**PACE Policy Research Paper:
Strategies and Mechanisms for Mainstreaming Climate Change
into Agriculture and Irrigation Sector Reforms**

For Support To:

“Transformation of the Indus Basin with the Introduction of Climate Resilient Agriculture and Sustainable Water Management Project” and “Strengthen Food Security and Nutrition Information Systems (FSNIS) in Pakistan”

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Abbreviations

asl	Above Sea Level
BCM	Billion Cubic Meter
CRI	Climate Risk Index
GDP	Gross Domestic Product
GHG	Green House Gases
IBIS	Indus Basin Irrigation System
IPCC	Inter-Governmental Panel for Climate Change
KPK	Khyber Pakhtunkhwa
m	Meter
MAF	Million Acre Feet
Mha	Million hectare
PMD	Pakistan Meteorological Department
TDS	Total Dissolved Solids

I. Background

Global warming is unequivocal, and since 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere has warmed (0.85°C over the period 1883 to 2012). Glaciers have continued to shrink almost worldwide. The amounts of snow and ice have diminished. The Greenland and Antarctic ice sheets have been losing mass. The sea level has risen and on a global scale, the ocean warming is largest near the surface, and the upper 75 m warmed by 0.11°C per decade over the period 1971 to 2010. The increase in greenhouse gas (GHG) emissions, driven largely by economic and population growth, together with other anthropological drivers have caused changes in climate system. Continued emission of greenhouse gases is expected to cause further warming and changes in the climate system increasing the possibilities of severe and irreversible impacts for people and ecosystem. Surface temperature is projected to rise over the 21st century (0.3 to 1.7°C) and it is likely that heat waves will occur more frequently and last longer. The global ocean will continue to warm during the 21st century, with the strongest warming projected for the surface in tropical and Northern Hemisphere subtropical regions. The global glacier volume excluding glaciers on the periphery of Antarctica (and excluding the Greenland and Antarctic ice sheets) is projected to decrease by 15 to 55%.¹ Therefore, limiting climate change would need substantial and sustained reduction in greenhouse gas emissions through adaptation and mitigation strategies. These include innovation and investment in environmentally sound technologies and infrastructure, sustainable livelihoods and behavioural and lifestyles choices as well as effective institutions and governance.

II. Climate Change Trends in Pakistan

2. **Pakistan ranks seventh in the Global Climate Risk Index (CRI) 2017²** (see Table 1). The country's geographical location, largely in a semi-to-hyper arid area, makes it highly vulnerable to climatic changes. The mean temperature has increased by 0.5°C since 1960 which is significant at 95 percent level.³ The frequency and intensity of extreme weather events and natural disasters has increased considerably. 22 major floods since 1950 caused a cumulative losses of about \$ 22 billion, killing a total of over 9,400 people (\$ 13 billion in 2010 and 2011), and affecting 148,500 villages. Indirect losses, though not quantified, included health hazards, land and water quality degradation, temporary disruption of transport and the slowing down of economic growth.⁴

¹ IPCC Climate Change Report 2014 (published in 2015).

² David Eckstein, Vera Künzel and Laura Schäfer, Global Climate Risk Index 2018 – Who suffers Most from Extreme Weather Events? Weather-related Loss Events in 2016 and 1996-2016

³ The warmest years recorded by Pakistan Meteorological Department are 2005 and 2007.

⁴ Asian Development Bank, Indus Basin Floods: Mechanisms, Impact and Management, 2013.

Glaciers melting, which contribute 70 percent of the water in river flows, could lead to fluctuations in water availability in the Indus Basin. The changing climate is evident from: (i) rising temperature; (ii) increased intensity and frequency of floods and droughts; and (iii) changing annual precipitation and seasonal patterns. Temperatures and rainfall levels are also projected to increase in Pakistan, leading to a mean temperature increase of 1.4–3.7°C by 2060 (higher than the expected global average). This will likely increase the frequency of extreme event.

Table 1. The Long-Term Climate Risk Index (CRI): 1996 to 2015 (annual averages)

Country	CRI 1996-2015	Country CRI Score	Death Toll	Death per 100,000 inhabitants	Total Losses in Million US\$ PPP	Losses Per Unit GDP in %	Number of Events Total 1996-2015
Philippines	5	20.17	859.55	0.98	2893.41	0.611	289
Bangladesh	6	26.50	641.55	0.44	2311.07	0.678	187
Pakistan	7	30.50	523.10	0.33	3816.82	0.605	141

3. **Pakistan ranks relatively low among global emitters both on total Greenhouse Gas (GHG) emission (31st) and per capita GHG emission basis (135th)⁵ contributing 0.8 percent (369 million tons of carbon dioxide equivalent).⁶ Total GHG emission increased from 182 mtCO₂ equivalent in 1994 to 309.2 mtCO₂ in 2008 and 369 mtCO₂ equivalent in 2012.⁷ The GHG emission increased by 2.9 percent annually while GDP grew at annual growth rate of 3.8 percent (Figure 1).**

Source: World Resources Institute CAIT

⁵ The Global Economy Carbon Dioxide Emission 2015-Country Ranking; www.theglobaleconomy.com

⁶ National Inventory of Pakistan GHG for 2011-2012

⁷ K. A. Mir and M. Ijaz. 2015. *Greenhouse Gas Emission Inventory of Pakistan for the Year 2011–2012*. Islamabad: Global Change Impact Studies Centre (GCISC).

4. The sectoral shares in total GHG emission includes 45.9 percent from energy, 44.8 percent from agriculture and livestock sector (78 percent of total agriculture sector), 3.9 percent share of Industrial processes and 2.6 percent share of land use change for forestry sectors (Figure 2).

CO₂ = carbon dioxide, GHG = greenhouse gas, LUCF = land use change for forestry

5. Pakistan GHG emission is lower than most of its neighboring countries. Pakistan's per capita GHG emission is 0.90 MtCO₂ compared with 1.74 MtCO₂ in India and 8.28 MtCO₂ in Iran, but nearly three times Afghanistan (0.30 MtCO₂) and nearly twice of Bangladesh's emission (0.46 MtCO₂). However, the combined contribution of the energy and agricultural sectors to national emissions is similar across Pakistan, India, and Iran. Pakistan's energy and agricultural sectors account for 85 percent of total national emissions. Figure 3 shows main sources of GHG emissions in Pakistan's agriculture sector.

Figure 3. Main Sources of GHG Emissions in Agriculture Sector

Source: Food and Agriculture Organization of the United Nations 2014

6. If the GHG emission intensity for these sectors maintains this trend, it will double by 2020 compared to emission in 2008 and increase by around 14 times by 2050 (see Table 2).⁸

Table 2. Projected Greenhouse Gas Emissions by Sector in 2020 and 2050
Under Business as Usual Scenarios (in MtCO₂e)

Sector	1994	2008	2012	2020	2050
Energy	86	157	169	358	2,685
Agriculture	72	120	165	245	1,395
Industrial Processes	13	18	14	26	67
Land use change and Forestry	7	9	10	14	38
Wastes	4	6	10	7	15
Total national emission	182	309	369	650	4,200

MtCO₂e = million ton of carbon dioxide equivalent.

7. The climate change findings, based on Pakistan Metrological Department (PMD)'s computed temperature and precipitation change for different regions from 2011 to 2050, shows a maximum rise in the northern areas of Pakistan, central and south Punjab, and lower parts of Khyber Pakhtunkhwa Province. However, mixed trends are projected for precipitation over different regions of Pakistan. Table 3 shows the region-wide changes in temperature and precipitation over Pakistan.⁹ PMD's time series from 2010 to 2099 climate change scenarios (May 2015) show a 3°C-5°C rise in mean temperature under the Representation Concentration Pathways (RCP). The rainfall is highly variable. Sea level rose (SLR) by 1.1 mm/year during the past century.

⁸Government of Pakistan, Ministry of Planning, Development and Reforms. 2010. *Task Force Final Report on Climate Change*. Islamabad; K. A. Mir and M. Ijaz. 2015. *Greenhouse Gas Emission Inventory of Pakistan for the Year 2011–2012*. Islamabad: Global Change Impact Studies Centre (GCISC).

⁹ Q. Z. Chaudhry et al. 2009. *Climate Change Indicators of Pakistan*. Technical Report. No. 22. Islamabad.

