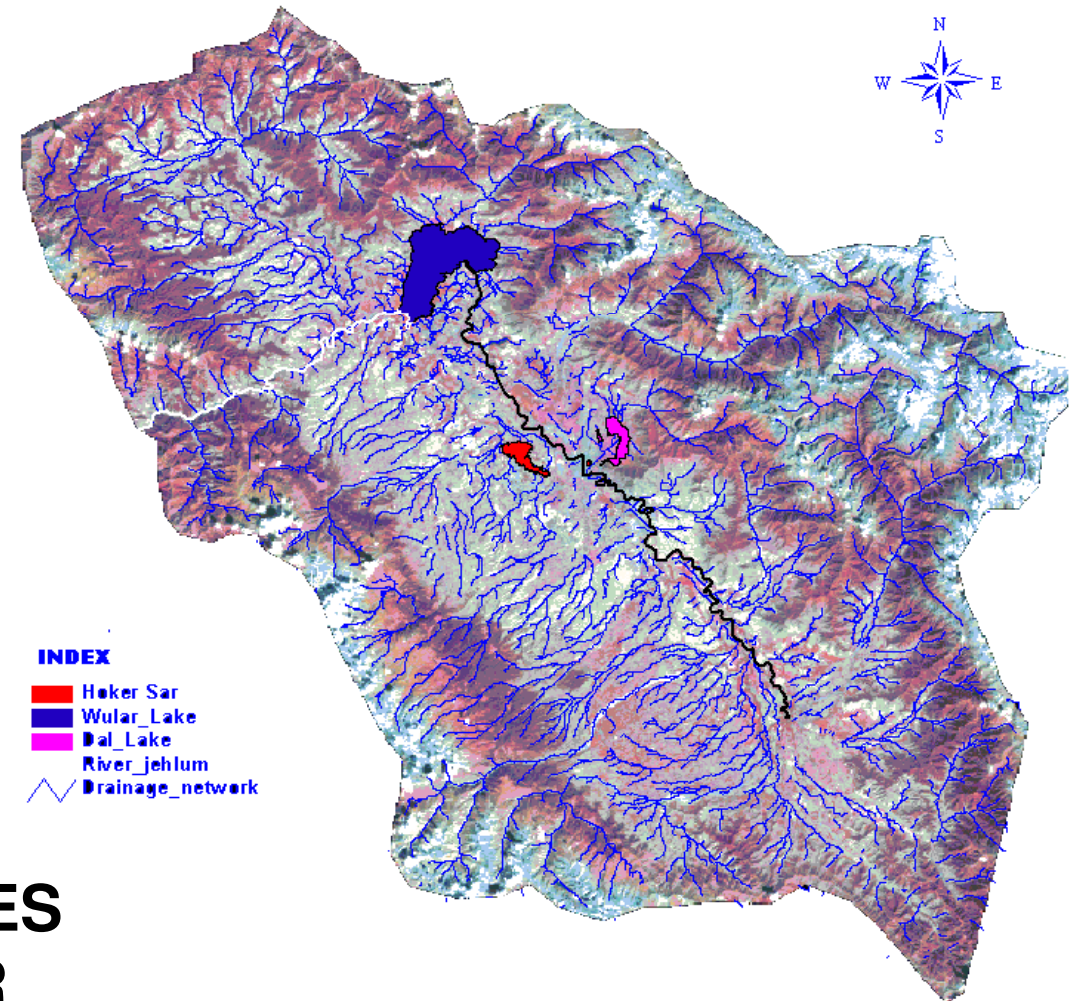


# INDUS WATER SYSTEM UNDER THREAT: A CASE STUDY OF JHELUM



**SHAKIL A ROMSHOO  
DEPT OF EARTH SCIENCES  
UNIVERSITY OF KASHMIR**



# **PRESENTATION OVERVIEW**

## **➤ INDUS RIVER SYSTEM**

➤ (Western sub-system: Jhelum)

## **➤ DYNAMIC COMPONENTS**

➤ WETLANDS/LAKES

➤ CRYOSPHERE

➤ LAND SYSTEM CHANGES AND PROJECTIONS

➤ LAND DEGRADATION

➤ WQ CHANGES

➤ STREAM FLOW CHANGES

➤ CLIMATE CHANGE SCENARIO AND PREDICTIONS

## **➤ CONCLUSIONS**

- ① Indus River
- ② Jehlum River
- ③ Chenab River
- ④ Ravi River
- ⑤ Beas River
- ⑥ Sultlej River





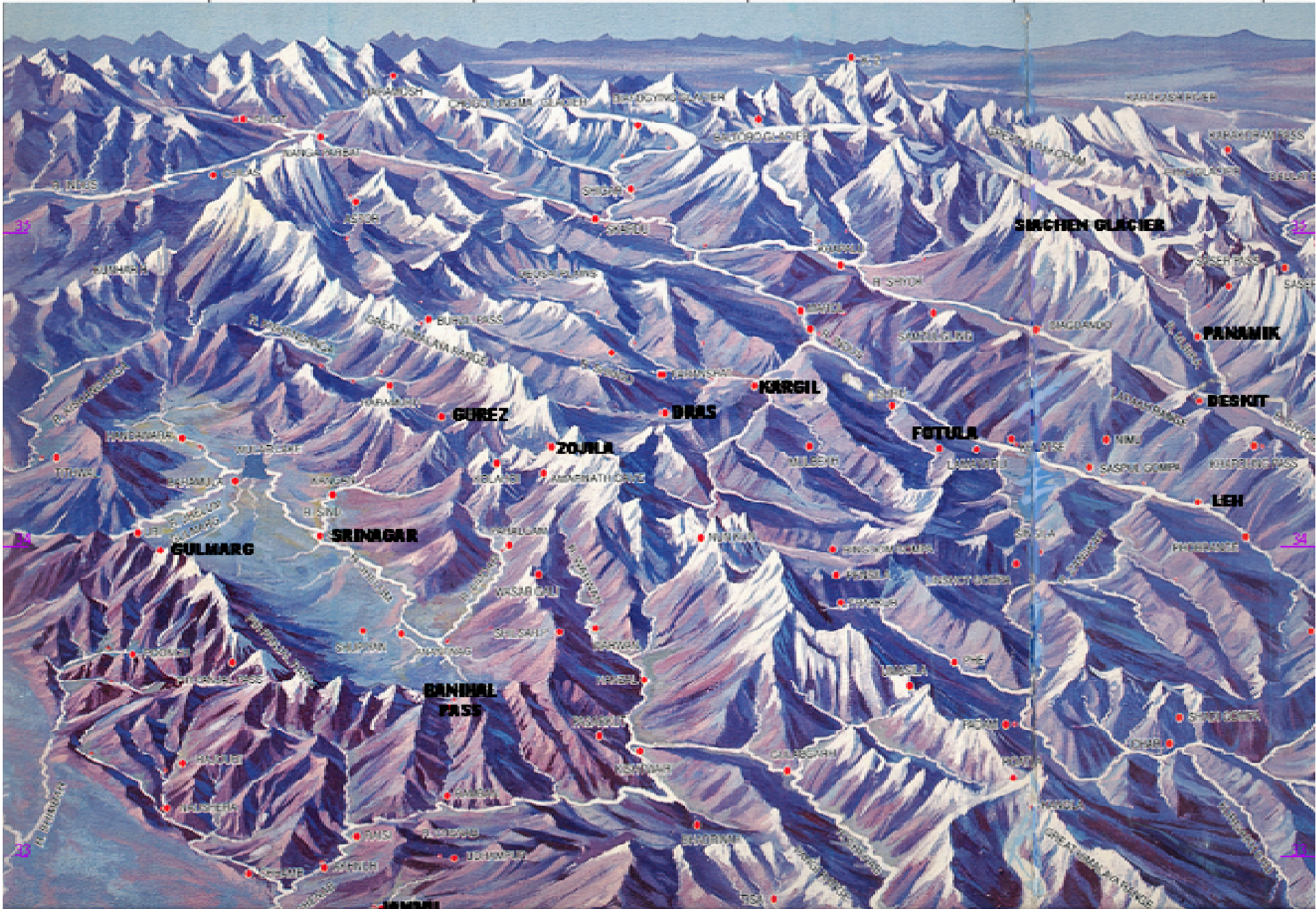
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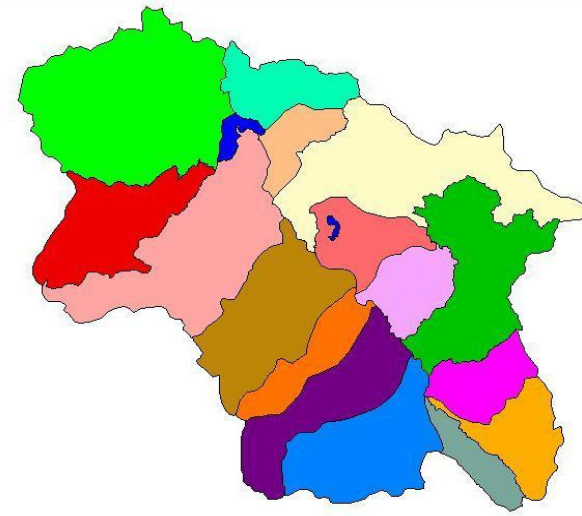
# Jammu & Kashmir

**IRS LISS-III 2007**



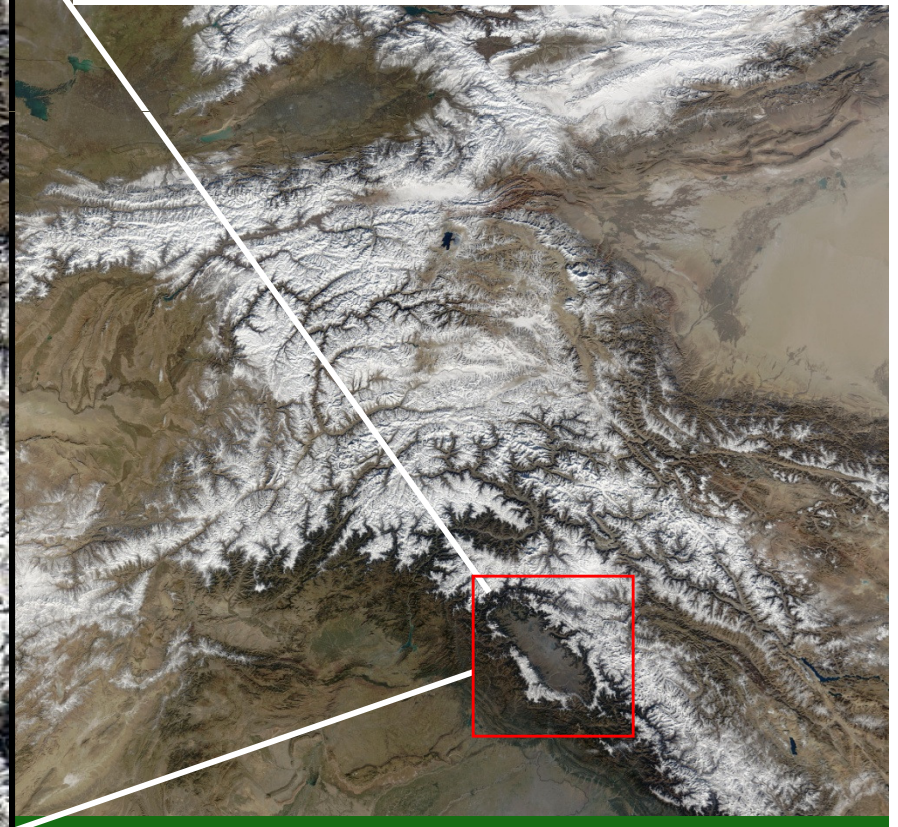
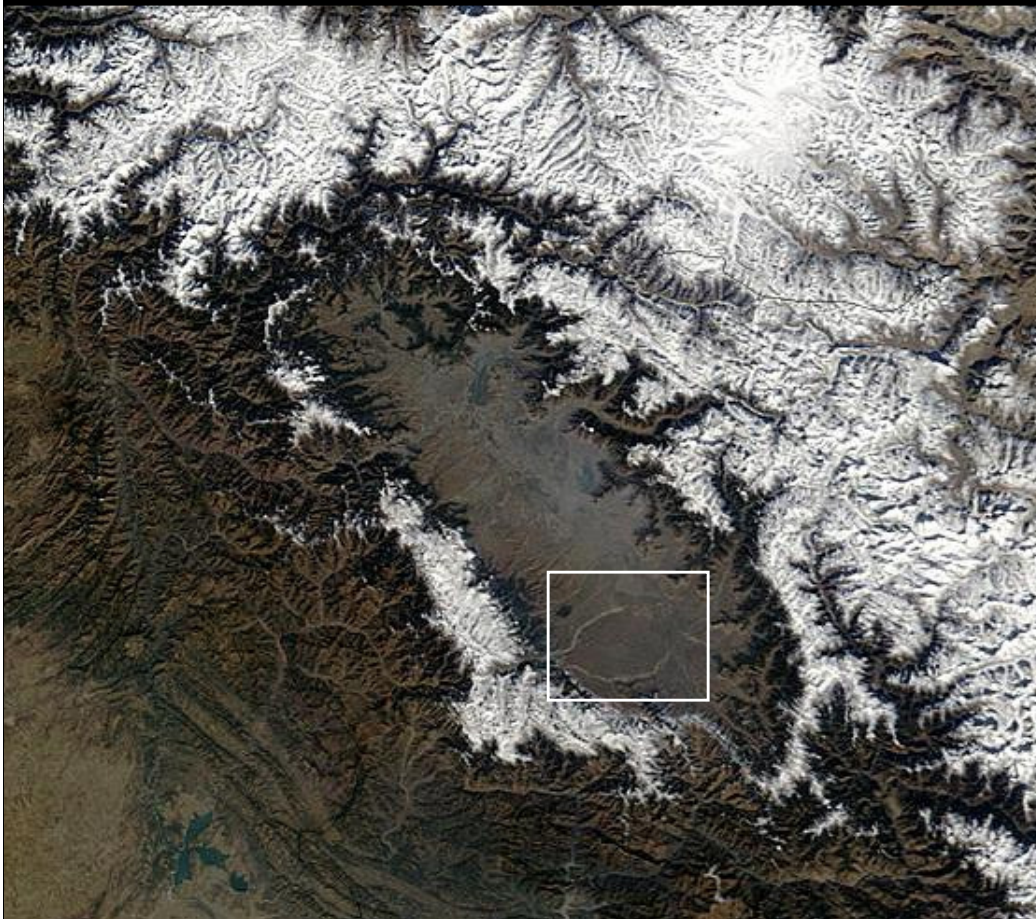


# Jhelum Basin

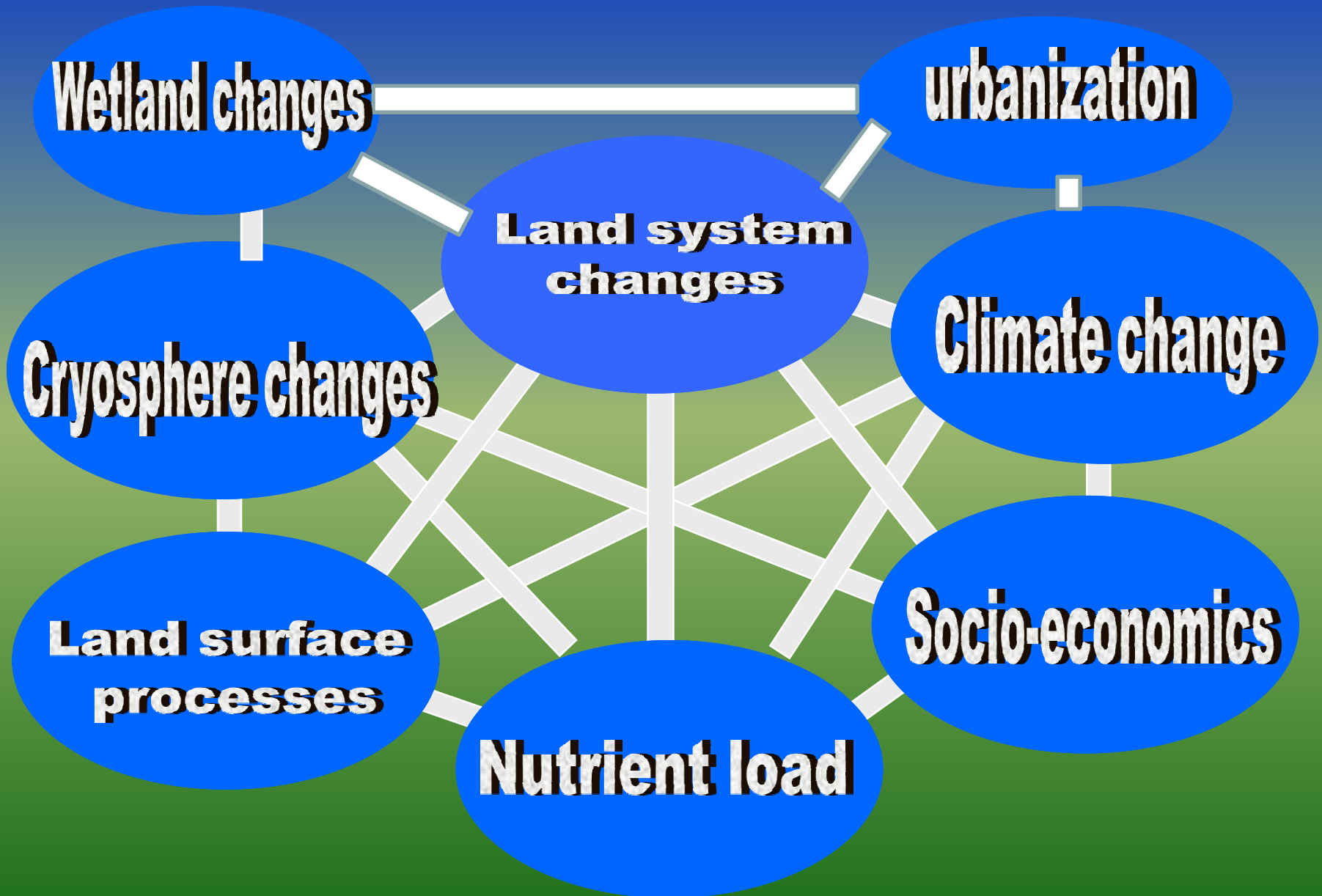


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Arapat	Arapat kol
Bring	Erin
Harwan	Lidder
Madmati	Ningal
Pohru	Ranbiara
Romoshi	Sandran
Sind	Sukhnag
Viji-Dakil	Vishiv
Dal Lake	Wullar Lake

