ASSESSMENT OF RISING TEMPERATURE DUE TO CLIMATE CHANGE. A COMPERETIVE STUDY OF ISLAMABAD AND LAHORE (2010-2022)

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A thesis submitted to Bahria University, Islamabad in partial fulfilment of the requirement for the degree of B.S in Environmental Sciences

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ABSTRACT

This study focuses on how temperatures and precipitation are changing as the climate in Islamabad and Lahore changes. The Pakistan Meteorological Department in Islamabad provided the meteorological information for these metrics during the years 2010–2022. Graphs were created to display monthly and yearly fluctuations. The contrast between the two cities demonstrates the disparities that have developed through time as well as how the amount of precipitation and temperature are increasing. Lahore's temperature and precipitation levels are significantly impacted by smog, whereas Islamabad's temperature is rising due to increased urbanization and anthropogenic activities that contribute to global warming. The overall graphs demonstrate an increase in precipitation in Islamabad, with an average rainfall of 1313.7mm and 749.3mm of Lahore's having a difference of 54.7%. The discrepancy is attributed to Lahore's growing population, industrialization, air pollution, and smog. The graphs of mean maximum temperature show an average temperature of 28.5°C in Islamabad and 30.3°C in Lahore with a difference of 6.1%, even though Islamabad is a planned city surrounded by greenery and present in a good geologic location. This is because of various anthropogenic and natural causes, and Islamabad's temperature is approaching that of Lahore. The average minimum temperatures of Islamabad and Lahore, which are separated by 29% on the graphs of mean minimum temperatures, are 14.1°C and 18.9°C, respectively. The increase in rainfall that makes the nights cool and breaks the scorching weather is the main cause of the temperature reduction. Rainfall has shown a positive relation and maximum temperature displays a negative relation. Each class has a different impact on the climatic variables. If the presence of one class improves the atmosphere, it might not apply to the second class as well. Despite Islamabad having less population, urbanization, and pollution than Lahore, the temperature has been rising over the past decade and is now posing a threat to the city.

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ABREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
RS	Remote sensing
PMD	Pakistan meteorological department
GIS	Geographic information system
SDG	Sustainable development goal
Tmax	Maximum Temperature
Tmin	Minimum temperature
IEA	International energy agency

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INTRODUCTION

1.1 Background of Islamabad & Lahore

1.1.1 Islamabad

Islamabad, Pakistan's capital, is situated on the Potohar Plateau in the northwest of the nation. Due to its location at the intersection between the Northwest Frontier Province and Rawalpindi, this region has had a considerable historical impact. The city was created in 1960 to take the role of Karachi, which has served as Pakistan's capital since 1963. Islamabad and Rawalpindi are regarded as sister cities because of their proximity.

Islamabad is a tidy, roomy, tranquil city with an abundance of greenery compared to other cities in the nation. The city's location has a history dating back to some of Asia's first human settlements. The initial settlement of Aryans from Central Asia took place here (Aslam et al., 2021).

The Margalla Hills are to the north of the city. Nearly all descriptions of the climate in this region include hot summers, monsoon rains, and cold winters with little snowfall in the hills. In addition, Islamabad is home to a variety of animals, from leopards to wild boars.

In order to reflect the diversity of the Pakistani nation, it was thought that a new and permanent Capital City ought to be constructed after Pakistan's establishment in 1947. It was deemed important to situate the new capital somewhere that could be cut off from Karachi's commerce and commercial activities while still being conveniently reachable from the farthest reaches of the nation.

As a result, a commission was established in 1958 with the mandate to choose a suitable location for the new capital, paying particular attention to factors like as geography, climate, logistical and defense requirements, aesthetics, and scenic and natural beauty.

1.1.2 Lahore

Lahore's origins can be traced back to somewhere between the 1st and 7th centuries AD. However, historians deduce that Lahore was in fact founded by Loh e son of Rama, considered the Hindu god Ramayana. According to Sir Robert Montgomery, Lahore arose between the 2nd and 4th centuries. According to the Greek geographer Ptolemy, Lahore was founded around the end of the first century. According to the book, ood-e-Aalamahore appeared as a city in AD 882.

When the people of Lahore want to emphasize the uniqueness of their city, they say “Lahore is Lahore”. The traditional capital of Punjab for a thousand years, it was once the cultural center of northern India stretching from Peshawar to New Delhi. This preeminent position he also occupies in Pakistan. Lahore is a city of poets and artists and the center of the film industry. It has the largest number of educational institutions in the country and some of the most beautiful gardens on the continent (Sajjad et al., 2009).

The city as we know it today reached its peak under the Mughal rulers, especially during the reign of Akbar the Great, who made it his capital. His son, Jehangir, is buried on its outskirts and his mausoleum is one frequented by tourists and Lahorites alike. Nearby is the mausoleum of the famous Mughal Queen, Nur Jehan, known for introducing rose bushes and initiating several cultural movements in the subcontinent.

Akbar the Great held court in Lahore for 14 years from 1584 to 1598 and built the fortress of Lahore, as well as its 12-gate wall. Some of them still survive. Jehangir and Shah Jehan, the builders of the Taj Mahal in Agra and the Shalimar Gardens in Srinagar and Lahore, built palaces and tombs. The last great Mughal emperor, Aurangzeb (1838 - 1707) built Lahore's most famous landmark, the Badshahi Grand Mosque. At that time, the river Ravi, a few kilometers from Lahore, touched the ramparts of the Fort and the Mosque. A stream still flows there and is called "Old River". The Sikhs ruled it in the 18th and 19th centuries, and although it was their capital, they were in the habit of vandalizing Islamic monuments and had little interest in gardens. It is said that they took enough marble from the Mughal ruins in Lahore to build the Golden Temple of Amritsar twice. Most of the jewelry that decorated the palace and fortress was also removed.

1.2 Climate of Islamabad

The hot season lasts for 3.0 months, from May 5 to August 5, with an average daily high temperature of more than 92°F. June is the hottest month of the year in Islamabad, with an average high temperature of 99°F and low temperature of 75°F.

The cool season lasts from December 4 to March 1 and the average daily maximum temperature is below 69°F throughout that time. The coldest month of the year in Islamabad is January, with an average low of 39°F.

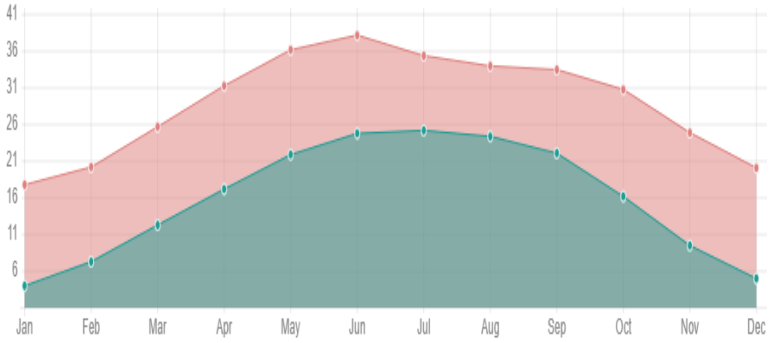


Fig.1 Average High and Low Temperature in Islamabad

1.2.1 Clouds

Throughout the year, there are substantial seasonal variations in Islamabad's average percentage of the sky that is covered in clouds. The sunnier part of the year begins around May 4 and lasts 6.5 months in Islamabad, finishing around November 19. With the sky remaining clear, mostly clear, or partly overcast 98% of the time in Islamabad, September is the clearest month of the year. The cloudier time of the year, which starts around November 19 and lasts for 5.5 months, ends around May 4. February is the cloudiest month of the year in Islamabad, with the sky being overcast or mostly cloudy 41% of the time on average (Intergovernmental Panel on Climate Change, 2015).

1.2.2 Precipitation

Wetness is defined as the presence of at least 0.04 inches of liquid or liquid-equivalent precipitation. The likelihood of rainy days varies greatly throughout the year in Islamabad.

From June 24 to September 10—the start of the 2.5-month wetter season—there is a greater than 30% chance of precipitation on any given day. July is the wettest month in Islamabad, with an average of 15.2 days with at least 0.04 inches of precipitation.(Ahmad, 2015).

Between September 10 and June 24, or 9.5 months, is the drier season. With an average of just 1.6 days with at least 0.04 inches of precipitation, November is the month with the fewest wet days in Islamabad.

1.2.3 Humidity

Because it regulates whether sweat will evaporate from the skin and cool the body, the dew point serves as the basis for figuring out the ideal humidity level. Lower dew points feel dryer while higher dew points feel more humid. A muggy day is frequently followed by a muggy night because dew point changes more slowly than temperature, which frequently varies greatly between day and night, even though the temperature may drop at night. In Islamabad, there is a significant seasonal variation in perceived humidity.

1.2.4 Wind

The wettest part of the year is from June 13 to October 2, lasting 3.6 months, during which time the comfort level is at least 24% muggy, oppressive, or dismal. In Islamabad, August is the month with the wettest days.

This section covers the broad-area hourly average wind vector (speed and direction) at 10 metres above the ground. The wind at any one site is greatly influenced by the local terrain and other factors, and instantaneous wind speed and direction fluctuate more considerably than hourly averages.(Fischer et al., 2021).

The hourly average wind speed in Islamabad varies seasonally throughout the year. The 5.3 months with the most wind, from January 25 to July 4, have an average wind speed of more than 5.2 miles per hour. Islamabad experiences an average hourly wind speed of 5.9 miles per hour in May, which is the highest of the year.(Sajjad et al., 2009). From July 4 to January, which is 6.7 months, is when things are calmer.

1.3 Climate of lahore

In Lahore, the summers are short, sweltering, humid, and clean and the winters are short, cool, dry, and usually clean. Over the path of the 12 months, the temperature commonly varies from 46°F to 103°F and is hardly ever below 41°F or above 110°F.

Based on the beach/pool score, the great instances of 12 months to go to Lahore for hot-climate sports are from mid-April to early May and from overdue September to overdue October (Fischer et al., 2021).

1.3.1 Average temperature of lahore

The hot season lasts nine months, from April 23 to July 20. The average daily high temperature during this time is over 94°F. With a median high of 102°F and a low of 83°F, June is the hottest month of the year in Lahore.

The chilly season has a median daily excessive temperature below 73°F and lasts for five months, from December 6 to February 21. January is the coldest month of the year in Lahore, with a median low of 46°F and a high of 66°F. (Sajjad et al., 2009).

1.3.2 Clouds

Over the course of a year, Lahore has significant seasonal variation in the average proportion of the sky covered by clouds. In Lahore, the brighter portion of the year begins about August 17 and lasts for 3.2 months, ending around November 23.

In Lahore, June is the clearest month of the year. At some point in June, 97% of the time, the sky is either completely clear or partly cloudy. Beginning about November 23 and lasting for eight months, the cloudier portion of the year ends around August 17.

March is the cloudiest month of the year in Lahore, with the sky being overcast or cloudy 31% of the time at some point during the month.

1.3.3 Precipitation

A day that has at least 0.04 inches of liquid or liquid-equivalent precipitation is considered wet. In Lahore, the risk of rainy days varies greatly throughout the year. From June 23 to September 9 is the wetter season, which has a 2.5-month duration with a greater than 26% chance of precipitation on any one day. With a median of eight days with at least 0.04 inches of precipitation, July has the most damp days in Lahore(Ahmad, 2015).

Nine months make up the dry season. The period from September 9 to June 23 is five months. With a median of nine days with at least 0.04 inches of precipitation, November has the fewest damp days in Lahore. We discriminate between individuals who encounter snow alone, rain alone, or a combination of the two on damp days. With an average of eight days, July has the most days with just rain in Lahore. According to this classification, rain alone is the most common type of precipitation throughout the year, with a top probability of 51% on July 23.

1.3.4 Rainfall

We display the rainfall accumulated over a sliding 31-day period targeted around each day of the year in order to show variation in the months rather than just monthly totals. Extreme seasonal variations in monthly rainfall can be found in Lahore.

Five months of the year—from December 31 to October 15—are rainy, with a typical 31-day rainfall total of at least five inches. The wettest month in Lahore is July, which has a mean rainfall of five inches.

Between October 15 and December 31, there are five months without rain. November has a mean rainfall of 0.2 inches, making it the month with the least amount of rain in Lahore.

1.3.5 Humidity

We calculate the humidity comfort level using the dew factor, which determines whether perspiration will evaporate from the skin and chill the body. Lower dew factors feel dryer and better dew factors seem more humid. The dew point tends to vary more slowly than temperature, which normally varies substantially between night and day, therefore even while the temperature may also drop at night, a muggy day is typically first recognised by a muggy night..

Extreme seasonal variations in perceived humidity are experienced in Lahore. From June 4 to October 11, which is 4.2 months, is when it gets the hottest. During this time, at least

25% of the time, the temperature is muggy, oppressive, or disagreeable. August has 30 days that are muggy or worse, making it the month with the hottest days in Lahore.

In Lahore, January has 0 days that are particularly humid. No days with excessive heat or humidity.

1.3.6 Wind

The wide-location hourly common wind vector (velocity and path) at a height of 10 metres is covered in this section. The local topography and other variables have a significant impact on the wind experienced at any given location, and the instantaneous wind speed and direction can vary significantly from hourly averages. Lahore's typical hourly wind velocity changes slightly seasonally throughout the year.

From January 21 to July 18, the nine months with the most wind, have average wind speeds of more than three miles per hour. With a typical hourly wind speed of 6.2 miles per hour, April is the windiest month of the year in Lahore.

From July 18 to January 21, which is 6.1 months, is when things are most tranquil. With a median hourly wind speed of three miles per hour, September is the calmest month of the year in Lahore.

1.4 Population of Islamabad

1.4.1 Islamabad demographics

Islamabad, city, capital of Pakistan, on the Potwar Plateau, nine miles (14 km) northeast of Rawalpindi, the former interim capital. The city’s web website online become selected with the aid of using a fee in 1959 after Karachi become determined fallacious because the capital. Construction started in 1961 with an attempt to mixture traditional Islamic structure with contemporary-day styles and requirements.

Such world-famed names in metropolis planning and structure as Konstantínos Doxiádes, Edward Durell Stone, and Gio Ponti were related to the city’s development. It is a compact city (vicinity 25 rectangular miles [65 square km]), mendacity at elevations

starting from 1,500 to 2,000 feet (450 to six hundred meters). The 2nd section of production ended with crowning glory of the Secretariat, Pakistan House, President's House, National Assembly Building, Grand National Mosque, and housing for authorities staff. The University of Islamabad become set up in 1965 and the People's Open University (later renamed the Allama Iqbal Open University) in 1974. The battle with India in 1971 slowed production temporarily.

The city location is split into 8 zones: administrative, diplomatic, residential, institutional, industrial, and industrial areas, a greenbelt, and a countrywide park. It consists of an Olympic village and gardens and dairy, poultry, and vegetable farms, in addition to such establishments because the Atomic Research Institute and the National Health Centre. The call Islamabad ("City of Islam," or "City of Peace") became selected to mirror the country's ideology (Aslam et al., 2021).

The deliberate capital location of 350 rectangular miles (906 rectangular km) is an expanse of herbal terraces and meadows surrounding the city. A in addition four hundred rectangular miles (3,626 rectangular km) of hinterland, called the Specified Areas, is difficulty to making plans control, with the Margala Hills, 3,000 to 5,000 feet (900 to 1,500 meters) high, withinside the north and northeast. The southern element is an undulating plain. It is tired with the aid of using the Kurang River, on which the Rawal Dam paperwork a lake maintaining approximately 50,000 acre-feet (61,650,000 cubic meters) of water.

1.4.2 Islamabad population growth

Islamabad, the capital of Pakistan, this takes a look at extracts city region from 4 durations of Landsat photos among 1990 and 2018 the use of an modern object-primarily based totally backdating extrude detection technique and standards for extracting city land from impervious floor. We show that impervious floor cowl and concrete region elevated 273.10% and 426.21%, respectively, over the past three decades. We discovered 5 elements gambling vital function in city increase: population, transportation systems, grasp planning, commercial and actual property development, and neighbor city effect. In this take a look at, we determine the socio-financial sustainability related to slum increase

and census data, and the environmental sustainability in terms of the versions of normalized distinction plants index (NDVI) in woodland areas. We observed that slums elevated with the corresponding increase of city region and population, reflecting slow financial growth in Islamabad. We observed that the region of forest elevated 9.29%, however its NDVI reduced from 0.668 to 0.551, implying a deteriorative fashion of environmental condition (Aslam et al., 2021).

1.5 Population of Lahore

1.5.1 Lahore Demographics

Of the people in Lahore, 87% of them speak Punjabi; however, this language can be broken down into many different dialects which makes for a diverse speaking population. Other languages spoken include Urdu – the national language, and English - which is spoken and understood by many people, especially those from an educated background.

The main religion in Lahore is Muslim – mostly Sunni or Shia- which makes up 94% of the population. The remaining 6% are nearly all Christians. There are also a small number of minority religions such as Sikh and Hindu (Sajjad et al., 2009). The Lahoris are a cultural bunch of people celebrating many festivals around in the year – some religious, some historical and some are combinations of ancient and modern- even western – celebrations.

Lahore is a young country with over 40% of its inhabitants below the age of 15. The average life expectancy stands at less than 60 years of age. Another interesting statistic is that less than 40% of the population of the city are literate.

1.5.2 Lahore Population Growth

Many prestigious universities and schools, outstanding examples of historic architecture, and museums can be found in Lahore. In allusion to the numerous historic gardens located all around Lahore, the city is also referred to as the Paris of the East or the Mughal City of Gardens. Lahore is also Pakistan's engineering centre, with businesses

in the auto, heavy machinery, steel, information technology, chemical, and computer industries all contributing to the city's 13.2% share of the country's GDP. Its GDP is currently rated 122nd in the world, and it is expanding at an average pace of over 6% (Sajjad et al., 2009).

