

ANALYSIS OF CLIMATE CHANGE USING TEMPERATURE AND RAINFALL ANOMALIES AND DIURNAL TEMPERATURE RANGES

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ABSTRACT

The problem of climate change is worldwide and causing diverse effects on all aspects of life. Altering rain patterns could cause floods in certain areas and droughts in the other causing a direct threat to our food security. This study was conducted to analyze different indicators of climate change in three cities of Punjab Province of Pakistan (Lahore, Faisalabad and Multan). Secondary data was collected from Pakistan Meteorological Department. Study parameters were minimum temperature, maximum temperature, annual rainfall and diurnal temperature rainfall. Results showed that minimum temperature anomaly decreased during most of the years from 1977 to 1998. 10-years moving average of minimum temperature anomaly remained negative till early 21st century for Lahore, Faisalabad and Multan. Afterwards, 10-years moving average of minimum temperature anomaly increased gradually and became positive. Maximum DTR was 1.75, 2.0 and 1.50 for Lahore, Faisalabad and Multan, respectively. A great variation in annual rainfall has been observed from 1977 to 2016. 10-years moving average of annual rainfall anomaly remained positive in most of the years. A great variation in maximum temperature anomaly was observed during the entire study period for all districts. Considering the climatic variations in the study area, there is need to analyze vulnerability of Punjab Province of Pakistan.

Keywords: Urbanization, Global warming, Extreme temperature, Climatic variation, Precipitation



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Introduction

Climate change in one of the leading global environmental issues. It is affecting all types of ecosystems directly or indirectly in different ways. Varying rainfall events may have different implications for different areas. Like heavy rains may cause floods in some areas. While decreased rainfall ratio may lead to drought in some areas. In both conditions crops will be affected. This may directly challenge our food security. Season shifting is another factor which damages not only crops but also the habitats [1]. This season shifting and severity of weather badly affect maturation cycle of the crops, which in turn lower the crop yield [2]. People of this globe have to suffer from the impacts of varying climate. Climate variability has been increased to greater extent in different

parts of the globe. From 1996 to 2015, about 528,000 people died around the world because of severe weather conditions. The Global Climate Risk Index (CRI) established by Germanwatch analyses the quantified impacts of worse weather conditions—both in terms of sufferers and economic losses that had been experienced [3, 4].

The Germanwatch Global Climate Risk Index found that Honduras, Myanmar and Haiti were the countries most affected by severe weather conditions from 1996 to 2015. Pakistan is one of the top ten most susceptible countries around the globe [3, 4]. Total carbon dioxide (CO₂) emissions for Pakistan from fossil fuels and industry are estimated as 234.75 million tones (0.67% of world emissions) with per capita emission of 1.06 tones for the year 2020. Oil consumption is the highest source of CO₂ emissions with 88.69 million tones [5]. The climate changeability causes complicated issues for Pakistan. Climate change is causing a variety of effects in Pakistan including droughts and heat waves, floods, sea storms and landslides. Intensity and frequency of such events are expected to increase due to climate change [6]. From 2010, Pakistan is experiencing floods on annual basis. The flood of 2010 inundated 20% land of the country. More than 2000 people died and over 20 million people were affected in 2010 [7]. A data analysis from 52 meteorological departments in Pakistan over a 40-year period (1961-2000) showed that the frequency of maximum daily temperatures and heaviest rainfall in 24 hours have been increased than past. These recorded floods affected about 20 million inhabitants [8, 9].

Pakistan is not a major contributor to global emissions of greenhouse gases. However, It is a major prey of global climate change and very vulnerable to climate change. There is likelihood of more severity, occurrence and frequency of different disasters including drought, floods and cyclones. Such events have serious social and economic impacts. Warm climate, arid and semi-arid lands and rivers' dependence on shrinking glaciers due to global warming have increased vulnerability to climate change. Pakistan's economy largely depends on agriculture sector and is at risk due to climatic variability, changes in seasons of the country, droughts and large floods. Climate change may cause energy crisis, food insecurity and water scarcity in the country. Considering these factors, present study was conducted to find variation in minimum and maximum temperatures, changes in seasonal rainfall and examine diurnal temperature range of the selected districts of the province. It is important to see the changes that have occurred due to climate change and propose sustainable solutions and recommendations.

Research Methodology

The present study was conducted in three districts of the Punjab Province of Pakistan. These districts include Lahore, Faisalabad and Multan. All selected cities lie in the Punjab Province of Pakistan. Lahore is one of the major cities of Pakistan with a population of 13,541,764 and the annual growth rate of 3.41 [9, 10]. Faisalabad is also one of the major cities with a population of 3,624,804 and the annual growth rate of 2.34%. Population of Multan is 2,105,987 and its annual growth rate is 2.26% [9, 10].

