Rainfall Trends in Different Climate Zones of Pakistan

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Abstract

In this paper, the study was conducted across the country to assess the rainfall trend in different climate zones of Pakistan over the past three decades. For this purpose dataset comprising 30 years for the period 1976 to 2005 were acquired from 30 meteorological observatories from different parts of the country. The whole data was analyzed through Analysis Of Variations (ANOVA) along Dunnett T3 test. The result has shown a decreasing trend (-1.18mm/decade) all over the country, which may be attributed to the presence of drought period during 1998-2001. Stations located in different zones of the country mainly from North, North West, West and Coastal areas respectively show overall significant decreasing trend whereas plain areas and South West of the country have been observed with no significant trend. Adverse consequences of the rainfall have already been observed in Pakistan in the form of droughts and super floods which have badly affected human settlements, water management and agriculture sectors.

Keywords: Rainfall trend, Climate zones, ANOVA test along Dunnett T3 test.

Introduction

The issue of climate change has emerged very strongly during the last two decades on global scale in view of its projected implications on the environment of vulnerable states. Steadily rising temperature and its impacts on the cryosphere and rainfall are evident in many regions around the world. There are indications that Pakistan has had its share of the large climatic variations that are known to have taken place in northwest India in the past. The dominant component of the climate variations was spatial shifts in the rainfall patterns, associated with fluctuations in the general circulation of the atmosphere in the region (Rodo, 2003).Changes in rainfall pattern directly affect water, agriculture and disaster management sectors. According to the report of Task Force on Climate Change (2010) in Pakistan, the country is exposed to a number of natural disasters, including cyclones, floods, drought, intense rainfall, and earthquakes. In the last couple of decades there has been an increase in the incidence, frequency, and intensity of extreme climatic events: about 40% of the people of Pakistan are highly prone to frequent multiple disasters with variations in rainfall patterns, storms, floods and droughts (Hussain et al, 2010, Oxfam Report on Climate Change, 2011). In most areas of the country, rainfall patterns have become very unreliable and unpredictable, making it difficult for communities to make necessary arrangements for their safety, crops and livestock. For instance on 29th July 2010, the country has faced super flood, after heavy monsoon rainfall hit Khyber Pakhtunkhwa, Sindh, Punjab and parts of Balochistan in over eighty years. In this worst flood, an estimated 2000 people were dead and has damaged or destroyed over 700,000 homes. A record-breaking 274 mm rain fell in Peshawar during 24 hours; the previous record was 187 mm of rain in April 2009. On the other hand, in 1998 to 2001 severe droughts occurred in the southern and central parts of the country.

The variability of rainfall has increased geographically, across seasons, and annually in Asia over the past few decades. Decreasing trends in rainfall patterns along Pakistan's coastal areas and arid plains have also been observed (IPCC, 2007). According to Pakistan Meteorological Department, major parts of Pakistan experience dry climate. Humid conditions prevail but over a small area in the north. The whole of Sindh, most of Balochistan, major parts of the Punjab and central parts of Northern Areas receive less than 250 mm of rainfall in a year.

Pakistan has a reasonably good network of observatories having a century of records of the basic climate parameters of rainfall and temperature. Chaudhary (1994) attempted to construct an all- Pakistan summer monsoon rainfall series, by taking the area- weighted average of 38 stations, excluding the hilly regions of

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the country parallel to the Himalayan mountain range, and covering about 88% of the total area of the country. Chaudhary obtained a value of 13.3 cm for all Pakistan mean summer monsoon rainfall, which accounts for about 58.5% of the annual rainfall, based on the data during 1901-1990.

Another attempt has been made by Singh and Sontakke (1996). They used 34 stations for precipitation and 15 stations for temperature. The earliest records available are from 1856 for precipitation and 1876 for temperature. They computed the monthly percentage departures from the long term mean at the available stations and then average all the available months and stations to obtain the all- Pakistan mean annual rainfall anomaly series for the period 1856-1993. They obtained a low –frequency variability of all Pakistan mean annual rainfall, in terms of 31 year moving averages and decadal means of both mean rainfall and variability.

