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INTERACTION OF CLIMATIC AND SOCIOECONOMIC DRIVERS ON TRANSMISSION OF DENGUE VIRUS IN FAISALABAD, PAKISTAN

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ABSTRACT

A comprehensive study was conducted to investigate the factors contributing to the proliferation of dengue in the Faisalabad district of Pakistan. The research focused on analyzing demographic parameters through an examination of dengue hotspot areas and assessing the impact of climatic factors on the spread of dengue infection. To establish the relationship between dengue infection and climatic factors, various data extraction approaches, statistical analyses, and GIS mapping techniques were employed. The study covered the epidemic period from 2013 to 2019. Pearson correlation coefficients for temperature, relative humidity, and precipitation were calculated to understand the correlation between climatic factors and dengue cases. The analysis revealed that the highest number of dengue cases occurred in Tehsil Faisalabad city during the post-monsoon season, specifically from September to November, with the peak in October reaching 63 cases. This finding indicated a direct correlation between dengue-infected cases and population density. The correlation coefficients between dengue-infected cases and climatic factors (temperature, rainfall, and relative humidity) in district Faisalabad from 2014 to 2019 were 0.58, -0.421, and -0.364, respectively. These values demonstrated a 58% positive correlation between dengue cases and temperature, a negative 43% correlation between rainfall and dengue cases, and a 36% negative correlation between relative humidity and the number of dengue cases. The relationship between climatic variables and dengue cases was found to be complex. While an increase in temperature was associated with higher dengue transmission, the other two variables (rainfall and relative humidity) showed a decrease in dengue transmission potential. This complexity explains the inconsistent statistical correlation between climate and dengue. This research provides valuable insights and future projections for analyzing the climatic influence and conducting epidemiological analyses of dengue infection in the region.

Keywords: Dengue Virus, Climatic Factors, Epidemiological Aspects, Pearson Correlation

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1. INTRODUCTION

The climatic parameters, including precipitation, temperature, wind, daylight period, and increase in sea level, are significant considerations of vector-borne diseases such as Dengue Fever. Temperature changes can modify the duration of the transmission season. Precipitation variations may have direct consequences for contagious disease eruptions (cMichael et al. 2003).

There are several outbreaks of dengue that Pakistan has experienced, and it was first reported in 1994 (Jamil et al. 2007). The main risk factors for a rise in dengue activity include climate variability, a lack of efficient vector control programs, unchecked urbanization, and increased international travel. The growth and dispersal of the mosquito vector and the risk for dengue outbreaks are thought to be influenced by temperature (Banu et al. 2011).

The possibility of transmission may also rise while visiting areas where dengue fever is endemic. Other significant variables that encourage dengue transmission include unplanned urbanization, a decline in public health resources, and a lack of sufficient vector control measures (Hu et al. 2012). In terms of morbidity and economic impacts dengue is the most significant vector-borne disease of humans probably more important than malaria globally since 2012 (Gubler et al. 2012).

The variability of precipitation impacts the quality of shelter for the larvae and pupae of Ae. *aegypti* and Ae. *albopictus*. Temperature also deals with precipitation as the primary control of evaporation, which often impacts the

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quality of water ecosystems. Conversely, humidity, temperature, and precipitation have an impact on land cover and land use, which can help or inhibit the expansion of mosquito vectors. The prevalence of DF was associated with vegetation types, tree cover, quality of housing, and existing land cover. Climate change may also modify how humans communicate with the environment, changing its usage and effect on mosquito population size and genetic variation (Morin et al. 2013).

The attempts to control transmission of dengue, concentrate on the vector and exploit the biochemical combinations aiming for *Aedes* mosquitoes to destroy breeding places of dengue vectors (Bhatt et al. 2013).

In addition to climatic factors, other forces or factors such as urbanization, population density, globalization with increased transport of people and goods, herd immunity, government vector control capacity, and changes in serotypes are considered to develop an inverse relationship in the transmission of dengue (Minh and Rocklöv 2014).

Destroying the reproduction sites of dengue virus is an important plan to lessen larval development and the population of adult mosquitoes. The changes in larval development and adult survival times, temperature, and other climatic factors affect the transmission of disease. Extreme temperatures are frequently fatal to the survival of disease-causing microorganisms, but temperature changes by degrees may have varying outcomes (Li et al. 2014).

