Climate Change and the Changing Rainfall Patterns in Karachi

Yasmeen Anis, Sheeba Afsar, Syeda Zainy, Ghuffran Saeed
Department of Geography, University of Karachi
*Correspondence: yasmeen_rehan@yahoo.com

Citation | Anis. Y, Afsar. S, Zainy. S, Saeed. G, "Climate Change and the Changing Rainfall Patterns in Karachi" IJIST, Vol. 07 Special Issue pp 85-93, Aug 2025
Received| July 15, 2025 **Revised|** July 28, 2025 **Accepted|** Aug 02, 2025 **Published|** Aug 04, 2025.

Abrupt weather phenomena, including heat waves, frequent intense storms, forest fires, glacier melting, and flash floods, are experienced worldwide. Pakistan lies in the South Asian region, which falls under the monsoon climatic regime and experiences summer rainfall. The city of Karachi, a highly urbanized area located in southern Sindh, receives secondary monsoon rainfall from July to September. During the 1960s, the city received appreciable rainfall during the monsoon, but the amount of rainfall started declining during the 1980s. At the end of the 20th century, the rainfall pattern was quite abrupt, associated especially with the passage of cyclones, which developed in the Arabian Sea and, after touching Oman, reached Karachi, or, moving from Gujrat in India, reached Karachi. So, the rainfall which received annually is now received within a day. The study represents the statistical analysis as well as the GIS and remote sensing perspective of the changing patterns over the last fifty years.

Keywords: Climate Change, Monsoon, Precipitation Pattern, Karachi, Statistical Analysis, GIS.

Introduction:

Climate Change is a burgeoning issue in today's world. In the current century, most countries are facing: heat waves, glacier melting, forest fires, droughts, intense floods, furious storms, coastal flooding, chilling winters or cold waves, and so on. All these phenomena are faced around the globe frequently with the progress of time, in the respective seasons. [1] stated that climate change is an inevitable phenomenon and affirmed its substantial effects on multiple sectors encompassing marine and coastal ecosystems, arid land environments, agricultural and livestock, forests, biodiversity, and human wellbeing.

According to report published in Daily Dawn, dated December 31st, 2024, related to the initiatives undertaken by WMO (World Meteorological Organization) and UN: the frequency of extreme weather, make necessary to launch Early Warnings before any weather extreme, and the WMO is preparing to implement the Global Greenhouse Gas Watch initiative, and supporting the United Nations Framework Convention on Climate Change (UNFCCC) and Conference of All Parties (COP).

The year 2025 is the International Year of Glaciers' Preservation, designated by UNESCO and WMO. There will be a strong focus on the cryosphere, including sea ice, ice sheets, and frozen ground**.** (by Ahmed, A. Daily Dawn, 31st December, 2024.)

Recently, Southern Europe has been facing a heat wave in June. Spain, France, Portugal, Greece, and Italy have experienced severe conditions over the weekend. The temperature exceeded up to 37.8◦C. In Portugal, it was 46.6◦C on 29th June, in Athens, Greece, it was 40◦C on 28th June. (by Povoledo, E. The New York Times, 30 June 2025). Due to the heat waves, forest fires started in parts of France and Spain, reported on 8th July, 2025, and then also in Britain. (19th July, 2025. The New York Times)

Pakistan is also facing the wrath of climate change, as it encounters frequent flash floods, especially during the months of Monsoon season, cyclones, and heat waves. A horrible heat wave struck the city of Karachi in the year 2015 and continued till 2019, still being faced in different parts of the country.