1.6 Objectives

1. To analyze the changes in temperature and precipitation in Islamabad and Lahore, Pakistan, over the period of 2010-2022. This includes comparing the monthly and yearly fluctuations in temperature and precipitation levels between the two cities and identifying any disparities that have developed over time.
2. To identify the causes of the changes in temperature and precipitation in Islamabad and Lahore.
3. To assess the potential impacts of the increasing temperature and precipitation levels on the health, environment, and economy of Islamabad and Lahore, and to identify potential mitigation strategies that can be implemented to reduce these impacts.

1.7 What is climate change and how is it caused?

Climate change is the long-term alteration in average weather patterns across the world. It is caused by the increased levels of carbon dioxide, methane, and other greenhouse gases released by human activities into the atmosphere. These emissions trap heat and prevent it from escaping the atmosphere, causing the planet to become warmer. As the planet warms, many aspects of the climate system are disrupted, such as weather patterns, ocean currents, and the frequency and intensity of extreme weather events. Climate change also has an impact on ecosystems, leading to species extinctions, changes to habitats, and ecosystem collapses. Human activities, such as burning fossil fuels, cutting down forests, changing land use, and intensive farming, are the primary contributors to climate change. To mitigate the effects of climate change, we need to

reduce emissions of greenhouse gases, increase the efficiency of energy use, and develop renewable energy sources that don't produce emissions. It is also important to protect and restore habitats to help species adapt to climate change, and to reduce the amount of waste we produce (Esfandiari et al., 2020). Climate change is one of the biggest challenges facing humanity, and it is essential that we take action now to slow down and eventually reverse its effects. Some major causes of changing climate are:

1. Transportation
2. Industries
3. Agriculture
4. Greenhouse gas emissions

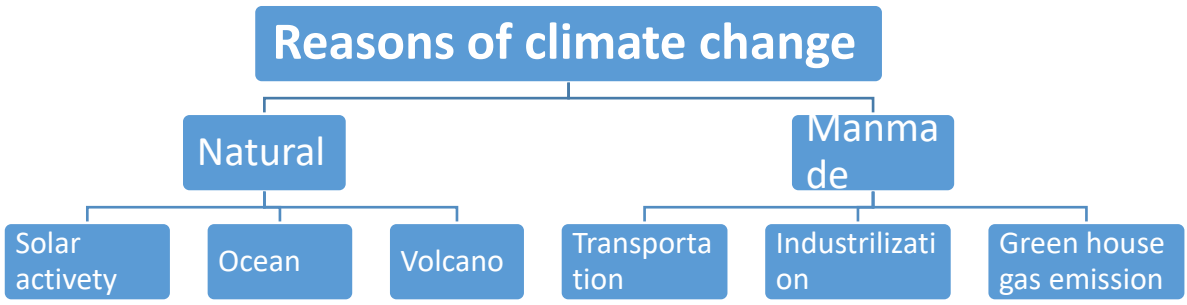


Fig.2 Reasons Of Climate Change

1.7.1 The impact of transport on climate change

Mobility is crucial to both society and the economy. A reliable and accessible transportation infrastructure is essential for the wellbeing and quality of life of the planet's inhabitants.

But this industry nevertheless contributes significantly to our environmental issues.

According to the International Energy Agency (IEA), road vehicles are responsible for 75% of the direct carbon dioxide (CO2) emissions from the burning of fossil fuels that are attributed to transportation.

Additionally, the amount of emissions caused by transportation is rising rather than falling. Since 1990, for example, emissions from the transportation sector have increased in Europe while emissions from other economic sectors, such as the production of energy or industry, have fallen.

Despite the advancements achieved in moving toward electric automobiles and roads (the number of electric cars on the road in the world surpassed seven million in 2019). The IEA attributes this to two primary causes:

a) More and more often, we purchase bigger, heavier automobiles.
b) E-commerce has grown, necessitating the use of road transportation for order delivery.

We already understand how CO2 contributes to global warming (see this article for more information). It is crucial to reduce these gas emissions in order to slow down climate change and keep temperature increases to a minimum.

Transport also adds to the problem of air pollution, a risk that, according to data from the WHO, results in more than seven million avoidable deaths each year (Jones & Kammen, 2011).

In actuality, a significant transition is taking place in the transportation sector. Existing initiatives to increase efficiency and reduce energy use must be expanded and made more ambitious in order for countries to comply with Agenda 2030 and the Paris Agreement.

1.7.1.1 How to promote sustainable mobility

Improving transportation's energy efficiency, reducing activity, and, of course, reducing its dependency on fossil fuels are the most crucial and urgent initiatives that need to be taken.

For transportation to be sustainable, it is essential to promote emission-free vehicles, whether they be battery electric or green hydrogen fuel cell vehicles.

According to reports, in the future, green hydrogen will take the place of conventional fuel. As a fuel source for fuel cells, which generate energy through chemical reactions, this material can be used (Jones & Kammen, 2011).

Although this technology is already used in some road cars today, much more work needs to be done on it before it can be considered an essential component of sustainable transportation on a worldwide basis.

1.7.2 Impact of industries on climate change

A significant contributor to human-caused climate change is industry. Carbon dioxide and other greenhouse gases are released into the atmosphere when fossil fuels like coal, oil, and natural gas are burned to produce energy. The globe gradually warms as a result of these gases' ability to trap solar energy. Other air pollutants released by industrial activity can also result in the creation of smog and acid rain. Along with greenhouse gases, these pollutants have the potential to seriously harm both the environment and human health. Additionally, industrial operations can result in habitat damage, biodiversity loss, and deforestation, all of which contribute to climate change (Afzal et al., 2020). To reduce the impacts of industry on the climate, governments and businesses can implement policies that promote the use of renewable energy sources such as wind and solar, as well as energy efficiency measures. Businesses can also take steps to reduce their carbon footprints by investing in green technologies, improving energy efficiency, and reducing waste. These measures can help reduce the amount of carbon dioxide released into the atmosphere and the impacts of climate change.

Since the Industrial Revolution, human activities have had a significant negative impact on the environment. Pollution and carbon emissions are to blame for the deterioration of our natural ecosystem and atmosphere. The negative repercussions of industrial activities pose a threat to both human civilisation and all other living forms on Earth.

1.7.2.1 How Industrial Revolution Cause Environmental Pollution

The 18th century saw the start of the Industrial Revolution, which later extended throughout Europe and the rest of the world. Nations move away from agrarian economies and toward industrial economies as a result of new industrial practices. These industrial methods required the burning of fossil fuels, which decreased the quality of the environment.

The Industrial Revolution also brought about changes in land use. More acreage was developed for industrial practices as industry expanded. Because there was less land set aside for cultivation, farming methods had to change. Farming itself evolved become an industry.

Industrial farming involves techniques include the use of fossil fuel-powered machinery, hazardous fertilizers, and pesticides. Other tactics include providing less humane living conditions and administering hormones and antibiotics to livestock. Increased greenhouse gas emissions, soil degradation, and air and water pollution are all results of these activities.

A general decline in natural carbon sinks is another effect of changing land use on the ecosystem. Greater greenhouse gas concentrations result from deforestation and urbanization, which reduce the land's natural capacity to absorb carbon from the atmosphere (Afzal et al., 2020).

Since pre-industrial levels, carbon dioxide (CO2) levels have increased by 50%. The rise in CO2 levels has aided in the process of climate change and global warming. Since the Industrial Revolution, there has been a growth in industrial practices all over the world, which is directly tied to the rise in carbon dioxide levels.

In developing countries today, industrialization is still taking place. Developing countries frequently lack the resources to support clean energy and must instead turn to age-old methods like burning coal, oil, or petroleum to power their industries.

Along with developing nations, many industrialized countries still depend on polluting industries to drive their economies, which raises greenhouse gas concentrations and contributes to global warming.

1.7.2.2 Environmental Impacts of Industry

Industrial pollution cause serious environmental harm. Industrial activities have a range of detrimental repercussions, including global climate change and localised pollution. The effects are devastating to our ecosystem and to all life on Earth. Below is a list of the numerous negative environmental repercussions of industry.

1.7.2.2.1 Pollution

Industry is to blame for soil, air, and water pollution. It goes without saying that soil, water, and oxygen are essential for maintaining human existence on Earth. Pollution poses a hazard to both human health and Earth's natural ecosystems.

1.7.2.2.2 Water pollution

It can be found in saltwater as well as freshwater. When used in industrial processes, water becomes contaminated when it comes into contact with radioactive waste, chemicals, or metals. The water is then released into rivers and the ocean, polluting freshwater ecosystems and sources. Contamination of drinking water poses a threat to public health. Crops that are irrigated by polluted water may also suffer. (Döll et al., 2015).

1.7.2.2.3 Air pollution

It is any physical, biological, or chemical change to the atmosphere. The quality of the air is lowered by pollutants like gas, smoke, or particle matter, which also makes it harder for people, plants, or animals to survive. Burning coal or natural gas, for example, can release pollutants that imperil the world's ecosystems and harm human respiratory and cardiovascular systems. Airborne pollutants can also cause acid rain, which kills crops and alkalizes fresh water.

1.7.2.2.4 Soil pollution

It happens when soil chemical levels are higher than normal and harm ecosystem health or human health. You might get soil pollution from

a) Industrial waste
b) The use of chemical pesticides and fertilizers
c) Oil spills
d) Landfills

Soil pollution has an effect on our ability to grow food and is bad for the ecosystem. Contaminated soil can lead to health problems in both people and animals.

1.7.3 Impact of agriculture on climate change

Climate change is also significantly influenced by agriculture. Keeping livestock and growing food both demand a lot of energy. Burning biomass, such as wood and crop waste, also contributes to the atmospheric release of carbon dioxide. The use of chemical fertilisers and pesticides releases nitrous oxide, a greenhouse gas, into the atmosphere, which furthers climate change. Farmers can use sustainable techniques including crop rotation, cover crops, and the use of organic fertilisers and pesticides to lessen the effects of agriculture on the environment. They can also run their businesses using renewable energy sources including solar, wind, and geothermal energy. Farmers may lessen their carbon footprint and lessen the effects of climate change by implementing these actions.

Before it reaches our plates, our food is produced, stored, processed, packed, delivered, prepared, and served. At every level, the food supply releases greenhouse gases into the sky. Nitrous oxide and methane, two highly strong greenhouse gases, are emitted in significant volumes, particularly in agriculture. Enteric fermentation occurs during animal digestion and results in the production of methane, which is then belched out. Additionally, it might escape from the manure and organic waste storage areas of landfills. Organic and mineral nitrogen fertilisers indirectly cause nitrous oxide emissions.

Agriculture was responsible for 10% of the EU's overall greenhouse gas emissions in 2012. The EU reduced its agricultural emissions by 25% between 1990 and 2012 as a result of a significant decrease in the number of animals, more efficient fertiliser use, and improved manure management.

However, agriculture in the rest of the globe is moving in the opposite direction. Between 2001 and 2011, global emissions from agriculture and animal production rose by 14%. The growth was especially noticeable in emerging countries due to an increase in global agricultural output. This resulted from changes in food consumption habits brought on by increased affluence in some developing countries, as well as an increase in the global demand for food. In 2011, the sector's total emissions of greenhouse gases from enteric fermentation increased by 11%, accounting for 39% of those emissions.

Changes in consumption can help to further reduce greenhouse-gas emissions related to food in addition to such efficiency increases. In general, compared to other foods, meat and dairy products have the biggest per-kilogram global carbon, raw material, and water footprints. Livestock and the production of feed each contribute more than 3 billion tons of CO2 equivalent to greenhouse gas emissions. Only a small portion of the emissions related to food are caused by post-farm processing and transportation. We can help reduce agriculture's greenhouse gas emissions by cutting back on food waste and the amount of food we consume that is produced with a lot of emissions (Zang et al., 2022).

1.7.4 Global Emissions by Gas

The principal greenhouse gases that human activity emits on a global scale are (Blandford et al., 2015)**:**

CO2 (carbon dioxide)

The burning of fossil fuels is the primary source of CO2. Deforestation, terracing for agriculture, and soil deterioration are a few examples of indirect human-induced effects on forestry and other land uses that can emit CO2. Similar to how soil can reduce atmospheric CO2 through reforestation, soil enhancement, and other mechanisms.

Methane (CH4)

The usage of energy, burning of biomass, handling of garbage, and agricultural practises all result in CH4 emissions.

N2O (Nitrous Oxide)

Agriculture, notably the use of fertilisers, is the primary source of N2O emissions. N2O is also created when fossil fuels are burned.

F-gases or fluorinated gases

F-gas emissions, which are created by industrial operations, refrigeration, and the use of a range of consumer items, include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6).

1.7.4.1 Global Emissions by Economic Sector

The following are the economic activities that contribute to the production of global greenhouse gas emissions:

1.7.4.1.1 Generation of heat and electricity

(25% of the greenhouse gas emissions in the world in 2010): Burning coal, natural gas, and oil for heat and electricity is the primary cause of greenhouse gas emissions worldwide.

1.7.4.1.2 Industry

The primary source of industry's greenhouse gas emissions, which made up 21% of all global greenhouse gas emissions in 2010, is fossil fuels utilised on-site at facilities for energy. Additionally, emissions from waste management activities, as well as those from non-energy-related chemical, metallurgical, and mineral transformation processes, are included in this category. (Note: Emissions from the use of electricity in industry are covered by the Electricity and Heat Production category.)

1.7.4.1.3 Land Use, Agriculture, and Forestry

(24% of the greenhouse gas emissions in the globe in 2010) The primary sources of greenhouse gas emissions in this sector are deforestation and agriculture (the growing of crops and livestock) (Zang et al., 2022).

This computation excludes the amount of carbon dioxide that ecosystems absorb in the form of biomass, decomposed organic matter, and soils to offset around 20% of this sector's emissions.

1.7.4.1.4 Transportation

(14% of the greenhouse gas emissions in the globe in 2010) The burning of fossil fuels for land, rail, air, and sea transportation is the main cause of greenhouse gas emissions from this industry. Petroleum accounts for 95% of the energy used for transportation globally, mostly in the form of gasoline and diesel.

1.8 Smog

Smog is a form of air pollution that impairs vision. Smog was first used to describe a mixture of smoke and fog in the early 1900s. Typically, the smoke came from coal burning. There used to be a lot of pollution in industrial areas, and some cities still do today.

Today, the majority of the pollution we see is caused by photochemical haze. Photochemical smog is produced when sunlight reacts with nitrogen oxides and at least one volatile organic compound (VOC) in the atmosphere. Nitrogen oxides are produced by industrial pollution, coal-fired power plants, and automobile exhaust. VOCs are released by gasoline, paints, and a number of cleaning solvents. When these compounds are exposed to sunlight, they mix to produce ground-level ozone and airborne particles that contribute to smog.

Ozone has both positive and negative effects. The ozone layer, high in the atmosphere, protects us from the sun's damaging UV rays. When it is near the earth, ozone, however, poses a threat to human health. Ozone can damage lung tissue, and persons with respiratory diseases like asthma are particularly at danger. Ozone can also cause eyes to burn and itch (Sawlani et al., 2019).

Smog is harmful for both people and animals and may cause plants to be destroyed. Smog is awful as well. It shades or lightly grazes the sky. Smog typically occurs in large cities with a lot of industry and traffic. Because the pollution is contained in the valley and cannot be transported by the wind, smog problems might arise in towns with mountainous environs.

One of the countries that have passed regulations to avoid smog is the United States. Some laws place restrictions on the kind of chemicals that industries can release into the atmosphere or the times at which they can do so. Some communities hold "burn days" where residents are allowed to burn yard waste like leaves. These limitations on chemical emissions into the atmosphere reduce smog levels.

1.8.1 How is it caused?

Smog is a type of air pollution that is caused by a combination of smoke and fog. It is a result of the chemical reactions between pollutants, such as nitrogen oxides, sulfur dioxide, and other particulate matter, with the sun's ultraviolet radiation. The most common source of smog is the burning of fossil fuels, such as gasoline and diesel, for transportation and other industrial activities. In cities, the burning of coal and oil in power plants also contributes to smog. The burning of these fuels releases pollutants, such as nitrogen oxides and sulfur dioxide, into the atmosphere. When these pollutants mix with the water vapor in the atmosphere, they form smog. This smog is then further oxidized by the sun's ultraviolet radiation, forming ozone and other chemical compounds. The ozone and other compounds are what give smog its characteristic yellowish-brown color. Smog can be particularly dangerous for those with existing respiratory conditions, as it can cause irritation of the eyes, nose, and throat, and can even lead to difficulty breathing. In addition to the burning of fossil fuels, other activities such as the usage of aerosol sprays, the burning of rubbish and wood, and agricultural operations can also contribute to smog. Smog can be carried by wind currents and travel great distances as well, producing issues in places far from where it was first observed (Sawlani et al., 2019). Smog can have harmful consequences on the environment and human health that are both short-term and

long-term. In order to safeguard human health and the environment, it is crucial to reduce air pollution and enhance air quality.

1.8.2 Effects of smog in Lahore

Smog has been descending annually in November and December in Lahore and the surrounding areas for the past few years. Even flights to Lahore are cancelled as a result because it is so thick. Due to poor air quality and a significant increase in pollution from industry and cars over the past five years, this smog has become significantly worse. The rapid industrialization and tree-cutting have not improved the situation, and the development-focused authorities would be well to take note of this. Today, Lahore is regarded as one of Asia's most polluted cities. Due to rain, cold spells, and dry conditions, all pollutants tend to gather in the lower levels of the atmosphere throughout the winter. Experts claim that given their dependency on coal use, factories in Eastern Punjab of India are also to blame. On this side of the border, emissions, and contaminants from there worsen the situation.

The smog has had a significant impact on the health of the people of Lahore. It has been linked to an increase in respiratory illnesses such as asthma, bronchitis, and other chronic respiratory illnesses. It has also been linked to an increase in cardiovascular diseases, such as heart attacks, strokes, and heart failure. The smog has also been linked to an increase in cancer rates as well. The smog has also influenced the environment in Lahore. The smog has caused an increase in ground-level ozone, which is a pollutant that has been linked to a decrease in crop yields, an increase in water pollution, and an increase in air pollution.