In Pakistan, the dengue outbreaks were limited to the Northeastern city of Lahore with over 20,000 cases and mostly dengue transmission occurred in the Southern city of Karachi up to the year of 2011 (Wesolowski et al. 2015). The binomial variations in transmission of dengue virus are attributable to various several factors and causes with the interactions are very complicated. *Ae. aegypti* and *Ae. albopictus* are altered well to urban areas where urbanization is initiated by development of the economy (Atique et al. 2016).

In tropical and subtropical areas, dengue fever is one of the most common infections. Aedes *albopictus* and Aedes *aygepti* mosquitoes carry the dengue virus, which causes infection (Atique et al. 2016). There is increased international travel, rapid increase in urbanization, climate change, local and regional climatic phenomena. So, dengue is expanding to other regions such as Europe which are not located in tropical or subtropical regions (Atique et al. 2018).

Dengue disease appears as a health issue and is transmitted by *Aedes* mosquitoes in Nepal. Dengue cases reported from hilly areas have spread the potential threat to the region, which is far away from the lowland zone (Tuladhar et al. 2019).

Dengue transmission is influenced by a variety of factors, including climatic change and many socio-ecological factors, due to the inherent intricacy of virus-vector-human relationships. Climate variations in temperature, precipitation, humidity all have an impact on dengue transmission in three ways: the dengue virus itself and the way it spreads. Dengue incidence is also linked to socio-ecological factors such as urbanization, travel, bodies of water, and vegetation. As a result, research on the correlation between climate and socio-ecological parameters and dengue transmission has erupted (Li et al. 2021).

2. MATERIALS AND METHODS

2.1. Study Area

The study area of this research is district Faisalabad. Geographically, it is located between 31^{o} 25 N Latitude and 73^{o} 5 E Longitude and is situated in the northeast region of the country at an elevation of 186 m above sea level. The need for businesses and industries is great in Faisalabad, Pakistan's third-most populous metropolis. The city has a population of about 3.7 million people. Even if it has greatly increased over the past few decades, there are still economic differences across various parts of the city. Although other industries, like IT and tourism, have started to gain ground recently, the textile industry still dominates and employs a sizable number of people.

2.2. Data Source

To study the influence of climatic parameters on dengue proliferation, two types of datasets were obtained. The data on dengue cases for the period 2013–2019 was obtained from the main District Health office in Faisalabad (https://faisalabad.punjab.gov.pk/health_department), and then climatic data (rainfall, temperature, and humidity) for the period 2014–2019 was collected from the Pakistan Meteorological Department (https://www.pmd.gov.pk/en/). The period of historic dataset used for dengue cases and climate change was seven years. The research has been divided into two segments for analysis. The first part related to the epidemiology study of dengue infected cases and then climatic factors that affect the proliferation of the dengue virus.

2.3. Epidemiological and Climatic Parameters

To identify hotspot areas for dengue infection in district Faisalabad by a significant map showing the areas that were most affected by the infection were analyzed through the GIS mapping system during 2013-19.

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Changing climatic situations are believed to be the primary cause of the propagation and appearance of dengue, which is widely distributed in warm and humid parts of the world (Azman and Karim 2018). Firstly, all dengue fever influencing climatic variables (temperature, rainfall, and relative humidity) were individually analyzed to find the variability trends for the period of 6 years from 2014 to 2019 (Table 1). Then, to find the impact of climatic variables on dengue growth, a correlational analysis between climatic parameters and dengue cases was performed.

Table 1: Month based average precipitation, relative humidity, temperature, (max., min., Avg. Temp.) and dengue cases of district Faisalabad from 2014-2019

Variables	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Av. Temp	13.9	16.9	22.2	29.1	34.4	31.0	35.7	34.6	31.8	27.3	21.2	16.1
Rainfall	440	510	1010	960	540	1500	3360	1630	590	150	100	70
RH	39.1	37.5	38.5	30.2	22.1	27.9	43.1	44.1	28.4	29.9	29.2	28.8
Dengue Cases	1	0	0	3	6	5	3	9	36	63	48	10

2.4. Statistical Analysis

Data analysis consisted of dengue cases recorded monthly to determine the impact of rates of change in temperature, RH, and rainfall on dengue distribution rates and analyze statistical significance tests for observed correlations. To examine the relationship between climatic factors and DF, Pearson correlational analyses were employed on the data from 2012-2019 (Naqvi et al. 2019). The analyses of the dengue distribution in the Faisalabad area were done using ArcGIS software 10.8.1(https://www.arcgis.com/index.html). The SPSS software version 22.0 was used to analyze data on dengue cases, rainfall, mean temperature, and mean relative humidity, as well as for correlational analyses.