Seen in the context of Pakistan, a country with very large population, agriculture based economy and high vulnerability index to natural disasters, it was important to determine trends of rainfall in different climate zones of Pakistan over the last three decades and its considerable spatial and temporal variability in the study area. The Pakistan Meteorological Department reported that in recent year there has been a slow but steady change occurred in the location where major rainfalls concentrate. In the past, monsoon rains fell most intensely over the Punjab. But slowly and steadily, the concentration of rainfall has moved north and west to Khyber Puktonkhuwa.

Study Area

Pakistan is geographically situated approximately between 24-37 °N latitudes and 62-75 °E longitudes in the western zone of south Asia. The distribution of rainfall in Pakistan varies on wide ranges, mostly associated with the monsoon winds and the western disturbances, but the rainfall does not occur throughout the year. Like, Khyber Pukhtonkhuwa (northern mountains) and Balochistan provinces receive maximum rainfall in the months of December to March while in Punjab and Sindh receive 50-75% of rainfall during monsoon season (Kazi et al, 1951; FAO, 1987; Khan, 1993 & 2002; Kureshy, 1998; Luo and Lin, 1999). The precipitation received in the country can be divided into two main seasons, summer or monsoon and winter precipitation. The monsoon rainfall enters Pakistan from east and north east during the month of July to September. During this duration a good amount of rainfall is received in the north and northeastern areas of the country. Winter precipitation (December to March) are mainly received from western disturbances entering from Iran and Afghanistan. The weather systems entering from Afghanistan are called the primary western disturbances and cover only the north and north western parts of the country, whereas those approaching from the Iran are secondary and cover a large area of the country including Balochistan, Punjab, Khyber Pukhtonkhuwa, Kashmir and northern areas and sometimes Sindh province. A large amount of snowfall is received in the northern areas, upper Khyber Pukhtonkhuwa, Kashmir and northern Balochistan and is the main source of water supply for water reservoirs of the country in dry season. This water received from the snow melt and from the seasonal rains plays an important role in the agricultural and socioeconomic activities of the country. Agriculture of Pakistan is mainly climate dependant and every area has its own crops and fruits according to its climate. The country’s most important crops and fruits are grown in winter season in different areas according to its climate conditions. If there is any abnormality in the usual climate condition the nation suffers for the whole year and there is also a huge loss to the economy (Shah, 2008).

Zonal Classification of the Study Area

Detection of rainfall trend is subject to limitations: there is no clear altitudinal trend of rainfall. Therefore, for analysis, a dataset spreads over a period of 30 years (1976-2005) covering the whole country i.e. 30 stations from extreme north to south and east to west have been selected. The stations included in this study were selected on the basis of their latitudinal position, elevation from sea level, length of record, completeness and reliability of data so that a synoptic view of the entire country could be obtained. Further the selected stations have been divided into five different microclimatic zones. These zones were named A, B, C, D and E as shown in Figure 1, along with their latitudinal extent.