Intergovernmental Panel on Climate Change (IPCC)-5 has projected a global mean SLR of 0.2-0.6 meter by the end of this century and for South Asia ranges between 0.42-1.42 meters.

Table 3. Region-wide Climate Projections for Pakistan for Alternative Scenarios 2011–2050

Region	Precipitation (mm/decade)			Temperature (°C/decade)		
	A2	A1B	B1	A2	A1B	B1
Pakistan	+1.73	+1.26	-0.89	+0.51	+0.41	+0.24
Northern Areas	+4.60	+2.90	-1.30	+0.76	+0.63	+0.39
Potohar and Upper KPK	+6.10	+3.80	-0.50	+0.01	-0.34	-0.01
Central/Southern Punjab And Lower KPK	-2.98	-1.78	-3.50	+0.63	+0.71	+0.05
Upper Balochistan	+1.48	+0.92	-0.57	+0.15	+0.26	+0.03
Southeastern Sindh	+5.10	+3.00	-0.10	0.00	-0.10	+0.01
Sindh and Lower Balochistan	-1.80	-0.98	-0.05	0.50	0.27	0.01

mm = millimetre

Notes: A2 shows business as usual, A1B shows balanced scenarios, and B1 shows Ideal World (SRECS Report IPCC 2001) based on greenhouse gas emissions likely in the 21st century.

III. The Indus Basin

8. The River Indus¹⁰ is a major trans-boundary river in Asia¹¹ with nine tributaries.¹² Based on the stream hydrology and morphology, the Indus River can be broadly divided into three segments: (i) the upstream segment, from the Singi Khahad spring down to Jinnah Barrage; (ii) the midstream segment, between Jinnah and Guddu barrages; (iii) and the downstream segment, from Guddu Barrage to the Arabian Sea. The upstream segment is largely a hilly catchment area; the midstream segment is an upper floodplains area dominated by a braided pattern of channels and tributary inflows; and the downstream segment is a lower floodplains area and has a flat topography, a meandering channel pattern and deltas. The upper Indus Basin catchment is further

¹⁰ The Indus River is about 2,800 kilometres (km) long, with 2,682 km in Pakistan. Its alluvial plain area is about 207,200 km², while its deltaic area is about 20,000 km². It originates in the Tibetan tableland at Singi Kahad spring, on Kailas Parbat (mountain) near Mansarwar Lake. It then passes through the Himalayan range, and collects runoff from the Hindu Kush and Sulaiman ranges. Its annual water runoff is about 200 cubic kilometers, and sediment discharge is approximately 200 billion kilograms yearly (Pakistan Water Gateway; accessed 29 November 2011)

¹¹ Others include the Amu Darya (Afghanistan, Turkmenistan, and Uzbekistan), Amur (People's Republic of China [PRC] and Russian Federation), Brahmaputra (Bangladesh, PRC, and India), Euphrates (Iraq, Syria, and Turkey), Ganges (Bangladesh and India), Mekong (Cambodia, PRC, Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam), and the Tigris (Iraq, Syria, and Turkey).

¹² Five of them are on the left bank with upper catchments of Beas, Ravi, and Sutlej in India while Chenab and Jhelum are in Pakistan. The main right bank tributaries are the Gomol, Kabul, Swat and Kurram rivers.

sub-divided into four zones based on basin's geophysical and hydro-climatic characteristics:¹³ zone one - more than 5,500 m asl; zone two - 4,500–5,500 m asl; zone three, 3,000–4,000 m asl; and zone four, 1,000–3,000 m asl.

9. **Indus Basin Irrigation System (IBIS), with three major multipurpose storage reservoirs (Mangla, Tarbela and Chasma), 19 barrages, 12 inter-river link canals, 45 major irrigation canal commands (about 56,000 km) and more than 120,000 km of watercourses in tandem with vast and** growing process of groundwater extraction through private tubewells delivering water to farms and other productive uses, is the backbone of the country's agricultural economy (see Figure 4). The infrastructure developed under the Indus Water Treaty of 1960 has helped improved water resource availability basin wide increasing canal diversions from 67 MAF in 1949/50 to about 106 MAF out of total annual flows of 146 MAF. The designed live while storage capacity of Indus Basin is 18.92 MAF, which includes 9.7 MAF of Tarbela, 8.51 MAF of Mangla and 0.71 MAF of Chashma is around 14 percent against world average storage capacity 35-40 percent. But due to silting, this live storage capacity has been reduced to 12.32 MAF showing a loss of 35 percent, which is for 30 days requirement against India's storage capacity of 120 days. Overall, Indus irrigates about 18 million hectares (ha) of land in Pakistan.

Figure 4. Schematic Diagram of Indus Basin

¹³ Hewitt, K. 1989. The Altitudinal Organization of Karakoram Geomorphic Processes and Depositional Environments. *Zeitschrift für Geomorphologie, Supplementband*. 76. pp.9–32.

IV. Agriculture Sector of Pakistan

10. The agriculture sector employs approximately 42.3% of the country's labor force and contributes 19.5% of GDP¹⁴, of which 8.8% and 11.4% is shared by the crop and livestock subsectors respectively. In addition, the sector contributes about 80% of the country's foreign exchange earnings mainly from textile sector exports (62%) e.g. cotton. Another 18% comes from the export of raw and processed agriculture, livestock, and fisheries commodities. The threat of climate change has harsh socio-economic implications, particularly on the country's agricultural production systems. For those living in the Punjab and Sindh provinces (accounting for 101.4 and 56 million people, respectively – also known as Pakistan's food basket), a change in climate will mean a change in food security situation and social and economic wellbeing.

¹⁴ Pakistan Economic Survey 2016/17. Economic Adviser's Wing Economic Adviser's Wing, Finance Division, Government of Pakistan, www.finance.gov.pk Islamabad.

11. With rapid population growth and urbanization occurring in the country, the above-mentioned climatic impacts on food production may result in decreased yields which would cause both national and household food insecurities, increased levels of extreme poverty and subsequent increases in climate vulnerability, if appropriate measures are not in place. It is widely recognized that rural societies in Pakistan would be further undermined by extreme weather events such as floods¹⁵ and droughts¹⁶, as these occurrences are expected to rise. The impact of climate change will also aggravate the existing social inequalities of resource use and intensify social factors leading to instability, conflicts, displacement of people and changes in migration patterns.

V. Water Sector Challenges in Pakistan

12. **Notwithstanding increase in availability of water, the water sector of Pakistan is facing serious challenges.**¹⁷ These challenges include: (i) Pakistan's dependence on a single river system and does not enjoy multiplicity of river basins and diversity of water resources like India, therefore it cannot mobilize additional water intervention than what it has now; (ii) the delta, deprived of the water and silt, is degrading fast in addition to large scale uncontrolled pollution of surface and groundwater from increasing quantities of pesticides as well as fertilizers used in agriculture and sewage; (iii) *laissez-faire* approach to ground water mining for agriculture for the past fifty years is now showing signs of over-exploitation, accumulation of salt in the system and effect on quality of water; (iv) climate change is affecting western glaciers on which Indian Basin depends heavily which will cause flooding and drainage problems especially in the lower parts of the basin; (v) Pakistan's water infrastructure is in poor shape as it is not financially sustainable because of low user charges and require effective Asset Management Plan; (vi) Pakistan has little water storage capacity of only 150 cubic meters per capita against 5000 cubic meters in the United States and 3000 cubic meters in China¹⁸; (vii) per capita availability of water in Pakistan is well below Afghanistan, India, Bangladesh and Somalia¹⁹ and this stress is likely to worsen further in view of growing population, urbanization and stagnant supply;²⁰ and (viii) demand for water is

¹⁵ Economic losses from floods in 2010 were estimated to be higher than USD 10 billion (ADB and World Bank, 2010), with more than 20 million people affected.

¹⁶ Two droughts that occurred between 1999-2000 and 2000-2001 stretched existing systems to the limits of their coping abilities and have placed the country on the brink of a catastrophe. In areas where drought has overstressed Pakistan's rangelands, human and livestock populations are shifting away from their original locations and moving towards riverine areas and mountainous regions.

¹⁷ Jhon Briscoe and Usman Qamar, "Pakistan's Water Economy-Running Dry", The World Bank, 2005.

¹⁸ The dams of the Colorado and Murray-Darling Rivers can hold 900 of river runoff, South Africa can store 500 days in Orange River, India between 120-220 days in its major rivers whereas Pakistan can barely store 30 days of water.

