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Research Article

# The urban expansion and its effect on temperature trends of Faisalabad city, Pakistan

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**Abstract:**
Rapid urbanisation on the global stage is a source of worry over its environmental impacts as far as local climate patterns are concerned. This research analyses the effects of urbanisation indices on local temperature anomalies in Faisalabad, Pakistan, from 1972 to 2022. Trends of mean, maximum, and lowest temperature, urban population, built-up area, the number of factories, and the number of automobiles were analysed in the data of five decades. The plot shows that the warming trend recorded from Faisalabad's temperature data is evident from an increase in both mean maximum and minimum temperature and the increase in mean temperature by 2°C. The city underwent rapid urbanisation during this period, which resulted in an increased urban population six times, while the extent of built-up areas was extended four times, and industrial and vehicular activities also increased considerably. This provides a statistically excellent correlation between years and temperature measures, yielding coefficients as shown (R2 = 0.9615, 0.9931, and 0.9839), which indicate that the period under study has a solid relationship with these temperature patterns. The research underscores the significant climatic impacts of urbanisation and calls for environmentally responsible urban planning, suggesting global solutions to tackle urban climate change and sustainable development.

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## 1. Introduction

The main platform where all activities are founded is on land. Land usage is dynamic in space and time (Yang *et al.*, 2023). An urban heat island is created when surface changes brought about by urbanisation cause the thermal environment to shift, resulting in higher temperatures than in other regions of the nation. This phenomenon is related to population expansion and urbanisation (Wu *et al.*, 2022). The majority of research on urban sprawl is conducted in industrialised nations, while it is also performed in emerging nations like Pakistan and India (Mumtaz *et al.*, 2023). The move from the twentieth to the twenty-first century was characterised by a period of glory in which global advancement and change occurred. The world witnessed a remarkable urbanisation and technological revolution, especially in developing countries (Rahman & Thelen, 2016). These significant advances resulted in many benefits and several serious environmental issues that must be addressed. Two such challenges that have lately emerged on the global environmental agenda are accelerated urbanisation and its impact on temperature trends. To address these changes, the concept of the 'Urban Heat Island' (UHI) effect was coined to describe the development of our cities and metropolises (Ravanelli, 2018).

The urbanisation and how it impacts temperature tendencies in Faisalabad, Pakistan are explored in the current study. Faisalabad is an interesting case study because the city's environmental problems are linked to growing urbanisation. It allows us to analyse and understand these universal processes in a much more personal and smaller space. Thus, the reader is prepared to investigate urban expansion fully, its intricate relationship with temperature patterns, and the broader implications for humanity and our typical home, earth (Tariq & Shu, 2020). Over time, continuous study and scientific discoveries have significantly increased our understanding of climate dynamics and their underlying causes. Since its formation around four billion years ago, the earth's climate has followed a predictable pattern of warm and cold intervals (Zalasiewicz & Williams, 2012). However, the statistics show that some of the most drastic and alarming shifts in our planet's climate have occurred only in the previous century and a half.

Surprisingly, human activity is to blame for a large percentage of the recent climate variations. The Anthropocene epoch is distinguished by considerable human influence on Earth's ecosystems. Population growth, city expansion, industrial development, and greenhouse gas emissions have significantly impacted our planet's current state. These activities have far-reaching consequences that extend beyond simple statistics graphs (Houser, 2018). Climate change effects are actual, lived experiences, not intangible ideas. They have real-world consequences for civilisations worldwide, influencing where people choose to reside, how they migrate, and how profitable their communities are overall. These rapid changes substantially influence our climate, with metropolitan regions suffering the most globally. Cities such as Beijing, Delhi, and Shanghai are prime examples of the negative consequences of rapid urbanisation on regional microclimates (Grover & Singh, 2020).

These international tendencies are not unfamiliar to Faisalabad, located in the heart of Pakistan. The story of this city is similar to that of many other cities. At the turn of the 20$^{th}$ Century, Faisalabad, originally known as Lyallpur, had a population of only a few thousand people. Faisalabad has changed dramatically over the last century, with its population and physical size increasing exponentially. Faisalabad has grown into a vibrant metropolis with a population of

over three million people, serving as the textile industry's hub in Pakistan (Farooqi *et al.*, 2020). As a result of the city's rapid industrialisation and expansion, once-green areas have been converted into a sprawling concrete jungle. Urban landscapes are emblems of progress and growth but can also have some detrimental environmental consequences.

Several studies have investigated how the climate changes in large metropolitan areas and financial centres (Kabisch *et al.*, 2016). According to Roy and Balling's (2005) research of the seasonal fluctuation in temperature, diurnal temperature range, and cloud cover over India from 1931 to 2002, the Deccan Plateau witnessed a significant increase in temperature, while northwest Kashmir experienced a fall. According to Sajjad *et al.* (2009a), Karachi is more likely to experience mean maximum temperatures than mean minimum temperatures for the period from 1947-2005. Sajjad *et al.* (2009b) investigated temperature trends in Lahore due to procedural urbanisation between 1950 and 2007. While the highest temperature remained steady, scientists discovered an increasing trend in the mean annual and lowest temperatures. Duhan *et al.* (2013) assessed the impact of urbanisation on temperature change in Madhya Pradesh between 1901 to 2001. The study found evidence of rising temperatures, with winters warming more quickly than summers and temperatures rising dramatically as cities grew. Jeganathan and Andimuthu (2013) examined temperature trends from 1951 to 2010 and found that Chennai, India, experienced an increase in temperature of 1.3°C.

