Research Article

Descriptive Analysis of Water Resources in Pakistan: A Perspective of Climate Change

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Abstract | Water is among the key requirement for survival on earth. Pakistan was surplus in water resources in the past is moving towards deficiency. Although water crisis is fundamentally a global issue, however its implications will be more severe in developing countries. Nevertheless, the climate change impacts will have greater risk for developing countries like Pakistan. Pakistan with a high and fast growing population lacks enough economic resources to satisfy the basic needs of masses. Furthermore, the future of Himalayan glaciers at risk due to emerging climate change in the region. Pakistan is located in rid region where the issue of water security is forefront problem particularly for agricultural sector. While its use in various sectors like industrial and urban push the country further into water crises. The purpose of present research is to highlight the significance of water resources and shift in rainfall trend in Pakistan focusing on agriculture sector. Data on rainfall and temperature was taken from (PMD) Pakistan Metrological Department for the period of 1980-2011. The data was analyzed through descriptive statistical tolls and Arc GIS 9.8. Result suggests that climate change has severe implications on variation in temperature and rainfall of Pakistan. The after effects of climate change are variation in temperature, changing precipitation patterns and vulnerability of glaciers to climate change. Based on the findings it is suggested the effective climate change adaptation strategies and policies must be taken serious in the country. The government may formulate long term and short term climatic risk strategies to analyze the existing and future effects due to climate change. To avoid water shortage in the country construction of new dames are necessary for future requirement of the country.

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1. Introduction

The water crisis today will have long-lasting aftereffects in future. The current demand for water is insufficient to fulfil our needs. There is urgent need to draw the attention of governments to resolve the water security. The water shortage will disturb the lives of billions of people around the globe World Water Vision Report (2015). Water resources are the backbone of country's economy. Without it, the survival of mankind is critical as well for economic sustainability. The demand and allocation of water resources are for agricultural sector, domestic purposes, industrial and commercial usage. The economy of Pakistan is mostly based on agricultural sector which covers 24.3 % in labour force. The main resources of Pakistan waters are the Karakoram heights, Himalayas which possess the larger glacier water reservoirs in Pakistan. The major utilizable resources of Pakistan are surface water contain the Indus River and its tributaries and other small rivers. The estimated data shows about 138 (MAF) million

acre feet of water resources are available on annual basis. Rainfall is another major source of water in Pakistan. An average rainfall in Pakistan is 11.4 inches which is around 17 (MAF). Furthermore, the volume of ground water is hardly measurable and the total capacity and estimate of Pakistan ground water is 55 MAF. Another major source of water is dames in Pakistan which are Tarbela, Mangla and Chashma deam. The total capacity to store water reservoirs is about 18.53 MAF. The main reason behind this gloomy scenario is the fuzzy whimpering of climate change, lack of water management institutions, trans-boundary wars wreak the state of affairs, which creates water scarcity issue in the country Kahlown and Majeed (2003).

The major sources of water in Pakistan are surface water, rainfall, ground water and glaciers. A concise narrative of water resources is given to understand the water scarcity of Pakistan. Indus river basin is major source of water in Pakistan originate from the foothill of Himalayas. The other sources originate from Indus are Jhelum, Chenab, Beas, Ravi, and Sutlej. The Indus River and its tributaries are main sources of surface water, about 138 million-acre feet (MAF) and 65% of total water per annum. Jhelum and Chenab provides 17 and 19% correspondingly. While flow of these rivers during the Kharif (summer) is 84% and during Rabi (winter) season is about 16%. The alluvial plains of Pakistan have the capacity of 50 MAF, about 38 MAF is utilized. The rainfall is irregular and not enough to meet the growing demands. Most of rain falls from July to September and Glaciers contribute around 70 percent of water demand Kahlown and Majeed (2003).

While, on the side Indus River is the main source of water in Pakistan. The huge amount of water outflow into the sea without storage. Additionally, the capacity of water flow in the river is decreasing on annual basis. The Table 1 show the flow of the Indus River IRSA (2012). The biggest water consumption sector in Pakistan is agriculture sector. Total irrigated area is about 45.9 million acres. More than 60 % of the population is depended on agriculture. For estimated population of 208.4 million by year 2025, the demand for agriculture water use will be 128 MAF, Qadir (2008). According to Sufi *et al*. (2010). The water demand for industrial, Agricultural, and domestic use is projected as 123 MAF for 2025.

The population of Pakistan is growing at alarming level. According to Pakistan bureau of statistic 2012 the current population of Pakistan is 180.71 million. According to global standard per capita water 1000 m^3 is standard for water scarcity. Pakistan is presently not far from water scarcity because water availability per capita is only 103 m^3. According to global criteria the current water requirement of water will be additional reduced to 751 m^3 by 2030 (Sufi *et al*., 2010).

Despite of huge potential for water resources, Pakistan is faced by enormous water security threat which is affecting all aspects for livelihood and development of a country. But climatic change and global warming may have shocking impact on water resources. While in the present situation the rainfall is not enough to meet the agriculture demand because current rainfall is less than 240mm per year Ahmad (2008). Pakistan is now water scarce country. Water scarcity will further increase with growing population and increasing demand for water with climate change will have appealing impacts in Pakistan. Agreeing to IPCC (2007), that Himalayan glaciers are diminishing at alarming rate with the rise in temperatures. This rapid melting of glaciers will have negative results on water demand of Pakistan.

The significance of water and threat of climate change cannot be denied. The study is noteworthy because it highlights the variation in rainfall, temperature of Pakistan and the vulnerability of water resources. The conflict over water resources is another dilemma at local and international level as will the (IWT) Indus water treaty with India will add fire to the ashes. The findings of this study will help the government and policy makers to understand the nature of global and local water issues in the contemporary domain and may suggest remedies for water resources in presence of climate change.

The study was conducted to estimate the consequences of climate change for Pakistan water resources. For this purpose, the case study of rainfall and temperature was analysed. By dividing the country into five climatic zones on regional basis for the period of 1982-2011. It focus on impact of climate change and its implication for Pakistan water resources. It also studies the impact of variation in rainfall and temperature on the different climatic zone of Pakistan.

