Climate & Climate Change in Indus Basin

How Can Research Help ?

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Sequence of Presentation

- Brief Description of Indus Basin
- Climate of Indus Basin
- Climate of Upper Indus Basin
- Climate Trends
- Climate Projections
- How research can help ?

Introduction to Indus Basin

Indus River basin, with 833,788 km2 of drainage area, is one of the major river basins of the world. The Indus is a noteworthy river for various reasons.

It is a transboundary river. Its drainage basin is distributed in China (8%), India (22%), Pakistan (61%), and Afghanistan (9%).

It is one of the mightiest rivers in Asia in terms of its volumetric flow and sediment load on an annual basis.

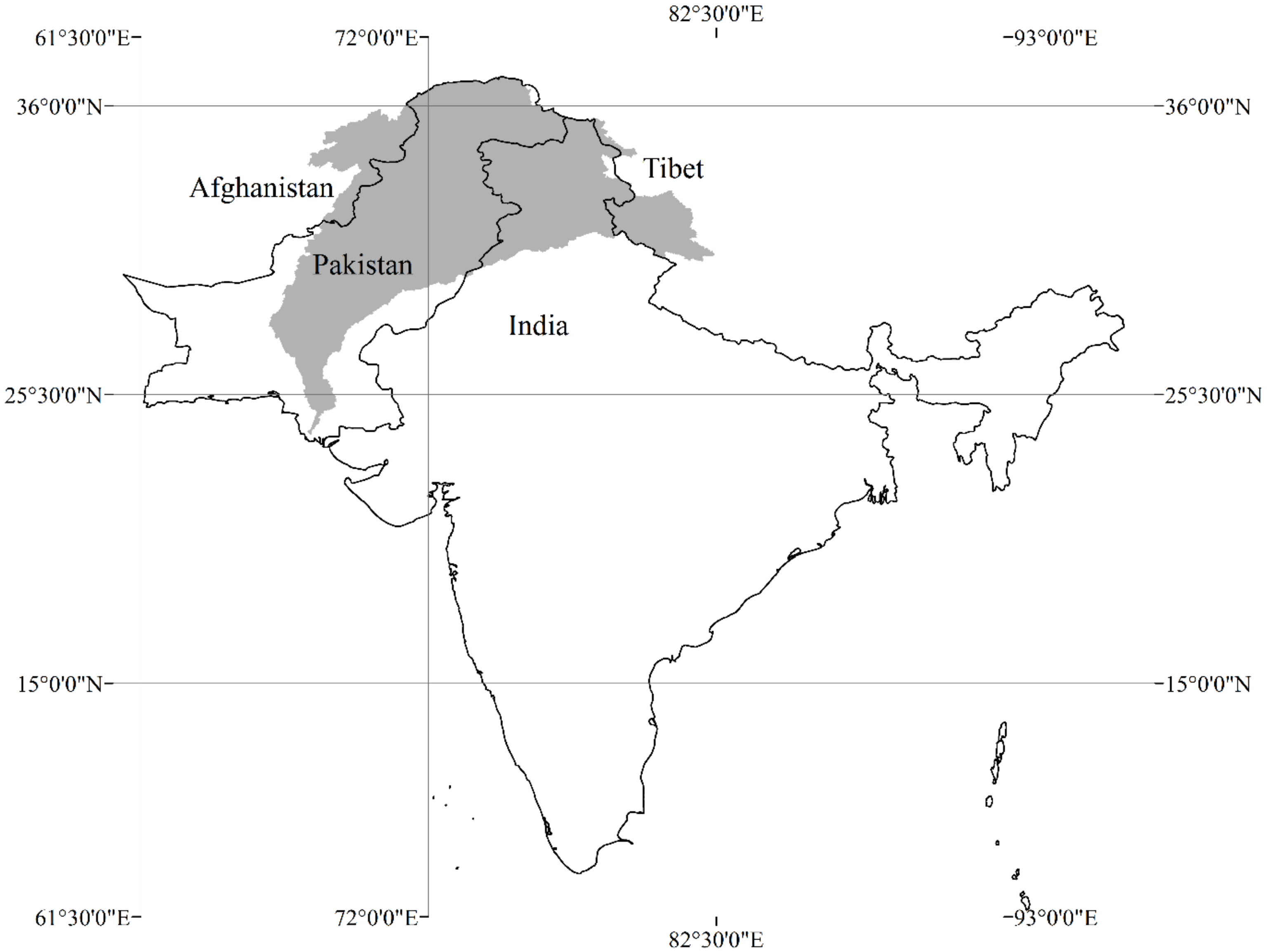
It originates from Mount Kailas ,Tibetan Plateau, and passes through a high altitude terrain spanning the Greater Himalayas and the Karakoram mountain ranges where the glaciers and snow packs, that are the main sources of river flows, are vulnerable to climate change.

Numerous tributaries, some of which by themselves are major rivers of the basin, join the Indus throughout its course.

The river network of this basin has been extensively engineered to create extremely important irrigation systems for vital agriculture and hydroelectricity in both India and Pakistan. With these, it carries significant hydro-politics as well.

An estimated 237 million people, projected to increase to 319 million in 2025 inhabit this river basin.