1.9 GIS and RS

GIS (Geographic Information System) and RS (Remote Sensing) are two powerful technologies used to gather, store, analyze and present geographic data. GIS is a system used to capture, store and analyze spatial data, while Remote Sensing is a technology used to collect information about objects and phenomena from a distance, usually via aircraft or satellite. GIS and Remote Sensing are often used together to analyze, interpret,

and present data on the Earth's surface. GIS provides a way to visualize and analyze spatial data by combining layers of data into a single map. It is used to analyze data such as population density, land use, infrastructure, weather patterns, soil types, vegetation, and more. GIS can also be used to create 3D models of the Earth's surface and to identify patterns and trends. Remote Sensing is a technology used to collect and interpret data about objects and phenomena from a distance. Remote sensing is often used to acquire data about the Earth's surface, including land cover, land use, vegetation, and water. Remote sensing data can be used to create maps and 3D models of the Earth's surface, as well as to detect changes in landscapes over time.

1.9.1 Analysis of climate change

Geographical information systems and remote sensing, also known as GIS and RS, are two effective techniques used in the analysis of climate change. A computerised mapping system called a GIS enables users to make personalised maps and analyse geographical data. GIS is used to evaluate how climate change may affect land use and cover, as well as to pinpoint the most vulnerable regions. The impacts of climate change on biodiversity and ecosystems can also be foreseen, as well as prospective changes in land use and cover. RS is a technique that uses a variety of sensors to gather information about the environment, such as topography, land usage, and land cover. When it comes to measuring changes in vegetation, land use, and land cover as a result of climate change, RS data can be employed. Additionally, RS data can be used to pinpoint regions most at risk for drought and other climate-related calamities, as well as to track how climate change is affecting water availability. Understanding the effects of climate change and creating plans to cut carbon emissions and boost climate resilience need the use of GIS and RS(Saeed et al., 2017).

Applications of GIS in the detection of climate change:

1. The easiest and fastest strategy to reduce CO2 (Carbon Di Oxide) in the atmosphere and slow global warming is to increase forest cover and eliminate deforestation. Monitoring carbon content requires GIS techniques. Using GIS technology, it is feasible to trace forest carbon.

2. Using a computer Geographic planning, identifying environmental changes, and furthering the implementation of action plans can all benefit from GIS mapping and analysis.
3. Using GIS data, climate mapping and projections are made for upcoming anticipated changes in climate.
4. Additionally important for predicting effects on the sites is GIS climate change modelling.
5. This method may be used to create a web-based GIS application for detecting climate change and making future climate predictions. GIS approaches include creating queries, applying statistical GIS functions that are appropriate to climate forecasts, and displaying GIS for use in viewing and interpreting maps, graphs, and charts.

1.10 REVIEW OF LITERATURE

Any study should start with an analysis of the existing literature on the subject to determine any gaps that need to be filled. To discover and review the literature, the study is divided into the following sections. There are several parts to the literature review.

Although the terms "climate change" and "global warming" are sometimes used interchangeably, they have different meanings because "warming" refers to only one stage of the Earth's wider climate system, which is always undergoing change. Scientists have learned from physical evidence from Earth and space that a variety of causes can contribute to the long-term alteration of the planet's temperature. Solar radiation levels, Earth's orbit around the sun, volcanic activity, ocean currents, and even plate tectonics are a few examples of these variables. The periods of warming and cooling are referred to as interglacial and glacial, respectively. The glacial epoch is distinguished in part by huge sheets of ice that extend from the poles. The Little Ice Age and the Medieval Warm Period (A.D. 1000–1270) were recent periods of transition in human history. Climate change was envisioned in ancient times, and understanding of the subject grew as the technology to research it advanced over time, according to a history of climate change discussion that is older than one might think. Guy Stewart Calendar, a key person in the

history of climate research who foresaw potential issues, had the hypothesis that carbon dioxide acts as a heat-trapping agent, which was confirmed by computer climate models in the 1970s "Even minute modifications to the Earth's orbit could have a significant impact. Many people were shocked to learn from studies of ancient climates that the date of the ice ages had been somewhat determined by astronomical cycles. It seems that the climate is so delicately balanced that practically any minor disturbance could cause a significant shift. The Intergovernmental Panel on Climate Change, a group of scientists with expertise in climate research, has more recently researched Earth's climate. In the past few years, the IPCC has published four reports that examined the links between human activities and climate change. According to the group's most recent report, there is 90% consensus that greenhouse gas emissions from people are directly responsible for global warming. The IPCC received the Nobel Peace Prize for its efforts to draw attention to this issue on a global scale (Weart el at.,2008).

There are people who disagree with the idea of "anthropogenic" warming despite the expanding body of knowledge about the dynamics of the Earth's climate and the scientific community's declarations to that effect. Regardless of one's position on the matter, there are a lot of unanswered concerns surrounding climate. According to this study, it is important for people to comprehend climate change because it is in the public eye where political pressure manifests itself. Public opinion is important because it shapes the sociopolitical environment in which decision-makers function. Political, economic, and social action to address certain hazards can be fundamentally compelled or constrained by public opinion. Various surveys from recent years can provide information on questions concerning current thinking in the nation, even though there is not a significant amount of data from which to draw judgements about how American individuals perceive the risk of climate change. Leiserowitz found that American worry about climate change was at a modest level and was characterised by the idea that potential changes were more global in nature but not necessarily local. A different survey that specifically asked Americans to rank the effect regions as they viewed them, both locally and worldwide, provided more evidence to support this information. In the study, 68% of respondents expressed the greatest level of care for "people all over the world" and "non-human nature," whereas 13% of respondents expressed the greatest level of concern for

themselves, their families, and their local community. While it is clear from the data that many Americans agree that global warming is a current matter of concern, it should be underlined that there are also a significant number of people who have doubts about it. The following may be some of Leiserowitz's most intriguing findings: whereas 71% of Americans believe that global warming is occurring, only 48% of them think that there is scientific consensus over why it is occurring, and 40% think that there is significant dispute on the subject (Leiserowitz et al., 2007).

The SDG 2030 agenda of the UN calls for immediate action for "sustainable cities and communities" due to the urban heat island effect that has been brought on by the unchecked urbanization's rapid pace. The instance of Islamabad, a developing metropolis, is explored in this context in light of development policy debate on pertinent environmental issues. By analysing variations in minimum and maximum variability from the 1960–2012 dataset available from the Pakistan Meteorological Department along with MODIS LST images from January 2000 to December 2015, time-series trends of surface temperature were constructed. With R 2 values of 0.2507 (Tmin) and 0.1868, the configurations for the highest (Tmax) and lowest (Tmin) temperatures both exhibit an ascending trend (Tmax). Islamabad's evolving seasonal pattern, with longer summers and harsher winters, is depicted in boxplots of Tmin and Tmax. The Mann-Kendall test was also used to confirm the slope of the R2 linear trend map, illustrating temperature regression in densely forested metropolitan areas and the Margalla Hills National Park. According to these findings can serve as a guide for urban planners and futurists as they work to preserve standardised urban heat islands and advance sustainable urban designs Castán Broto and Bulkeley (2013).

2 Chanpter 2
Methodology

On the basis of the objectives, the work is divided into parts. The procedure for analyzing variations in temperature and precipitation is as follows. At this point, the literature review is complete, and the task is broken down into the following sections as shown in figure 3.

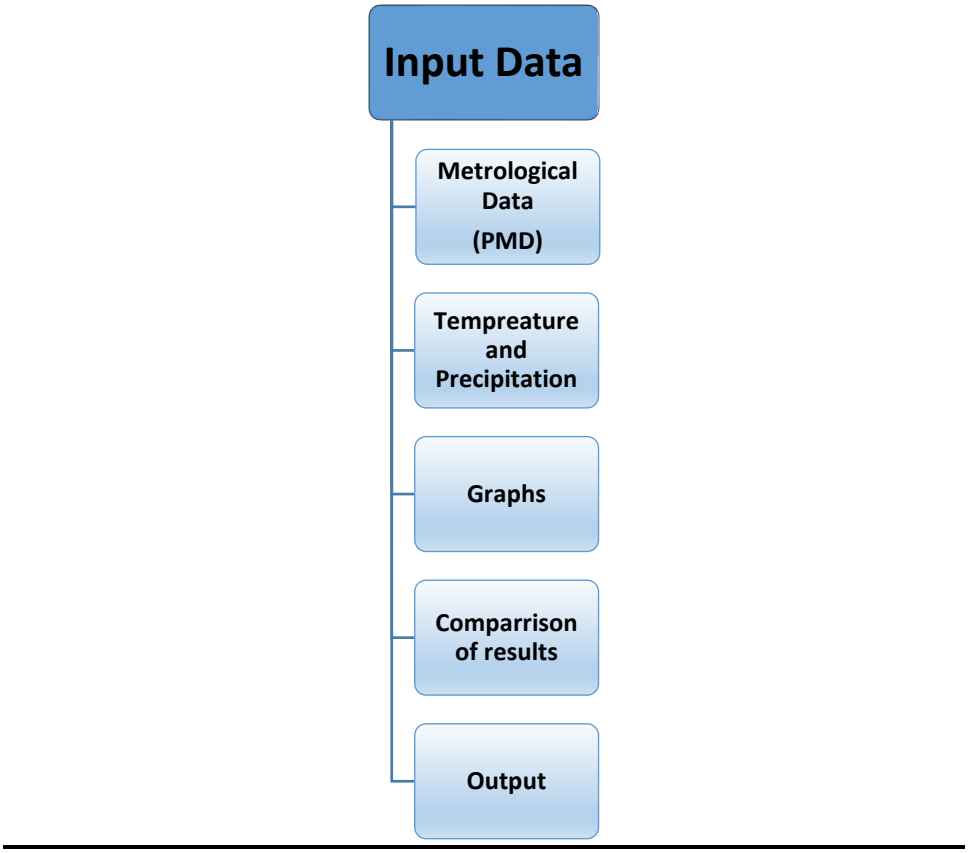


Fig.3 Work Methodology

1. **Data collection:** The Pakistan Meteorological Department in Islamabad provided the statistics for precipitation, lowest temperature, and maximum temperature for the years 2010 through 2022.
2. **Data processing:** The data was processed and analyzed to calculate the average monthly and yearly precipitation and temperature levels for both Islamabad and Lahore.
3. **Data visualization:** The data was then visualized using graphs, with separate graphs created for precipitation, minimum temperature, and maximum temperature. The graphs were created using software such as Excel.
4. **Data interpretation:** The graphs were then interpreted to identify patterns, trends, and fluctuations in precipitation, minimum and maximum temperature levels over time in both cities, and to compare the data between the two cities.
5. **Comparison and contrast:** The data from the two cities were compared to identify the disparities that have developed through time as well as how the amount of precipitation and temperature are increasing.

Finally, the graph was used to demonstrate the monthly and yearly fluctuations in precipitation, minimum, and maximum temperature levels, which helped us to conclude the changes occurred in the climate and the reason behind it.

2.1 Data acquisition

We gained data from PMD about temperature and precipitation from 2010-2022 by utilizing its database of climate information. The database contains records of various climate variables, such as, temperature and precipitation, over a given period of time. We accessed this database and used it to generate graphs and tables that show the average temperature and precipitation levels for a given time period. Furthermore, the data from PMD also allowed us to compare the climate records for different locations and to analyze the trends in temperature and precipitation over time. Overall, PMD provided us with a comprehensive dataset that clarified the patterns of temperature and precipitation in a given region.

2.2 Study Area

2.2.1 Islamabad

The city of Islamabad is located on the Potohar Plateau in the country's northwest, between the northern latitudes of 33° 49 and 72° 24° East of Greenwich, and at elevations between 457 and 610 metres. The city has a total area of 906.56 km2, of which urban parts take up 220.15 km2.

Islamabad is one of Pakistan's most cosmopolitan and urbanised cities because it draws individuals from all around the country. As the nation's capital, it has played host to a number of significant gatherings, notably the South Asian Regional Cooperation Summit in 2004. The city was affected by the 7.6-magnitude Kashmir earthquake in October 2005.

The Rawalpindi-Islamabad Metrobus' construction, the area's first commuter route, started in February 2014 and was finished in March 2015. The project was constructed by the Rawalpindi Development Authority at the expense of the Punjabi federal and provincial governments.

2.2.2 Lahore

Lahore, Pakistan's second-largest municipality, has a long and documented history. The largest city in the Punjab area and the post-medieval or contemporary capital is Lahore. Since its establishment, it has been ruled by Hindus, Buddhists, Greeks, Muslims, Mughals, Afghans, Marathas, Sikhs, and British. As a result, it has developed into a cultural hub and the heart of contemporary Pakistan.

Lahore is a significant cultural hub for Pakistan and the Punjab area with a long, rich history. Lahore, one of the densestly populated cities in the world, continues to be a centre for business, politics, transportation, entertainment, and education. 31 degrees 38 feet 4.79 north. Lahore, the present capital of Pakistan's Punjab province, is regarded as the country's beating centre. Large-scale rioting between Muslims, Sikhs, and Hindus broke out right after independence, resulting in several fatalities and destruction of

important historical structures including the Lahore Fort, the Badshahi Mosque, and other imperial structures. The government was able to rebuild Lahore with the assistance of the UN, mostly removing the scars left by the violence of the independent community. Today, the trenches and battlefield are still visible not far from the Wagah border.

2.3 Location Map

2.3.1 Islamabad

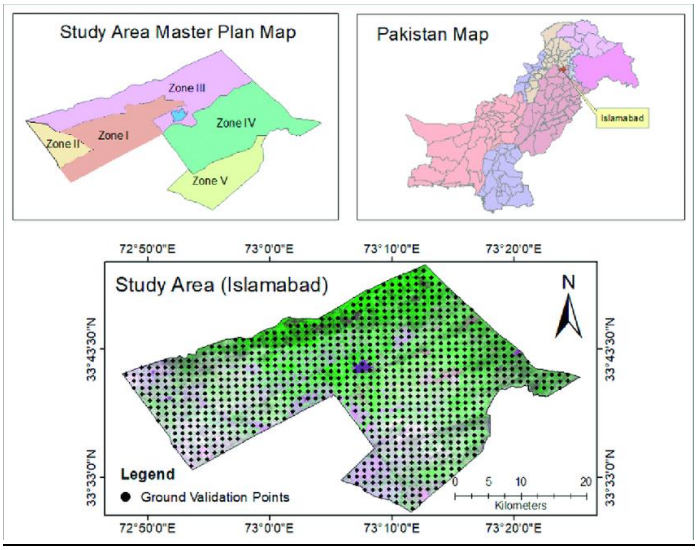


Fig. 4 Map of study area of Islamabad

2.3.2 Lahore

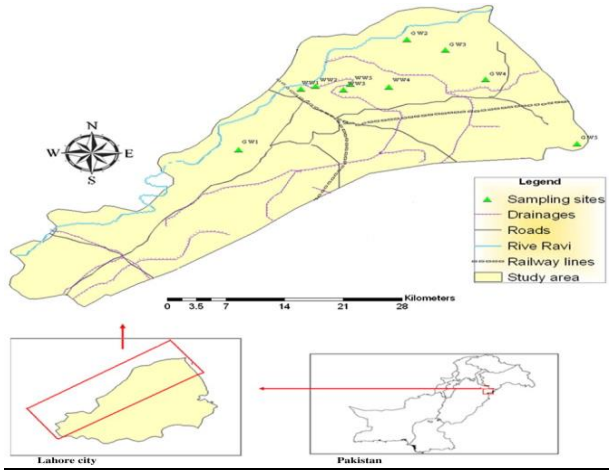


Fig.5 Map of study area of Lahore

2.4 Meteorological data

Variations in various climatic parameters can be linked to the rapid development being brought about in the cities. Trapping and penetration of heat into the atmosphere have resulted in increased temperatures. Removal of vegetation is another factor that lessens the environment's capacity to keep the temperature low. The temperature and precipitation patterns were taken for the time period of the last twelve years i.e., 2010 to 2022. An average of parameters on a yearly basis was plotted as line graphs on excel sheets. A correlation was also established between the selected parameters.

2.5 Demographic analysis

Comparative analysis of the two cities shows that population increases day by day, the analysis was done based on last 20 years. The information was obtained from the official websites of the population census organization. It indicates the stretch of population growth from 2010 to 2022 from half million to 1.2million accordingly of Islamabad and Lahore currently having a total population of 1.4million.

2.6 Expected outcomes

The graphs and comparisons between the two cities that is Islamabad and Lahore tells us that urbanization, Industrialization and greenhouse gas emissions are playing a vital role in increasing temperature and precipitation levels in both the cities without any master plan these variations in temperature can cost us a lot in the shape of weather parameters, both cities have faced the high temperatures in summers and flash rains and in winters the smog season affecting the lives of people specially in Lahore.

2.7 Data Limitation

Data acquired for temperature and precipitation was limited, it was available on a per month basis from the year 2010 to 202. The average was calculated, and graphs were plotted for the provided data of the last twelve years. For literature writing, several articles, research papers and journals were reviewed. Yet, many others were inaccessible. This study has not proven to be a very vast one as the number of helping hands was very small and because some of the quality data could not be obtained.

