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TRENDS AND VARIABILITY IN CLIMATE PARAMETERS OF PESHAWAR DISTRICT

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Abstract

Rain fall pattern, daily minimum and maximum temperatures and humidity are the main factors that constitute the climate of an area. In Pakistan, consecutive positive anomalies have been observed in minimum, maximum and mean temperatures and rainfall since mid 1970's. The objective of the current study was to investigate the recent trends and variability of annual minimum, maximum and mean temperatures, relative humidity and rainfall of Peshawar. Annual meteorological parameters for 30-years (1981-2010) of Peshawar observatory have been analysed to determine indications of variations from long-term averages. Different statistical methods were used to analyse the data. For this purpose, Mann-Kendall test was applied to Meteorological data of Peshawar (1981-2010) to study any trend, which were revealed to be in a mixture. The final results show that rainfall is decreasing, minimum temperature, mean temperature and relative humidity are increasing and maximum temperature has no change. Various factors could be responsible for the contemporary trends in climate like rise in number of vehicles and industries from reviewing available literature, keeping in mind the nature of the study. Trends found may have negative implications for agriculture, health and socioeconomic conditions of the region that require the attention from relevant stakeholders.

Keywords: Climate parameters, Mean temperatures, Relative humidity, Rainfall.

Introduction

The physical conditions in the environment and atmosphere such as precipitation, temperature, wind, pressure and humidity, which have direct or indirect consequences upon the biosphere, are termed as weather while the pattern of weather in a region over a period of time is called climate (Cunningham et al., 2005). The main cause of climate change according to majority of scientists is anthropogenic activities of various kinds that began during the industrial revolution of 1700-1800s (United Nations Environment Programme, 2001). Since then, scientists have observed noticeable changes in the climate of our planet. As a result, the climate of the planet is warming and scientific evidence to this effect has been collected from various regions of the Earth. Another important observation regarding the changing climate of the Earth is the rise in the average surface temperature of the planet (Newton, 2001). Rise in temperature is linked with increase in extreme weather events with detrimental effects for human societies. The population growth rate and rapid urbanisation of areas vulnerable to extreme weather events have resulted in increased vulnerability of the societies (Easterling et al., 2000a). Global Climate Models or Global Circulation Models are used to project changes in the climate. The Intergovernmental Panel on Climate Change (IPCC) of United Nations monitors these computer-based experiments. Experiments are carried out both on regional and global scales. A rise of 1.5 to 3.5 ^{o}C in the mean global surface temperature is predicted by the year 2100, which is a significant rate of warming (IPCC, 2007). Greater fluctuations in rainfall, whether increase or decrease, are forecasted mainly in the region under the tropics. Change in climate is expected to affect the occurrence and intensity of extreme weather events like floods and storms around the globe. Rise in sea level due

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to the thermal expansion of oceans and the melting of the mountain glaciers are largely attributed to climatic change (United Nations Environment Programme, 2001). The mean global sea level is predicted to rise up to 15 to 95cm by the year 2100 (Cunningham et al., 2005). This increase in sea level rise may result in vulnerable situations like coastal flooding and storm surges (Houghton et al., 1996). Thus, more the climatic changes, the more will be the risk of damage to the natural environment. Climatic zones like ecosystems and agricultural zones are expected to move toward the poles by 150 to 550km by the year 2100. Climatic change may affect the ecosystems and it is expected that wild species have chances to become extinct due to declination and fragmentation in ecosystems. IPCC in their Second Assessment report concludes that climatic change has most likely already begun (Watson et al., 1996).

Change in the climate may affect the human health of billions of individuals and most of the population will be at high risk in the coming years due to impact of climatic change on health and agriculture (Costello et al., 2009). Easterling et al. (2000b) concluded that human population and infrastructure are rapidly increasing in areas which are vulnerable to severe events like storm damage, flooding and remarkable heat and cold waves. One of the most pivotal concerns related to anthropogenic variation in climate is an increase in severe events that could have a profound effect on both natural environment and human socio-economic conditions. Ahmed and Ahmad (1999), in their research for Bangladesh found that climate change, climate variability its causes and consequences are of great importance around the globe. The climate conditions of country are showing a noticeable change and are more unpredictable each year. Changes in temperature and rainfall due to global warming are already marked in many parts of the world, as well as in Bangladesh. Mann and Jones (2003) in their research study present the reconstructions of the Northern and Southern Hemisphere surface mean temperature over the past two millennia based on high resolution proxy temperature data set which calculates variability of millennial scale. The results of these reconstructions point out that in the late 20th century in the Northern Hemisphere, the warmth is unparalleled at least approximately for the past two millennia. For the Southern Hemisphere, the proxy data at present is limited for the conclusion of the global mean temperature.