Indus Basin



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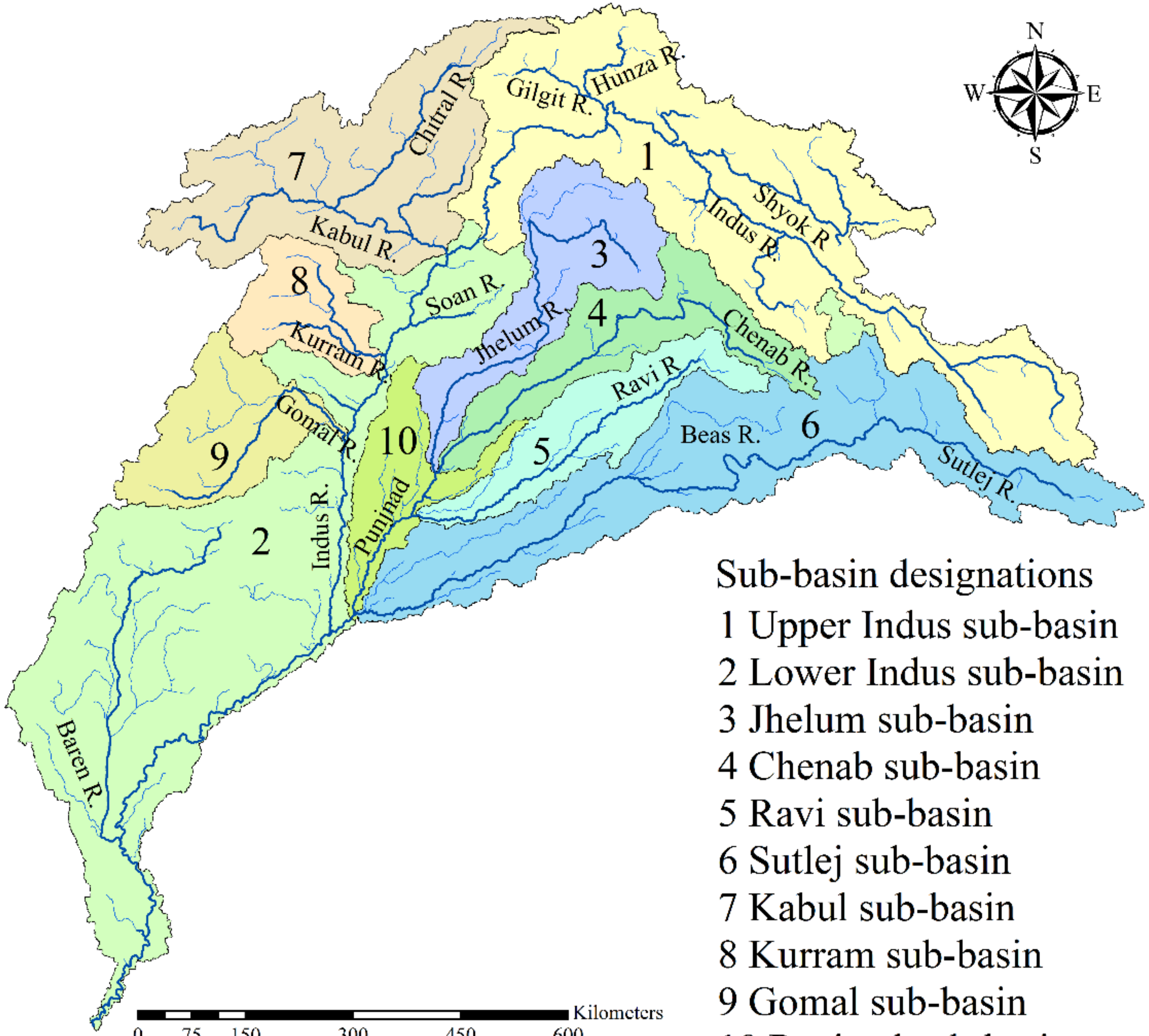