2. Materials and Methods

The study followed descriptive and literature based

study approach. The research is mostly based on secondary data. For this purpose, the data was taken from various government and non-government institution. The official documents were taken from various state ministries and authorities such as climate change policy makers, the previous reports of "Ministry of Environment and Climate Change" IRSA (Indus River System Authority), Pakistan Flood Commission institute of Sustainable, WAPDA (Water and Power Development Authority), Pakistan Bureau of Statistics, Sustainable Development Policy Institute (SDPI) and various national and international reports on water and climate change. While for detail analysis of rainfall and temperature in the whole country, the data was obtained from (PMD) Pakistan metrological department. The updates regarding the global and national level were also observed via ongoing research and media highlights for climate change issue. The Annual mean rainfall and temperature data from 1982 to 2011 were analyzed. For this purpose, data was divided into three decades to compare means and deviation of each decade. The purpose of study is to observe variance in rainfall and temperature for selected stations. Excel spreadsheet was used to calculate the average rainfall and temperature. The bar graph for each station were developed and the average rainfall and temperature data of 30 years was calculated to find positive and negative changes in temperature and rainfall.

3. Results and Discussion

This section analyzes the results of annual mean rainfall and temperature of different climatic zones of Pakistan.

3.1 Rainfall

Climatic zone 1: This zone is consisted of ten different metrological stations covering Gilgit Baltistan, five stations of Khyber Pakhtunkhwa and one metrological station from Kashmir. These areas are mostly Himalayan regions which receives most of the precipitation.

Figure 1 showing maximum average rainfall trend in Muzaffarabad and minimum at Gilgit metrological station. Maximum rainfall received at Muzaffarabad station in the last decade from 2002 to 2011. Similar higher rainfall trend is observed at Dir followed by Kakul, Swat and Drosh. While the minimum rainfall trend is observed after Gilgit, ChillasSkardu, and Astore respectively.

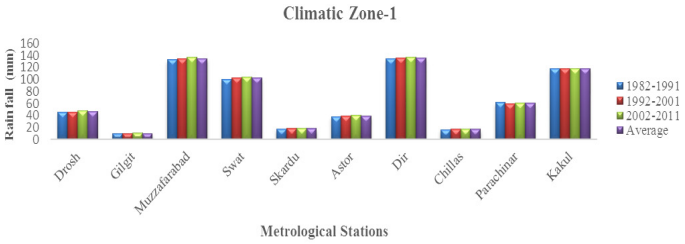

Figure 1: Graph showing 30 years mean annual rainfall of zone 1.

Table 1 show variation (increasing and decreasing trend) in rainfall by calculating the average values of each decade from 1982-2011. The rainfall of climatic zone 1 from 1982-2011 (67.58mm- 65.42mm) indicate negative trend of -2.16mm after three decades.

The above observed a decrease in rainfall climatic zone 1 (Northern areas) is supported by the published data of Pakistan metrological department (PMD) and findings of Chaudhry *et al.* (2009).

The variation in rainfall are the aftershocks of climate change. The rise in temperature virtually effected fluctuation in rainfall trends directly. The repercussion was observed in the northern region; the snow fall ratio is varying in the past decade. The study of Chaudhry *et al.* (2009) argue that precipitation and snow fall trend disturbed the analyses of past decades snow fall ratio. Moreover, Salman *et al.* (2012) have similar argument as fluctuation has been observed in rainfall and snowfall. Throughout November to January, the peak period of winter spell in Pakistan, there is anomaly in snowfall trend recorded through observing preceding decade, the data of her study reveal change in rainfall and precipitation in Dir, Muzaffarabad, Skardu, and Saidu Sharif were detected with a significant trend ($p<0.05$). The overall mean difference in average rainfall for each individual station and for the country shows a decrease from 1976-90 to 1991-2005 epochs. The international research panel on climate change also support the existing variation in rainfall observational decrease in rainfall data published in IPCC (2007) report, which discuss approximately 0.3% average cut off in rainfall per decade for subtropical land areas as opposed to tropical lands with 0.3% increase per decade. In 2010 flood, about 78 districts were effected either directly or indirectly Bukhari and Rizvi (2015).

Climatic zone 2: The climatic zone 2 is consisted of six different stations. The weather of these areas is mild cold. The stations include in this zone are: Dera Ismail. Khan, Islamabad, Peshawar, Cherat and Lahore. The selected stations cover capital and other major cities of Punjab.

The Figure 2 shows maximum average rainfall trend for Islamabad and minimum at Dera Ismail khan. Maximum rainfall is received at Islamabad station in the last decade from 2002 to 2011, followed by Sialkot and Lahore. While minimum rainfall trend is observed at Dera Ismail Khan, Peshawar and Cherat correspondingly.

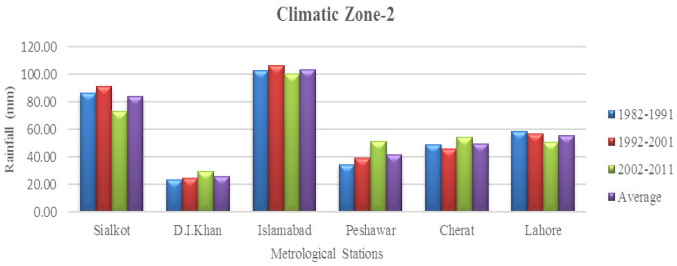

Figure 2: Graph showing 30 years mean annual rainfall of zone 2.

By calculating mean average rainfall of three decades from Table 2 between 1982-2011 (59.19-60.03) showing positive trend of 0.84 mm increases in rainfall after 3 decades.

The above increase in rainfall of climatic zone 2 is also observed by the study of Chaudhry *et al.* (2009). There is a significant increase in rainfall in Islamabad and non-significance for extreme events in rainfall. While the study of Islam (2009) also find a substantial variation in the rainfall pattern and has unfavourably hit the Potohar region of Pakistan, which include Rawalpindi, Murree and Islamabad

Climatic zone 3: The selected station in climatic zone 3 have cold and hot weather in winter and summer, respectively. These are mostly mountain areas of Baluchistan and its surroundings.

The Figure 3 shows the graphs displaying three decade (1982-2011) average rainfall observations for each station. In the above graph maximum rainfall is received by Zhob and minimum rainfall in Kalat. The maximum mean annual rainfall is received in last decade by Zhob, Khuzdar, and Quetta whereas minimum rainfall is received in Kalat.

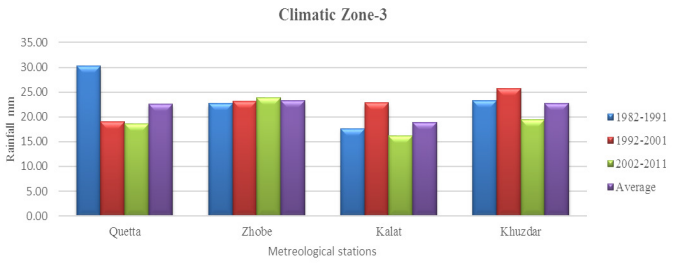

Figure 3: Showing 30 years mean annual rainfall for Zone 3.

