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CLIMATE CHANGE & FRESH WATER SUPPLY OF PAKISTAN

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By

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SYNOPSIS

At the end of 20th Century, it was still being debated whether the climate change phenomena due to global warming has set into motion. However, in the of first quarter 21st Century it has started with a bang and engulfed the entire globe. Thus, it needs to be addressed on now or never basis. Furthermore, early 21st Century projections on global temperature rise by the end of the century are proving to be over-conservative.

Being ranked as 5th vulnerable country to climate change, implications for Pakistan are graver. Consequently, temperature rise, both in summer and winter, is projected to be higher in comparison with global trends. Precipitation trends are already becoming erratic and extreme, as demonstrated by unprecedented 2022 flooding in Southern Pakistan and drought of 2024-25.

First target of climate change is Pakistan's lifeline fresh water supply from Western Rivers. These rivers derive their supplies from snow-cum-glacial melt in Upper Indus Basin (UIB) and monsoon precipitation in the sub-mountainous catchments.

Particularly, 86% flows of Kharif are crucial for: early season sowing of cash crops; mid-season surplus flow for storage; late season crop maturing; and supplementing of low Rabi supplies through carry-over storages. Trend analysis based on recent rim-station inflow data from 2000-2024 shows a significant fall during Kharif except minor rise in September. The position is being further exacerbated by Indian water aggression on Western Rivers.

A recent (November 2024), ADB Report projects that with continued inaction even by 2035 the climate change impact may cause reduction of: 2.5% in GDP; and cereal crops between 5 to 10%. This short-term impact may significantly reduce national capability to provide food and fiber requirements of the burgeoning population.

Though Pakistan framed its National Climate Change Policy (NCCP) in 2012, its follow-up has been lax. Therefore, need of the hour is to gear up

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this effort through preparation of: framework for implementation of NCCP; and National Action Plan for implementation by Federal, Provincial and Local Governments.

To cope with impending and projected adverse impacts of Climate Change, national level actions of Pakistan should focus on: enhancing institutional capability for river flow forecasting; water conservation for efficient irrigated agriculture; and after commissioning of Diamer Bhasha Dam in 2030, addition of about 16 MAF storage on Western Rivers through projects being engineered by WAPDA upto 2050 horizon.

At international level, Pakistan should: immediately join Carbon Credit Mechanism; and exploit the platform of Conferences of Parties (CoPs) for eliciting technical/financial support for combating the grave adverse impacts of climate change.

1. Introduction

Global Warming and Climate Change

Till last decade of 20th century, it was being debated whether global warming was posing a real threat to the humanity? However, by the start of 20th Century it assumed reality and triggered world-wide climate change with adverse all-round impacts, which are accentuating every year and engulfing both developing and developed countries of the World.

With the above serious alert, in the first decade of 21st Century, UN sprang into action and along with multiple related agencies, established International Panel for Climate Change (IPCC). Further, the issue of climate change was periodically discussed / reviewed in Conferences of Parties (COPs). Last COP 29 was held in Baku (Azer Baijan) in November 2024. CoP 30 is going to be held during 2025 in Brazil.

Projected Global Temperature Changes Till End of 21st Century

According to IPCC Fourth Assessment (AR4, 2007), future increases in global average temperature were expected to be in the range 1.8 °C-3.4°C over the 21st Century. This document contained a Special Report on Emission Scenarios (SRES) based on various green house gas (GHG) levels. These were labeled: B1 – low GHG emissions and 1.8°C temperature increase; A1B – Medium GHG emissions with 2.8°C temperature increase; and A2-high GHG emissions with 3.4°C temperature increase.

Latest (2023) projections indicate that above scenarios were conservative. With increasing global GHG emissions and other related factors, it is

projected that the global temperature changes over the 21st Century may be much higher under the worst high-end scenario. The projections are:

i. Temperature rise upto 2060: 2.6°C.

ii. Temperature rise upto 2070: 4.5°C.

iii. Temperature rise upto 2090: 8.5°C.

As per latest information, during 2024 the average global temperature remained above 1.5 °C. If this warming trend persists the above predicted high end emission scenarios may not only be achieved but much exceeded.

All emission scenarios are labeled as Representative Concentration Pathways (RCPs). All RCPs under various scenarios are expected to be accompanied by much increased global impacts including: extreme events of flooding and droughts; precipitation extremes; accelerated melting of glaciers including Polar ice caps; and sea level rise, etc.