3. RESULTS AND DISCUSSION

3.1. Time-Series Epidemiological Study

There was a total of 224 cases of dengue infection reported in the entire period from 2013 to 2019. The maximum number of cases in 2016 was reported as 101, whereas in 2014 only 2 cases were reported. The Graph does not show a defined pattern in the year wise distribution of cases. That indicates there are various factors affecting the epidemiology of this virus, such as the high incidence of dengue, which may have resulted from increased population and uncontrolled urbanization (Gubler et al. 2012). To check the epidemic patterns of dengue infection, a monthly and yearly distribution of cases through graphical representation has been designed (Fig. 1).

A maximum number of cases has been observed between the months of September to November, as it is the post monsoon season when a huge number of dengue cases are reported due to the monsoon season's production of dengue mosquitoes where a relatively high amount of rainfall occurs during the rest of the year, leading to a higher rate of infection in the coming months. Another Indian study reported the same trend of an increasing number of cases from the post-monsoon season to October and then steadily decreasing (Garg et al. 2011).

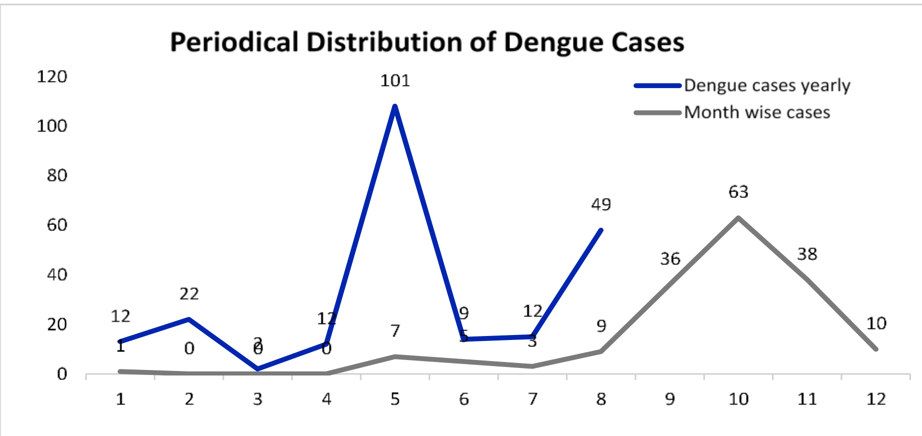

Fig. 1: Yearly and Monthly Distribution of Dengue Cases.

3.2. Graphical Presentation of Area-Wise Distribution

Unrestrained urbanization is one of the causes that makes Pakistan more vulnerable to dengue epidemics. Congested living areas, unhygienic working conditions, and slums contribute significantly to the transmission of

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this disease. Under such conditions, controlling and managing the dengue vector population has become difficult for authorities (Ahmad et al. 2015). To identify and analyze the most affected areas throughout Faisalabad and particularly the city area with dengue infection, a spatial distribution of maps has been generated. The map of the period from 2013 to 2019 was created to estimate the dengue hotspot area. Dengue outbreaks have been observed in most countries worldwide. Delhi has a population of around 13 million and is endemic to dengue fever. Overpopulation has caused poor sanitary conditions and drainage problems in many locations, which result in dengue infection (Chakravarti and Kumaria 2005).

3.3. Spatial Distribution of Dengue Cases from 2013-2019

The Faisalabad district has been divided into six tehsils, whose names are Chak Jhumra, Faisalabad City, Faisalabad Sadar, Jaranwala, Samundri and Tandlianwala. Most of the cases were reported from the tehsil of Faisalabad city (Fig. 2). This high transmission rate in the city area is due to favorable conditions for dengue to prevail, such as a high density of infection in residences with a dense population that facilitates dengue vectors by decreasing the flying distance of mosquitoes. Thus, congested living promotes rapid dissemination of infection, which leads to outbreak situations (Sapir and Schimmer 2005).