According to Kirshen *et al.* (2008), urban regions rely on a sophisticated infrastructure system to deliver services for people, the environment, and the economy. Due to the migration of people from rural to urban regions, cities worldwide have been gradually developing (Opoko & Oluwatayo, 2014). Urban warming is often defined as the temperature differential between a city and its rural surroundings, and this temperature difference is referred to as an 'urban heat island' (Martilli *et al.*, 2020). In addition to regional meteorological changes like urban effect, Choi *et al.* (2003) suggest that non-climatic factors including station location, instrumentation, and observation time may also contribute to the long-term warming trend. Global yearly urban warming rates range from 0.01 to 0.42°C. Compared to rural and maritime sites, metropolitan cities' annual temperature increase is greater (Parker, 2010). In large towns, the temperature differential between urban and rural areas can be up to 10°C (Fujibe, 2009). Global warming is now believed to impact local temperatures less than regional urbanisation, and urban warming is associated with population growth (Chung *et al.*, 2004).

Kishtawal *et al.* (2010) argue that the number of ways in which the urban environment contributes to climate change is also increasing. Local climates are shifting because of the rate of urbanisation, which causes urban heat islands and air pollution (Ooka, 2007). Urbanisation and industrial activity are interconnected with climate change, and the effects of these factors are currently one of the biggest concerns and issues to be studied on a global level. Environmental change affects urban areas all over the world. This study seeks to examine how urban development influences temperature fluctuations in Faisalabad. This research will enable there to be a better understanding of the intricate relationship between climate change, population growth, industrialisation, and urbanisation.

## 2. Profile of the case study area

Faisalabad formerly Lyallpur is located in the province of Punjab Pakistan which has gained the nickname 'Manchester of Pakistan' because of its strong industrial base, especially in the textile industry. According to the latest census, Faisalabad is Pakistan's third most populous

metropolis, with more than three million residents. This paper provides a detailed discussion of Faisalabad, the case study city we used to see how temperature changes are influenced by urbanisation. Faisalabad is a city with an area of over 1,300 square kilometres that lies at a latitude of 31.4181° N and a longitude of 73.0794° E. It is a relatively flat city with an average elevation of 186 meters above sea level.

Parveen *et al.* (2019) look at changes in land use in the Faisalabad metropolis in Pakistan using Landsat images from 2003 to 2017. As per the analysis, agricultural land fell from 36% in 2003 to 10% in 2017, whereas built-up land significantly rose from 30% in 2003 to 50% in the urban population of Faisalabad increased from two million in 1998 to three million in 2017, with several problems that have evolved. By understanding the factors that contribute to the land use changes and their consequences, the urban planners and the local governments have a better chance of controlling the future areas of human settlements, thus reducing their environmental impact on the world.

This study employed statistical methods. It scrutinised land-use changes and spatiotemporal analysis to determine how these changes affect the ecosystem. As reported, agricultural land markedly decreased from 1985 to 2016 (37.79% to 10.23%), open space (29.94% to 1.89%), and, conversely, built-up area (33.07% to 88.19%) as reported by Arshad *et al.* (2019). Conversion of open space and agricultural land into built-up areas augmented Faisalabad's annual temperature and rainfall patterns. There has also been a significant correlation coefficient between land-use alteration and mean annual increase in temperature and rainfall. Urban planners can use this study to facilitate the management of urbanisation in Pakistan’s major cities.