Global Warming Triggers

Global warming, and consequently the climate change, is resulting from increasing concentrations of GHGs in the atmosphere, caused by the use of fossil fuels and other anthropogenic activities.

Basic cause of this phenomenon is increase of CO^2 concentration (main component of GHGs) in the atmosphere from a pre-industrial (mid-18th Century) value of about 280 ppm to 379 ppm in 2005 (IPCC AR4, 2007). According to this IPCC Report, the concentration increased by only 20 ppm over 8000 years prior to industrialization. However, it had risen by nearly 100 ppm since 1750. The annual concentration growth rate was larger during the ending 10 years from 1995-2005 with an average of 1.9 ppm / year, which came largely from fossil fuel consumption and the effects of land use change. It was estimated that since 1750 about 2/3rd of anthropogenic CO^2 emissions had come from fossil fuel burning and about 1/3rd from land use change.

2. Climate Change Implications for Pakistan

Pakistan, located in sub-tropical temperate region, has a warm climate and its economy, being largely agrarian, is highly climate sensitive. According to '2023 Global Climate Risk', Pakistan was ranked as the 5th most vulnerable country to climate change.

Immediate threat of climate change induced temperature rise to Pakistan is relatively accelerated trend as compared to the globe. In turn, this will cause

large variations in annual precipitation trends with consequent impact on the primary fresh water supply source of Indus River System (IRS).

2.1 Projected Temperature Trends

Till about middle of 20th Century, temperature tends over Pakistan were seen very much tallying with the global trend. However, future projections showed that the rate of increase of average temperature over Pakistan could be higher as compared to the global trend.

Area average mean annual temperature over Pakistan increased by 0.6 °C over the period of 1901-2000 in agreement with the global trend. However annual temperature increase over Pakistan during 48-year period of 1960-2007 was about 0.24 °C per decade as compared to the global 0.06°C, reflecting trend of much increased rate of warming.

During the period of 1901-2000, increase in mean annual temperature in northern half of Pakistan was 0.8°C versus the national average of 0.6°C. Early summer (April & May) temperatures (both mean and maximum) increased in all parts of Pakistan during the period of 1951-2000. During the same period, Balochistan Plateau became warmer in all the seasons. Temperatures (both mean and maximum) during the monsoon season dropped throughout Pakistan during 1951-2000 except in Balochistan Plateau. During 1951-2000, Greater Himalayan region (the abode of sizeable glaciers feeding the Indus River System) had a warming trend on annual basis as well as in all seasons except monsoon season and in post-monsoon season (Oct-Nov), where it dropped slightly.

Latest temperature trends in Pakistan indicate that these are rising significantly higher than previous projections. This is manifested in increasing trend of unseasonal heat waves, particularly in southern Pakistan. Recent (2024) example of Northern Pakistan was that till November, which used to be onset of winter, actual temperatures were somewhat similar to late September. Similarly, January 2025, normally the month of severe cold, was warmer.

Even considering the extreme high-end A-2 scenario of IPCC (AR4, 2007) with global temperature rise to 3.4°C by 2080, projected average temperature changes over Pakistan as well as its Northern half (above 31° N) and Southern half (below 31° N) were as shown in **Table-1.**

Table-1: Projected Temperature Changes in Pakistan By 2080 Under A2 Scenario of IPCC (AR4, 2007)

Period	*Changes in Temperature (°C)*		
	Overall Pakistan	*Northern Pakistan*	*Southern Pakistan*
Annual	*4.38 ± 0.44*	*4.67 ± 0.23*	*4.22 ± 0.18*
Summer	*4.13 ± 0.26*	*4.56 ± 0.28*	*3.90 ± 0.26*
Winter	*4.47 ± 0.20*	*4.72 ± 0.24*	*4.33 ± 0.18*

Table-1 indicates that temperature increases in both summer and winter would be higher in Northern than in Southern Pakistan. However, temperature increases in Northern and Southern parts of Pakistan could be somewhere higher in winter than in summer.

2.2 Projected Precipitation Trends

2.2.1 Overall

Area averaged mean annual precipitation over Pakistan increased by 25% during the previous century (1901-2000). During 1951-2000, monsoon precipitation increased everywhere except in coastal regions (where there was a significant drop) and the Western Balochistan Plateau. During the same period, winter rains increased by 26-57% in Sub-Montane, Central & Southern Punjab, and North-Eastern Balochistan and decreased by 13-20% in Sindh and Western Balochistan. During 1951-2000, Greater Himalayan region experienced the highest growth in monsoon precipitation (86%) and a nominal decrease (2%) in winter (December-March) precipitation.