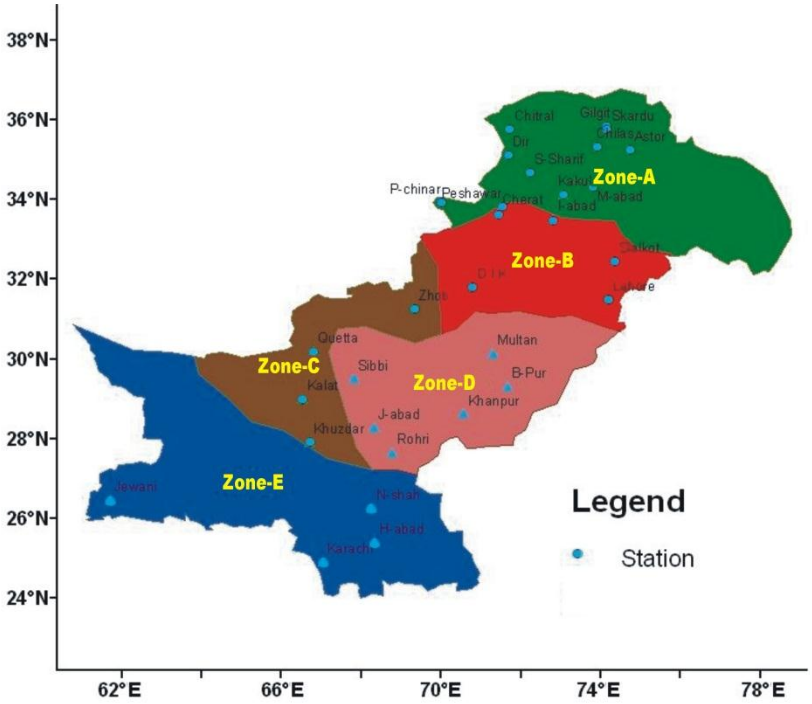

Figure 1: Map showing the climatic zones of the study area

Zone A

Zone A comprises those stations having cold climate and high mountains, situated in the north of Pakistan. These stations are Chitral, Gilgit, Muzaffarabad, Said-u- Sharif, Skardu, Astor, Dir, Chilas Parachinar and Kakul. These are mostly hill stations located between 34 N to 38 N in the Himalaya, Hindukash and Koh-e- Sufaid mountain ranges.

Zone B

This zone has mild cold climate and Sub Mountains, located between 31N to 34 N. The stations are Sialkot, D.I.Khan, Islamabad, Peshawar, Cherat and Lahore.

Zone C

Climate is cold in winters and hot in summers. Most of them are mountainous stations with high elevations from mean sea level and cover an area between 27 N to 32N and 64 E to 70 E. Stations included in this zone are Quetta, Zhob, Kalat and Khuzdar.

Zone D

This is the hottest and dry zone of the country where highest maximum temperatures are recorded in stations of Sibbi and Jacobabad. The area is almost plain with some area included in Thar Desert. Stations included are Sibbi, Jacobabad, Bahawalpure, Khanpur, Multan and Rohri.

Zone E

Zone E is a big zone having many stations and coastal cities, near to Arabian Sea. The coastal part comprises only a small part of this region and climate above coastal parts in Balochistan as well as in Sindh province is mostly arid to hyper arid. The selected stations from this zone are Hyderabad, Karachi, Nawabshah and Jewani.

Data and Method

Rainfall data of five climate zones included 30 meteorological stations spreading all over the country and covering the period from 1976 to 2005 has been used in this study as shown in Figure (1). Therefore, a simple methodology was applied by using the Mean Annual Rainfall data of the above stations and their geographic location. All the data used and processed in this study was provided by the Pakistan Meteorological Department (PMD). In order to statistically analyze variations in the mean rainfall of the study area ANOVA test was applied, using SPSS version 17. For trend determination, average values were analyzed carefully by dividing the data on the basis of decades, fifteen years interval and the entire period 1976-2005 as a whole for each zone and for the whole Study area as well. During the analysis it was observed that rainfall distribution is not normal with large year to year differences. Therefore, the above mentioned data was analyzed using Dunnett T3 test along ANOVA for multiple comparison of alpha 0.05. Analysis was performed assuming unequal variances of precipitation distribution. The principle feature of these methods is that they can be used for the analysis of data sets which do not display a normal distribution. Further, for visualization of data ArcGIS software was used for the mapping based on geo-referenced plotting, editing and map-based query and analysis.

Results

Trend Determination

10 Years Trend (Individual Zone)

In order to show the deviation of annual data from the average value, statistical indicators such as standard deviation, standard error, skewness, 5% trimmed mean and median were calculated. The descriptive statistical analysis results are presented in Tab (1) with ANOVA result of the rainfall for the whole study area in different microclimates.

Table 1: Descriptive statistics and ANOVA result for rainfall

Rainfall Trend in the whole Study Area (F=71.64, p=0.00)						
		ZoneA	**ZoneB**	**ZoneC**	**ZoneD**	**ZoneE**
Stations		10	6	4	6	4
30 Years	Valid/Missing values	297/3	175/5	116/4	172/8	118/2
Mean	All value used	66.64	66.99	32.92	22.65	32.10
	5%trimmed Mean	64.72	64.42	31.74	21.76	29.62
Median		57.22	57.05	30.47	19.29	25.04
Std. Error		2.70	2.77	1.39	1.05	2.35
95%CI	Lower Bound	61.31	61.52	30.16	20.58	27.45
	Upper Bound	71.96	72.46	35.68	24.72	36.75
Skewness		0.46	1.12	1.56	1.15	1.45
F- Value		1.93	0.91	3.81	1.53	5.92
Sig.		0.15	0.41	0.03	0.22	0.00