Figure 1: Location of the study area, Faisalabad City, Punjab, Pakistan

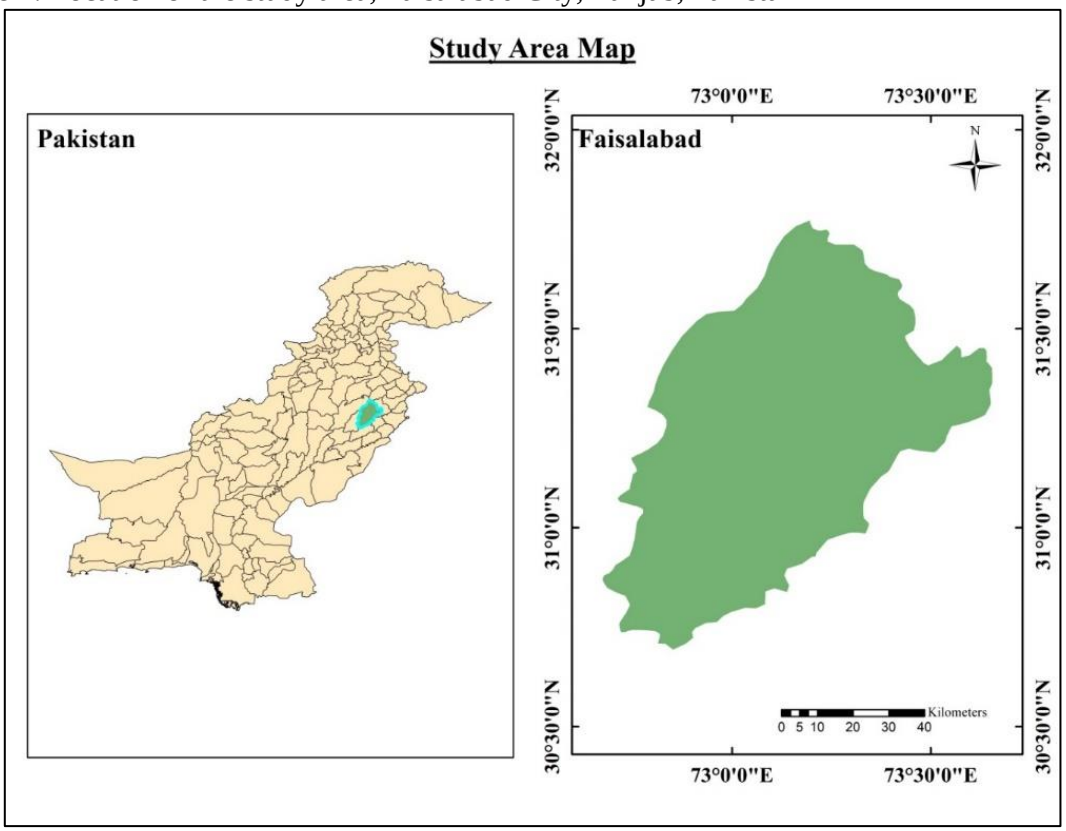
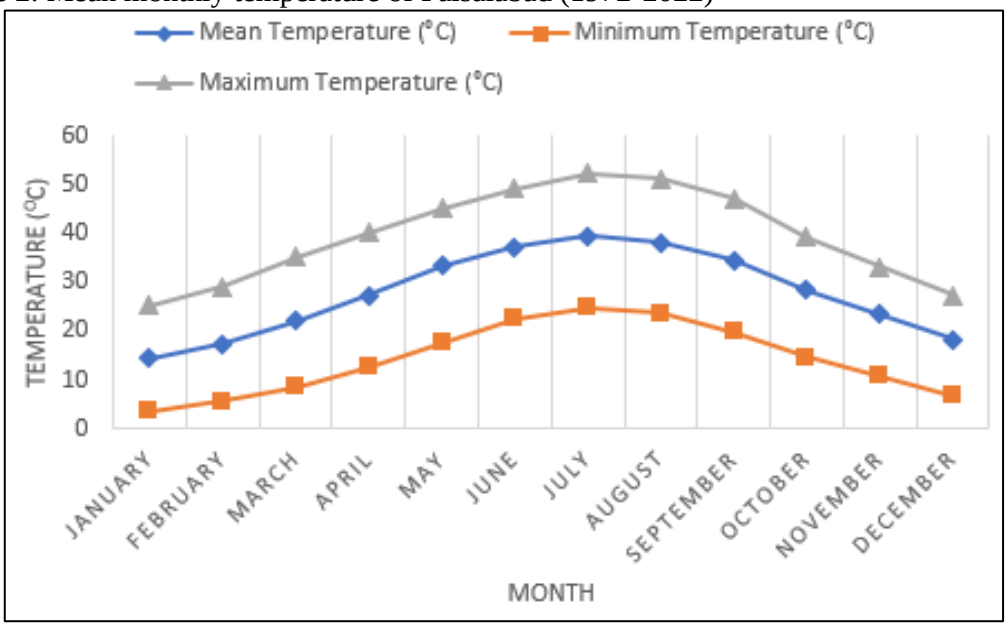


Figure 2: Mean monthly temperature of Faisalabad (1972-2022)




The land of Punjab is contributing in vastly in the agricultural productivity. The semi-arid climate of Faisalabad is marked by scorching summers and cold winters. The typical temperature range is between a summer high of around 40 degrees Celsius and a winter low of about 7 degrees Celsius. The city regularly receives monsoons from July to September, with 400 mm of rain falling annually, primarily during these months. Faisalabad transformed from a tranquil hamlet to a large metropolis in a few decades due to unparalleled industrialisation and increase. The city is one of the major commercial and industrial centres of today, with various factories, business centres, houses, and all kinds of public infrastructure. Subsequently, due to the rapid development of urban sprawl, which has caused a serious loss of green areas, most of the city's green spaces have only remained in parks and private gardens.

The textile industry has a large chunk of the city's workforce and contributes significantly to Pakistan's national GDP. Many textile spinners are found in the city, significantly increasing the export of textiles from the country. Other important industries include the manufacture of chemicals, food, and pharmaceuticals. Faisalabad is one of the most cosmopolitan cities with diverse populations and languages, making this city such a multicultural society. The second most prevailing language in Pakistan is Urdu. Annual festivals and events also help to demonstrate the city's great social unification alongside rich cultural practices. Inevitably, urbanisation has its positive and negative aspects in Faisalabad. Social and economic benefits also arise from urbanisation, such as prosperity in terms of job creation that follows with easy access to amenities and services. However, it is characterised by the many challenges on infrastructure, including environmental burden. Among such problems are waste management issues, water and air pollution, and most notoriously of all, the Urban Heat Island (UHI) effect, where city temperature is much higher than that of surrounding rural areas.

An appropriate example that can be used as a case study to assess the effects of urbanisation on temperature trends is the city of Faisalabad, which is rapidly developing. As we continue to analyse the particularities of this metropolis within its specific historical context and modern challenges, we aim to illuminate the broader global issue of urbanisation and climate change. For this discussion, we need to study the climatic profile of the city. The monthly temperature

record shows that the city has very marked seasonal changes. As can be seen from Figure 2, the average January temperature was 14.4°C below a minimum of 3.6°C and up to 25.2°C. In February, there is an increase of a little temperature in January, and this shows that summer will begin in March up to May.