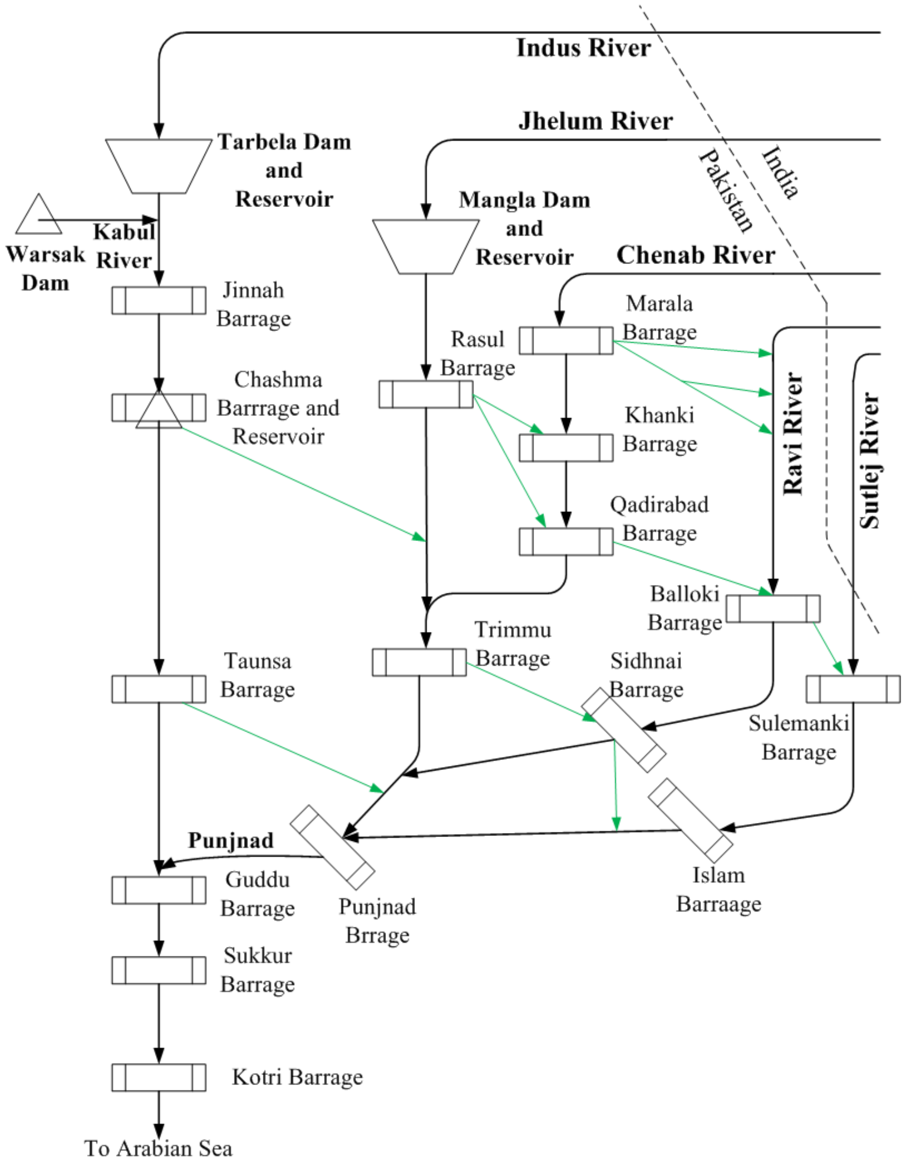
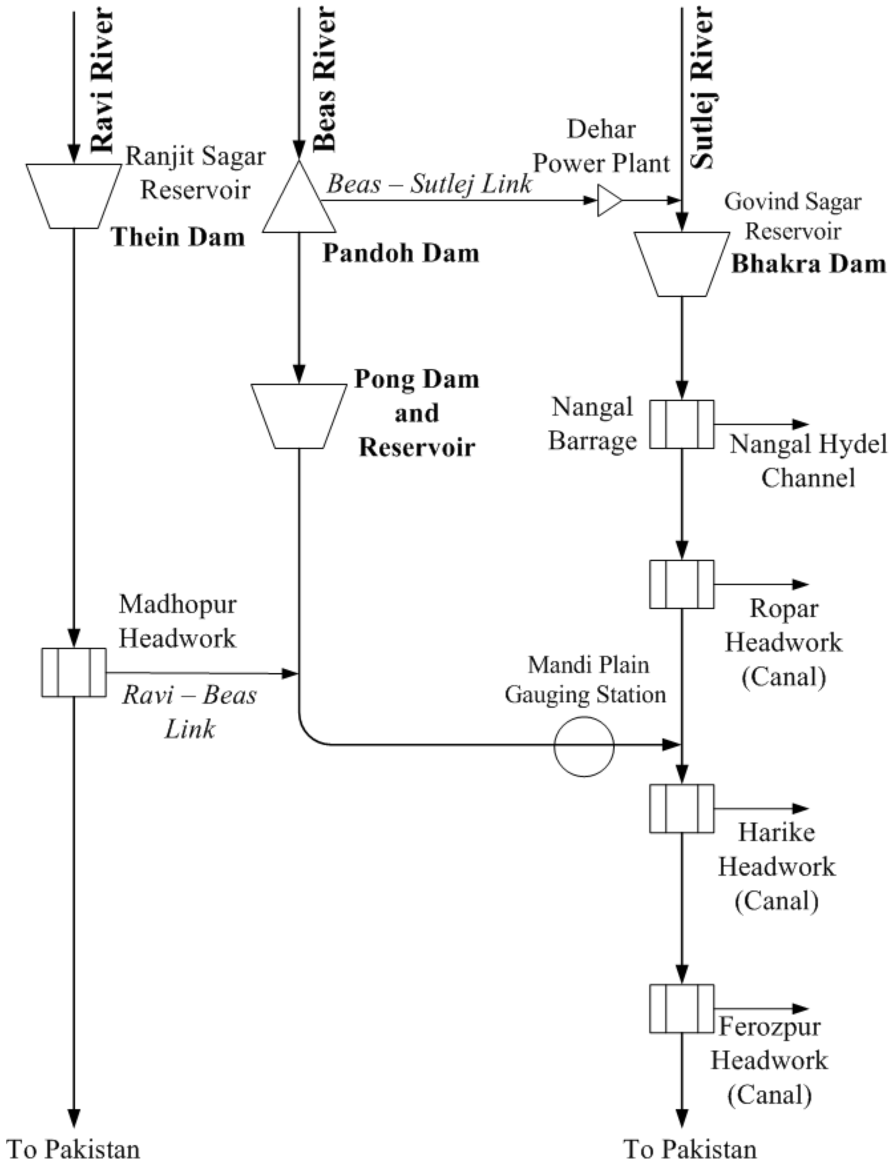
Indus Basin