Projected precipitation changes in Pakistan under A2 Scenario of IPCC (AR4-2007) were as shown in **Table-2.**

Table-2: Projected Precipitation Changes in Pakistan By 2080 Under A2 Scenario of IPCC (AR4-2007)

Period	*Changes in Precipitation (mm)*		
	Pakistan	*Northern Pakistan*	*Southern Pakistan*
Annual	*3.48 ± 5.78*	*1.13 ± 3.95*	*4.28 ± 9.46*
Summer	*12.16 ± 8.91*	*1.08 ± 8.35*	*51.07 ± 39.78*
Winter	*-5.12 ± 4.78*	*-2.24 ± 4.10*	*-20.51 ± 9.05*

Rather large variations in Table-2 made it difficult to draw any definite conclusions about change in precipitation with time. However, subsequent observations (2011, 2012 & 2022) showed precipitation increase in summer and decrease in winter in the Southern parts of Pakistan. Particularly, 2022 unprecedented summer rainfall increase in South (Sindh and Balochistan) caused excessive flooding with vast devastation. Simultaneously, in Northern Pakistan the monsoons have become less pronounced through late occurrence; and shifting their center of gravity form north to north west. Conversely, during current winter of 2024-25, Pakistan was facing a serious drought.

2.2.2 Spatial Variability

Annual precipitation in the country is low and erratic, with national average of around 278 mm. It varies from about 160 mm during a dry year (2002) to over 440 mm in a wet year (1994). This precipitates an average of 180 MAF of rainwater over the country's total land area. Spatial variation of rainfall is also huge. It varies between 1500 mm in the northern mountainous areas and northern Punjab to less than 100 mm in the south with southern Punjab and upper Sindh getting about 150 mm per annum. About 80% of the annual rainfall occurs during the monsoon period of July to September. In Pakistan, being located at the western edge of the monsoons system, heavy summer rains normally used to occur in the north-eastern part of the country. However, as mentioned above the recent trend indicates shift toward north west. Monsoons are also becoming highly variable from year to year as well as unpredictable. Climate change is also enhancing variability of winter precipitation in upper Indus Basin comprising rainfall snow and ice over glaciers with consequent impact on the primary fresh water source of IRS.

3. Primary Fresh Water Source of Pakistan

3.1 Dependence on Western rivers

Primary fresh water source of Pakistan is Indus River System. After award of three Eastern Rivers to India Under Indus Waters Treaty (IWT) of 1960, Pakistan is now dependent on the three Western Rivers of: Indus Including Kabul; Jhelum; and Chenab.

3.2 Flow Contribution From Western Rivers

Historic flow contribution by Western Rivers of Indus River System (IRS) based on post-Tarbela data for 1977-2003 were as shown in **Table-3**.

Table-3: Historic Fresh Water Contribution By Western Rivers of Indus River System

Indus River System	Flow Contribution (%)	Seasonal Distribution (%)		Dominant Source of Water		Average Inflow (MAF)		
		Summer (Apr-Sep)	Winter (Oct-Mar)	Summer	Winter	Kharif	Rabi	Total
Indus	44	86	14	Snow/Glacier melt	Winter Rainfall + Baseflow	53.4	8.6	62.0
Kabul	16	82	18	Snow/Glacier melt	Winter Rainfall + Baseflow	18.5	4.1	22.6
Jhelum	16	78	22	Mainly Snow melt + Monsoon	Winter Rainfall + Baseflow	18.5	4.1	22.6
Chenab	19	83	17	Mainly Snow melt + Monsoon	Winter Rainfall + Baseflow	22.3	4.5	26.8
Others	5[a)]	100	0	Uncontrolled Floods		7.1	0	7.1
Total / Average	**100**	**86**	**14**			**119.8**	**21.3**	**141.1[b)]**

a. Unaccounted flows including uncontrolled floods from Eastern Rivers of Ravi and Sutlej.
b. For 26 year post-Tarbela period from 1977-2003 before onset of visible climate change impact.