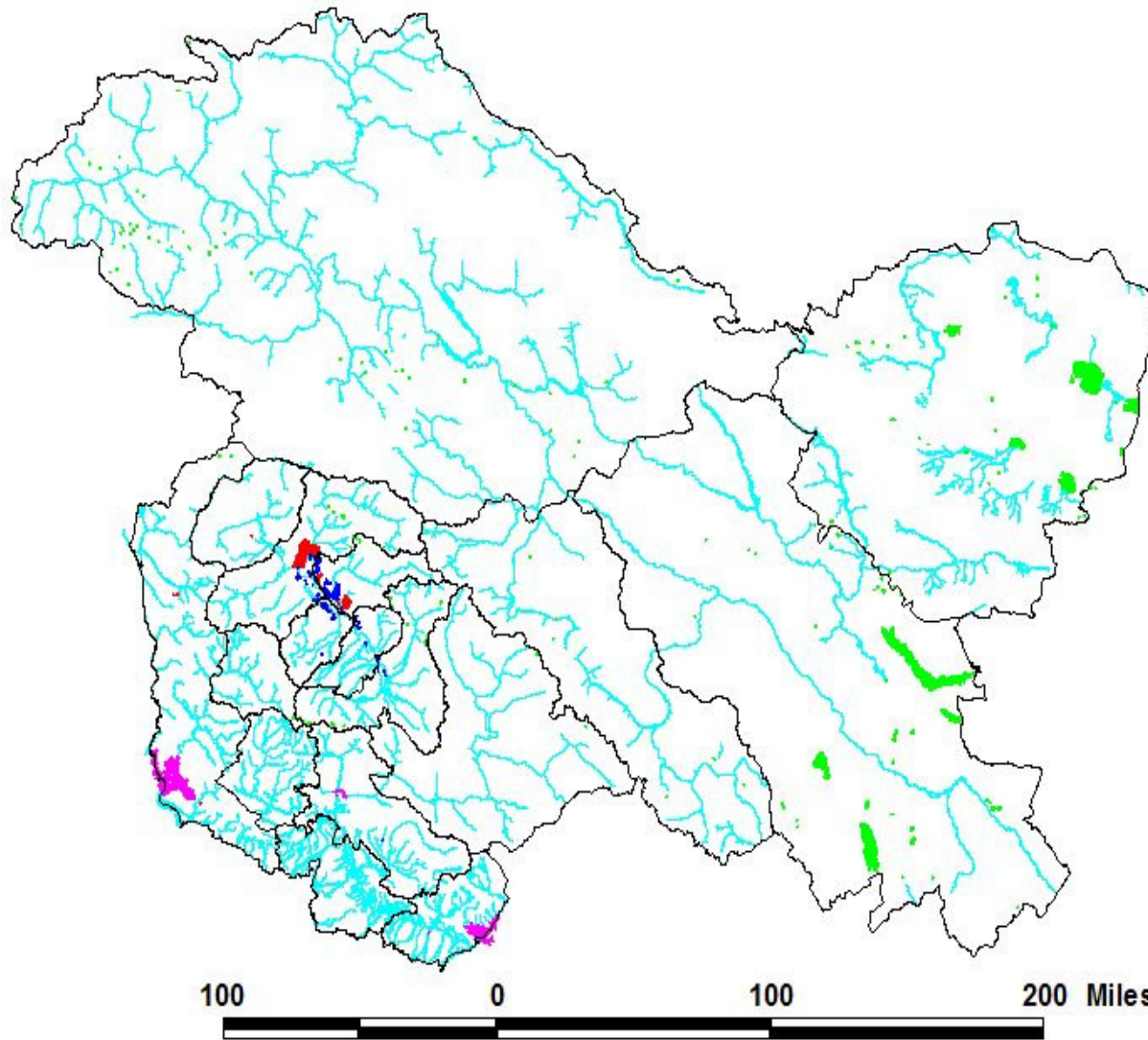


# RIVER ECOSYSTEM LINKAGES





# Water Resource Map of Jammu & Kashmir



- District Boundary
- Lakes
- High Altitude Lakes
- Riverine wetlands
- Rivers/Streams
- Dams/Barraiges
- Ponds/Tanks

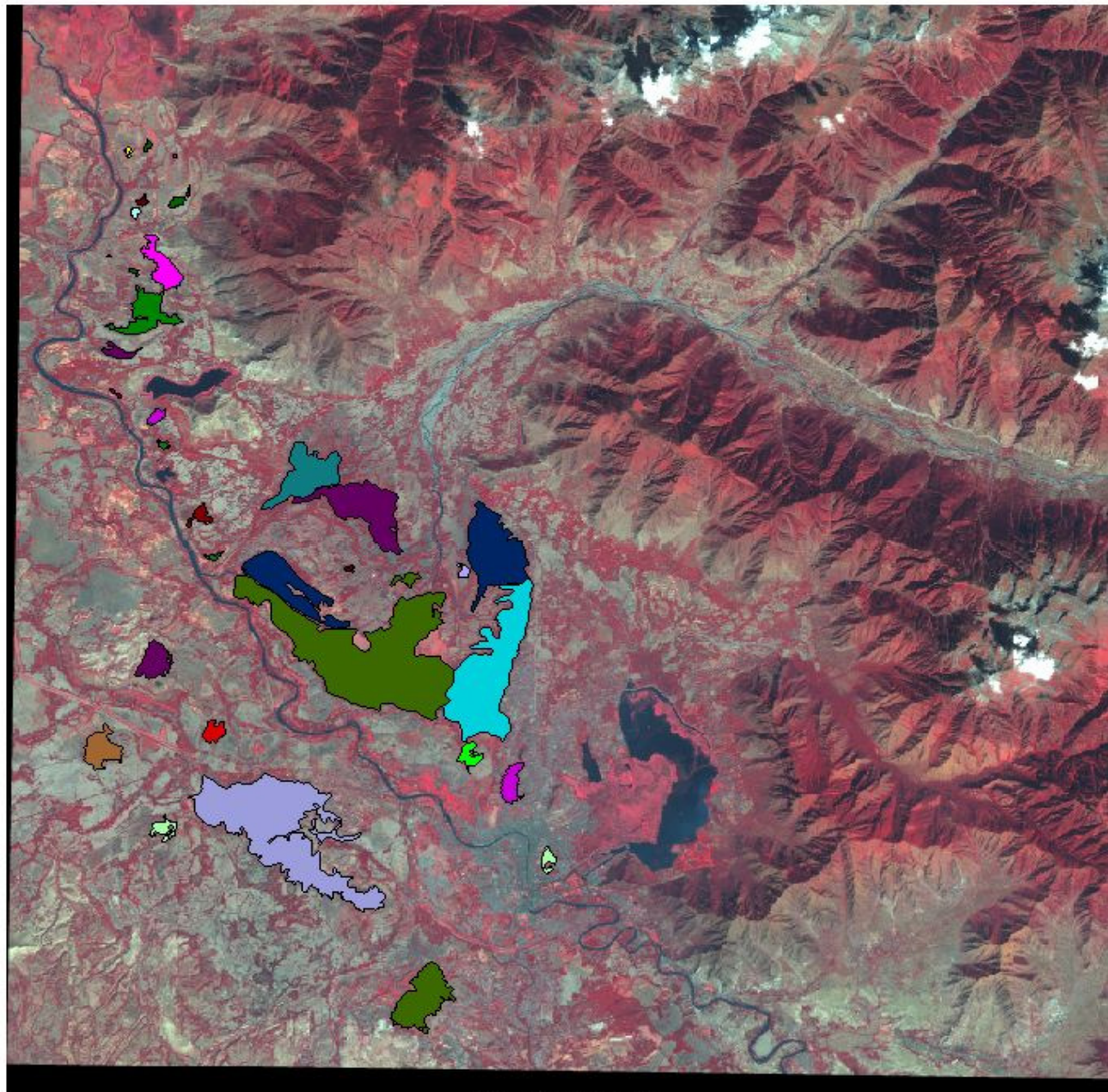
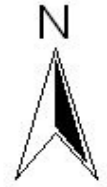
# Wetland statistics

Area in ha

Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
				Post-monsoon Area	Pre-monsoon Area
<b>Inland Wetlands - Natural</b>					
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
<b>Inland Wetlands -Man-made</b>					
Reservoirs/Barrages	4	25132	6.42	23115	25121
Tanks/Ponds	2	6	0.00	6	6
<b>Sub-Total</b>	<b>1411</b>	<b>389261</b>	<b>99.43</b>	<b>301818</b>	<b>314209</b>
Wetlands (<2.25 ha)	2240	2240	0.57	-	-
<b>Total</b>	<b>3651</b>	<b>391501</b>	<b>100.00</b>	<b>301818</b>	<b>314209</b>



# Wetland(2001)



- 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

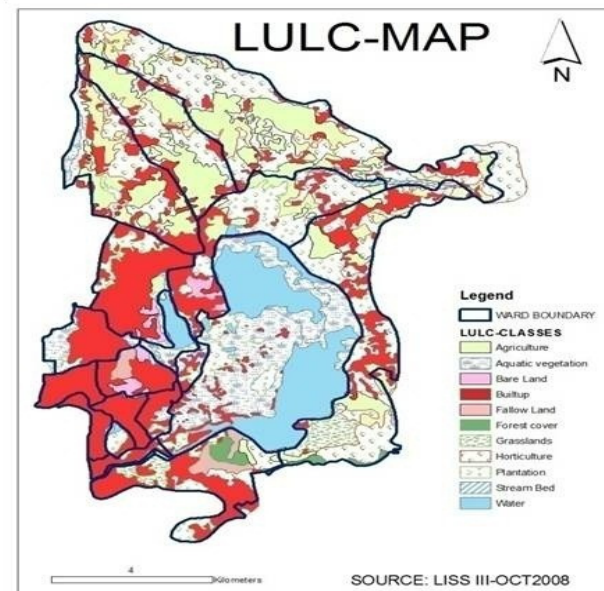
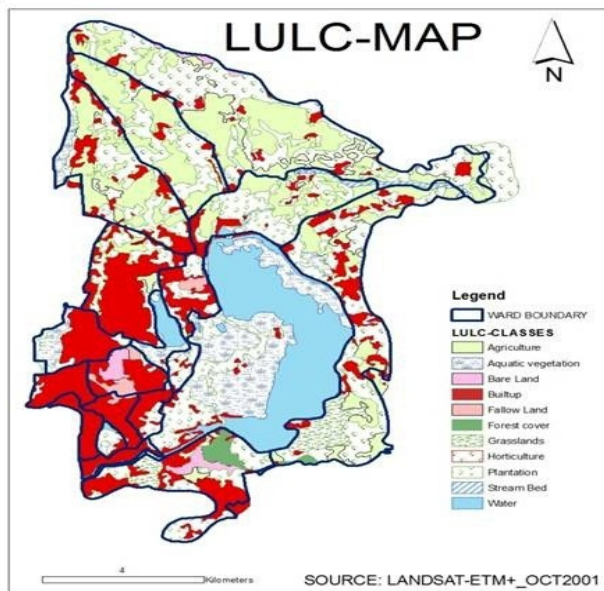
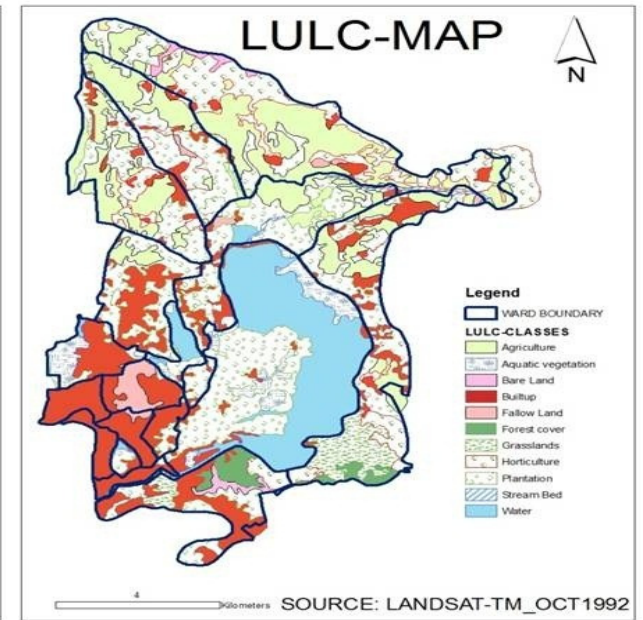
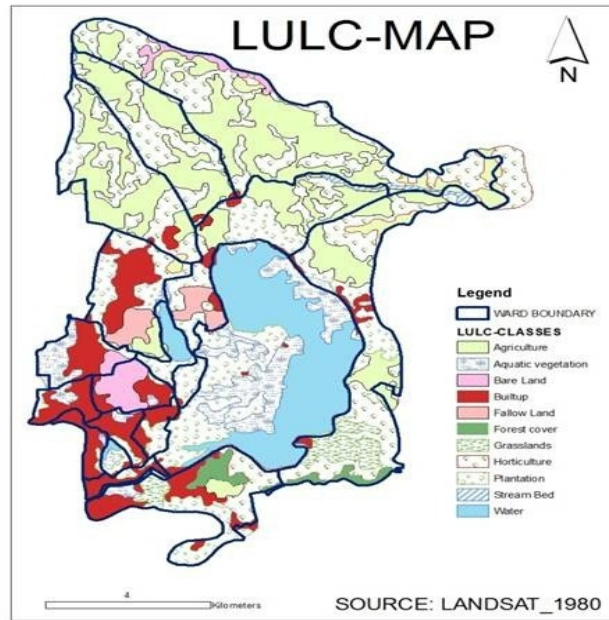
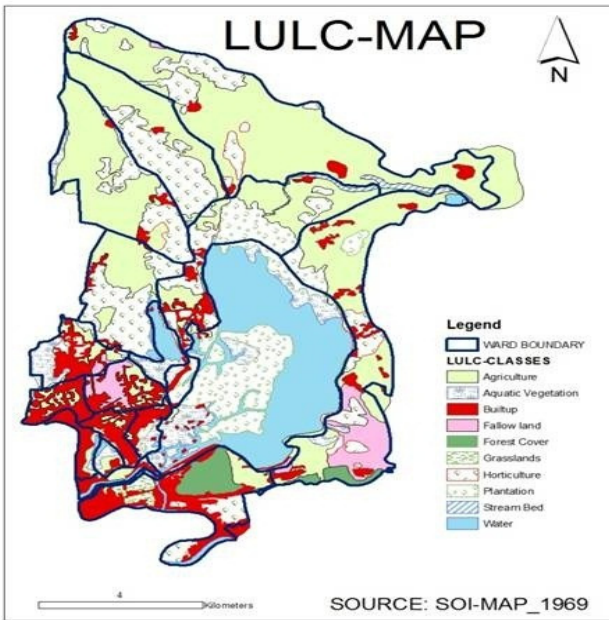
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20 Kilometers





# DAL LAKE ENVIRONS



# LULC CHANGES AROUND DAL LAKE (1969-2008)

<i>CLASS NAME</i>	<i>Area (hectares)</i>					
	<i>1969</i>	<i>1980</i>	<i>1992</i>	<i>2001</i>	<i>2008</i>	<i>Area change (1969-2008)</i>
Agriculture	4350.52	2717.17	2141.96	2242.43	1936.26	<b>-2414.26</b>
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	<b>1713.89</b>
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	<b>372.51</b>
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	<b>-381.70</b>

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

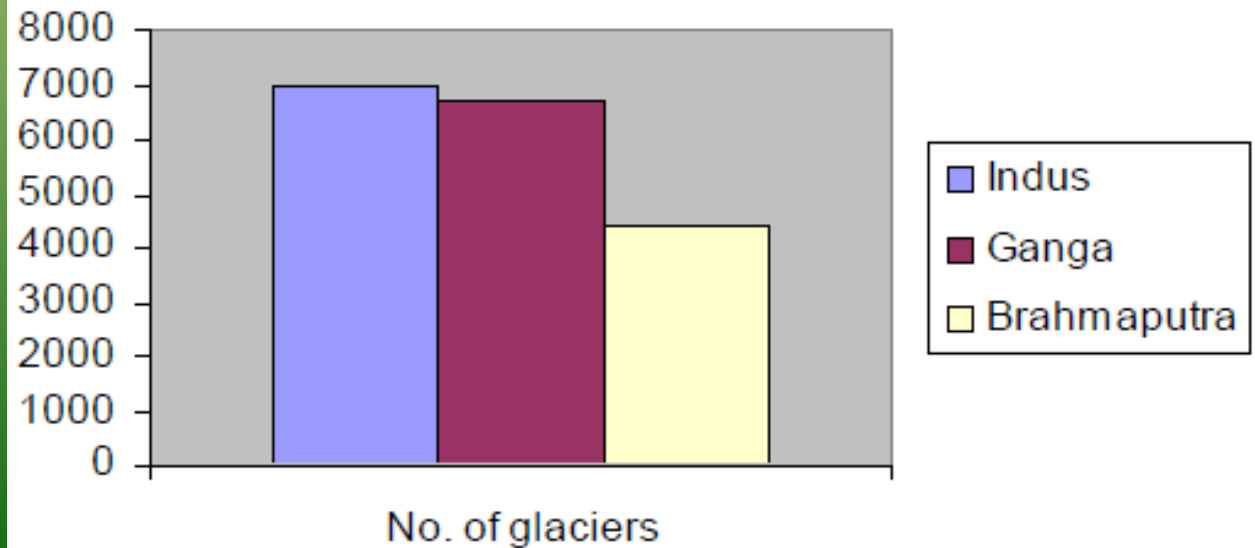
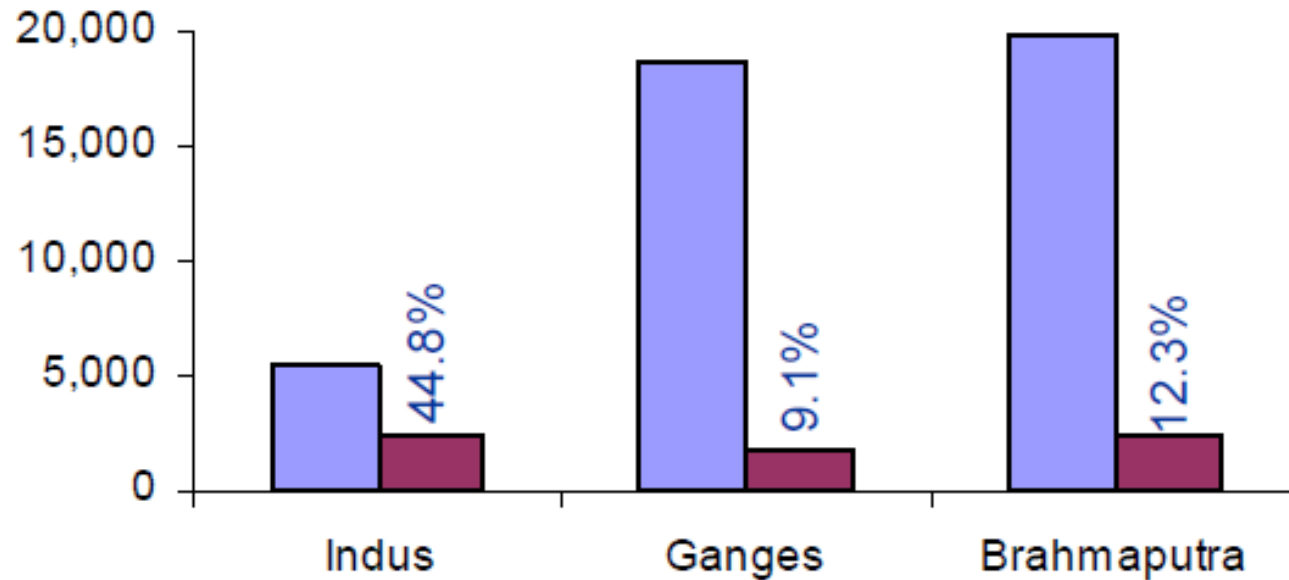
Hydrological Process	Year		Change (Tons/Yr)
	1992	2005	
Runoff (mm)	329.07	341.34	+12.27 (mm)
Erosion	1302.29	1953.66	<b>+651.37</b>
Sediment	232.45	354.65	<b>+122.2</b>
<b>NUTRIENT LOADS</b>			
Total Nitrogen (TN)	2037.13	2381.7	<b>+344.57</b>
Dissolved Nitrogen (DN)	1661.99	1865.87	<b>+203.8</b>
Total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