Shah et al. (2010) noted that during pre-monsoon season, i.e., April to June 2009, Khyber Pakhtunkhwa received a slightly above normal rainfall and during the study period across the entire region, the mean temperature remained normal. On the other hand, temperatures have increased in the high-mountain region of Pakistan during the last 30 years with some positive implications for agriculture related activities in these areas (Hussain et al., 2005).

Data and Methods

A data set of daily maximum, minimum temperatures and rainfall of Meteorological Observatory Peshawar from period (1981-2010) for single station Peshawar was obtained from Regional Meteorological Center (RMC), Peshawar. This is real time data manually recorded at 0300 GMT according to the international standards, i.e., minimum and maximum temperatures were measured at 8-o-clock 0800 GMT. The reliability of the data is a function of the measuring device and the observer (Shah, 2008).

Meteorological data were analysed for 3 spans of 10 years each and the variations are analysed using different statistical techniques. The decadal means computed for this station of minimum and maximum temperatures and rainfall were plotted for time series of thirty years and ten years to find out any possible trend using Microsoft Excel. To observe the changes, the magnitude of the trend was analysed for any possible increase and decrease in past years using Mann-Kendall Statistical test. Although the record length (30) years is not sufficient as compared to other similar studies conducted for the same purpose, however, they provided a good basis for assessing variations in climate of the region as well as for the country.

Results

To validate homogeneity and reliability of the data of Northwest of Pakistan (Peshawar) used for this study, it was statistically tested through the Mann-Kendall statistical tests using Microsoft Excel. Table 1 indicates average, median and standard deviation statistics for the real time data

(1981-2010) analysis of different weather parameters for Northwest Pakistan (Peshawar, Khyber Pakhtunkhwa).

Table 1. Frequency (Statistics) (Rain fall is in mm, Temperature in ^{o}C)

Weather Parameter	Rainfall (29 years)	Rainfall (30 years)	Min. Temp (30 years)	Max. Temp (30 years)	Mean Temp (30 years)
Average	**58.4**	**81.9**	**16.1**	**29.8**	**22.9**
Median	**64.0**	**64.5**	**15.9**	**29.8**	**23.1**
STDEV	**24.78**	**131.25**	**0.71**	**0.63**	**0.55**

There is difference in average and median rainfall for data analysed over the period of 29 years and 30 years because with the former, rainfall shows regular trends but in the latter, there was extra ordinary rainfall throughout the country that caused flooding and overall results showed deviation.

Mann Kendall test results for Minimum Temperature data

The Mann-Kendall test is a non-parametric test applied to the data set of the station from 1981-2010, i.e. 30 years to analyse the trends in the climate. Table 2 shows the results of Mann Kendall test applied to the minimum temperature trends of the study area. By applying Mann Kendall test, the time period from 1981-1990 shows stable trend for minimum temperature. The trend in minimum temperature for Peshawar for period 1991-2000 was probably increasing. The 3rd period from 2001-2010 for minimum temperature of Peshawar is showing decreasing trend by applying Mann Kendall statistical test. Overall results for 30 years of minimum temperature data shows definitely an increasing trend by applying Mann Kendall statistical test, as shown in Table 2, because the P(Z) value is greater than 95% and Standard score "Z" value is also greater than 0 which means that trend is definitely increasing for this data set.

Table 2. Mann-Kendall Results for Minimum Temp data of 30 years

	Min Temp 1981-1990	Min Temp 1991-2000	Min Temp 2001-2010	30 years Min Temp 1981-2010
Mann-Kendall Statistics "S"	**15**	**27**	**-27**	**160**
Standard Score "Z"	**1.25**	**2.32**	**-2.32**	**2.837**
Probability of Standard Score "P(Z)"	**0.79 or 79%**	**0.98 or 98%**	**-0.98 or -98%**	**0.995 or 99.5%**
Final Results of Mann-Kendall Test.	**If P(Z) < 90% then normal or stable trend.**	**If P(Z) > 95% then trend is probably increasing**	**If P(Z) > 95% and Z<0 then trend is decreasing**	**If P(Z) > 95% and Z>0 then trend is definitely increasing.**

