

IMPACT OF URBANIZATION ON CLIMATE CHANGE: A CASE STUDY OF PUNJAB, PROVINCE OF PAKISTAN

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Abstract

Punjab has seen a sharp increase in urbanization in the last 30 years; it brought the multiple kind of socioeconomic development along with drastic changes in the climate of the Punjab. To this analysis 30 years (1990 – 2020) have used to examine how urbanization affects climate change in Punjab. The main factors are land use changes, temperature increases, rainfall variability, urban population growth, and CO₂ emissions. The results of econometric modeling (ARDL bounds testing approach) show a strong and favorable correlation between urbanization and climate change indicators; Punjab gets hotter and more vulnerable as our cities expand more quickly. Emissions of carbon dioxide, +0.31 ($p < 0.05$) which are directly related to urban activities such as industry, transportation, and energy use, also have a major positive impact on climate change. Climate stress, such as rising temperatures or deteriorating air quality, increases by 0.31 units for every unit increase in CO₂ emissions. This demonstrates how unchecked urban growth is escalating climate instability, particularly emissions and surface temperature. The integration of climate resilience and sustainable urban planning is suggested as a policy.

INTRODUCTION

The process of urbanization is multifaceted and dynamic, defined by the growing population density in urban areas, such as cities, towns, and the neighboring zones. It entails the movement of people from rural to urban regions, the enlargement of urban borders, and the construction of housing, services, and infrastructure to support the expanding urban population (FAO 2016). Urbanization is a worldwide occurrence, with differing rates in different areas and nations.

A few interrelated causes, such as industrialization, developments in technology,

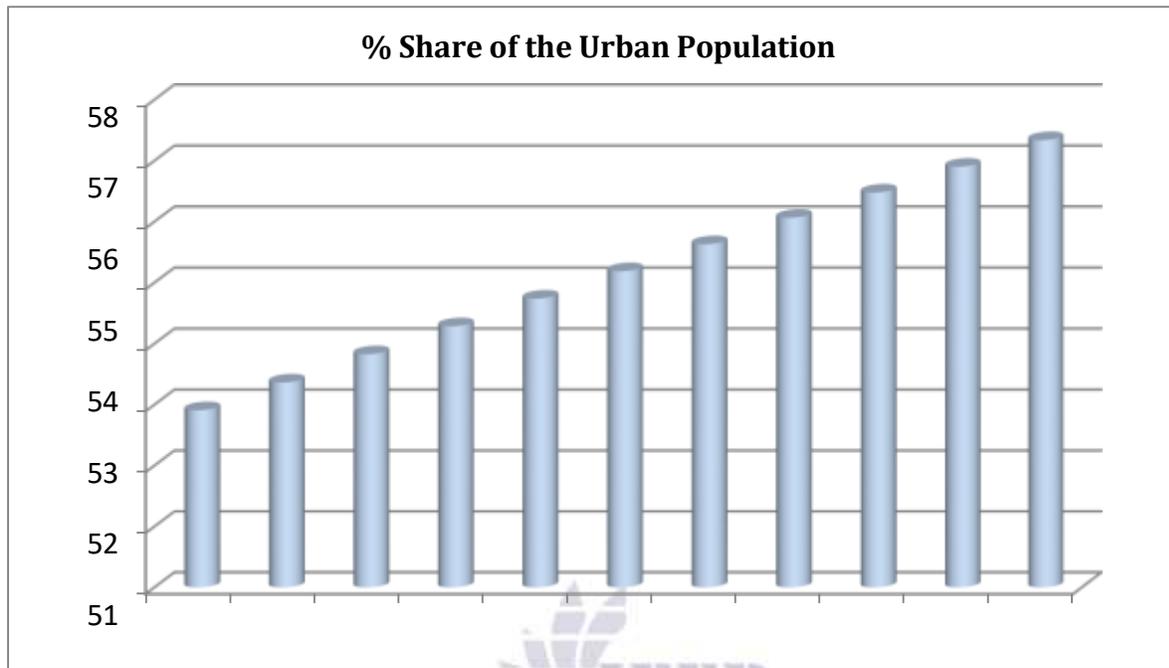
shifts in lifestyle preferences, and economic possibilities, all contribute to urbanization. It frequently results in a variety of beneficial and negative social, economic, and environmental changes that have an impact on people individually as well as in communities (Ayele .T. et al 2020).

