k * (LS)_k * C_k * P_k * AR_k$$

$$SR_m = 0.001 * C_s * Y_m$$

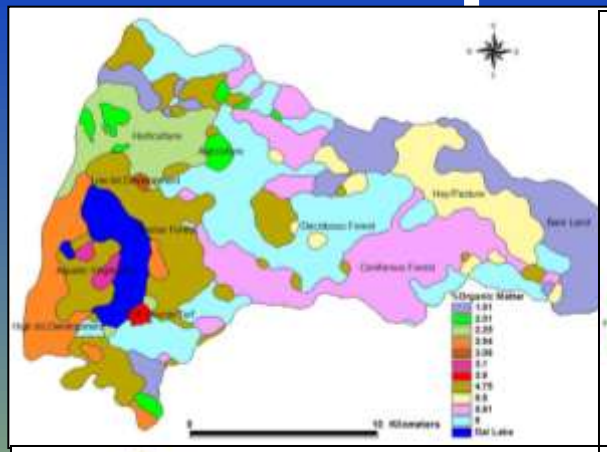
DATA SETS USED

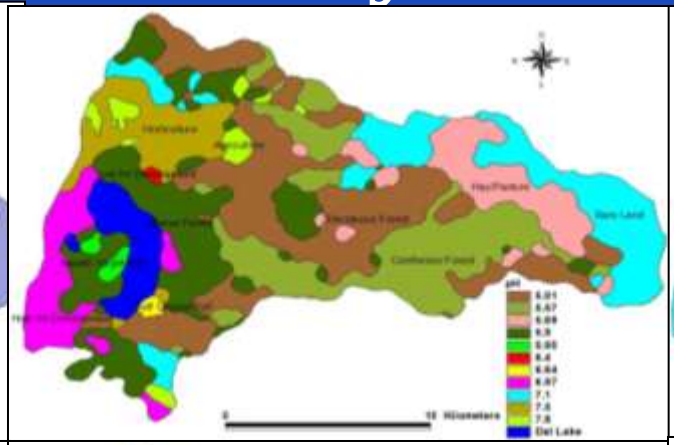
- **SATELLITE DATA/GEOSPATIAL DATA:**
  - LANDSAT- ETM (1992)
  - IRS: LISS III (2005)
  - Topographic data DEM (30m)
  - Time series of Hydrometeorological data

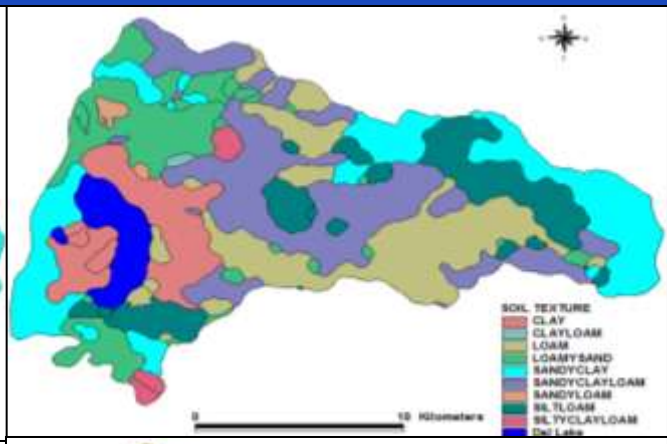
- **II) FIELD DATA/ LAB INVESTIGATION**
  - Physicochemical data generated for soil
  - Ground truth data

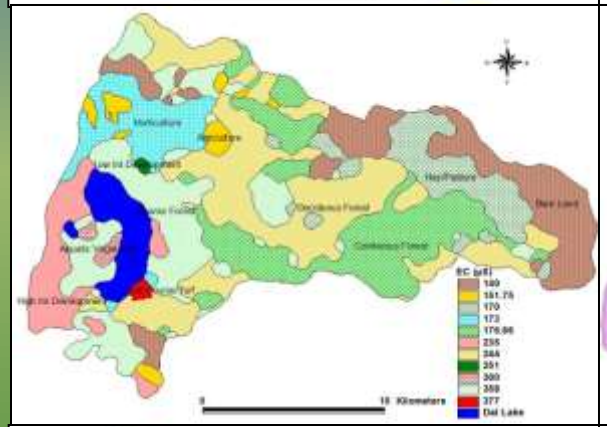
- **III) ANCILLARY DATA**
  - Published reports and journals