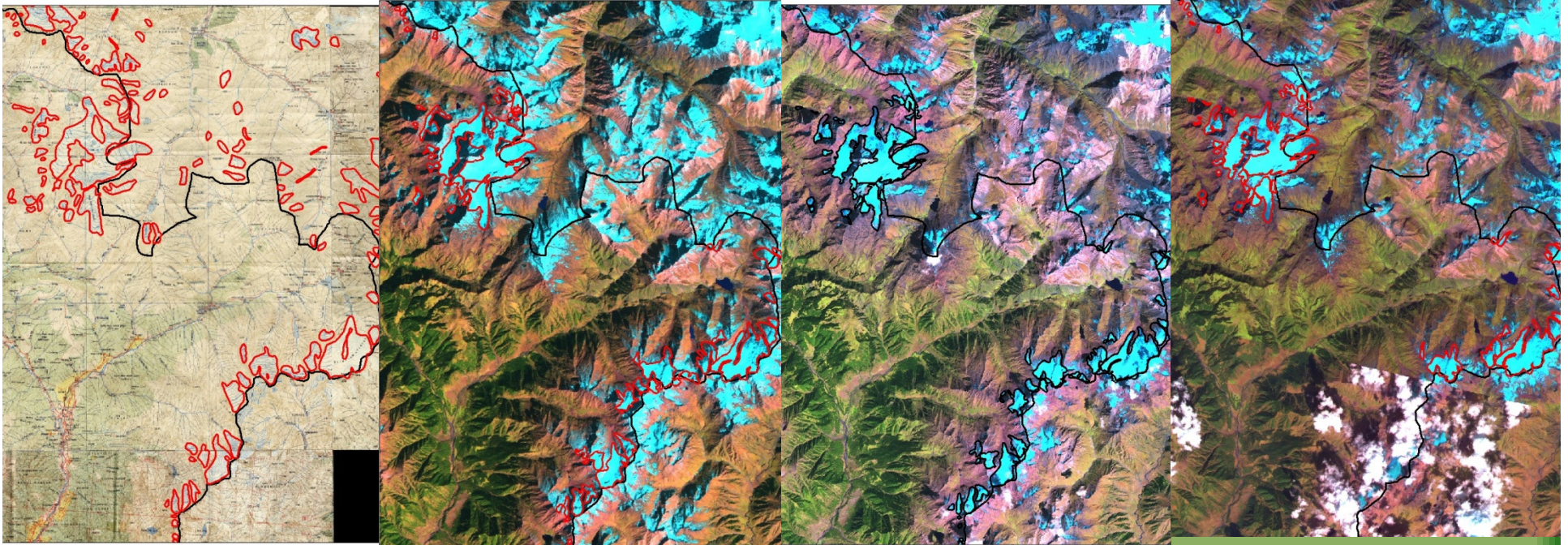
# Water Tower of Asia

Mean Discharge m<sup>3</sup>/s



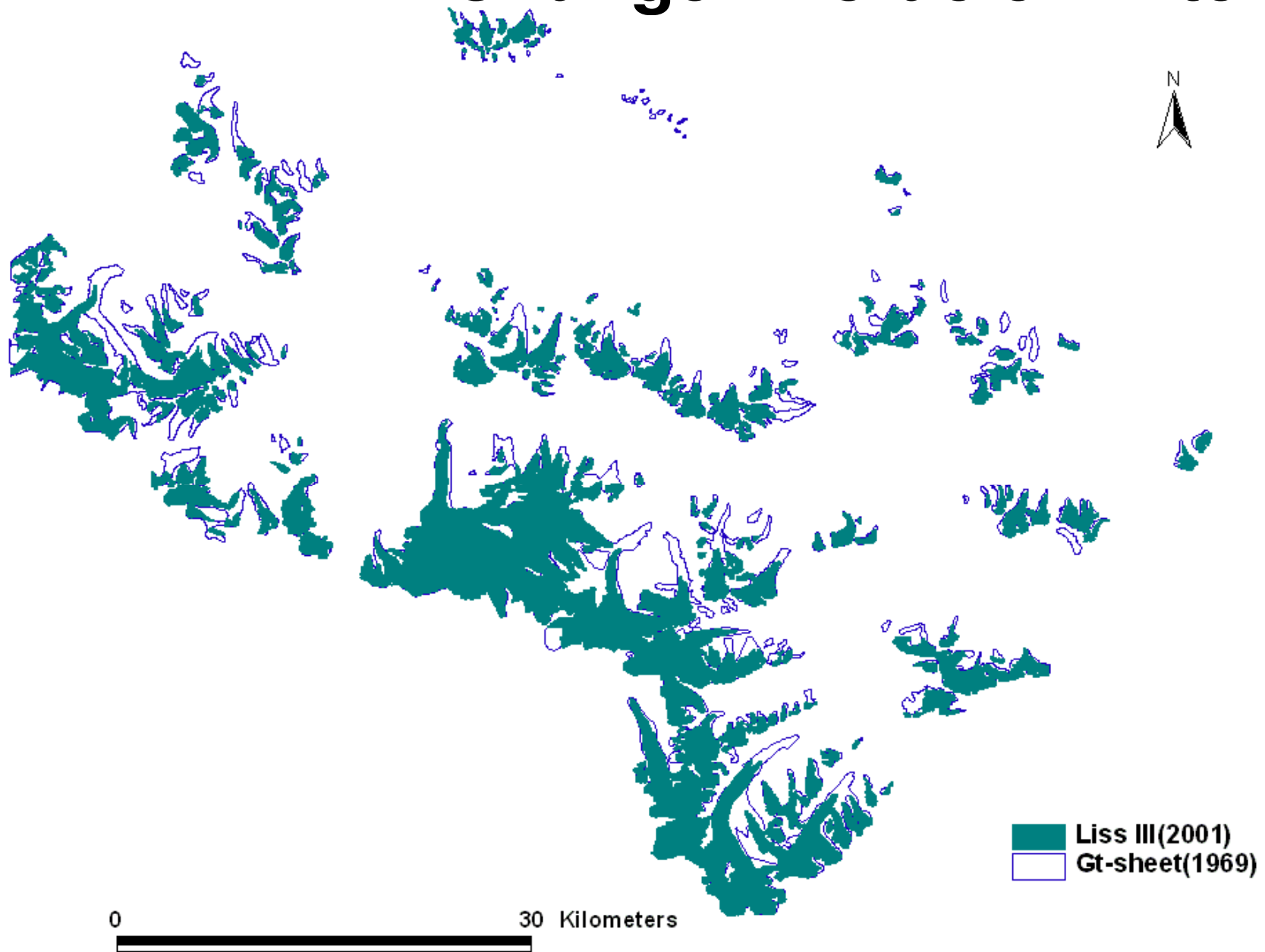


# Changes in Jhelum Cryosphere



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

# Change in Glacier Extent





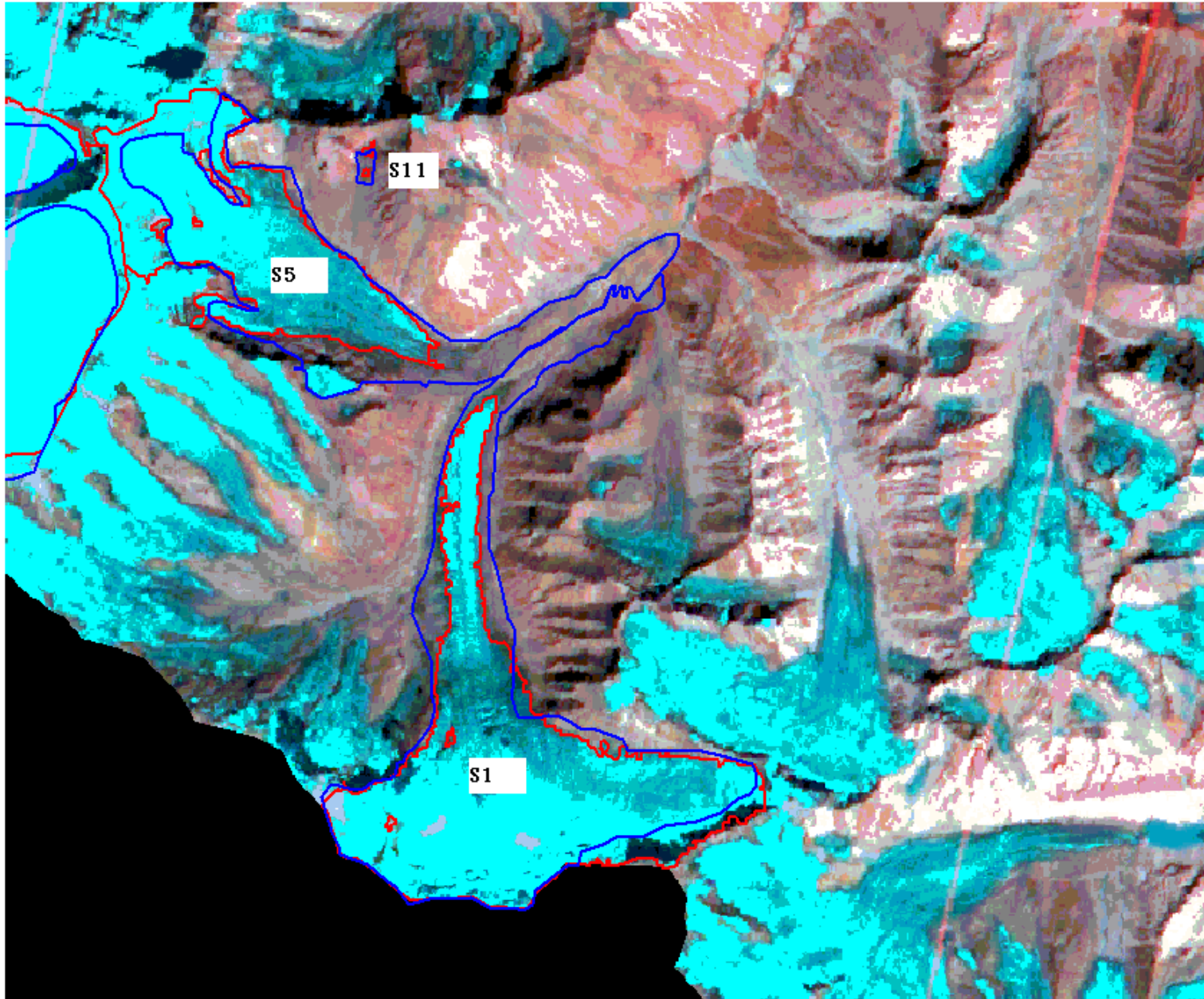
## Over all Change in Glacierized Area (Suru basin)

Categories (sq. km)	No. of Glaciers	Area 1969 (sq. km)	Area 2001 (sq. km)	%age Change
<= 2	172	80.04	55.20	31.04
> 2 & <= 5	28	89.25	67.21	24.70
> 5	15	398.36	351.99	11.64

**Total                      215                      567.65                      474.39                      16.43%**

**Glacier Area Lost = 93.26 Sq. km**

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



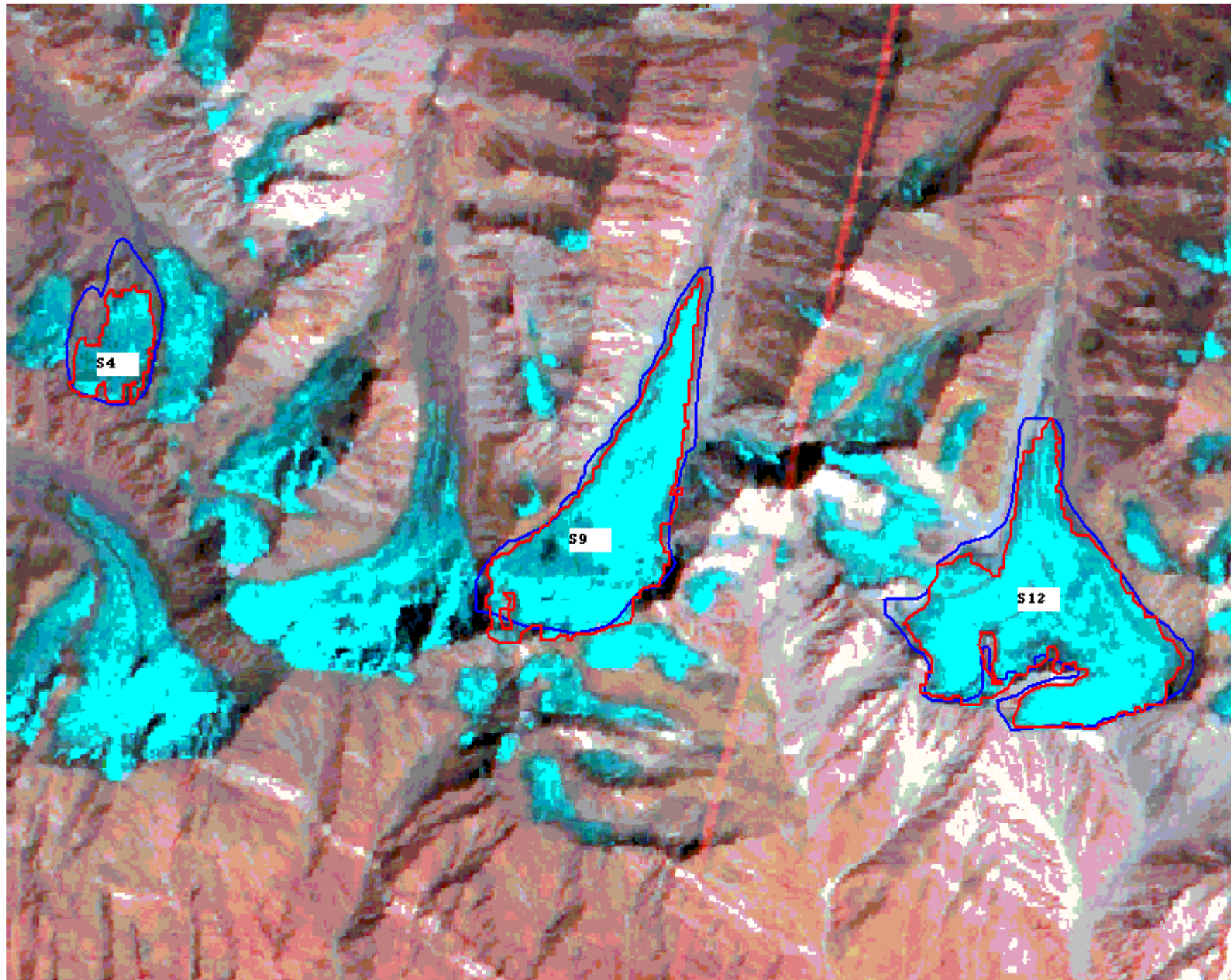
INDEX

— 1969

— 2001



FIGURE SHOWING CHANGE IN S4, S9 AND S12 FROM 1969 TO 2001.

