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Modelling the impacts of Climate Change and LULC dynamics on Ecosystem Services : A case study of Pindar Watershed in India Himalaya

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Introduction

- Himalaya considered as water tower of India as the mighty sacred rivers like Ganga and Yamuna originate in Uttarakhand.
- Up to 1.3 billion people receive food, energy, and ecosystem services from water coming from the HKH.
- The Pindar watershed is located in the Trans Himalayan zone where the biophysical system is very fragile due to rough terrain, high elevation and Extreme slope.
- Living in the Himalayas is difficult due to erratic rainfall patterns and steep slopes with interrupted water supply year-round.
- Quantification of Spatiotemporal distribution of water, and valuation of water-related ecosystem services play an important role in the policy planning for the glacial river watersheds.
- This region is facing LULC change along with climate change, the duo can be modeled for the futuristic scenarios for custom-made policy planning for the region.

Objectives

The study carried out with the following objectives for the Modelling impacts of Climate Change and LULC dynamics on Ecosystem Services

To delineate and analyze the Pindar river watershed using space based RS and GIS tools

To study decadal LULC change and predict the future LULC pattern of the watershed using TerrSet LCM tool

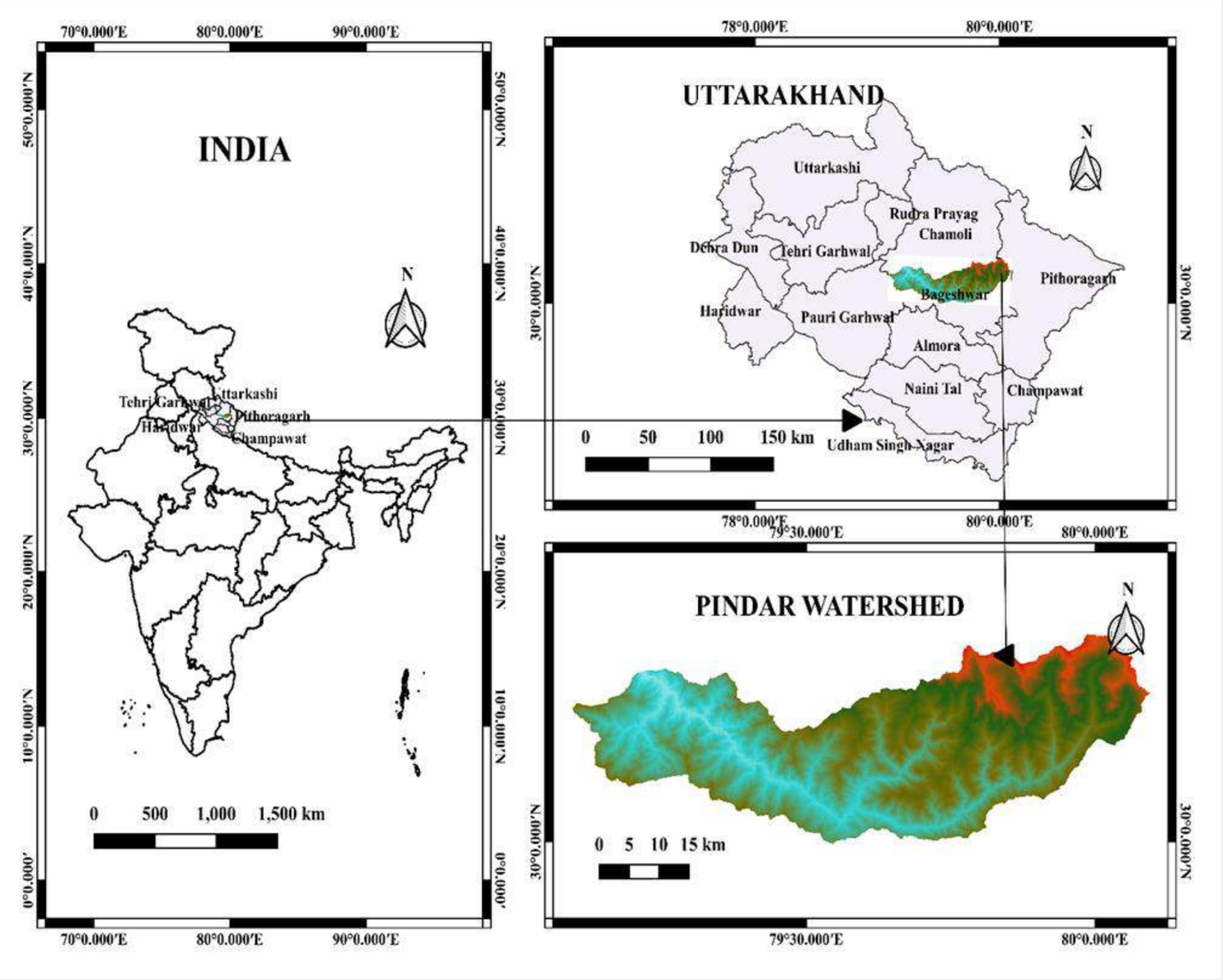
To access water yield of the watershed along with land cover dynamics for the watershed