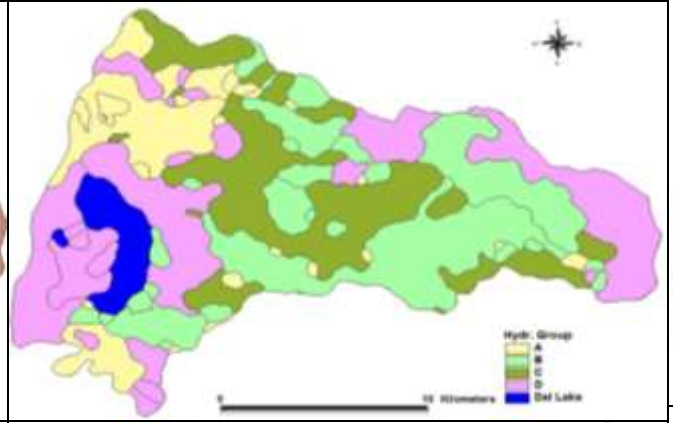
Geospatial Analysis-Parameters

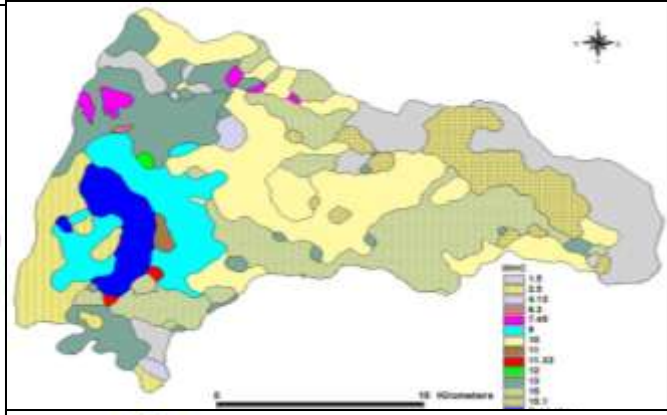


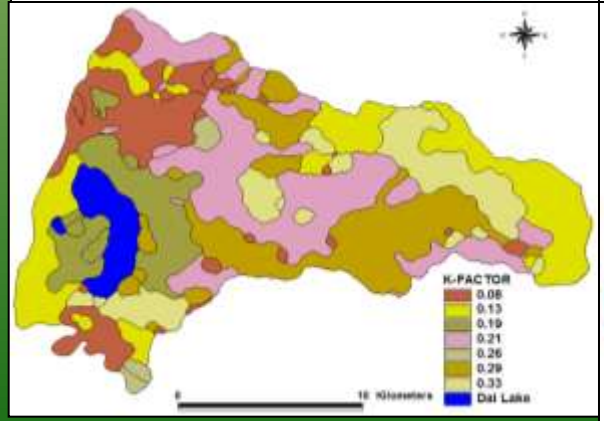


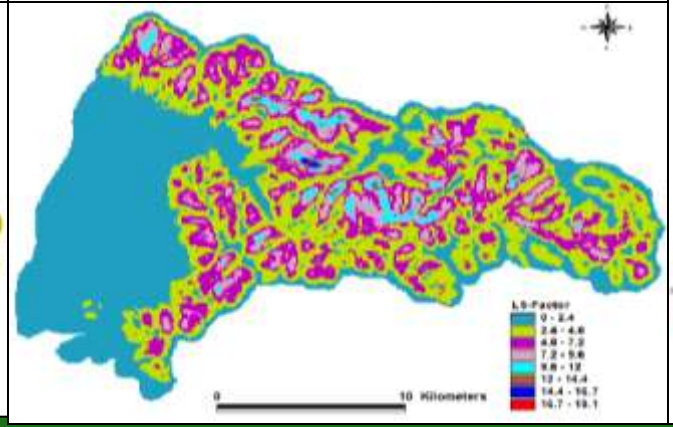


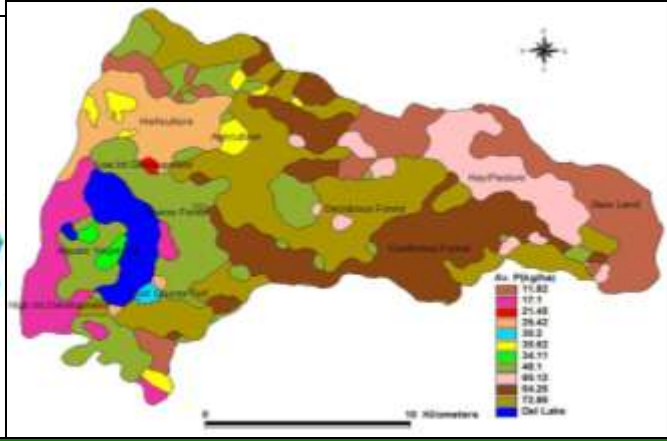












Input parameters used in the GWLF Model

Source Areas	Hydro Conditions	LS	C	P	K	WCN
Agriculture	Fair	2.609	0.42	0.52	0.169	82
Horticulture	Fair	3.206	0.05	0.1	0.186	87
Forest	Fair	46.33	1	1	0.226	68
Hay/Pasture	Fair	59.38	0.03	0.74	0.255	63
Low int Devel	N/A	1.964	0.08	0.2	0.159	80
High int Devel	N/A	0.488	0.08	0.2	0.13	94
Bare land	Poor	42.66	0.8	0.8	0.15	89

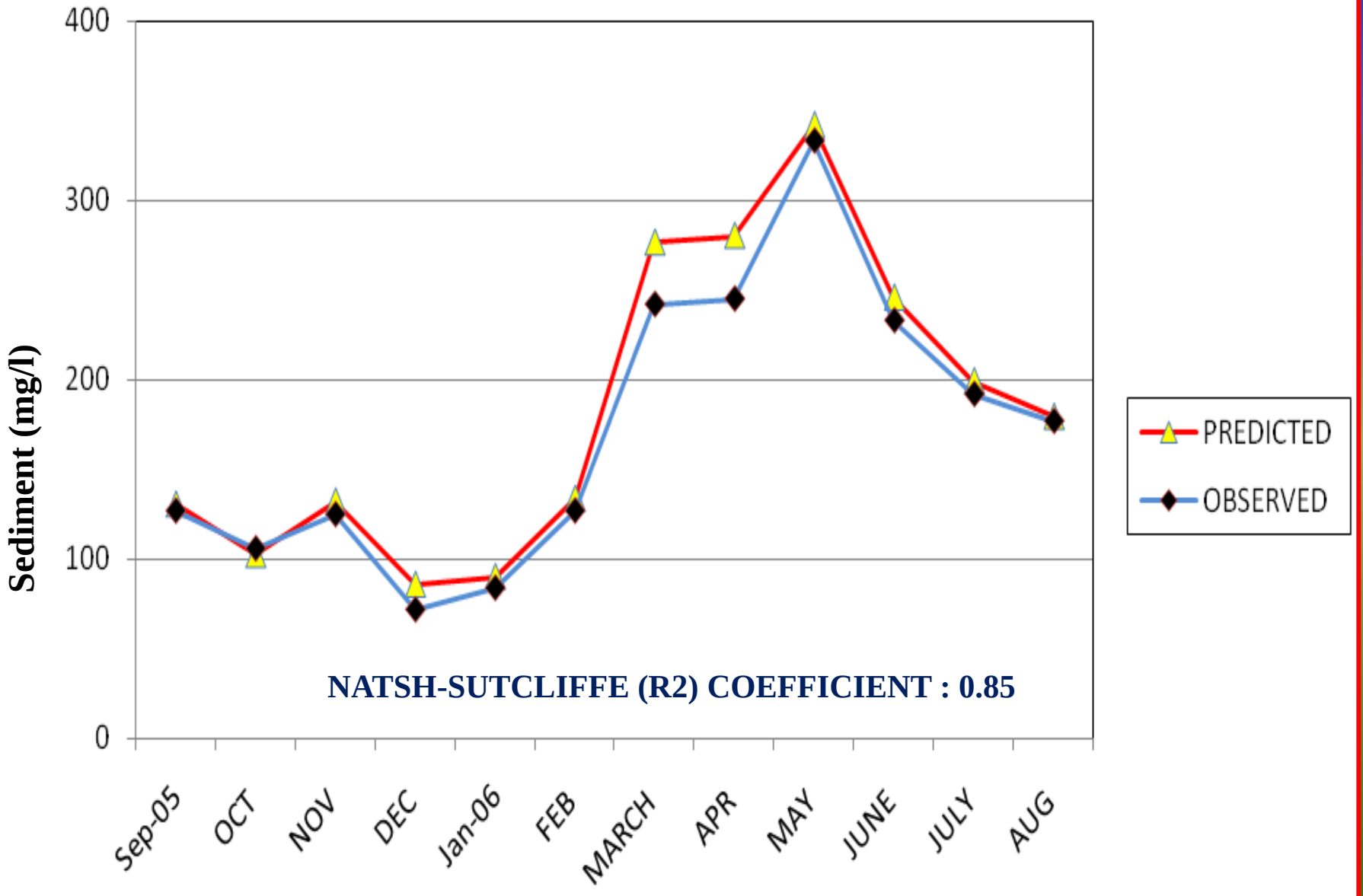
CHANGES IN NUTRIENT LOADING OF DAL LAKE (1981-2008)

Hydrological Process	Year		Change (Tons/Yr)
	1992	2005	
Runoff (mm)	329.07	341.34	+12.27 (mm)
Erosion	1302.29	1953.66	+651.37
Sediment	232.45	354.65	+122.2
NUTRIENT LOADS			
Total Nitrogen (TN)	2037.13	2381.7	+344.57
Dissolved Nitrogen (DN)	1661.99	1865.87	+203.8
Total Phosphorus (TP)	166.02	238.3	+72.28
Dissolved Phosphorus (DP)	60.89	76.19	+15.3

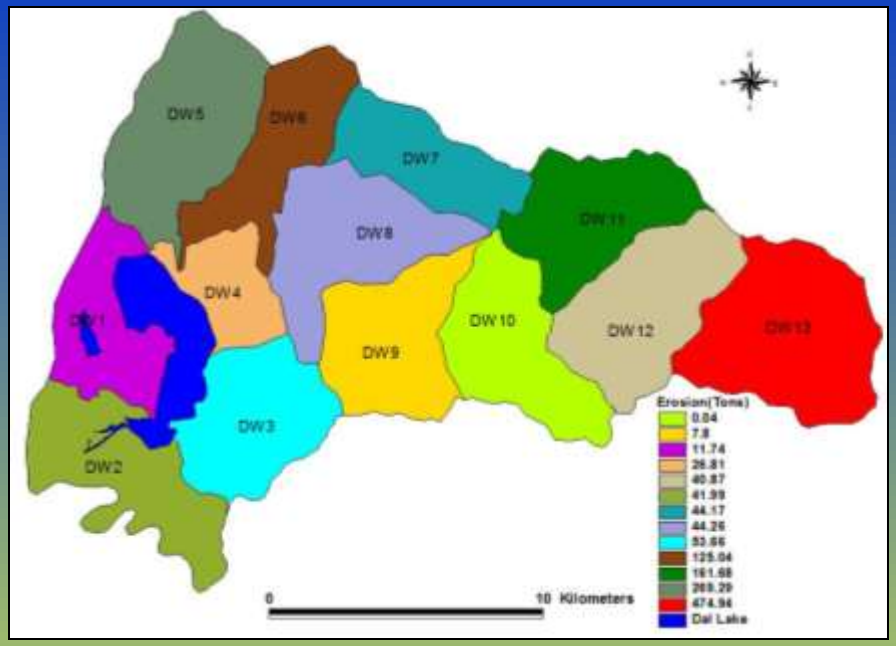
Source area contribution to sediment & erosion yields