3.3 Climate Change Impact on Western River Supplies

3.3.1 Climate Change Impact Vulnerability

As already mentioned, since turn of the Century after 2000, climate change impact has started accentuating in the from extremes. In respect of hydrology, particularly fresh flows, the climate change impact has engulfed not only Pakistan but almost the entire world through extreme snowfall, flooding and drought events.

According to 2023 Global Index, Pakistan is ranked as 5th climate change impacted country. Due to this vulnerability, the bulk fresh water supply

source of Western Rivers is being impacted with adverse socio-economic consequences.

3.3.2 Impact on Melting of Glaciers

About 2/3 of average annual river inflows into Pakistan are generated by snow and glacier melt in the Ranges of Hindu Kush-Karakoram and part of Western Himalayas. Upper Indus Basin (UIB) in Pakistan, mostly in Karakoram part, has more than 5,000 glaciers which cover a total area of about 5900 sq. miles (15,000 sq. km). Their importance can be judged from the fact that the stored volume of water in these glaciers is equivalent to about 14 years of average river flows. Therefore, their current and future status in the context of changing climate is of vital concern to Pakistan.

There is a serious lack of current knowledge and convergence of preliminary research findings regarding climate change impacts on glaciers in UIB and consequent projection of river flows. This requires understanding and modelling capability about the patterns of snow / glacier melt and precipitation contributing to water supply in UIB. These aspects need to be adequately addressed under an integrated programme of cooperative research through participation of: the concerned national agencies; and interested international entities. Basic focus of this research effort should be on:

i. Understanding and modelling of the climate change trends in UIB.
ii. Variations in inter-season and intra-seasons precipitation.
iii. Spatial / temporal variations in the extent of snow / glacier cover through use of latest technologies (satellite imagery / GIS) for projecting future trends.
iv. Projecting the overall long-term impact of hydro-meteorological changes on the flows of IRS.

Northern part of Pakistan is facing increased hazard of glacial lake outburst floods (GLOFs) due to accelerated snow / glacial melt. On the other hand, southern part is experiencing extreme flooding and droughts. During 2010 there was record flood on Indus River, which caused colossal damage to infrastructure, agriculture and human lives. Little later in 2014 Chenab River experienced a super flood, which caused 170 deaths and affected almost one million people. Besides, thousands of acres of standing agricultural crops were damaged.

3.3.3 Critical Importance of Kharif Water Supplies

It can be seen form **Table-3** that 86% of Western River inflows occur during Kharif season of April to September. Further, these flows are equally

important for the subsequent Rabi season for supplementing the low supplies through storages filled by the surplus in preceding Kharif.

For Kharif season itself, early part (April to June) is crucial for sowing of cash crops of sugar cane, cotton and rice.

Therefore, for comparative analyses of Western River historic flows the following Kharif season scenarios have been looked into:

i. Pre-active Climate Impact Period: -
   a. Post-Treaty period of 1961-99 (39 years).
   b. Post-Tarbela period of 1977-99 (23 years).

ii. Post-active Climate Change Impact Period of 2000-2024 (25 years).

3.3.4 Synthesis of Western River Kharif Inflows

For this purpose, Kharif season has been split into following three sub-seasons to account for variable impacts on irrigated agriculture:

i. Early Kharif: April – June (critical for early cash crop sowing).
ii. Mid Kharif: July & August (critical for reservoir storages from surplus flows as well as providing ecological flows below Kotri).
iii. Late Kharif: September (critical for crop maturing including any needed supplementing through storage releases).

Quantums of historic rim-station Kharif inflows on Western Rivers for record period of 64 years (1961-2024) are contained in Annex-01 and cover:

i. Indus at Tarbela.
ii. Kabul at Nowshera.
iii. Jhelum at Mangla.
iv. Chenab at Marala.

Corresponding average sub-season and total Kharif wise inflows are summarized in **Table-4**.