Sub-basin designations
1 Upper Indus sub-basin
2 Lower Indus sub-basin
3 Jhelum sub-basin
4 Chenab sub-basin
5 Ravi sub-basin
6 Sutlej sub-basin
7 Kabul sub-basin
8 Kurram sub-basin
9 Gomal sub-basin
10 Punjnad sub-basin

Indus Basin Irrigation Development Works





Climate of Indus River Basin

- Due to the marked physiographic variation in the basin, precipitation and temperature show remarkable spatial variation and seasonal fluctuations throughout the basin.
- In general, the basin covers arid to semi-arid climatic zones where average annual rainfall varies from 200-400 mm to 2000-2500 mm.
- The northern parts of the basin experience harsh winter when temperature dips down well below freezing (-30° C at Khunjerab 4750 masl) with significant snowfall whereas in the middle and southern parts winter is mild but summer is very hot when temperature crosses over 40°C.
- Largely due to variations in altitude, the climatic conditions range from hot and moist tropical in lower valleys to cool temperature at 1500 - 2000 m, above, this climate becomes progressively colder until an extreme polar type is reached at the highest altitudes.

Nourishment Source of Indus River Basin

The basin experiences two major climatic systems: the mid-latitude westerly or western disturbances from December to March and the South Asian monsoon from June to September.

The Karakoram and Western Himalayas, receive heavy snowfalls during the winter due to the incursions of the moisture laden winter westerly circulation and cyclonic storms from the Mediterranean, Black, and Caspian Seas.

Two-thirds of high altitude snow accumulation in the Karakoram occurs in winter. Even though the monsoon is more focused on the outer or lesser Himalayas, high altitude summer monsoonal snowfall accounts for the other one third snow accumulation in the Karakoram (Hewitt, 2011)

Climate of Upper Indus Basin

Towering ranges of the Himalayas interpose an insurmountable orographic barrier that halts the masses of monsoon clouds from the south and thus have created rain shadows in the landscape to the north. Naturally, rainfall in Upper Indus sub-basin is scarce. Basin-wide average annual rainfall is approximately 300 mm. However, this aridity of the basin is mostly at elevations in the range of 1000 – 2500 m.

Since the Karakoram is located at a considerable distance away from the seas and ocean, the bulk of the moisture to this mountain range is transported from the west and southwest in the middle troposphere by winter westerlies. As a result, the bulk of precipitation in the Karakoram falls out at elevations higher than 4000 – 5000 m during the winter. Furthermore, there is orographic enhancement of precipitation. Although the valley floors are quite arid, precipitation amounts increase substantially with increasing altitude. At 4000 m, annual snowfall of greater than 600 mm can be expected whereas snow accumulation of 1500 mm to greater than 2000 mm occurs at elevations of 5500 m and above .

Climate of Indus River Basin

In the Himalayan parts of the basin, seasonal as well as annual precipitation increases from the Greater Himalayas to the Middle Himalayas and reaches maximum in the outer Himalayas and the foothills (Singh et al., 1995). From the Himalayan foothills to the plains, rainfall decreases from northeast to southwest. Average annual rainfall in Jhelum sub-basin is 1052 mm, in Beas watershed it is 1146 mm, in the upper parts of Chenab, Ravi, and Sutlej sub-basins are 1334 mm, 1215 mm, and 1157 mm respectively, as determined form 34 years (1971 – 2004) of station records. In the middle parts of the basin average annual rainfall is around 500 mm (e.g. 516 mm in the middle Chenab and 555 mm in the middle-lower Sutlej), also based on 34 years (1971 – 2004) of station records (CWC-NRSC, 2014).

In the plains of Lower Indus sub-basin, mean annual rainfall varies between 90 mm in the downstream segment to 500 mm in the midstream segment (Ali, 2013).

Annual and Seasonal Average Precipitation by Elevation Zones 1951-2000

Region	*Annual average*	*Monsoon average*	*Winter average*	*Apr–May average*	*Oct–Nov average*
Greater Himalayas (winter dominated)	436.3	99.7	185.1	116.6	36.5
Sub-mountain region (monsoon dominated)	1272.9	710.4	352.2	146.1	68.2
Western Highlands	571.1	238.6	201.5	97.8	34.5
Central and Southern Punjab	286.9	189.1	54.7	32.1	10.8
Lower Indus Plains	148.7	120.4	15.1	6.3	5.0
Balochistan Plateau (Northern)	246.0	112.5	92.2	32.2	9.6
Balochistan Plateau (Western)	74.6	13.4	50.5	8.1	3.1
Coastal Belt	155.7	89.3	55.9	4.9	5.9

Source: Sheikh et al. 2009.