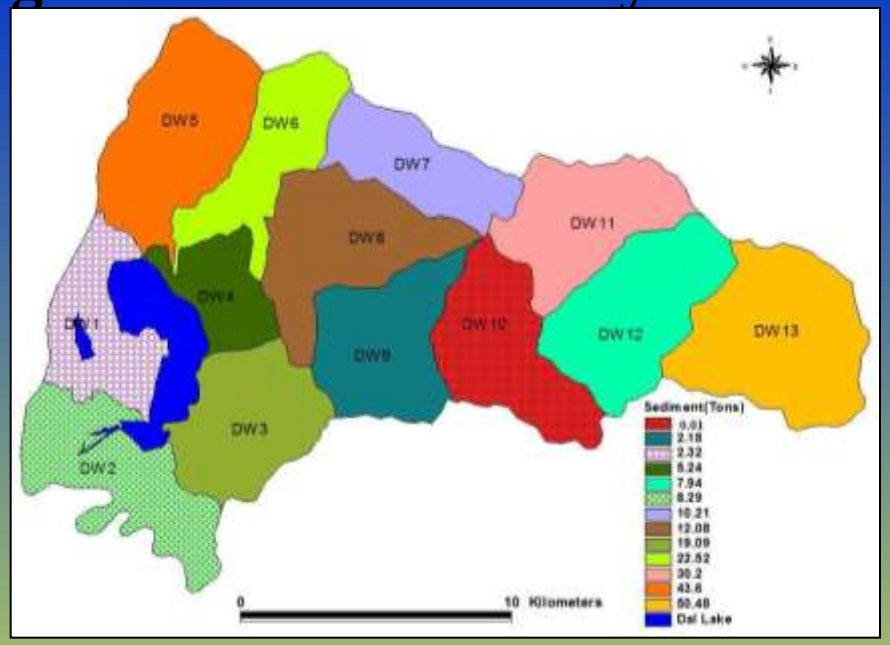
SOURCE	1992 LULC Erosion Tons/yr	2005 LULC Erosion Tons/yr	1992 LULC Sediment Tons/yr	2005 LULC Sediment Tons/yr
pastures	11.41	57.55	3.20	26.19
Cropland	94.25	117.15	30.1	49.68
Forest	25.16	27.88	1.3	8.64
Horticulture	1.33	1.57	0.0007	.01
Bare	1,171.16	1,750.06	90.7	121.31
Lo_Int_Dev	0.018	0.054	0.00097	.02
Hi_Int_Dev	0.164	0.444	.0084	.0023
Stream bank			106.2	148.8
Total	1302.295	1953.66	232.4	254.65

