INVESTIGATION OF CLIMATE CHANGE VARIABILITY UNDER CLIMATE CHANGE CONDITIONS OVER THE SEMI-ARID REGION

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Abstract

The purpose of the study was to investigate the variation in climatic parameters and possible climate effects in the Hyderabad region. The least-square regression method was used to find a linear change in climatic parameters (Temperature and Precipitation). The maximum, minimum, and mean temperatures; annual, and monsoon precipitations were considered under the study. In the last 100 years, the global temperature has been increased by 0.6 or 0.74 °C. In Hyderabad city, we predicted that the minimum temperature \(T_{\text{min}}\), maximum temperature \(T_{\text{max}}\), and mean temperature \(T_{\text{mean}}\) are varied in the range of 0.0049°C/year to -0.0133°C/year. The variability in the precipitation was observed in the last 30 years. Yearly and monsoon precipitation was decreasing with the rate of 1.24mm/year, and 1.34mm/year. The maximum precipitation occurs in July, August, and September; in the rest of the months, no or little precipitation occurred which may lead to a shortage of fresh water.

Keywords: Meteorology, Climate change variance, Least Square Regression analysis, Hyderabad region, Temperature and precipitation variance
I. Introduction

Climate change has diverse physical and socio-economic consequences for communities in the semi-arid areas (Ali and Erenstein 2017). Climate variability is the deviation around the average climate, ranging from daily/weekly, seasonal and intra-decadal variations (Alamgir, A., et al., 2016). Climate is the long-term average of weather change, a period of 30 years or more. United Nations Framework Convention on Climate Change (UNFCC) has stated that climate variation is a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and change observed over comparable periods (Ackerman and Stanton 2013). Climate change occurs due to the increasing concentration of Green House Gasses (GHGs) in the atmosphere, and these gasses released into the atmosphere by using fossil fuels and other human activities which become a worldwide problem (Ackerman and Stanton 2013). The earth's climate is naturally moving on all time scales (Bardin and Platova 2019).

However, its long-term state and the average temperature is changed by the balance between incoming and outgoing energy (Babina and Semenov 2019, Bodansky D 1993). Large changes in some major components of the climate system, with rapid, widespread effects are called abrupt climate change (US EPA). The Climate system means the totality of the atmosphere, biosphere, hydrosphere, and Geosphere and their interaction (Alamgir, A., et al., 2016, Babina and Semenov 2019). Weather is the state of the atmosphere, to the degree that it is hot or cold, calm or stormy, wet or dry, clear or cloudy (Chandio and Magsi et al., 2020, Chapra, SC 2008). Weather phenomena occur in the troposphere, the weather generally refers to change in precipitation, and temperature on daily, hourly, and climate is the term for the average atmospheric temperature and precipitation over longer periods (Alamgir, A., et al., 2016).

Different researches have been made for determining temperature and precipitation trends of various parts of the world (Change IC 2014, Change IPOC 2007, Cook and Weisberg 2009, Cheema SB et al., 2011). In the context of Pakistan, Qureshi, M.S (2010) reported an increase in temperature in major cities of Pakistan except for Quetta and also average rainfall increases in Quetta and decreases in other major cities of Pakistan (Alamgir, A., et al., 2016). Mustafa, Z (2010) reported that climate change raises concerns with tremendous social and environmental economic impacts (Commission P 2010). The magnitude of warming often exceeds 5 °C/century (Fischer and Knutti 2015). The seawater intrusion up to 65-100kms within the land (Golberg and Cho 2004). The climate change was more for northern regions as compared to the southern parts of the country (Hussain, Siddique et al., 2020). According to the Inter-Governmental Panel on Climate Change IPCC (2005), the last 100 years' global average temperature has increased by about 0.74 °C. Average global temperature, which increased by 0.6 °C over the past century (Hussain M et al., 2020).