China's urbanization has resulted in significant changes in both agricultural land and agricultural land use (Li 2013). The dominant anthropogenic activity on Earth is urbanization (Dawson. R. J et al, 2009). In the last fifty years, many developing countries have experienced the most rapid growth

in the number of cities and towns (Jiang, L. et al 2013). This paper explores how urbanization in Punjab has contributed to climate change and

what can be done to mitigate its effects while planning for a sustainable urban future.

Urbanization in the World (Figure 1)

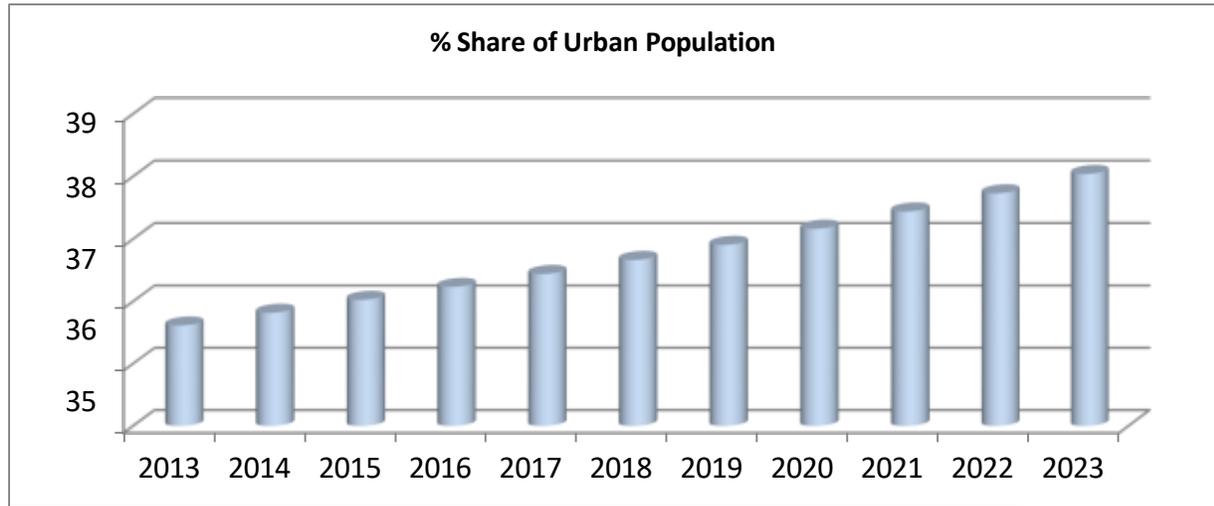


Source: World Bank Reports 2023

Over the past 50 years the share of the world's population living in urban areas has risen from 37 % to 56 % (World Bank, 2023).The demographic shift from rural to urban areas is set to continue, with the share of the urban population at the global level expected to reach 68 % by 2050 (UN, 2022).Lower-income countries are currently experiencing rapid urban expansion and land-use change (Amour, 2021).

It is estimated by United Nations Population Division that nearly half of the country's population will be living in urban areas by 2030 (Jadoon & Mubasher, 2019). In Pakistan, while the number and size of cities is increasing, the country is unable to take advantage of this since the cities are poorly governed (Hussain, 2018). Pakistan has about 36.5% of the total population lived in the urban area, due to rapid urbanization and industrialization cities were facing several problems (Ghalib et al., 2018).