The city reaches its mean maximum temperatures in June and July, whereby July is at 52.2°C, the highest measured temperature during the year. Temperatures decrease because the city changes from summer to autumn throughout August, September, and October. Winter starts in November, and December is the coldest month. These temperatures give a vivid picture of the climate Faisalabad has to offer, marked by cold winters and intense heating summers. This information about baselines will be helpful in the future when we take a deeper look at the effects of urbanisation on temperature fluctuations in the following sections. It will enable us to understand how these trends have evolved due to urbanization and how these changes could affect the city's environment and its inhabitants' quality of life.

## 3. Theoretical framework

Considering the UHI effect theory, the study looks into the dynamic relationship between urbanisation and local climatic changes in Faisalabad over the last 50 years. It merges environmental science, climate studies, and urban geography to analyse the impacts of land use changes, industrialisation, and population increase on temperature patterns. The approach used by the framework is mixed method, combining qualitative assessment of urban planning and sustainability with quantitative analysis of historical temperature data and urban growth indices. The paper underpins the longitudinal approach and gives a comprehensive case study on the urban climate dynamics in the Faisalabad city. It connects its findings to the phenomenon of global urbanisation and prospects for sustainable development, thus reflecting worldwide ramifications in the regional growth patterns on the climate before it may affect the human beings.

## 4. Data and methodology

This research uses the linear regression method to assess mean annual minimum temperature, mean annual maximum temperatures, and mean annual temperature averages from 1972-2022 to ascertain significant changes in this climatic variable. Climate data was collected from the Pakistan Meteorological Department (PMD). It will discuss differences between rural and urban areas in the lowest and highest mean annual temperatures. Statistical data is used to examine the relationship between temperature and population density in the examination zone. The association between the research area's temperature and population density is investigated using demographic data. Pakistan's Population Census Organisation (PCO) provided most of the population data used in this study. For the empirical inquiry, the time duration is used as an independent factor, and quantitative estimation of mean minimum, mean maximum and mean annual temperature is used as a dependent factor.

- The dependent variables in the study are the minimum, maximum, and mean annual temperatures.
- Time duration, measured in years, is used as the independent variable.
- The linear regression model applied for this empirical investigation is represented by the equation:

$$Y = a + bx + c$$

Where,

Y = dependent variable as a finding of the temperature of Faisalabad,
a = minimum temperature,
b = maximum temperature,
c = annual temperature, and
x = time duration in the year.

a+bx = Relationship between Y dependent and x independent factor and how much brings a change in one unit change of dependent variable in the independent variable.

a = y-intercept means when x= 0
b = The variation in the average value of the independent factor, however, the X value rises
E = calculates the error randomly between duration

The equation to calculate "a" value is given below.

$$a = \left(\sum y\right)\left(\sum y^2\right) - (\sum y)(\sum xy)/n(\sum x^2) - (\sum x^2)$$

The equation to calculate "b" value is given below.

$$b = n\left(\sum y\right)\left(\sum y^2\right) - (\sum y)(\sum xy)/n(\sum x^2) - (\sum x^2)$$

Where, n is the number of the intervals and $\sum xy$ is the product of x and y variables in regression, $(\sum x^2) - (\sum x)^2$ is the difference between the square of the independent variable and the sum of x independent variable squares.

## 5. Results and discussion

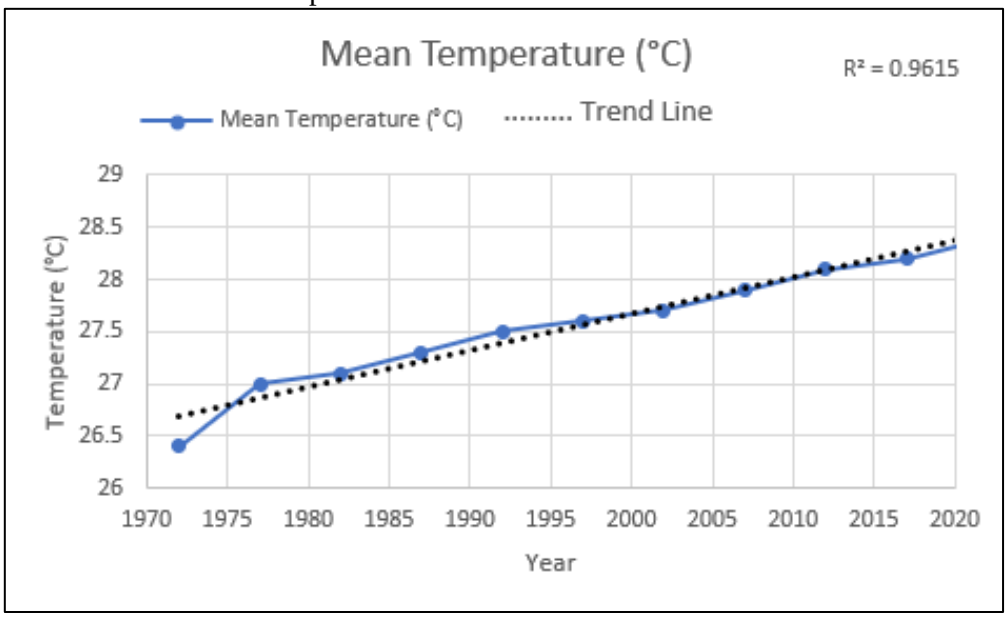
There has been an upward trend in Faisalabad City's mean temperature between 1972 and 2022. According to the coefficient of determination, or R2, which is 0.9615, the trend line accounts for around 96.15% of the variance in the mean temperature. Unknown factors account for the remaining 3.85% of the disparity. The trend line for mean temperature rises, indicating a considerable positive influence.