Table-4: Average Sub-season and Total Kharif Wise Inflows to Western Rivers

Sr. No.	River / Rim Station	Average Kharif Inflows (MAF)			
		Early Kharif (April – June)	Mid Kharif (July & August	Late Kharif (September)	Total
1.	Indus at Tarbela:				
	i. 1961-99*	16.5	30.0	6.6	53.1
	ii. 1977-99*	16.3	29.9	6.5	52.7
	iii. 2000-24**	15.6	27.3	6.3	49.2

Sr. No.	River / Rim Station	Average Kharif Inflows (MAF)			
		Early Kharif (April – June)	Mid Kharif (July & August	Late Kharif (September)	Total
2.	Kabul at Nowshera:				
	i. 1961-99*	9.6	7.4	1.3	18.3
	ii. 1977-99*	9.1	7.2	1.3	17.6
	iii. 2000-24**	8.5	6.7	1.3	16.5
3.	Jhelum at Mangla:				
	i. 1961-99*	10.2	6.4	1.5	18.1
	ii. 1977-99*	10.7	6.6	1.6	18.9
	iii. 2000-24**	8.9	4.8	1.4	15.1
4.	Chenab at Marala:				
	i. 1961-99*	7.5	11.4	2.9	21.8
	ii. 1977-99*	8.0	11.9	2.9	22.8
	iii. 2000-24**	6.5	9.3	2.5	18.3
5.	Total:				
	i. 1961-99*	43.8	55.2	12.3	111.3
	ii. 1977-99*	44.1	55.6	12.3	112.0
	iii. 2000-24**	39.5	48.1	10.1	97.7

* Pre-active Climate Change Impact Period.
** Post-active Climate Change Impact Period.

Table-4 shows that on the aggregate, there was:

i. Nominal increase from 111.3 MAF to 112.0 MAF over Pre-active Climate Change Impact scenarios of 1961-99 and 1977-99.
ii. Significant decrease to 97.7 MAF under Post-active Climate Change impact scenario of 2000-24.

As there was no apparent difference between 1961-99 and 1977-99 scenarios, for the purpose of comparative analyses, data series 1977-99 and 2000-24 have been selected. Corresponding sub-season wise comparison of aggregated Western River Kharif inflows under these two scenarios is summarized in **Table-5.**

Table-5: Average Sub-Season and Total Kharif Wise Western River Inflows Over Pre & Post Climate Change Impact Scenarios

Sr. No.	Sub-Season / Total	Average Western River Inflows	
		1977-99 (MAF)	2000-24 (MAF)
1.	Early Kharif (April-June)	44.1	39.5
2.	Mid Kharif (July & August)	55.6	48.1
3.	Late Kharif (September)	12.3	10.1
4.	**Total Kharif**	**112.0**	**97.7**

3.3.5 Inflow Trend Analysis

For trend analysis overall 49 year rim-station data has been evaluated. Individual and cumulative sub-season and Kharif wise plots are contained in Annex-02. Super-imposition of best-fit lines over these plots reveal trends as summarized in **Table-6**.

Table-6: Western River Rim-Station Sub-Season and Kharif Wise Inflow Trends Over 1977-2025

Sr. No.	Sub-Season	Inflow Trend Over 1977-2025				
		Indus at Tarbela	Kabul at Nowshera	Jhelum at Mangla	Chenab at Marala	Overall
1.	Early Kharif (April – June)	Falling	Slightly Rising	Falling	Significantly Falling	Falling
2.	Mid Kharif (July & August)	Falling	None	Significantly Falling	Significantly Falling	Falling
3.	Late Kharif (September)	Slightly Rising	Slightly Rising	No Change	Significantly Falling	Slightly Rising
4.	Total Kharif	Falling	Rising	Falling	Falling	Falling

4. Projected Climate Change Impacts on Pakistan

Recently, Asian Development Bank (ADB) has issued 'Asia-Pacific Climate Report 2024'. Regarding climate impacts on Regional Countries including Pakistan, it projects that:

i. Gross domestic product (GDP) will be substantially decreased.
ii. Impact will be very serious on agriculture with disproportionate effect on poor and vulnerable communities.
iii. Changes will be most pronounced in terms of increasing extremes.

4.1 Impact on Gross Domestic Product

Projected impact of climate change on gross domestic product (GDP) of Pakistan in this ADB Report is summarized in **Table-7.**

Table-7: Projected Effect of Climate Change on Gross Domestic Product of Pakistan Under High End Emission Scenario Against 2020 Base

Horizon Year	Projected Effect on GDP
2035	-2.5%
2050	-11%
2070	-21%

4.2 Impact on Major Crop Yields

This ADB Report further examines the climate change impacts on crop yields. Taking 2020 as base under High End Emission Scenario of GHGs (now likely), the Report projects regional / country-wise effects on major crops corresponding to 2035, 2050 and 2070 horizons. Projected impacts on yields of major crops of rice, maize and wheat in Pakistan are quite alarming as shown in **Table-8**.