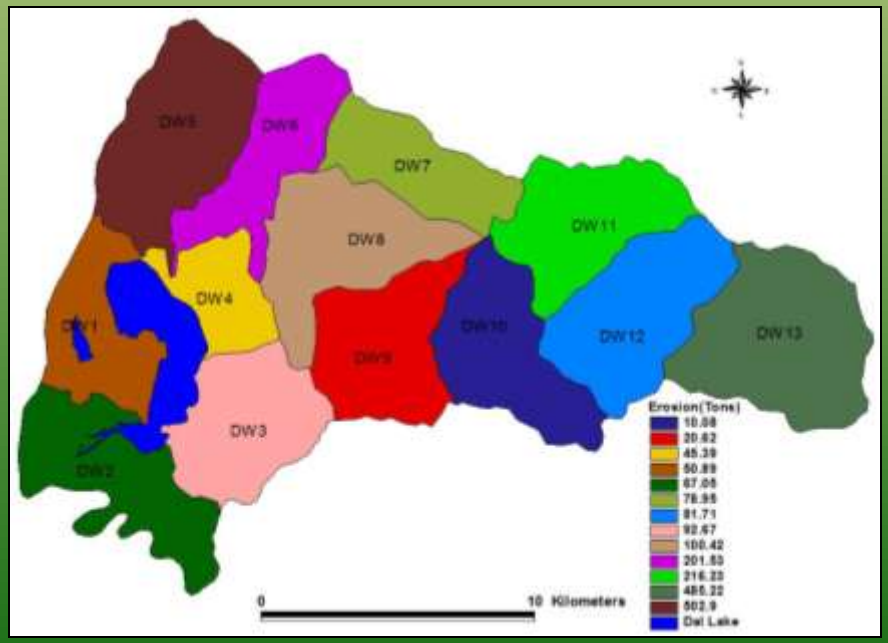
VALIDATION STUDY RESULTS

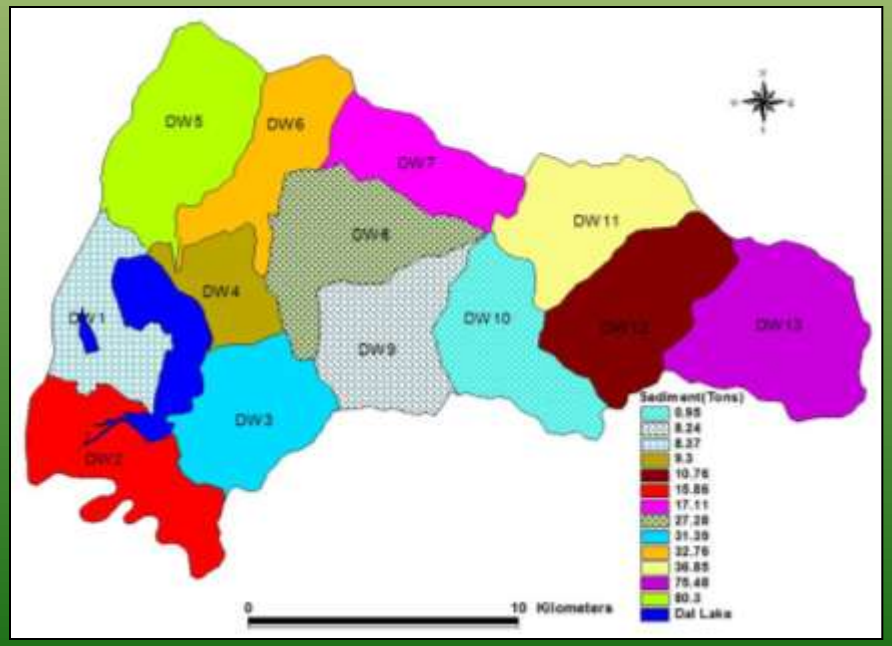


Source area contribution to avg. sediment & erosion yields









SCENARIO MAPPING

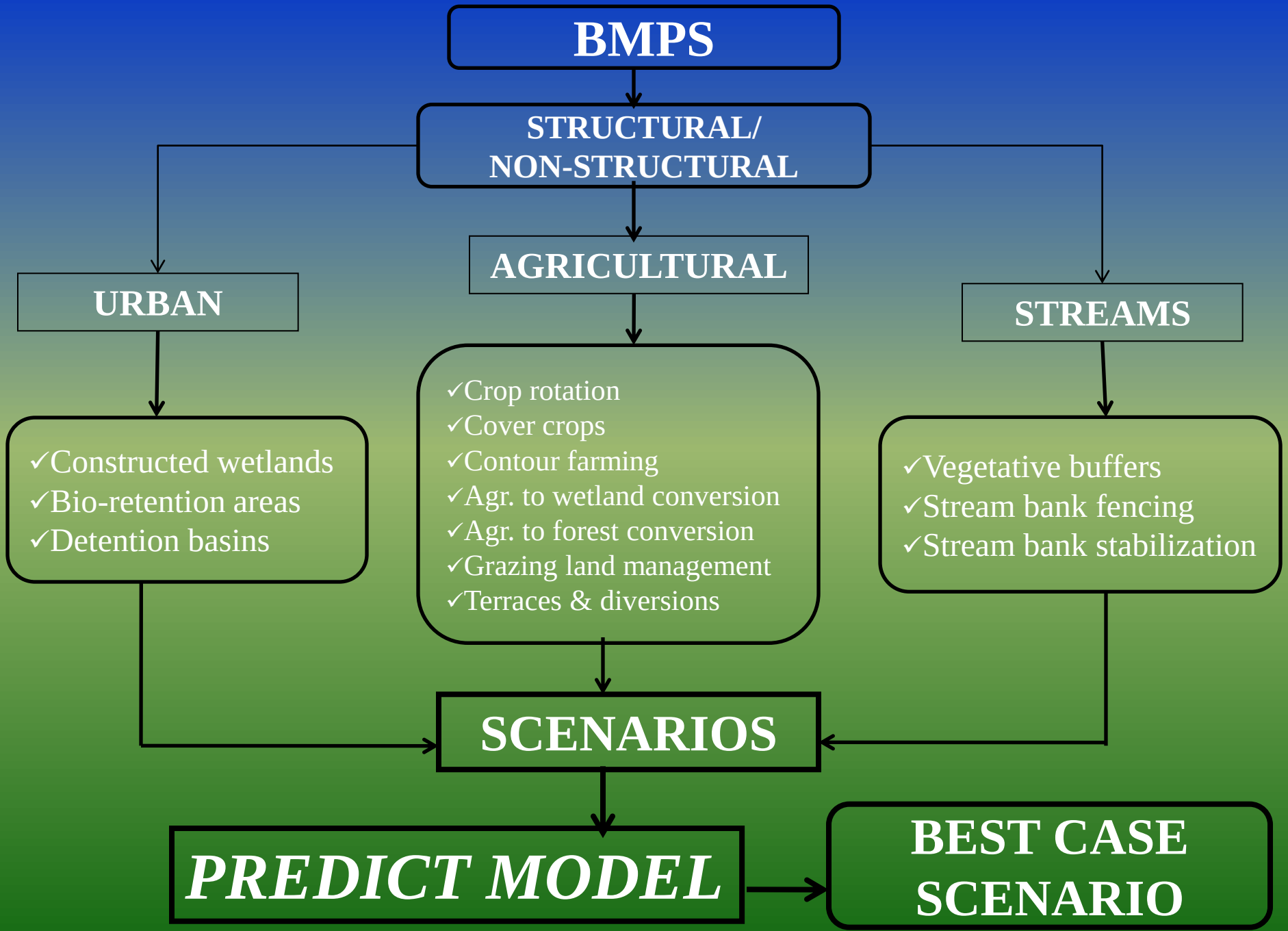
PREDICT

POLLUTANT REDUCTION IMPACT COMPARISON TOOL

- developed for use in evaluating the implementation of both rural and urban pollution reduction strategies at the watershed level.

- allows the user to create various “scenarios” in which current landscape conditions can be compared against “future” conditions that reflect the use of different pollution reduction strategies.

METHODOLOGY ADOPTED FOR PREDICT MODEL



SOME OF THE BMPs

Nutrient load reduction in response to BMP

SOURCE	Baseline Scenario	MSCN1	MSCN2	Baseline Scenario	MSCN1	MSCN2
	Nitrogen (Tons/Yr)			Phosphorus (Tons/Yr)		
Hay/Pasture	195.2	140.01	100.13	20.32	16.17	12.7
Agriculture	751.4	600.3	454.8	89.64	59.82	51.2
Forest	160.2	128.94	98.82	7.73	5.97	4.8
Horticulture	85.45	65.76	40.54	21.23	17.9	14.9
Turf /Golf course	4.82	3.9	2.27			
Bare Land	246	200.65	168.15	30.61	22.49	18.54
Low Int. Dev	10.32	7.45	3.27	2.04	1.5	0.7
High Int. Dev	315.7	250.9	141.9	46.23	35.05	28.27
Stream Bank	7.51	6.83	3.98	6.09	5.81	4.18
Ground water	605.2	500.9	486.8	14.45	10.04	7.71
Totals	2382	1905.6	1500.66	238.34	174.75	143.0
% Reductions		20.0%	37.0%		26.6%	40.0%

Reduction in sediment loads in response to different scenarios

SOURCE	Baseline Scenario	MSCN1	MSCN2
	Sediment (Tons/Yr)		
Hay/Pasture	26.19	21.43	16.71
Agriculture	49.68	34.92	18.56
Forest	8.64	6.54	5.1
Bare Land	121.31	95.31	78.76
Low Int Dev	0.002	0.001	0.001
Hi Int Dev	0.02	0.005	0.001
Stream Bank	148.80	130.84	105.93
Total Sediment	354.65	289.04	225.07

Conclusions

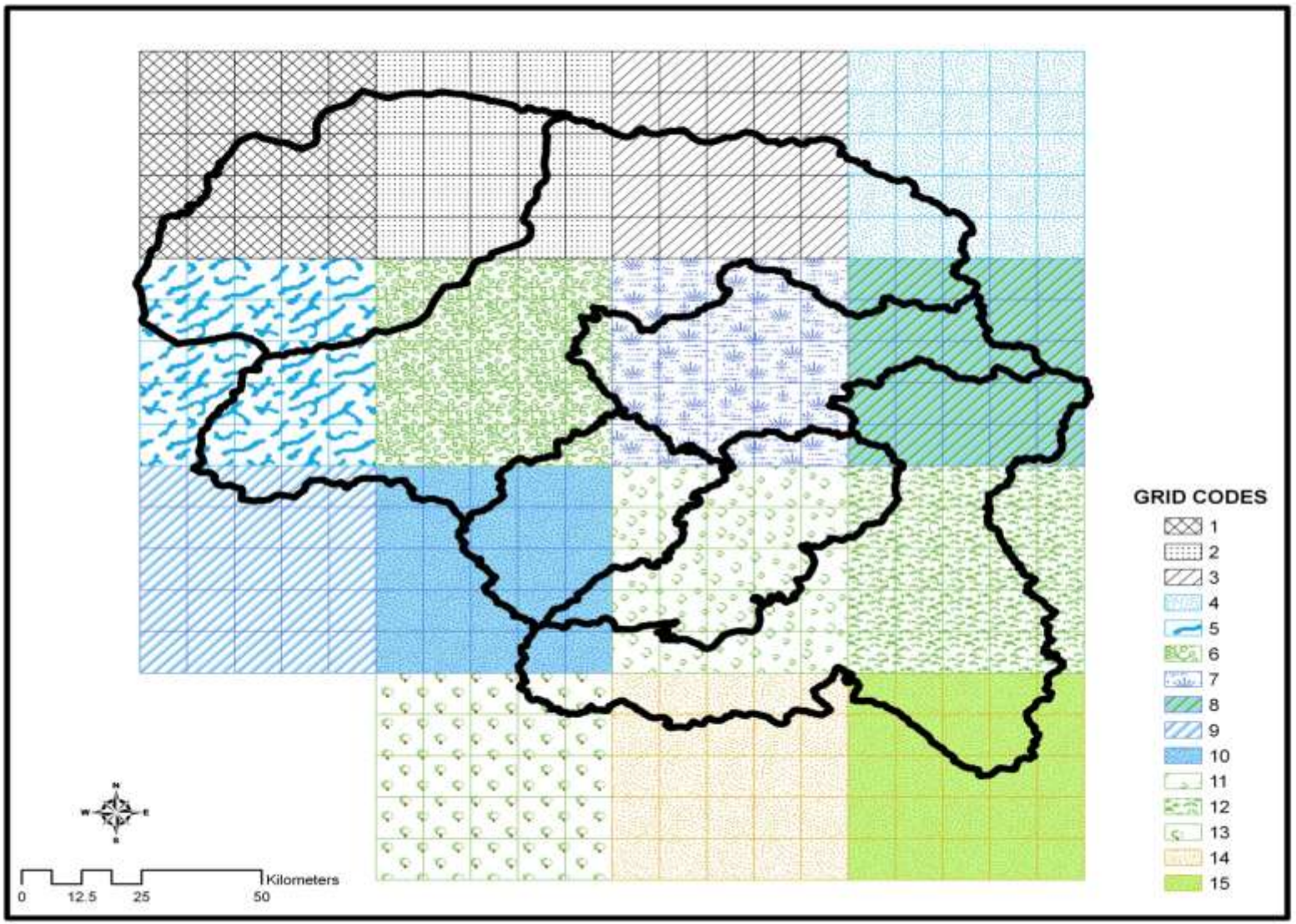
- The study demonstrated the effectiveness of the GIS based Modeling system in quantifying the hydrological processes and nutrient loads from the critical source areas at the catchment scale.