For example, the average temperature rose from 26.4°C to 27.0°C between 1972 and 1977, as shown in Figure 3. Other historical periods with temperature ranges of 27.1°C to 27.3°C, 27.5°C to 27.6°C, 27.7°C to 27.9°C, and 28.1°C to 28.2°C, correspondingly, were 1982-1987, 1992-1997, 2002-2007, and 2012-2017.

The conclusions of the data patterns indicate a notable temperature spike in Faisalabad City's urban region. After 2012, this trend accelerated, with 2022 recording the warmest year on record at 28.4°C. The rise in mean temperature that began in 1997 is linked to an increase in the city's mean lowest temperature. The rise in the mean minimum temperature in Faisalabad City is connected with an increase in the urban population.

According to the study's findings, one of the biggest contributors to climate change has been the rise in temperature in Faisalabad City. The temperature fluctuated relatively little between 1972 and 1997, but after 1999, it rapidly climbed, particularly in metropolitan areas.

Figure 3: Trend line of mean temperature of Faisalabad



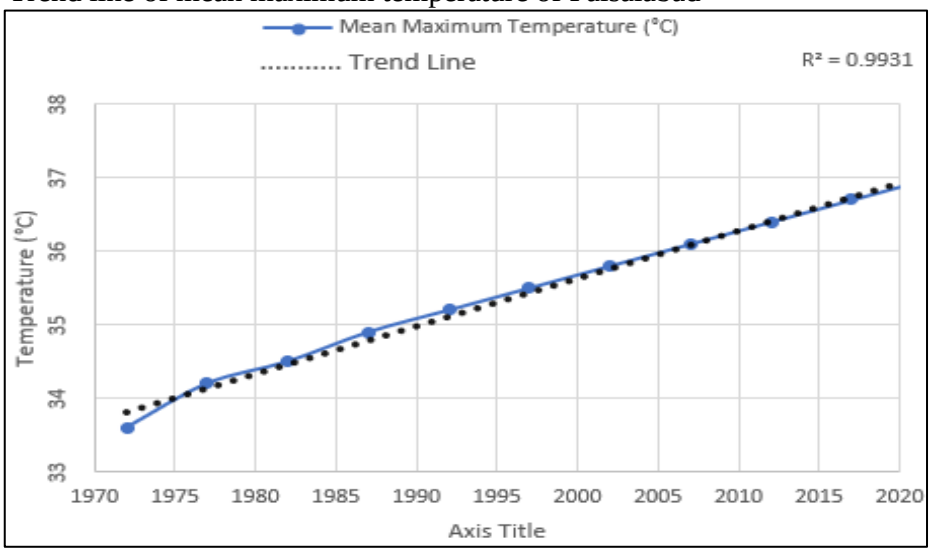

The data for the mean maximum temperature in Faisalabad city between 1972 and 2022 shows a clear rising trend. The coefficient of determination, or R2, is 0.9931, as shown in Figure 4. This means that the trend's fit line can explain 99.31% of the variation in mean maximum temperature throughout this period. Other undisclosed factors account for the remaining 0.69% of the variation.

The trend in mean maximum temperature growth has been notably upward. For example, the temperature rose from 33.6°C in 1972 to 34.2°C in 1977. Temperatures increased from 34.5°C to 34.9°C, 35.2°C to 35.5°C, 35.8°C to 36.1°C, and 36.4°C to 36.7°C during other key periods such as 1982-1987, 1992-1997, 2002-2007, and 2012-2017.

The data analysis demonstrates that the mean maximum temperature in Faisalabad city has increased significantly, particularly since 2012. The year 2022 is notable for having the highest mean maximum temperature ever recorded, at 37°C. According to the findings of this study, considerable changes in climatic conditions have been attributed to a rise in the mean maximum temperature in Faisalabad city. Even though the temperature difference between 1972 and 1997 is relatively minimal, there is a more visible increase after 1999, particularly in metropolitan regions.

Despite a definite upward trend in mean maximum temperatures, the general climatic conditions in Faisalabad city of Pakistan are affected by a wide range of diverse causes. According to Faisalabad city data, the mean lowest temperature has risen from 1972 to 2022. According to the coefficient of determination, R2, which remains at 0.9839, the fitted line can account for approximately 98.39% of the variation in the mean minimum temperature throughout these years. However, the remaining 1.61% can be attributable to the factors that this model does not consider.

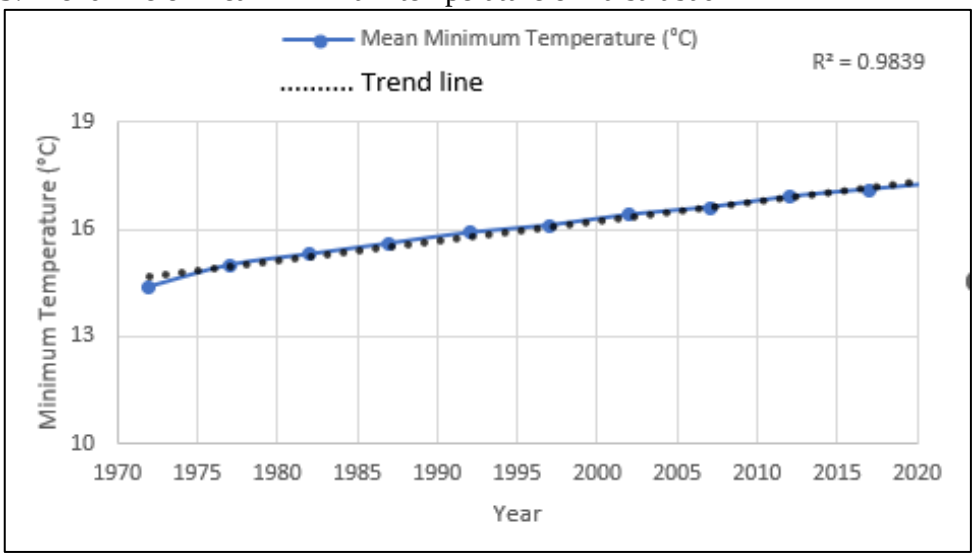
Figure 4: Trend line of mean maximum temperature of Faisalabad