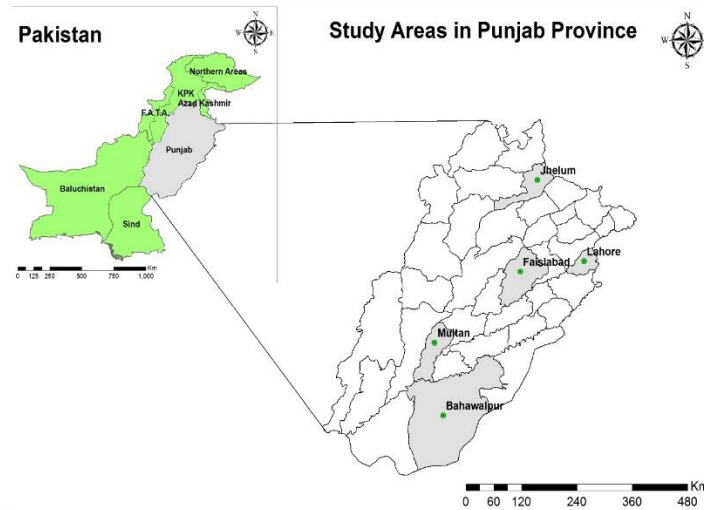


Fig. 1: Map showing study areas in Punjab Province of Pakistan

Study Parameters

Temperature: Annual minimum temperature, annual maximum temperatures

Rainfall: Annual rainfall, monsoon rainfall

A record of daily precipitation levels was acquired as the other variable to find the changes in the climate of cities. The variations and the anomalies in the precipitation during the said time period were observed to conclude if there was a climate change.

Data Collection: The present study was conducted using secondary data. The data was collected for a duration of forty years, starting from 1977 to 2016 from Punjab Meteorological Department (PMD), Lahore.

Data Analysis: Anomaly presents the difference of mean value of a parameter for current year from the mean value of same parameter for previous study period. Anomalies and diurnal temperature ranges were estimated using following equations;

- Diurnal Temperature Range = Mean Maxi. Temp. – Mean Mini. Temp.
- Annual Mean Mini. Temp Anomaly = Annual Mean Mini. Temp. for a year – Annual Mean Mini. Temp for 40 years
- Annual Mean Max. Temp Anomaly = Annual Mean Max. Temp. for a year – Annual Mean Max. Temp for 40 years
- DTR Anomaly = Annual Mean DTR for a year – Annual Mean DTR for 40 years
- Annual Rainfall Anomaly = Annual Rainfall for a year – Mean Annual Rainfall for 40 years

Results and Discussion

Temperature

Mean Annual Minimum Temperature Anomaly

Figure 2(a) shows mean annual minimum temperature for Lahore for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual minimum temperature. Minimum temperature anomaly decreases during most of the years from 1977 to 1997. 10-years moving average of minimum temperature anomaly remained negative till 1999. Afterwards, 10-years moving average of minimum temperature anomaly increased gradually and started to decrease in 2011. The increase in moving average of minimum temperature anomaly is due to increase in minimum temperature during the winter season.

Figure 2(b) shows mean annual minimum temperature for Faisalabad for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual minimum temperature. Minimum temperature anomaly decreases during most of the years from 1977 to 1998. 10-years moving average of minimum temperature anomaly remained negative till 1998. Afterwards, 10-years moving average of minimum temperature anomaly increased gradually and started to decrease in 2008. The increase in moving average of minimum temperature anomaly is due to increase in minimum temperature during the winter season.

Figure 2(c) shows mean annual minimum temperature for Multan for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual minimum temperature. Minimum temperature anomaly decreases during most of the years from 1977 to 1998. 10-years moving average of minimum temperature anomaly remained negative till 2002. Afterwards, 10-years moving average of minimum temperature anomaly increased gradually and became around 1 °C in 2016. The increase in moving average of minimum temperature anomaly is due to increase in minimum temperature during the winter season. Varying climate had severe impacts on the water systems of the globe. It is causing more floods and droughts [11].