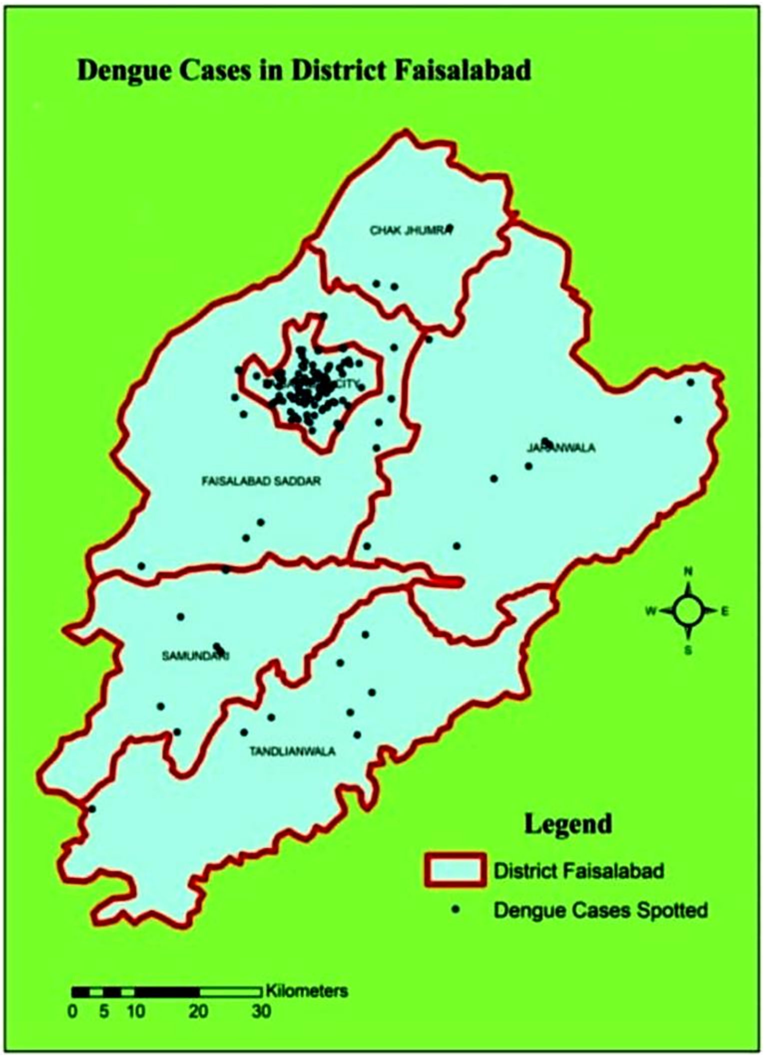

Fig. 2: The Distribution Map of dengue at Faisalabad from 2013–2019.

A detailed study of the of dengue infected cases was done inside Faisalabad City. A total of 224 cases were reported from 2013 to 2019. The highest number of cases was recorded in 2016, and the lowest was in 2014, with 101 and 2 cases, respectively. Many major predictors of the 2016 dengue outbreak have been identified in the literature, including socioeconomic or demographic characteristics, imported dengue cases, urbanization, and

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local weather conditions (Cheng et al. 2021). In the month wise distribution of cases for the whole period, the maximum number of cases was observed in October (63 cases). In February and March, no cases were reported throughout the period. The high density of dengue fever has been observed in urban areas where the density of residents is high with a high population rate, which creates a positive environment for the transmission of the dengue virus.

The most dengue affected areas from 2013–2019 included Sir Syed Town, Mansoorabad, Samnaabad, Muslim Town, Civil Lines, Sargodha Road, Peoples Colony, Sumandri Road, and Madina Town, where the dengue outbreak prevalence happened the most in the period of 7 years.

There are several other variables that have also been linked to dengue transmission, including population density, insufficient water supply, poor solid waste management, climate change, and a low socioeconomic level (Bisht et al. 2019).