¹⁹ World Bank data retrieved from <http://data.worldbank.org/indicator/ER.H2O.INTR.PC>, 2015

²⁰ The estimates on total water availability differ considerably: according to Pakistan Water Partnership (PWP), total surface water available in Pakistan is about 153 MAF, and the total ground water reserves are approximately 24 MAF (Source: <http://pwp.org.pk>)

likely to reach 267 million MAF by 2025, whereas supply would remain stagnant at around 150 MAF (barring the impact of the climate change), resulting in a gap of approximately 117 MAF.²¹

13. Pakistan is already facing variations in average water flows in the rivers (Table 4). 2001-2002 average reflects impact of drought in Pakistan

Table 4. Declining Average Annual Flow²²

River	Average Annual Flow 1922-1961	Average Annual Flow 1985-1995	Average Annual Flow 2001-2002	Average Annual Flow 1961-2010	Standard Deviation 1961-2010
Indus	93.0	62.7	48.0	60.30	7.37
Jhelum	23.0	26.6	11.9	22.08	4.70
Chenab	26.0	27.5	1.4	25.48	4.03
Sutlej	7.0	5.0	1.5	2.59	2.99
Ravi	14.0	3.6	0.0	4.13	2.83
Kabul	26.0	23.4	18.9	15.93	3.89
Swat				4.69	1.06
Soan				1.07	0.47
Harro				0.73	0.54
Total	189.0	148.8	92.6	135.85	16.05

14. **Groundwater.-** The underlying aquifer covers about 16 million ha (Mha) of surface area, of which 6 Mha are fresh and the remaining 10 Mha are saline.²³ The volume of usable ground water in storage is 2.470 billion cubic meter (BCM). The safe yield is estimated for agriculture, domestic and industrial sectors is about 68 BCM whereas the extraction is already approaching to about 51 BCM.²⁴ The gap between crop water requirements and surface water availability is met through groundwater leading to rapid expansion of private tube-wells. Currently, around 1.355 million small capacity private tube-wells are operating in Pakistan, out of which 1.02 million²⁵ are located in Punjab, extracting 52 BCM of groundwater.²⁶ These tube-wells (exclusively) and combined with canal water irrigated 19 percent and 42 percent of cultivated land, respectively, in Pakistan accounting for more than 60 percent of farm gate water.²⁷ This uncontrolled and

²¹ Kahlowan, M. Akram, and A. Majeed. (2002). 'Water resource situation in Pakistan: Challenges and future strategies'. Science Vision Quarterly, Vol. 7, No. 3&4, Jan-Jun 2002

²² Pakistan Water Gateway and Winston Yu, Yi-Chen Yang, Andre Savitsky, Donald Alford, Casey Brown, James Wescoat, Dario Debowicz, and Sherman Robinson. 2012. *The Indus Basin of Pakistan: The Impacts of Climate Risks on Water and Agriculture*, Washington, DC: World Bank, p.80.

²³ A.S.Qureshi, M.A.Gill, and A.Sarwar, 2010, *Sustainable groundwater management in Pakistan: Challenges and opportunities*, Irrigation and Drainage, Vol. 59, Issue 2:107-116.

²⁴ Arshad Rafiq and Khawar Shahzad (eds.), *Groundwater Management in Pakistan: An Analysis of Problems and Opportunities*, LEAD Pakistan 2016

²⁵ Development Statistics of Punjab, 2015-16

²⁶ A.S. Qureshi, op.cit.

²⁷ Statistical Supplement of Economic Survey of Pakistan, 2016-17

unregulated extraction of groundwater in excess of recharge is lowering the water tables making groundwater inaccessible in 5 percent and 15 percent of the irrigated areas of Punjab and Balochistan provinces, respectively, which are likely to reach 15 and 20 percent if the current trend continues.

15. It is also causing increase in the salt-affected soils to more than five million hectares, over 22 percent of Pakistan's irrigated lands. The quality of groundwater ranges from fresh (salinity less than 1000 mg/l Total Dissolved Solids (TDS) near the major river (49 percent), to moderate salinity between 1000-3000 mg/l TDS (15 percent) and high salinity with more than 3000 mg/l TDS (36 percent), farther away. Some 14.2 million acres are underlain with groundwater having salinity less than 1000 mg/l TDS, 4.54 million acres with salinity from 1000 to 3000mg/l TDS and 10.57 million acres with salinity more than 3000 mg/l TDS.

16. **Water losses in agriculture, which is highest user of water (93 percent), are abnormally high because of (a) evaporation; (b) seepage; and excess discharge into the sea which aggravates the water scarcity further.** The evaporation losses are not only hard to account for, but also difficult to control. According to estimates, losses due to seepage are high: around 25-30 percent of available water is lost in canals and water courses, followed by another 25-40 percent in water application. Although this seepage recharges the underground aquifer (and is recoverable), a significant supply is lost to saline aquifers.²⁸ Controlling this loss requires heavy investment in water infrastructure. As far as discharge into the sea is concerned, this is a function of the seasonal mismatch in water inflow and its usage; available storage; and the need to maintain a balance between sea-water and freshwater in the coastal areas.

Table 5. Pakistan's Irrigation Water Uses (MAF)²⁹

Location	Delivery at Head	Losses	
		Percentage	MAF
Main & Branch Canals	106	15	16
Distributaries and Minors	90	8	7
Watercourses	83	30	25
Fields	58	29	17
Crop Use	41		
Total		61	65

17. **Of the 106 MAF of irrigation water that goes into the system, only 41 MAF reaches crops, a loss of about 61 percent of the water delivered at the canal heads (Table 5).** About 25 MAF are lost in watercourses and 17 MAF in fields, the most vulnerable components of the

²⁸ John Brisco and Usman Qamar, op.cit.

²⁹ Winston Yu, Yi-Chen Yang, Andre Savitsky, Donald Alford, Casey Brown, James Wescoat, Dario Debowicz, and Sherman Robinson. 2012. *The Indus Basin of Pakistan: The Impacts of Climate Risks on Water and Agriculture*, Washington, DC: World Bank.

irrigation system. Therefore, inefficient use of water is a major challenges facing Pakistan's agriculture. The economic cost of water is estimated at \$1-2 billion per MAF and by virtue of it, at the lower level, Pakistan wastes a potential of \$65 billion (22% of GDP) every year.

18. **Water productivity is considerably low in Pakistan compared to other countries.** The crop yields, both per hectare and per cubic meter of water, are much lower than international benchmarks (**Table 6**). This is due to excessive reliance on traditional irrigation methods (flood irrigation) which causes huge water losses due to excessive run-off, deep percolation and evaporation. It not only damages the land quality (water logging), but also reduces crop yields as excessive water leaches the nutrients out of the root zone.³⁰

Table 6. Comparison of Water Productivity

	Productivity Per Unit of Land	GDP Per Cubic Meter of Water	Productivity per Unit of Water
Country	Tons/Hectare	Constant 2005 US\$	Kg/m ³
USA	7.34	30.20	1.56
Germany	7.32	98.33	
Egypt	7.25	1.88	
France	7.10	74.54	
Japan	6.10	53.13	
China	5.89	8.86	0.80
Vietnam	5.42	1.12	
Indonesia	5.15	3.96	
Brazil	4.83	16.09	
Bangladesh	4.36	3.12	
India	2.96	1.96	0.39
Kyrgyz Republic	2.90	0.44	
Pakistan	2.72	0.78	0.13

Source. World Bank Indicators Database 2015

19. **Water Use and Intensity.- Water withdrawals globally have increased as result of rising population and economic growth.** It has risen by a factor of 40, from 100 BCM in year 1700 to 4,104 BCM in 2010, exceeding 11-fold increase in population over the same period and far less than 144-fold increase in global GDP, surging from US\$ 371 billion in 1700 to US\$53,394 billion.³¹ Table 7 includes 10 countries withdrawing the most water, seven populous countries in the world, six largest economies and five countries with the most land cultivated for agriculture. Pakistan's water use per unit of income is the highest which indicates inefficient use of water.

³⁰ Kahlown, M. Akram., M. Ashraf and M. Yasin. (2003), '*Water Management for Efficient Use of Irrigation Water and Optimum Crop Production*', Pakistan Council of Research in Water Resources, Islamabad.