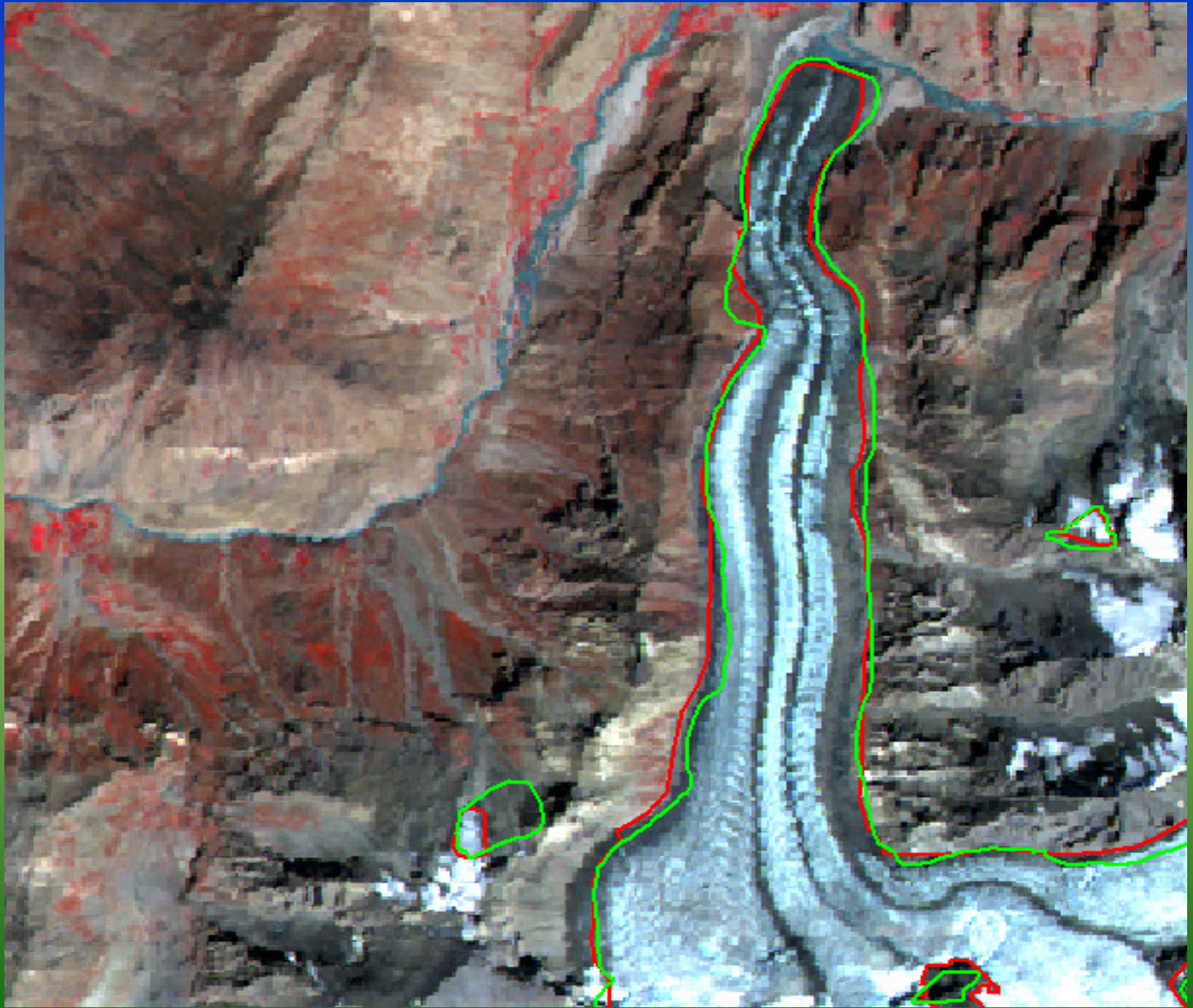


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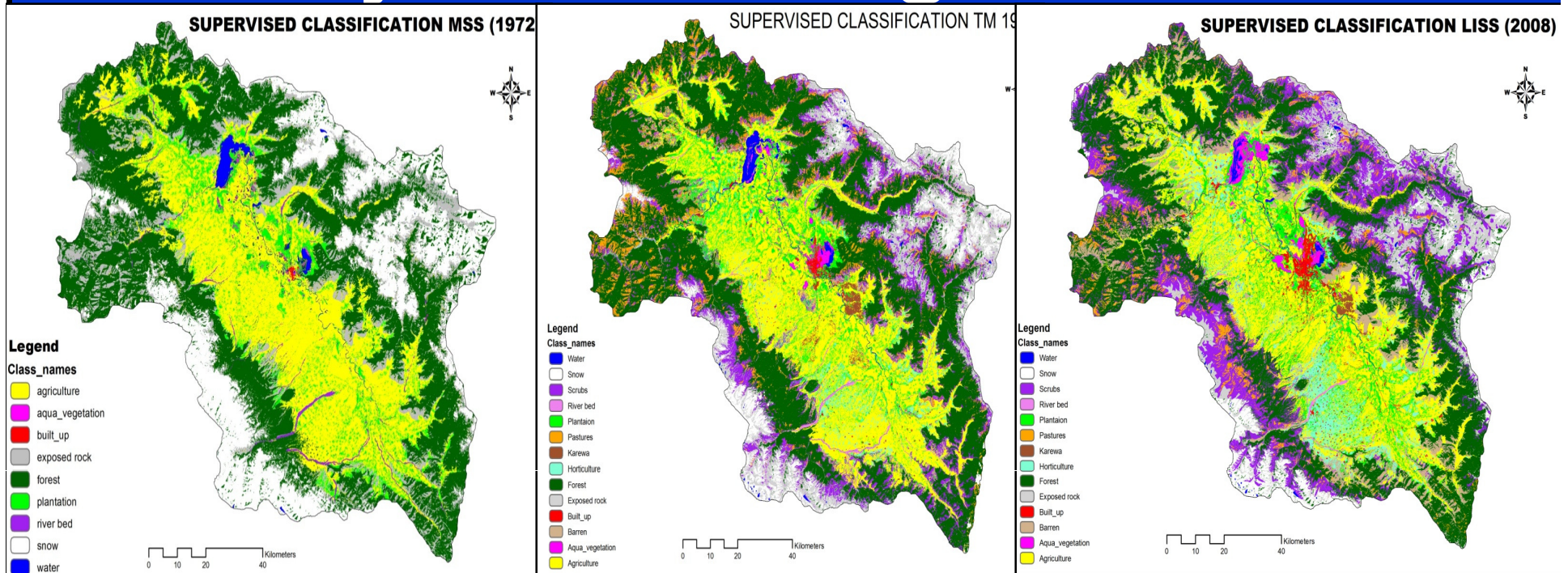
— 20







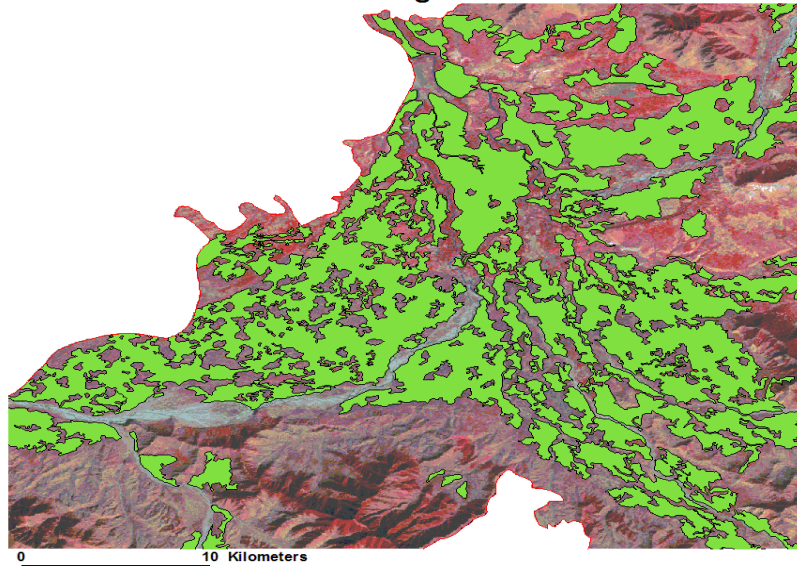
# Land System Changes in Jhelum



CLASS NAME	1972 AREA (HA)	1992 AREA (HA)	2008 AREA (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

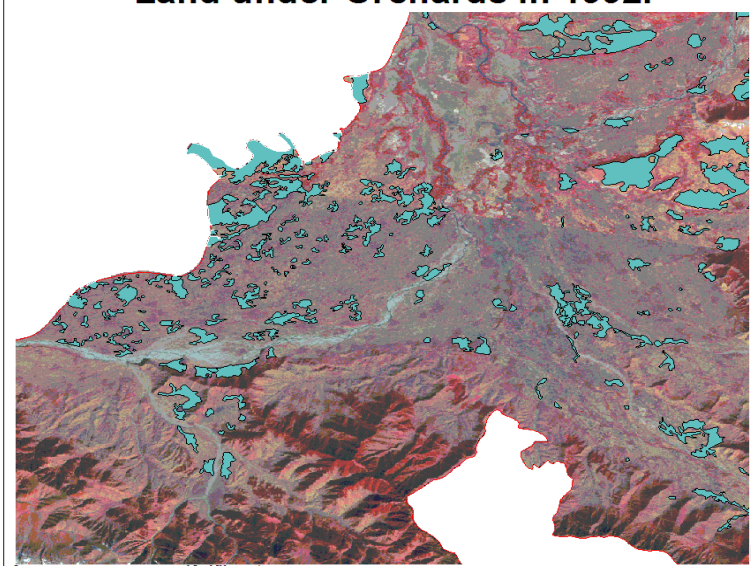


**Land under Agriculture in 1992.**



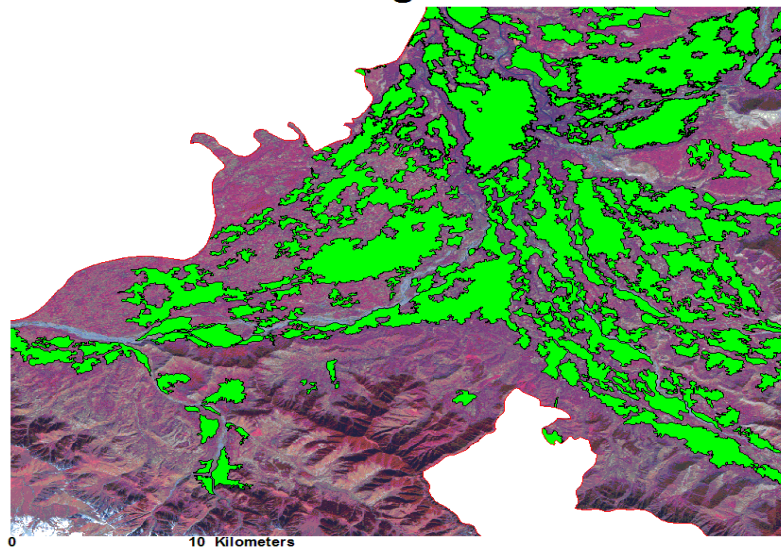
Agri, 1992

**Land under Orchards in 1992.**



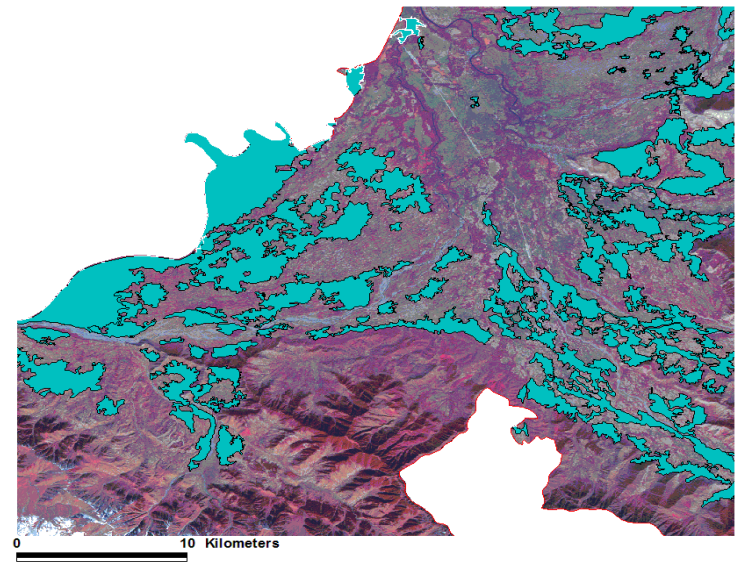
Orchards, 1992

**Land under Agriculture in 2005.**



Agri, 2005

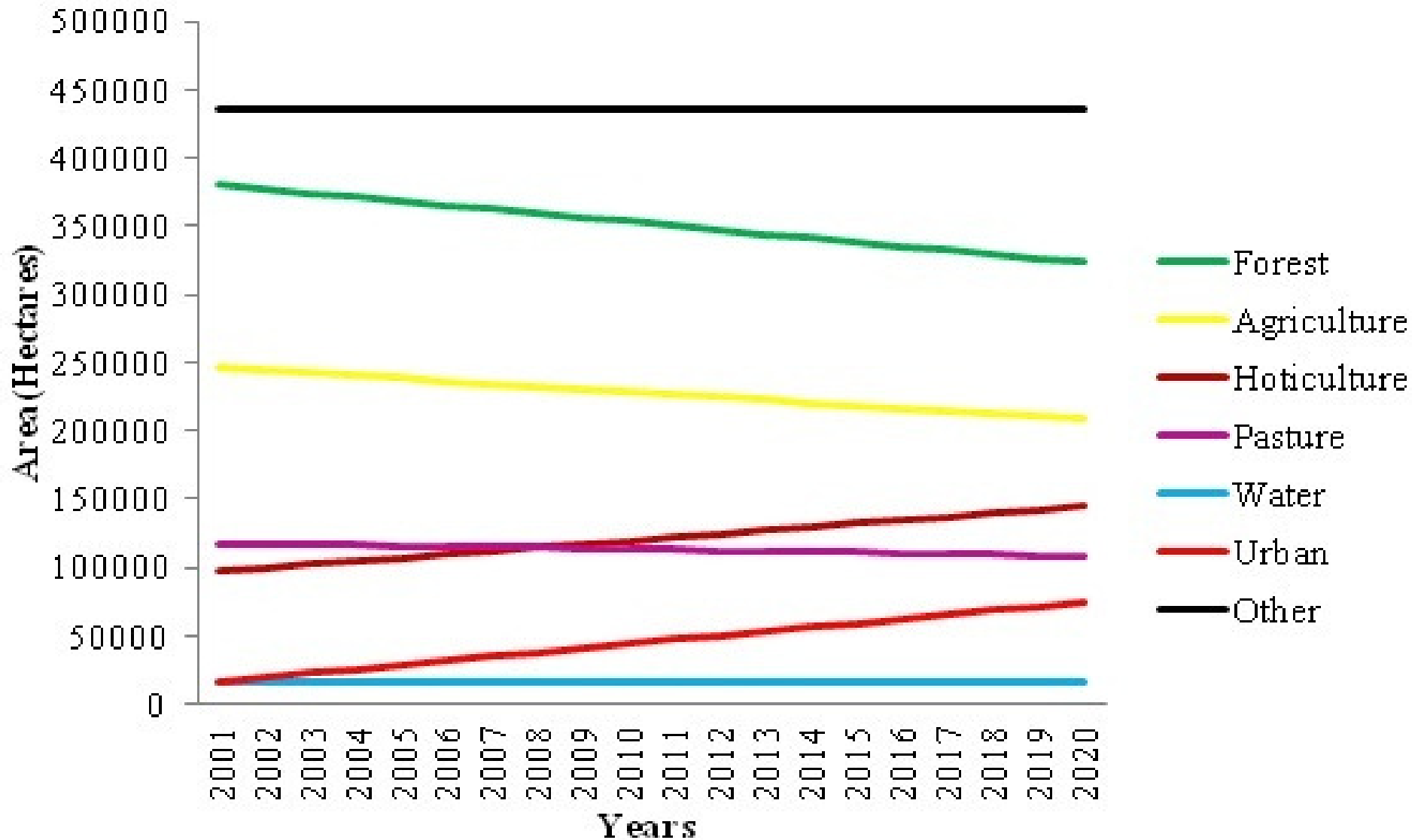
**Land under Orchards in 2005.**



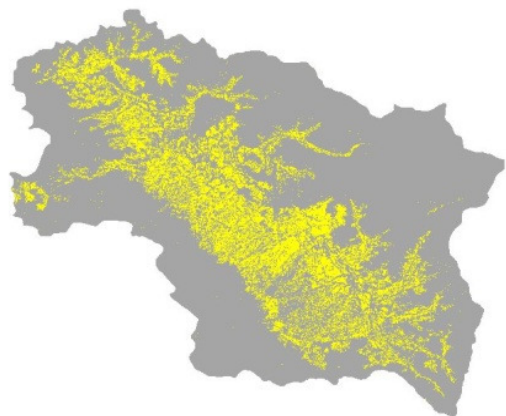
Orchards, 2005



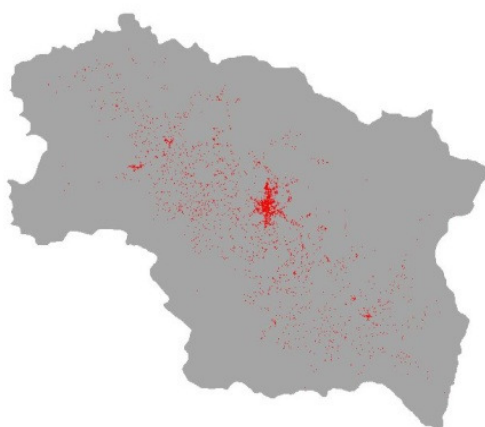
# Land System Change Projections (2001-2020)



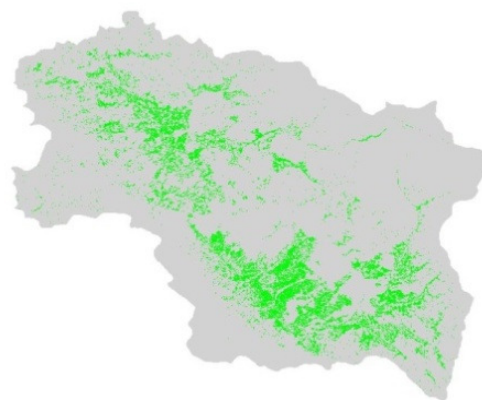
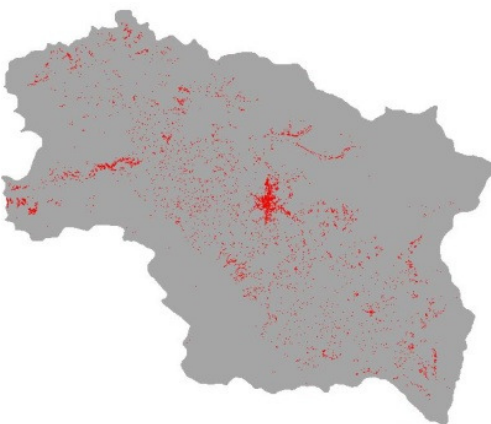
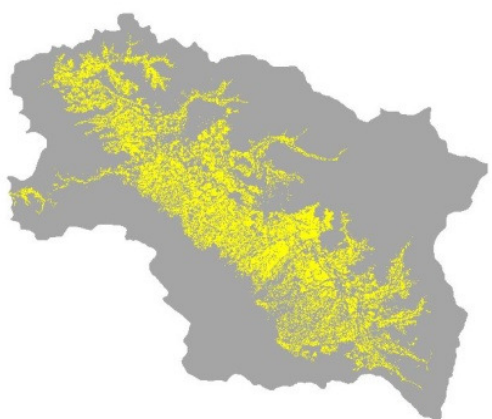
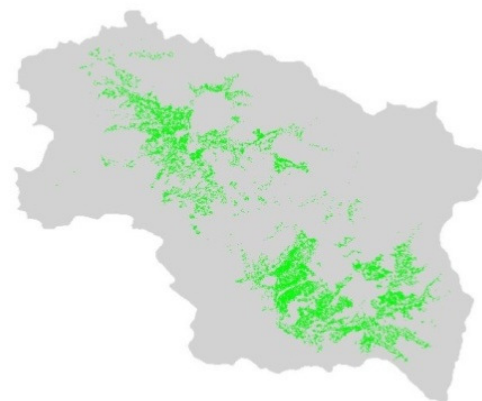
### Agriculture Map of 2001