The rise in the mean lowest temperature indicates a strong upward trend. For example, the mean lowest temperature increased from 14.4°C in 1972 to 15°C in 1977. Temperatures increased from 15.3°C to 15.6°C, 15.9°C to 16.1°C, 16.4°C to 16.6°C, and 16.9°C to 17.1°C during other key periods such as 1982-1987, 1992-1997, 2002-2007, and 2012-2017 as demonstrated in Figure 5. The examination of this dataset reveals a considerable rising trend in the mean minimum temperature of Faisalabad city, which became more evident after 2012. The highest mean low temperature ever recorded was 17.3°C in 2022.

The findings of this investigation illustrate how rising mean minimum temperatures influence changing climatic conditions in Faisalabad City. Despite the extremely minor temperature change between 1972 and 1997, development accelerated after 1999, particularly in urban areas. According to statistics, the population of Faisalabad has increased between 1972 and 2022. In 1972, Faisalabad's urban area had 572,000 residents out of the district's total population of 2,011,000. The urban population has increased dramatically during the last five decades, reaching 3,857,000 people in 2022.

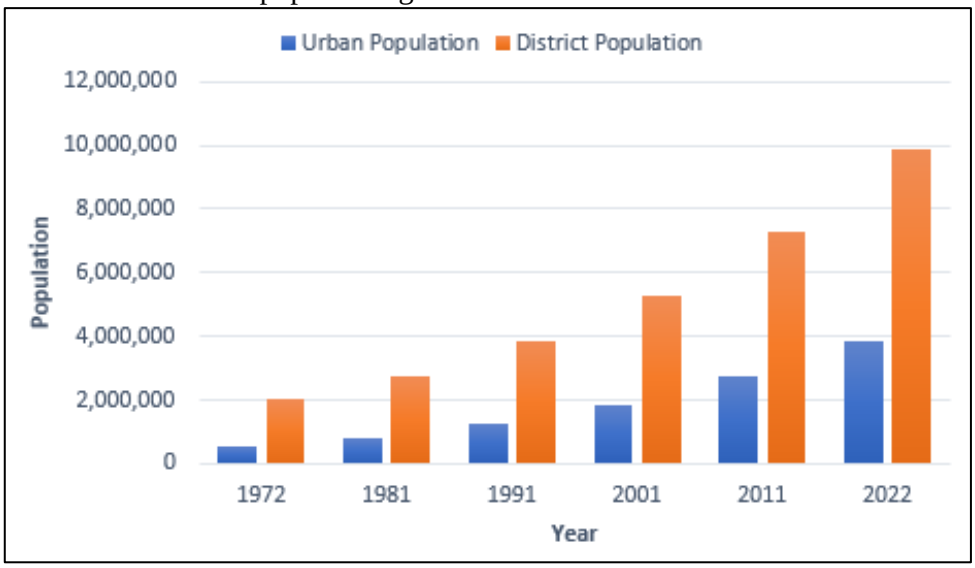
Figure 5: Trend line of mean minimum temperature of Faisalabad



Faisalabad's population has likewise grown dramatically, rising from 2,011,000 in 1972 to 9,844,000 in 2022, as shown in Figure 6. The considerable rise in the urban population demonstrates Faisalabad's strong urbanisation tendency. For example, in 1972, the share of urban residents in the district's overall population was 28.4%, but it would be raised to 39.2% by 2022. Faisalabad's urbanisation has been steady and rapid. Typically, urbanisation alters the local economy, way of life, and environment.

Growth, however, generates a variety of concerns, including increased demand for resources and infrastructure, environmental degradation, and the formation of urban heat islands, which can contribute to local temperature increases. To comprehend the temperature changes recorded in Faisalabad, it is necessary to understand how this urban heat impact influences the local climate and temperature trends.