³¹ International Monetary Fund, *Is the Glass Half Empty or Half Full? Issues in Managing Water Challenges and Policy Instruments*, July 2015

Table 7. Water Withdrawals in 2010: Top 10 Countries

Country	Freshwater Withdrawal (BCM)	Population (In Million)	PPP GDP (in billions US\$)	Agricultural Land Area (in thousands of square kilometre)	Withdrawals (cubic meters per capita)	Withdrawals (Cubic meters per unit of GDP)	Withdrawals (Cubic meters per square kilometre)
India	760	1,206	4,130	3,287	631	18	231
China	627	1,360	10,040	9,597	461	6	65
USA	441	312	14,958	9,629	1,413	3	46
Pakistan	183*	179	487	796	1,022	38	230
Indonesia	166	241	1,026	1,905	691	16	87
Iran	89	74	942	1,648	1,202	9	54
Russia	80	144	2,222	17,075	558	4	5
Mexico	80	118	1,603	1,958	676	5	41
Philippines	79	93	365	300	848	22	264
Japan	76	127	4,351	378	596	2	201
World	4,104	6,837	73,658	131,077	600	6	31

*Heavy Flood Year

20. As noted in Figure 2, energy sector is now the biggest contributor to GHG with 46 percent share of which 26 percent is attributed to electricity consumption, 25% to manufacturing, 23% to transportation and the remaining 25% to other energy subsectors, followed by the agriculture sector (45 percent), industrial process (4 percent) and other activities. It is estimated that extracting 1 m³ groundwater required 0.820 kWh of energy in Pakistan. It requires around 43 billion kWh to pump 52 BCM of groundwater which is increasing GHG emission in Pakistan.

VI. Climate Change in South Asia

21. Table 8 provides a summary of observed climate change in South Asia, based on Working Group II Report of IPCC's Third Assessment³², which characterizes variability by increase in air temperature which are more pronounced during winter than in summer and precipitation with decreasing trend in annual mean rainfall in the coastal belts and arid plains of Pakistan.

22. Table 9 provides a summary of observed changes in extreme events and severe climate anomalies in South Asia.³³

23. Observed climate change in South Asia based on Fifth Assessment of IPCC Working Group II Report, 2014 is iterated below:³⁴

³² Rex Oafallas Cruz, Murari Lal, and Mostafa Jafari, *Asia. Climate change 2007: Impacts, Adaptation and Vulnerability*, August 2007.

³³ Cruz, op.cit.

³⁴ Inter-Governmental Panel on Climate Change Report, 2014, (Asia Chapter)

Table 8. Summary of key observed Past and Present Climate Trends and Variability in Some countries in South Asia

Country	Change in Temperature	Change in Precipitation
Bangladesh	Increasing trend of about 1°C in May and 0.5°C in November from 1985 to 1998	Decadal rain anomalies above long term averages since 1960s
India	0.68°C increase per century with increasing trends in annual mean temperature and warming more pronounced during post monsoon & winter	Increase in extreme rains in northwest during summer monsoon in recent decades and lower number of rainy days along east coast
Nepal	0.09°C increase per year in Himalayas and 0.04°C in Terai region with more in winter	No distinct long-term trends in precipitation records for 1948–1994
Pakistan	6–1.0°C increase in mean temperature in coastal areas since early 1900s	10–15% decrease in coastal belt and hyper arid plains and increase in summer and winter precipitation over the last 40 years in northern
Sri Lanka	0.016°C increase per year between 1961 to 90 over entire country and 2°C increase per year in central highlands	An increase trend in February and decrease trend in June

Table 9. Extreme Events and Severe Climate Anomalies

Climatic Event	Observed Change
Heat waves	Frequency of hot days and multiple-day heat wave has increased in past century in India with an increase in deaths due to heat stress in recent years
Intense rains and floods	Serious and recurrent floods in Bangladesh, Nepal and north-east states of India during 2002, 2003 and 2004; floods in Surat, Barmer and in Srinagar of India during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain.
Droughts	50% of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in Pakistan and Northwest India led to sharp decline in water tables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected ~11 million people in Orissa, India; droughts in Northeast India during summer monsoon of 2006.
Cyclones/typhoons	Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity is increasing causing severe floods in terms of damages to life and property.

- Precipitation has declined in South Asia from 1900 to 2005.
- Future climate change is *likely* to affect water resource scarcity with enhanced climate variability and more rapid melting of glaciers.
- Increased risk of extinction for many plant and animal species in Asia is *likely* as a result of the synergistic effects of climate change and habitat fragmentation.
- Projected sea level rise is *very likely* to result in significant losses of coastal ecosystems.
- Due to projected sea level rise, a million or so people along the coasts of South and Southeast Asia will likely be at risk from flooding.
- Climate change is likely to impinge on sustainable development of most developing countries of Asia as it compounds the pressures on natural resources and the

environment associated with rapid on natural resources and the environment associated with rapid urbanization, industrialization, and economic development.

- Vulnerabilities of industry, infrastructure, settlements, and society to climate change are generally greater in certain high-risk locations, particularly coastal and riverine areas.

VII. Vulnerability of Pakistan to Climate Change

24. Pakistan's geographical location and socioeconomic fragility makes it one of the most vulnerable countries to environmental, social and economic implications of climate change.³⁵

The Hindu Kush-Karakoram-Himalaya (HKH) region from where Indus Basin originates is susceptible to climate change as it is influenced by three major weather systems:³⁶ (i) the sub-Mediterranean regime of winter, westerly storms; (ii) Indian summer monsoon originating in the Bay of Bengal; and (iii) Tibetan anticyclone.

25. Pakistan is classified as Arid country. Table 10³⁷ reflects the extent of dry areas showing that around 11 percent of the area has annual rainfall of 250-500 mm, about one half has rainfall ranging from 150-250 mm and about one-third has less than 150 mm annual rainfall.

Table 10. Extent of Dry Areas, Based on Aridity Index, in Pakistan

Area	Rainfall Regime	Million hectares	% of Total
Total Area	<150-> 1,000 mm	79.61	100
Semi-Arid	200-500 mm Aridity Index 16-31	8.76	11
Arid	150-250 mm Aridity Index 8-16	38.21	48
Hyper Arid	<150 mm Aridity Index <8	26.27	33

Note: Aridity Index = $\sum 1.65 (\text{Precipitation/Temperature} + 12.2) * 0.9$

26. **IPCC (2007) projects high seasonal variations for South Asia.** Water resources of the Indus basin are at risk from changes in temperature, glacier retreat, floods and droughts and sea level rises (Table 11).³⁸ This causes seasonal variations in Indus River flows, 84 percent in Kharif³⁹

³⁵ J. Burck, F. Marten, and C. Bals. (2014). The Climate Change Performance Index 2014. German Watch, 2014. 28 pages.

³⁶ T.G. Huntington, (2006). Evidence for intensification of the global water cycle: review and synthesis. Journal of Hydrology, 319(1): 83-95

³⁷ Muhammad Mohsin Iqbal, M. Arif Goheer, Arshad M. Khan, *Climate-Change Aspersions on Food Security of Pakistan*, Science Vision, Vol.15, No.1, (January to June 2009)

³⁸ Adapted from Heather R. Hosterman, Peter G. McCornick, Elizabeth J. Kistin, Anju Pant, Bharat Sharma, Luna Bharati, "Water, Climate Change, and Adaptation", August 2009

³⁹ Autumn crops sown at the beginning of summer rains

and about 16 percent during Rabi.⁴⁰ Shortages of water have been estimated from 1 percent in 1994-95 to 49 percent in 2001-02.

Table 11. Country-wise climate risks for the Indus-Gangetic basin countries

Climate risks	Pakistan	India	Nepal	Bangladesh
Temperature rise	High	High	Very high	High
Glacier retreat	High	High	High	---
Frequent floods	Low	High	High	Very high
Frequent droughts	High	High	High in some areas	High in some areas

27. **Precipitation and Rainfall.- Pakistan experiences all the three types of rainfall: orographic, frontal and convective depending upon the location and season of the year.** Pakistan's total annual precipitation ranges between 500mm and 800 mm with northern half receiving the higher share from both winter and summer. Southern parts of Pakistan (Balochistan and Sindh) receives 50 percent of the northern. Sindh adjoining the coastal belt covering the Indus Delta receives better rainfall than upper Sindh. Visible changes have been observed in precipitation pattern, cropping patten, droughts, water availability periods, frequency and intensity of heat waves and weather induced natural disasters in Pakistan. Winter now is experiencing significant decline in precipitation in northern mountainous region during the last few years. Summer precipitation in northern parts has decreased in terms of total amount but its inter-annual variability has increased.