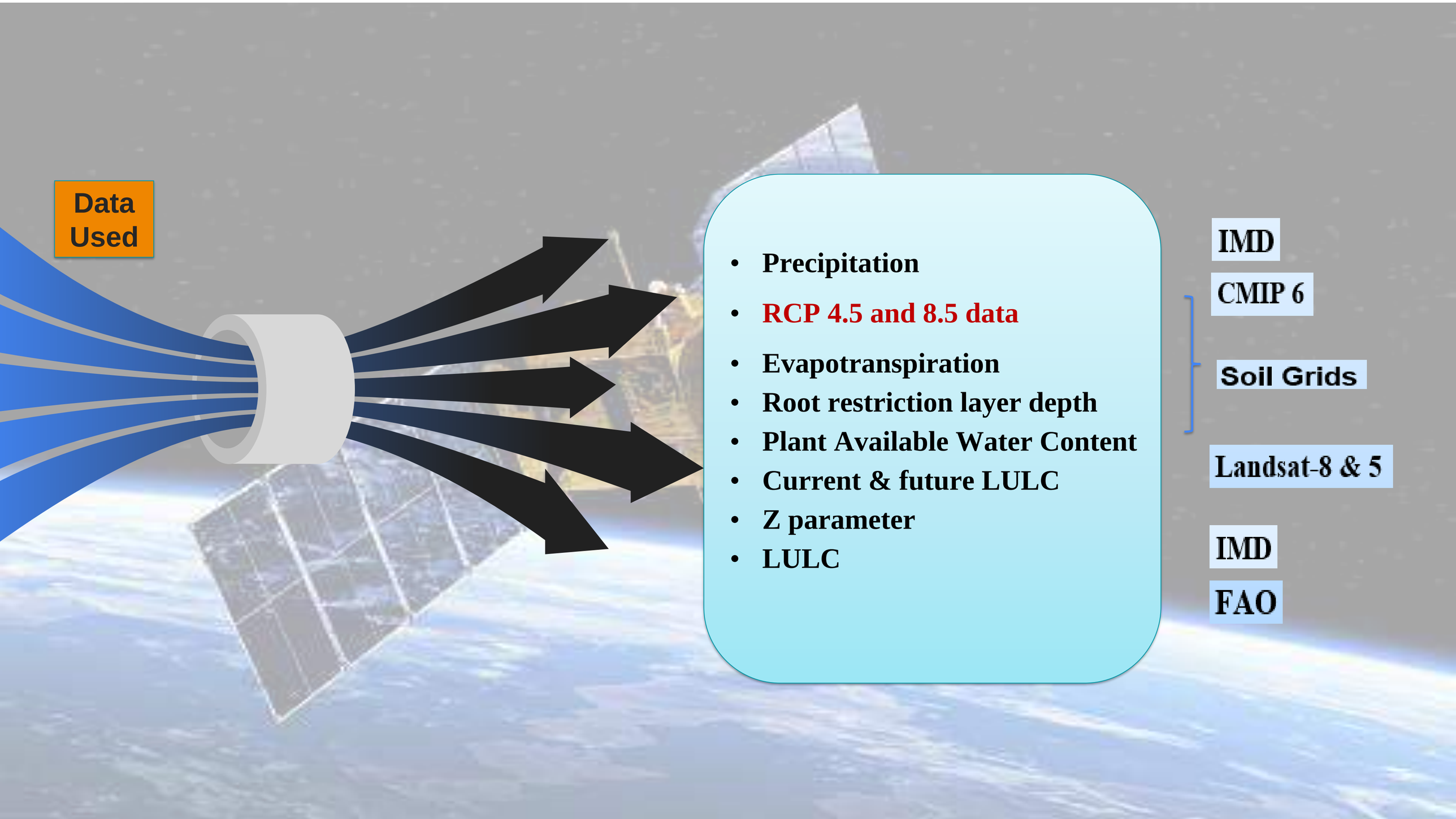
Valuation of the water-ecosystem services of the watershed

Study Region

Pindar Watershed

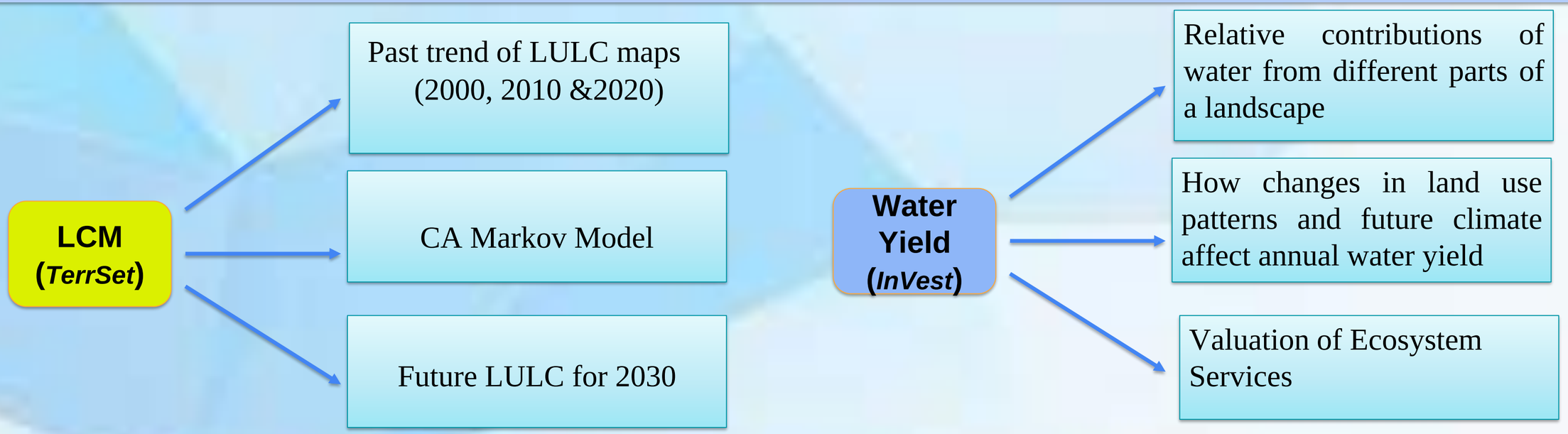
- Country: India
- State: Uttarakhand
- District: Bageshwar & Chamoli
- Area: 1903.78 km^2
- Latitude & Longitude: 30°18′N to 29°54′N
  80°3′E to 79°8′E.
- Elevation: 763 m to 6851 m.