By calculating average annual rainfall of three decades from Table 3 between 1982-2011 (23.47-19.50) showing negative trend -3.97 mm decreases in rainfall after three decades. The above decreasing trend in rainfall of climatic zone 3 (Baluchistan) is supported by the study of IPPC (2007). It observed 0.3 % per annum decrease and fluctuation in rainfall over the per ten years data analysis as the inverse effect on tropical region with rise in the average rainfall per year which resulted the same findings of Salman *et al.* (2012). The Quetta displays (-13.77 mm) and Karachi (-14.72 mm) analysis with significantly lower mean value and Jacobabad (-12.2 mm) slightly significant mean value in the second half period during 1976-2005.

Climatic zone 4: The selected station of climatic zone 4 having hottest and dry weather. The temperature of these station is highest in country. The climate of this region is dry. Stations in this zone is almost plain which include Thar Desert and some parts of Sind.

The Figure 4 shows bar graph for 3 decades showing average annual rainfall observation for each metrological station, Sibbi, Jakab abad, Bhawalpure, Khairpure, Multan, and Rohri for 1982 to 2011. The above graph showing maximum rainfall for Multan and minimum rainfall for Rohri from 2002-2011. Similarly, higher rainfall trend is observed for Khairpure, Bahwalpure and Sibbi while minimum rainfall trend for Jakab abad.

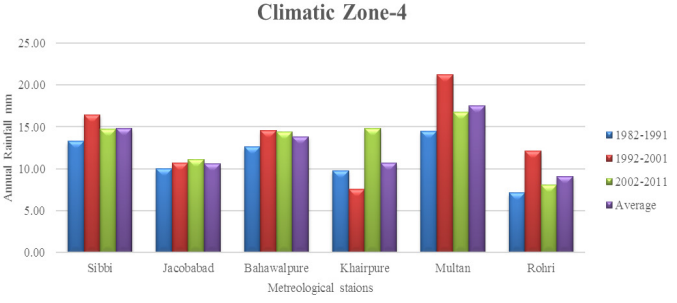

Figure 4: Showing 30 years mean annual rainfall for Zone 4.

Table 1: Average 10 year's rainfall for each station.

Year	Drosh	Gilgit	Muzzafarabad	Swat	Skardu	Astor	Dir	Chillas	Parachinar	Kakul
1982-1991	45.69	10.10	132.98	100.46	17.90	38.58	133.93	16.59	61.65	117.88
1992-2001	46.18	10.26	134.12	102.93	18.50	39.50	136.07	17.38	59.92	117.81
2002-2011	47.53	10.75	136.59	104.43	18.52	40.62	137.56	17.97	60.58	118.26
Average	46.46	10.37	134.56	102.61	18.31	39.57	135.85	17.31	60.72	117.99

Table 2: Average 10 year's rainfall for each station climatic zone 2.

Year	Sialkot	D.I. Khan	Islamabad	Peshawar	Cherat	Lahore
1982-1991	86.73	23.30	103.21	34.30	49.16	58.43
1992-2001	91.68	24.43	106.64	39.51	45.64	57.10
2002-2011	73.51	29.55	100.67	51.41	54.50	50.83
Total average	83.98	25.76	103.51	41.74	49.76	55.45

Table 3: Average 10 year's rainfall for each station.

Year	Quetta	Zhob	Kalat	Khuzdar
1982-1991	30.23	22.70	17.66	23.31
1992-2001	18.96	23.23	22.86	25.70
2002-2011	18.61	23.86	16.15	19.40
Average total	22.60	23.26	18.89	22.80

The Table 4 showing that average rainfall for each decade is not constant. The overall change from 1982-2011 by calculating the average rainfall (11.21-13.30) showing positive trend +2.09mm increase for last three decades. The above increasing trend in rainfall of climatic zone 4 (selected parts of Punjab) is supported by technical report of Chaudhry *et al.* (2009). Where he found significant increase in the rainfall by 7.5mm during 1914 to 2007. While the study of Anjum *et al.* (2012) shows negative rainfall trend in summer.

Table 4: Average 10 year's rainfall for each station.

Year	Sibbi	Jaco-babad	Baha-walpure	Khair-pure	Multan	Rohri
1982-1991	13.29	10.00	12.60	9.79	14.48	7.11
1992-2001	16.46	10.69	14.57	7.54	21.26	12.13
2002-2011	14.70	11.11	14.37	14.80	16.74	8.09
Total average	14.82	10.60	13.85	10.71	17.49	9.11

Climatic Zone 5: Climatic zone 5 having four stations. Which cover the coastal area of Karachi. This zone includes some parts of Baluchistan and Sindh. These regions are mostly arid with minimum rainfall and high temperature. The selected stations are: Karachi, Hyderabad, Nawab shah, and Jewani.

The Figure 5 is bar graph showing 30 years (three Decades) annual mean rainfall observations for zone 5. The above graph shows that the rainfall for each decade is not regular. The maximum rainfall in this climatic zone is received by Hyderabad and minimum for Jewani in the last decad. Whereas Karachi and Nawabshah also shows maximum trend in the last decade.

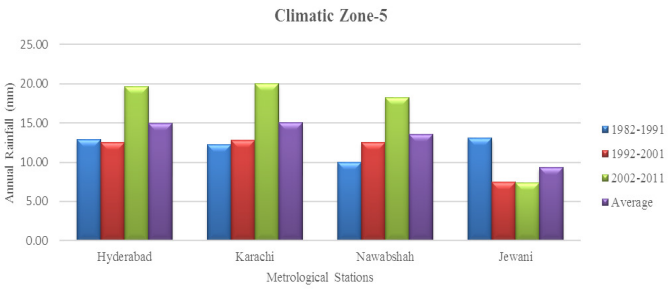

Figure 5: Showing 30 years mean annual rainfall trend for Zone 5.

The Table 5 displays average rainfall for each decade is not regular. There is increasing and decreasing trend. The overall change for three decades from 1982-2011 is (12.02-16.33) showing +4.31 increasing trend. These results are supported by Pakistan Meteorological Department Technical Report (2009). Which also show positive variation in rainfall for most part of coastal areas.

Table 5: Average 10 year's rainfall for each station.