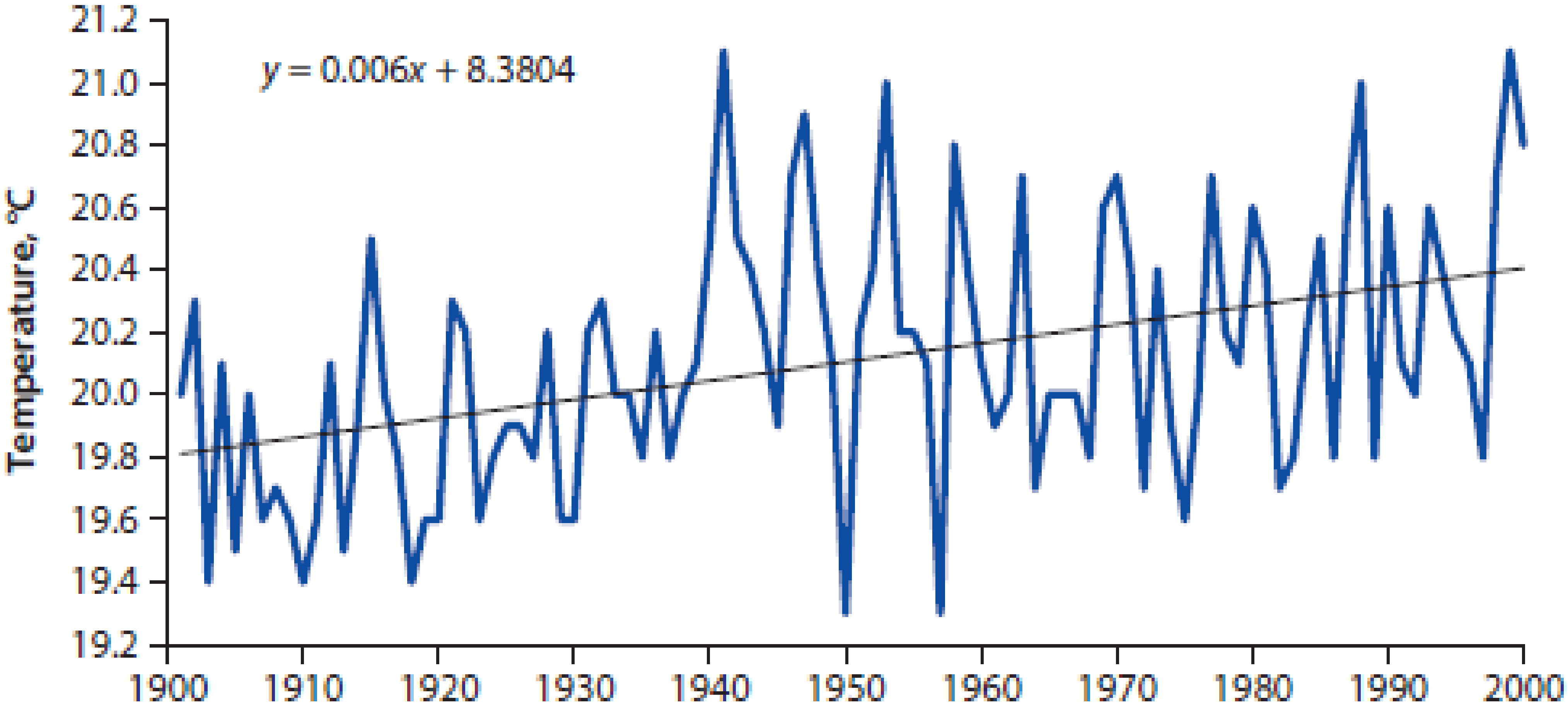
Temperature Trends

Analyses of temperature records from a limited number of valley-based meteorological stations within Upper Indus sub-basin tend to indicate that winter and annual temperatures exhibit rising trends in line with global warming but summer temperatures, particularly minimum temperatures show a declining trend (Fowler and Archer, 2006; Khattak et al., 2011).

On the other hand, analyses by Bhutiyani et al. (2007) reveal significant rise in air temperatures in the northwest Himalayan region, that includes parts of Indus Basin, by about 1.6°C, a rate higher than global average, in the last century with real warming starting from late 1960s and with winters warming at a faster rate.

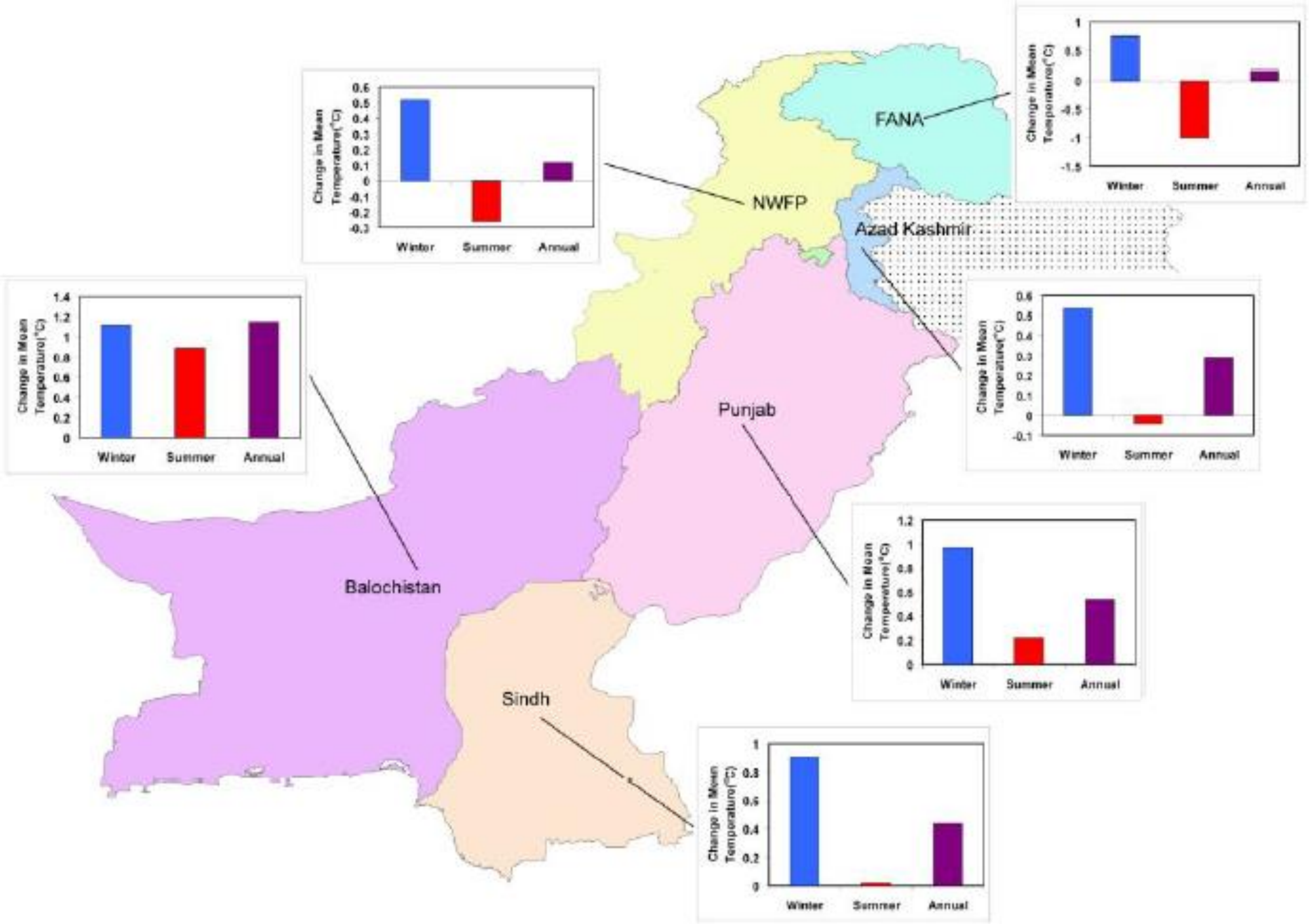
Nevertheless, it is not certain whether these trends, observed at a few points at relatively lower elevations along valley floors, can be safely extended to the entire sub-basin with an areal extent of 172,173 km2 covering mostly very high altitude mountainous terrain.