Mann-Kendall test results for Maximum Temperature data

Table 3 shows the results of Mann-Kendall test applied to the Maximum Temperature trends of Peshawar for 30 years. By applying Mann-Kendall test, the time period from 1981-1990, shows stable trend for maximum temperature. The trend in maximum temperature for Peshawar form period 1991-2000 is stable or normal. The 3rd period from 2001-2010 for maximum temperature of Peshawar is showing stable or normal trend by applying Mann-Kendall statistical test. The overall results for 30 years of maximum temperature data shows stable or normal trend by applying Mann-Kendall statistical test for the data of Peshawar as shown in Table 3, because the P(Z) value is less than 90% and Standard score "Z" value is also greater than 0 which means that trend is stable or normal for this data set.

Table 3. Mann-Kendall Results for Maximum Temp data of 30 years

	Max Temp 1981-1990	Max Temp 1991-2000	Max Temp 2001-2010	30 years Max Temp 1981-2010
Mann-Kendall Statistics "S"	**9**	**21**	**11**	**27**
Standard Score "Z"	**0.71**	**0.71**	**0.89**	**0.46**
Probability of Standard Score "P(Z)"	**0.52 or 52%**	**0.52 or 52%**	**0.63 or 63%**	**0.35 or 35%**
Final Results of Mann-Kendall Test.	**If P(Z) < 90% then trend is normal or stable.**	**If P(Z) < 90% then trend is normal or stable.**	**If P(Z) < 90% then trend is normal or stable.**	**If P(Z) < 90% then trend is normal or stable.**

Mann-Kendall test results for Mean Temperature data

Table 4 shows the results of Mann-Kendall test applied to the mean temperature trends of Peshawar for 30 years. By applying Mann-Kendall test, the time period from 1981-1990 shows stable or normal trend for mean temperature. The trend in mean temperature for Peshawar for the period 1991-2000 was probably increasing. The 3rd period from 2001-2010 for mean temperature of Peshawar shows stable or normal trend by applying Mann-Kendall statistical test. The overall results for 30 years of mean temperature data shows an increasing trend by applying Mann-Kendall statistical test for the data of Peshawar because the P(Z) value is greater than 95% and Standard score "Z" value is also greater than 0 which means that trend is definitely increasing for this data set.

Table 4. Mann-Kendall Results for Mean Temp data of 30 years

	Mean Temp 1981-1990	Mean Temp 1991-2000	Mean Temp 2001-2010	30 years Mean Temp 1981-2010
Mann-Kendall Statistics "S"	**13**	**21**	**-11**	**115**
Standard Score "Z"	**1.07**	**1.78**	**1.07**	**2.03**
Probability of Standard Score "P(Z)"	**0.72 or 72%**	**0.92 or 92%**	**0.72 or 78%**	**0.958 or 95.8%**
Final Results of Mann-Kendall Test.	**If P(Z) < 90% then trend will be normal or stable.**	**If P(Z) > 90% then trend is probably increasing**	**If P(Z) < 90% then trend will be normal or stable.**	**If P(Z) > 95% and Z>0 then trend is definitely increasing.**

Mann-Kendall test results for Rainfall Data (30 years)

Table 5 shows the results of Mann-Kendall test applied to the Rainfall data trends of Peshawar for 30 years. By applying Mann-Kendall test, the time period from 1981-1990 shows a decreased trend in the rainfall data of Peshawar. The trend in rainfall of Peshawar form period 1991-2000 remained stable or normal. The 3rd period from 2001-2010 for rainfall data of Peshawar also shows normal or stable trend by applying Mann-Kendall statistical test. For reliability of data and graphs, another data set from 2001-2009 is made i.e. comprises of 9 years in order to avoid any error due to the heavy amount of rainfall recorded by Met Observatory Peshawar in 3 months of Monsoon, 2010 (from July 2010 to September 2010). The excess amount of rainfall causes super flash floods in the

Province of Khyber Pakhtunkhwa including Peshawar. This decade (2001-2009) shows a decrease in the rainfall of Peshawar. The overall results for 30 years of rainfall data shows definitely a decreasing trend by applying Mann-Kendall statistical test for the data of Peshawar because the P(Z) value is greater than 95% and Standard score "Z" value is less than 0 which means that trend is definitely decreasing for this data set.