Year	Hyderabad	Karachi	Nawabshah	Jewani
1982-1991	12.86	12.22	9.96	13.05
1992-2001	12.50	12.86	12.54	7.51
2002-2011	19.67	20.01	18.23	7.41
Average	15.01	15.03	13.57	9.32

Summarizing the results of rainfall graphs and tables, by constructing the overall average of rainfall at each station in tabulated form. The Table 6 shows climatic

zones of selected stations with negative, positive and no change in rainfall. The climatic zone 01 consisting mostly the northern areas of Pakistan showing negative rainfall trend. Climatic zone 04 consist the areas of Baluchistan and Sindh experiencing positive rainfall of +2.09 mm. while at climatic zone 02 no change in the rainfall occur. The results indicates alarming situation for climatic zone 01 which is major source of water resource for Pakistan. With the negative changes in the areas like climatic zones are severely affected by climate change. The following maps based on the above findings shows the variation in rainfall during each decade.

Table 6: Overall variation of rainfall in each zone rainfall during 1982-2011.

Zones	Overall trend during 1982-2011	Increase /decrease in 30 years
Climatic zone 1	-2.16	Negative
Climatic zone 2	0.84	No change
Climatic zone 3	-3.97	Negative
Climatic zone 4	+2.09	Positive
Climatic zone 5	+4.31	Positive

Mapping precipitation: Figure 6 showing decade wise presentation of selected stations for rainfall. Maps were generated using ArcGIS 9.8, using spline and IDW tools for visual representation of difference between decades. Figure 6a (1982-1991), Figure 6b (1992–2001) and Figure 6c (2002-2011) reflecting 10 years of average rainfall of each climatic zone. The average mean rainfall data for 30 years was plotted in GIS 9.8 software from excel spread sheet. The white area or spots on the maps indicating the areas receiving high rain fall. The areas receiving high rainfall lying mostly in the northern areas of Pakistan and climatic zone 01. Areas receiving high rainfall after northern areas are both in zone 01 and zone 02.

Yellow colour on the map indicating the areas receiving moderate rainfall. This area covering major portion of climatic zone 02 followed by zone 01. Greenish colour on map indicates those areas which are receiving little rainfall. Receiving little rainfall as shown on the map are covering whole area of climatic zone 05 and 3/4th of the climatic zone 04.

Starting from the areas receiving minor rainfall, as map showing major areas of Pakistan are receiving little rain fall. On map A Khuzdar, Quetta, Zhob and D.I. Khan are receiving little bit more rain falls than other areas of same zone. On map B showing (second decade 1992-2001) areas like Khuzdar, Zhob, D.I. Khan and Multan are receiving little bit more rainfall than other areas and trend changed from 1st decade. While in the last decade only Zhob, D.I. Khan, Karachi and surrounding areas are receiving more rainfall than other areas.

The areas receiving highest rainfall are white highlighted which shows almost the similar pattern with minute changes. Areas receiving high rainfall in the 1st decade receives moderately less rainfall in 2nd and last decade. The pattern of rainfall is disturbed for the three consecutive decades. The areas receiving high rainfall are facing shortage of rainfall, while area receiving moderately high rain are receiving high rain fall as shown in the Figure 6.

Moderate rainfall occurs at climatic zone 01 and climatic zone 02. There are no such major changes occurred in these areas. These areas receiving moderate rainfall consistently for thirty years. Table 6 shows more clearly with yellow colour area, not facing changes on average basis in past thirty years.

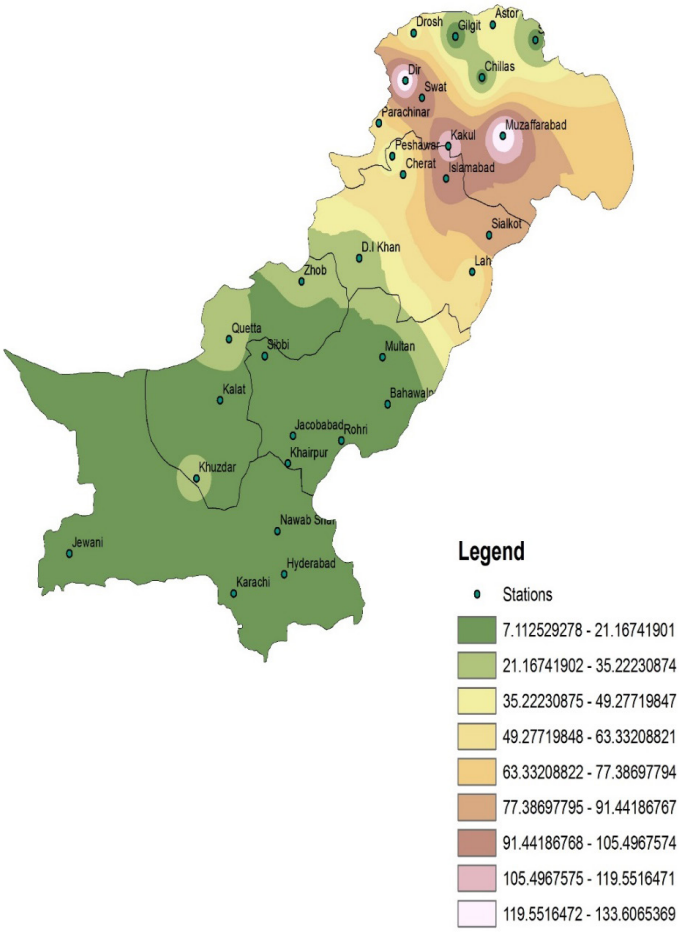

Figure 6a: Showing the average rainfall for all stations from 1982 – 1991.