Data Used
Precipitation
RCP 4.5 and 8.5 data
Evapotranspiration
Root restriction layer depth
Plant Available Water Content
Current & future LULC
Z parameter
LULC
IMD
CMIP 6
Soil Grids
Landsat-8 & 5
IMD
FAO

Methodology

- LULC prediction done by CA Markov Model in TerrSet Tool using past LULC maps
- Water Yield estimated by InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) Tool
- To estimate future Water Yield for 2030, RCP (Representative Concentration Pathway) 4.5 and RCP 8.5 data under CMIP-6 Model EC-Earth 3 has been used.



RESULTS AND DISCUSSION

- The Pindar River watershed was found to be fifth order watershed
- The watershed has 33 sub watersheds

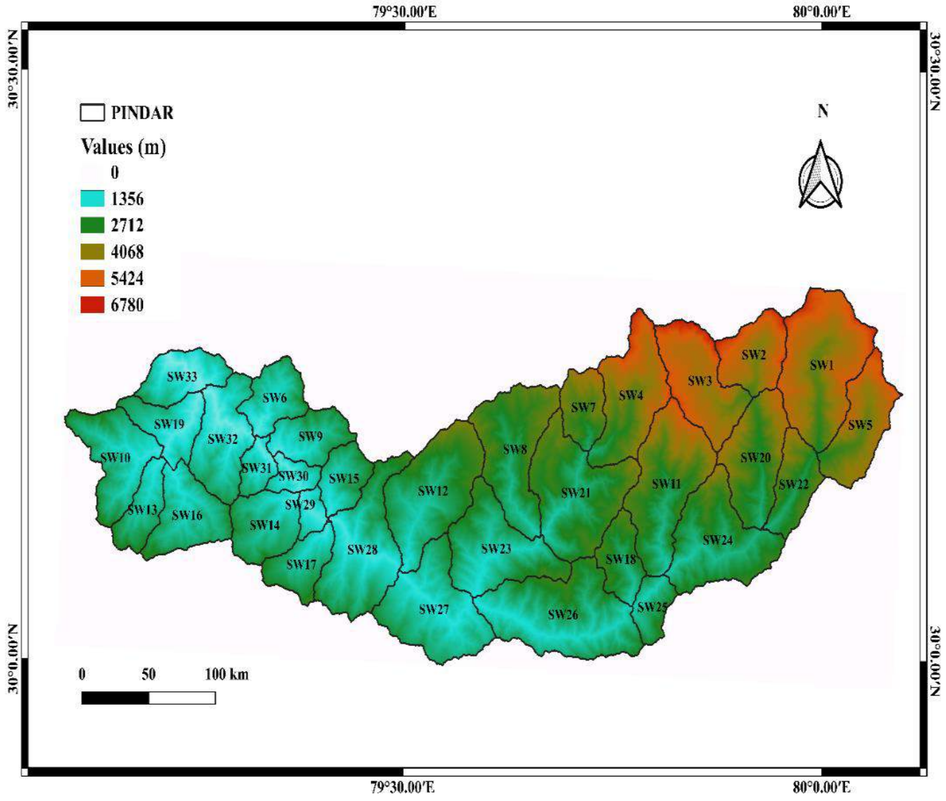


Fig.: Digital Elevation Model map of study area

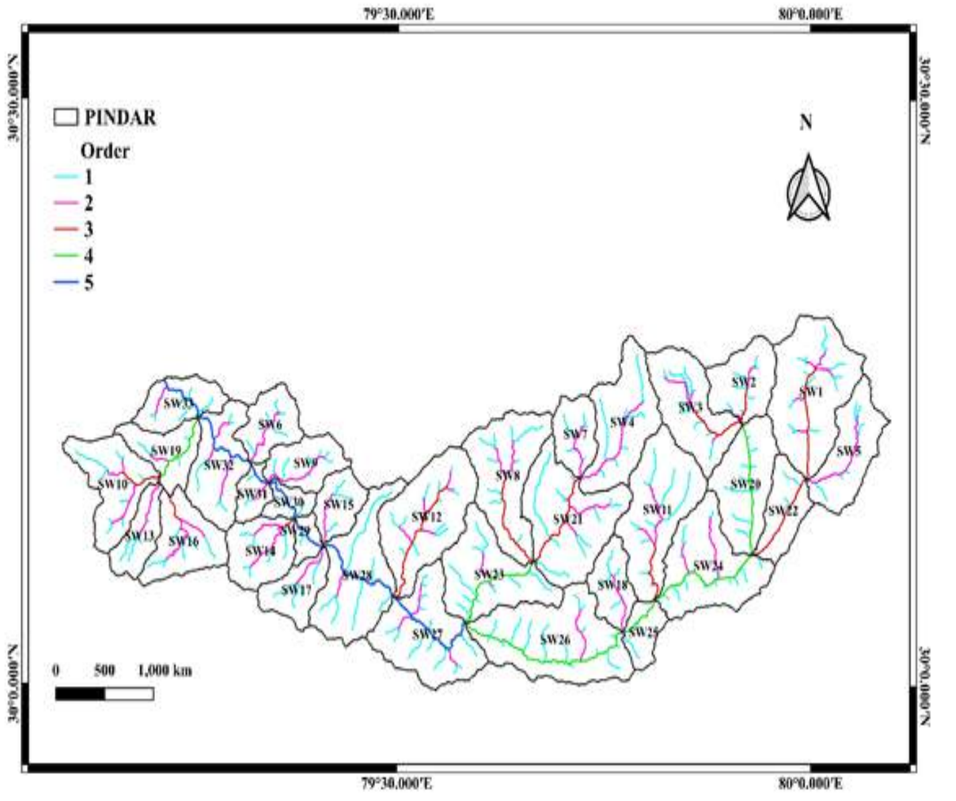


Fig.: Drainage network map of Pindar watershed

Morphometric Analysis of Pindar Watershed

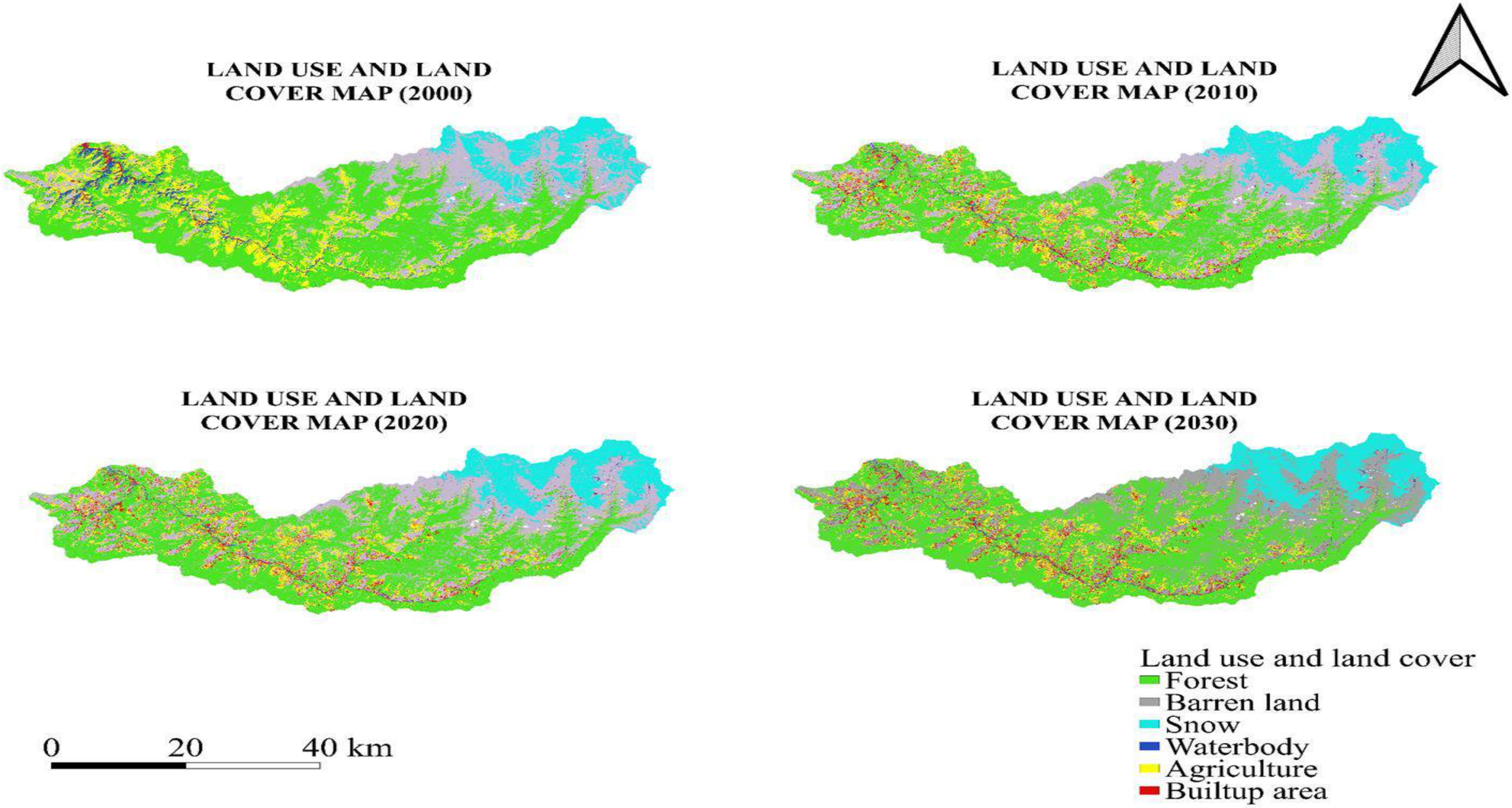
Table: Sub-watershed wise basic morphometric parameters of Pindar watershed