The frequency of Cyclones increased from the start of this century and the end of the 20th century. According to an economic survey,

- Pakistan is having a loss of 1.6 billion dollars on average per year. (92 News, 14th June. 11:11 pm)
- The provinces of Sind and Baluchistan especially faced the flooding due to storms and associated intense rainfall.
- In Sind, floods during the monsoon season created a great loss in the years 2010 and 2022, and proved to be highly expensive. (92 News, 14th June. 11:11 pm)
- In 2010, Pakistan faced the loss of 855 billion dollars. (92 News, 14th June. 11:11 pm)
- Whereas, floods of 2022 created a loss of 14.5 billion dollars in Pakistan. Comparatively, Pakistan suffered a loss of 1.7 billion dollars due to five major storms. (92 News, 14th June. 11:11 pm)

In southern Sind, especially Thatta, Badin, and Karachi, storms occur. From the beginning of this century, storms have been frequently encountered every year, travelling from the Oman coast, through Balochistan and eventually, Karachi and southern Sind.

Due to climate change, Pakistan has faced a 36 billion dollar loss over the past 34 years. (92 News, 14th June. 11:12 pm).

Karachi, one of the largest cities of Pakistan, experienced the storms and torrential rain that disrupted the whole city. These fierce storms began in the last decade of the 20th century. The Cyclone 2A in the year 1999. The cyclone was recorded to be the strongest

cyclone in Pakistan. According to JTWC (Joint Typhoon Warning Center), the 4th strongest cyclone of the Arabian Sea is.

Karachi ((Pakistan Weather Portal™, 2011). The Cyclones are listed below:

- Cyclone 2A _ May 1999
- Gujrat Cyclone (not effective in Karachi) _May 2001
- Cyclone Onrill _2004
- Cyclone Gonu and Cyclone Yemyin _June 2007
- Cyclone Phet _ 2010
    - Cyclones that created either lighter rains or dusty winds in Karachi but did not approach as powerful storms were:
- Cyclone Phyan _ November 2009
- Cyclone Jal _ November 2010
- Cyclone Keila _early November 2011.

All these cyclones arrived in the winter month of November,*i.e.*, the post-monsoon period. A fact important to note. (Pakistan Weather Portal™, 2011).

Cyclone 2A in the year 1999 developed in the Indian Ocean and affected the western coast of India, reaching southern Sindh after affecting Gujrat.

After Cyclone 2A, Cyclone Asna in the year 2024 took a route similar to Cyclone 2A.

Objectives of the Study:

The main objective of this study is to examine the precipitation pattern in Karachi and its deviation from 1960 to 2024. To achieve this objective following sub-objectives are undertaken:

- To gather and analyze the precipitation data collected from PMD and the newspapers
- To calculate the time ser*ies* of the average annual precipitation of the data from 1960 to the year 2010.
- To generate precipitation patterns of the precipitation values recorded during special weather events faced in Karachi in the ArcGIS environment.
- To conclude that climate change is happening within this century.

Study Area:

Karachi, one of the largest cities of Pakistan and the busiest port, lies on the coast of the Arabian Sea in southern Sindh (Figure 1). The latitude is 24.9 N and 67.0 E. The city is surrounded by the highlands in the north, east, and west, which are the offshoots of the Kirthar ranges. Towards the south lies the Arabian Sea. The location of the Sea in the south influences the daily temperatures due to the generation of sea breezes, both in the summer and winter months. The western boundary is marked by the Hub River. Karachi is the confluence of the two seasonal rivers: the Lyari and the Malir.

It falls in the secondary monsoon regime, i.e., receives rainfall from the month of July to September. Rainfall occurs in the month of June only in the case of cyclone development. Due to the monsoon winds, cloud cover occupies the city in the month of June and keeps the city away from the temperature maxima of June. [2]