### Urban Map of 2001



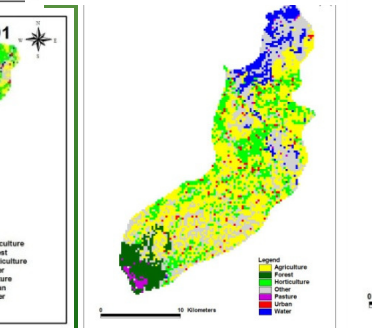
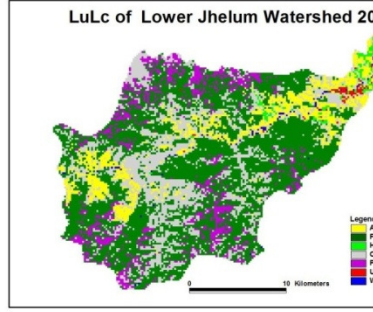
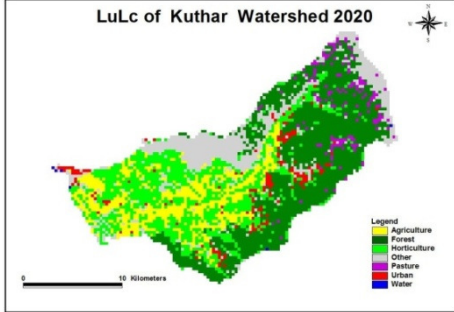
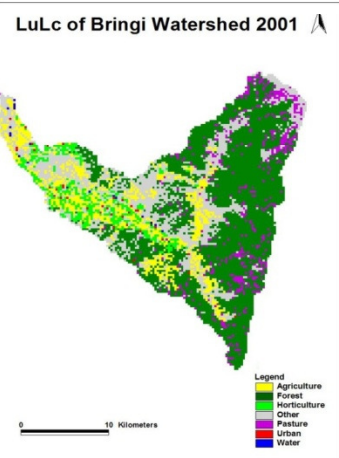
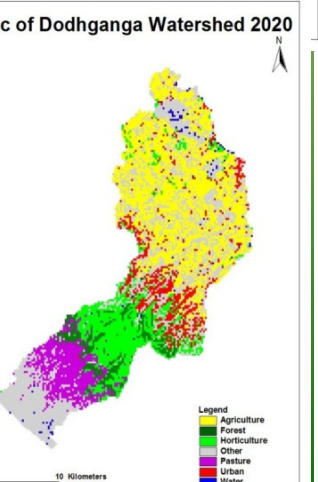
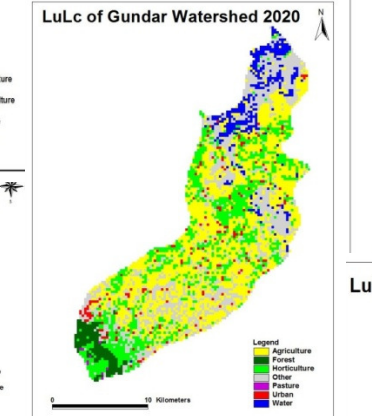
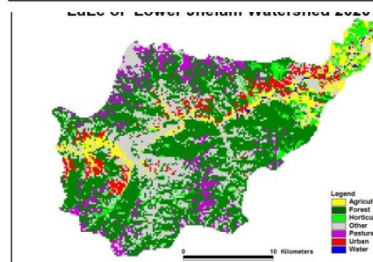
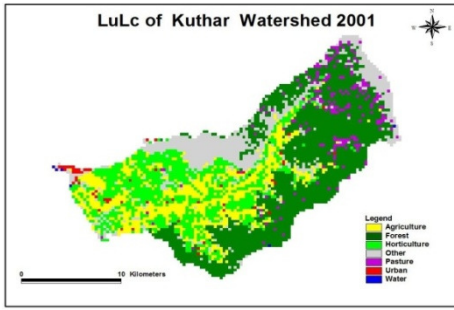
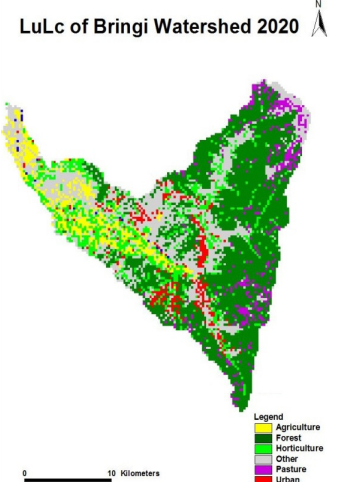
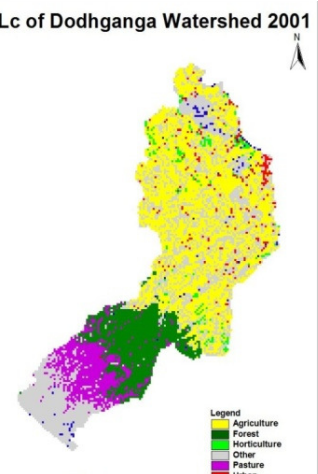
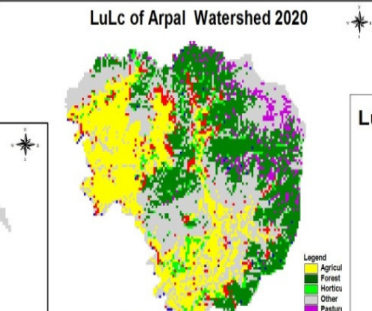
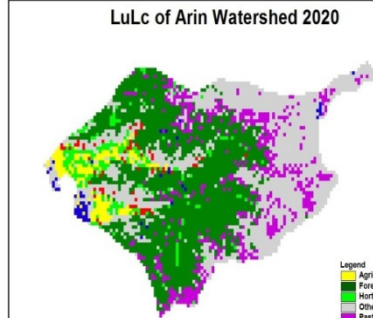
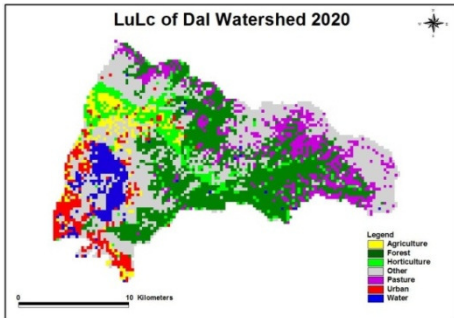
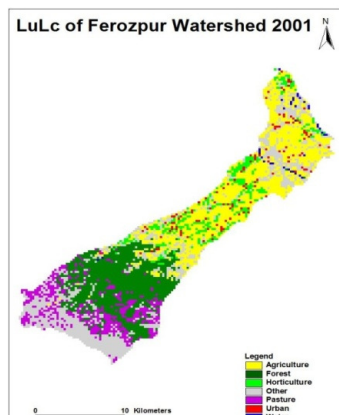
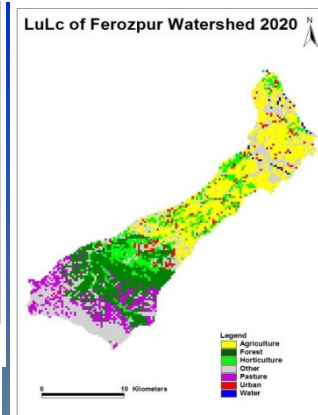
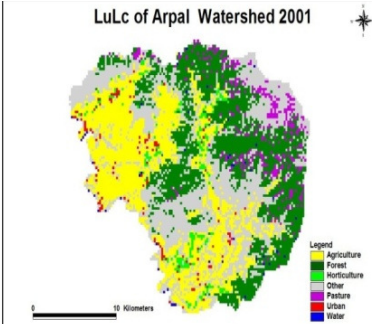
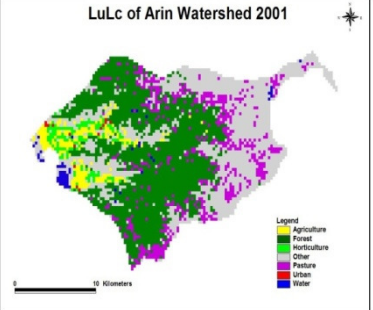
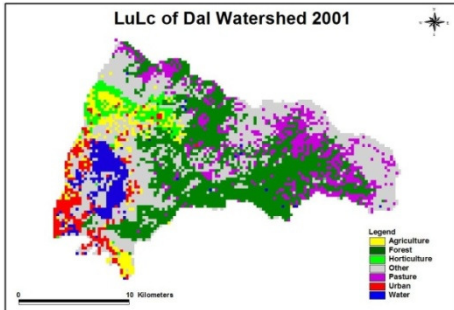
### Horticulture Map of 2001



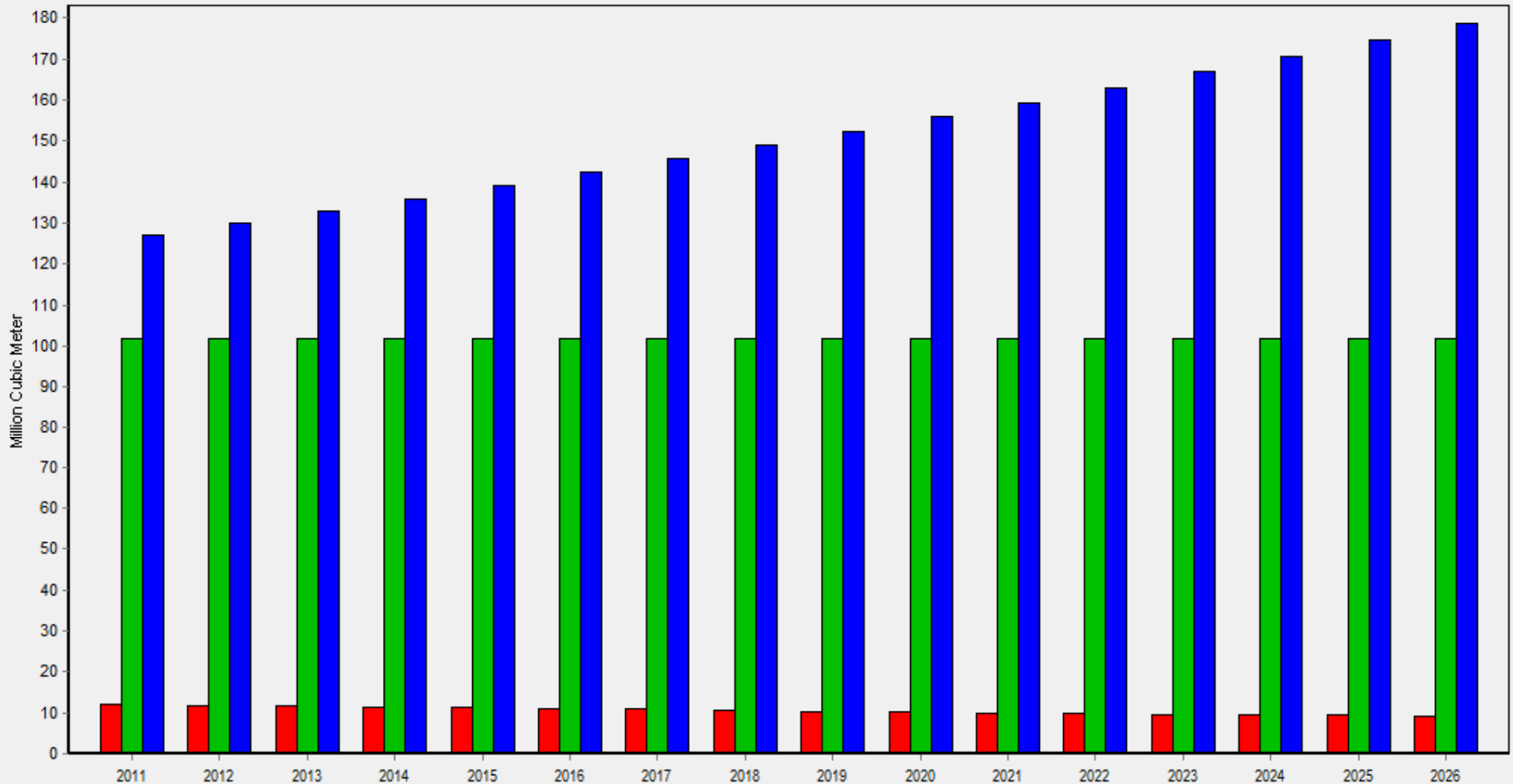
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# LULC 2001-2020



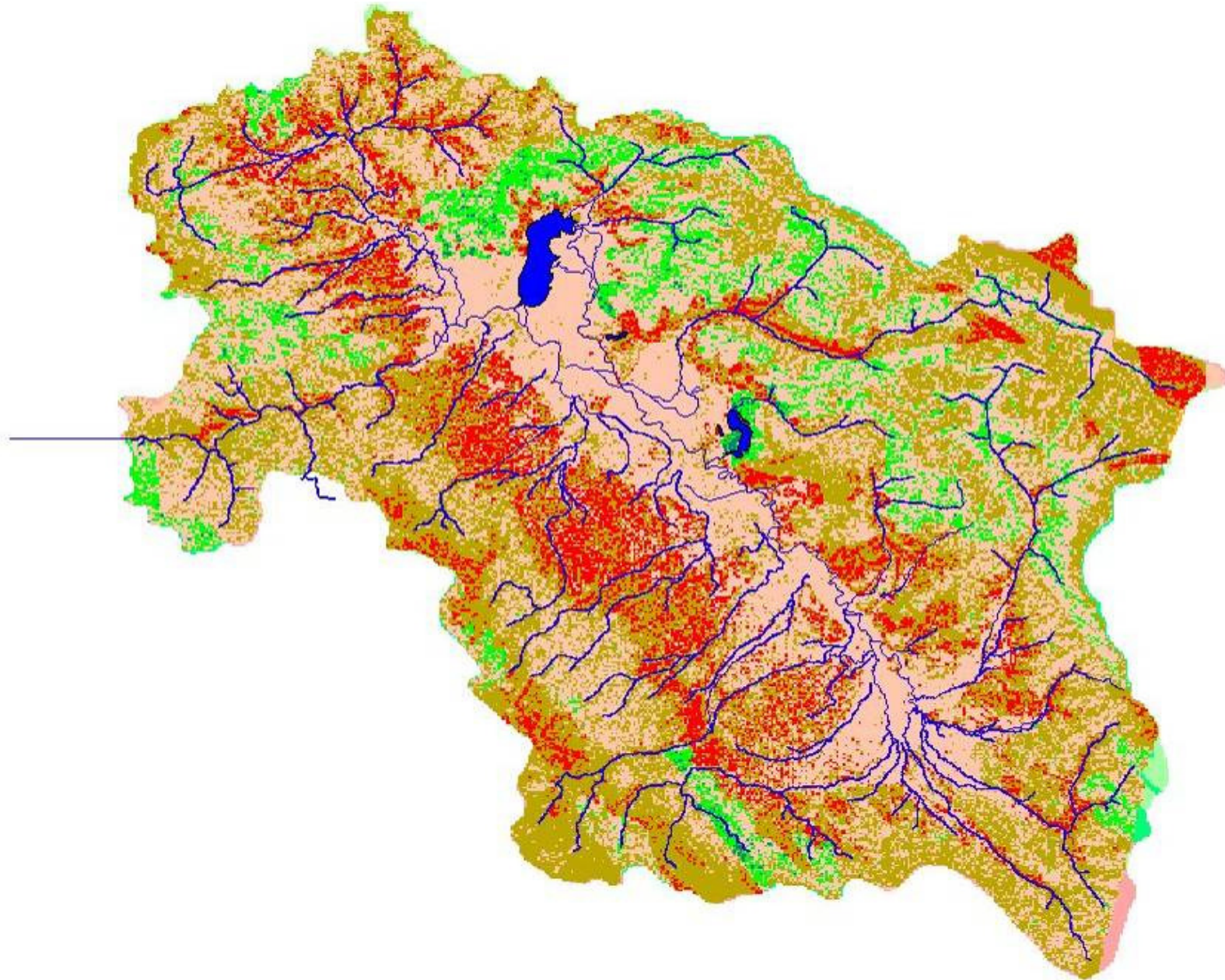
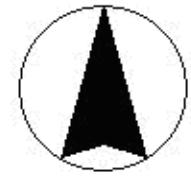
# Water Demand in Srinagar City



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Sum
Agri_Dachigam	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.2	10.0	9.9	9.7	9.5	9.3	9.2	168.8
Agri_Sindh	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	101.7	1,626.9
Sgr_city	127.0	129.9	132.9	135.9	139.1	142.3	145.5	148.9	152.3	155.8	159.4	163.1	166.8	170.6	174.6	178.6	2,422.6
Sum	240.7	243.4	246.2	249.0	252.0	254.9	258.0	261.2	264.4	267.7	271.1	274.6	278.2	281.8	285.6	289.4	4,218.4