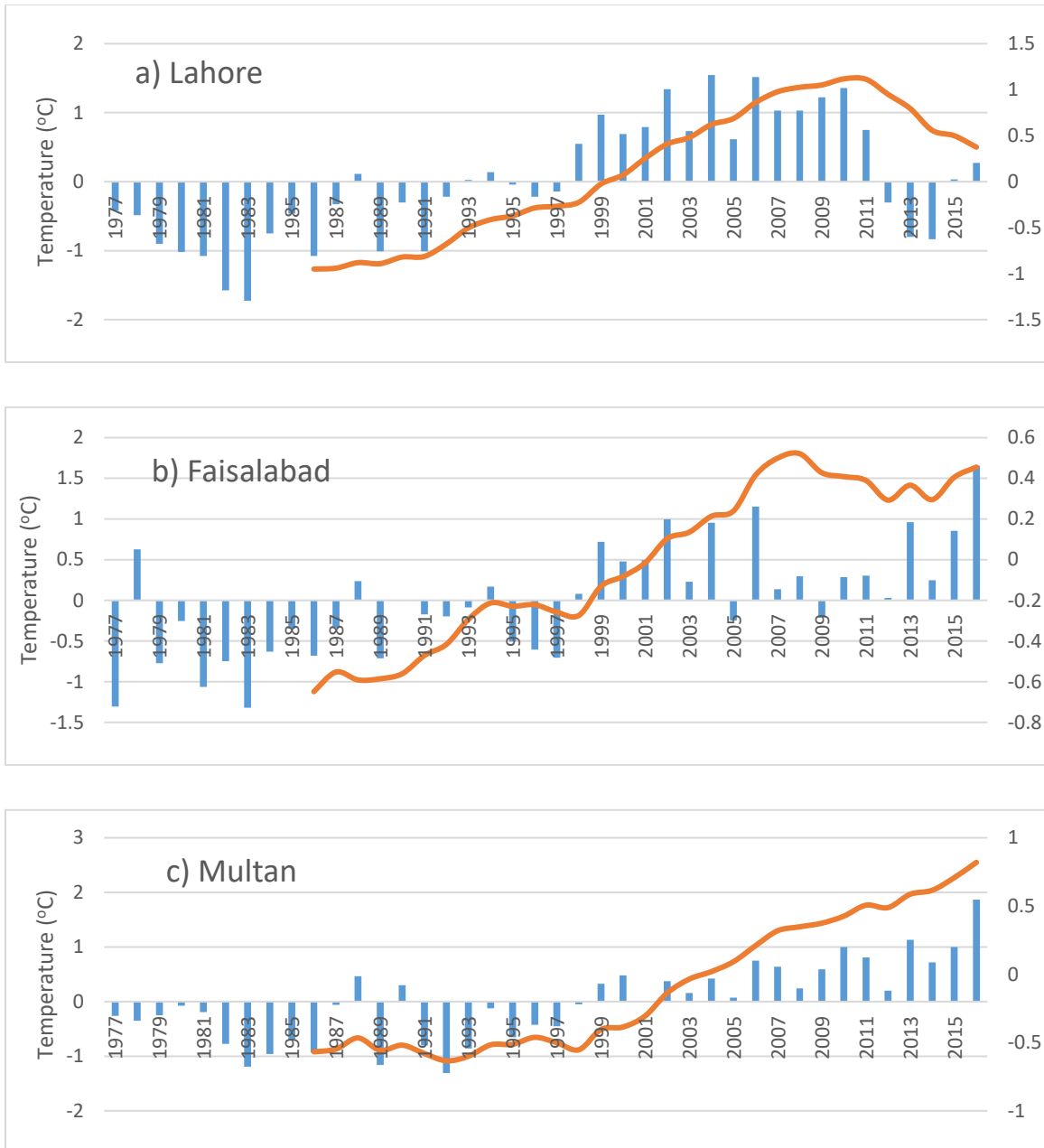


Figure 2: Mean annual minimum temperature anomaly with 10-years moving average

Mean Annual Maximum Temperature

Figure 3(a) shows mean annual maximum temperature anomaly for Lahore for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual maximum temperature. Significant variation was found in maximum temperature anomaly. Negative anomaly for 10-years moving average of maximum temperature was found except a period from 1989 to 1996. During this period, moving average became higher than 0.6 °C in 1993. Afterwards, 10-years moving average of minimum temperature anomaly decreased gradually and dropped to -0.3 °C in 2008.

This decrease in moving average of minimum temperature anomaly is due to decrease in maximum temperature during the summer season.

Figure 3(b) shows mean annual maximum temperature for Faisalabad for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual maximum temperature. Variation was also found in anomaly of maximum temperature. Negative anomaly was found for maximum temperature till 2006. Afterwards, 10-years moving average of maximum temperature anomaly climbed to 0.4 °C and dropped to below -0 °C in 2015. This increase might be due to emissions from deforestation in other sectors [12]. The increase in temperature in cities is has also been observed by van Wilgen, et al. [13]. The rise in the mean temperatures of the world is causing glacial melt down at a faster rate with higher risks of floods [14].

Figure 3(c) shows mean annual maximum temperature for Multan for a period of 40 years (1977-2016). It also presents 10-years moving average of mean annual maximum temperature. Significant variation in anomaly of maximum temperature was observed. It remained mostly negative, except a period between 1989 and 1996. During this period, highest moving average was found to be 0.65 °C in 1993. Afterwards, 10-years moving average of maximum temperature anomaly started to decline and dropped to below -0.3 °C in 2015.