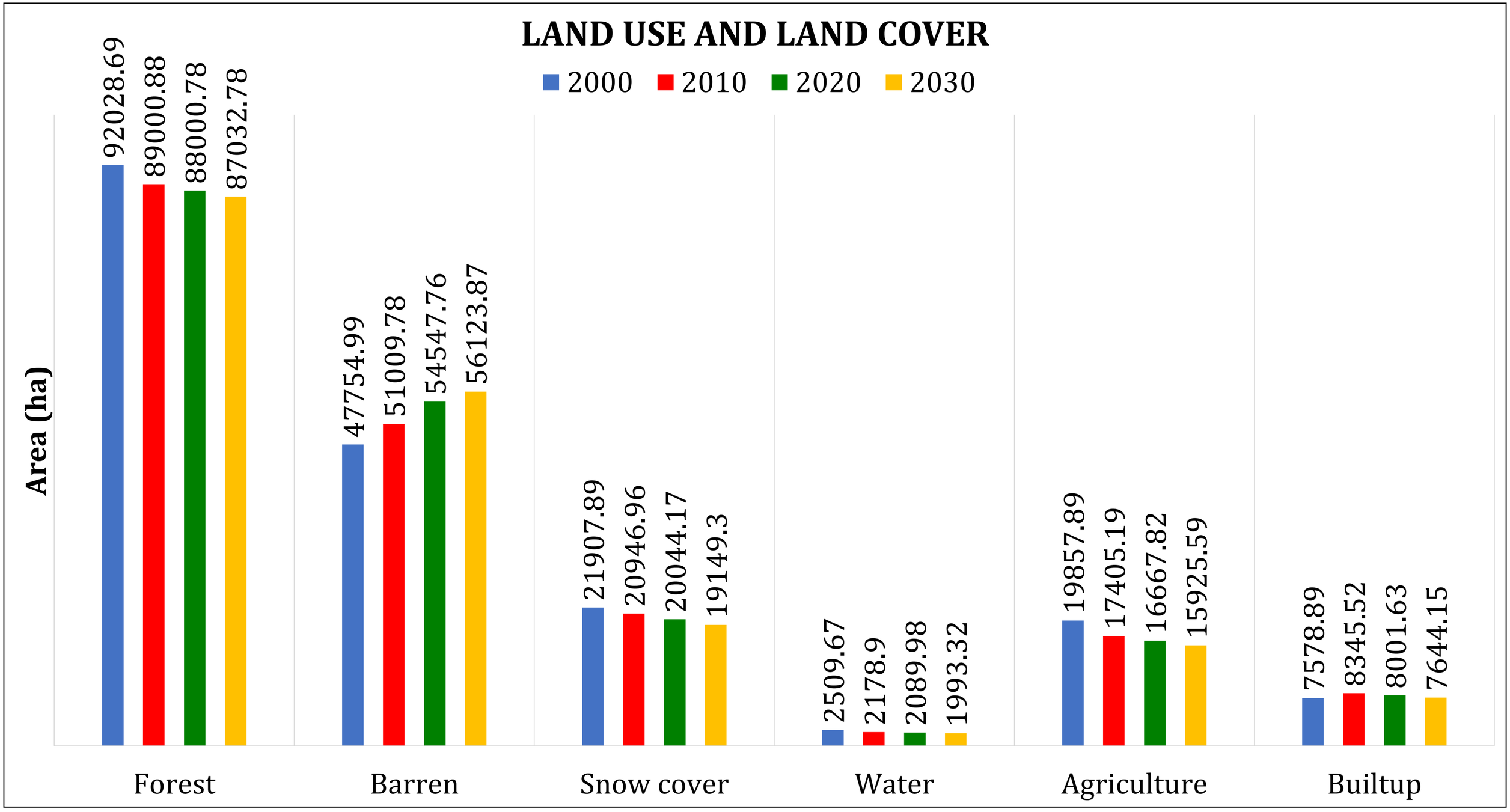
Sub-watersheds	Area (km^2)	Perimeter (km)	Stream number of different orders						Order wise total stream length (km)					
			I	II	III	IV	V	Total	I	II	III	IV	V	Total
SW1	110.81	60.96	16	5	1	-	-	22	20.08	8.54	12.86	-	-	41.49
SW2	46.53	38.15	8	3	1	-	-	12	9.97	4.76	4.22	-	-	18.97
SW3	70.46	52.91	11	3	1	-	-	15	18.43	7.74	9.48	-	-	35.67
SW4	77.32	58.60	8	1	-	-	-	9	20.68	12.79	-	-	-	33.45
SW5	58.26	50.93	8	1	-	-	-	9	9.96	12.46	-	-	-	22.43
SW6	35.95	36.17	7	1	-	-	-	8	9.63	7.91	-	-	-	17.55
SW7	32.10	30.96	6	1	-	-	-	7	6.53	7.31	-	-	-	13.84
SW8	84.28	61.66	9	2	1	-	-	12	17.55	7.75	11.63	-	-	36.94
SW9	36.90	36.28	7	1	-	-	-	8	8.96	9.36	-	-	-	18.33
SW10	61.97	52.43	11	3	1	-	-	15	13.2	9.25	5.65	-	-	28.10
SW11	95.51	61.88	10	2	1	-	-	13	23.37	9.96	7.13	-	-	40.47
SW12	94.24	57.74	14	5	1	-	-	20	15.45	8.16	15.57	-	-	39.18
SW13	29.86	35.04	4	1	-	-	-	5	7.62	7.11	-	-	-	14.73
SW14	46.38	35.42	6	2	1	-	-	9	10.57	10.93	2.20	-	-	23.70
SW15	29.50	30.53	3	1	-	-	-	4	6.92	5.92	-	-	-	12.84
SW16	53.71	48.78	7	2	1	-	-	10	12.01	10.16	4.89	-	-	27.07
SW17	33.38	35.90	4	1	-	-	-	5	10.34	5.75	-	-	-	16.10