Table 5. Mann-Kendall Results for Rainfall data of 30 years

	Rainfall 1981-1990	Rainfall 1991-2000	Rainfall 2001-2010	30 years Rainfall 1981-2010
Mann-Kendall Statistics "S"	**-23**	**-14**	**-9**	**-114**
Standard Score "Z"	**-1.97**	**-1.17**	**-0.72**	**2.05**
Probability of Standard Score "P(Z)"	**0.98 or 98%**	**0.88 or 88%**	**0.76 or 76%**	**0.96 or 96%**
Final Results of Mann-Kendall Test.	**If P(Z) > 95% and Z< 0 then trend is definitely decreasing.**	**If P(Z) < 90% then trend will be normal or stable.**	**If P(Z) < 90% then trend will be normal or stable.**	**If P(Z) > 95% and Z < 0 then trend is definitely decreasing.**

Mann-Kendall test results for Rainfall Data (29 years)

The overall results for 29 years of rainfall data explains definitely a decreasing trend by applying Mann-Kendall statistical test for the data of Peshawar as shown in Table6, because the P(Z) value is greater than 95% and Standard score "Z" value is less than 0 which means that trend is definitely decreasing for this data set.

Table 6.Mann-Kendall Results for Rainfall data of 29 years

	Rainfall 1981-1990	Rainfall 1991-2000	Rainfall 2001-2009	29 years Rainfall 1981-2009
Mann-Kendall Statistics "S"	**-23**	**-14**	**-27**	**-143**
Standard Score "Z"	**-1.97**	**-1.17**	**-2.33**	**2.70**
Probability of Standard Score "P(Z)"	**0.98 or 98%**	**0.88 or 88%**	**0.99 or 99%**	**0.99 or 99%**
Final Results of Mann-Kendall Test.	**If P(Z) > 95% and Z< 0 then trend is definitely decreasing.**	**If P(Z) < 90% then trend will be normal or stable.**	**If P(Z) > 95% and Z<0 then trend is definitely decreasing.**	**If P(Z) > 95% and Z < 0 then trend is definitely decreasing.**

Mann-Kendall test results for Relative Humidity at 0300Z

The trend in mean relative humidity for Peshawar for the period 1991-2000 also remains stable as shown in Table 7. The 3rd period from 2001-2010 for mean relative humidity of Peshawar is showing an increasing trend by applying Mann-Kendall statistical test. The overall results for 30 years of mean relative humidity 0300Z data shows an increasing trend by applying Mann-Kendall statistical test for the data of Peshawar because the P(Z) value is greater than 95% and Standard score "Z" value is also greater than 0Table 7 also shows the results

of Mann-Kendall test applied to the mean relative humidity recorded at 0300Z trends of Peshawar for 30 years. By applying Mann-Kendall test, the time period from 1981-1990 shows stable or normal trend for mean relative humidity.

Table 7. Mann-Kendall Results for Mean R/H 0300Z data of 30 years

	Relative Humidity 1981-1990	Relative Humidity 1991-2000	Relative Humidity 2001-2010	Relative Humidity 1981-2010
Mann-Kendall Statistics "S"	**-10**	**8**	**21**	**175**
Standard Score "Z"	**0.98**	**0.63**	**1.79**	**3.10**
Probability of Standard Score "P(Z)"	**0.67 or 67 %**	**0.47 or 47 %**	**0.93 or 93 %**	**0.99 or 99%**
Final Results of Mann-Kendall Test.	**If P(Z) < 90% and Z< 0 then trend will be normal or stable.**	**If P(Z) < 90% and Z > 0 then trend will be normal or stable.**	**If P(Z) > 90% and Z > 0 then trend is probably increasing.**	**If P(Z) > 95% and Z > 0 then trend is definitely increasing.**

Mann-Kendall test results for Relative Humidity at 1200Z

Table 8 shows the results of Mann-Kendall test applied to the mean relative humidity recorded at 1200Z trends of Peshawar for 30 years. By applying Mann-Kendall test, the time period from 1981-1990 shows stable or normal trend for mean relative humidity. The trend in mean relative humidity for Peshawar for period 1991-2000 also remains stable. The 3rd period from 2001-2010 for mean relative humidity shows a stable or normal trend by applying Mann-Kendall statistical test.