In this study, we used the regression method to analyze climate change in the Hyderabad city of Sindh. The study consisted of Pakistan Meteorological data which was collected from the Pakistan Meteorological Department (PMD), Karachi, Sindh, and the regression method was used to predict the climatic parameter variability.
II. Materials and Method

Modeling approach

The data provided by PMD for rainfall was in the trend of monsoon period and annual rainfall period; whereas data for temperature was on a mean monthly basis, $T_{\text{mean}}$, Maximum Temperature $T_{\text{max}}$, and Minimum Temperature $T_{\text{min}}$. These values were incorporated in the least square method, equations are as a fellow.

$$a = \frac{\sum x_i y_i}{\sum x_i^2} \quad 2.1$$

$$b = \bar{Y} - a\bar{X} \quad 2.2$$

Where,

$$\bar{X} = \frac{\sum x_i}{n}$$

$$\bar{Y} = \frac{\sum y_i}{n}$$

$$x_i = X_i - \bar{X}$$

$$y_i = Y_i - \bar{Y}$$

$$Y_i = a x_i + b \quad 2.3$$

Eq. 2.1 and 2.2 are known as the least square regression method and 2.3 known as a linear equation. Whereas; $X_i$ (Years in the time series considered ($X_0$ for the year 1983, first-year)), $Y_i$ (Weather parameters), $T_{\text{mean}}$ (Mean temperature), $T_{\text{min}}$, and $T_{\text{max}}$ (Maximum temperature), and annual monsoon precipitation (all addition from $i = 0$ to 29 total of 30 years). And n equals the numbers of data values considered 30 in this study.

Least Square Regression

Least Square Regression is a technique for finding a line that summarizes the relationship between the two variables, at least within the domain of the descriptive variable Chandio and Magsi et al., 2020, Chapra SC 2008). The method of least square is a method to find the best fit line to data, the proof uses simple calculus and linear algebra. The basic problem is to find the best fit straight line $y = ax+b$ given that, for $n$ belongs to (1,…..n) the couples $(X_a, Y_a)$ are observed. The method easily generalizes to finding the best fit of the form, $y = a_1 f_1(x) + \cdots + a_k f_k(x)$ it is not necessary for the function $f_k$ to be linearly in x all that is needed is that y is to be a linear combination of these functions (Israr M 2016). The goal of the Least-Squares Method is to find a good estimation of parameters that fit a function, $f(x)$, of a set of data, $X_1 \cdots X_n$. The Least-Squares Method has two categories, linear and non-linear. Linear Least-Squares (LLS) Method assumes that the data set falls on a straight line. Therefore, $f(x) = ax+b$, where a and b are constants. Linear least-squares regression also gets its name from the way the estimates of the unknown parameters are computed (Chandio and Magsi et al., 2020, Chapra SC 2008, Khan JA 1993).

III. Results and Discussion

The $T_{\text{mean}}$ is defined as the average of $T_{\text{max}}$ and $T_{\text{min}}$ during the day. The $T_{\text{max}}$ usually occurs in the afternoon of a sunny day while the lowest temperature termed as
minimum reaches just before the sunrise under cloud-free sky conditions. In broader terms, \( T_{\text{max}} \) is generally referred to day time and \( T_{\text{min}} \) to night time temperature. To be on the safer side letting both daily extremes occur in the observation time domain, the \( T_{\text{max}} \) is recorded at 5 PM local time in each country and minimum at 8 AM local time according to World Meteorological Standard (WMS) (Lysenko and Loginov 2020). Rainfall data were classified into two seasons monsoon and annual rainfall.

**Temperature Variations**

Climate assessment essentially contains a good understanding of temperature and precipitation patterns (Alamgir, A., et al., 2016). As such, there are many factors to be considered while studying climate (Alamgir, A., et al., 2016). The purpose of the study was to see the variation in climatic parameters. The temperature data was in three forms as presented in figure 3.1. Equations 2.1, 2.2, and 2.3 were used to draw the trend line from the PMD as seen in Figure 3.1a, 3.1b, and 3.1c. The day’s lowest temperature (\( T_{\text{min}} \)) the night time temperature important for biological life. The trend for \( T_{\text{min}} \) shows that the temperature was increasing at the rate of 0.0049°C/year (fig. 2.1a). Rasul, G. et al (2012) incorporated the 40 years minimum temperature data; in his findings, the night temperature has increased which tends to the respiration of plants have increased which means the net gain is inversely proportional to the night temperature (Lysenko and Loginov 2020). \( T_{\text{max}} \) was decreasing with the rate of -0.0133°C/year (fig. 2.1b), and \( T_{\text{min}} \) was decreasing with the rate of -0.003°C (fig. 2.1c). In the past 10 decades, the global average temperature has increased by 0.74 °C (IPPC-2007). In contrast to the IPPC-2007 report in our analysis reveals that the average temperature was decreasing in the Hyderabad premises Bodansky D 1993).