28. **Southern parts of Pakistan, particularly the Indus Delta, demonstrating a moderate increase in rainfall due to localized heavy spells during monsoon season.** Nevertheless, this is not supporting the socio-economic activities as heavy soils with poor drainage leave the rainwater stagnant destroying the standing crops. 1960 to 1997 witnessed inter-annual variability of mean daily temperature. However, failure of summer rains due to El-Nino effect in 1998 affecting 75 out of 106 districts in Pakistan with drought.⁴¹ The precipitation during the years 1997-2000 over most of Pakistan was less than 50 percent of the normal and heat continued to persist causing severe loss to agriculture production. Recent changes and extreme weather events are at Box 1.⁴²

29. **Water and agriculture sectors are most sensitive to climate change.** Agriculture. Increasing temperature, severe drought, flood conditions, and soil degradation are expected to affect agriculture productivity. Forest ecosystems are likely to suffer from floods and increased melting of permafrost regions. Increasing temperature would negatively affect yield. However, increased irrigation offset this negative effect.⁴³ Temperature rise will negatively impact rice and

⁴⁰ Spring crops sown during winter (October)

⁴¹ 143 human-beings and 2.48 million livestock died during November 1999 and end July 2000. Loss was more pronounced in arid areas of Balochistan and Sindh.

⁴² Pakistan Meteorological Department, Climate Change in Pakistan: Focused on Sindh Province

⁴³ Jesse Tack *et al* 2017 *Environment Research Letters*. 12 114027

wheat yields in tropical parts of South Asia where these crops are already being grown close to their temperature tolerance threshold.⁴⁴ Wheat yields are predicted to decline by 6–9% in sub humid, semiarid, and arid areas with 1°C increase in temperature,⁴⁵ while even a 0.3°C decadal rise could have a severe impact on important cash crops like cotton, mango, and sugarcane. Rain-fed wheat grown at 450 ppm CO₂ demonstrated yield increases with temperature increases of up to 0.8°C, but declines with temperature increases beyond 1.5°C; additional irrigation was needed to counterbalance these negative effects.⁴⁶

Box 1. Extreme Weather Events in Pakistan 1999-2017

Cloud Burst Events: 2001, 2003, 2007, 2008, 2009, 2010, 2011, 2017

Prolonged Drought: 1999-2002

River Flooding: 2010, 2011, and 2014

Tropical Cyclones: 1999, 2001, 2004, 2007, 2009, 2010, 2011

Severe Urban Flooding: 2001, 2003, 2007, 2008, 2009, 2010, 2011

Heat Waves in Spring: 2006, 2007, 2010, 2011 (Reduced the wheat yield)

Snowmelt flooding: 2005, 2007 and 2010

Drought at sowing stage: 2004, 2006, 2007, 2009, 2010 and 2011

30. Agriculture sector is the major water user consuming 93 percent of water, far higher than the domestic (5 percent) and industrial sector (2 percent). Of the total cropped area of 23.4 million hectares (Mha), 18.63 Mha is irrigated, 77 percent of which is located in Punjab, 14 percent in Sindh, 5 percent in Khyber Pakhtunkhwa (KPK), and 4 percent in Balochistan.⁴⁷ 3.8 Mha is under spate irrigation farming system (includes Sailaba/Rod Kohi, riverine and Barani).⁴⁸ The potential area under spate irrigation is estimated to be around 6.935 Mha. Evidence also suggests that crops grown⁴⁹ in irrigated as well as spate farming areas are sensitive to water availability and temperature variability.

⁴⁴ Kelkar U, Bhadwal S (2007) South Asian regional study on climate change impacts and adaptation: Implications for human development. Human Development Report Office, Occasional Paper. United Nations Development Programme, 2007.

⁴⁵ Muhammad Mohsin Iqbal, M. Arif Goheer, Syed Sajidin Hussain, and Humaira Sultana, *Climate Change and Wheat Production in Pakistan: Calibration, Validation and Application of CERES-Wheat Model*, 2009.

⁴⁶ Sivakumar, et al.

⁴⁷ Government of Pakistan, Bureau of Statistics. 2011. *Agricultural Statistics of Pakistan: 2010–2011*. Islamabad.

⁴⁸ The spate irrigation farming system refers to a type of water management unique to semiarid environments. Flood water from mountain catchments is diverted from river beds and spread over large areas.

⁴⁹ The major patterns of crops in Pakistan include: (i) rice–wheat, (ii) maize–wheat, (iii) cotton–wheat, (iv) sugarcane–wheat, and (v) coarse grain–wheat, and some other minor crops patterns, such as pulses, vegetables, etc.

31. The evidence suggests that an increase of 1°C in mean temperature would reduce wheat yield by 5-7 percent in Pakistan, a major staple food in Pakistan (Sivakumar and Stefanski, 2011). Cereal crops are already at the margin of stress. An increase in temperature is likely to result in decline in yields mainly due to shortening of crop life cycle. Direct impact is associated with rise in temperature. However, water availability and changes in soil moisture, pest and disease incidence would have indirect impact. The most vulnerable would be the small landholders and rain-fed farmers and possess low financial and technical capacity to adapt to climate variability and change. Expected decreases in yield by 2050 range between approximately 6-12% for cereal crops and 5-13% for vegetables and tropical fruits.

32. Following vulnerabilities in agriculture and water sector have already been observed in the Indus Basin:

- **Shortening Length of Growing Period.** Increase in average temperature is expected to shorten growing season cycle (Growing Degree Days) maturing the crops earlier which would affect crop production.
- **Yield Losses.** Shortening of the crop cycle may lead to yield-loss and the rainfed areas of wheat production in South and Southeast Asia are likely to suffer substantial losses. The drop in yield in non-irrigated wheat and rice would be significant for a temperature increase incurring farm level net revenue, depending on regional difference.⁵⁰
- **Production Loss in arid and semi-arid areas.** Rising temperatures, resulting in enhanced heat and water stress conditions, particularly in arid and semi-arid regions leading to reduced agricultural productions.
- **Projected Recession.** Rising atmospheric temperature is likely to increase the glacier melt resulting in increased flooding in the next 2-3 decades (IPCC-2014) followed by receding water availability for agriculture. It would affect inter-annual pattern of rivers flows, increased dependency on rainfall and may threaten energy security (Hydropower).
- **Increased Evaporation.** Evapotranspiration losses (evaporation from soil surface as well as transpiration from the plant leaves) will increase with rise in average temperature implying increased irrigation water to maintain plants' optimum growth.
- **Land Degradation.** About 43 percent (7.06 Mha of the area in IBIS (16.7 Mha), such as Gujranwala, Muzafar Garh, Khairpur, Jhang, Multan, Thatta, Badin, and parts of Sindh, is classified as waterlogged with depth to water table of <3 meter of which 81 percent (4.63 Mha) is located in Sindh (Table 12).

⁵⁰ Gunther Fischer, Mahendra Shah and Harrij Van Velthuisen, 2002. Climate change and agricultural variability, A special report on 'Climate change and agricultural vulnerability', Contribution to the World Summit on Sustainable Development, Johannesburg, South Africa.

- **Salinity.** 27 percent of the area is salt affected (Table 13).⁵¹ Rise in temperature is likely to aggravate the challenge of salinity further as evaporated waters leaves salts on surface soil. Makhdum and Ashfaq suggests that salinity and waterlogging are negatively associated with wheat production⁵² besides having adverse social and economic implications.