pip install matplotlib seaborn pandas numpy

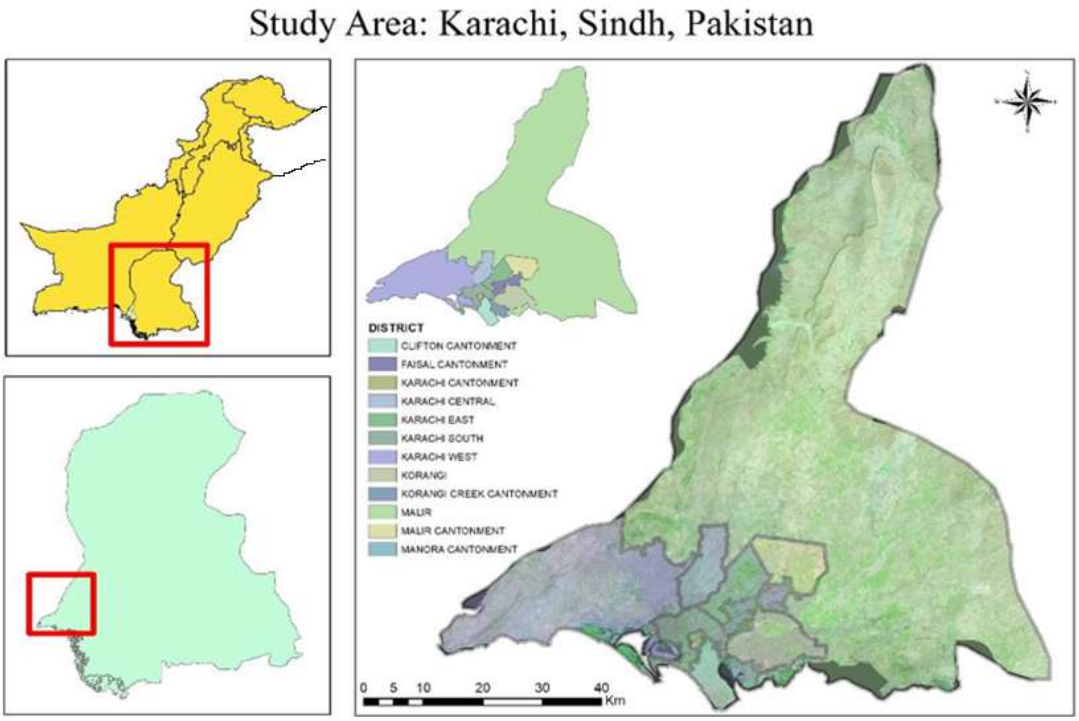

Figure 1. Study Area- Karachi.

Materials and Methods:

The study was carried out using the following methodology:

Data Collection:

To perform the analysis of climate change in Karachi, precipitation data collection is the most important step. The average annual precipitation data from 1960 to 2010 (Table 1) have been collected from PMD (Pakistan Meteorological Department) and other resources like newspapers providing the PMD reports of daily rainfall. (Table-2)

Time Series Analysis:

Next, the time Series of the average annual precipitation was calculated (chart 1). Time series of temperature and precipitation for the assessment of climatic changes are usually preferred in many climate-related studies. [3][4][5]. The reason behind the frequent use of time series analysis in climate-related phenomena lies in the fact that it always predicts long-term and short-term variations in the climatic data. [6][7].

Data Comparison:

The average annual precipitation data is also compared with the daily rainfall data to figure out the degree of intensification that has been going on, as an impact of climate change. In climatic analysis, rainfall is considered the crucial climatic indicator to evaluate its spatial and temporal patterns that produce substantial consequences. [8][9]

Spatial Analysis:

Precipitation patterns of the daily rainfall data had been extracted in the ArcGIS environment to figure out the overall scenario of the areas of the city affected most by the precipitation. Further, to plan the future strategies during the rainfall season, and for the warning and rehabilitation of the normal civilian activities of the city. To evaluate the impact of rainfall variability and patterns on the community and environment, the spatial and temporal patterns of rainfall and their anomalous changes can yield valuable and versatile information. This information can be combined with other datasets to acquire a deeper understanding. [10]. Planning and management of water resources, hydrological modeling,

and agricultural research are all dependent upon the spatial and temporal patterns of rainfall distribution. [11].