Diurnal Temperature Range

Figure 4(a) shows diurnal temperature range (DTR) anomaly for Lahore for a period of 40 years (1977-2016). It also moving average (10-years) of DTR. Results showed positive anomaly till 1996, then It became positive till 1999. Afterwards, 10-years moving average of DTR anomaly decreased and became negative.

Figure 4(b) shows diurnal temperature range (DTR) anomaly for Faisalabad for a period of 40 years (1977-2016). DTR anomaly showed both values, positive and negative. Positive anomaly was observed till 1998. Afterwards, 10-years moving average of DTR anomaly decreased and became negative.

Figure 4(c) shows diurnal temperature range (DTR) anomaly for Multan for a period of 40 years (1977-2016). DTR anomaly showed both values, positive and negative. Positive anomaly was found from analysis till 2011. 10-years moving average of DTR anomaly decreased and became negative for 2012 to 2016. Climate change can be a biggest threat for the agriculture sector [15]. The changes in duration of the seasons causes such ecological disturbances that have negative effects on the agricultural outputs and habitat [1].

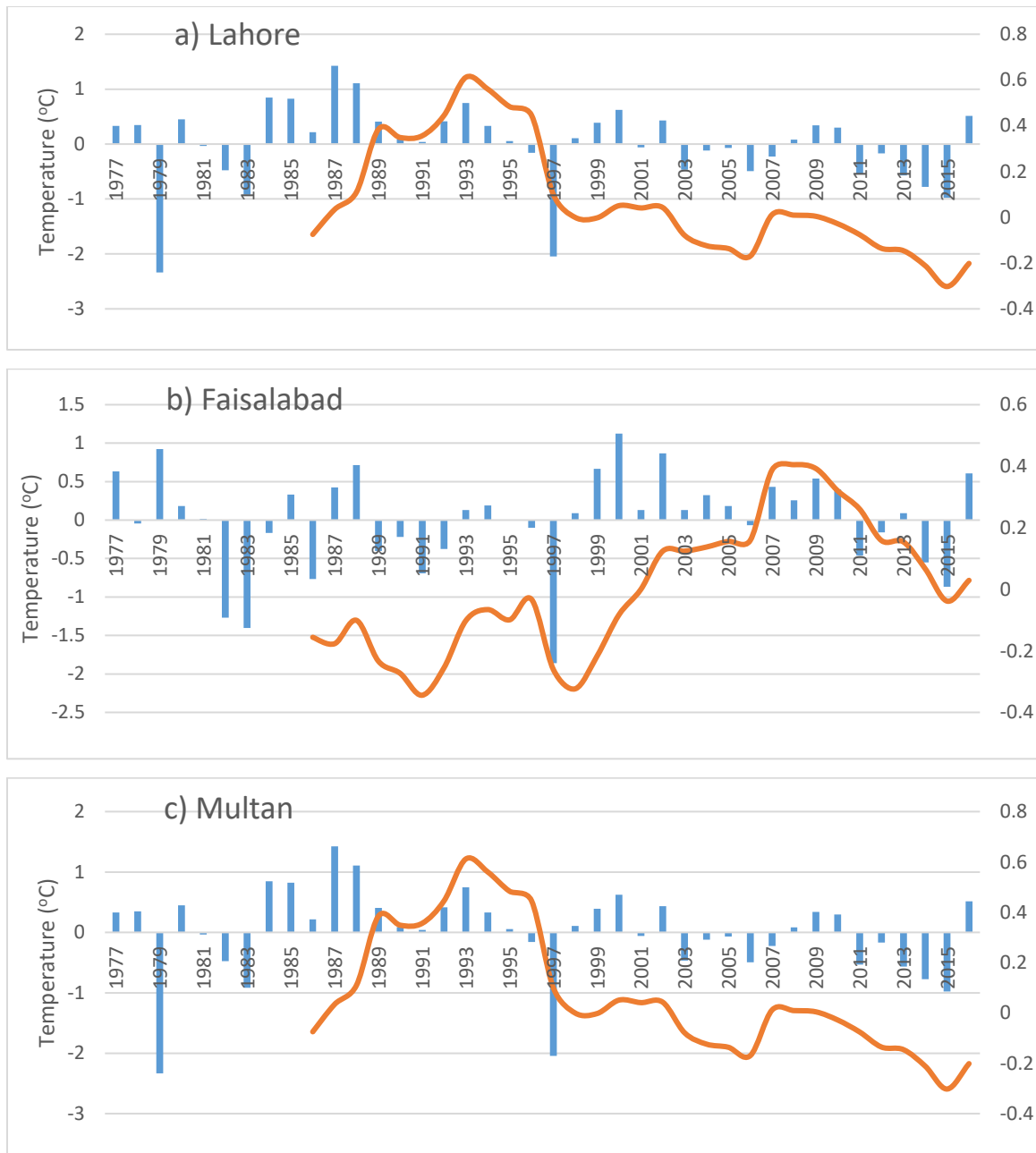


Figure 3: Mean annual maximum temperature anomaly with 10-years moving average

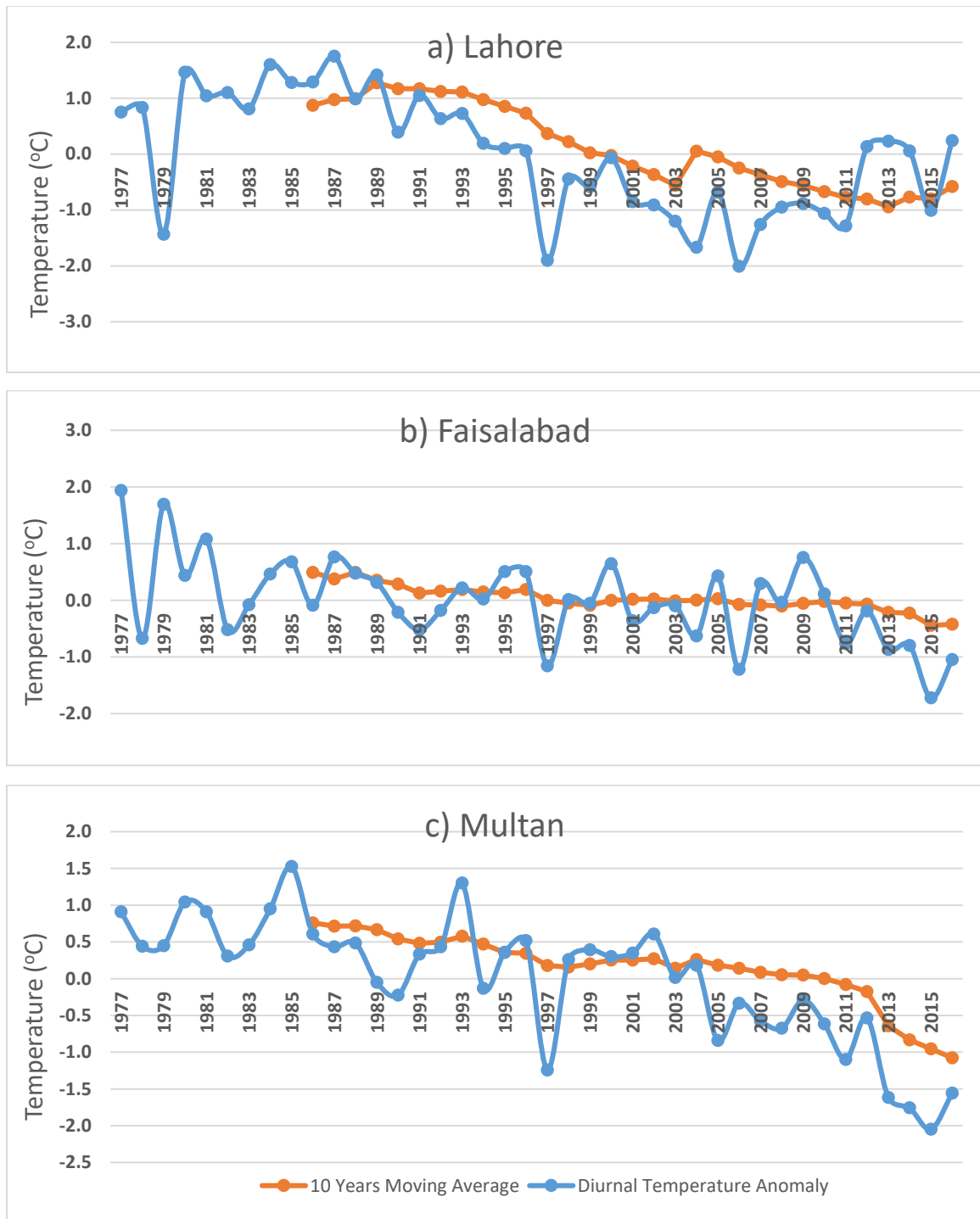


Figure 4: Diurnal temperature range anomaly with 10-years moving average

Rainfall

Annual Rainfall

Annual rainfall anomaly for Lahore for a period of 40 years (1977-2016) is presented in the Figure 5(a). It also shows 10-years moving average of annual rainfall. A great variation in annual rainfall has been observed from 1977 to 2016. Anomaly (10-years average) was found positive till 2005. Moving average of annual rainfall anomaly became negative from 2006 to 2013.

Annual rainfall anomaly for Faisalabad for a period of 40 years (1977-2016) is presented in the Figure 5(b). It also shows 10-years moving average of annual rainfall. Annual rainfall anomaly has been found negative from 1984 to 2004 (except for 1997 and 2003). 10-years moving average of annual rainfall anomaly remained negative from 1991 to 2008. Negative value of moving average is due to negative trend of annual rainfall anomaly.