Table 12. Extent of Water Logging in Pakistan (Depth to Water Table) 2011⁵³
000 Hectares

Province	Area under Various Depth to Water Table Ranges						Total Area
	0-90 cm	90-150 cm	150-300 cm	300-450 cm	450-600 cm	>600 cm	
Punjab	232.92	399.27	1340.34	1506.42	1423.50	5060.55	9964.00
Sindh	485.55	1672.67	2557.49	536.25	247.67	236.27	5735.90
KPK	12.57	127.81	126.03	30.65	26.92	75.12	399.10
Balochistan	8.80	10.98	87.15	102.05	66.63	311.89	587.50
Total	740.84	2210.73	4111.01	2175.37	1764.72	5683.83	16686.50

Table 13. Province Wise Surface Salinity Status (Hectares)

Province	Total Acreage	Salt Free (S1)	Slightly Saline (S2)	Moderately Saline (S3)	Strongly Saline (S4)	Misc. Land Type
Punjab	24,954,966	21,754,266	913,426	444,647	398,757	1,443,870
%		87	4	2	1	6
Sindh	14,045,599	6,148,594	2,736,729	1,339,110	2,855,168	965,998
%		44	19	10	20	7
KPK	1,859,105	1,859,105	37,580	26,920	7,191	54,624
%		88	2	2	*	8
Balochistan	862,214	382,690	252,788	108,699	90,638	27,399
%		44	29	13	11	3
Total	41,721,884	29,918,340	3,940,523	1,919,376	3,351,754	2,591,891
%		73	10	4	7	6

- **Sea Intrusion.** Increased cyclones result in sea encroachment in the costal belt causing soil degradation and salinization of fresh water ponds. Increased intrusion of saline water in the Indus delta, would adversely affect coastal agriculture. The shoreline erosion rate is estimated to be 45.69 meters per year in zone I and 52.1m per year in zone II. In zone III and zone IV, 27.21m per year and 31.43m per year erosion was calculated respectively. The sea has encroached upon 1.24km in zone II, followed by zone I where 1.1km was conquered by the sea.⁵⁴
- **Indus Delta.** The Indus River Delta mangroves, only arid mangroves of the entire ecozone, represent an ecosystem which is highly adaptable to extreme temperature,

⁵¹ Soil and Reclamation Directorate of WAPDA, 2006, and Agriculture Statistics of Pakistan, 2015-16.

⁵² M.S.A. Makhdum and M. Ashfaq (2008). *An economic evaluation of negative impact of water-logging and salinity on wheat productivity*, Soil & Environment 27(1): 105-108.

⁵³ Agriculture Statistics of Pakistan, 2015-16

⁵⁴ Study of United States-Pakistan Centre for Advanced Studies in Water (USPCASW) in Mehran University of Engineering and Technology (Findings published in Tribune Express, 3 March 2018).

high salinity levels, and minimal rainfall. Due to excessive salinity, species diversity of mangroves is poor with distinct dominance of salt tolerant *Avicenna Marina*. These mangroves are reported to be adversely affected by massive reduction of freshwater flow downstream Kotri Barrage.⁵⁵

- **Extreme Climate Events.** Frequency and intensity of flash floods, cloud bursts, droughts, cyclones, hail storms, and dust storms is likely to increase in future (IPCC 2014) which could spoil standing crops and cause food security challenge.

VIII. Climate Change Risk Perception and the Farmers

33. Farmers' decisions to pursue adaptation strategies are influenced by their perceptions of the risks associated and their experiences with climate variability. The upturn in the intensity of climate variability impacts at farm level would drive farmers to perceive threat of climate change and to take preventive measures---adaptation strategies---acquiring new technologies, adjusting current practices and agriculture insurance, etc. Understanding the relationships between farmers' climate change beliefs, risk perceptions, and attitudes towards innovation and adaptation is a key step towards formulating a comprehensive climate change policy.⁵⁶ Based on their risk perception about changes in climate, the farmers and stakeholders can adopt any one of the following strategies for mitigation:

- Adjustment in current practices to cope with increasing climate variability, in inputs and crop choices, cropping pattern, and scale of production.
- Acquire new technologies
- Procure crop insurance
- Diversifying sources of household income including off-farm job
- Connect to early warning system and weather forecasting

IX. Mainstreaming Climate Change

34. Generally, the activities for mainstreaming climate change include:

- Diagnostic of the challenges, assessment of risks, and evaluation of current policies
- Identification of policies, measures and practices that might need modification to reduce vulnerabilities.
- Analysis of appropriate institutional and participatory mechanisms to address wider environmental externalities such as adaptation to climate change.

⁵⁵ Rajarshi Das Gupta and Rajib Shaw, *Cumulative Impacts of Human Interventions and Climate Change on Mangrove Ecosystems of South and Southeast Asia: An Overview*, Journal of Ecosystems, Volume 2013 (2013), Article ID 379429, 15 pages, <http://dx.doi.org/10.1155/2013/379429>

⁵⁶ Amber Saylor Mase a,†, Benjamin M. Gramig b, Linda Stalker Prokopy, *Climate Change Beliefs, Risk Perceptions, And Adaptation Behavior Among Midwestern U.S. Crop Farmers*, Climate Risk Management 15 (2017) 8–17

- Framing of policies and legislation to deal with the risks and challenges.
- Mainstreaming involves the integration of information, policies and measures to address climate change into ongoing development planning and decision-making making a more sustainable, effective and efficient use of resources rather than designing and managing climate policies in isolation.⁵⁷

Huq and Ayers (2008) proposed a framework for mainstreaming at the national level (see Figure 5).⁵⁸

Figure 5. Four Step to Mainstreaming Climate Change

35. Step 1 in mainstreaming climate change needs investment in developing national level capacity to generate local appropriate evidence to ensure that adaptation priorities are country owned and locally responsive. Step 2 suggests presentation of required information to the decision-makers and highlights the needs for policy response. Step 3 proposes pilot activities and to assess responses to projected interventions as well as adaption and step 4 involves full integration of climate change into policy and planning across all sectors shifting from ‘business as usual’ to investment and planning seeking climate change resilience and bringing Planning, Finance and Climate Change ministries on board.

⁵⁷ R.J.T. Klein, L. Schipper, & S. Dessai. (2003). *Integrating mitigation and adaptation into climate and development policy: Three research questions*. Tyndall Centre Working Paper 405. Tyndall Centre.

⁵⁸ Huq, S., & Ayers, J. (2008). Streamlining adaptation to climate change into development projects at the national and local level. In European Parliament (Ed.), *Financing climate change policies in developing countries* (pp. 52–68). Brussels: European Parliament.

X. Approaches to Adaptation

36. Recent literature on climate change suggests two principal strategies for developing climate resilience: **mitigation**, which concerns all policies and measures aimed at reducing the emission of GHG such as CO₂ or at capturing them in forests, oceans, or underground reservoirs;⁵⁹ and **adaptation**, which seeks adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC). Article 4.1 of the United Nations Framework Convention on Climate Change (UNFCCC) requires of the parties to factor in climate change adaptation in development planning and develop National Adaptation Programmes of Action (NAPAs) under the UNFCCC and that NAPAs should be mainstreamed into national development planning processes.

37. Climate change adaptation is aimed at reducing the vulnerability of natural, social, economic and institutional systems to such climate variability. It requires developing adaptation priorities through vulnerability assessments to address adaptation deficit such as **climate smart agriculture, water use efficiency, rehabilitation and maintenance of water drainage systems, forest cover loss and soil erosion, land use and coastal protection and flooding in rural and urban areas due to poor development**. It will help in building resilience (see figure 6).

⁵⁹ Richard J.T. Klein, Mainstreaming climate adaptation into development policies and programmes: A European perspective. In European Parliament (Ed.), Financing climate change policies in developing countries (pp. 38–50). Brussels: European Parliament.

⁶⁰ J. Carew-Reid, T. Ketelsen, A. Kingsborough, and S. Portar, 2011. *Climate Change Adaptation and Mitigation (CAM) Methodology Brief*. ICEM-International Center for Environmental Management, Hanoi, Vietetnam.