# Erosion Risk Map of Jhelum Basin



# JHELUM BASIN EROSION RISK VULNERABILITY

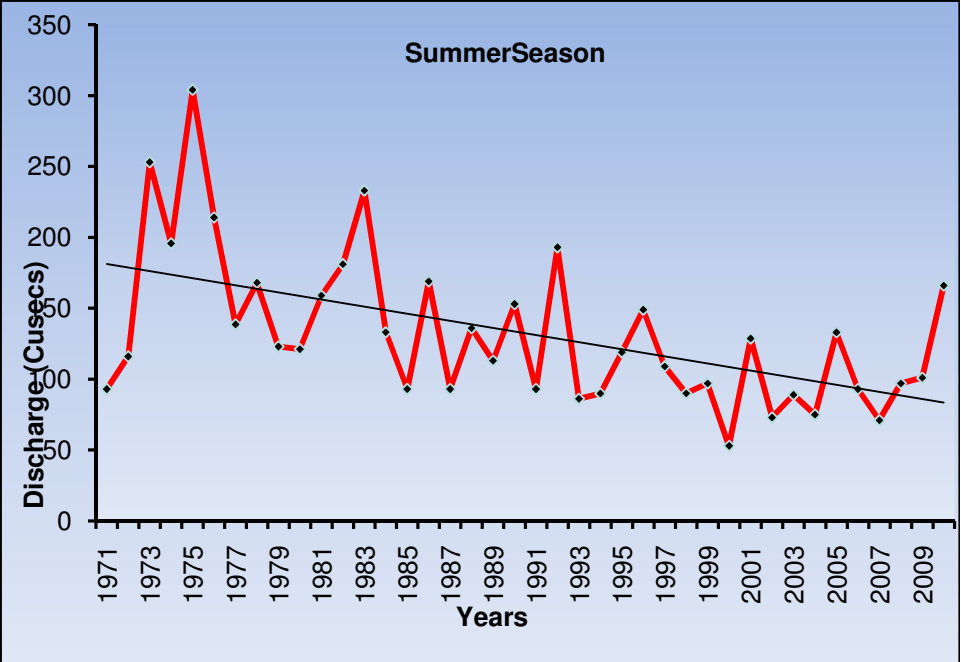
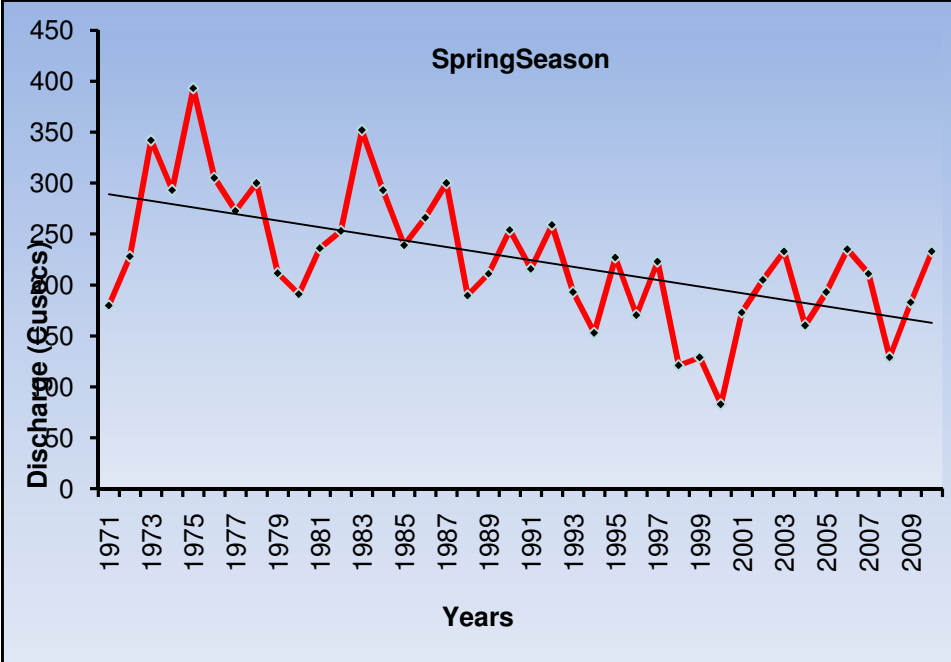
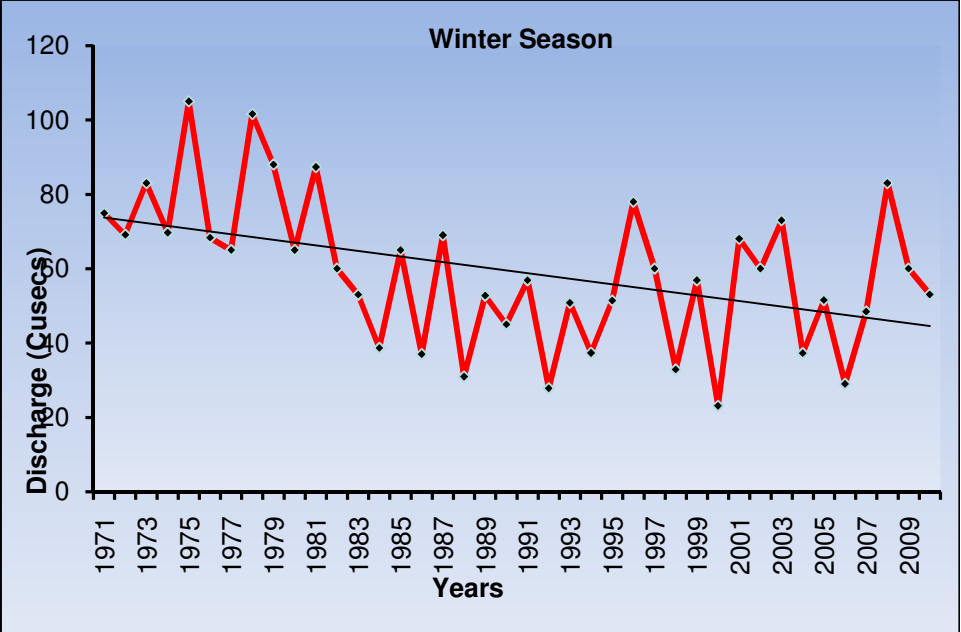
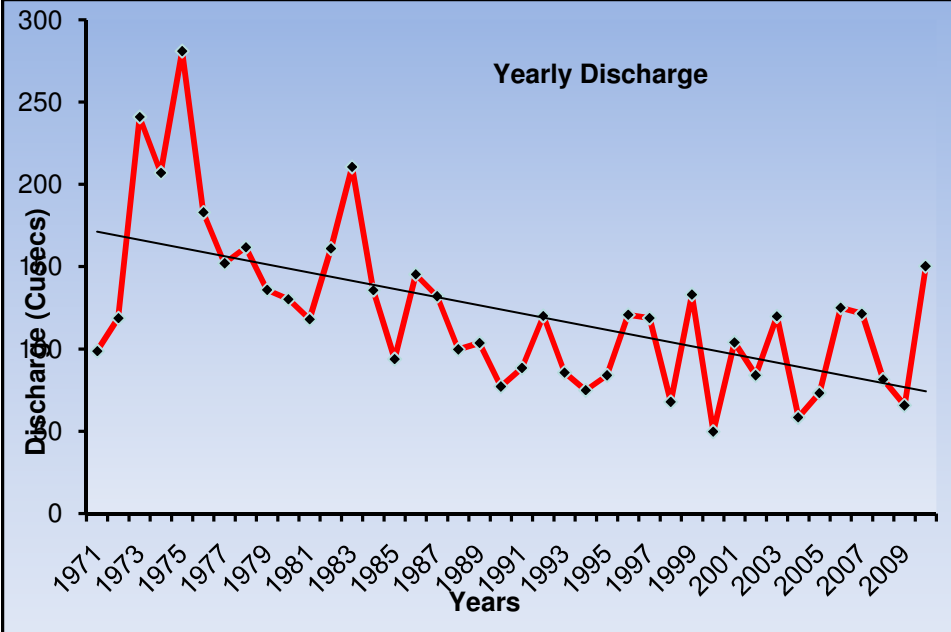
Level of Erodibility	Area sq km	Area%
Very Low Erosion	93.83	0.59
Low Erosion	1064.2	6.74
Moderate Erosion	7031.28	44.4
High Erosion	5845.8	36.9
Extremely high Erosion	1800.9	11.3
<b>Total</b>	<b>15836</b>	<b>100.0</b>



## Change in physico-chemical characteristics of river Jhelum (1982–2002)

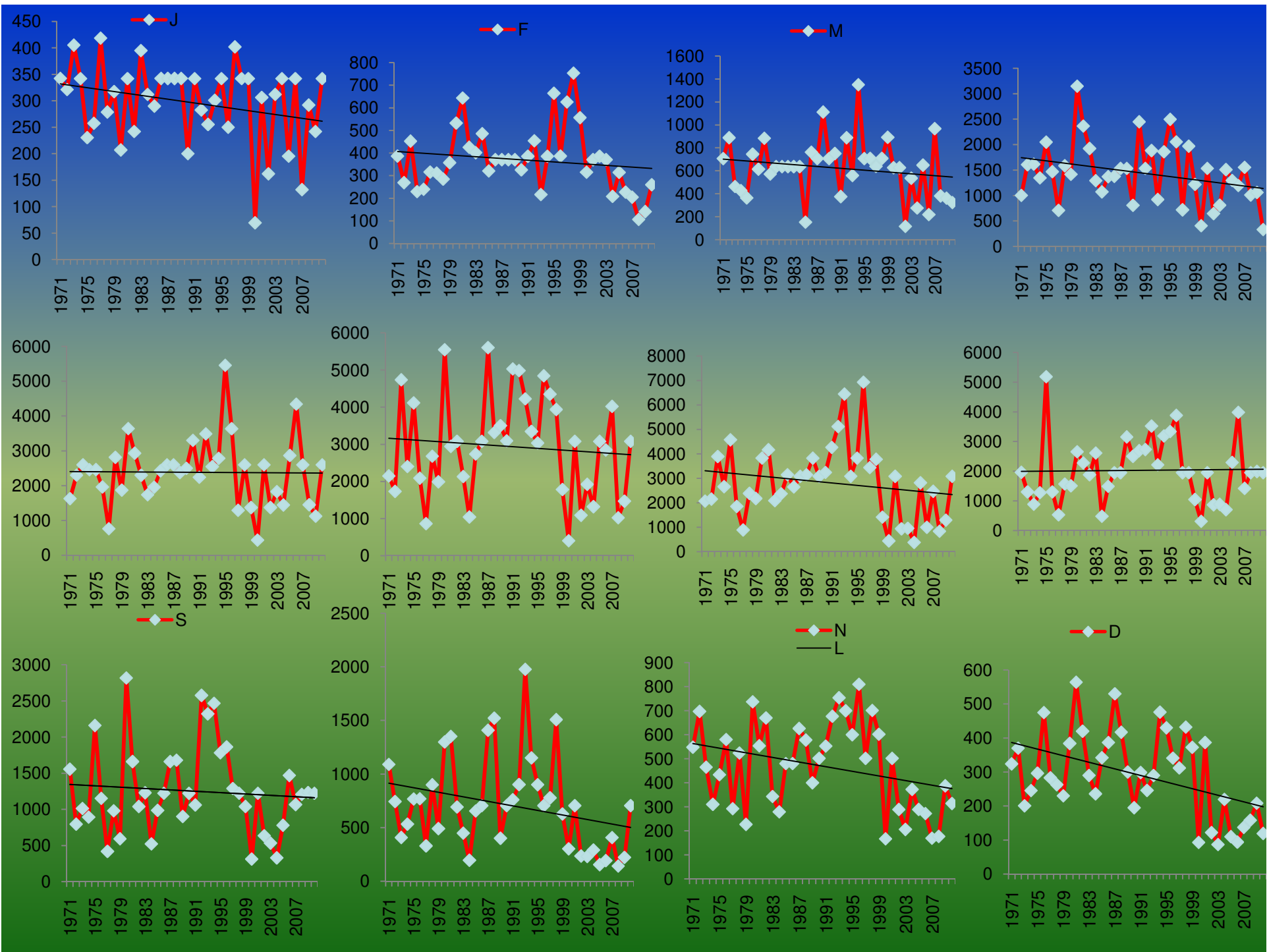
Chemical components	1982	2002	Change
NH <sub>4</sub> -N(μg/l)	14.9	85.0	70.1
NO <sub>3</sub> -N(μg/l)	44.7	317.0	272.3
PO <sub>4</sub> -P(μg/l)	17.5	40.0	22.5
Total P (μg/l)	55.9	228.0	172.1
Cl (μg/l)	11.9	13.5	1.6
Ca (μg/l)	23.7	56.5	32.8
Mg (μg/l)	2.8	22.0	19.2

# Observed Stream Flow Changes



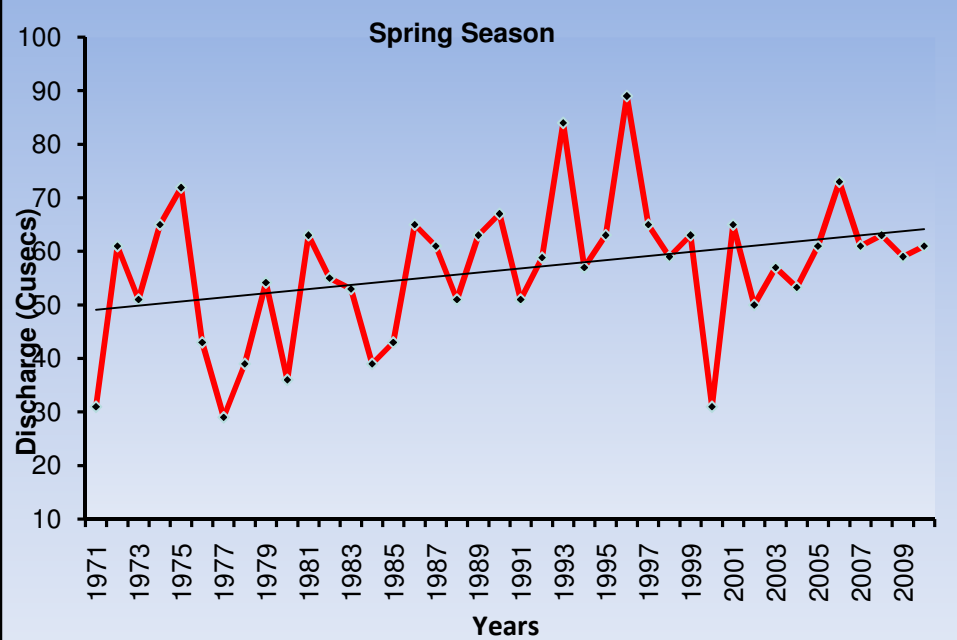
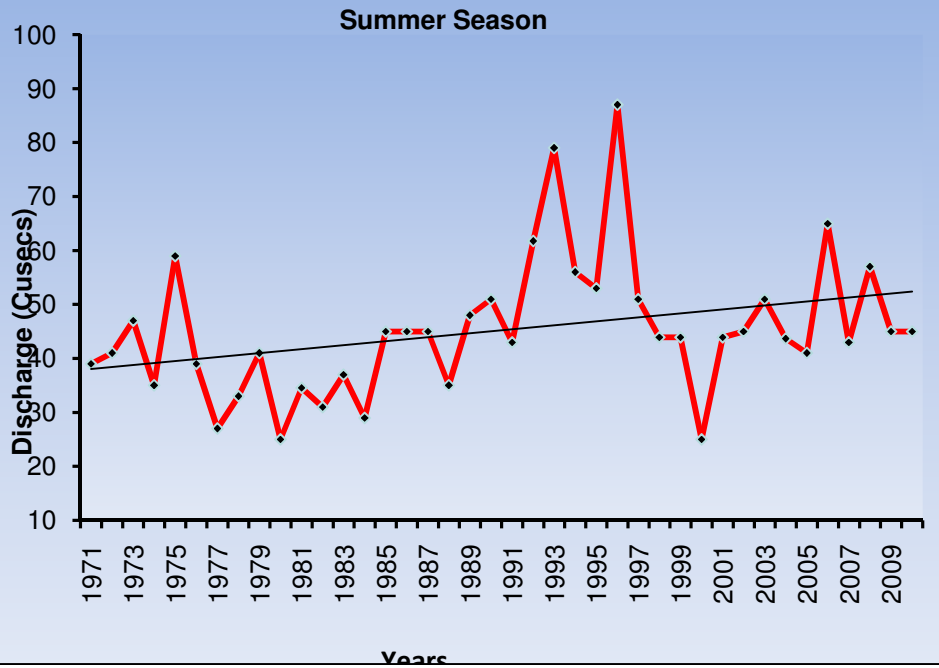
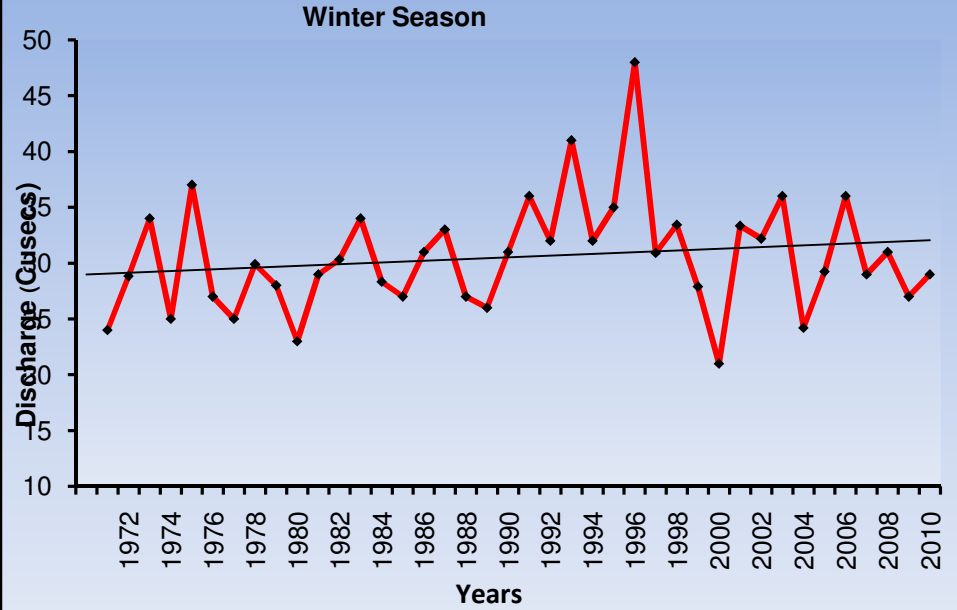
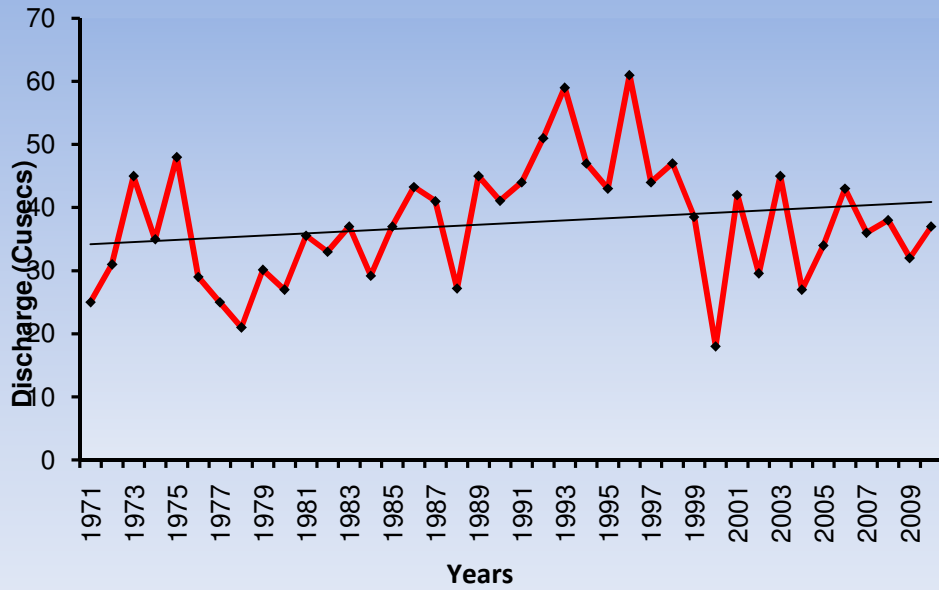