In the above table, the number of valid/missing values indicate the length of data i.e., from 1976-2005. It is evident from these statistical indicators that highest zonal means and medians were observed for zone A (66.64 mm, 57.22 mm) and zone B (66.99 mm, 57.05 mm) for 30 years average rainfall while zone D shows the lowest value of mean (22.65 mm) and median (19.29 mm) respectively. Similarly other statistics such as standard error and 95% confidence interval all are also higher for zone A and B as compared to other zones. The skewness shows positive values for all five zones with zone C and E being higher. Results of the ANOVA test are most significant (F=71.64, p=0.00) not only within each zone but also for inter-zonal analysis on decadal and inter-decadal scales. Similarly for each individual zone, analysis of variance show different results, like probability for zone A (F=1.93 p=0.15) is not found significant. The result shows higher value than the critical tabulated value ($p > 0.05$). Further, for zone B, and zone D, ANOVA test display non significant results for all of the included stations ($p > 0.05$ or 0.1). While in contrast the ANOVA results for the zone C (F=3.81, p=0.03) and zone E (F=5.92, p=0.00) are found most significant to the change and it is also obvious from inter decadal significance of the zones through Dunnett T3 (Table 2).

Table 2: Dunnett T3 for Homogenous subset of alpha (Inter-Decadal Analysis)

Zones	N	Mean	(I) Decade	(J) Decade	Mean Diff (I-J)	Sig.
Zone A	99	62.39	1	2	-11.65	0.25
				3	-0.98	1.00
	100	74.04	2	1	11.65	0.25
				3	10.67	0.30
	98	63.37	3	1	0.98	1.00
				2	-10.67	0.30
Zone B	59	72.11	1	2	8.66	0.52
				3	6.71	0.73
	60	63.44	2	1	-8.66	0.52
				3	-1.96	0.98
	56	65.40	3	1	-6.71	0.73
				2	1.96	0.98
Zone C	36	35.12	1	2	-0.97	0.99
				3	7.34	0.14
	40	36.09	2	1	0.97	0.99
				3	8.31	0.01
	40	27.78	3	1	-7.34	0.14
				2	-8.31	0.01
Zone D	59	23.15	1	2	-1.51	0.92
				3	2.91	0.59
	55	24.65	2	1	1.51	0.92
				3	4.42	0.23
	58	20.23	3	1	-2.91	0.59
				2	-4.42	0.23
Zone E	40	34.76	1	2	-5.48	0.70
				3	13.04	0.02
	38	40.24	2	1	5.48	0.70
				3	18.52	0.01
	40	21.71	3	1	-13.04	0.02
				2	-18.52	0.01

15 years trend (Single Station)

In single station analysis the entire data is divided into two periods (1976-1990 and 1991-2005) for whole study area and for each single station. The average rainfall of the whole study area (country) is calculated as 50.48mm for first half period 1976-1990 and 47.50mm for the second half period 1991-2005 which become 2.98mm lower than the first half with non-significant mean variance (F=1.273, p=0.26).

Table 3: Single Station analysis for the determination of significant trend in two time periods