The overall results for 30 years of mean relative humidity 1200Z data shows an increasing trend by applying Mann-Kendall statistical test, because the P (Z) value is greater than 95% and Standard score "Z" value is also greater than 0.

Table 8. Mann-Kendall Results for Mean R/H 1200Z data of 30 years

	Relative Humidity 1981-1990	Relative Humidity 1991-2000	Relative Humidity 2001-2010	Relative Humidity 1981-2010
Mann-Kendall Statistics "S"	**-13**	**-13**	**17**	**158**
Standard Score "Z"	**1.25**	**1.25**	**1.43**	**2.8**
Probability of Standard Score "P(Z)"	**0.79 or 79%**	**0.79 or 79%**	**0.84 or 84%**	**0.99 or 99%**
Final Results of Mann-Kendall Test.	**If P(Z) < 90% and Z< 0 then trend will be normal or stable.**	**If P(Z) < 90% and Z< 0 then trend will be normal or stable.**	**If P(Z) < 90% and Z > 0 then trend will be normal or stable.**	**If P (z) > 95% and Z > 0 then trend is definitely increasing.**

It may be concluded from the above mentioned results that rainfall pattern is in decreasing trend; minimum temperature, mean temperature and relative humidity is in increasing trend and maximum temperature shows a stable trend in the study area. These variations in temperature, rainfall and humidity indicate climatic drift which may be the result of anthropogenic activities like fuel combustion, industrial activities and deforestation. Efforts

should be made to minimise the effect of these activities by adopting standard precautionary measures.

References

Ahmed, A.U. and M. Ahmad. 1999. 'Development of Climate Change Scenarios with General Circulation Models' In: Huq, S., Karim, Z., Asaduzzaman, M & Mahtab, F. (eds.) *Vulnerability and Adaptation to Climate Change for Bangladesh*. :13-20.

Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J. Patel, J.A. de Oliveira, N. Redclift, H. Rees, D. Rogger, J. Scott, J. Stephenson, J. Twigg, J. Wolff and C. Patterson. 2009. 'Managing the health effects of climate change: Lancet and University College' *London Institute for Global Health Commission. The Lancet*. 373 (9676): 1693–1733.

Cunningham, W.P., M.A. Cunningham and B. Saigo. 2005. *Environmental Sciences: A Global Concern*. 8thed. New York: Published by McGraw-Hill : 16-316.

Easterling, D.R., G.A. Meehl, C. Parmesan, S.A. Changnon, T.R. Karl and L.O. Mearns. 2000a. 'Climate extremes: Observations, modeling, and impacts.' *Science Journal*. 289:: 2068-2074.

Easterling, D.R., G.A. Meehl, C. Parmesan, S.A. Changnon, T.R. Karl and L.O. Mearns. 2000b. 'Observed variability and trends in extreme climate events: a brief review' *Bulletin of the American Meteorological Society*. 81: 417-425.

Houghton, J.T., L.G. MeiraFilho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell Eds. 1996. 'The Science of Climate Change' *Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Hussain, S.S., M. Mudasser, M.M. Sheikh and N. Manzoor. 2005. 'Climate Change and Variability in Mountain Regions of Pakistan Implications for Water and Agriculture' *Pakistan Journal of Meteorology*. 2(4) : 1-16.

Intergovernmental Panel on Climate Change. 2007. *4th Assessment Report: Climate Change*. Cambridge: Cambridge University Press.

Mann, M.E. and P.D. Jones. 2003. 'Global surface temperatures over the past two millennia'. *Journal of Geophysics*. 30(15): 1820.

Newton, P.W. 2001. 'Human Settlements Theme Report' Available at: http://www.environment.gov.au/soe/2001/publications/themereports/settlements/glossary.html .

Shah, M.A. 2008. *Impacts of climate change on minimum temperature trends of Pakistan*. M. Phil. University of Liverpool, United Kingdom.

Shah, M.A., A. Khan and S. Mehmood. 2010. 'The Rainfall Activity and Temperatures Distribution over NWFP during the Pre-Monsoon Season (April to June) 2009' *Pakistan Journal of Meteorology*. 6(12):1-20.

Watson, R., M.C. Zinyowera, R.H. Moss and D. Dokken. 1996. *Climate Change 1995. Impacts, Adaptations, and Mitigation of Climate Change: Scientific and Technical Analyses. Second Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

United Nations Environment Programme. 2001. "Technical summary". Climate Change 2001.