Annual rainfall anomaly for Multan for a period of 40 years (1977-2016) is presented in the Figure 5(c). It also shows 10-years moving average of annual rainfall. Annual rainfall anomaly remained positive from 1992 to 2002 and negative from 2003 to 2009.

Monsoon Rainfall

Monsoon rainfall anomaly for Lahore for a period of 40 years (1977-2016) is presented in the Figure 6(a). It also shows 10-years moving average of monsoon rainfall. It was found mostly positive during the study duration, except 2007 to 2010. Maximum moving average was found to be around 75 mm in 1997.

Monsoon rainfall anomaly for Faisalabad for a period of 40 years (1977-2016) is presented in the Figure 6(b). It also shows 10-years moving average of monsoon rainfall. 10-years moving average of monsoon rainfall anomaly remained negative in from 1991 to 2003. Maximum moving average was found to be around 50 mm in 1986 and 2015.

Monsoon rainfall anomaly for Multan for a period of 40 years (1977-2016) is presented in the Figure 6(c). It also shows 10-years moving average of monsoon rainfall. It was found positive from 1992 to 2003. Moving average became negative for a period from 2004 to 2011. Maximum moving average was found to be around 48 mm in 2001. This season shifting and severity of weather badly affect maturation cycle of the crops, which in turn lower the crop yield [2]. Similar findings were found in other relevant study on Lahore for a period of 31 years (1985-2015) [16]. The variability of rainfall and the onset of monsoons are affected by shifting of monsoon season in the region [17, 18]. Scientists, researchers, and policy developers require the skill to review the possible impacts of varying climatic parameters on particular ecosystems in particular geographic regions at related spatial scales [19].