Name of the Test		DACHIGAM (yearly)				
		Test Static	a=0.1	a=0.5	a=0.01	Result
Mankendall		-3.787	1.645	1.96	2.576	S (0.01)
Spearman's Rho		-3.449	1.645	1.96	2.576	S (0.01)
Linear Regression		-4.468	1.687	2.025	2.713	S (0.01)
Test Type	DACHIGAM (Seasonal)					
	Season	Test statistic	a=0.1	a=0.05	a=0.01	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)





# Observed Stream Flow Changes

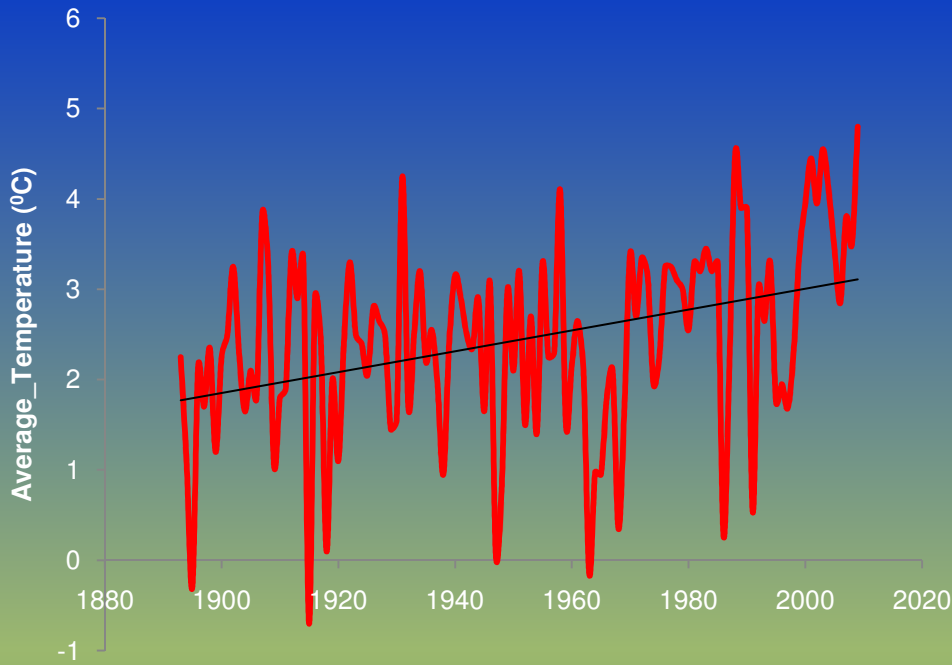


Name of the Test	DAKIL (yearly)				
	Test Static	a=0.1	a=0.5	a=0.1	Result
Mankendall	1.478	1.645	1.96	2.576	NS
Spearman's Rho	1.544	1.645	1.96	2.576	NS
Linear Regression	1.337	1.687	2.025	2.713	NS

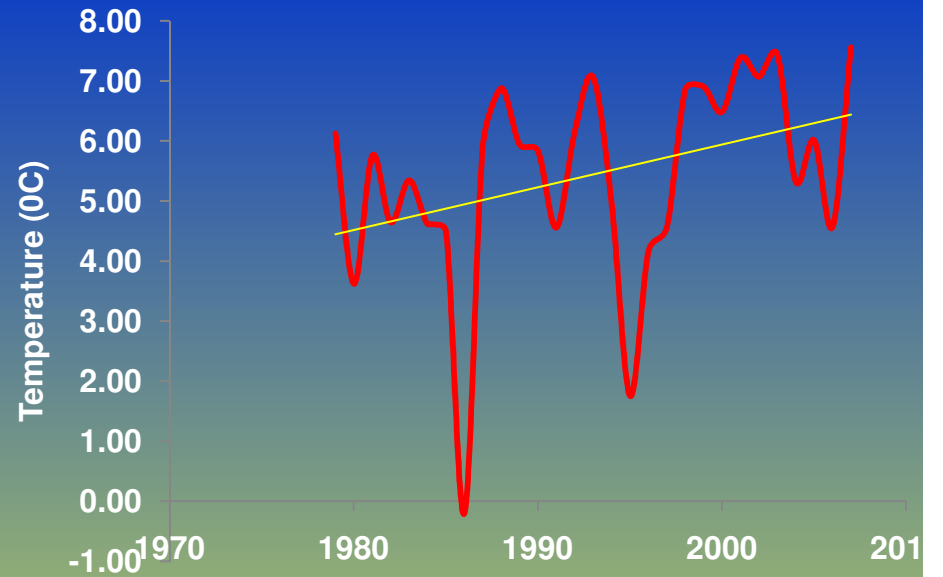
Test Type	DAKIL (seasonal)					
	Season	Test statistic	a=0.1	a=0.05	a=0.01	Result
Mann-Kendall	Winter	1.27	1.645	1.96	2.576	NS
	Spring	1.934	1.645	1.96	2.576	S(0.1)
	Summer	2.4	1.645	1.96	2.576	S(0.05)
Spearman's Rho	Winter	1.497	1.645	1.96	2.576	NS
	Spring	2.185	1.645	1.96	2.576	S(0.05)
	Summer	2.771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



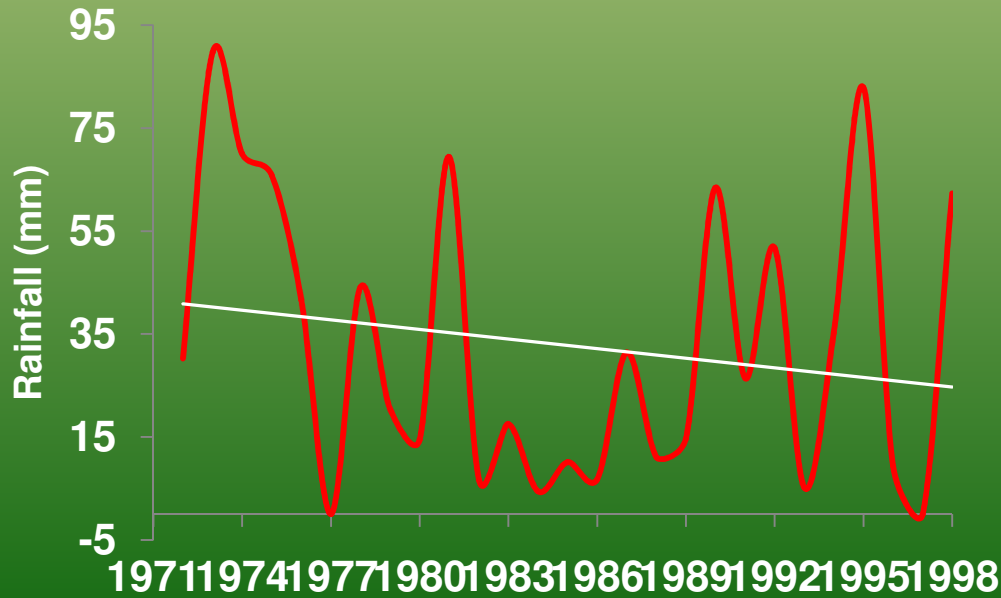
Average Temperature (Dec. & Jan.) (°C)



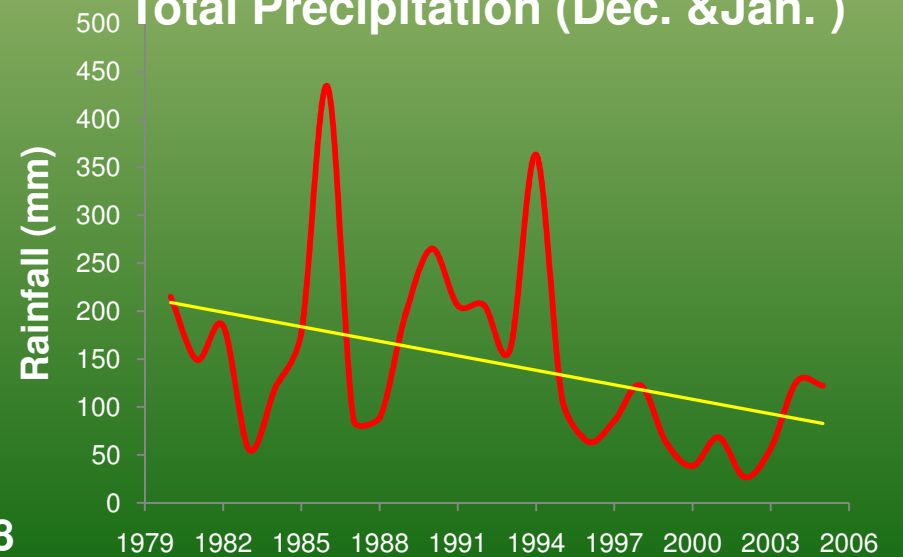
Average Temperature (Dec & Jan)



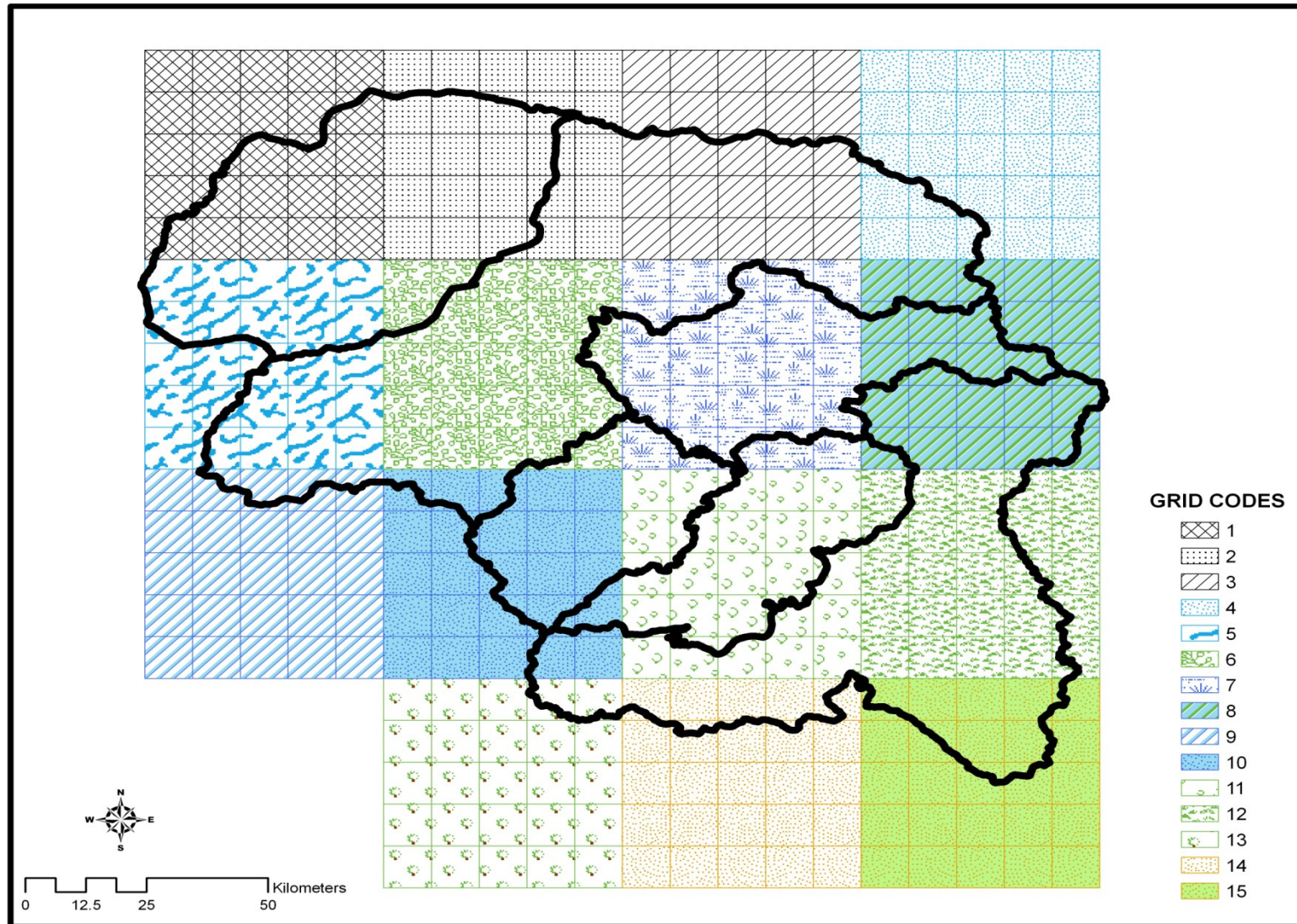
Total Precipitation Dec-Jan



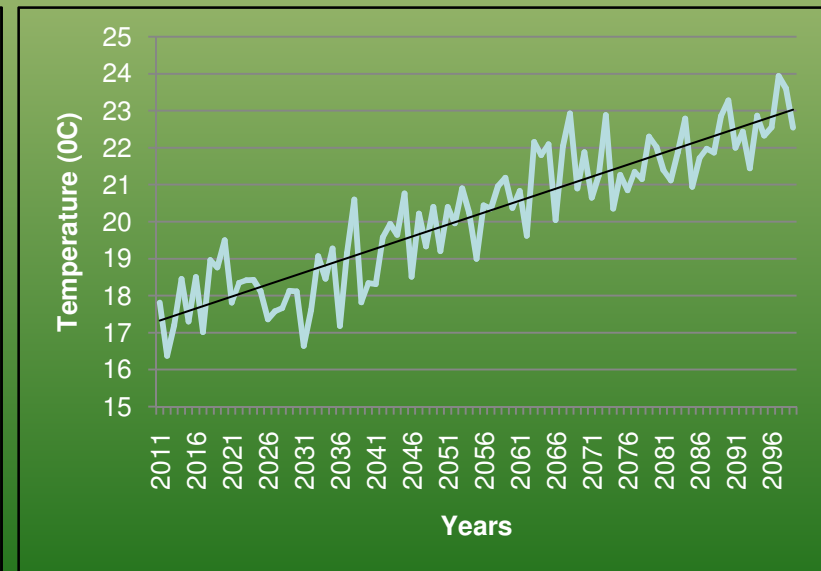
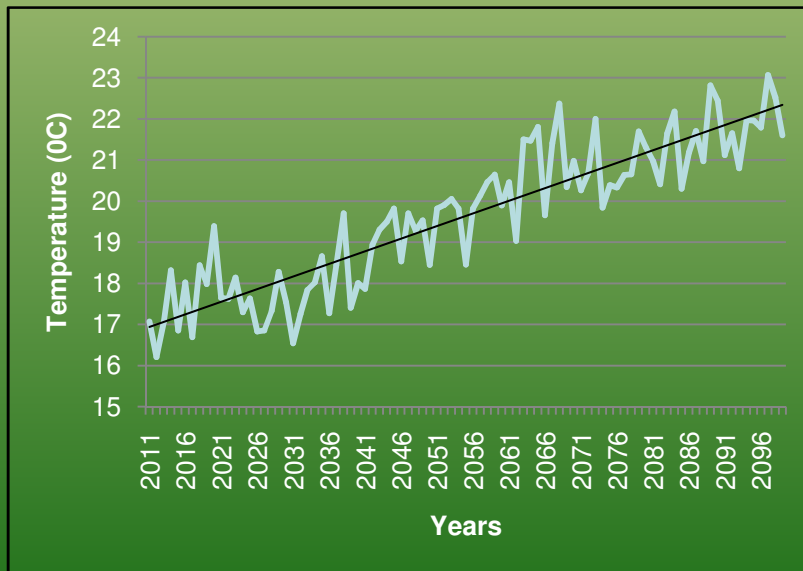
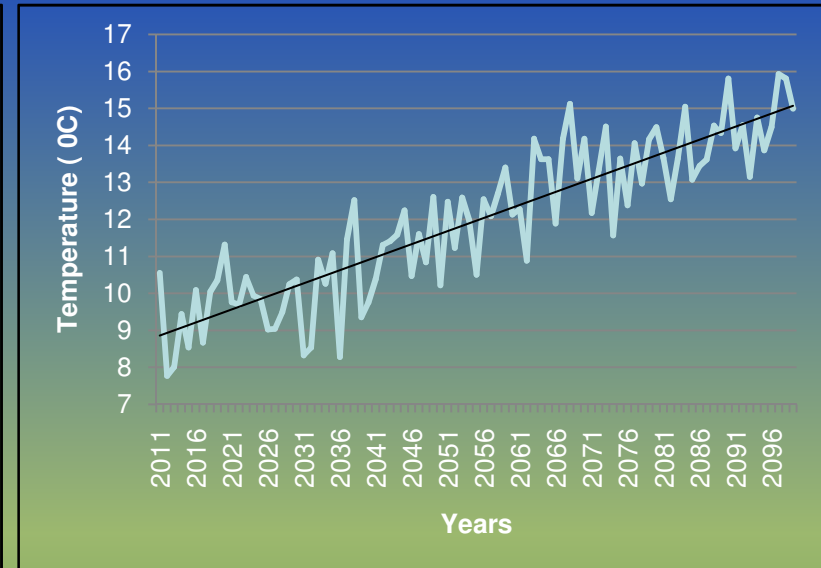
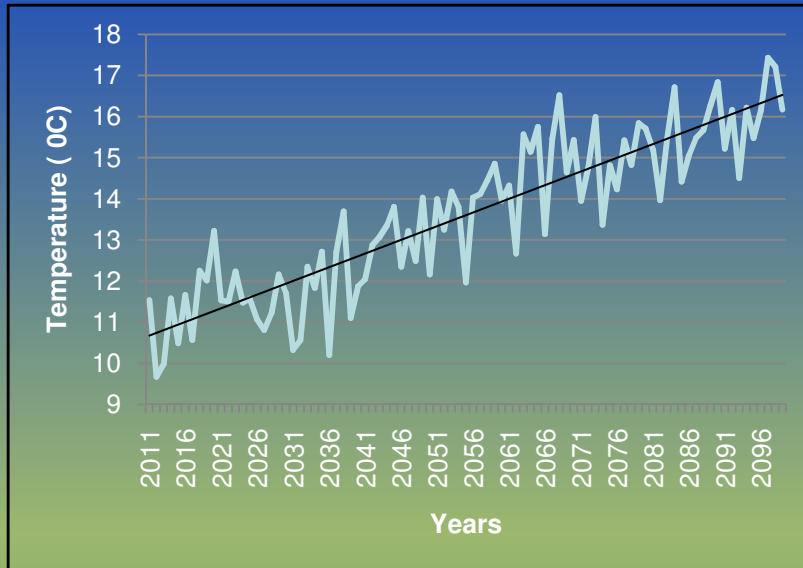
Total Precipitation (Dec. & Jan. )