Links Researchers

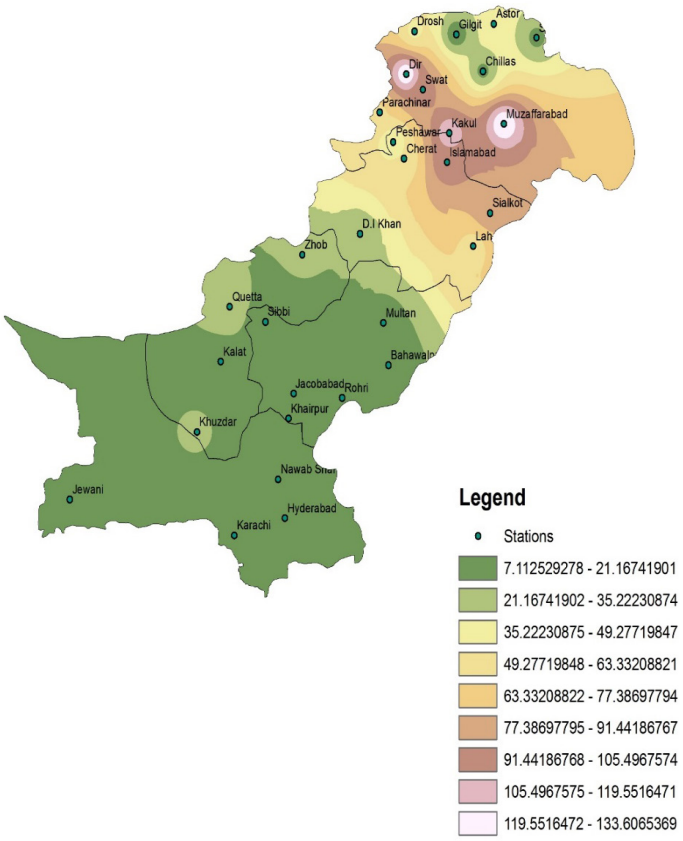

Figure 6b: Average rainfall for all stations from 1992–2001.

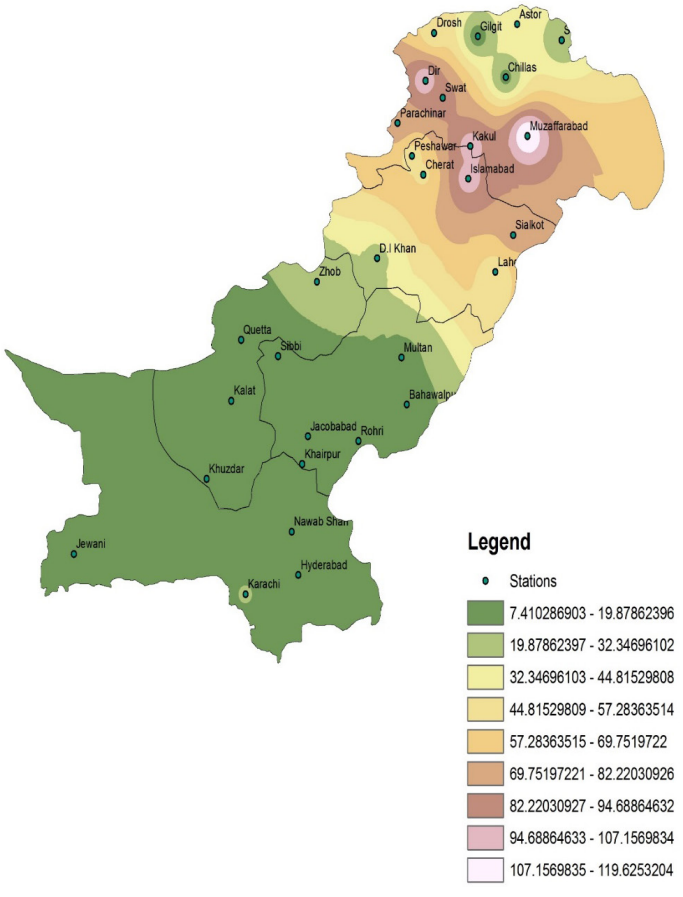

Figure 6c: Average rainfall for all stations from 2002 – 2011.

3. Temperature

The impact of climate change on temperature is of great importance. For the analysis of variation in temperature the mean average temperature of stated zones were calculated in excel spread sheet. The graph below clearly indicates that the temperature of all above zone is not constant (indicating clear variation).

As we observe the graph shows increasing trend for 30 years of selected stations for phenomenon of climate change impact on water resources. Temperature plays a vital role as side partner for climate change over the globe. Figure 7 clearly reflect increasing trend from decade to decade. The 1st decade (1982-1991) shows variation in temperature i.e. the starting years of decade showing no significance increase while the year 1987 and 1988 showing increase in temperature to succeeding years. The rise occurs in the same decade by 1 °C, 0.5 °C rise on average per year. Following by the 2nd decade 1992–2001 also shows net increase in temperature from the last decade. The last decade showing fluctuation in temperature, also they have the years like 1985, 1989 and 1997 that have the same value for temperature as for the staring of 1st decade. The 3rd decade 2002-2011have clearly showing rise in temperature. Most of the years in this era has maximum temperature of 21.8 °C and the minimum 20.8 °C for single year.

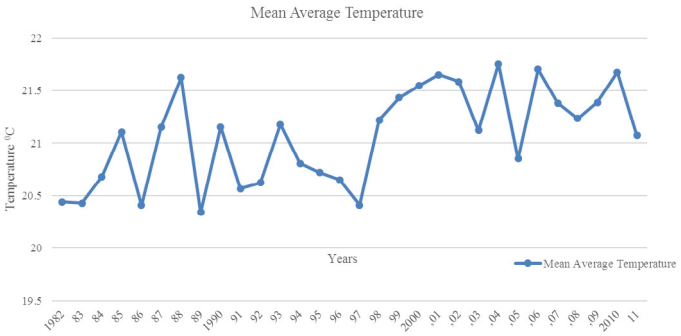

Figure 7: Mean annual temperature trend for 30 years 1982-2011.

Table 7 showing different climate zones of the study area with some positive trends in temperature. As already explained in the above graph that all climates are observing the positive trend in the temperature. By calculating the available data of each stations, the result reflects that there is positive change in temperature. The maximum rise in temperature occur from the last thirty years in Pakistan are at climatic zone 04 which is 0.96 °C. Climatic Zone include areas of Baluchistan and Sindh are experiencing much increase in

temperature with the passage of time. Climatic zone 02 also experiencing the rise in temperature by 0.71 °C followed by climatic zone 03. Climatic Zone 01 and climatic zone 05 shows rise of 0.63 °C, 0.37 °C and 0.33 °C for the 3 decades respectively.

Table 7: Change in temperature during 1982-2011.