3.4. Climatic variables

Dengue viruses and their insect carriers are environmentally sensitive. Temperature, rainfall, and humidity all play considerable roles in the transmission process. Variations in these situations contribute to an increase in incidence. The relationship between dengue incidence and weather conditions appears to vary by location (Choi et al. 2016). Several reports demonstrate the close association between dengue growth and factors of climate change, mainly relative humidity, precipitation, and temperature, that influence pandemics of dengue fever. The effect of precipitation on mosquito development and distribution depends on the research area's geography. For instance, depending on the provinces, research in Thailand found both positive and negative relationships between dengue disease and precipitation (Gomez et al. 2022). Many researchers employed statistical analysis, like Pearson correlation analysis, to analyze the association between climate conditions and the rate of dengue incidence (Karim et al. 2012).

3.5. Climatic Variables Analysis

The monthly average values of climatic factors (temperature, precipitation, and relative humidity) correlated with dengue cases showed a 58% positive correlation between the change in temperature and the number of dengue cases. While negative 42% precipitation and negative 36% relative humidity showed a negative pattern with respect to the increase in the number of dengue cases for the period of 2014–2019, The Pearson correlation between climatic factors and dengue cases in Faisalabad district is presented in Fig. 3. A Caribbean study also found that high dengue incidence is linked to regions with lower rainfall and higher temperatures. Less rain may be the source of A. *aegypti*-transmitted outbreaks, which could explain why dengue incidence is high in areas with lower rainfall. The prevalence of dengue is low during periods of heavy rain, but it rises as soon as the rain stops, indicating a 3-4 week lag between heavy rain and dengue epidemics (Sirisena et al. 2017).

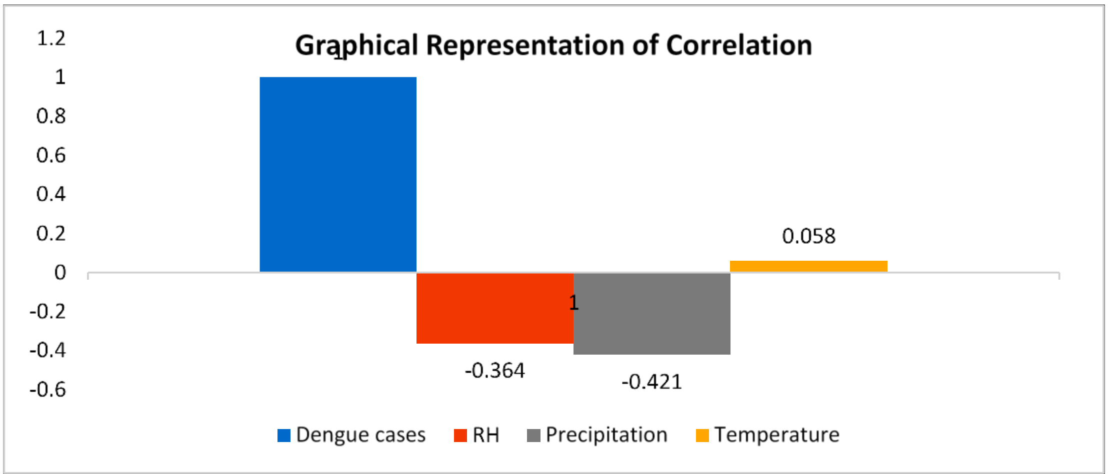

Fig. 3: Pearson Correlation among precipitation, relative humidity, temperature, and dengue cases of district Faisalabad from 2014-2019.

3.6. Temperature

A study of the impact of seasonal variation and weather variability on larval development of Aedes *aegypti* and transmission of dengue fever showed that mean and minimum temperatures are positively associated, while maximum temperatures build a negative correlation between dengue incidences (Wongkoon et al. 2013). During the

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period 2014–2019 monthly temperature trends were analyzed with the same period and monthly data on dengue cases. Then a Pearson correlation between monthly temperature data and the number of dengue cases was performed. The correlation is significant at the 0.05 level. Temperature showed relatively high positive correlation as compared to humidity, which showed a negative correlation with dengue cases. These results can be used as model predictors as by increase in temperature, there are 58% chances of having dengue infection (Fig. 4). Thus, temperature formed a positive correlation with the number of dengue infected cases. That showed a highly significant relation between the number of dengue incidence cases and temperature change in district Faisalabad.