Figure 6: Urban and district population growth of Faisalabad from 1972 to 2022

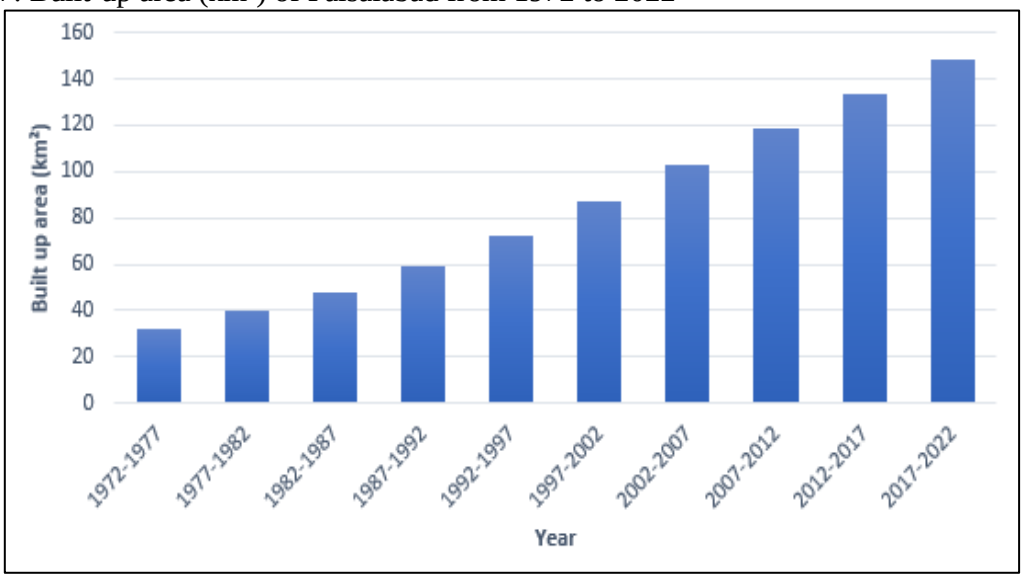



Between 1972 and 2022, the built-up area of Faisalabad and its urban population both increased significantly. Between 1972 and 1977, a total of 32.4 km2 of land was developed. This climbed to 148.6 $km^2$ in the five years from 2017 to 2022, a more than fourfold rise, as shown in Figure 7. The growth of Faisalabad city's built-up area shows a trend toward the city's rapid urbanisation. This pattern, driven by population increase and economic expansion, has converted enormous expanses of rural and agricultural land into urban, commercial, and industrial regions.

The urbanisation offers advantages for both the economy and society, but it can also put a burden on the environment of a city and its infrastructure. For instance, the development of built-up areas often leads to the emergence of urban heat islands – localised areas with elevated temperatures compared to their rural surroundings. This process can make regional temperature trends more pronounced and contribute to the general climate of the city.

This data on the increasing built-up area in Faisalabad along with temperature and population statistics show a relatively high correlation between the urbanisation in Faisalabad and its climate. Investigation of these instances can shed some light on urban planning strategies that can serve to reduce the environmental impact of increasing urbanisation.

Figure 7: Built-up area (km²) of Faisalabad from 1972 to 2022




The enormous increase in the number of factories over the previous five decades is evidence of Faisalabad's tendency toward industrialisation. From 5,000 manufacturers between 1972 and 1977, the number progressively climbed to 68,000 factories between 2017 and 2022, signifying a nearly 14-fold rise, as shown in Figure 8.

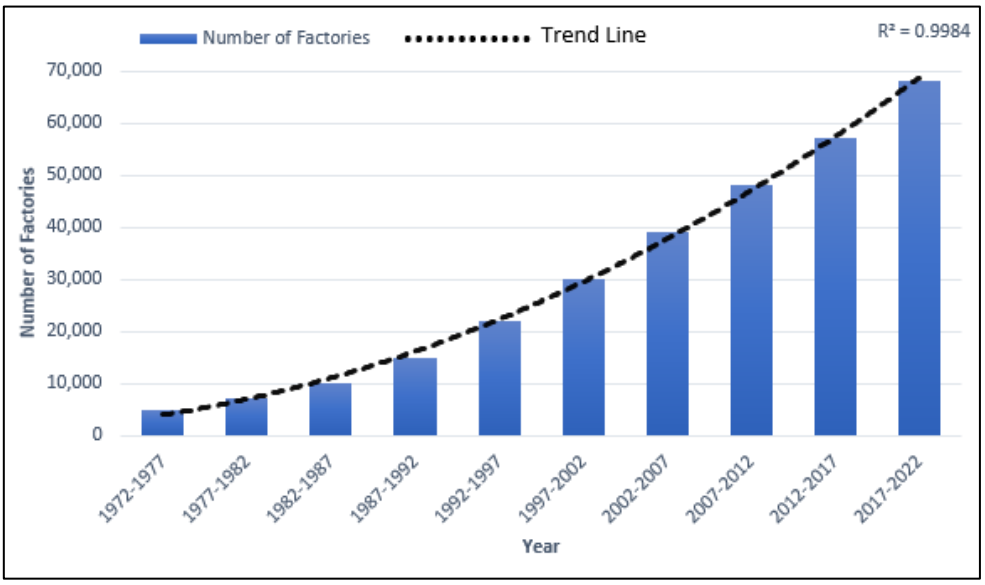
This growing industrialisation has had a tremendous impact on Faisalabad's urban expansion. It supports economic growth by encouraging trade, creating jobs, and raising the city's GDP. Industrialisation has many good economic consequences, but it also generates environmental concerns, such as water and air pollution and increased energy use, which can impact regional climate. Additional evidence of Faisalabad city's rapid urbanisation may be found in the rise of factories, the extension of built-up land, and population growth. A thorough understanding of the influence of this growth and industrial development on the regional temperature patterns is required so that the policy makers may establish sustainable urban and industrial development plans for the city.

This was the period of the great industrial revolution in Faisalabad; many manufacturers rose over these 5 decades, starting when Faisalabad was still known as Lyallpur. Over the period 2017-2022, there were 68,000 manufacturers compared to the number of 500 in 1972-1977. This can be considered as an increase of over 13 times in the number, which is a confirmation of the rapid industrialisation of Faisalabad.