Zones	Trend during last 30 years	Ranges Inc/dec (°C)
Climatic Zone 1	Positive	+0.37 °C
Climatic Zone 2	Positive	+0.71 °C
Climatic Zone 3	Positive	+0.63 °C
Climatic Zone 4	Positive	+0.96 °C
Climatic Zone 5	Positive	+0.33 °C

The above results for increasing temperature is supported by many studies. Where study of Anjum *et al.* (2012) observed increase in temperature from 0.2 to 1.0°C for most part of Pakistan. While the study of Chaudhry *et al.* (2009) observed increase in the annual maximum temperature 0.87 °C in the country during 1960 to 2007. The World Meteorological Organization (2011) has noted due to rise in temperature the first decade of 21 century was ranked the warmest decade over globe and the year 2010 was graded as the warmest year (+0.53 °C, over average global temperature) followed by 2005 (+0.52 °C) and 1998 (+0.52 °C). In Pakistan, there has been recorded a 0.76 °C rise in temperature for the last 40 years. However, the country witnessed 1.5 °C rise in temperature over the mountain region hosting thousands of glaciers during the same period (Chaudhry *et al.*, 2009). In contrast to the increasing temperatures, the data of PMD (Pakistan Metrological Department) stations network showed that there is somewhat cooling trend over Khyber Pakhtunkhua at a rate of -0.15 °C per decade for January, however, they found statistically significant rise of January temperatures in rest of the country (Ahmad, 2008).

3.3 The following Maps showing the rising trends of temperature in various zones of Pakistan

Mapping temperature: By using same techniques of Spline and IDW tools of Arc GIS 9.8 for mapping and visually representing the data of temperature throughout Pakistan for easily understanding. Figure 8a, 8b and 8c showing the average annual mean of temperature data of each station and decade 1982-1992, 1992-2001 and 2002–2011, respectively. The average mean temperature data for 30 years was plotted in GIS 9.8 software from excel spread sheet. The areas with high temperature are indicating by white spots/ colours and low temperature with green colour or spots.

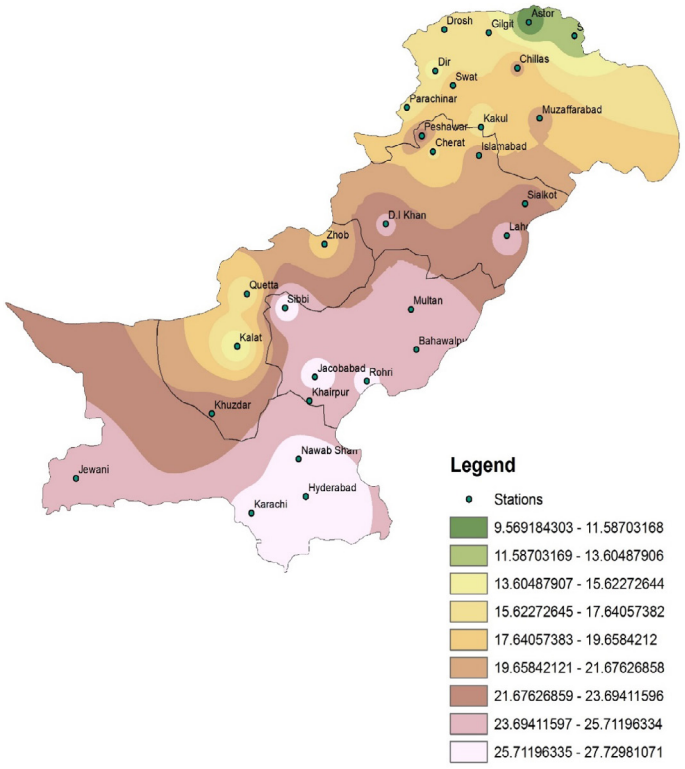

Figure 8a: Average temperature for all stations from 1982 – 1991.

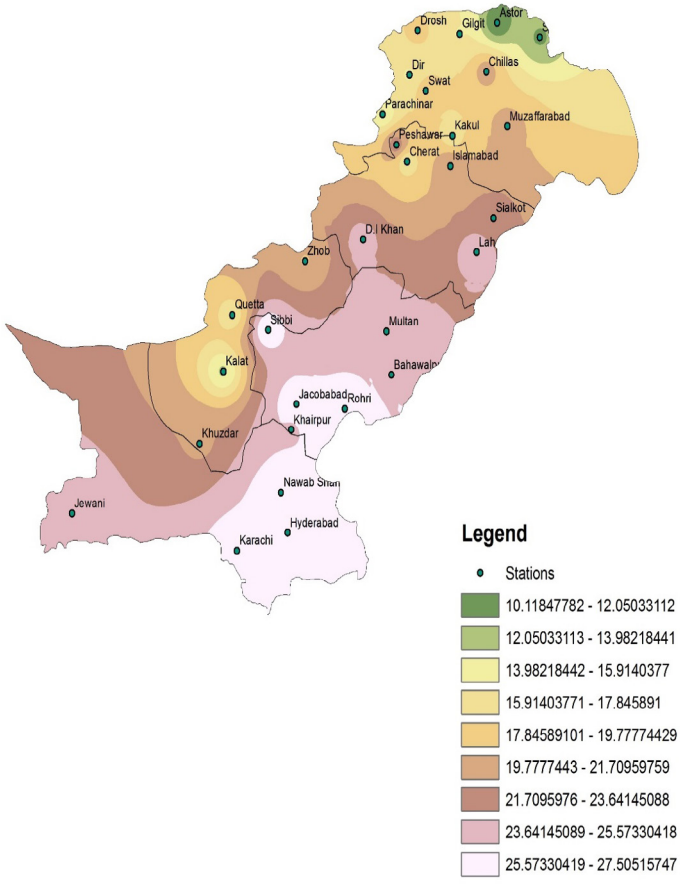

Figure 8b: Average temperature for all stations from 1992 – 2001.

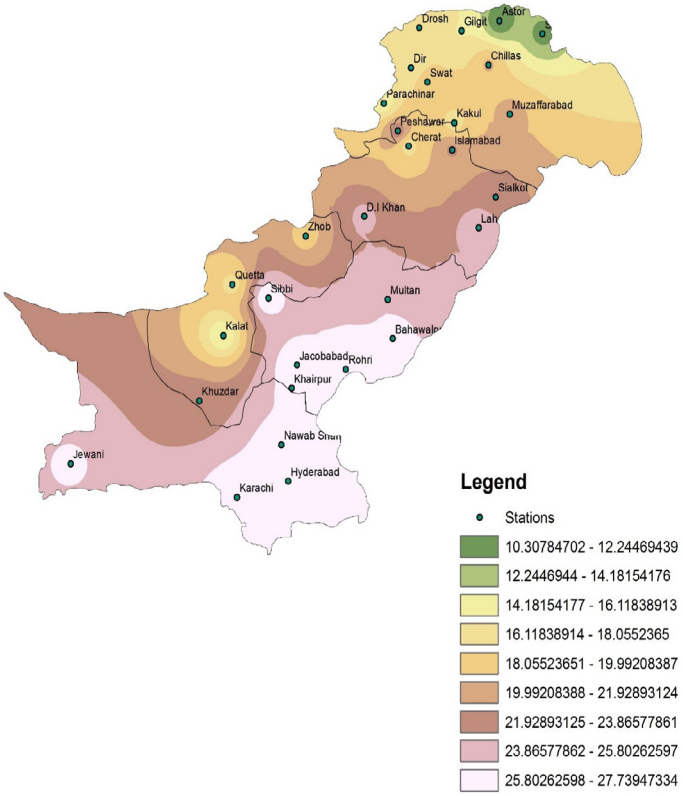

Figure 8c: Average temperature for all stations from 2002 – 2011.