...continued

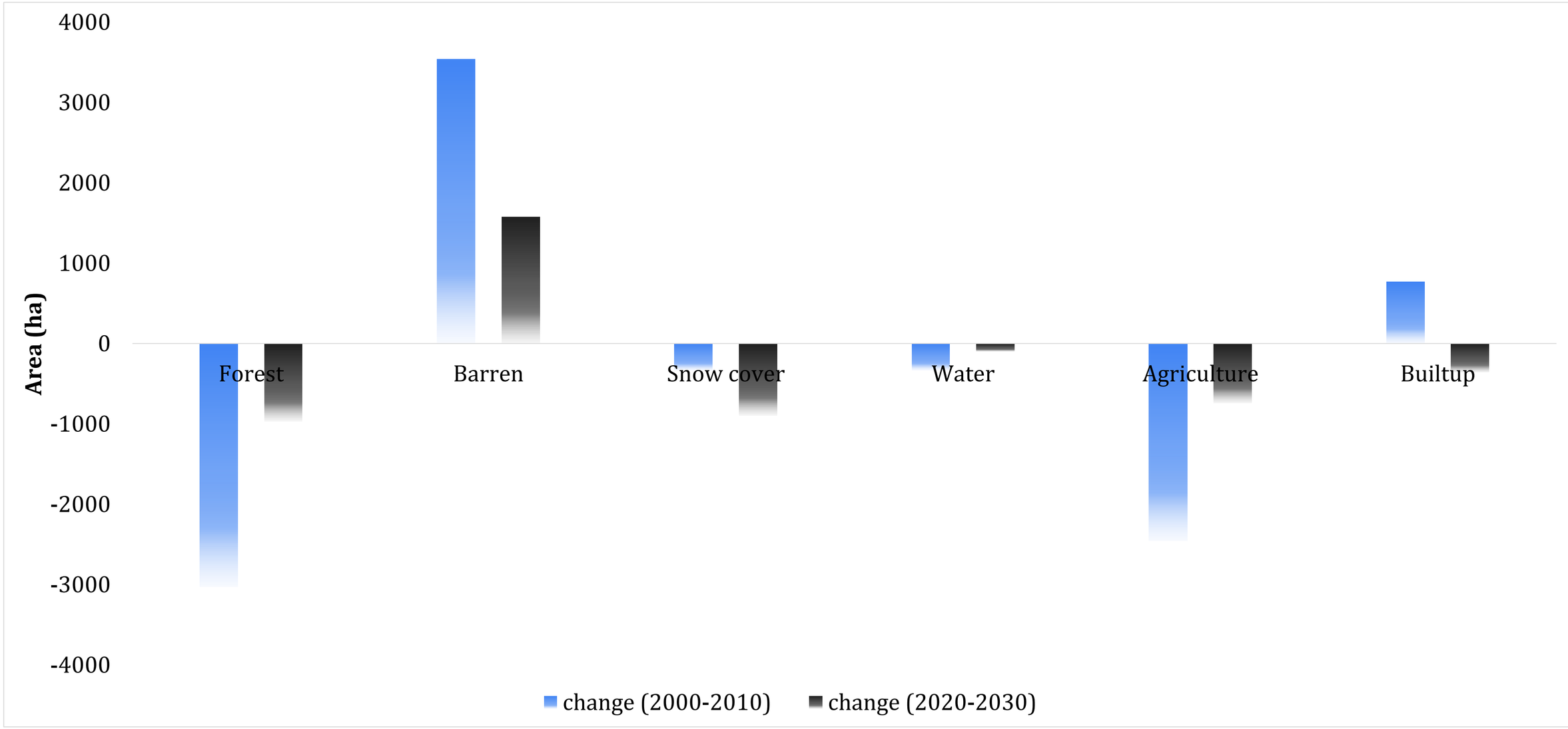
Sub-watersheds	Area (km^2)	Perimeter (km)	Stream number of different orders						Order wise total stream length (km)					
			I	II	III	IV	V	Total	I	II	III	IV	V	Total
SW18	32.36	34.18	5	1	-	-	-	6	8.82	6.79	-	-	-	15.61
SW19	37.44	42.29	5	1	1	1	-	8	4.67	2.48	0.77	8.73	-	16.66
SW20	68.37	49.05	9	-	-	1	-	10	15.10	-	-	14.19	-	29.3
SW21	100.72	65.20	11	3	1	-	-	15	29.51	13.02	11.94	-	-	54.48
SW22	38.41	39.60	3	-	1	-	-	4	4.51	-	11.13	-	-	15.65
SW23	80.65	60.00	10	2	-	1	-	13	22.93	4.22	-	12.79	-	39.95
SW24	88.69	62.52	14	2	-	1	-	17	16.14	10.34	-	16.81	-	43.30
SW25	22.33	26.40	2	-	-	1	-	3	4.2	-	-	6.905	-	11.10
SW26	116.4	70.52	16	1	-	1	-	18	25.29	9.99	-	24.05	-	59.34
SW27	89.24	58.50	14	3	-	-	1	18	23.45	8.34	-	-	13.33	45.13
SW28	88.39	67.94	6	1	-	-	1	8	28.66	2.94	-	-	14.95	46.55
SW29	12.10	21.25	1	-	-	-	1	2	1.37	-	-	-	9.42	10.79
SW30	15.53	24.84	2	-	-	-	1	3	3.18	-	-	-	8.84	12.03
SW31	16.87	26.03	3	1	-	-	1	5	3.11	3.95	-	-	3.47	10.53
SW32	60.32	50.61	8	3	-	-	1	12	9.33	11.02	-	-	9.71	30.07
SW33	38.62	37.19	6	1	-	-	1	8	9.03	3.46	-	-	10.09	22.6
Total	**1903.78**	**1520.65**	**254**	**54**	**12**	**6**	**7**	**333**	**430.73**	**222.49**	**97.52**	**83.51**	**69.85**	**904.10**