2.8 Software Used

1. MS EXCEL 2017
2. ARC GIS 10.4

3 Chapter 3

Results and Discussion

3.1 Mean Minimum Monthly Temperature of Islamabad and Lahore 2010-2022

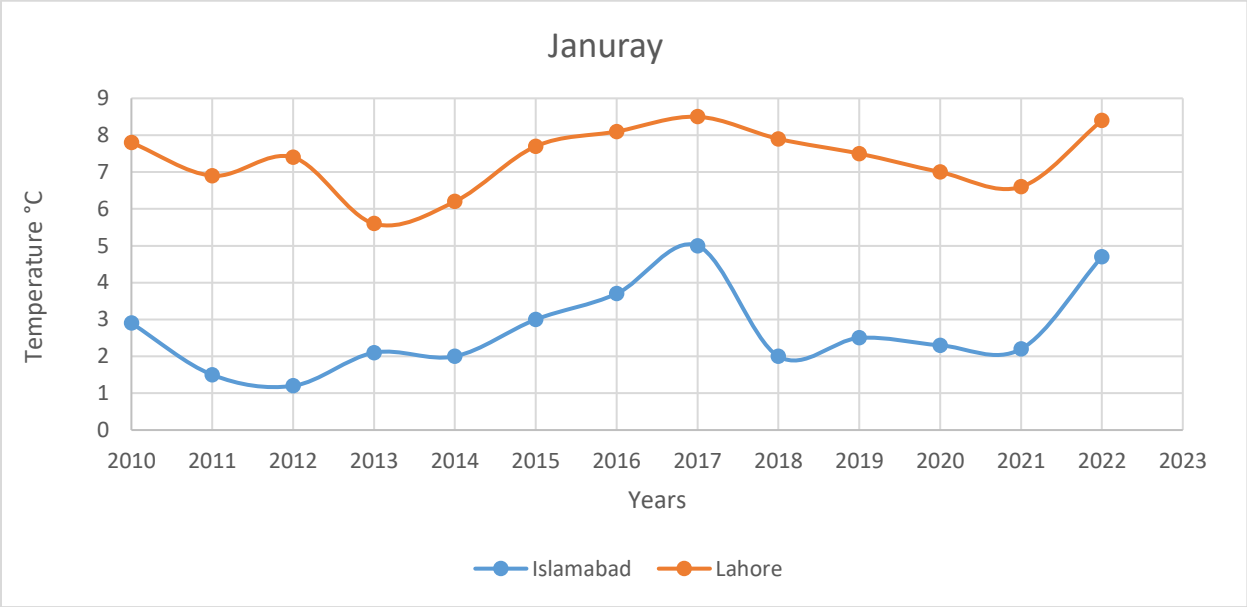


Fig.6 Mean Minimum Monthly Temperature of Islamabad and Lahore in January

The minimum temperature for January in Islamabad rose from 2.9°C in 2010 to 5°C in 2017, which is the highest for January. Since 2012, the temperature has continually increased, climbing a few degrees every year and currently at 4.7°C in 2022.

Whereas the temperature of Lahore has never been that good as compared to Islamabad it rose from 7.8°C in 2010 to 8.5°C in2017, which is the highest for January in Lahore as well the temperature slightly decreased over the years then regained its height at 8.4°C in 2022.

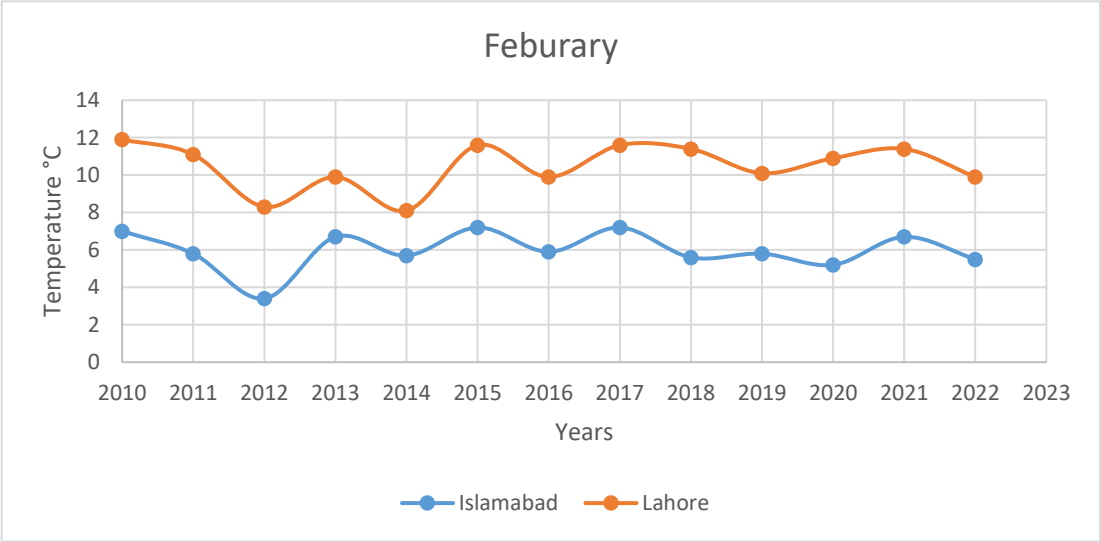


Fig.7 Mean Minimum Monthly Temperature of Islamabad and Lahore in Febuary

February shows a mixed variation in temperature for both Lahore and Islamabad. Starting at 7°C in 2010 to 5.5°C in 2022 for Islamabad and 11.9°C in 2010 to 9.9°C in2022 for Lahore.

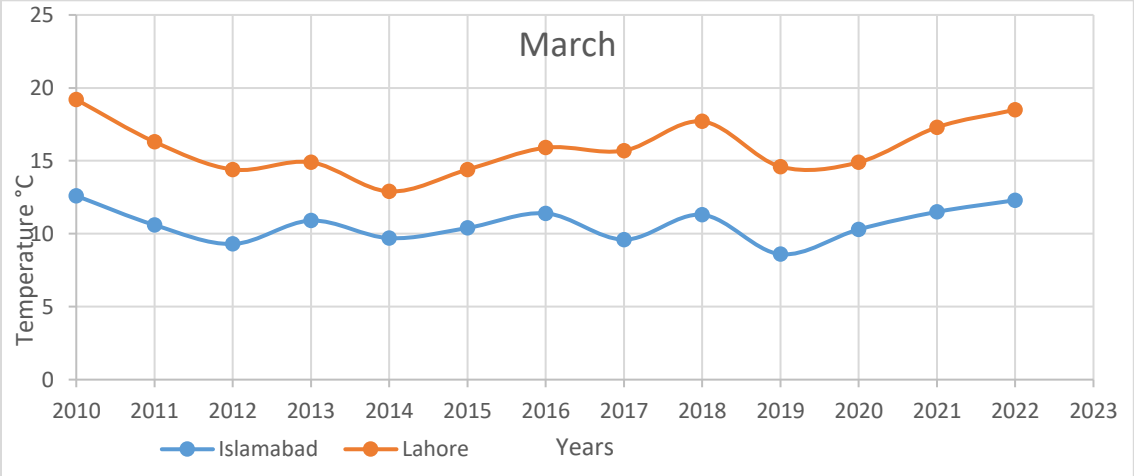


Fig.8 Mean Minimum Monthly Temperature of Islamabad and Lahore in March

The temperature of march remained above 8°C for the past twelve years for both Lahore and Islamabad. Starting at 19.2°C in 2010 that is also the highest for Lahore to 18.5°C in 2022 and 12.6°C in 2010 that is the heights for Islamabad to 12.3°C in 2022

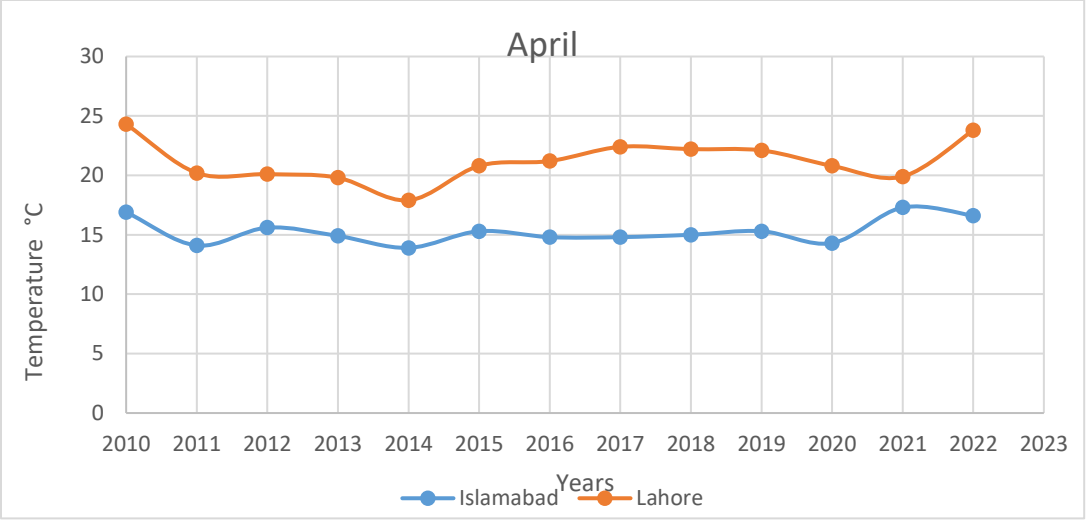


Fig.9 Mean Minimum Monthly Temperature of Islamabad and Lahore in April

April shows a slight change in variation over the past twelve years for both Islamabad and Lahore. The temperature went from 16.9°C in 2010 to 16.6°C in 2022 in Islamabad and 24.3°C in 2010 to 23.8°C in 2022 for Lahore.

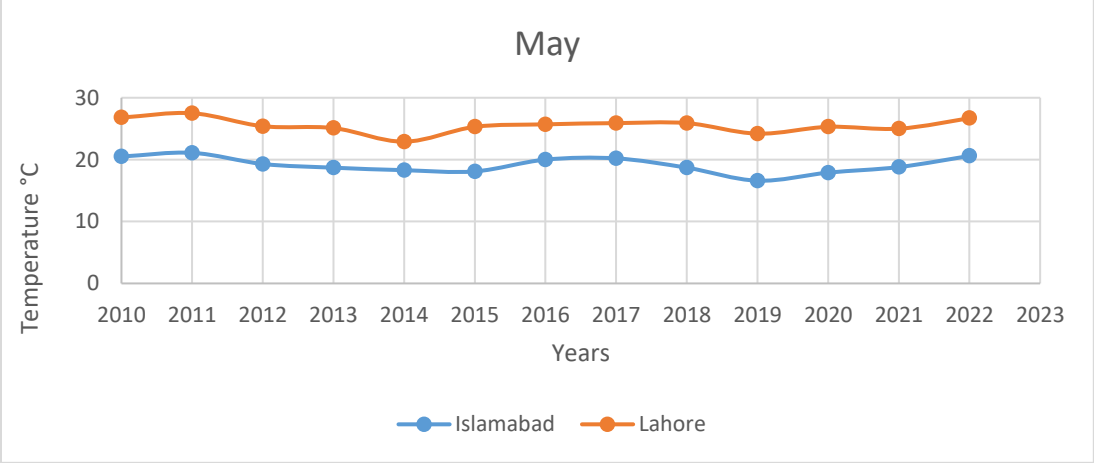


Fig.10 Mean Minimum Monthly Temperature of Islamabad and Lahore in May

May also shows slight variations in changing temperature over the past years in both Islamabad and Lahore in which the lowest temperature recorded for Lahore was 22.9°C in the year 2014 and 16.6°C in 2019 for Islamabad.

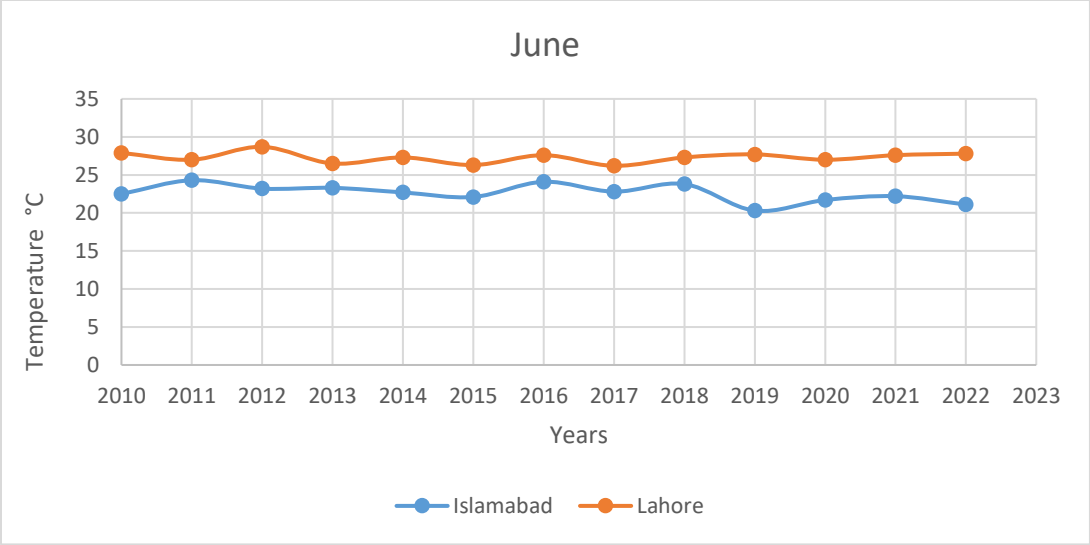


Fig.11 Mean Minimum Monthly Temperature of Islamabad and Lahore in June

The start of summer shows almost constant temperature levels with some slight drop in temperature for Islamabad in 2019 and for Lahore in 2012.

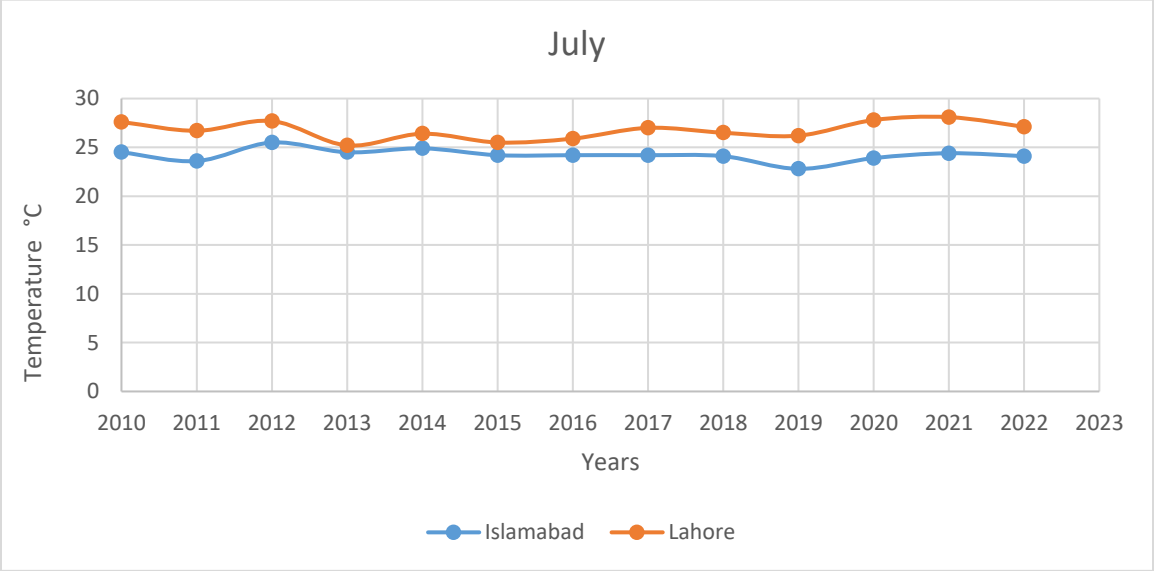


Fig.12 Mean Minimum Monthly Temperature of Islamabad and Lahore in July

The graph for July shows that the mean minimum temperature for Islamabad has not gone below 22°C and it has not gone below 25°C in Lahore.

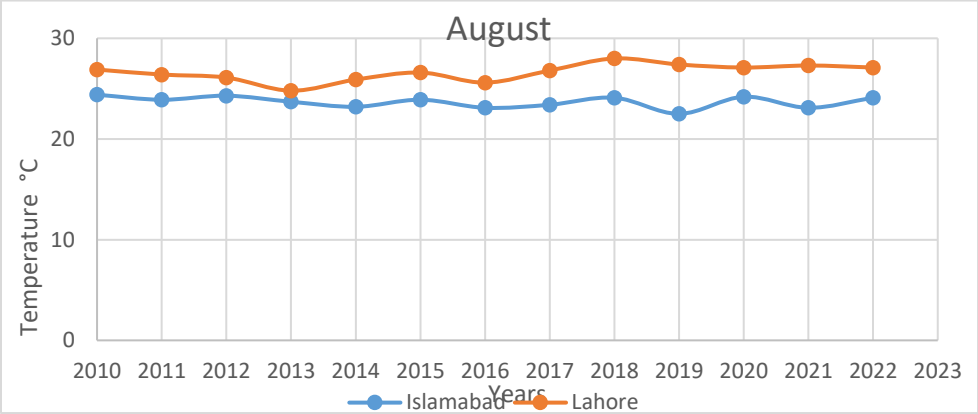


Fig.13 Mean Minimum Monthly Temperature of Islamabad and Lahore in August

The mean minimum temperature of august shows slight variations in temperature over the past years. With a slight down fall of temperature in 2019 in Islamabad and in 2013 in Lahore.

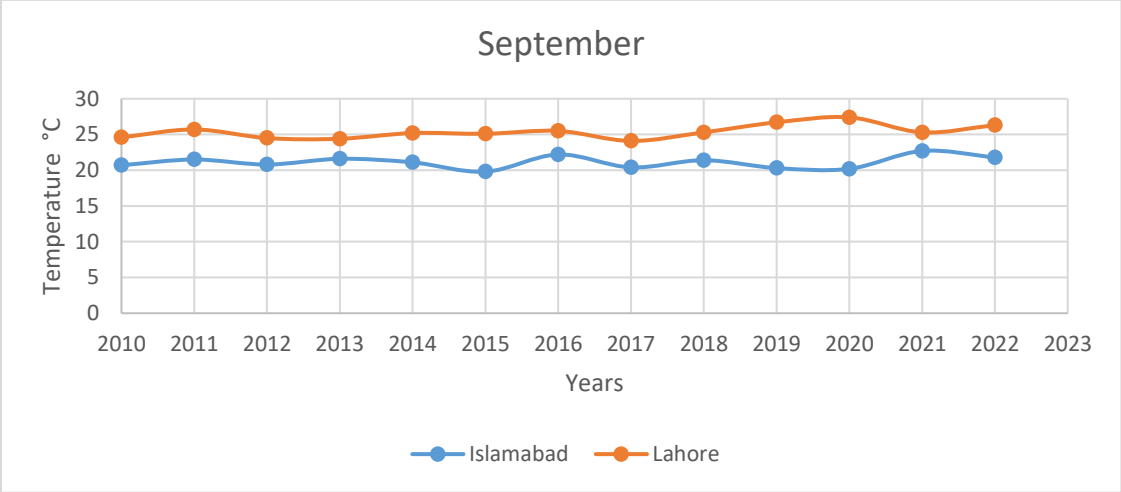


Fig.14 Mean Minimum Monthly Temperature of Islamabad and Lahore in September

Over the past years in the month of September the temperature does not go below 19°C in Islamabad and 24°C in Lahore.