Table-8: Projected Effects of Climate Change on Yields of Major Crops in Pakistan Under High End Emission Scenario Against 2020 Base

Crop	*Projected Effect on Yield Through 2070 Against 2020 Base*		
	2035	*2050*	*2070*
Rice	*-5%*	*-20%*	*-35%*
Maize	*-10%*	*-25%*	*-40%*
Wheat	*-5%*	*-30%*	*-45%*

4.3 Impact on Agricultural Economy

Irrigated agriculture is the backbone of Pakistan economy as 55% livelihood of the total population is dependent on it. Textile sector is the second largest employer providing livelihood to 42 percent of work force but it is also agriculture centric being dependent on the production of cotton crop in the country. Unfortunately, this sector is being also affected by climate change and poor people are most likely to lose their livelihood. For instance, due to adverse climate conditions cotton production during 2024 was the lowest in recent years. Loss of livelihoods in agriculture and industrial sectors will put downward pressure on other occupations and increase competition by creating scarcity of jobs.

As already mentioned, temperature increases in Pakistan are expected to be higher than the global average resulting in reduced national agricultural productivity. Decreasing growing season length with increase in temperature will reduce crop yields. Yields of wheat, rice, other cereals and some important cash crops including cotton could decline in all regions of the country (refer Table-8).

Agriculture dependent livestock production could also decline by 20-30 percent due to rising temperature creating crises in milk, meat and poultry supplies and pushing prices beyond reach of the common man.

4.4 Adverse Fallouts

Due to snow-balling of these climate change impacts and predominant dependence on agrarian economy, Pakistan will be faced with the following adverse fallouts:

i. Significantly reduced capability to provide food and fiber requirements of its bourgeoning population.

ii. Sizeable reduction in GDP particularly due to lesser contribution by Agriculture and Industrial Sectors (refer Table-7).

iii. About US$16 billion projected per annum loss by the end of 21st Century.

4.5 International Vulnerability

With 5th ranked vulnerability to climate change impact, Pakistan may be required to invest heavily for managing the consequent adverse socio-economic fallout. To achieve this, sizeable / continuous international technical and financial support may be necessary. On the other hand, will be serious challenges of:

i. Apathy of developed nations towards providing adequate or even committed funding for mitigation / adaptation / amelioration of adverse climate impacts (latest example of CoP 29 held in November 2024 at Baku).

ii. Hostile neighboring India with aggravating water aggression.

5. Initiatives by Pakistan to Combat Climate Change Impacts

5.1 Establishment of Climate Change Task Force

With serious alert starting from turn of the Century, Pakistan started efforts to tackle climate change issues. In 2008 Planning Commission set up a Climate Change Task Force (CCTF) to provide appropriate guidelines for ensuring security of vital resources of the country such as agriculture, water and energy and contribute to formulation of climate change policy. CCTF issued its final report in February 2010. Report described Pakistan's vulnerability due to climate change impacts on various socio-economic sectors. It recommended various mitigation and adaptation measures based on initial assessment and reviewed country's ongoing and planned responses. Findings of this report helped subsequent formulation of Pakistan of Climate Change Policy.

5.2 National Climate Change Policy

Pakistan was the first South Asian country to develop Climate Change Policy showing its commitment for mitigation and adaptation.

Resultantly, Government of Pakistan set up an exclusive Ministry of Climate Change in 2012. Ministry developed National Climate Change Policy (NCCP) in 2012, on the basis of guidelines provided by CCTF. NCCP comprehensively addressed all possible challenges of climate change including adaptation and mitigation in foreseeable future.

To address the impacts of climate change on water resources and to enhance water security, it recommended the following policy measures:

i. Infrastructure for mega water storages be built not only for meeting initial needs but making up of about one-third loss of storage capacity in on-line reservoirs due to rapid sedimentation.

ii. Hill torrents be harnessed to control not only flooding but enhance storage capacity.

iii. Existing aging irrigation infrastructure be rehabilitated early.

iv. Water conservation strategies be adopted by reducing irrigation system losses and introduction of high efficiency irrigation systems (HEIS) and rainwater harvesting techniques.

v. Integrated water resources management be adopted through: rationalised water allocations; equitable water distribution; protection of ground water resources; recycling of wastewater; water-shed management in critical catchment areas; and active participation of farmers in water management.

vi. Legislative framework be developed / implemented to protect water resources for efficient management and protection of glaciers.

vii. Institutional capacities be enhanced by developing efficient technologies, monitoring of irrigation water delivery, preparing inventory of all water resources and application of remote sensing and GIS techniques.

viii. Awareness be raised among all public / private sector stakeholders.