Station	**F**	**Sig**	**Mean (1976-1990)**	**Mean (1991-2005)**	**Mean Diff**	**Zone**
			Increase in Rainfall			
Chitral	8.09	0.01	34.67	45.90	11.23	A
			Decrease in Rainfall			
Quetta	4.43	0.04	47.36	33.59	-13.77	C
Karachi	3.87	0.05	42.82	28.10	-14.72	E
			No change in Rainfall			
Astor	0.04	0.84	43.31	44.32	1.01	A
Chilas	2.87	0.10	16.03	22.63	6.60	A
Dir	0.43	0.52	126.91	121.05	-5.86	A
Gilgit	0.56	0.46	15.85	13.79	-2.06	A
Kakul	1.68	0.21	121.19	111.83	-9.36	A
M-abad	0.25	0.62	134.76	130.28	-4.48	A
P-Chinar	0.35	0.56	66.16	68.90	2.74	A
Skardu	0.62	0.44	19.64	22.03	2.38	A
S-Sharif	0.02	0.91	88.42	89.51	1.10	A
Cherat	0.03	0.85	54.86	53.80	-1.06	B
DIK	0.27	0.61	28.73	30.43	1.70	B
Isl-bad	0.91	0.35	115.58	105.41	-10.18	B
Lahore	2.02	0.17	77.94	60.76	-17.18	B
Peshawar	1.73	0.20	39.68	46.00	6.33	B
Sialkot	0.03	0.87	91.78	93.56	1.79	B
Kalat	0.00	1.00	28.48	28.46	-0.02	C
Khuzdar	0.09	0.77	31.83	30.42	-1.40	C
Zhob	0.01	0.92	31.19	30.85	-0.34	C
B-Pur	0.48	0.49	25.12	21.26	-3.86	D
Jaco-bad	3.69	0.07	27.48	15.28	-12.20	D
Khanpur	0.08	0.78	16.54	15.43	-1.11	D
Multan	0.09	0.77	25.03	26.25	1.22	D
Rohri	0.04	0.85	25.18	26.36	1.18	D
Sibbi	0.59	0.45	21.67	24.67	3.00	D
H-abad	0.77	0.39	41.39	30.63	-10.77	E
Jewani	1.57	0.22	29.53	22.33	-7.20	E
N-Shah	0.10	0.76	33.06	29.74	-3.32	E

The trend analysis for individual stations is presented in Tab.3 and Figure 2 (A and B). The intensity of the map color shows mean inter-zonal rainfall variation from 134.19 - 16.09 mm in Figure 2(A) to 130.19 - 14.26 mm (B) for different zones from the first half study period to the second half. Among the stations Chitral shows a significantly higher trend with 11.23 mm increase between the two 15-years periods while rest of the stations show an increasing trend in the range of 1 – 6 mm but with no significance value ($p > 0.05$). On the other hand rainfall data for Quetta (-13.77 mm) and Karachi (-14.72 mm) stations indicate a significant decrease in the mean rainfall during the second half period. Similarly Dir, Gilgit, Kakul, Muzaffarabad, Islamabad, Lahore, Kalat, Khuzdar, Bahawalpure, Khanpur, Hyderabad, Jewani, and Nawabshah stations also show decrease in the average rainfall, albeit with a non-significant trend. The overall difference in mean rainfall for each individual station is observed with a decreasing trend in the 1991-2005 as compared to 1976-90 periods.

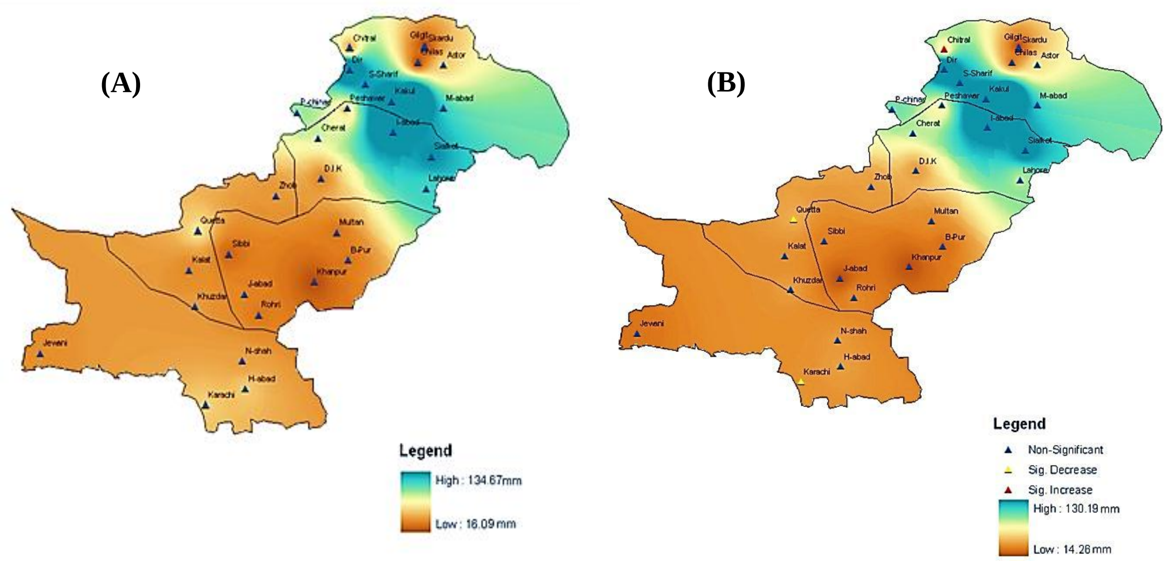

Figure 2: Station-wise mean annual rainfall showing significant increase, decrease and no change from the period 1976-1990 **(A)** to 1991-2005**(B)**