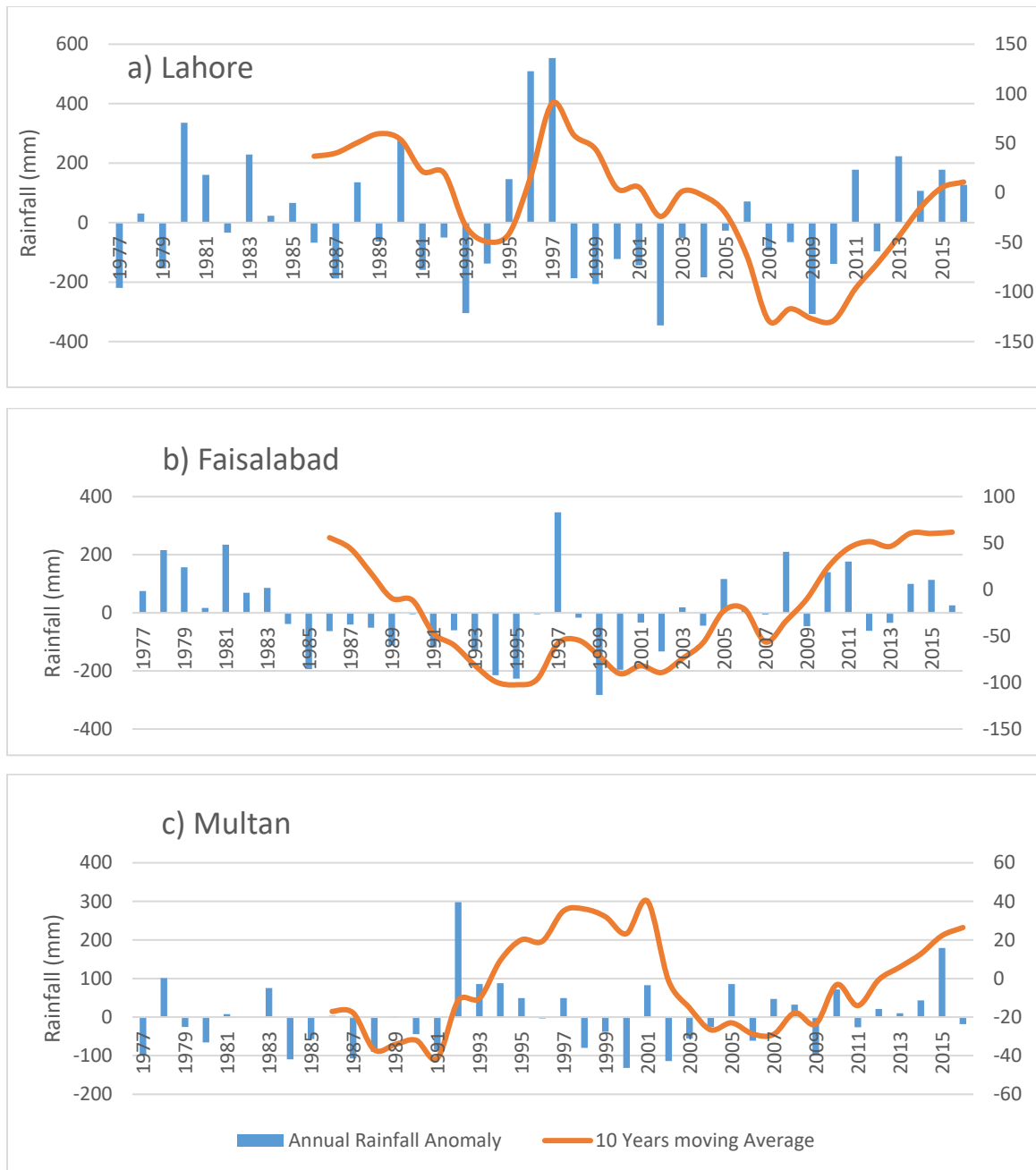


Figure 5: Annual rainfall anomaly with 10-years moving average

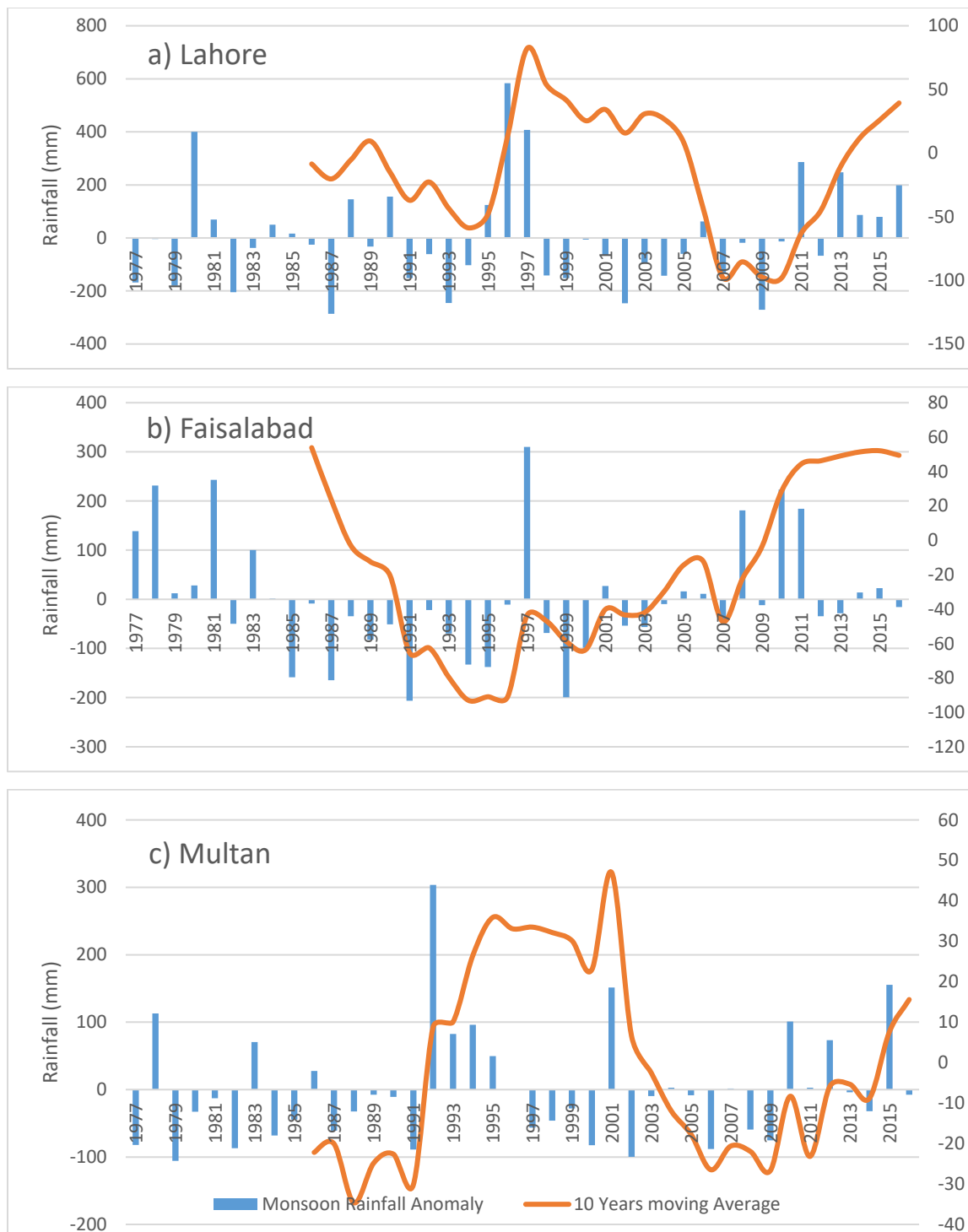


Figure 6: Monsoon rainfall anomaly with 10-years moving average

Conclusion

Present study was conducted to analyze different indicators of climate change in selected districts of Punjab Province of Pakistan (Lahore, Faisalabad and Multan). There was a decreasing trend in minimum temperature anomaly during most of the years from 1977 to 1998. Negative values of 10-years moving average of minimum temperature anomaly were found till early 21st century for Lahore, Faisalabad and Multan. Maximum DTR was 1.75, 2.0 and 1.50 for Lahore, Faisalabad and Multan, respectively. A great variation in annual rainfall has been observed from 1977 to 2016. Annual rainfall anomaly (10-years moving average) was mostly positive. A great variation in maximum temperature anomaly was observed during the entire study period. Awareness campaigns of climate change adaptation should be raised among public. Most suitable practices of climate change adaptation should be implemented to reduce the impacts of climate change. Such adaptation strategies include shifting of sowing times of crops according to climatic variability and sowing drought resistant crops in areas facing problem of water scarcity. There is need to conduct research study on climate change vulnerability in Punjab Province.

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REFERENCES

- [1] Bates, B., Kundzewicz, Z., and Wu, S., *Climate change and water*. Intergovernmental Panel on Climate Change Secretariat, 2008.
- [2] Singh, V. K., (2012)."Climate change and its impact on agriculture: a review.," *International Journal of Agriculture, Environment and Biotechnology*, 5(3): 297-302.
- [3] Eckstein, D., Kunzel, V., and Schäfer, L., *Global climate risk index 2018*. Bonn: Germanwatch, 2017.
- [4] MoCC, *The Environment and Climate Change Outlook of Pakistan*. Ministry of Climate Change (MoCC). Government of Pakistan (GoP) and United Nations Environment Program (UNEP). 2013.
- [5] Ritchie, H. and Roser, M. (2022). *Pakistan: CO2 Country Profile*. *Our World in Data*. Available: <https://ourworldindata.org/co2/country/pakistan>
- [6] IRFC. (2021). *International Federation of Red Cross and Red Crescent Societies. Climate change impacts on health and livelihoods: Pakistan assessment*. Available: <https://reliefweb.int/report/pakistan/climate-change-impacts-health-and-livelihoods-pakistan-assessment>