In the field of agriculture, following policy measures were recommended:

i. Research for assessment of climate change impacts on various agro-ecological zones, by developing new variety of crops, better breeds of livestock, quality database, sustainable land management and enhancing capacity of farming community.

ii. Technology for improving crop productivity, energy efficient farm mechanization, modern techniques, financial incentives and improved agronomic and irrigation practices.

iii. General management by establishing climate change units.

iv. Risk management by insurance of crops and by enhancing agricultural drought farming.

5.3 Framework For Implementation of National Climate Change Policy

A Framework for Implementation of National Climate Change Policy was developed in November 2013 to implement NCCP. This framework was developed by keeping in view current and future anticipated threats due to climate change to various sectors of Pakistan. Appropriate actions relating to disaster preparedness, capacity building, institutional strengthening and awareness raising in relevant sectors were also proposed.

5.4 National Action Plan

Due to lukewarm follow-up of NCCP, it has not been possible so far to come up with National Action Plan (NAP). This requires to be developed immediately and implemented by Federal, Provincial and Local Governments along with firm financial commitment. In this respect, Pakistan can benefit from a number of financial incentives for mitigation / adaptation of climate change being offered by international agencies including UN and some developed countries through CoPs.

6. Coping strategy for Adverse Climate Change Impact on Fresh Water Resource

It is evident from the forgoing that climate change will have adverse socio-economic impacts on Pakistan due to front-line vulnerability. In this regard, Pakistan's lifeline fresh water resource of Western Rivers is the first target. Instead of waiting for the axe to fall, Pakistan should take up the following national / international level priority coping measures.

6.1 National Level

i. Integrating climate change impact mitigation / adaptation into the planning and implementation of all public and private sector developments by pursuing the objectives of NCCP.

ii. Switching over from high delta crops (rice and sugarcane) to low delta crops (beet root and maize).

iii. Focus on water / agriculture sectors, through:

   a. Enhancing institutional capability for river flow forecasting.

   b. Water conservation through efficient irrigated agriculture by reduction of losses on water conveyance systems and vigorous

pursuit of On Farm Water Management measures comprising: water-course lining; mechanized farming; land leveling; and adopting high efficiency irrigation systems (HEIS) of drip and sprinkler along with agronomic practices.

c. Continued progressive addition of carry-over water storage capacity on the Indus River System after anticipated commissioning of Diamer Basha Dam at the end of current decade. Fortunately, WAPDA is already planning to add 16 MAF storage to IRS by 2050 through engineered projects of Chiniot, Kalabagh, Akhori and Low Skardu.

6.2 International Level

In addition to the above national level measures, Pakistan should redouble the efforts to seek foreign financing from the developed countries, which are primarily responsible for the global warming and its adverse impacts. The two key areas could be:

i. Joining Carbon Credit Mechanism.

ii. Effective use of CoPs platform for eliciting international financing and technical support.

6.2.1 Carbon Credit Mechanism

Carbon credit mechanism is a specific initiative or activity aimed at reducing GHG emissions, generating thereby the carbon credits. These credits can then be sold or traded in carbon markets to help offset emissions from other entities or industries. Pakistan should get registered immediately for joining this mechanism. Recently, GoP established a Committee for this purpose, which should provide firm recommendations not only for joining this mechanism but getting early financial benefits from this mechanism.

Pakistan's existing / upcoming hydropower projects (large as well as small) displace the need for fossil fuel based power generation which emits GHG. These projects also reduce the need for coal, natural gas or oil, which would otherwise contribute to carbon emissions. Each megawatt-hour (MWh) of this clean electricity generated can be used to offset carbon emissions elsewhere.

To ensure credibility, each such project will need to be validated by a recognized standard, such as VERRA, Gold Standard, or Clean Development Mechanism (CDM) under the UN Framework Convention on Climate Change. This process involves third-party verification to ensure that the project delivers real, measurable, and additional reductions in

emissions. This is based on: monitoring and reporting; verification and certification; issuance and trading; and post-project reporting and auditing.