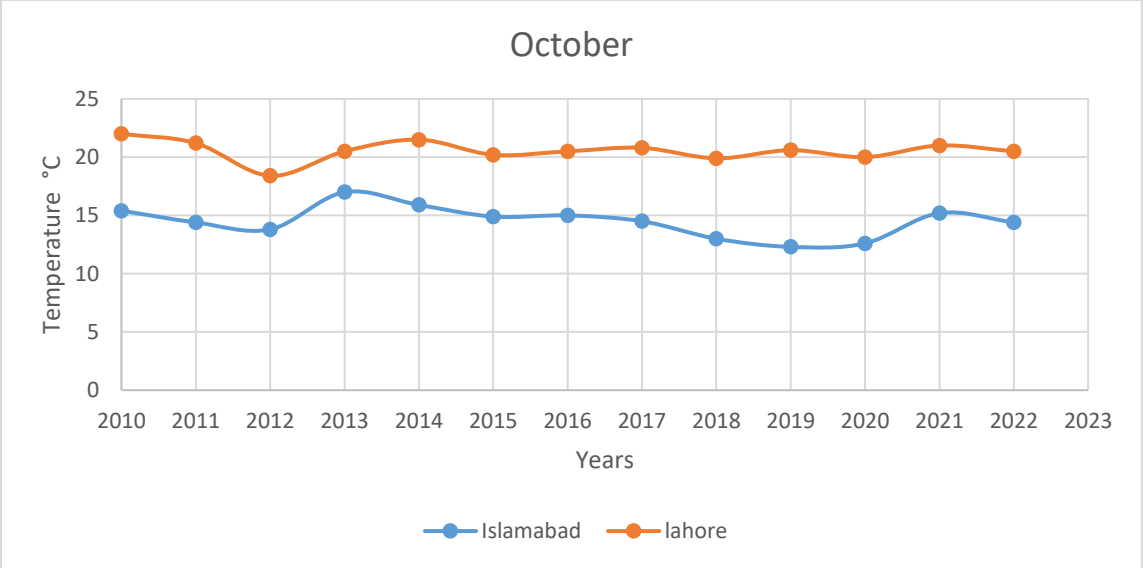


Fig.15 Mean Minimum Monthly Temperature of Islamabad and Lahore in October

The mid Fall month of October shows a drop in temperature level for both Lahore and Islamabad in 2012 and an increase in temperature level with 17°C in 2013 in Islamabad and 22°C in Lahore in 2010.

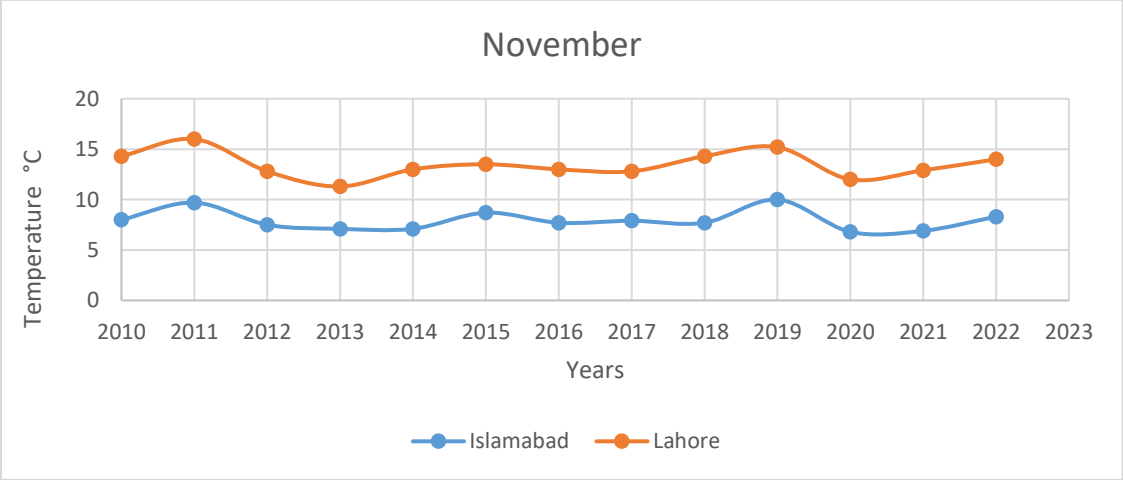


Fig.16 Mean Minimum Monthly Temperature of Islamabad and Lahore in November

The month of November shows an increase in the mean minimum temperature for both Islamabad and Lahore in 2011 and 2019.

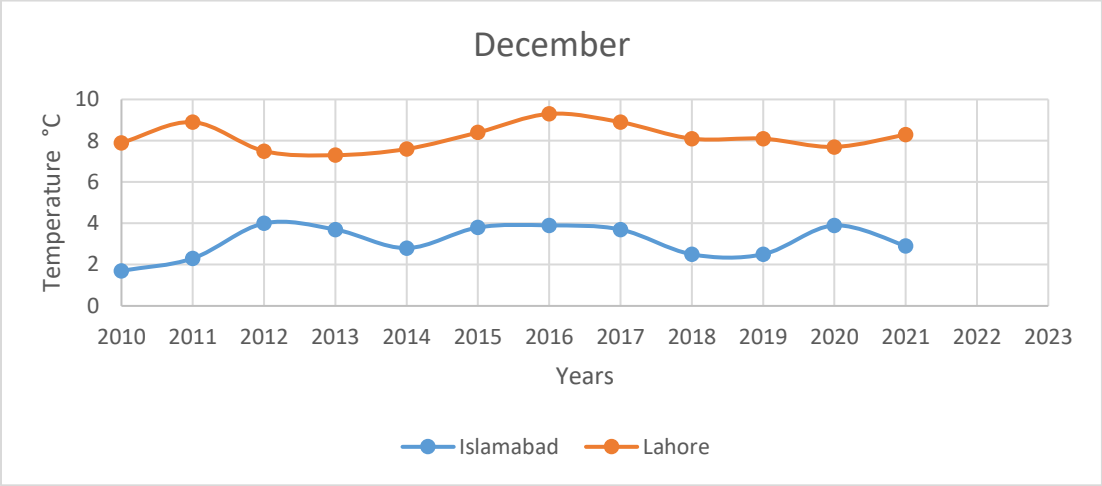


Fig.17 Mean Minimum Monthly Temperature of Islamabad and Lahore in December

The start of winter shows different temperature variations in Lahore and Islamabad, Whereas the lowest temperature level of Islamabad is 1.7°C in 2010 and Lahore had 7.3°C in 2013.

3.2 Mean Maximum Monthly Temperature of Islamabad and Lahore 2010-2022

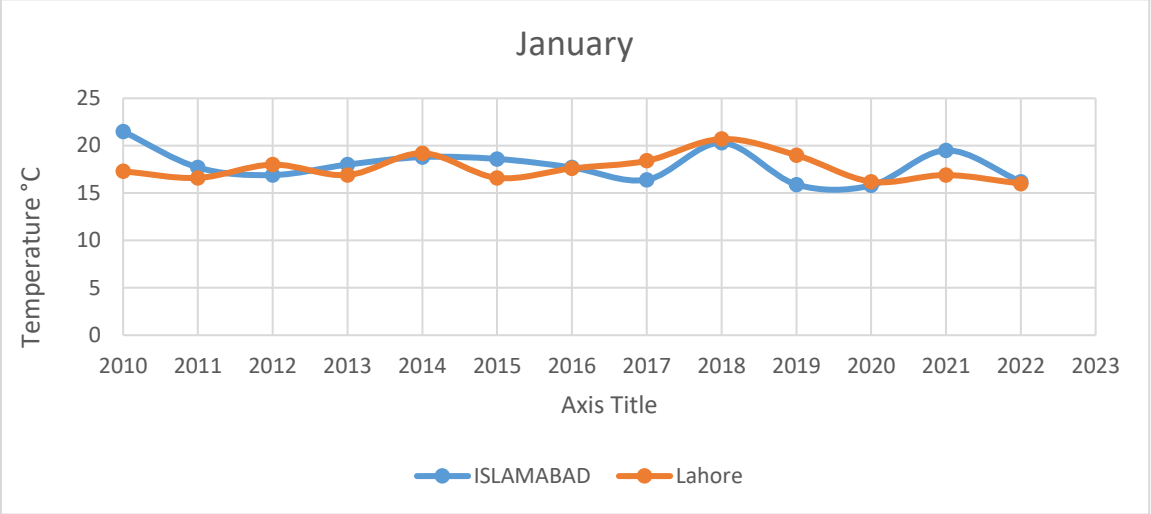


Fig.18 Mean Maximum Monthly Temperature of Islamabad and Lahore in January

As the tendency for the mean maximum temperature is declining, the range of the mean maximum temperature for January in Lahore is 21.5°C to 16.2°C. Smog in Lahore is the primary factor causing a drop in the mean temperature.

From 2010 through 2022, Islamabad's mean maximum temperature for January ranges from 16°C to 17.3°C, with a trend showing that this variation is due to changes in the pattern of precipitation.

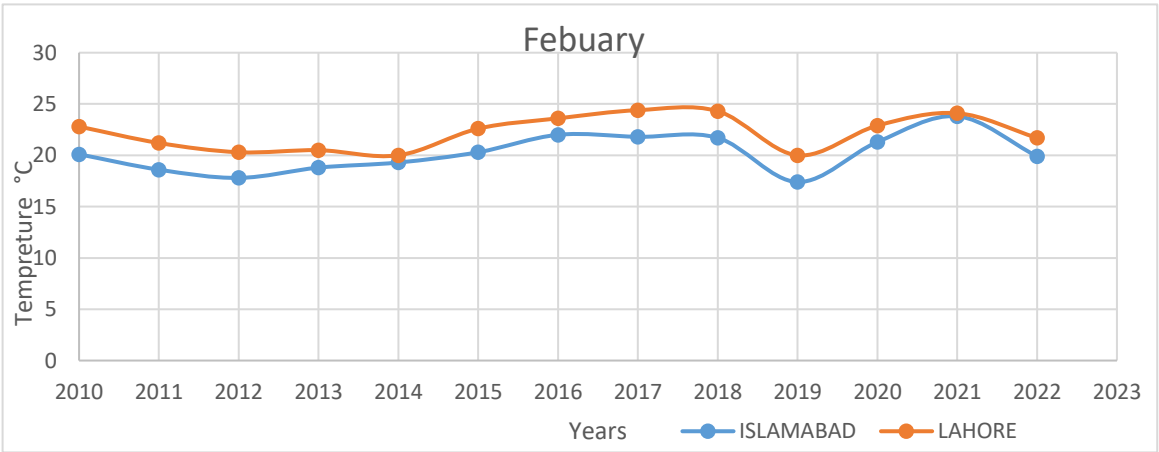


Fig.19 Mean Maximum Monthly Temperature of Islamabad and Lahore in Febuary

The lowest temperature was 20°C in 2019 and the mean high temperature for February in Lahore in 2017 was 24.4 °C. The pattern of precipitation and the density of fog, particularly in Lahore, determine the month of February's average maximum temperature.

The lowest temperature was 17°C in 2019 while the mean high temperature for February in Islamabad was 23.8 °C in 2021. The pattern of precipitation in Islamabad affects the average monthly high temperature.

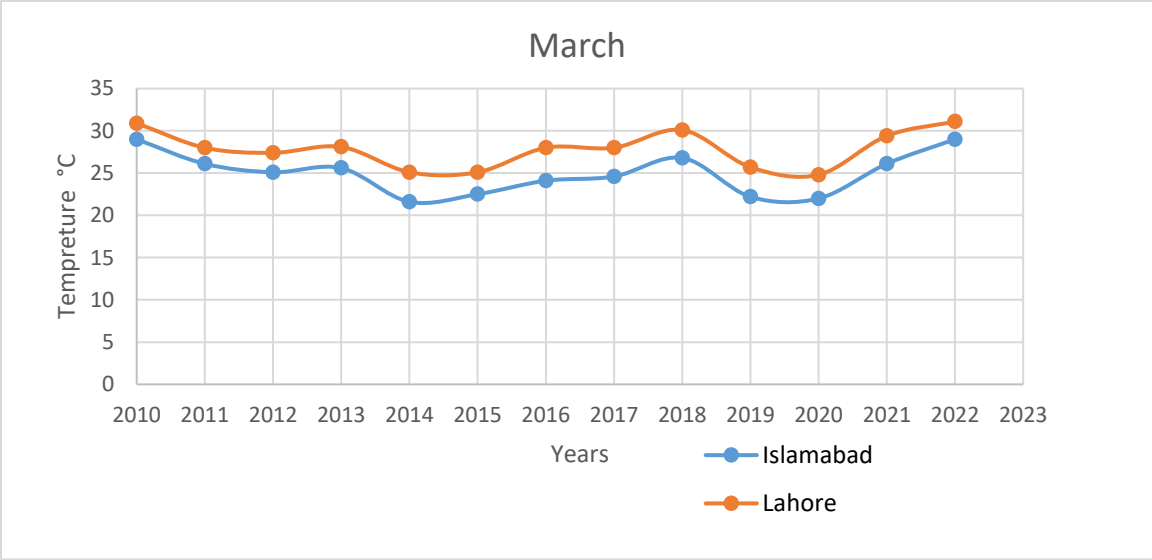


Fig.20 Mean Maximum Monthly Temperature of Islamabad and Lahore in March

The lowest maximum temperature was 25.1°C in 2014 and 2015, and the mean maximum temperature for March in Lahore in 2022 was 31.1°C. Since the days were growing longer and more sunshine was reaching the ground, the temperature of the earth began to rise, affecting the mean maximum temperature of March.

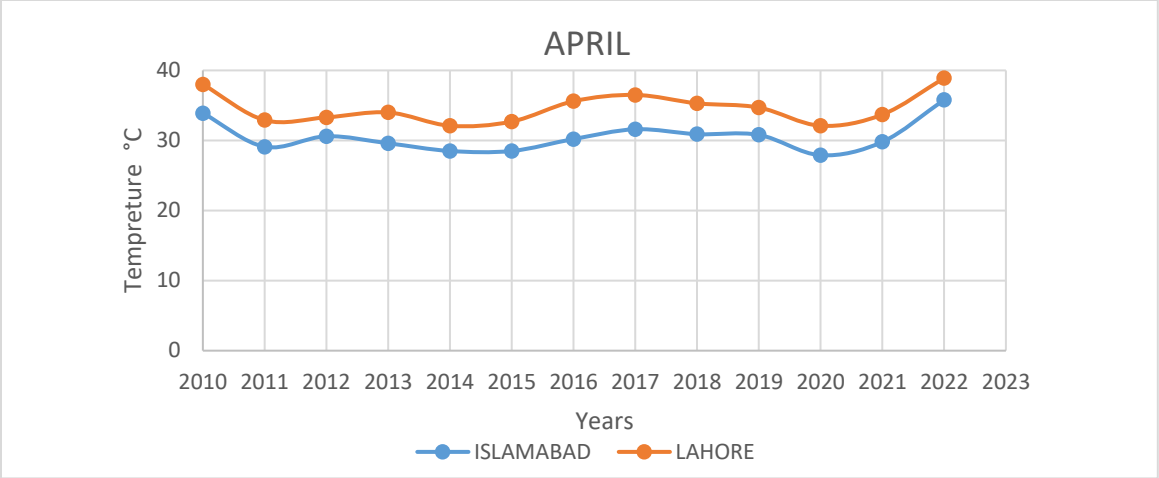


Fig.21 Mean Maximum Monthly Temperature of Islamabad and Lahore April

The minimum temperature was 17°C in 2019 while the mean maximum temperature for February in Islamabad was 23.8°C in 2021. The pattern of precipitation in Islamabad affects the average monthly high temperature. The peak of the summer season in Lahore began in April, as shown in the graph, and the year 2022 had the city's highest mean maximum temperature. Lahore saw a frightening 38.9 °C temperature in April 2022. Less precipitation in April is another factor contributing to the month's rising temperatures.

According to the data, the highest mean maximum temperature ever recorded in Islamabad occurred in the year 2022, which is when the summer season began to reach its peak. Islamabad's March 2022 temperature of 35.8°C is a wake-up call for us. Less precipitation in April is another factor contributing to the month's rising temperatures.

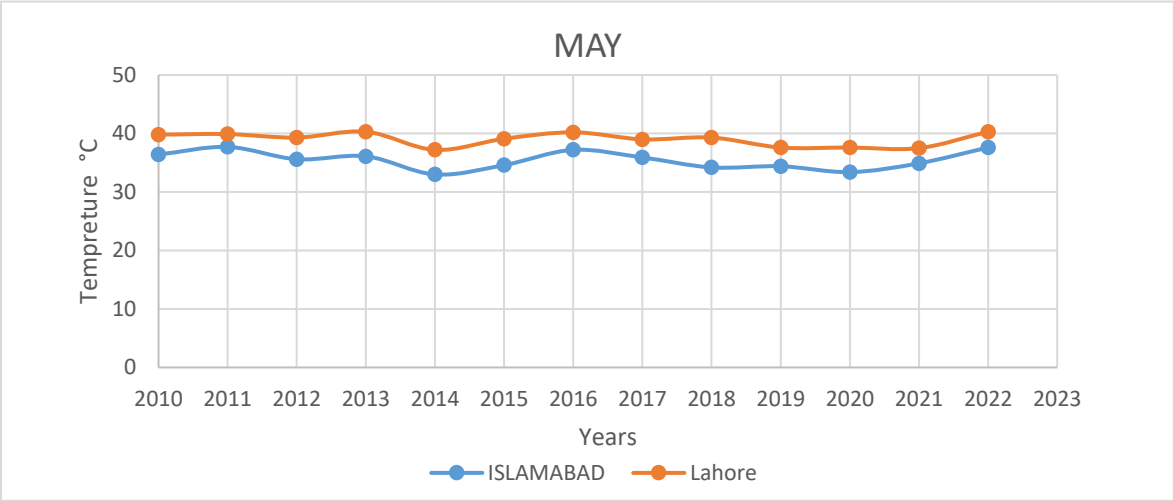


Fig.22 Mean Maximum Monthly Temperature of Islamabad and Lahore in May

As can be observed from the graph, Lahore's temperature peaked in the month of May. The mean highest temperature for that month was 40.3°C in 2022, and the city's lowest maximum temperature was 37.2°C in 2014.