Table 8: Total water resources available in Pakistan (Water available in MAF).

Major sources	Year 2001	Year 2003
Surface water availability	84.3	84.9
Ground water availability	50.1	50.0
Total availability	134.4	134.9

Source: Strategy for development, conservation and utilization of water resources of Pakistan. Prepared by Pakistan council of research in water resources. Yearly surface water availability.

Astor and Skardu are areas experiencing low temperature in the 1st decade. With the passage of time from 1982 to 2011, there is no significant changes occurs in temperature. Areas which are experiencing moderate temperature exist in climatic zone 01 and some areas in zone 04 including Kalat and Quetta. Sibbi, Jackob abad, Rohri, Nawabsha, Hyderabad and Karachi experienced low temperature in 1st decade. In 2nd decade these areas experienced high temperature including khairpur. In the last decade, these areas were expanded and experienced rise in temperature from the last two decade. The areas under rise in temperature with passage of time including Jewani, Bahawalpur, D.I. Khan and Kalat.

Overall temperature pattern is changing with time as shown by Figure 8. The areas having low and moderate temperature indicates rise in temperature decade wise Maps colour generated via ArcGIS are clearly indicated variation (increasing trend). These changes in temperature with passage of time and rapid industrialization and population growth also contributed to climate change. With these changes some positive and negative effects on water was observed.

3.4 Future projected changes in rainfall

According to SCHENGEN model use for generating climate change scenario during next half of 21ist century based on 1930-1990 data. The result for temperature indicates progressive variation. Nevertheless, the changes in rainfall was not uniform. While Climatic zone 4 (south-western coastline) and climatic zone 5 (western Baluchistan) may experience low rainfall. According to the results the climatic zone 1 northern areas showing positive changes in rainfall of +5%. The climatic zone 2 (Punjab) showing negative results -5 % and -10 to -5 % in Sind and Baluchistan respectively Farooqi *et al.* (2005).

3.5 Background of water crisis in Pakistan with respect to rainfall and temperature variation

The major sources of water are surface water, rainfall, groundwater and glaciers. A concise narrative of water resources is given to understand the water scarcity of Pakistan. Indus river basin is major source of water in Pakistan originated from the foothill of Himalayas with total length of 2900-kilometer cover about 966,000 Km^2. the other branches originate from Indus are Jhelum, Chenab, Beas, Ravi, and Sutlej. The Indus River and its tributaries are main sources of surface water, about 138 MAF and 65%of total water per annum and Jhelum and Chenab provides 17 and 19% correspondingly. While flow of these rivers during the Kharif (summer) is 84% decrease during Rabi (winter) season to 16%. The alluvial plains of Pakistan have the capacity of 50 MAF and about 38 MAF is utilized. The rain fall is irregular and not enough to meet the growing demands. Most of rainy season occur in July to September. Glaciers are other main source of water. The ground water resources are potential of 50 MAF is being utilized to a level of about 38 MAF by over 5, 62,000 private and 10,000 public tube wells meeting the domestic and agriculture water demands Kahlown and Majeed (2003). The total availability of water in 2001 to 2004 is given below.

While on the side the Indus River which is biggest

sources of water in Pakistan. The huge amount of water outflow into the sea without storage. Additionally, the capacity of water flow in the river is decreasing on annual basis. The Table 9 show the flow of the Indus River IRSA (2012).

Table 9: Indus river flow up to 2012.

Period	Kharif	Rabi	Total	MAF Inc/dec
2003-04	65.9	31.5	97.4	-5.9
2004-05	59.1	23.1	82.2	-20.6
2005-06	70.8	30.1	100.9	-2.5
2006-07	63.1	31.2	98.7	-8.9
2007-08	70.8	27.9	98.7	-4.6
2008-09	66.9	24.9	91.8	-11.3
2009-10	67.3	25	92.3	-10.8
2010-11	53.4	34.6	88	-15
2011-12	60.4	29.4	89.8	-13

Source: Indus River System Authority, 2012.

Table 10: Future water demand for each sector.

Usage	Present and future water requirements				Additional requirements in 2025
	2010	2015	2020	2025	
Agricultural	107	111	115	119	12
Industrial	4.02	4.28	4.54	4.8	0.78
Municipal	6.90	8.10	9.30	10.50	3.60
Environmental	1.46	1.54	1.62	1.70	0.24
Total	119.38	124.92	130.46	136	16.62

Source: Sufi *et al.* (2010) Water resource of Pakistan.

Table 11: Estimated growth of population up to 2030.

Year	Population (million)	Water availability (Cubic meter)
1951	34	5260
2010	172	1038
2020	204	877
2025	221	809
2030	238	751

Source: Sufi *et al.*, 2010 water resources of Pakistan.

3.6 Non-Climatic factors contributing to water scarcity in Pakistan

Although Pakistan has substantial water resources, but there are various challenges to water sector of Pakistan. It may lead conflict within and outside the country. The allocation of water dispute between provinces antagonism around water resources are leading cause of water crisis. Such mounting opposition can show the way to crisis and potential conflict, particularly it leads to unequal water access and availability. Water can also be corresponding foundation of peace and cooperation if managed in fair and sustainable mode according to changing scenario. Main challenges face in water sector of Pakistan is below.

Population growth: The population of Pakistan is growing at alarming level. According to Pakistan bureau of statistic 2012 the current population of Pakistan is 180.71 million. Global standard per capita shows that water below 1000 m^3 is considered as scarcity. Pakistan is presently not far from water scarcity because water availability per capita is only 1038 m^3. According to global criteria the current water requirement of water will be further reduced to 751 m^3 by 2030 Sufi *et al.* (2010).