LULC (2000, 2010 & 2020) and FUTURE LULC FOR THE YEAR 2030 for Pindar Watershed

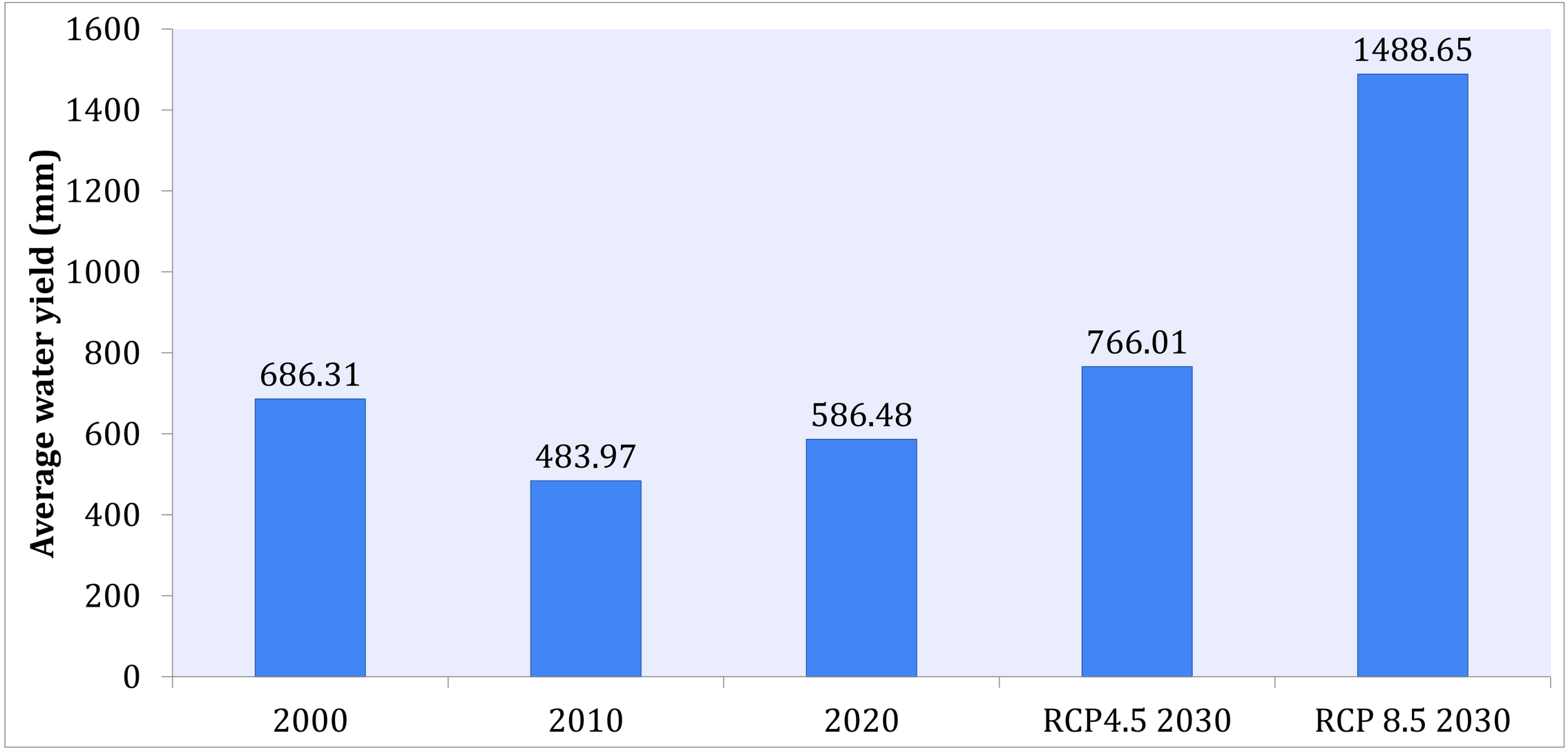



LAND USE AND LAND COVER
2000
2010
2020
2030
Area (ha)
92028.69
89000.88
88000.78
87032.78
47754.99
51009.78
54547.76
56123.87
21907.89
20946.96
20044.17
19149.3
2509.67
2178.9
2089.98
1993.32
19857.89
17405.19
16667.82
15925.59
7578.89
8345.52
8001.63
7644.15
Forest
Barren
Snow cover
Water
Agriculture
Builtup