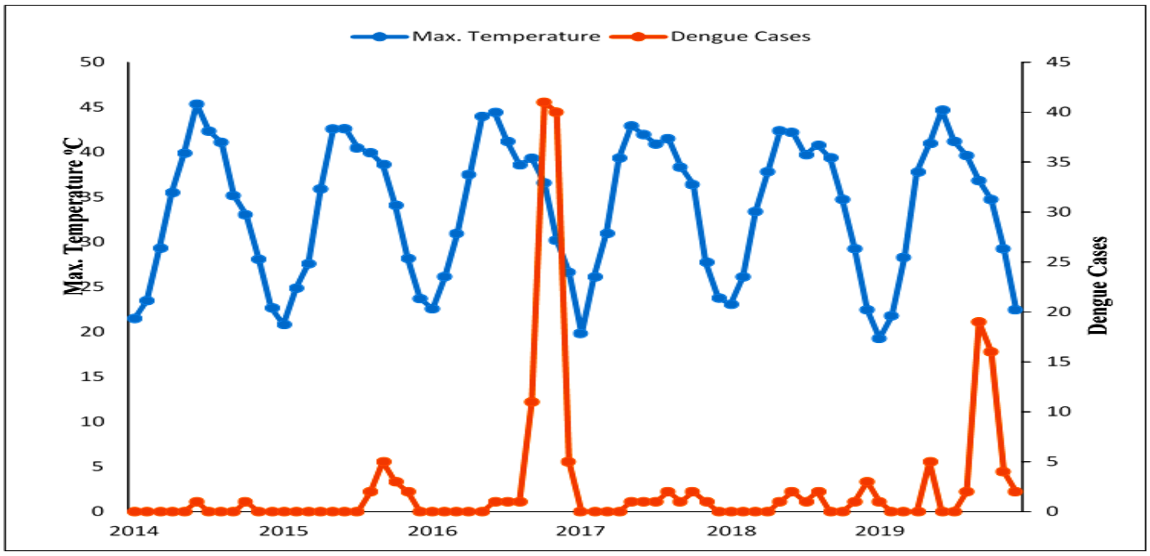

Fig. 4: Time-series graph between Max. Temperature and Dengue Cases.

3.7. Relative Humidity

Optimal humidity has been observed and reported to facilitate oviposition, larval egg hatching, and the behavior of dengue vector (*Aedes aegypti*) feeding and transmission of virus. Former studies reported a variable impact of RH on the transmission of dengue virus. (Mohammed et al. 2011). The correlation of relative humidity and dengue cases has been analyzed for the period 2014–2019 in Fig. 5.

The association between relative humidity and dengue was heterogeneous across different districts. Relative humidity was the only factor associated with the second seasonal peak of dengue (Xu et al. 2020). There are also optimal ranges of relative humidity and rainfall for dengue transmission, below or above which dengue transmission would be restricted (Morin et al. 2013).

A Pearson correlation analysis between monthly relative humidity and the number of dengue cases was performed. Relative humidity showed about a 36% negative correlation with dengue infected cases. An increase in RH results in a decrease in cases, according to the data that has been used to run the software to find the link. This highlighted that the number of dengue incidence cases was negatively correlated with the relative humidity rate in Faisalabad. Relative humidity was shown to be inversely related to dengue cases in this research. Due to the inverse relationship between humidity and pressure, we were able to conclude that air pressure was more strongly associated with dengue than humidity. In contrast, a decline in dengue cases was associated with low temperatures above 21.3°C (Gomez et al. 2022).

3.8. Precipitation

It has been observed that the rainfall was suitable for DF breeding and dispersal from monsoon to post-monsoon times. The post-monsoon time was especially significant because of a high incidence peak of DF during this phase every year (Gonzalez et al. 2013). According to several other studies, persistent rain may help prevent the spread of dengue fever by decreasing the Aedes aegypti mosquito's ability to survive. Statistics on dengue fever morbidity from Trinidad and Tobago, a twin island nation, show an inverse relationship with precipitation (Lai 2018). These post-monsoon conditions are considered very favorable for the dengue mosquito's (Aedes *aegypti*) replication and maturation (Suleman et al. 2016).