Recommendations for Adaptation in Agriculture Sector

39. It is in this context of potential economic consequences that Pakistan needs adaptation measures urgently to reduce the likely adverse impacts of ensuing from climate change. These include:

- (i) **Redefining Agro-Ecological Zones:** Pakistan is classified in nine agro-climatic zones by Pinckney (1989) and ten agro-ecological zones.⁶¹ These zones were last defined during the 1980s. Since then, not only the soil has undergone changes but also the the impact of climate change is getting visible. The availability of surface and underground water, and rainfall variations have been observed. These changes necessitates redefining Agro-ecological zones in Pakistan.
- (ii) **Water Management System:** As highlighted *supra*, water losses in Pakistan are abnormally high (61 percent of the total water availability) because of evaporation, seepage and excess discharge into the sea which exacerbates the water scarcity. Provincial Irrigation Departments are not well equipped to count water evaporation or seepage. The water management system is in poor shape and is managed in traditional way. Therefore, it is critical to build institutional capacity of Provincial Irrigation Departments as well as at the Federal level for developing water accounting system, both surface and groundwater, establish technology driven evapotranspiration based water monitoring and management system.
- (iii) **Water pricing and subsidies.** Water subsidies generally benefit upper-income groups in developing economies, as the poor often have limited or no water access. Current water pricing in Pakistan and agricultural input and crop subsidies (fertilizer, pests, sugarcane) promote water-intensive cropping (sugarcane and rice). Similarly, subsidized electric supply for tube-wells encourages over-abstraction of ground water and poor irrigation practices. The federal and provincial governments may have a deeper look at the current subsidies regime and water pricing to align with the challenges caused by climate change. It requires gradual phasing out of current subsidies and divert a part of these subsidies to promote climate resilient agriculture and smart water management as well as efficiency. The technology based water

⁶¹ Agro-climatic zones are: Barani Punjab, Mixed Punjab, Low-intensity Punjab, Rice/Wheat Punjab, Cotton/Wheat Punjab, Cotton/Wheat Sindh, Rice/Other Sindh, Southern KPK and Foothills/Plains KPK, and Balochistan. While Agro-climatic zones are based on (i) geographic and climatic conditions including access to surface water or groundwater irrigation; (ii) the farming system and practices employed by farmers who work at land; and (iii) the cultivation of crops associated with two main agricultural seasons, the Agro-ecological zones based on soil, landform and climate characteristics. The Agro-ecological zones are: Indus Delta, Southern Irrigated, Sandy Desert, Northern Irrigated plain, Barani lands, Wet Mountains, Northern Dry Mountains, Western Dry Mountains, Dry Western Plateau, and Suleiman Piedmont.

management system will help better monitoring the irrigation water consumption at field level and its pricing as well as full cost recovery. The system will be able to store data of water consumption over a period of time and can monitor shifts in water consumption and improvements.

- (iv) **Establish Early Warning System:** Given the variability in climate and precipitation, it is important to build human and technical capacity and to equip local systems for effective response to climate risks for sustaining agricultural growth rates and improving rural livelihood. The Government must prepare a short, medium, and long term plan for installing automated weather stations from provincial to district levels for weather forecasting in terms of rainfall and frost and establish central linkage with Global Information Early Warning System for early warning of drought conditions.
- (v) **Establish Agri-Climate-Water Information Portal:** The above arrangements will necessitate to establish Agri-Climate-Water Information Portal at the Federal as well as Provincial level to disseminate timely information to the farmers to adjust to the changes quickly. It will help in building farm level and farmers 'resilience to climate change.
- (vi) **Research on and dissemination of climate resilient agriculture:** Location specific research and climate resilient agricultural technologies require considerable investment and effective systems of extension and dissemination. The Government in collaboration with the private sector as well as development partners can play a key role in encouraging research, modernizing extension system and facilitating the adoption of climate resilient technologies, such as, drought-pest and saline resistant crop varieties.
- (vii) **Strengthening Extension System.** The current extension system is not geared to deal with climate change risks and effective response regime. It will need restructuring of the department, retraining extension workers and equipping them (ICT based) to strengthen extension services. The government may establish information kiosks, community agro-climatic atlases and service centers to provide farms farmers with real time climatic information. Such arrangements can also remove existing barriers to adaptation. The government may also harness the potential of private sector which is currently involved at various places, such as Engro, Telenor, etc. It will also help engaging the rural educated youth in agriculture and water management.
- (viii) **Shift in cropping pattern.** The provincial extension services need to educate and reorient farmers to planting resilient crop varieties, changing planting dates, and adapting farming practices to a shorter growing season. Early maturing varieties of maize—a moderately adopted adaptation strategy---in KPK is considered as climate

smart given its strong effects on productivity improvement. Pest tolerant varieties of onion are also widely adopted in Punjab and Sindh provinces. Likewise, drought tolerant varieties of wheat and cotton, and heat tolerant varieties for cotton are being practices across in Pakistan. In addition to adjusting crop calendars and planting dates, maintenance of proper row spacing, constructing agroforestry, and crop rotation with legumes (wheat-maize) practices are also needed to be encouraged. What is needed is organized and effective extension services and awareness.

- (ix) **Rehabilitation and maintenance of irrigation systems.** Irrigation systems in the provinces requires proper maintenance to avert water losses. It is important to develop water storages, improve irrigation systems, and increase access to water in dry land farming areas and areas vulnerable to recurrent droughts. Flood-prone areas may be equipped with improved drainage systems and flood protection works. There is a need to develop capacity of Provincial Irrigation Departments to plan for shifting from “Build-Neglect-Rehabilitate” philosophy to allocate resources for maintaining the irrigation infrastructure on sustainable basis.
- (x) **Laser land-levelling.** Poor field design and surface unevenness cause water accumulation or leave dry pockets resulting in water losses. Resultantly, germination is often inconsistent and uneven growth of crops. The use of laser beam allows farmers to achieve uniformity in field preparation for uniform water and moisture distribution. Some of the provincial governments are promoting laser land-levelling techniques which will discourage flood irrigation and efficient use of scarce water resource.
- (xi) **Zero-Tillage.** Farmers in Punjab and Sindh are moving to zero-tillage (rice-wheat crops). Wheat is planted immediately after the rice harvest without tilling the land and shallow channels sufficiently deep for seed germination, minimizing the soil disturbance and maximizing carbon storage. Soil ripping is yet another water-efficient technique.
- (xii) **Conservation of soil and water.** The extension staff in coordination with irrigation department may train the farmers in soil and water conservation techniques, such as dry seeding or rice, furrow irrigation, and drip irrigation. It can help in improving productivity of land and scarce water resources. The provincial governments in Pakistan have already embarked upon a phased program of lining canals, water courses and high efficiency irrigation system.
- (xiii) **Rain-fed Areas.** Development policies in the agriculture and water management sectors generally neglect the needs of rainfed agriculture relative to the policy support provided to high potential irrigated areas. This underinvestment has contributed to an adaptation deficit especially in dry-land areas. Moisture limitations resulting in

chronically low crop productivity in rainfed cropping systems are generally attributed to poor seasonal distribution of rainfall regarding sensitive crop growth and low utilization of incident rainfall by the crop. Farmers of rainfed areas can better manage risks associated with climate change and narrow adaptation deficit by adopting rainwater harvesting, improved soil fertility management, and soil conservation practices. Better capture and utilization of rainfall through rain water harvesting (RWH) is a priority issue for enhancing climate risk management in semiarid and dry subhumid rainfed agriculture areas and will thus better position these systems to adapt to climate change.

- (xiv) **Integrated Pest Management (IPM).** It aims at promoting natural pest control methods and reducing environment and human impacts. IPM is considered to be highly climate smart along with bio-fertilizer, bio-pesticides, and weed control practices which can reduce GHG emission and solid waste pollution. To control white fly population in chili crop, natural predators such as ladybugs, lacewings, or whitefly parasites are released.
- (xv) **Policies for managing barriers and risks.** The government needs to recognize that barriers to adaptation often exist because of policy shortcomings, weak forecasting and early warning systems, markets and pricing of agricultural produce, resource constraints including lack of credit or savings, lack of access to quality seeds and inputs and inadequate agricultural research and technology. To mitigate this high degree of uncertainty, the provincial governments need to introduce new innovative financial mechanisms to protect the agricultural assets of the farmers, such as, crop and livestock insurance, social safety nets for the most vulnerables, research on and real time dissemination of flood, heat and drought resistance crops, and conservation of traditional plant varieties. Mapping vulnerable areas and developing and implementing area/region specific contingency plans will help better preparing communities/farmers for climate variability challenges.
- (xvi) **Complimentary reforms.** These measures may be combined with complimentary reforms including contract farming, grading of produce, right pricing and better market access for high-value products. Mainstreaming climate change and climate-risk issues into broader economic and development agenda is critical. Pakistan is already making considerable headway to incorporate renewable energy technologies into its agricultural production system including windmills, solar panels, and bio-energy production units for water supply and storage.
- (xvii) **Livestock Sector.** Livestock diet improvement can improve both their productivity and reduce methane emission. Feed conversion efficiency can be improved through: (i)

replacement of roughages with concentrates and a change in composition of concentrates and a change in composition of concentrations; (ii) modification in feeding (e.g. alkali/ammonia treatment of low digestibility straws); (iii) supplementation with molasses or urea nutrient blocks.⁶²

- (xviii) **Reduction in Carbon Dioxide.** Carbon dioxide emission can be reduced by slowing deforestation; changes in agricultural land management such as conservation tillage, agroforestry, and rehabilitation of degraded crop and pasture land, utilizing storage and capture technologies for manure; and conversion of emissions into biogas.