# 50 km<sup>2</sup> RCM data downscaled to 10 km<sup>2</sup> grids

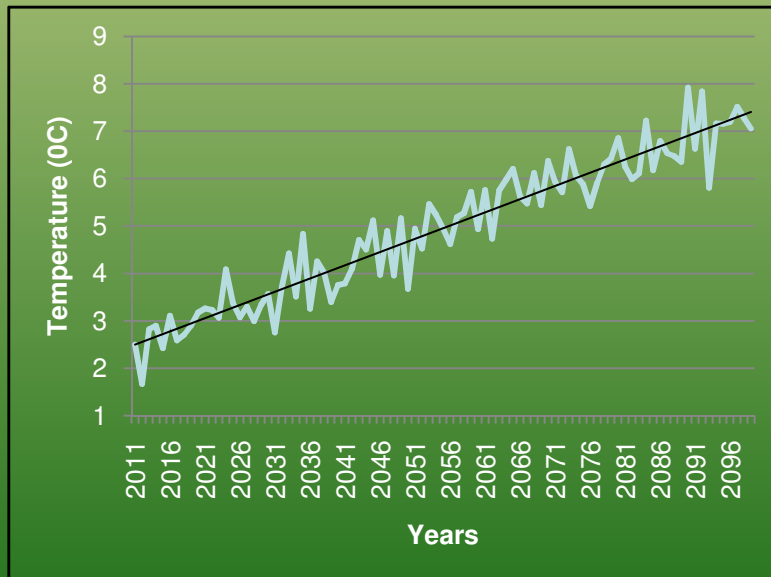
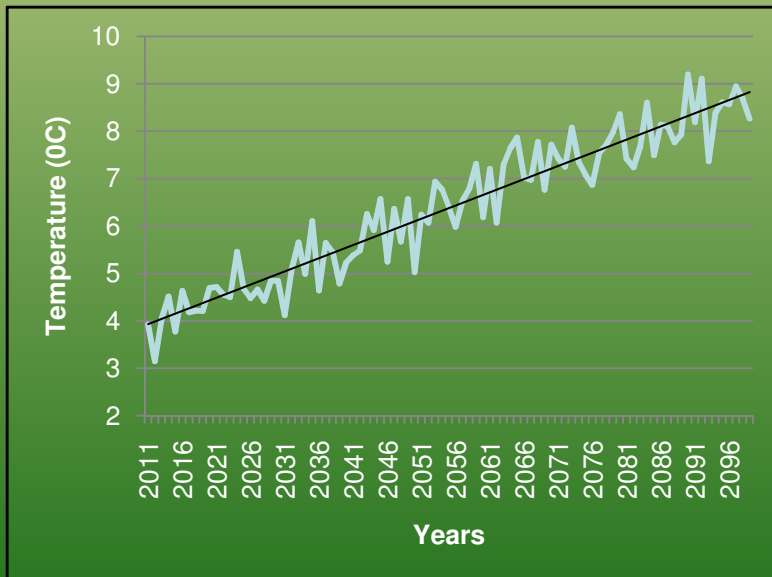
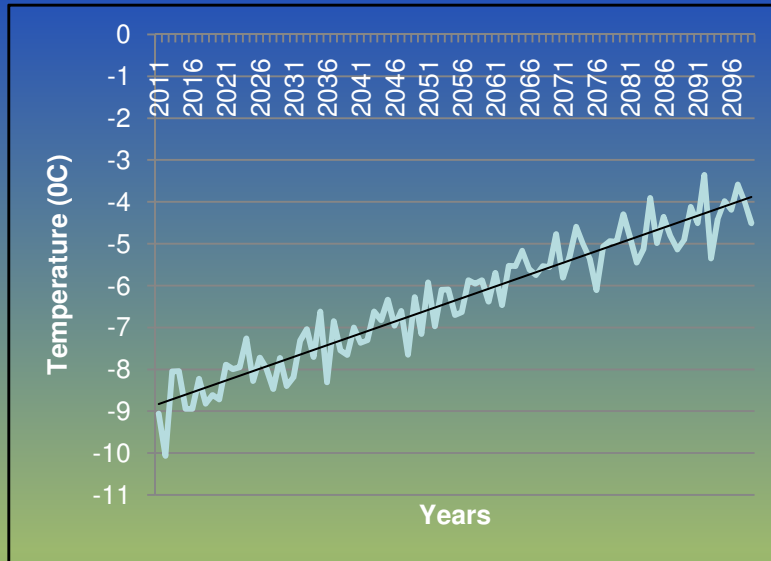
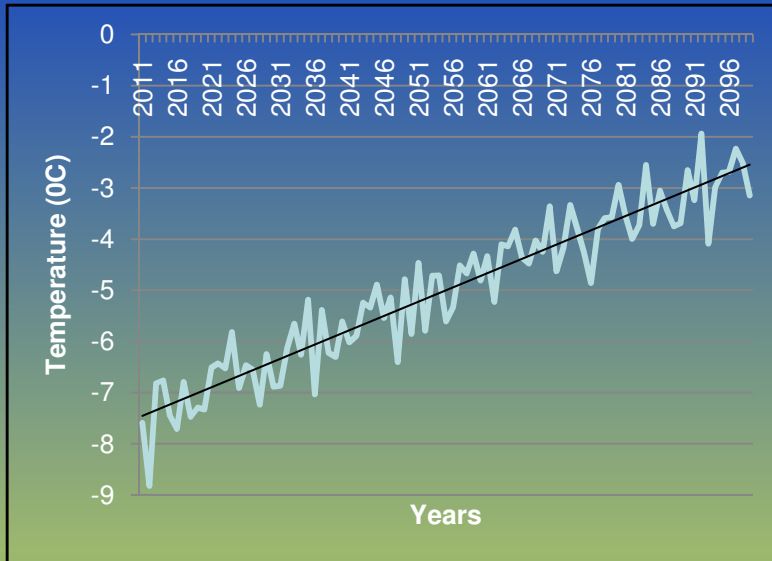


# ANNUAL AVERAGE MAXIMUM TEMPERATURE



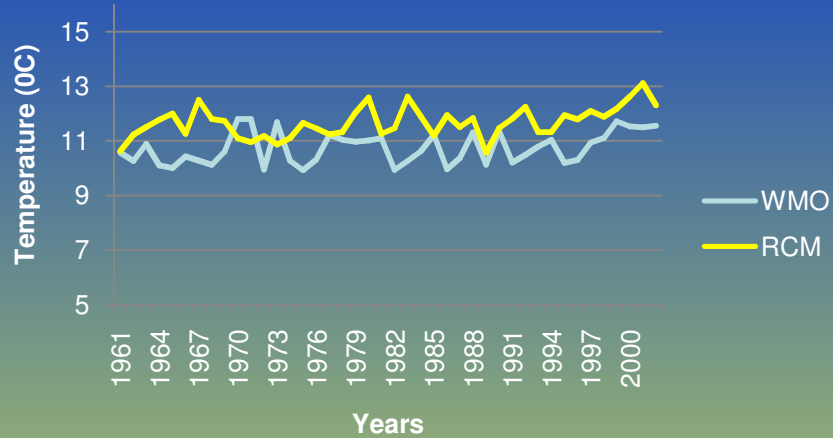


# ANNUAL AVERAGE MINIMUM TEMPERATURE

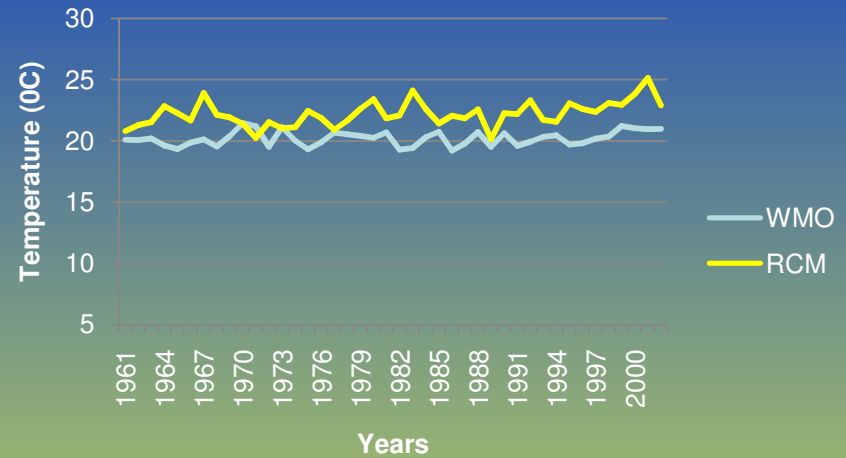


# Validation of mean maximum temp

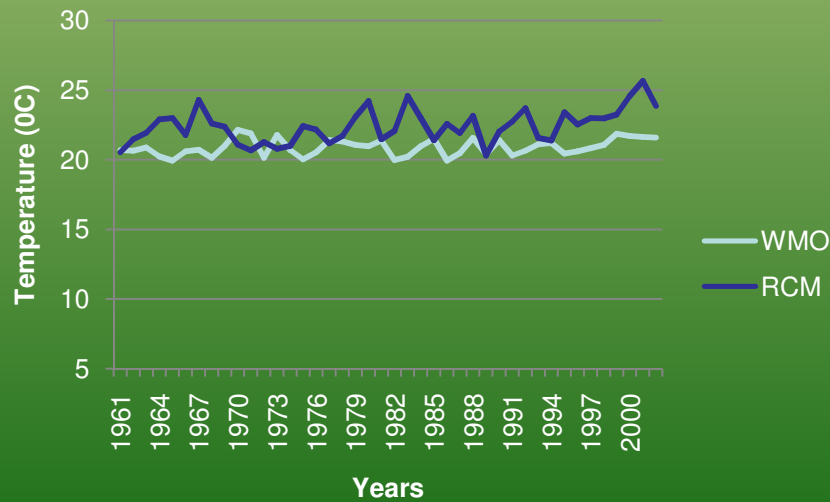
## Kupwara



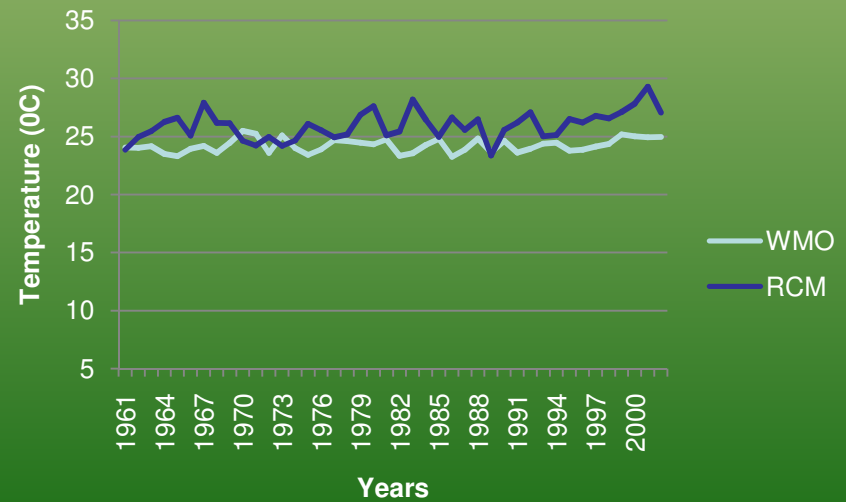
## Anantanag



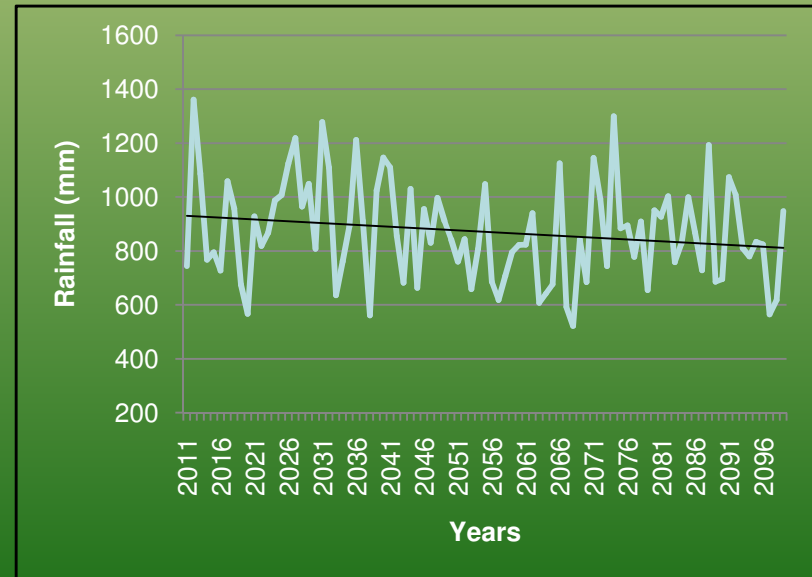
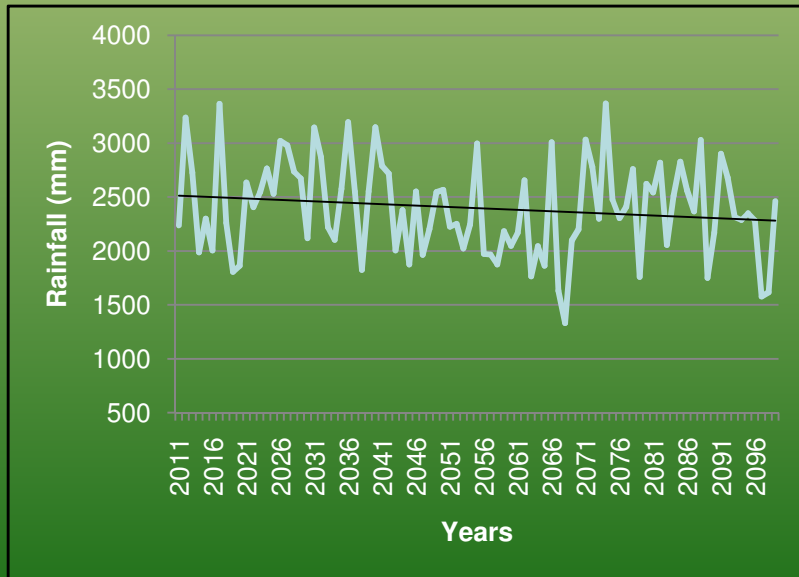
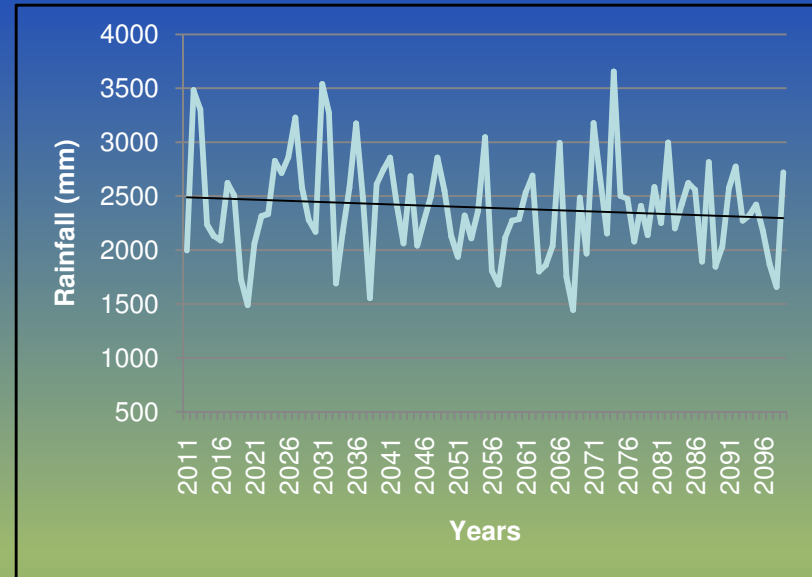
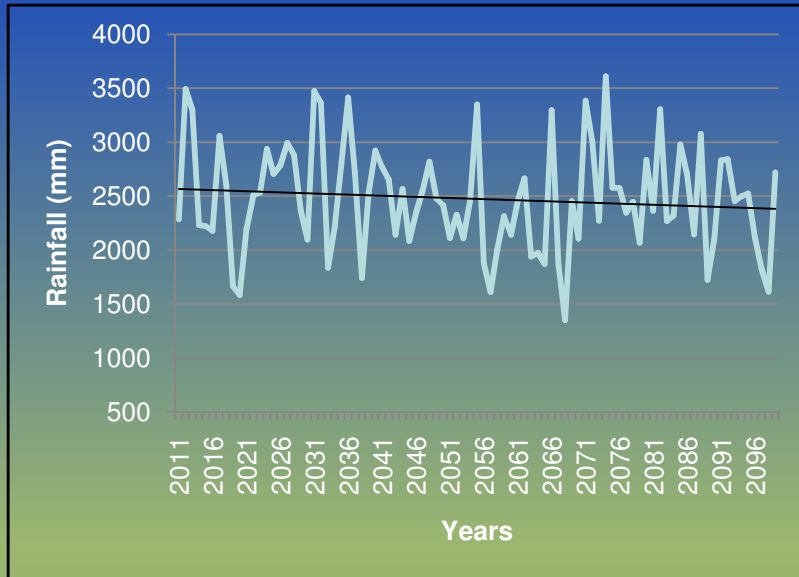
## Baramulla



## Budgam



# ANNUAL AVERAGE PRECIPITATION





The maximum mean annual temperature is projected to increase by  $2^{\circ}\text{C}$  ( $\pm 0.9$ ) from 2011 to 2040 and  $3.38^{\circ}\text{C}$  ( $\pm 1.17$ ) from 2040 to 2099.

The minimum mean annual temperature is projected to increase by  $2.33^{\circ}\text{C}$  ( $\pm 0.61$ ) from 2011 to 2040 and  $2.75^{\circ}\text{C}$  ( $\pm 0.88$ ) 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.

# **IN CONCLUSION .....**

**THE OBSERVED ECOLOGICAL AND SOCIO-ECONOMIC CHANGES AND THE CONSEQUENT CHANGES IN THE HYDROLOGICAL AND ECOLOGICAL PROCESSES IN THE JHELUM BASIN HAVE ADVERSELY AFFECTED ITS FUNCTIONALITY AND ECOSYSTEM SERVICES**

**THERE IS A NEED FOR A ROBUST BASIN SCALE ACTION PLAN BASED ON THE INTEGRATED ANALYSIS OF ALL THE RELEVANT FACTORS AND PROCESSES THAT AFFECT THE RIVER SYSTEM**



**Thank you**