Whole Study Area Analysis (Country wide)

The data of all zones in Tab (4) and Figure (3B) showing a decrease in mean rainfall in two fifteen yearly periods. Spatial variation in mean rainfall across the country ranges from 68.23 - 23.37 mm during 1976-90 period in Figure (3A) while it decreases to 66.41- 21.91 mm during 1991-2005 period in Figure (3B). ANOVA test for the two periods is found most significant only for zone E (F=3.719, p=0.05) which indicates a negative change in the mean rainfall (-8.96mm) followed by zone C (-4.33mm) that also shows a higher decreasing trend with a relatively higher p-value (F=2.439, p=0.1) than the significant tabulated value.

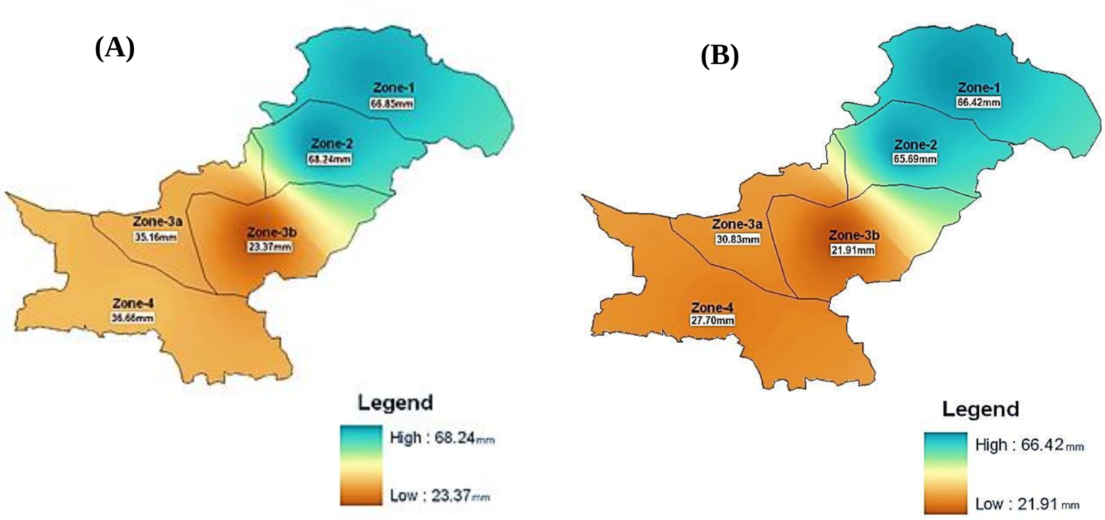

Figure 3: Country wide analysis of the mean annual rainfall showing significant increase, decrease and no change between the two 15-years periods; **(A)** 1976-1990, **(B)**: 1990-2005.

Overall mean rainfall (Tab.4) is observed with downfall trend of (-3.55mm) for the two time periods and per decade (-1.18mm).

Table 4: Mean difference in rainfall data for the two periods along with ANOVA result

Zones	F-value	Sig.	Mean (1976-1990)	Mean (1991-2005)	Mean Diff
Zone A	2.483	0.12	66.85	66.42	-0.43
Zone B	0.21	0.65	68.24	65.69	-2.55
Zone C	2.439	0.1	35.16	30.83	-4.33
Zone D	0.735	0.39	23.37	21.91	-1.46
Zone E	3.719	0.05	36.66	27.7	-8.96

30 Year Trend

The time series of 30 years annual mean rainfall clearly showed that the overall change is found most significant at ($p<0.05$) as shown in Tab. (5) along with descriptive statistics. In the Overall results in Dunnett T3 test (Tab.6) show that mean rainfall decreased with fluctuations but have the significant trend of downfall in the rainfall trend during the whole study period but this change in last two decade is more significant than the first one decade.