6.2.2 Exploitation of CoPs Platform

Being one of the front-line countries facing adverse climate change impacts, Pakistan should seize the first opportunity of Conference of Parties (COP) 30 to be held in Brazil during 2025, as a platform to consolidate its international presence as well as to shape discussions on climate policies affecting it. Given the fact that climate change is arguably the biggest threat facing humanity today, Pakistan can position itself as a key player in the global dialogue, advocating for climate justice while simultaneously seeking solutions for its environmental challenges.

Pakistan's preparations for CoP30 should not only focus on domestic policy priorities but also on building alliances with like-minded countries. Collaboration with nations in the G77, the alliance of Small Island States (AOSIS) and other climate-vulnerable regions, can help Pakistan present a unified voice on issues such as climate finance, adaptation, loss and damage. Furthermore, Pakistan must engage all voices in the climate change debate, including non-governmental organisations, environmental activists, private businesses, and industries. Civil society, academics and youth movements can help raise awareness about Pakistan's climate challenges and advocate for more active global contributions towards climate goals.

7. Conclusions & Recommendations

7.1 Conclusions

i. Pakistan being ranked as 5th climate change vulnerable country, is already facing adverse impacts in the form of:
   a. Extreme flooding and droughts.
   b. Generally rising temperatures during summer and winter.
   c. Occasional cyclones, never heard of in the past.

ii. According to latest projections of IPCC, globe will face high end emission scenarios of GHG during remainder of 21st Century. Clear alert is that globally 2024 was the warmest on record since the industrial revolution of 18th Century.

iii. First target of climate change impact is Pakistan's primary surface water resource of Western Rivers. With 86% of river inflows in Kharif, this season is crucial for the irrigated agriculture dependent economy.

iv. As per recent historic data, average Kharif inflow of Western Rivers reduced by about 13% during 2000-25 (Post-active Climate Change Impact Period) as compared to 1977-99 (Pre-active Climate Change Impact Period).

v. As per prevailing trend, early and mid-Kharif inflows are reducing significantly.

vi. In 2024, ADB issued 'Asia-Pacific Climate Change Report'. Accordingly, under high end emission scenario of GHG, yields of major Pakistan crops of rice, maize and wheat could drop between 5-10% even by 2035.

vii. Besides impacting quantum of fresh water supplies, Pakistan may face serious threats in the form of:

   a. Glacial lake outburst floods (GLOFs) due to accelerated glacial melting in UIB.

   b. Extreme rainfall and drought events in the Indus Plains.

   c. Occasional cyclonic storms with devasting effect on coastal areas.

viii. Due to progressively diminishing fresh water supplies, Pakistan will face serious adverse impacts on:

   a. Agriculture with disproportionate effect on poor and vulnerable communities.

   b. Pronounced changes in terms of increasing extremes.

   c. Substantial decrease in national GDP.

ix. Position may be further aggravated by unabated Indian water aggression on Western Rivers.

7.2 Recommendations

i. National Level:

   a. Active pursuit of National Climate Change Policy (NCCP) of 2012 through Development of National Action Plan (NAP) for implementation by all stakeholders.

   b. Integrating climate change impact mitigation / adaptation into the planning and implementation of public and private sector developments.

   c. Improved water use efficiencies though adoption of latest technologies in irrigation water conveyance system and agriculture by introduction of mechanized farming and agronomic practices.

d. Switching over from high delta crops (sugarcane and rice) to low delta crops (beat root and maize).

e. Progressive addition of storages on Western Rivers after Diamer Basha Dam commissioning by the end of current decade though prioritization of the storage projects being already planned by WAPDA till 2050 horizon.

ii. International Level:

a. Joining carbon credit mechanism.

b. Effective use of CoPs platform for eliciting international financing and technical support for coping with upfront adverse impacts of globing warming with only about 1% contribution to GHGs.

8. References

1. Papers contributed by Riaz Nazir Tarar to Pakistan Engineering Congress:
   i. Impact of Climate Change on Pakistan Rivers – A Case for Cooperative Research, World Water Day. March 2013
   ii. Pakistan's Water Security Issues and Addressing Strategy, 73rd Annual Session. December 2015
   iii. Water and Climate Change - National Context, World Water Day. March 2020
   iv. Climate Change Impact on Snow-Cum-Glacial Melt Flows of Western Rivers in Early Kharif and Its Mitigation, 76th Annual Session. October 2021
   v. What Next After Diamer Basha Dam?, 77th Annual Session. December 2024
2. Asia – Pacific Climate Report, Asian Development Bank. November 2024