Based on all the Above Methods Following Results are Inferred:

Results:

By comparing the average annual rainfall of 1960to 2010 (Table 1) with daily rainfall (Table 2), the following facts are revealed:

- From Table 1, it's quite clear that from 1960 to 1980 Karachi experienced heavy average annual rainfall amounts, ranging between 200 to 700 mm.
- For example: in the year 1961 =621.8 mm, 1967 = 713 mm, 1970 = 475 mm, 1976 = 406.1 mm, 1977 = 413 mm.
- The rainfall diminished from 1980, i.e., rainfall remained around 100 mm, except in 1994 the rainfall was 481.5 mm.
- In the year 1987, there was a monsoon failure, and 0 mm of rainfall was recorded in
- Even during the cyclones from 2001 to 2010, the rainfall fluctuates between 100 mm to 400 mm.
- Except for the year 2007, when average annual rainfall was 465.6mm, the year when Cyclone Gonu reached Karachi.

On the other hand, in the year 2020, when 89 records were broken, the total downpour within a day was around 1114 mm. (Table 2) If the rainfall pattern is analyzed (Figure 2), then we can notice the concentration was in the south-central city,*i.e., PAF Faisal Base.* In the year 2024, on 5th August, the rainfall received was = 131.5mm, and on 31st August, when cyclone Asna was passing by, the total rainfall value was = 153.5 mm. The total rainfall of only two days in August 2024 was around 285 mm. (Table-2) The rainfall pattern on 31st August due to cyclone Asna reveals the maximum concentration was in the north (Surjani) and in the east (Quaidabad) of the city. (Figure-2)

Table 1: Karachi- Rainfall Data (1960-2010)

YEAR	RAINFALL (mm)	YEAR	RAINFALL (mm)	YEAR	RAINFALL (mm)
1960	129.54	1981	185	2001	100.4
1961	621.8	1982	161.2	2002	55.8
1962	278.7				
1963	43.7	1983	281.5	2003	324.9
1964	140.1	1984	269.3	2004	65.9
1965	129.5	1985	155	2005	97.2
1966	70.1	1986	92	2006	301.2
1967	713	1987	0	2007	465.6
1968	29	1988	160	2008	121.6
1969	39.4	1989	189.7	2009	280.07
1970	475	1990	136.4	2010	373.01
1971	68	1991	24.5		
1972	44.2	1992	273		
1973	213.4	1993	35.5		
1974	7.1	1994	481.5		
1975	159.9	1995	259.8		
1976	406.1	1996	99		
1977	439	1997	150.1		
1978	386.5	1998	82.4		

1979	381	1999	14.5		
1980	193.8	2000	46.9		

Source: (Pakistan Meteorological Department, 2012).

Table 2: Daily Rainfall (Karachi)

Location	27-07-2020 (mm)	Location	5/8/2024 (mm)	location	31-08-2024 Cyclone Asna
Surjani Town	44	Nazimabad	46.5	Quaidabad,	24 mm
North Karachi	50	Quaidabad	27	Surjani	38.4mm
Nazimabad	91	Sharae Faisal	23	Korangi	17mm
Saadi Town	72	Old Airport	22	North Nazimabad	16.5mm
University Road	79	Ibrahim Hyderi	13	North Karachi	16mm
PAF Faisal Base	345	Total	131.5	PAF Faisal Base	13mm
Jinnah Terminal	66			PAF Masroor Base	12.4mm
Old Airport	80			University Road	5 mm
Gulshan-i-Hadeed	120			Keamari	5mm
Saddar	83			Gulshan-i-Hadeed	4.2mm
landhi	84			Gadap	1mm
				Saddar	1mm
Total	1114			Total	153.5

Trend Analysis Plot for Rainfall:

Actual Rainfall Data: The graph represents the actual rainfall data points connected by a black line, illustrating fluctuations in rainfall over time.

Fitted Lines: A red line represents the fitted values based on the linear trend model, indicating a relatively stable trend with a slight downward slope.

Forecasted values: Green dots signify forecasted rainfall values beyond the observed data, continuing the trend established by the linear model.