Table 5: Descriptive statistics and ANOVA result for the whole Study Area

Whole Study Area							95% CI for Mean			
	N	F	Sig.	Mean	Std. Dev	Std. Error	Upper	Lower	Min	Max
Mean Rainfall	30	3.65	0.04	48.99	7.57	1.38	46.16	51.82	32.85	63.90

Table 6: Dunnett T3 for homogenous subset of alpha

(I) Decade	(J) Decade	Mean Diff. (I-J)	Sig.
1	2	-3.71	0.60
	3	4.71	0.36
2	1	3.71	0.60
	3	8.42	0.03
3	1	-4.71	0.36
	2	-8.42	0.03

Trend Forecasting

After the bifurcation of data into decades, fifteen years and entire period, it was analyzed for trend forecasting. The Time Series Modeler procedure in SPSS estimates ARIMA (Autoregressive Integrated Moving Average) model for mean annual rainfall forecast. The procedure includes an Expert Modeler that automatically identifies and estimates the best-fitting or exponential smoothing model for one or more dependent variable series. Figure (4A) forecasts a downward trend for mean annual rainfall in the real time series with included drought period of 1998-2000. But this downward trend of rainfall is just a seasonal fluctuation or variability and not a trend of average pattern change as shown in Figure (4B). This is also in line with studies by Awan, (2002) and Chaudhry, (2001, 2002) wherein they have shown that Pakistan has experienced several droughts in the past, of which the most severe one occurred in 1998-2002. Furthermore the trend generated by the software through observational data (Figure 4B) projects an upward trend upto 50mm till 2030 with excluded drought period from the real time series. The upper critical limit is about 64.47mm and lower critical limit is 35.51mm.

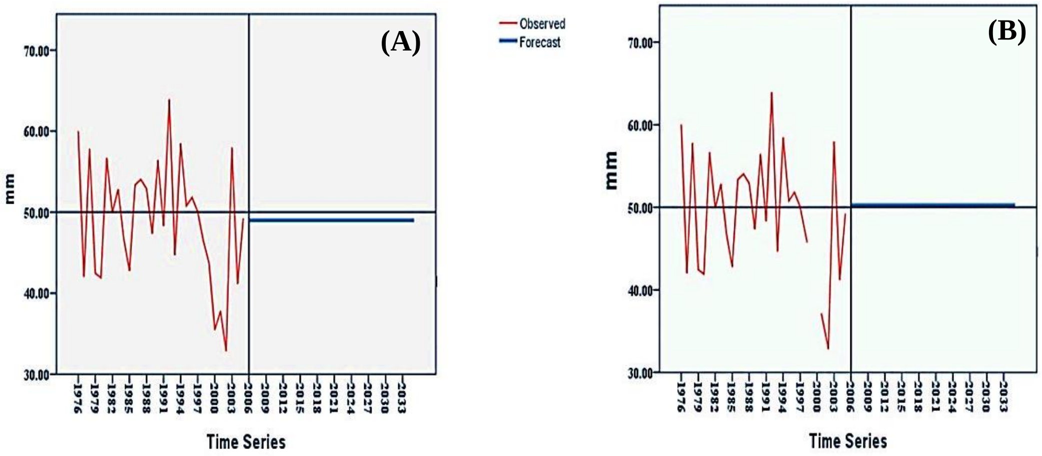

Figure 4: Trend Forecasting of 30 years of mean rainfall data of the whole country with included drought period from 1998-2001 **(A)** to **(B)** with excluded drought period from 1998-2001