- [7] GFDRR, (2011) "Vulnerability, Risk Reduction and Adaptation to Climate Change. Climate Risk and Adaptation Country Profile for Pakistan. Global Facility for Disaster Reduction and Recovery (GFDRR)," The World Bank, Washington D.C.

- [8] Thomas, A. and Rendon, R., (2010) "Confronting climate displacement: Learning from Pakistan's Floods," Refugees International, Washington.
- [9] Sheikh, M. M., Manzoor, N., Adnan, M., Ashraf, J., and Khan, A. M., (2009) "Climate profile and past climate changes in Pakistan," Global Change Impact Studies Center (GCISC), vol. RR-01.
- [10] Review, W. P. (2022). *World City Population 2022*. Available: <https://worldpopulationreview.com/world-cities>
- [11] WWF. (2016). *Worldwide Fund for Nature. The Effects of Climate Change*. Available: <https://www.wwf.org.uk/updates/effects-climate-change>
- [12] Tubiello, F. N., M. Salvatore, Rocio D. C ndor Golec, A. Ferrara, S. Rossi, R. Biancalani, S. Federici, H. Jacobs, and Flammini, A., *Agriculture, forestry and other land use emissions by sources and removals by sinks*. Rome, Italy, 2014.
- [13] van Wilgen, N. J., Goodall, V., Holness, S., Chown, S. L., and McGeoch, M. A., (2016."Rising temperatures and changing rainfall patterns in South Africa's national parks," *International Journal of Climatology*, 36(2): 706-721.
- [14] Byravan, S. and Rajan, S. C., (2015."Sea level rise and climate change exiles: A possible solution," *Bulletin of the Atomic Scientists*, 71(2): 21-28.
- [15] Rosenzweig, C. and Parry, M. L., (1994."Potential impact of climate change on world food supply," *Nature*, 367(6459): 133-138.
- [16] Ghafoor, A. and Nawaz, R., (2020."Changes in Climatic Parameters in Metropolitan City of Lahore, Pakistan,"
- [17] Zhisheng, A., Guoxiong, W., Jianping, L., Youbin, S., Yimin, L., Weijian, Z., Yanjun, C., Anmin, D., Li, L., Jiangyu, M., and Hai, C., (2015."Global monsoon dynamics and climate change," *Annual review of earth and planetary sciences*, 43(29-77.
- [18] Loo, Y. Y., Billa, L., and Singh, A., (2015."Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia," *Geoscience Frontiers*, 6(6): 817-823.
- [19] Julius, S., West, J., Joyce, L. A., Kareiva, P., Keller, B. D., Palmer, M., and Peterson, C., (2008."Preliminary review of adaptation options for climate-sensitive ecosystems and resources," *National Parks*, 1(6):