- The change in the LULC of the catchment has contributed significantly towards increased nutrient loads at the catchment scale.

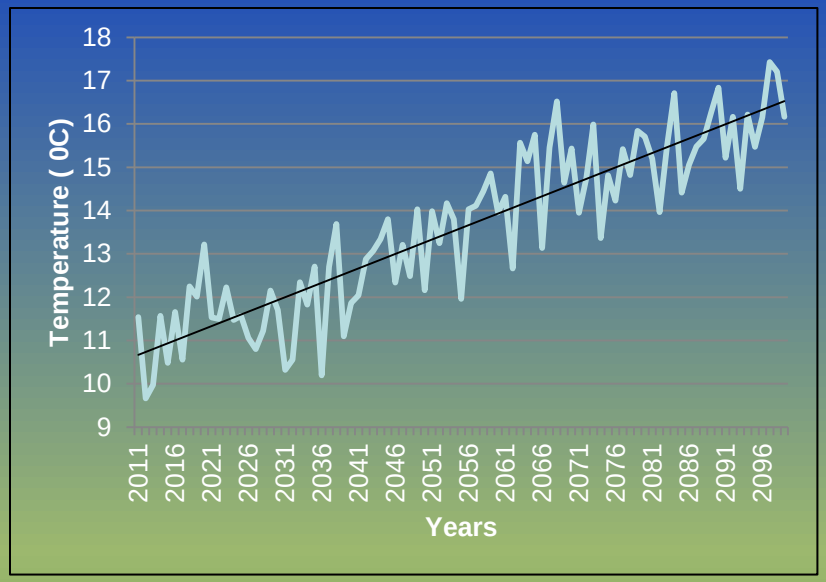
- The implementation of different BMPs can prove quite effective in controlling the nutrient pollution of water body and thus improve the ecological condition of the lake including the water quality

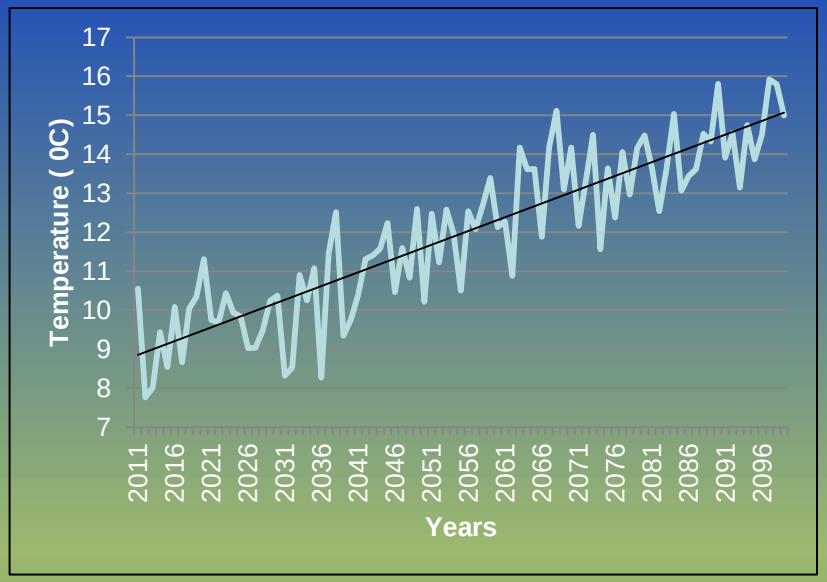

Thank you

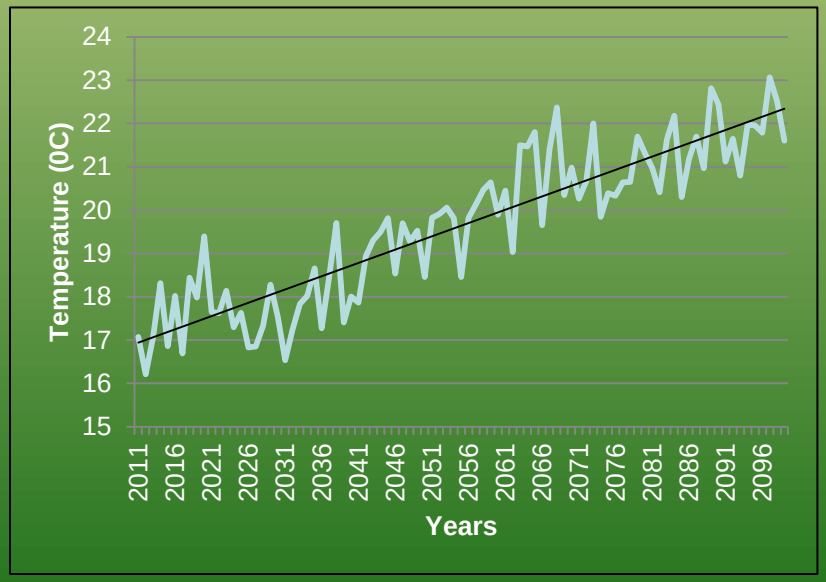
50 km^2 RCM data downscaled to 10 km^2 grids