Mismanagement: Constitutionally, Pakistan is federal state and water resources are managed by federal government. Federal and provincial government shares power, But the federal government dictate provincial government. The main institutional bodies involve in water management are, Water and power development authority (WAPDA) and Indus river authority. In the Constitution, a Council of Common Interests (CCI) is set to frame and regulate policies for matters in Part II of Federal legislative list: such as railways, mineral oil, natural gas, and the water and power development authority. The Federal Ministry of Water and Power is accountable for water sector policy. The water and power development authority (WAPDA) have multiple responsibilities. The Indus River Authority Authority (IRSA) and Provincial Irrigation Departments (PIDs) are responsible for irrigation and other matters at provincial level. The government of Asif Ali Zardari-led civilian government has agreed Eighteenth Amendment in 2010. This amendment has attempted to constitutionally reconcile the growing inter-provincial water struggles by introducing provisions like: Article 157 (I) "Provided that the Federal Government, prior to taking a decision to construct or cause to be constructed hydro-electric power stations in any Province, shall consult the Provincial Government concerned and; (3) In case of any dispute between the Federal Government and Provincial government in respect of any matter under this Article, any of the said Governments may move the Council of Common Interests for resolution of dispute" Amit (2012). Indus River is backbone of Pakistan agriculture, but the distribution of water among the provinces and

additional dams remain controversial throughout Pakistan's history. While on other hand, since the inception of Pakistan there is regular stress from India over water resources further fuel the existing situation.

Water crisis between Pakistan and India: The issue of water sharing started immediately after the partition in 1947. Though the issue was resolved through Indus water treaty in 1960. According to Indus water treaty, three rivers were given to India (Sutlej, Beas, and Ravi). While (Jhelum and Indus, Chenab) were owned by Pakistan. Where some rivers were remained controversial Asif (2007).

According to Falkenmark (1989a), Water enters a country in two principal ways: as vertical input from the atmosphere over the territory and as horizontal input from upstream countries entering rivers and aquifers. Major withdrawals reduce the flow in the system, with consequences for downstream countries. These withdrawals may provoke regional conflicts that can be resolved by treaties, river compacts, or other types of international agreements.

Similarly, very recently the crisis between Pakistan and India started due to creation of Baghlihar dam on the river Chenab and Wullar Barrage on river Jhelum by India. These rivers flow downwards to Pakistan and reserves the right of using water of river Chenab according to Indus water treaty. The construction of these dams is thought in Pakistani circles a rise in trouble condition of water crisis in the country (Asif, 2007). This issue between the two countries always remain ambiguous due to tension over the Kashmir issue. On the other side the population of both states are increasing at alarming level. Thus, by increasing demand of water the issue of water will further aggravated.

Water issues between provinces: The construction of new dams is indespensable. With the shortage of water being experienced by the country for previous 8 years, the stiffness between provinces has intensified. The Sindh province asking for more share of existing water from Punjab province. The same has been compounded by the controversies on interpretation of 1991 Water Accord and 1994 Inter Ministerial Meeting. Furthermore, disagreements have also ascended on the construction of Kalabagh Dam, which is regarded by Punjab as necessity while other provinces view it with distrust (Bengali and Qaiser, 2003). Pakistan according to global water standard is recognized as water scarce country. The future climate change will further exacerbate the current scenario between provinces.

Haleem Committee (1983) had previously endeavoured to settle the water sharing issues about water distribution strategy and plan among provinces. These efforts were not enough to safeguard water agreement which ensued in Sindh-Punjab (Draft) Agreement, 1945. Though due to the emergency after the partition of Subcontinent in 1947, the selected provincial assemblies could not approve the draft into mutual agreement. However, the Water Apportionment Accord of 1991 between all provinces of Pakistan consequently acknowledged as revered agreement in the history of Pakistan, which was reached through a political process and inter-provincial consensus. Vulnerabilities owing to climate change (Baksh,2010).

Conclusions and Recommendations

The study observed that water crises is orientated to water resources and susceptibility to climatic change. The temperature and rainfall of many regions of Pakistan were observed and analyzed. Where the rainfall shows less variation but on the other hand the temperature is showing alarming situation. Thus, the increasing temperature will have catastrophic impacts on water resources. As well as non-climatic factors were also analyzed such as lack of good governance, Trans boundary and inter provincial issues are also contributing to water crisis in Pakistan.

The contemporary research endeavor to limelight the impact of climate change and their aftershocks for Pakistan water resources. The objectives of the research was to evaluate the contemporary situation of Pakistan water resources through secondary data. The next objective was the documentation of the literature about the global and Pakistan vulnerability to climate change.

The water scarcity will be further increase with climate change. Although climate change has multi-dimensional effects. But the water and food security are of important concern because Pakistan is an agricultural economy depend on the availability of water. The impact of climate on developing country will be greater due to the greater risk of climate change compared to other part of the world. Multidimensional

research already highlighted that climate change exerts severe pressure on Pakistan's natural resources and particularly the water security issue. According to the (UN) United Nations and Pakistan's government officials rectify the 2010 Pakistan flood was the sign of climate change in the region (Oxfam, 2011). While it is also observed in the findings that rainfall was very high as compare to the rest of the years.

The modern techniques of agricultural adaption to climate change and variation in rainfall needs to be adopted. Water resources are prone and vulnerable to the impacts of climate change. Climate is the most important driving force for overall water supply and demand. In Asia, water scarcity will be intensified mainly in the areas dependent on water from Himalayan glaciers which are possibly melt-away because of climate change impacts (FAO, 2011).

Thus, the existing investigation of Pakistan rainfall and temperature argue the projected threats to water resources. On the other hand, there is lack of policy adaptation in water sector (Oxfam Research Reports, 2011). The awareness among the environmental protection and climate change is inevitable. The main steps are need to build the new dames such as Kalbagh dam and other small and medium dams. While the awareness among the people on importance of water and their use is inevitable. Redressing institutional and financial gap to adapt climatic changes as compare to the other Asian countries. The policy makers essentially need to expedite the adaptive capacity of Pakistan's institution to redress the vulnerability to current climatic events and future impacts on water resources for prosperous and sustainable country.

Novelty Statement

The present study will enable readers to understand the dynamics of water resources in perspective of climate change in Pakistan.

Author's Contribution

Ateeq Ahmad and Umar Hayat developed the idea and complied the paper. Shahid Ali and Hazrat Bilal wrote the literature. Dr. Khan Mir Khan, Naveed Ali and Khalid Khan analysed the data.

Conflict of interest

The authors have declared no conflict of interest.

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