As can be observed from the graph, Islamabad's temperatures peaked in May. The mean highest temperature for May in that year was 37.7°C, and the lowest maximum temperature was 33°C in 2014.

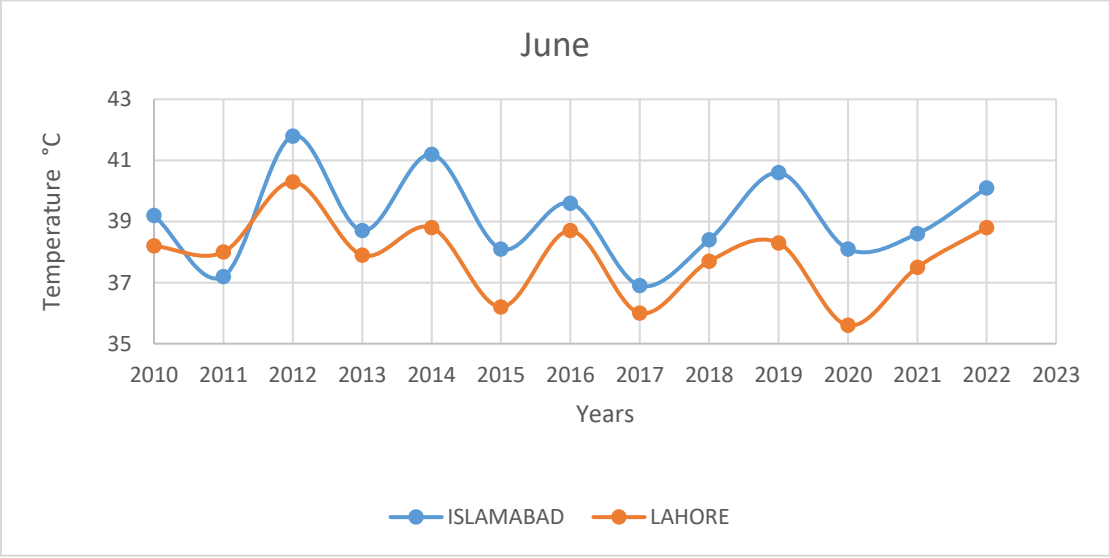


Fig.23 Mean Maximum Monthly Temperature of Islamabad and Lahore in June

Various fluctuations in the temperature levels can be observed in the month of June for both Lahore and Islamabad over the past years with an average maximum temperature of 39.1°C in Islamabad and 37.8°C in Lahore.

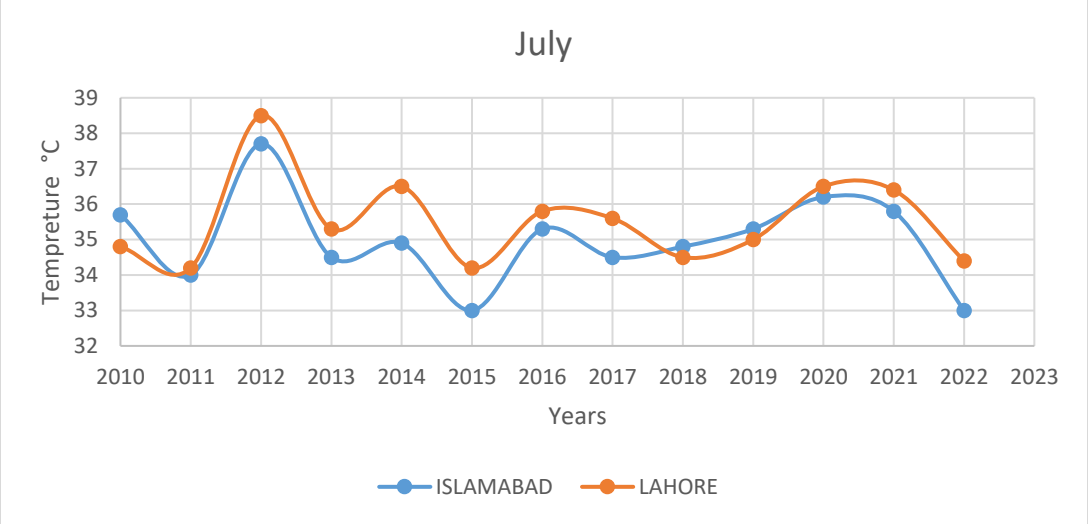


Fig.24 Mean Maximum Monthly Temperature of Islamabad and Lahore in July

While both Lahore and Islamabad's maximum temperatures were attained in 2012 Lahore with a maximum value of 38.5°C and Islamabad with 37.7°C the general graph shows a drop in maximum temperatures from 2010 to 2022 for both cities.

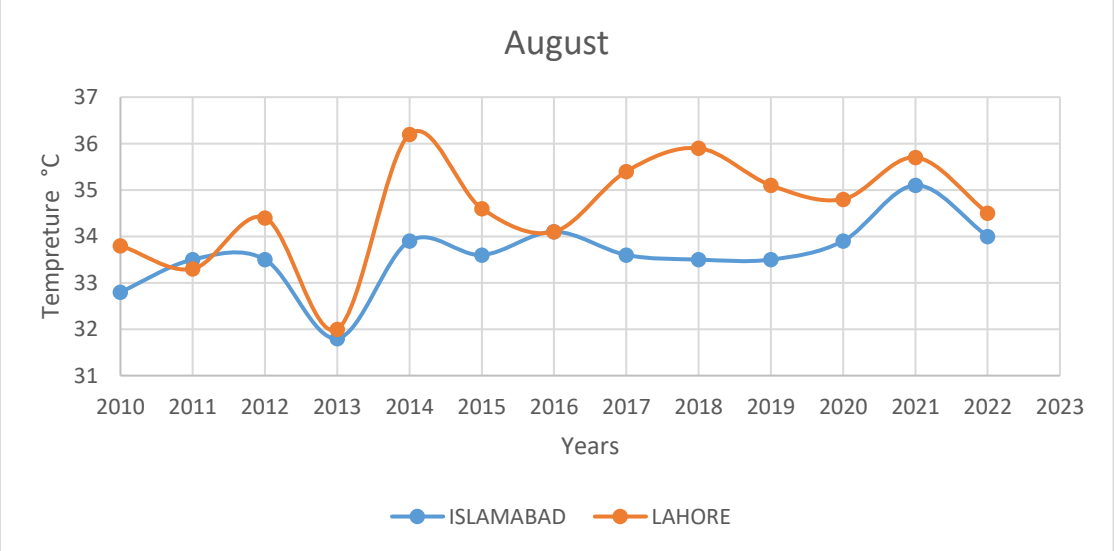


Fig.25 Mean Maximum Monthly Temperature of Islamabad and Lahore in August

The graph for august displays a decrease in both Lahore and Islamabad's maximum temperature values from 2013, when Lahore had a temperature of 32 °C and Islamabad had a temperature of 31.8 °C.

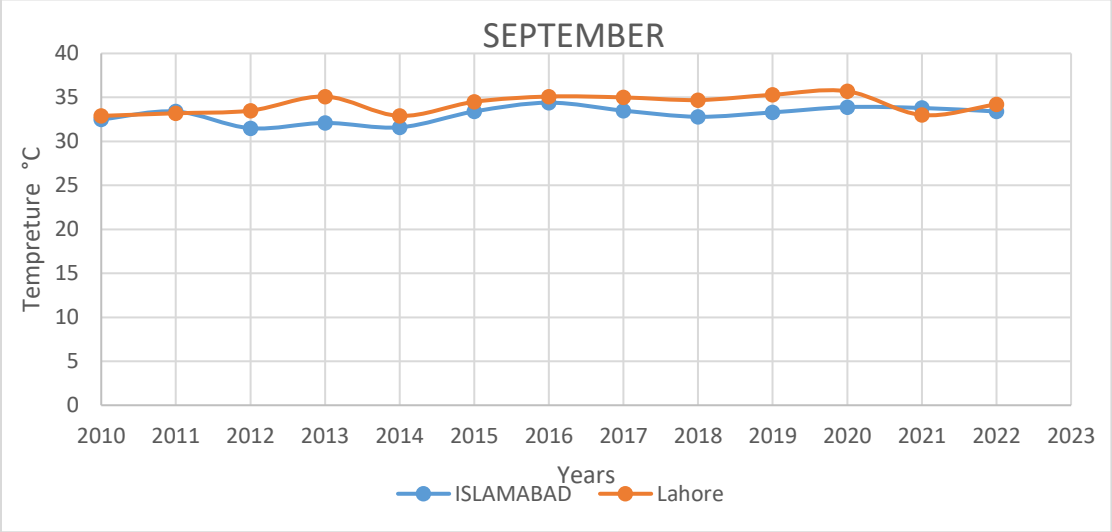


Fig.26 Mean Maximum Monthly Temperature of Islamabad and Lahore in September

In August, both Lahore and Islamabad experienced a consistent trend throughout the previous twelve years, with an average temperature of 33 °C in Islamabad and 34 °C in Lahore.

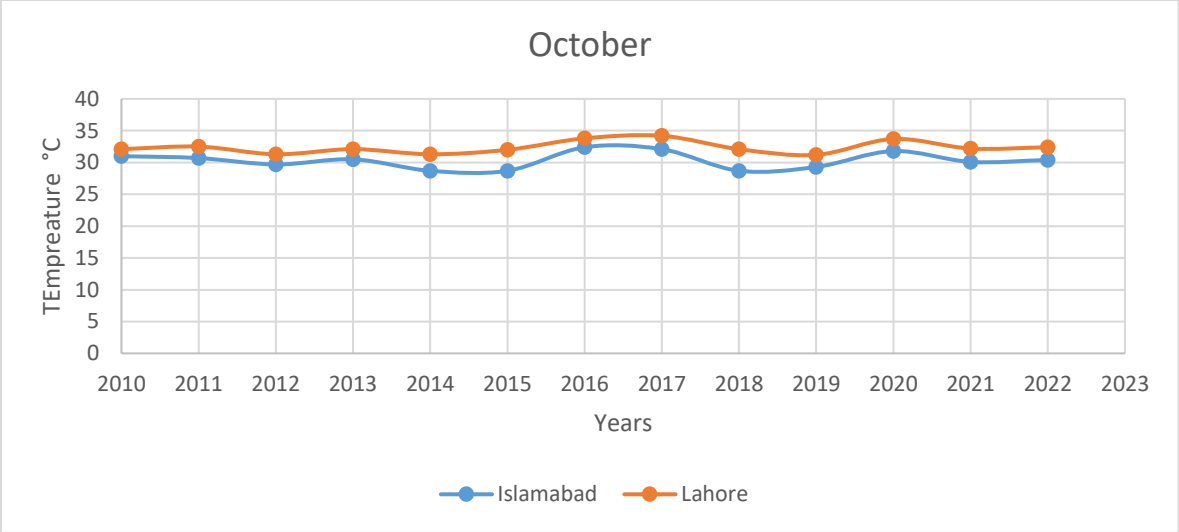


Fig.27 Mean Maximum Monthly Temperature of Islamabad and Lahore in October

Both Lahore and Islamabad have seen stable temperatures for the past twelve years, never falling below 28 °C.

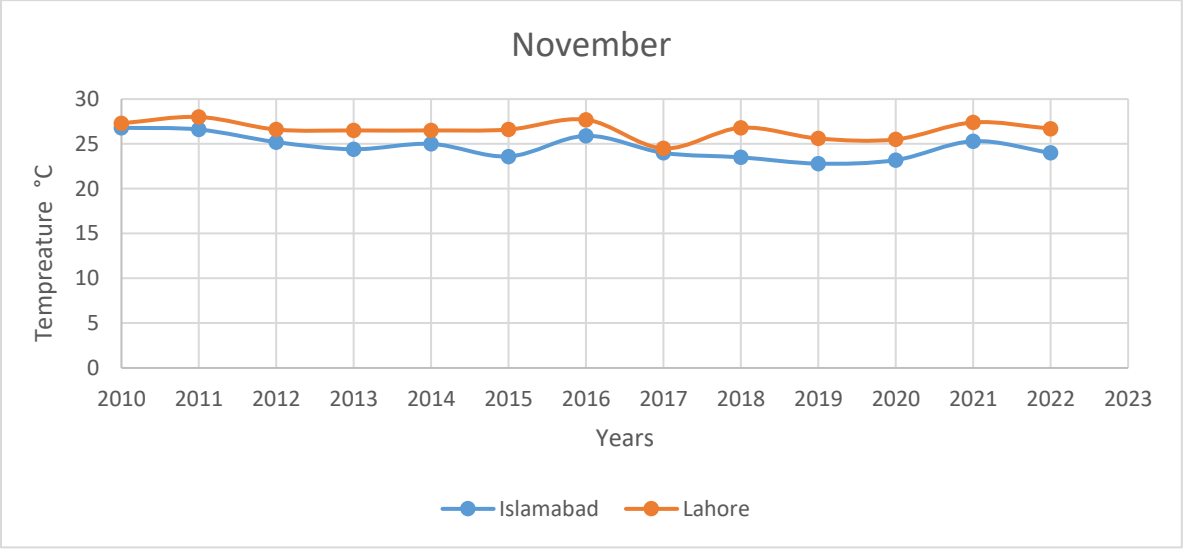
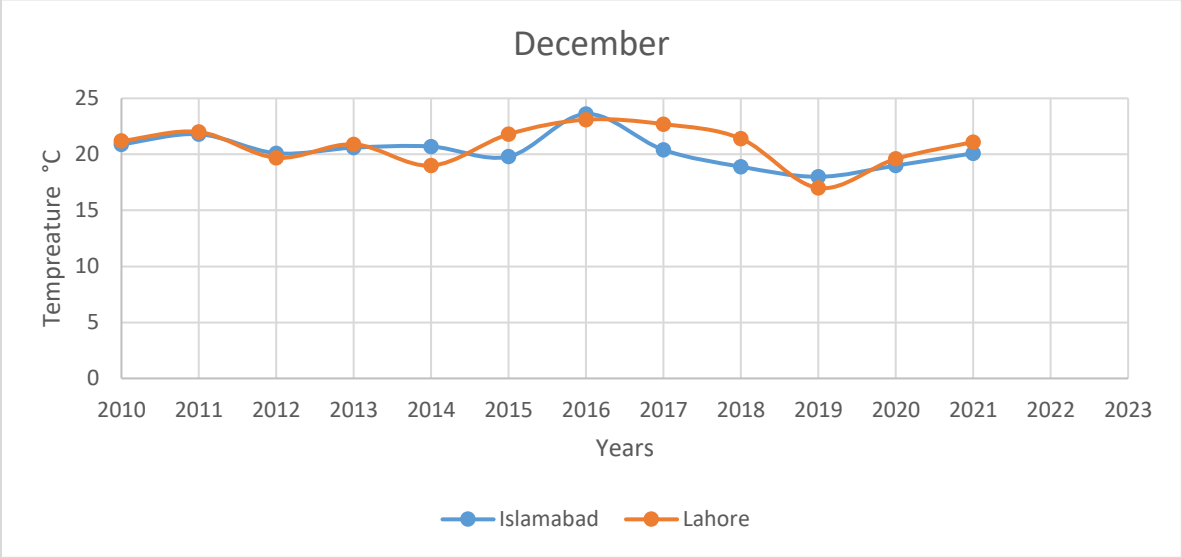


Fig.28 Mean Maximum Monthly Temperature of Islamabad and Lahore in November

Although the temperature has been the same in both Lahore and Islamabad, there was a minor change in 2017 when Lahore's temperature was 24.5 °C, which was nearly the same as Islamabad's temperature of 24 °C.



December marks the start of winters in which Lahore had its lowest maximum temperature of 17 °C and Islamabad had 18 °C, both in 2019.

3.3 Amount of Precipitation in Lahore and Islamabad 2010-2022

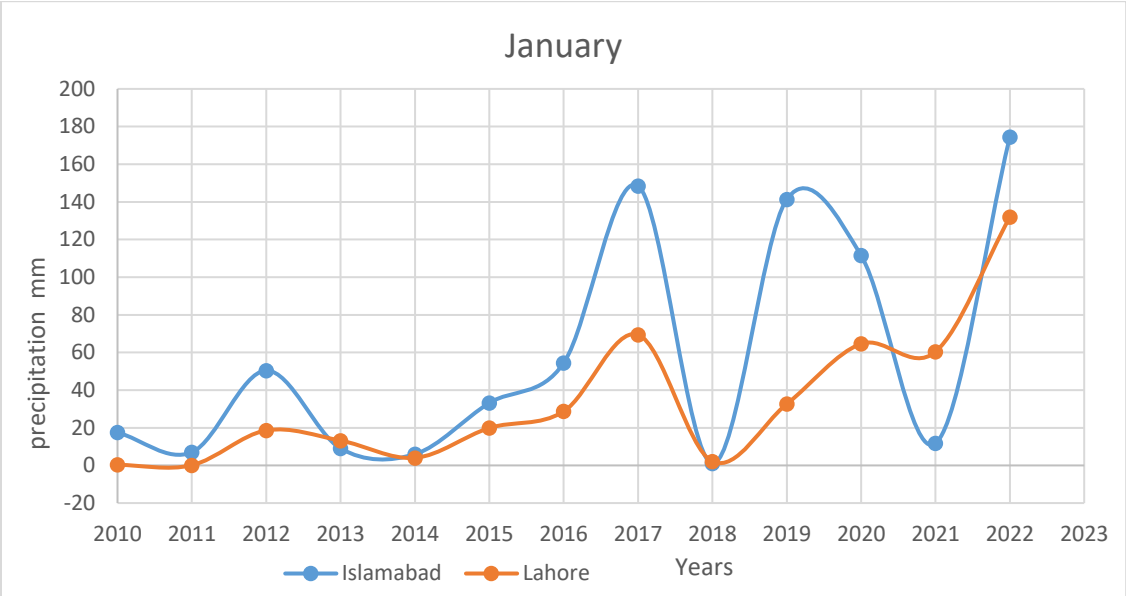


Fig.29 Amount of Precipitation in Lahore and Islamabad in January

Over the previous twelve years, the quantity of precipitation in January has increased in both Lahore and Islamabad, with a dip in precipitation in 2018 and then an increased amount of rainfall in 2022 in which Islamabad received 174.5mm of rainfall and Lahore received 131.9mm.