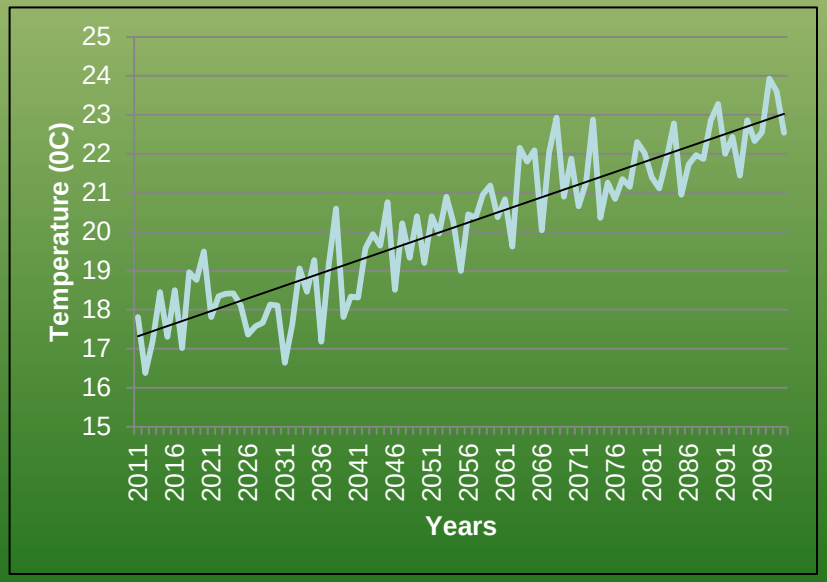


ANNUAL AVERAGE MAXIMUM TEMPERATURE

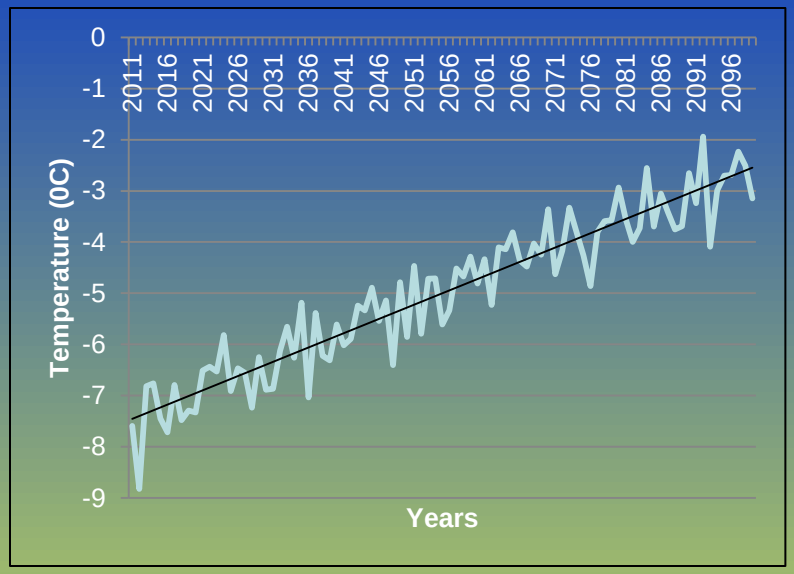


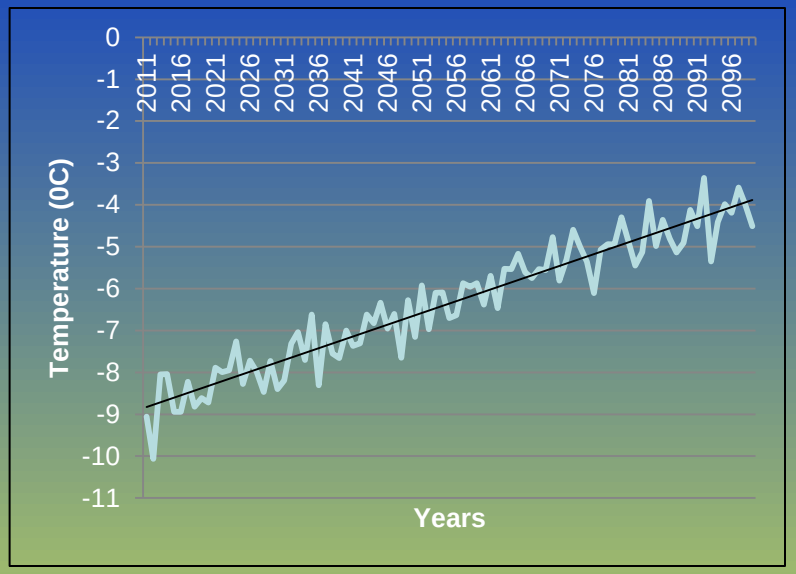


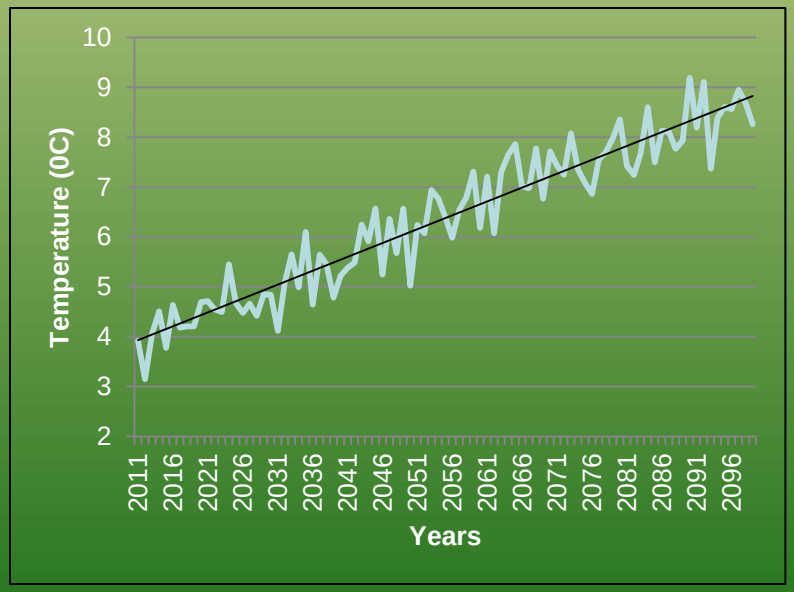


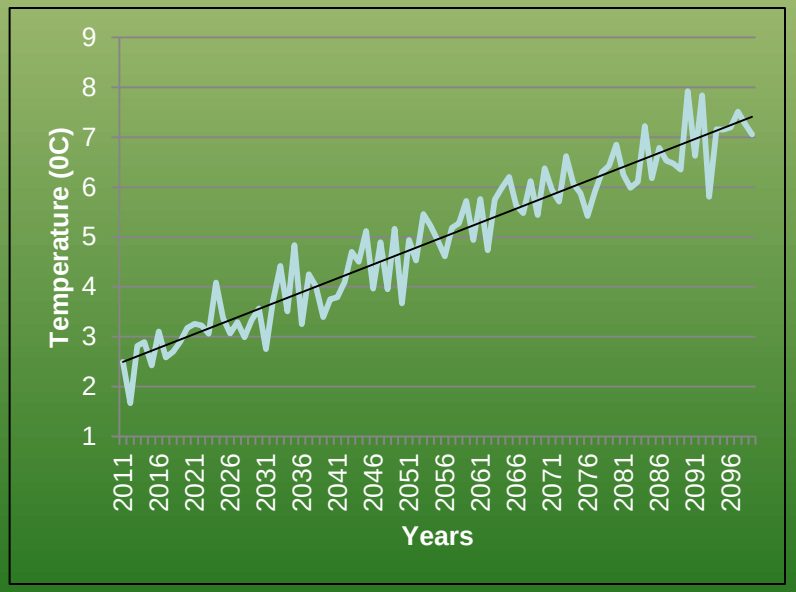


ANNUAL AVERAGE MINIMUM TEMPERATURE

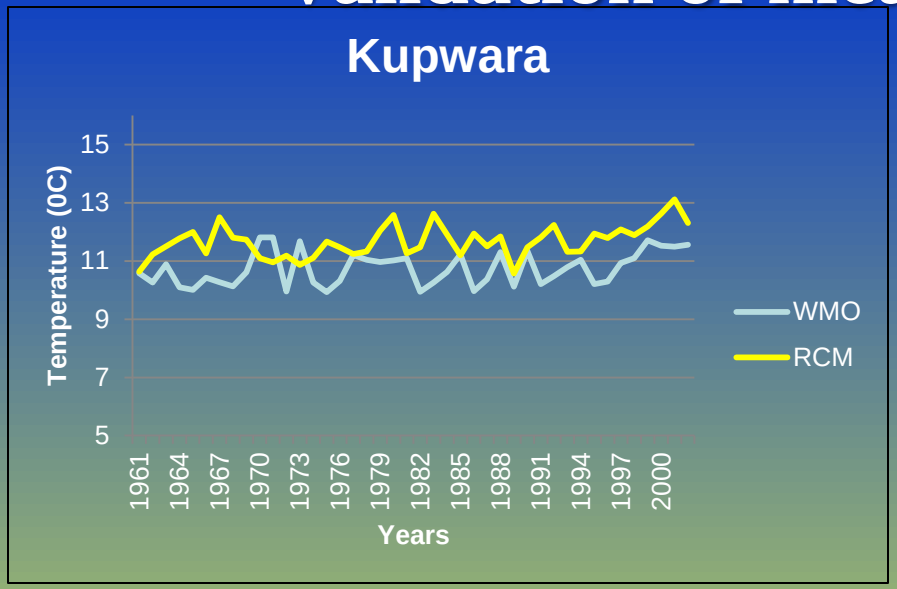


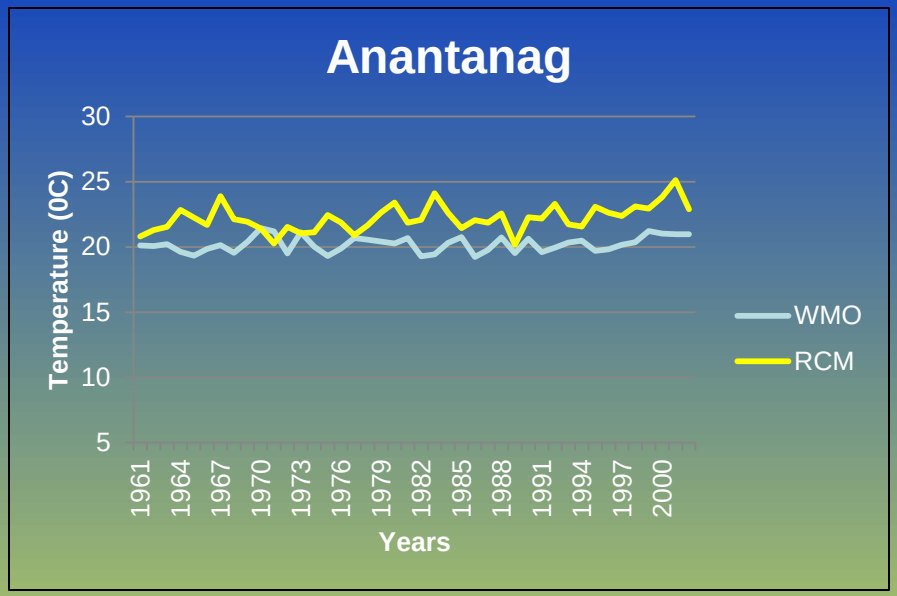


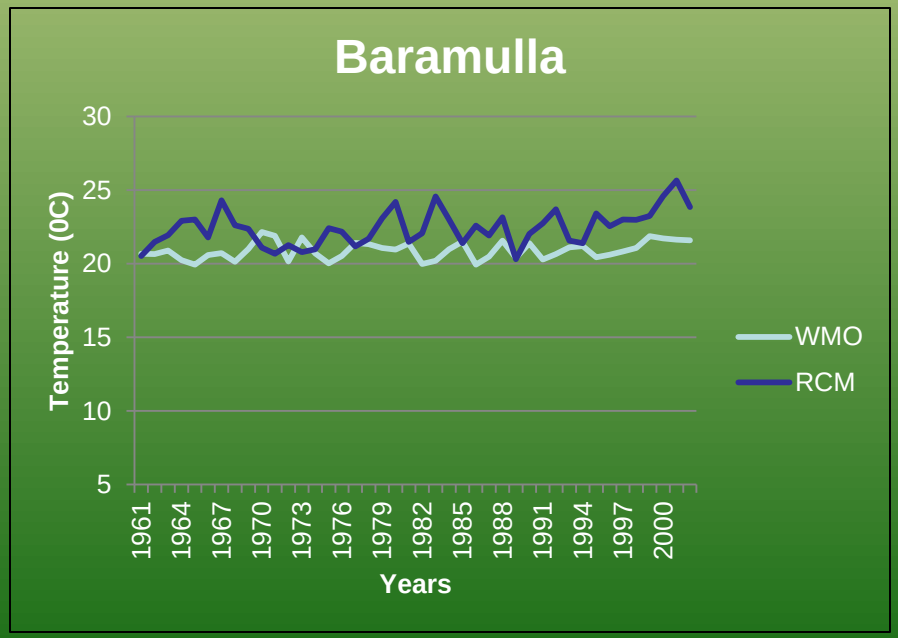