Discussion

The analysis of rainfall data shows that zone A (mean 66.64 mm and median, 57.22 mm) and zone B (mean 66.99 mm and median 57.05 mm) show higher standard error (2.7mm). In the ANOVA test for decadal analysis, zone C and zone E were found most significant ($p<0.05$) and zone A slightly significant, with probability approximately 85%. The station-wise analysis suggests that Chitral was found significantly higher with mean difference of 11.23mm in the two 15-year periods while rest of the stations were observed with a increasing trend in the range of 1 to 6 mm but with no significance value ($p>0.05$) except for Chilas ($p=0.09>0.05$) with approximately 90% of probability. Quetta (-13.77 mm) and Karachi (-14.72 mm) are observed with significantly lower mean value and Jacobabad (-12.2 mm) slightly significant mean value in the second half period. Similarly Dir, Gilgit, Kakul, Muzaffarabad, Islamabad, Lahore, Kalat, Khuzdar, Bahawalpure, Khanpur, Hyderabad, Jewani, and Nawabshah have shown decrease in the average rainfall with non-significant trend. But in the decadal analysis Dir, Muzaffarabad, Skardu, and Said-u-Sharif were observed with a significant trend ($p<0.05$). The overall mean difference in the average rainfall for each individual station and for the country shows a decrease in from 1976-90 to the 1991-2005 periods. Zone E was found most significant in comparison between the two time series ($p<0.05$) with a negative change in mean rainfall (-0.97 mm) followed by zone C with slightly higher p-value approximately ($p=0.1$). It is also clear that zone A, zone C and zone E situated in different regions of the country showed an overall positive trend while plain areas and southwest of the country have been recorded with no significant trend during the last two decades.

The negative difference observed in rainfall data for the whole country is (-3.55 mm) between the two 15-year intervals, which works out to -1.18 mm per decade. This observational decrease in rainfall data is supported by the published data in IPCC (2001) report, which talks about 0.3% average decrease in rainfall per decade for the subtropical land areas as opposed to tropical lands with 0.3% increase per decade. Similarly most parts of Europe and East Asia are observed with a positive trend in the annual maximum consecutive days having rainfall below 1.0 mm and a negative trend in the number of rainy days during 1950-1995 period (Kiktev et al, 2003). The results of Kiktev et al (2003) were found relevant with the research conducted on the Mediterranean areas by Trigo et al (2000) and Alpert et al (2002) during the period 1951-1995. Their research works, in the Mediterranean areas, indicate a larger frequency of drought periods, with associated impacts on agriculture, water resources and socio-economic activities. Decreasing trends in annual mean rainfall are observed in Russia, North-East and North China, coastal belts and most parts of North-East India, Indonesia, Philippines and some areas in Japan. Annual mean rainfall exhibits increasing trends in Western China, South-Eastern coast of China, Arabian Peninsula, Bangladesh and along the western coasts of the Philippines (IPCC, 2007). Liu et al (2005) analyzed heavy precipitation events in China over the period 1960-2000. They found that the increased frequency of heavy precipitation events in China contributed 95% of the total increase of precipitation and only 2% increase in total precipitation was observed over that time period. Otherwise total rainy days trend was observed negative. For India, Roy and Balling (2004), found about two thirds of increasing trend for precipitation extremes during all the study period from 1910–2000 and also observed some regions with significant anomalies all over India.

Conclusions

From the above discussion it is concluded that rainfall data show a significant decreasing trend all over the country. The declining trend is due to relatively drier period from 1998 to 2001 in which Pakistan has faced severe drought, mainly in the southern and central parts of the country. Therefore, Autoregressive Integrated Moving Averages (ARIMA) model used for rainfall analysis predicts downward moving trend (2006-2030). But with excluding drier period from the real time series, it showed upward moving trend upto 50mm till 2030 in the mean rainfall trend for the whole study area. The overall considerable difference in the average rainfall for each individual station and for the country is observed with a decreasing trend in 1991-2005 as compared to 1976-1990 periods. The whole study area trend in two time series for zone E was found most significant ($p<0.05$) with change in the mean rainfall almost (-0.97mm) followed by zone C with a slightly higher p-value approximately ($p=0.1$). The analysis makes it clear that zone A, zone C and zone E situated in different regions of the country mainly from North, Northwest, West and Coastal areas respectively showed an overall significant decreasing trend. Plain Areas and Southwest of the country have experienced no significant trend during the last two decades. . Furthermore, the trend observed in rainfall data for the whole country is (-3.55mm) in two time intervals and per decade it became (-1.18mm) which are found in consistent with the IPCC (2001) report. From the present study it is concluded that change in the rainfall pattern and prolonged droughts will pose severe risks to agriculture and water management sectors. Therefore, the present study will be useful to detect the changes in the rainfall pattern as a baseline data for future research work in fields of hydrology, agriculture and disaster risk management.

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