![Figure 3.1](image_url)

**Figure 3.1.** Temperature trends (a) Minimum, (b) Maximum and (c) Mean

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Precipitation Variations

Summer brings the monsoon to Pakistan which contributes 60% of the rainfall from July to September (Lysenko and Loginov 2020). Pakistan’s total annual precipitation ranges from 500mm to 800mm with higher amounts in the northern areas (Lysenko and Loginov 2020). Figure 3.2 shows the monsoon and annual rainfall in Hyderabad city. Monsoon and annual rainfall range between 0mm to 500mm and it is almost 37% less than the value reported by Rasul et al (2012) for Pakistan, this may result in a shortage of freshwater. Fig. 3.2 shows that the monsoon and annual rainfall, maximum rainfall occurs ~500mm and ~400mm only a few times, and most of the time 0 precipitation occurs. We used the regression method in 30 years of data to estimate the average rainfall each year. The rainfall values were estimated from equations 1,2 and 3. Yearly rainfall of the region was decreasing with a rate of 0.126mm/year, and monsoon rainfall was decreasing with a rate of 1.34mm/year. Maximum precipitation occurs in July, August, and September, and the rest of the month no or little rainfall occurs results show high precipitation variability in Hyderabad (fig. 3.3). Lahore and Islamabad receive maximum rainfall in July, August, and September (Alamgir, A., et al., 2016). It is because of the monsoonal depressions which are the main contributors to the annual rainfall in the plains of Punjab Lawson ET al., 2019).

![Rainfall trends (annual and monsoon)](image)

**Figure 3.2.** Rainfall trends (annual and monsoon)

Possible Climate change effects

The effects of climate change can be mostly understood. It can be classified into indirect and direct impacts when talking in the context of anthropological well-being Mahmood and Jia 2018). In the Global Risk Index (GRI) Pakistan is numbered as the 7th most susceptible country in the world (Cheema SB et al., 2011). Heat-strokes are more prevailing among outdoor labors in arid and semi-arid regions (Israr M 2016). Deaths due to heatwave have been found especially among the vulnerable communities: the old, poor people, and daily wage workers that include agricultural laborers and rickshaw drivers Golberg and Cho 2004, Mahmood and Jia 2018, Miller SJ 2006). The temperature variation has both positive and negative impacts on agriculture as reported by IPCC (2007) potential food yields to increase with the increase in local average temperature over a range of 1-3°C, but more than this it is predicted to decrease. Like in our study Lysenko and Loginov 2020) explained that $T_{min}$has increased largely than the $T_{max}$, which indicates their negative impact on crops

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and animals due to heat stress, increase water requirements, and a higher rate of respiration. The economy of Pakistan is dependent on agricultural activities which accounted for 80% of the country’s export with large irrigable land. The water supply of two-thirds of Pakistan’s irrigable land originates from northern snowfalls and melting glaciers (Rasul and Ahmad 2012). According to TFCC (2007) the temperature of 1-5°C range the yield of Wheat crops will increase in the mountainous region and decreases the yield of wheat crops in sub mountainous, arid, and semi-arid regions. 1°C rise in temperature, wheat yield in Pakistan can be decline by 6-9% and an even loss increase is accepted to severely impact cash crops like Mango and Cotton (Sadiq and Qureshi 2010). Figure 3.3 mean monthly ($T_{max}$ and $T_{min}$) reported. For the wheat crop, February is the most critical for crop yield. The day's lowest temperature was recorded in 2012 (figure 3.3) however the 4 °C difference was observed in the year 2012 and 2007 such variations in temperature may reduce the wheat crop yield. Furthermore, the effect of climate change on rice production in Pakistan was investigated by (Tishchenko, V.A., et al. 2019), it has been found that little change in temperature and CO$_2$ emissions positively affect rice production (Tishchenko, V.A., et al. 2019).
IV. Conclusion

In this study, the possible climate change effect, precipitation and temperature variance were analyzed by using a least-square regression method. The least-square regression method was used to observe the change in climatic parameters. For the minimum temperature, it was observed that the minimum temperature of Hyderabad city was increasing at the rate of 0.0049 °C/year. The maximum temperature of Hyderabad city was decreasing at a rate of 0.0133 °C/year. This decrease in temperature may increase the wheat productivity in the premises of Hyderabad city and increase the productivity of the livestock sector. The same method used for annual and monsoon rainfall patterns, the annual rainfall was decreasing at the rate of 0.216mm/year and monsoon rainfall was also decreasing at the rate of 1.34mm/year. With the rapid decrease in monsoon and annual rainfall patterns, the people of Hyderabad city may face the problem of freshwater.

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Conflict of Interest:

All authors have no conflict of interest

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