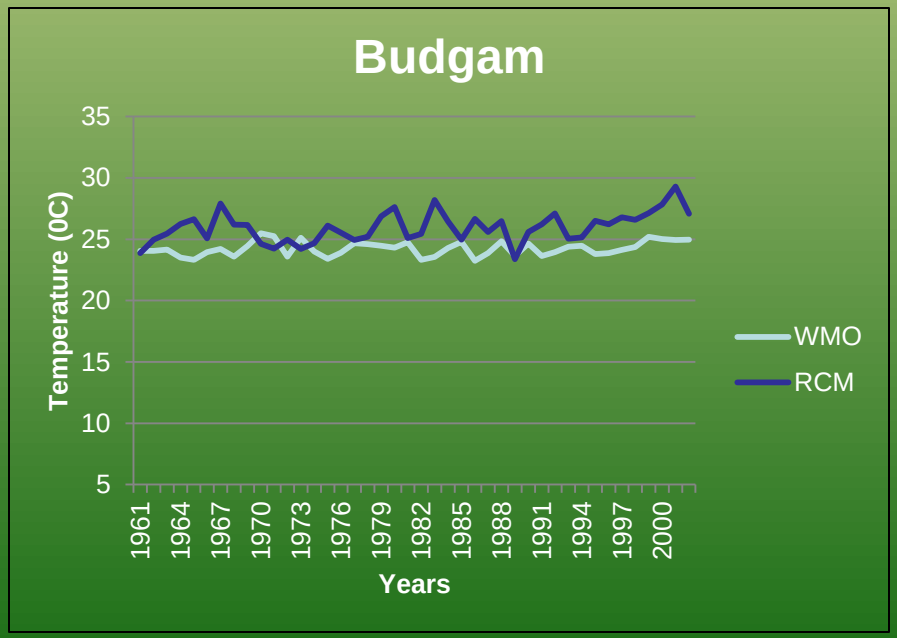


Validation of mean maximum temp

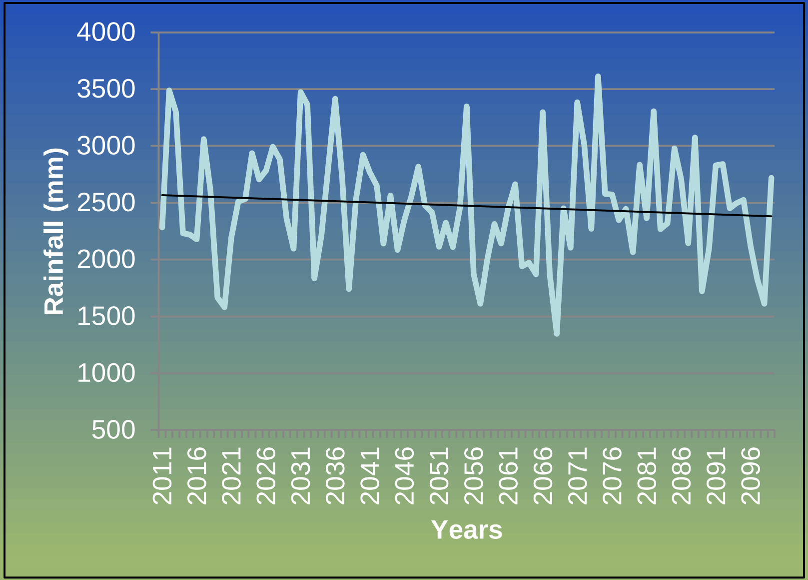


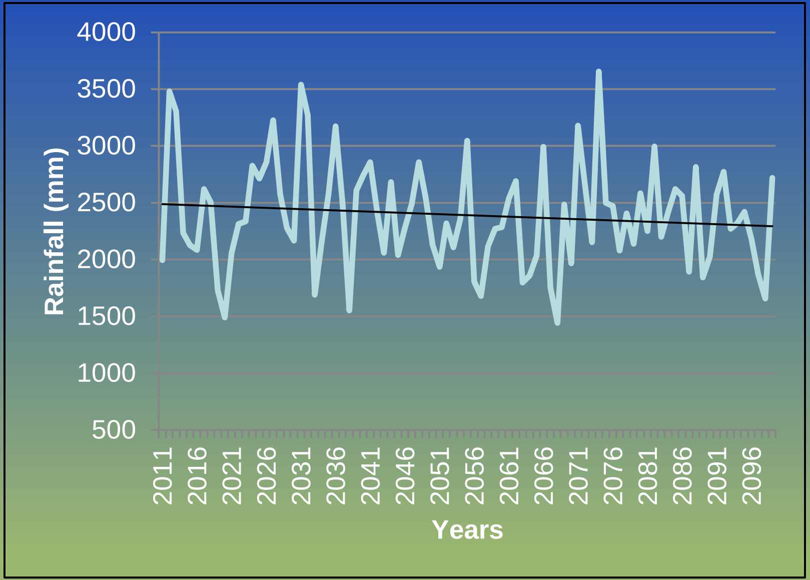


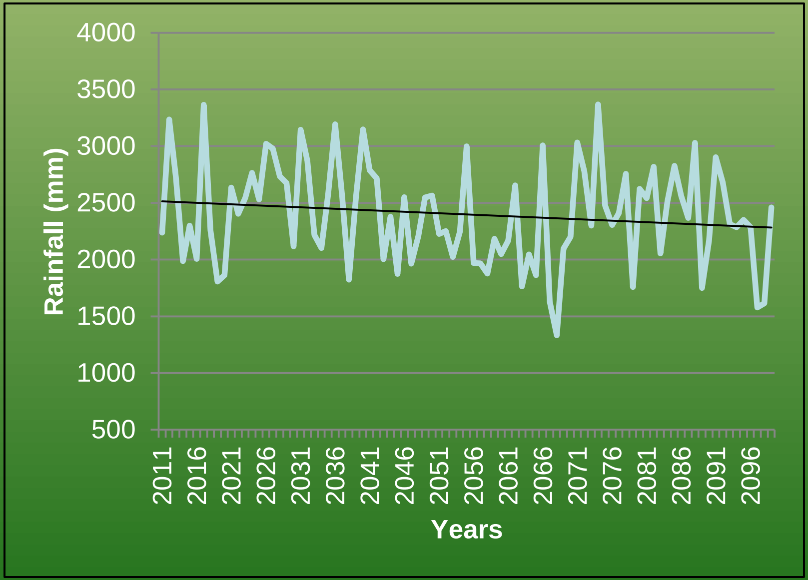


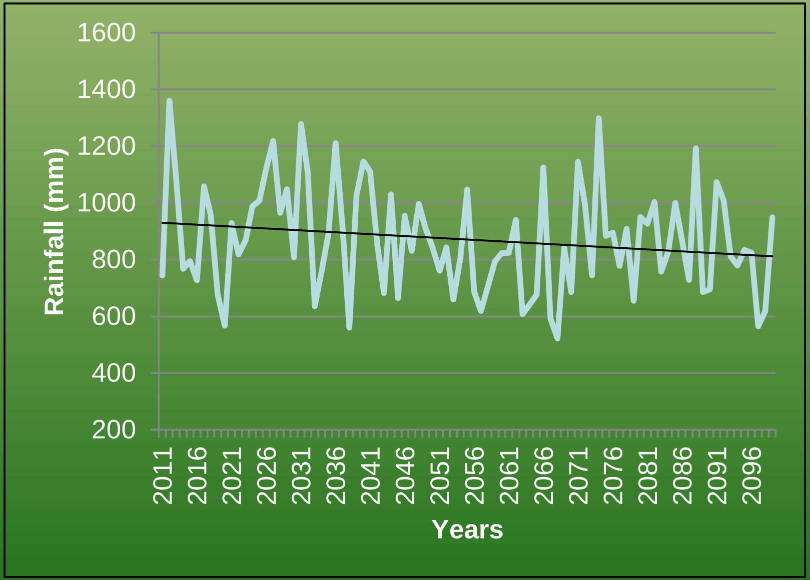


ANNUAL AVERAGE PRECIPITATION









The maximum mean annual temperature is projected to increase by 2^0 C (± 0.9) from 2011 to 2040 and 3.38^0 C (±1.17) from 2040 to 2099.