The comparison between the changing trend of rainfall on a monthly basis has been made using a time series graph that indicates peak lines of dengue cases right after peak of rainfall throughout the period that verifies post monsoon occurrence of dengue infection in Faisalabad (Fig. 6). Thailand's rainfall has individual effects, and it has been discovered that in some provinces, more rainfall is linked to a decline in dengue disease incidence. The Aedes *aegypti* mosquito population in Saudi Arabia has been the subject of research by a scientist who also claimed that dengue illness had a negative association with humidity and rainfall (Lai 2018).

A Pearson correlation analysis has been done between monthly rainfall and dengue cases to identify the relationship between rainfall and dengue occurrence. The precipitation variation showed a negative trend of 43 percent. By increasing precipitation, there was a decrease in the number of dengue infections that has been observed according to the data and was run by the software, but the model is fit. The results indicated a negative correlation between monthly precipitation and cases of dengue infection in Faisalabad.

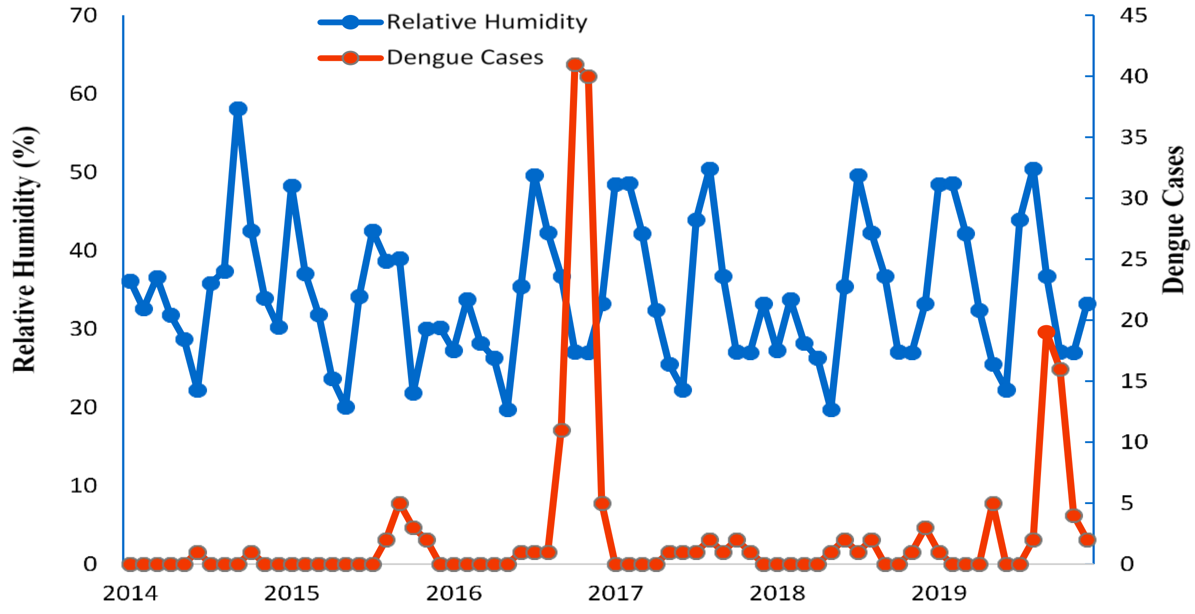

Fig. 5: Time-series graph between Relative Humidity and Dengue Cases

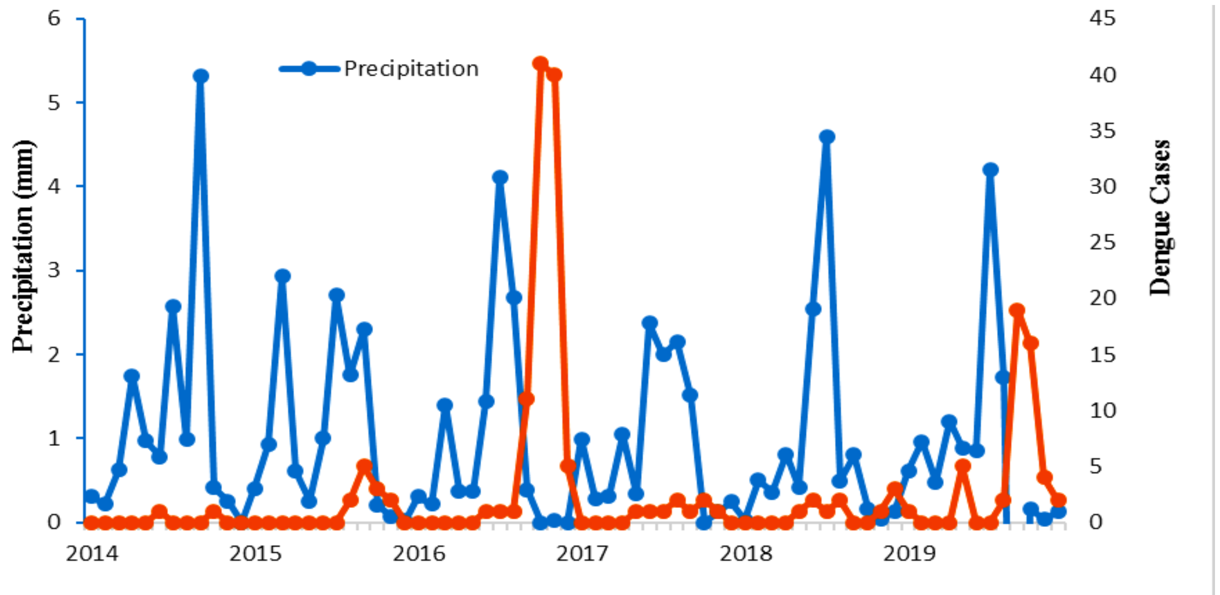

Fig. 6: Time-series graph between Precipitation and Dengue Cases

Various prior studies and the results of this research indicate that climatic factors do not have a significant impact on the proliferation of dengue disease, as they show an inconsistent and complex relationship with dengue cases, while socio-ecological factors have considerable capacity to explain dengue outbreaks (Li et al. 2021).

Dengue is more significantly impacted by interactions between pairs of socio-ecological and climatic factors than by any one element alone. This study shows majority of affected reported cases were from city areas of district Faisalabad, that explains the potential of epidemiological parameters such as high population density, congested living conditions (decrease the vector flying area), sanitation conditions (promote vector breeding capacity), economic status (access to health facilities), and education level (determine people's preference for health), along with public awareness level to control and mitigate dengue infection, play a vital role in an area that contributes to the rate of dengue infection, among these factors huge population density and low sanitation conditions make a direct relation with the prevalence of dengue infection in a case study of district Faisalabad (Ahmad et al. 2015).