Other Adaptation Strategies:

40. Stakeholders can adopt the following strategies to deal with various challenges emerging out of climate change in Pakistan (see Table 14).

Conclusion

41. Post-devolution following the Eighteenth Constitutional Amendment, the provincial governments have a vital role to play in addressing the challenges of climate change. They need to develop an effective framework for mainstreaming climate change in agriculture and water sector focusing on support for climate action, identifying effective strategies and measures to remove barriers for behavioral change. Governance of successful climate change actions and reform at provincial level must include:

- (i) **Institutional Coordination.** The provincial governments must establish political and bureaucratic mechanisms for creating synergies and effective coordination amongst key departments and policy makers. This must be supported by ICT based Monitoring and Evaluation system for regular monitoring of implementation and decisions.
- (ii) **Establishing Adaptation Fund.** Each provincial government may establish adaptation fund and seek support from various sources to finance climate change adaptation strategies and mitigation program and foster an enabling environment that promote private sector investment in climate actions.
- (iii) **Removal of Barriers.** Each provincial government and the federal government must identify current economic, financial, institutional and social policies that create barriers to effective climate actions; reevaluate the benefits and cost of such policies and develop a plan to phase out such policies.

⁶² Mahadeswara Swamy and Sumana Bhattacharya.2006. Budgeting Anthropogenic Greenhouse Gas Emission from Indian Livestock Using Country specific Emission Coefficients. *Current Science* 91,no. 10: 1340–

- (iv) **Building Database.** Federal and Provincial governments must develop capacity to collect precise data and information to feed into framing climate action and minimize uncertainty.
- (v) **Investment in Research.** The Federal and Provincial Governments must drive and fund research in climate action tailored to local requirements, engage with public and private sector universities and strengthen public sector research institutes to develop climate change programs and finance them.
- (vi) **Investment in Climate Resilient Technologies.** The provincial governments must enter into Public-Private Partnerships for developing climate resilient technologies, new quality seeds and farm level practices; develop platforms for the dissemination of data and information to stakeholders and work to enhance options available for farmers to facilitate climate action.
- (vii) **Extension and Agricultural Support Services:** Commonly used approaches include communication, training, demonstration farms and establishing producers' networks for knowledge sharing. Mobile veterinary services to cover remote and high pasture areas of the country; improved livestock vaccination systems through cold boxes. The Government must innovative approaches for extension establishing service centers, information hubs, and electronic communication. It will also require retraining and reorient existing extension staff to new technologies and innovative system.
- (viii) **Research and Development:** R&D is necessary to build the evidence base for mitigation intervention and technologies. R&D is also imperative to increase the supply of new technologies for mitigation and adaptation, which includes better agriculture inputs, modern farm level practices, climate resilient crops, genetic potential of indigenous livestock and providing information to farmers about forage for animals.

42. The provincial policy framework must be consistent with sustainable development goals, Pakistan's commitment under the Paris Accord and the challenges faced by Pakistan in agriculture and water sectors. The provincial governments must take leadership and guide an informed dialogue on sustainable development, promote technological innovation and facilitate stakeholders in capitalizing opportunities on climate action.

Table 14. Climate Challenges and Adaptation Strategies

Challenge	Effect	Farmers	Government	Research Institutions
Floods	Climate variability resulting in increasing number and intensity of flood events	<ul style="list-style-type: none"> • Sustain crop yields by avoiding cultivation in high risk locations and time periods. • Buffer the risk of crop loss by procuring crop insurance and diversifying sources of household income • Protect crops by increasing drainage capacity, building defense structures, and creating and restoring wetlands. 	Support farmers by instituting farm insurance schemes, improving disaster preparedness (early warning systems, emergency response, and relocation to safe zones), creating farm-level and regional contingency plans, providing technical support through extension services and knowledge transfer programs, and disseminating information on flood risk reduction and emergency preparedness.	Meet local technological demand by creating flood resistant crop varieties, creating early warning systems, and on-farm flood water storage and drainage equipment.
Droughts	Receding glaciers, variable precipitation, and declining snowmelt over time will decrease the water flow in the Indus River Basin, increasing the risk of severe droughts (World Bank 2013). Lack of irrigation water and soil degradation in drought conditions will decrease crop yields and agricultural incomes. A severe drought might lead to a significant reduction in food production and increase the risk of famine.	<ul style="list-style-type: none"> • Sustain crop yields by Switching to drought-resistant crop varieties, adjusting the crop-livestock mix, building soil health. • Buffer the risk of crop loss by procuring crop insurance and diversifying household income to non-farm sources • Ensure adequate irrigation applications by installing water catchments (storage ponds), adopting efficient irrigation systems (drip irrigation) 	Support farmers by instituting farm insurance schemes, improving disaster preparedness, creating water-use priority plans, creating farm-level and regional contingency plans, providing technical support through extension services and knowledge transfer programs, disseminating information on drought risk reduction and emergency preparedness	Meet local technological demand by creating drought resistant crop varieties, creating efficient irrigation systems, creating farm-level water management tools.

Challenge	Effect	Farmers	Government	Research Institutions
Soil Degradation	In semi-arid areas such as Punjab, changes in temperature, precipitation, and wind patterns can lead to significant soil degradation, including loss of vegetation and organic matter, wind and water-induced soil erosion, soil acidification, and soil salinization (Huang et al. 2015). Since soil degradation adversely affects crop yields and agricultural incomes, effective adaptation measures have to focus on improving soil health and reducing soil erosion.	<ul style="list-style-type: none"> • Improve soil quality by adopting soil conservation practices (zero-tillage, soil ripping), building soil health through application of organic nutrients and compounds • Reduce the risk of declining soil quality by participating in soil conservation programs • Protect soil erosion by installing soil conservation structures (terraces and grassed waterways) 	Support farmers by providing technical support through extension services and knowledge transfer programs and modifying existing land and water management policies to promote soil conservation	Drive local innovation by creating better soil conservation practices, creating soil amendments (biochar and stabilizing agents)
Pest Pressure	Increasing temperatures, desertification, and aridness increase the invasion of plant pests and diseases (Lamichhane et al. 2015), leading to potential decimation of crops. The indiscriminate use of pesticides in Punjab poses further challenges in improving health and environmental outcomes. Meeting the challenge of reducing pesticide use, while increasing food production, will require innovative changes in farm practices and public policy programs	<ul style="list-style-type: none"> • Control the invasion of pests and diseases by adopting integrated pest management practices—interventions that are economically viable and minimize health and environmental risks, shifting to pest-resistant crop varieties, employing farm-scaping—creation of a habitat for natural predators • Protect crops by installing pest protection structures and applying natural pesticides 	Support farmers by instituting farm insurance schemes, and providing technical support through extension services and knowledge transfer programs	Meet local technological demand by creating pest resistant crop varieties, creating organic pesticides, and creating pest suppression and capture technologies

Challenge	Effect	Farmers	Government	Research Institutions
Ecological Zones	Evidence suggests that ecological (agro-climatic) zones have gradually shifted over time (Adnan et al. 2017; Malik 2005). Since climatologists classify ecological zones according to climatic conditions, gradual changes in temperature and precipitation will spatially alter the ecology of the province in the future. The Pakistan Agricultural Research Council in collaboration with NARC and Provincial Governments will have to periodically adjust the ecological zoning of the country and help farmers determine the optimal cropping patterns for their zones.	<ul style="list-style-type: none"> • Sustain agricultural incomes by changing their cropping patterns • Keep farms operational by procuring equipment suitable for cultivation of the new cropping patterns 	Support farmers by instituting farm insurance schemes, instituting cost sharing schemes for procuring new equipment, providing technical support, extension services, and knowledge transfer programs on smooth transitioning to new cropping systems and disseminating information on changes in ecological zones	Meet local technological demand by producing new quality seeds which are tolerant to heat, flood, saline areas and creating farm equipment and practices for new cropping patterns