CRU Mean Temperature Trend for Pakistan over the 20th Century



Source: Sheikh et al. 2009.

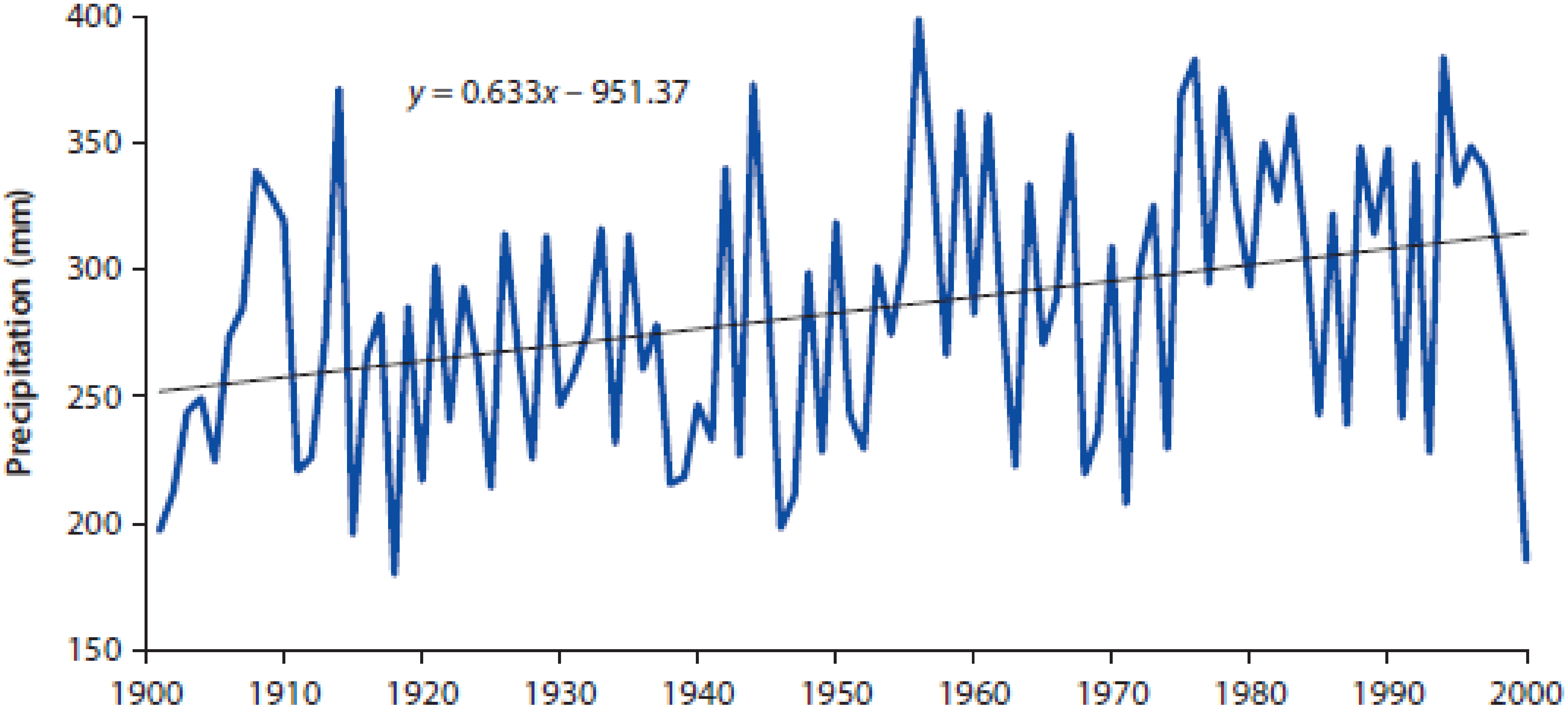
Change in Seasonal Mean Temperatures over Pakistan during 1960 – 2007 by PMD



Precipitation Trends

- Analyses of precipitation trends from the same station records show no statistically significant long-term trend in annual or seasonal precipitation time series (Khan, 2001; Archer and Fowler, 2004). On the other hand, precipitation patterns determined from ERA-40 and GPCP data indicate that summer-monsoonal precipitation has increased over the Karakoram Mountains in recent decades (Mukhopadhyay et al., 2014).
- Climate change is also expected to be accompanied by changes in the nature and frequency of extreme weather events (Vellinga and Van Verseveld, 2000). Furthermore, the increase in rainfall intensity, changes in rainfall patterns, and greater frequency of extreme rainfalls over Himalayas – Hindu Kush region (Turner and Slingo, 2009) potentially will aggravate flooding problems within Indus Basin whose signs are visible now.

CRU Precipitation Trend over Pakistan over the 20th Century



Source: Sheikh et al. 2009.