As for climatic impact, our study shows that temperature, with a 58% positive correlation, has a significant impact on the long-term trend of dengue incidence. Among all three, climatic parameters, temperature, precipitation, and relative humidity, temperature has the most persistent positive correlation with R2 = 38.0%, and above 28 °C, it works at its maximum potential. Whereas Rainfall and RH, do not appear to have a significant impact on dengue cases found during epidemics (Teurlai et al. 2015).

In our case, they show a negative correlation that can be explained by the fact that during monsoon (peak rainy time), dengue mosquitoes produce while at post moon soon season, they affect people, hence maximum cases reported at a time when rainfall and humidity drop while the reported dengue fever cases have increased.

4. CONCLUSION

The comprehensive profile of dengue distribution, analysis of seasonal variation, spatial distribution, and dengue influencing climatic factors provide three highlighted outcomes of this study.

1. Climate factors have no correlation with the occurrence of dengue infection.
2. Among all the reported cases for the entire period, 67% were reported in 2016 and 2019 alone, but the relative weather conditions were the same.
3. The hotspot areas for dengue infection are the most populous and congested areas.

This verifies the effect of socioeconomic conditions on the proliferation of dengue mosquitoes, so governmental authorities and researchers should focus on these parameters to control dengue transmission rather than climatic factors, which show inconsistent correlation in the majority of studies and in our case no relation. This study will open up future prospects for research and allow the authorities to better manage the disease, by keeping an eye on the trend analysis and results of this study. This study will also provide a baseline for future advanced-level research.

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