Statistics of land use and land cover change

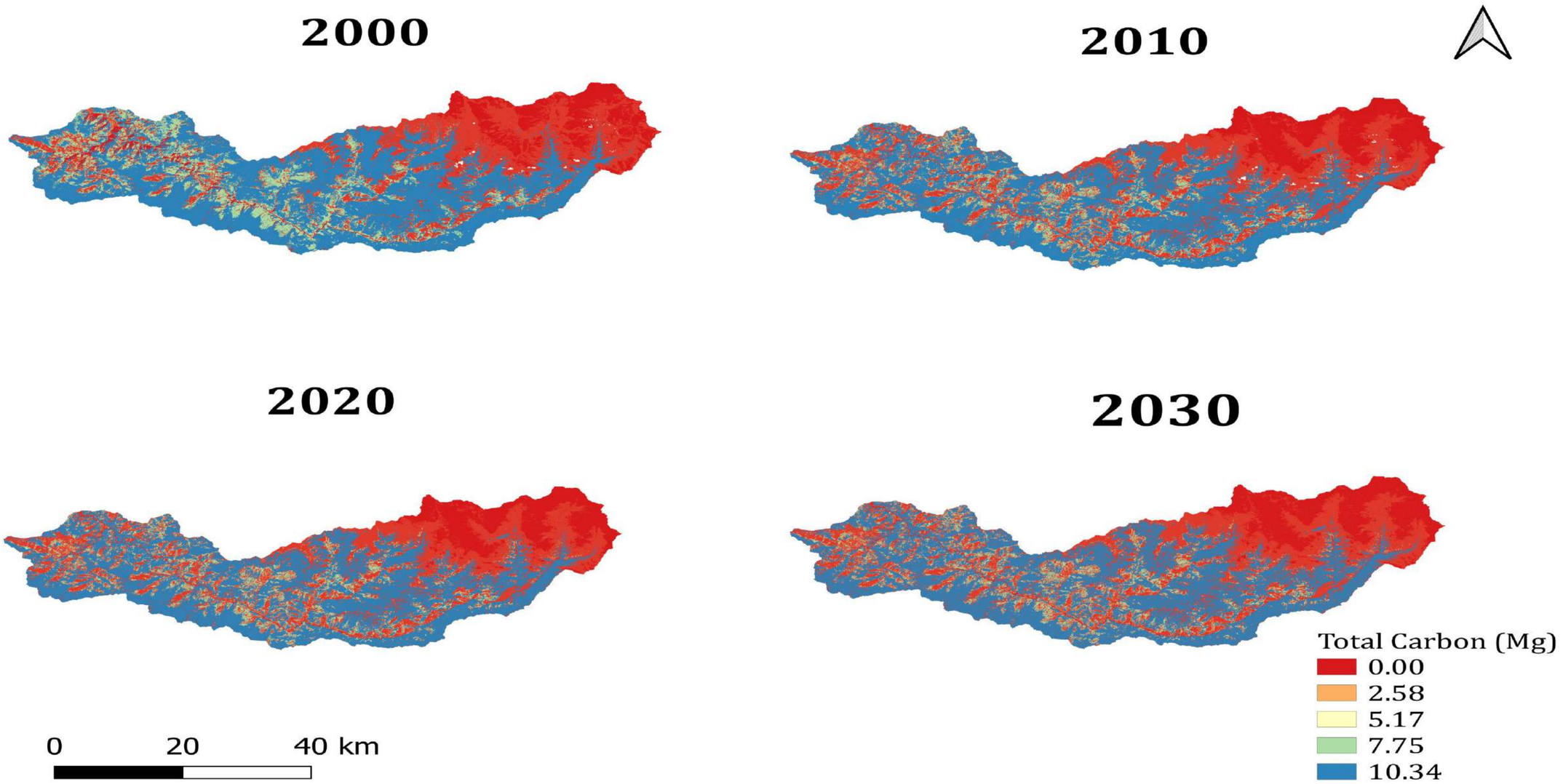


Statistical Representation of Water Yield (2000-2030)



Carbon Sequestration by Invest

Total Carbon



Water Economic Valuation

Service	Reference	Methodology	Price (Rs/Household)			Ecosystem Benefit Outcomes
Water Regulation Seri vice/Baseline Flow Maintenance	Sinha and Mishra 2015	Stated preference; Choice experiment	**5**	**47**	**89**	Benefits to nearby villages
Water Regulation Serivice/Baseline Flow Maintainance	Sinha and Mishra 2015	Stated preference; Choice experiment	–	**949**	**2411**	Benefits to Outsiders
Water Regulation Service/Baseline Flow Maintenance	Sinha and Mishra 2015	Stated preference; Choice experiment	**8**	**1186**	**2364**	Benefits to Core Villagers
Water Regulation Service/Peak Flow Mitigation	Sinha and Mishra 2015	Stated preference; Choice experiment	**5**	**47**	**89**	Indirect Services

Result and Discussion

- The Pindar watershed is located in the Trans Himalayan zone where the biophysical system is very fragile due to rough terrain, high elevation and Extreme slope.
- The watershed has sub-tropical dense forest of around 60% but over the period due to urban sprawl the forest area is decreased by 20% from the year 2000-2030.
- An abrupt decreased of agriculture area is shown from the year 2000-2010 due to the expansion of the built-up area.
- There is a need to focus on barren land because from the year 2000-2020 it is increased continuously and based on that it will increased also in the year 2030 as per prediction.
- In the future climatic scenario RCP 4.5 and RCP 8.5 the water yield is increasing for the year 2030.
- Increase in barren land, built-up area and snow melting, the runoff will be increased in the year 2030 which may causes flashflood and avalanches in future.


THANK YOU