Accuracy Measures:

MAPE (Mean Absolute Percentage Error):187.4

MAD (Mean Absolute Deviation): 132.2

MSD (Mead Squared Deviaton:26058.0

Trend: The linear trend model suggests a slight decrease in rainfall over time, as indicated by the negative slope (-0.846479) in the equation.

Accuracy: The accuracy measures (MAPE, MAD, MSD) provide insights into the models' performance. A high MAPE value (187.4) indicates significant variability between actual and predicted values, suggesting that the linear model may not be the best fit for this data.

Forecasting: The forecasted values (green dots) continue the downward trend, but their reliability is questionable due to the high error measures.

Discussions:

The overwhelming intense rainfall received in the year 2020, due to intense thunderstorms that developed during the monsoon, and the cloud burst phenomenon occurred. The highest rainfall readings at *PAF Faisal Base* (Table 2) indicate the location of the core of the thunderstorm (Figure 2). It was an unusual Monsoon outburst.

Normally, the monsoon rains in Karachi start from the eastern and north eastern direction as they are approaching from Gujrat (India) through Badin and Thatta. As a result, higher rainfall was recorded in SurJani (Table 2). Rainfall due to cyclones approaching Karachi from Oman through Baluchistan starts from the western direction. As in the case of Cyclone Asna that traveled through Gujarat (India) and approached Karachi, the cyclone developed from a deep depression over the Rann of Kutch and moved slowly west-

southwestward. It eventually emerged as a cyclone over the northeast Arabian Sea along the Sindh coast. (PMD, 2024)

After Cyclone 2A in the year 1999, Cyclone Asna followed this track about 25 years later.

Time Series analysis: The downward trend in the rainfall data, as indicated by the linear trend model (Yt = 229.9 - 0.846479*t), suggests that over the observed period, there has been a general decrease in rainfall. The negative slope (-0.846479) of the trend line is the key indicator of this downward trend. This means that for each increment in time (t), the rainfall (Yt) tends to decrease by approximately 0.846479 units.

Several factors could contribute to a downward trend in rainfall in a given region, including:

1. Climate Change: Changes in global climate patterns can lead to alterations in rainfall distribution around the world. Some regions may experience increased rainfall, while others may face droughts or decreased rainfall.
2. Local Environmental Changes: Urbanization, deforestation, and changes in land use can affect local climate conditions, potentially leading to changes in rainfall patterns.
3. Natural Climate Variability: Natural phenomena such as El Niño and La Niña can influence rainfall patterns. Long-term cycles or shifts in these patterns could contribute to observed trends.
4. Data Quality and Period: The observed trend could also be influenced by the quality of the rainfall data and the specific period over which the data was collected. Biases in data collection or a particularly dry period at the end of the dataset could skew the trend.

The presence of a downward trend does not necessarily imply a consistent or linear decrease in rainfall; the actual data shows significant variability around the trend line. The high MAPE value (187.4) also indicates that the linear model may not fully capture the complexity of the rainfall data, suggesting that other factors or non-linear patterns might be at play.

Conclusion:

The trend analysis plot for rainfall reveals a complex pattern with significant variability. While the linear trend model indicates a slight decrease in rainfall, the high error measures suggest that this model may not accurately capture the underlying dynamics. Therefore, it is essential to consider alternative models or more sophisticated analysis techniques to better understand and predict rainfall patterns.