The rapid expansion of the industry has an impact on both the socioeconomic system and the environment. On the one hand, it has hastened economic development by providing jobs, promoting local trade, and increasing the city's contribution to GDP. On the other hand, it causes environmental problems such as increased water and air pollution, higher energy demand, and subsequent effects on city microclimates.

Faisalabad is quickly urbanising, as demonstrated by an increase in the number of factories, an increase in urban population, and an increase in built-up areas. The interaction between these variables and their impact on regional temperature patterns must be studied in depth to build sustainable urban and industrial growth plans in the metropolis.

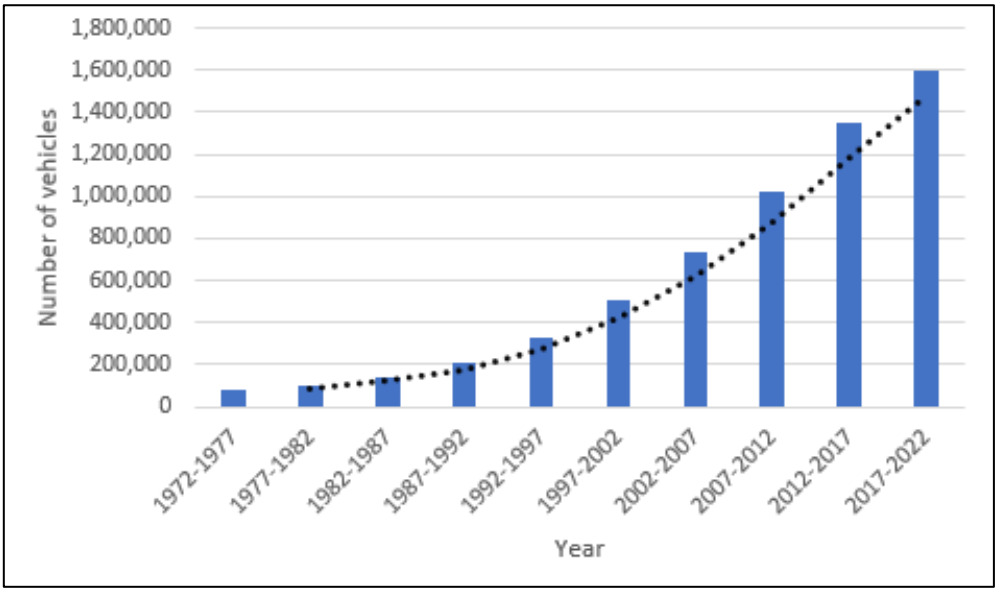
Figure 8: Trend of the number of factories in Faisalabad from 1972 to 2022




Faisalabad has seen a tremendous increase in the number of vehicles during the previous 50 years, indicating urban expansion and lifestyle changes, as shown in Figure 9. This rise, which is around twenty times the initial amount, reflects the urban population's growing transport needs as well as the rising demands of an industrialised city. However, this expanding trend portends increased environmental and health dangers. The growth in automobile traffic substantially contributes to air pollution, particularly in terms of greenhouse gas and particulate matter emissions. In addition to exacerbating the urban heat island effect and contributing to global warming, this pollution can impair human health by reducing air quality.

Urbanisation in Faisalabad is multidimensional and complex, as shown by increasing vehicle production, opening factories more frequently, growing urban inhabitants, and increasing non-agricultural land use. This combination of these factors affects the environment and climate; therefore, the eco-friendliness of urban planning and modes of transport need to be considered.

Figure 9: Trend of the number of vehicles in Faisalabad from 1972 to 2022



## 6. Conclusion

This study seeks to determine the role of urbanisation on trends in temperature evolution for Faisalabad between 1972 and 2022. The analysis of the findings revealed a very strong warming trend caused by an increasing impact of urbanisation on the growth of the built-up areas, population, industrial activity, and automotive traffic. The analysis found that the Faisalabad average temperature rose by 2°C over 50 years from 1972 onwards, with the temperature being 26.4° C in 1972 to 28.4° C in 2022. The average maximum and minimum temperatures may be noted to follow the same pattern. The highest temperature in the year 1972 was recorded to be 33.6°C which then increased to a high of 37°C in the year 2022, while the lowest temperature also went up from 14.4°C in 1972 to a high of climate change effects essay 17.3°C over. These trends for temperatures were well associated with the years and was reported through R2 values of 0, 9615, 0.9931, and 0.9839 for averages, maximums, and minima accordingly.

At the same time, a remarkable transformation took place within the city's urban landscape of Faisalabad. The urban population rose more than sixfold from 572,000 between 1972 and 2022 and reached to several people 3,857,000. The total built-up area has increased from 32.4 km2 in the middle of the 1970s to the current 148.6 $km^2$ as of 2022. In addition, the population of factories grew amazingly from merely 5,000 to a whopping figure of 68,000 in just the same period, showing that the city's economy was booming as well. In the end, vehicles increased massively from 80,000 in the early 1970s to a sensational 16,00,00 in 2022.

Lastly, this research presents evidence that the local climate changes owing to urbanisation are real despite being distorted by misleading factors such as the incorrect GHG estimation in high-rise cities. It also emphasises the need for strategic urban planning and the adoption of sustainable development principles to mitigate these effects to guarantee the long-term welfare of the urban population. The study's results, however, have implications not only for Faisalabad but also can be used as a basis for studying the effect of climate change in various rapidly urbanising towns worldwide. The following deepens our knowledge of urban climatology as future research may find ways to investigate the complex relationship between several elements of city-making and local climate.

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