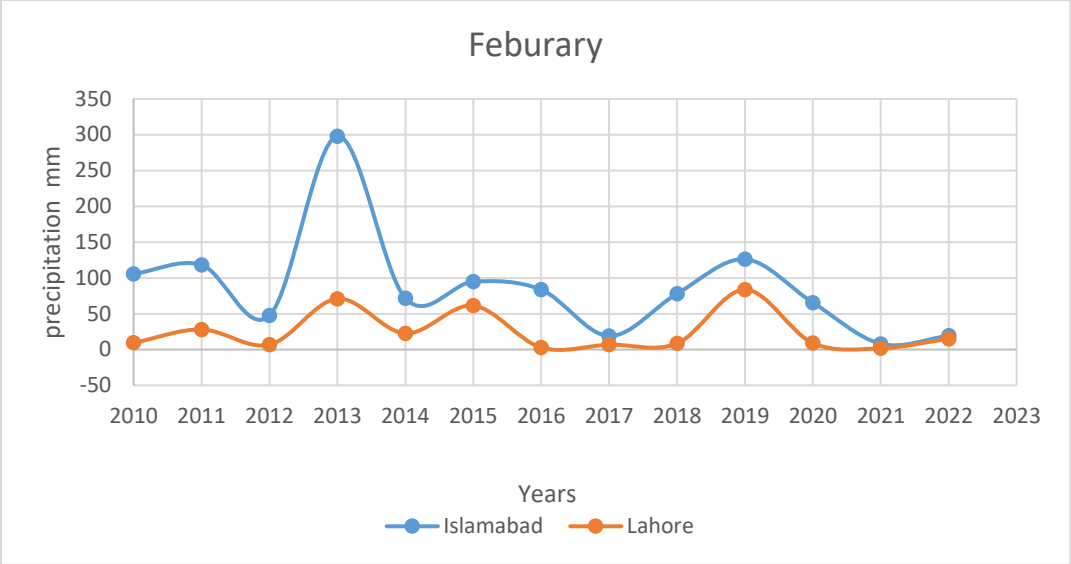


Fig.30 Amount of Precipitation in Lahore and Islamabad in Febuary

The overall graph demonstrates a reduction in precipitation levels in February for both Lahore and Islamabad. The lowest quantity of precipitation was recorded in 2021, when Islamabad had 8mm of rain fall and Lahore received 1.8mm of rain fall.

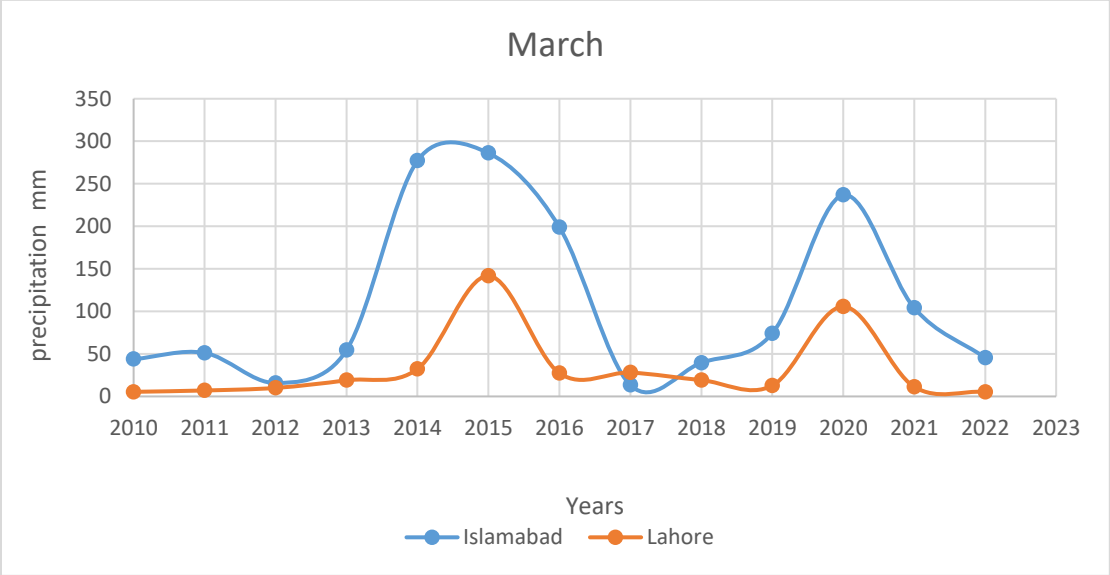


Fig.31 Amount of Precipitation in Lahore and Islamabad in March

Although Islamabad has had more quantities of rainfall in the month of March during the previous twelve years than Lahore, the graph reveals very modest fluctuations in precipitation levels in Lahore.

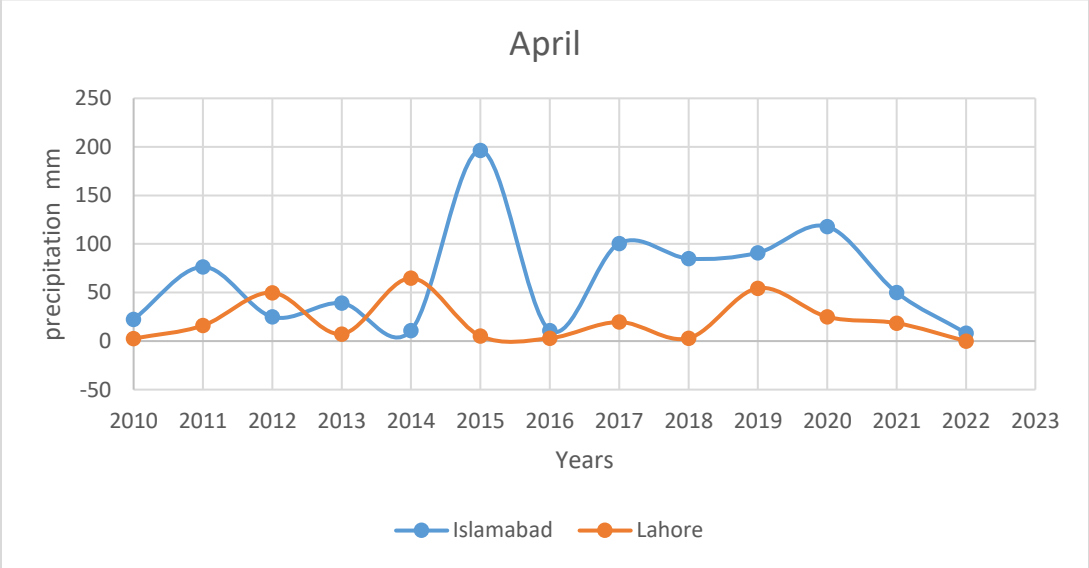


Fig.32 Amount of Precipitation in Lahore and Islamabad in April

The overall graph demonstrates a drop in the amount of precipitation for both Islamabad and Lahore, with the lowest amount of precipitation recorded in 2022, when Islamabad received 8.3mm and Lahore received only trace amounts.

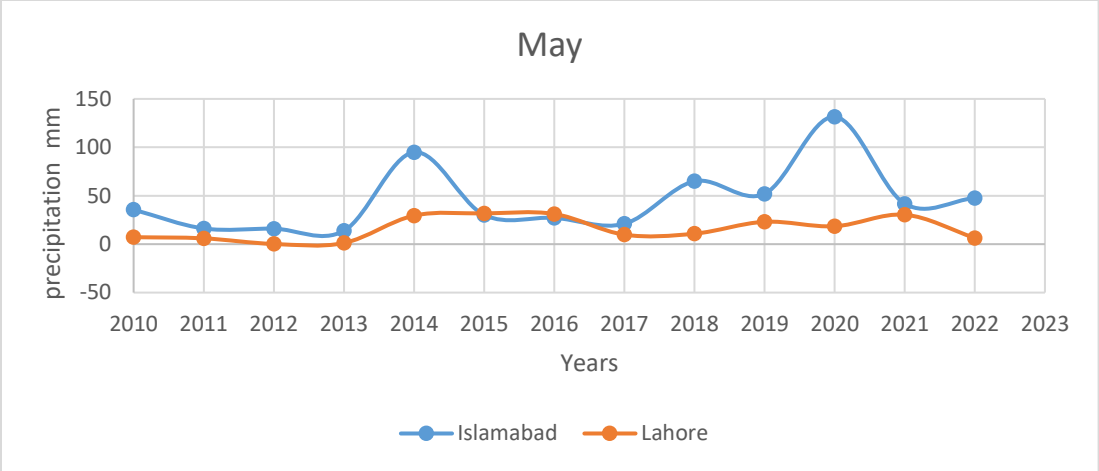


Fig.33 Amount of Precipitation in Lahore and Islamabad in May

Slight variations in precipitation levels have been observed in the month of May with Islamabad having the highest amount of rainfall in 2020 that was 131.6mm and Lahore having 31.7mm in 2015.

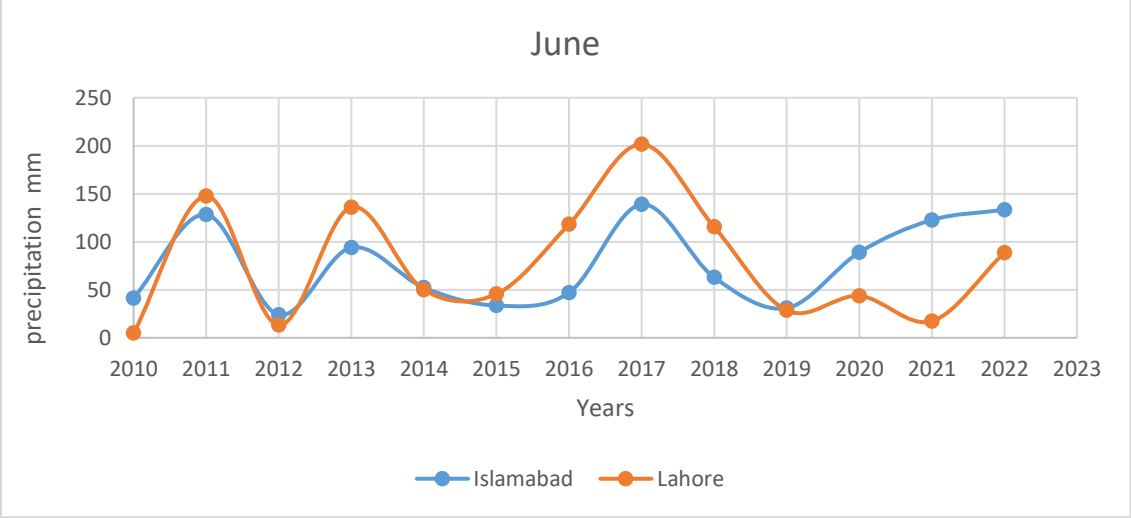


Fig.34 Amount of Precipitation in Lahore and Islamabad in June

The graph for June reveals that Lahore received more rain than Islamabad on average over the previous twelve years, with Lahore receiving an average of 77.7mm and Islamabad receiving 76.8mm.

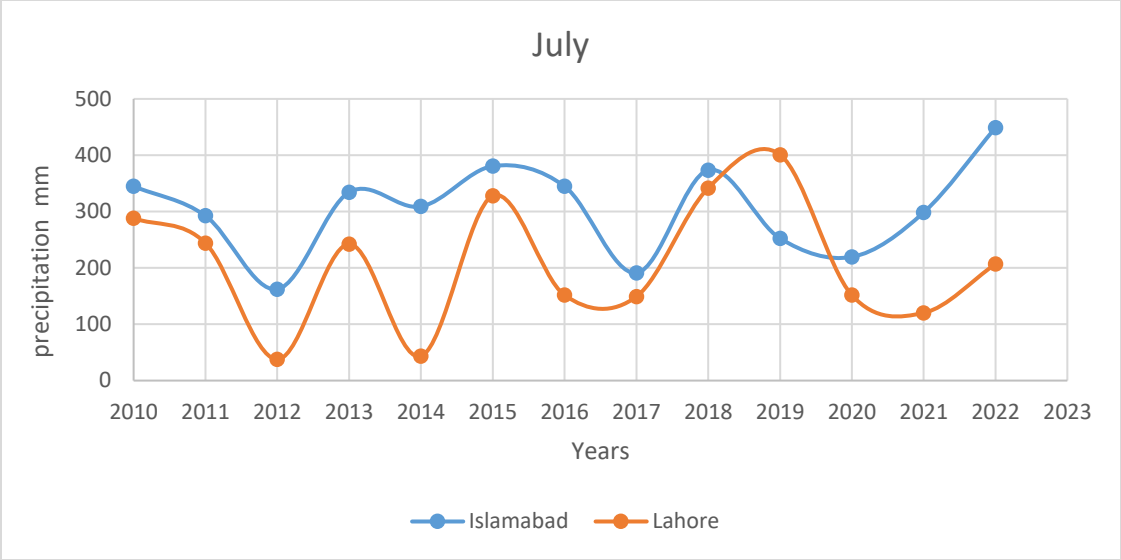


Fig.35 Amount of Precipitation in Lahore and Islamabad in Juy

July marks the start of monsoon season whereas the graph shows most of the precipitation levels are greater than 243mm, With Lahore having the most amount of rainfall of 400.9mm in 2019 and Islamabad having 449mm in 2022.

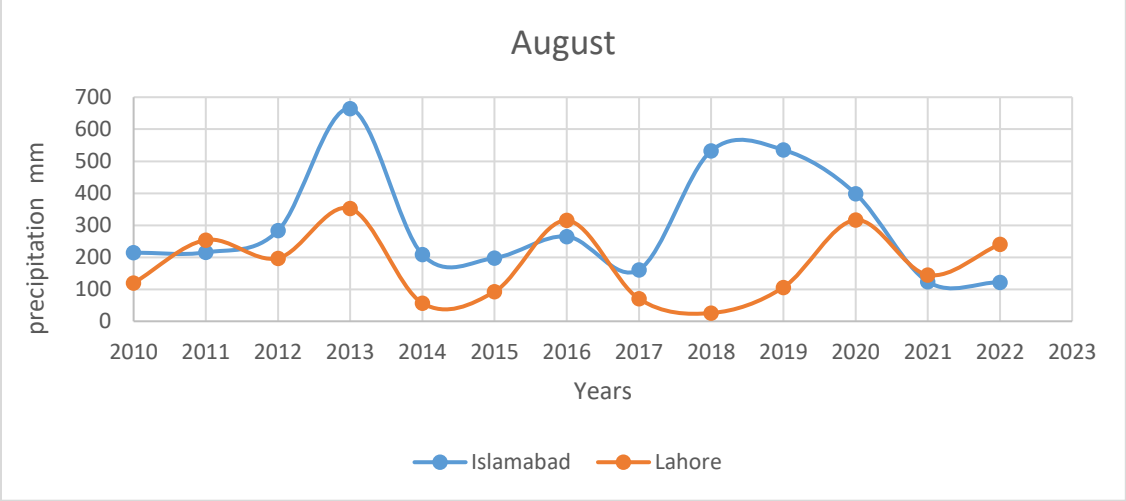


Figure 36Amount of Precipitation in Lahore and Islamabad in August

In comparison to Lahore, Islamabad has experienced approximately twice as much rain in the month of August over the past twelve years. However, both cities experienced their highest rainfall in 2013—Islamabad received 664mm and Lahore received 352.3mm.

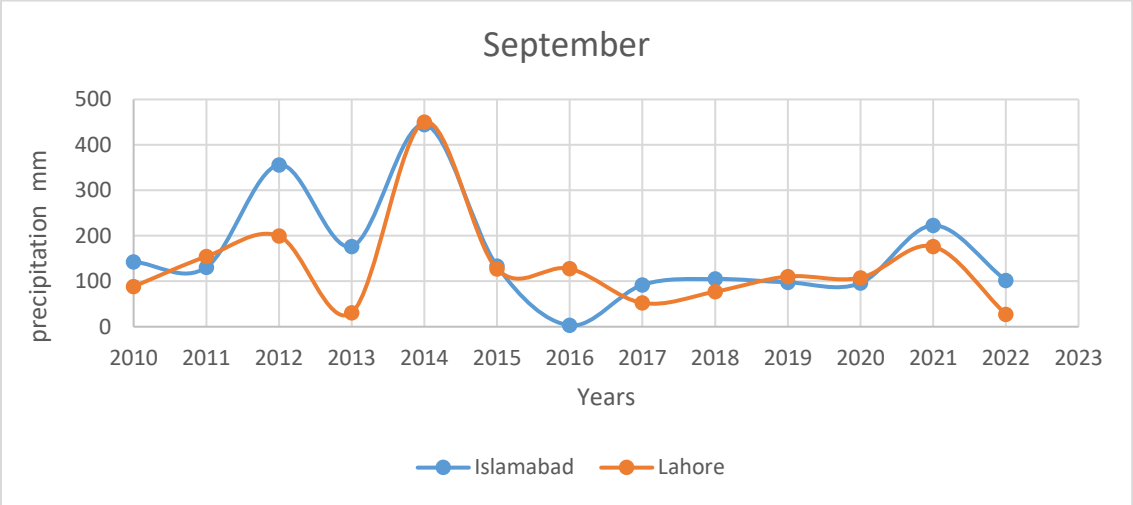


Figure 37Amount of Precipitation in Lahore and Islamabad in September

The graph depicts a general decline in precipitation throughout the years, with Islamabad seeing its lowest rainfall of 3 mm in 2016 and Lahore experiencing its lowest rainfall of 27.4 mm in 2022.