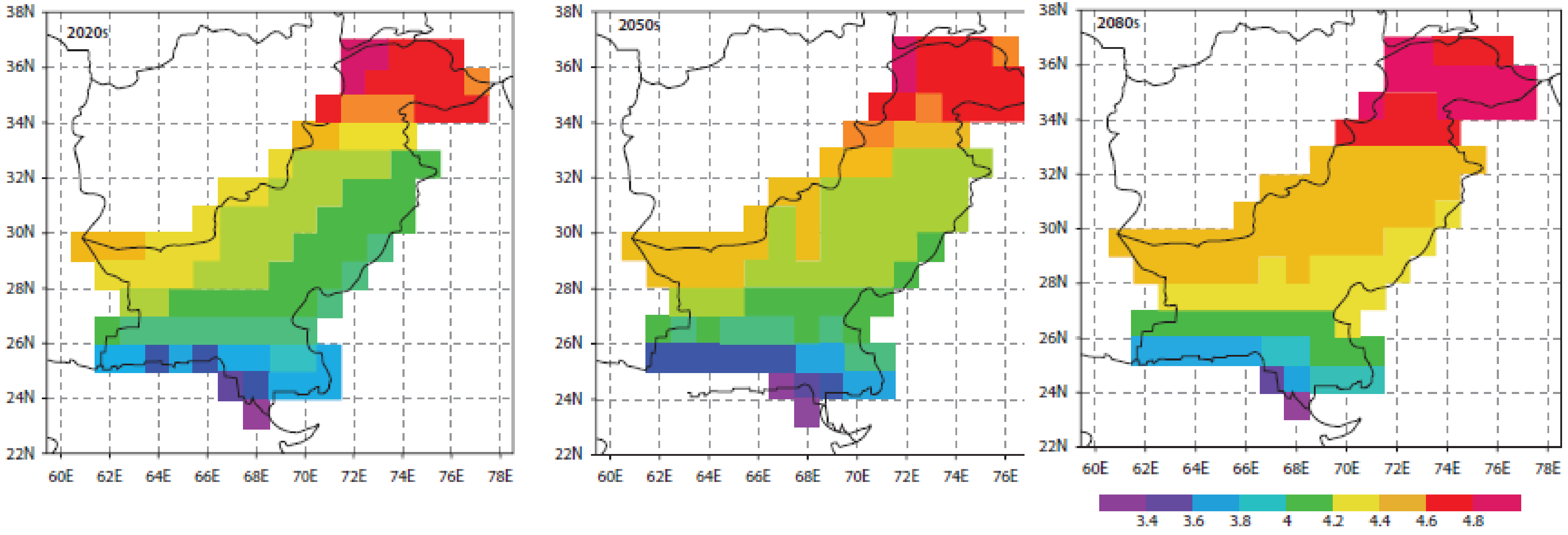
Future Climate in Indus Basin

Region wise Climate Projections for Pakistan during 2011-2100 by PMD

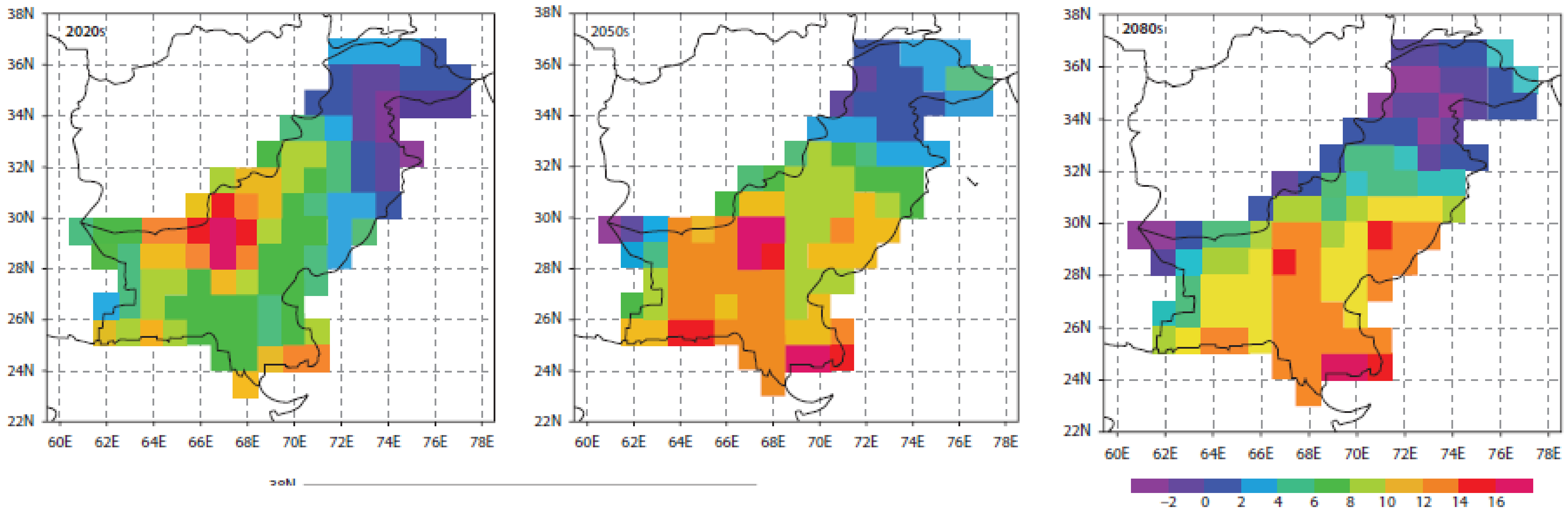
Region	Precipitation (mm/Decade)			Temperature (°C/Decade)		
	A2	A1B	B1	A2	A1B	B1
Northern Areas	+4.6	+2.9	-1.3	+0.76	+0.63	+0.39
Potohar & Upper NWFP	+6.1	+3.8	-0.5	+0.01	-0.34	-0.01
Central / Southern Punjab & Lower NWFP	-2.98	-1.78	-3.5	+0.63	+0.71	+0.05
High Balochistan	+1.48	+0.92	-0.57	+0.15	+0.26	+0.03
South-Eastern Sindh	+5.1	+3.0	-0.1	0.00	-0.1	+0.01
Sindh & Lower Balochistan	-1.8	-0.98	-0.05	+0.5	+0.27	+0.01