The minimum mean annual temperature is projected to increase by 2.33 ^{0}C (± 0.61) from 2011 to 2040 and 2.75^0C (± 0.88) in 2040 to 2099.

The annual precipitation is likely to decrease by about 13.1 % from 2011- 2040 and 4.07 % from 2040-2090 respectively.

FIGURE SHOWING CHANGE IN S1,S5 AND S11 FROM 1969 TO 2001.

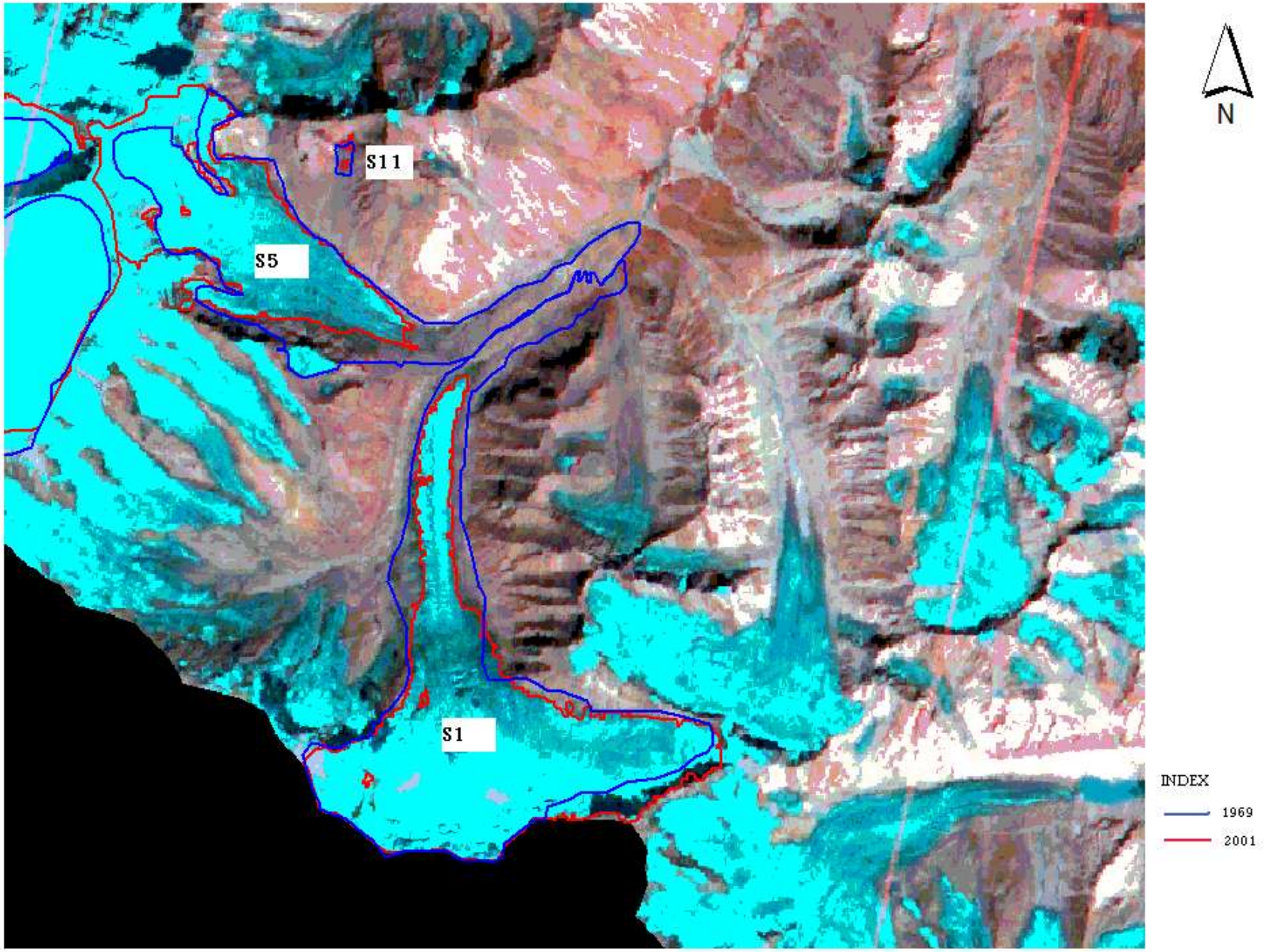


FIGURE SHOWING CHANGE IN S4, S9 AND S12 FROM1969 TO 2001.