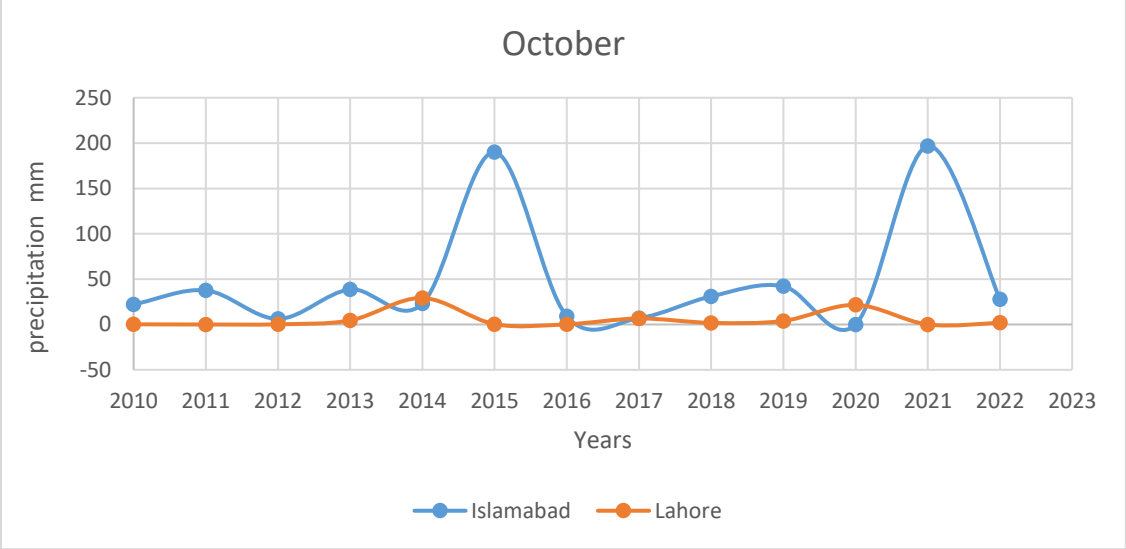


Fig.38 Amount of Precipitation in Lahore and Islamabad in October

In comparison to Islamabad, which had an average October rainfall of 48.5mm, Lahore had experienced relatively little precipitation over the preceding few years, with annual rainfall totaling just 5.4mm.

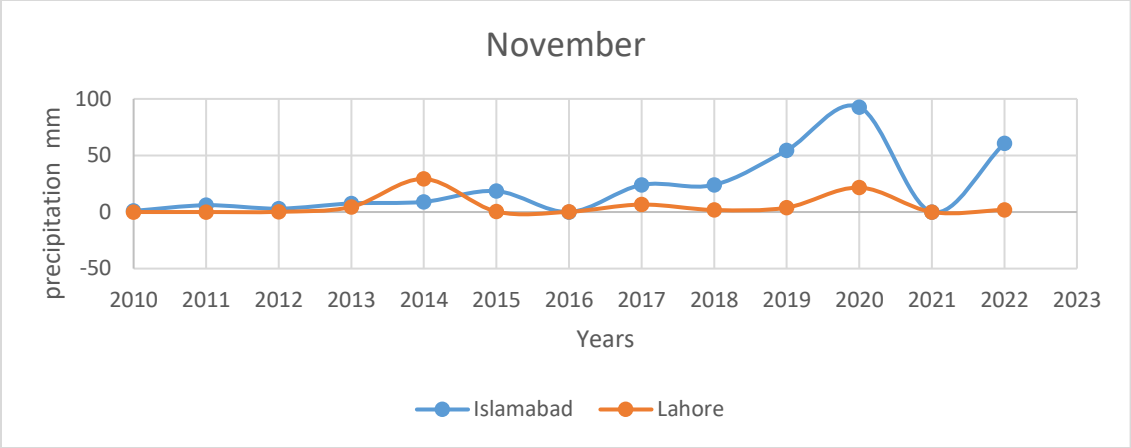


Fig.39 Amount of Precipitation in Lahore and Islamabad in November

The month of November saw typical rainfall for Lahore and Islamabad, whereas the year 2021 saw only a trace amount of precipitation in both the cities.

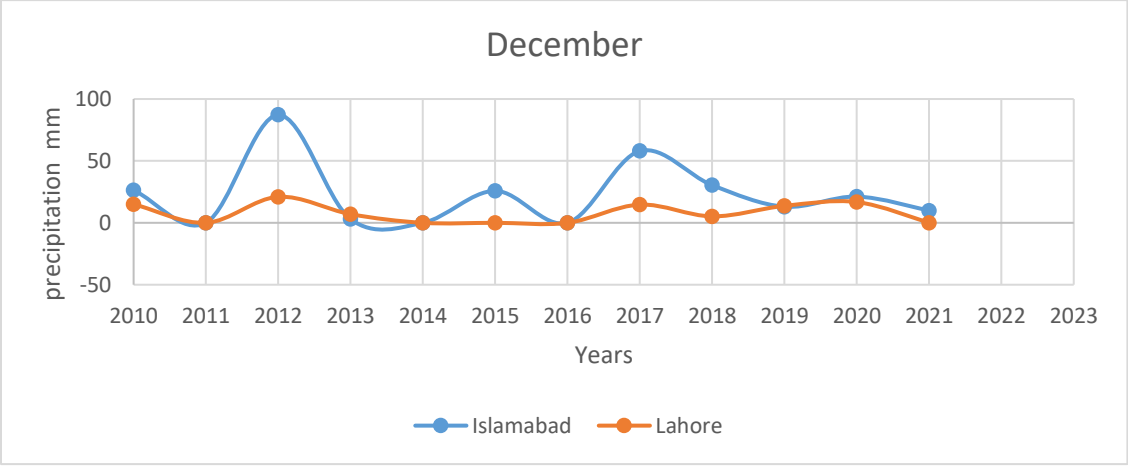


Fig.40 Amount of Precipitation in Lahore and Islamabad in December

The graph illustrates that the amount of precipitation in December has decreased throughout the years, but in 2012, both Islamabad and Lahore experienced their highest rainfall totals, with Islamabad receiving 87.2mm and Lahore receiving 21mm.

3.4 Annual Minimum, Maximum Temperatures and Precipitation Levels 2010-2022

Table 1 Annual Minimum, Maximum Temperatures and Precipitation

Years	Islamabad			Lahore		
	Temperature(°C)		Precipitation(mm)	Temperature(°C)		Precipitation(mm)
	Min	Max		Min	Max	
2010	14.8	29.9	1017.9	20.1	30.8	540.7
2011	14.4	28.9	1079.6	19.5	29.9	856.9
2012	14	28.7	1076.4	18.4	30.3	582.9
2013	14.5	28.3	1732.4	17.9	30	902.8
2014	13.9	27.9	1507.3	17.9	29.8	785.9
2015	14.3	27.7	1620.6	18.8	29.8	857.2
2016	14.7	29.6	1044	19	31.2	806.5
2017	14.5	28.7	974	19.2	30.9	628.1
2018	14.1	28.7	1428.1	19.5	31.1	610.6
2019	13.3	27.6	1513.9	19.2	29.7	897.9
2020	13.6	27.8	1580.6	19	29.8	880.6
2021	14.2	29.3	1189.7	19.2	30.5	641.5
Average	14.19	28.59	1313.7	18.97	30.31	749.3

The table above shows values of changing temperature and precipitation levels in Islamabad and Lahore over the past twelve years. The average temperature levels veries between the two cities due to various factors influencing the climate of the two cities.

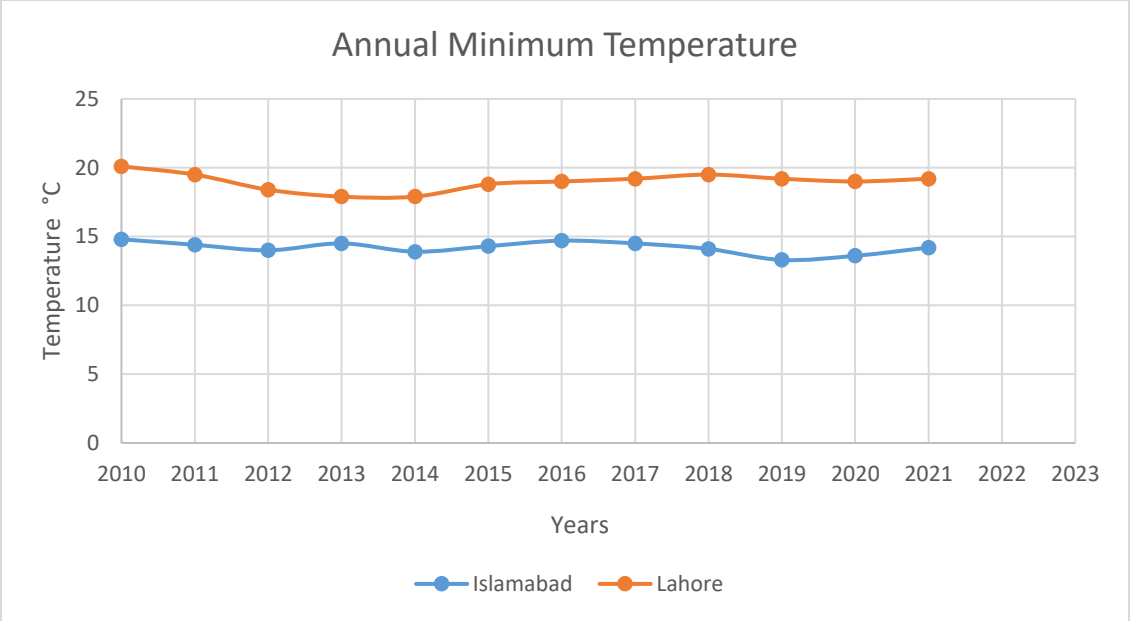


Fig.41 Annual Minimum Tempreture

With Islamabad's average minimum temperature being 14.1 °C and Lahore's being 18.9 °C during the previous twelve years, respectively, the annual graph of Lahore and Islamabad's minimum temperature levels indicates steady temperature variations.

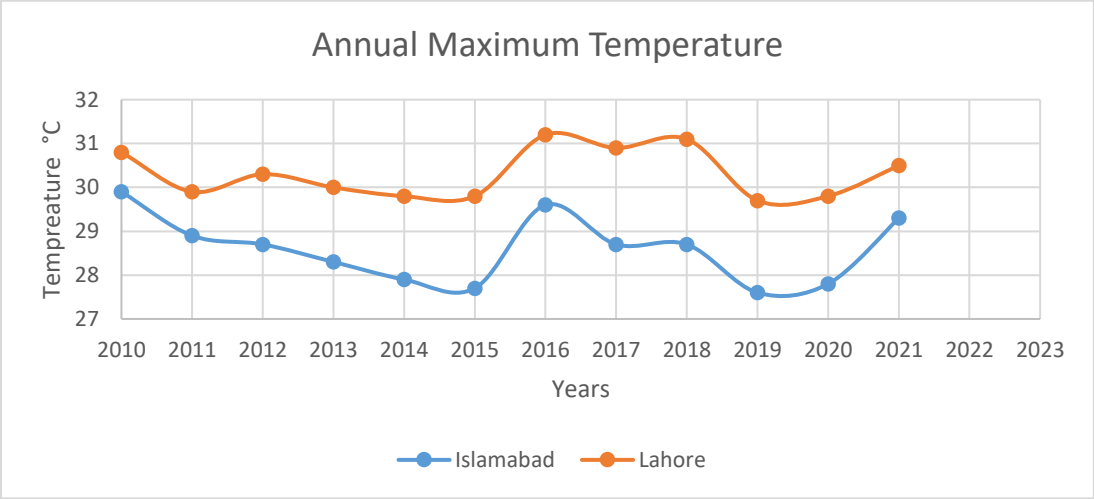


Fig.42 Annual Maximum Tempreture

The annual maximum temperature graph shows that Islamabad has an average temperature of 28.5 °C and Lahore has a temperature of 30.3 °C. Despite significant differences between the two cities, such as geologic location, climate, and industrial work, Islamabad's temperature is approaching that of Lahore's.

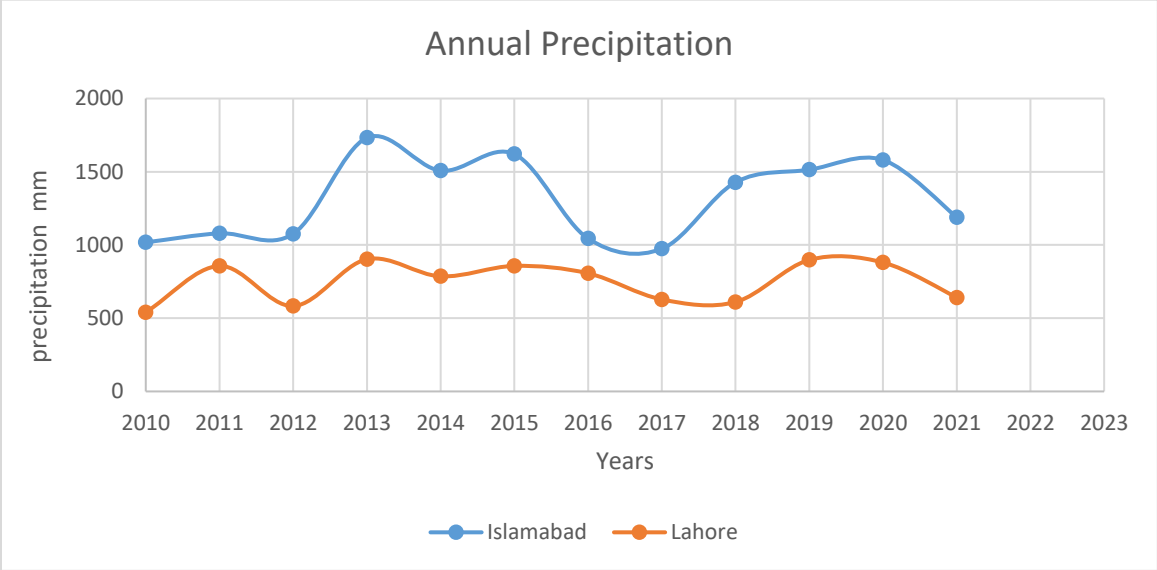


Fig.43 Annual Precipitation

In comparison to Lahore, which has an average annual rainfall of 749.3mm, Islamabad has a higher annual precipitation level of 1313.7mm. 2013 had the most precipitation for both Lahore and Islamabad, with Islamabad receiving 1732.4mm and Lahore receiving 902.8mm. Islamabad receives high levels of precipitation due to its high elevation, which causes more atmospheric moisture to condense and fall as rain.

4 Chapter 4

Recommendations

1. Encourage the use of public transportation, biking, and walking over personal vehicles to reduce carbon emissions.
2. Implement policies to promote energy efficiency and renewable energy sources in buildings and infrastructure.
3. Encourage and support the development of green spaces and urban forests to absorb carbon dioxide and improve air quality.
4. Encourage the sustainable management of natural resources like water and forests.
5. Encourage recycling and waste reduction programs to decrease the amount of waste sent to landfills.
6. Develop and implement regulations for industries and businesses to reduce their environmental impact.
7. Educate the public on the importance of taking action on climate change and how they can make a difference in their own lives.
8. Encourage and support local and sustainable agriculture to reduce the carbon footprint of the food system.
9. Create and put into action a thorough adaptation strategy to Islamabad's already felt effects of climate change.
10. Partner with other governments, organizations, and individuals to take collective action on climate change at the local, national, and global level.

5 Chapter 5
CONCLUSION

The study found that the climate in Islamabad and Lahore is changing, with increasing temperatures and precipitation levels. The increasing temperature in both Islamabad and Lahore will have a significant impact on the cities. The rise in temperature can lead to heat stress, which can cause health problems such as heat exhaustion, heat stroke, and dehydration. The elderly, young children, and those with pre-existing health conditions are particularly vulnerable to the effects of heat stress.

In addition to the health impacts, the rising temperature will also affect the environment and the economy. The increase in temperature can lead to droughts, which can cause water shortages and damage to crops. This will have a significant impact on the agricultural industry, leading to food shortages and economic loss. Furthermore, the increasing temperature will also exacerbate the issue of air pollution. The warmer temperatures will lead to the formation of ground-level ozone, which is a major component of smog. This will have a negative impact on the air quality in both cities, leading to respiratory problems and other health issues.

The rising temperature also causes discomfort which affects the productivity of people and can lead to absenteeism, which can have a significant impact on the economy, especially in Lahore, where the economy heavily relies on the productivity of the people.

The Pakistan Meteorological Department provided meteorological data for the years 2010-2022, which was used to create graphs to display monthly and yearly fluctuations. The contrast between the two cities demonstrates that Lahore's temperature and precipitation levels being significantly impacted by smog, while Islamabad's temperature is rising due to increased urbanization and anthropogenic activities that contribute to global warming. The study found that there is a significant difference in precipitation levels between the two cities, with an average rainfall of 1313.7mm in Islamabad and 749.3mm in Lahore. The study also found that the average minimum temperatures of Islamabad and Lahore are 14.1°C and 18.9°C, respectively, with an increase in rainfall being the main cause of the temperature reduction.

Despite Islamabad having less population, urbanization, and pollution than Lahore, the temperature has been rising over the past decade and is now posing a threat to the city. The increasing temperature in Islamabad and Lahore will have a significant impact on the health, environment, and economy of the cities, and it is important that steps are taken to mitigate these effects. This can be achieved through implementing policies that promote sustainable development, such as increasing green spaces, reducing emissions, and promoting energy efficiency.

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