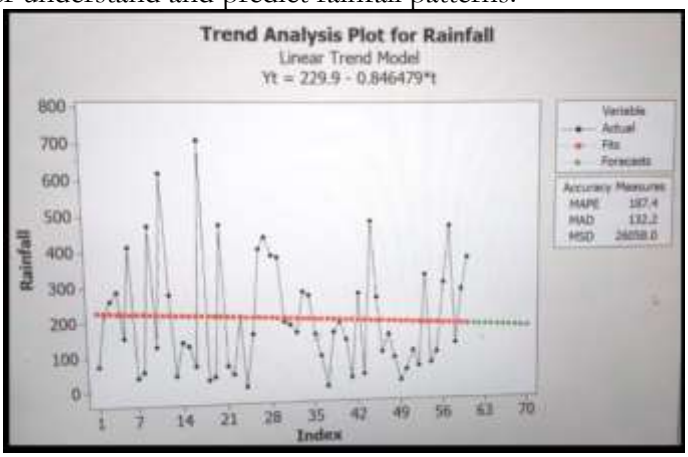

Chart 1. Trend Analysis plot for Rainfall. The graph represents rainfall data from 1951-2010

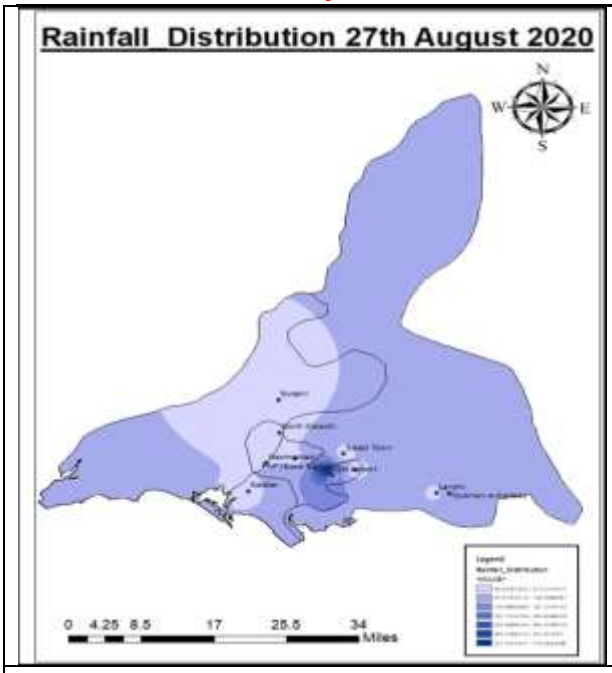

Figure 2. Rainfall patterns on27th August,2024

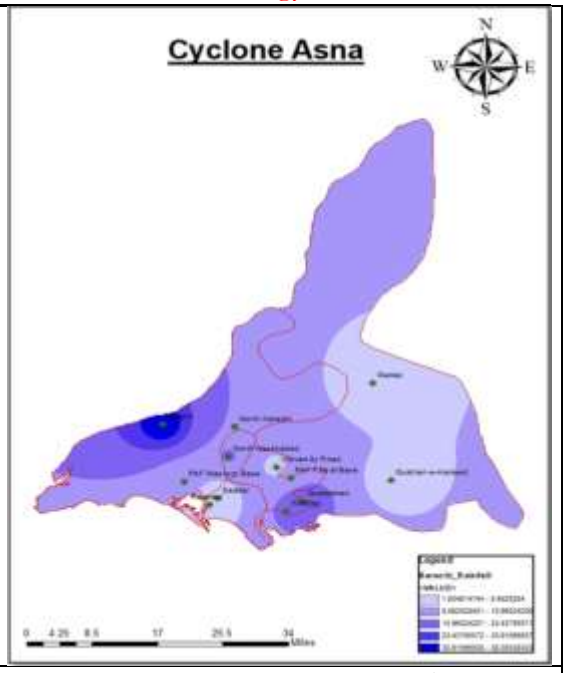

Figure 3. Rainfall patterns on 31st August, 2024

Conclusion:

If only the rainfall is observed, we can see that daily rainfall totals are greater than the average annual rainfall figures. In the year 2020, of 89 years was broken great deviation from the normal occurred, while the total rainfall of only two days in August 2024 is around 285 mm.

Climate change can be observed in the form of the intensification of phenomena like higher rainfall values.

The retrieval of the track of Cyclone after 25 years in the case of Cyclone Asna is yet another sign of a changing climate.