Climate Projections for Pakistan:
17 GCMs Ensemble Change in Mean Annual Temperature (°C)

(by Global Change Impact Study Centre – Pakistan)



Climate Projections for Pakistan:
17 GCMs Ensemble Change in Mean Annual Precipitation (%)
(by Global Change Impact Study Centre – Pakistan)



Climate Change in Indus Basin and its Hydrologic Consequences

The cryosphere of the Karakoram and the Greater Himalayas, the source of the headwaters of all major rivers of Indus Basin, is highly susceptible to climate change. Degradation of perennial snow covers by thinning, retreat, and negative mass balance of glaciers or ice losses have been widely observed in the Himalayas (Berthier et al., 2007; Kulkarni et al., 2007; Kehrwald et al., 2008; Kääb et al., 2012; Bolch et al., 2012; Gardelle et al., 2013).

Compared to such prevalent losses of the cryosphere in the Himalayas, several reports suggest glacial stability or even positive glacier mass balance in the Karakoram (Hewitt, 2005; 2007; Gardelle et al., 2012, 2013).

However, glacial growth and stability is not ubiquitous throughout Upper Indus sub-basin (see Kääb et al., 2012, 2015). Analyses of trends of August flows from the three most glacierized watersheds of upper Indus sub-basin, show that in the central and eastern Karakoram glacier mass balance is negative whereas in the western Karakoram it is positive (Mukhopadhyay and Khan, 2014b; Mukhopadhyay et al., 2014; Mukhopadhyay and Khan, 2015b).

Such findings have made the prediction and assessment of impacts of climate change on the future of the Upper Indus and associated flows downstream very uncertain.

Projected changes in the total UIB and five sub basins for the entire multi-model ensemble for two future periods (2031-2060 and 2071-2100) with respect to the reference period (1971-2000). By Immerzeel

Basin	Period	RCP	Model	ΔP (%)	Ratio rain / snow	ΔET (%)	Δtotal runoff (%)	Δglacier melt runoff (%)	Δsnow melt runoff (%)	Δrainfall-runoff (%)
Total UIB	2031-2060	RCP4.5	inmcm4_r1i1p1	-6	0.6 / 0.4	1	-7	-1	-21	2
			IPSL-CM5A-LR_r3i1p1	-9	0.66 / 0.34	5	-5	7	-38	17
			MRI-CGCM3_r1i1p1	8	0.6 / 0.4	8	11	15	-2	20
			CanESM2_r4i1p1	5	0.68 / 0.32	20	10	1	-27	41
		RCP8.5	MPI-ESM-LR_r1i1p1	-7	0.63 / 0.37	6	-5	15	-31	8
			IPSL-CM5A-LR_r3i1p1	-7	0.69 / 0.31	6	3	18	-40	32
			CSIRO-Mk3-6-0_r1i1p1	22	0.67 / 0.33	17	37	15	-10	83
			MIROC5_r3i1p1	18	0.7 / 0.3	20	33	12	-18	80
	2071-2100	RCP4.5	inmcm4_r1i1p1	-5	0.63 / 0.37	2	-6	-25	-24	14
			IPSL-CM5A-LR_r3i1p1	-10	0.69 / 0.31	7	-10	-44	-42	23
			MRI-CGCM3_r1i1p1	6	0.6 / 0.4	11	6	-10	-1	18
			CanESM2_r4i1p1	0	0.7 / 0.3	24	-3	-41	-38	34
		RCP8.5	MPI-ESM-LR_r1i1p1	-14	0.7 / 0.3	10	-15	-24	-51	15
			IPSL-CM5A-LR_r3i1p1	-16	0.74 / 0.26	13	-15	-44	-53	22
			CSIRO-Mk3-6-0_r1i1p1	40	0.73 / 0.27	36	61	-21	-6	143
			MIROC5_r3i1p1	29	0.78 / 0.22	33	51	-38	-34	147

How Research can Help?

- Develop reliable high resolution local level climate change scenarios.
- Improve Weather Forecasts to better manage the Indus Irrigation System
- Investigate impacts of Alnino on the weather forecasting for Indus Basin.
- Investigate moisture input above 4500 masl in the Upper Indus Basin
- Investigate into Flood Water Management by diverting flood waters to Wet Lands, by rehabilitating the abandoned wet lands. Diverting flood waters to abandoned river beds (Hakra in Cholistan and Sukh Beas).
- Research into the effective recharge wells to recharge depleting ground water.
- Improve design parameters for the hydraulic structures as the classical methods may not work under changing climatic conditions.
- Heat Wave has resulted in loss of more than 1200 lives in Karachi in 2015. Improve the building designs to cope with the changing clime extreme events.

There is a long list of research areas in Climate Change Policy that can help in adapting to Climate Change

Research Areas in Agriculture Sector

- Identify vulnerable areas within the rain-fed agriculture systems that are prone to increasing heat and drought related failures of crops. Identify the cropping mix package that would be most suited to that area under new vulnerabilities
- Develop new and hybrid climate change resistant crops that could survive both changes in temperature and precipitation, and still be high yielding, resistant to heat stress, drought tolerant, less vulnerable to heavy spells of rains, and less prone to insect-pests.
- Research on innovative techniques in cropping patterns to enhance agricultural productivity under reduced water conditions.
- improvement in cropping patterns and crop diversification with optimized planting dates and laser land levelling for reduced irrigation water consumption.
- Use biotechnology and genetic engineering for both crops and livestock to improve varieties and breeds, making them drought resistant.
- Develop Genetically Modified crops that are more carbon responsive to enhance productivity under increased GHGs conditions.

Thanks