So, it can be concluded that the climate is changing, and this change is visible through the intensification of different climatic elements - in this study, the rainfall in Karachi.

Acknowledgement:

The study is carefully carried out by all the authors and has not been published before in part or else. There is no funding or conflict of interest. All authors agree on the contents of the research

The contribution of all authors is as follows:

Dr Yasmeen Anis and Dr. Sheeba Afsar (main idea of research and writing, Calculations)
Guffran Saeed: Literature Review and Mapping
Syeda Zainy: Image processing and mapping, paper setting

Conflict of Interest: None

Funding: None

References:

[1] H. W. Muhammad Adnan, Baohua Xiao, Shaheen Bibi, Peiwen Xiao, Peng Zhao, "Addressing current climate issues in Pakistan: An opportunity for a sustainable future," *Environ. Challenges*, vol. 15, p. 100887, 2024, doi: https://doi.org/10.1016/j.envc.2024.100887.

[2] H. . Khan, A. J. and Arsalan, "General Climatology," *Karachi Dep. Geogr. Univ. Karachi.No match*, 2007, doi: 10.13140/RG.2.1.2327.6241.

[3] T. Dimri, S. Ahmad, and M. Sharif, "Time series analysis of climate variables using seasonal ARIMA approach," *J. Earth Syst. Sci.*, vol. 129, no. 1, pp. 1–16, Dec. 2020, doi: 10.1007/S12040-020-01408-X/METRICS.

[4] S. A. S. H. Babazadeh, "Modeling climate variables using time series analysis in arid and semi arid regions," *African J. Agric. Res.*, vol. 9, no. 26, p. 6, 2014, [Online]. Available: https://academicjournals.org/journal/AJAR/article-abstract/285C77845733

[5] S. T. Mesut BALIBEY, "A Time Series Approach for Precipitation in Turkey," *Gazi Univ. J. Sci.*, vol. 28, no. 4, pp. 549–559, 2015, [Online]. Available: https://dergipark.org.tr/tr/download/article-file/230930

[6] Pazvakawambwa G.T. and Ogunmokun A. A, "A time-series forecasting model for Windhoek Rainfall, Namibia," *UNAM*, 2013, [Online]. Available: https://core.ac.uk/download/pdf/232860109.pdf

[7] G. L. Shengwei Wang, Juan Feng, "Application of seasonal time series model in the precipitation forecast," *Math. Comput. Model.*, vol. 58, no. 3–4, pp. 677–683, 2013, doi: https://doi.org/10.1016/j.mcm.2011.10.034.

[8] T. A. Gado, R. M. El-Hagrsy, and I. M. H. Rashwan, "Spatial and temporal rainfall changes in Egypt," *Environ. Sci. Pollut. Res.*, vol. 26, no. 27, pp. 28228–28242, Sep. 2019, doi: 10.1007/S11356-019-06039-4/METRICS.

[9] M. Dawood, A. ur Rahman, S. Ullah, S. Mahmood, G. Rahman, and K. Azam, "Spatio-statistical analysis of rainfall fluctuation, anomaly and trend in the Hindu Kush region using ARIMA approach," *Nat. Hazards*, vol. 101, no. 2, pp. 449–464, Mar. 2020, doi: 10.1007/S11069-020-03881-5/METRICS.

[10] K. S. N. Archana Nair, K. Ajith Joseph, "Spatio-temporal analysis of rainfall trends over a maritime state (Kerala) of India during the last 100 years," *Atmos. Environ.*, vol. 88, pp. 123–132, 2014, doi: https://doi.org/10.1016/j.atmosenv.2014.01.061.

[11] F. S. & H. N. G. Ghaffar Ali, Muhammad Sajjad, Shamsa Kanwal, Tingyin Xiao, Shoaib Khalid, "Spatial–temporal characterization of rainfall in Pakistan during the past half-century (1961–2020)," *Sci. Rep.*, vol. 11, 2021, doi: https://doi.org/10.1038/s41598-021-86412-x.