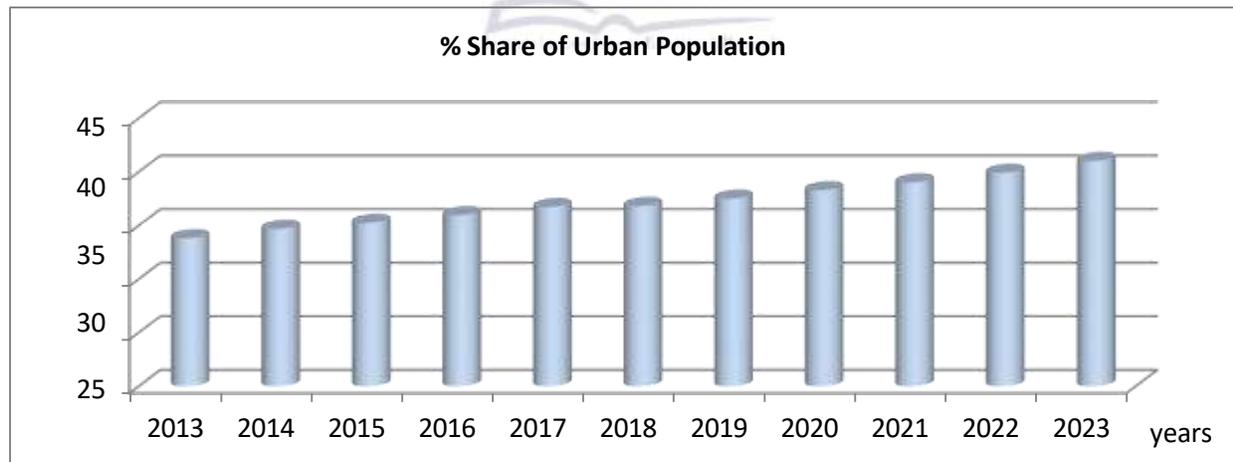
Urbanization in the Pakistan (Figure 2)



Source: Federal Bureau of Statistics 2023
About 31% of Punjab’s population lived in urban areas in 1998, a figure which rose to over 41% by 2023 (Federal Bureau of Statistics, 2023). Punjab - the most populous province covering an area of nearly 205,345 sq. km (Talat and Anwar, 2018).

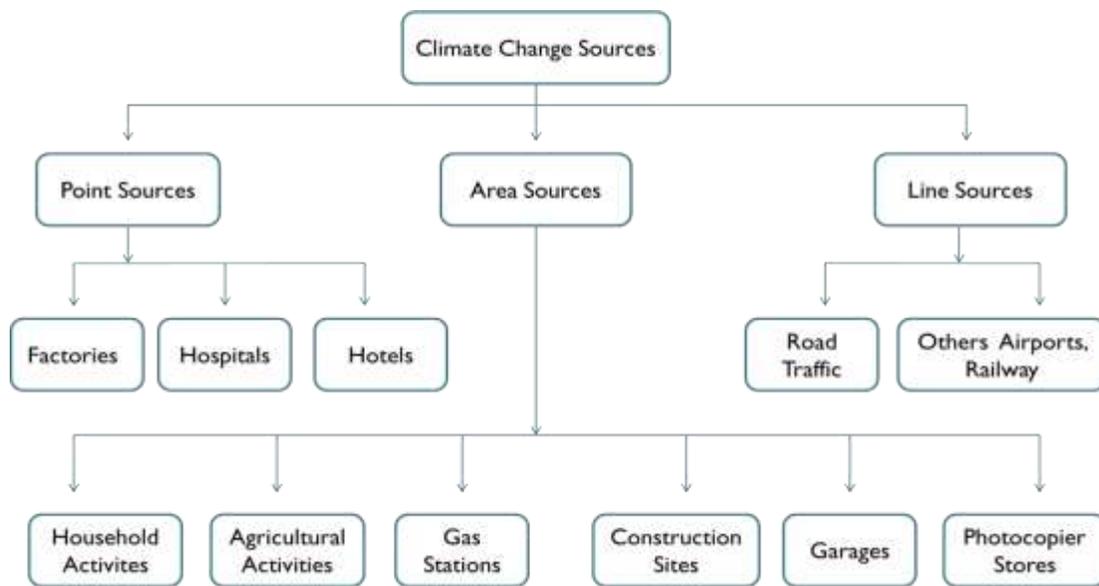
Urbanization in Pakistan creates issues such as environmental deterioration construction of residential societies that negatively impact the arable land and resultantly impact food production adversely (Rana & Bhatti, 2018).

Urbanization in the Punjab (Figure 3)



Source: Federal Bureau of Statistics 2023

(Figure 4)

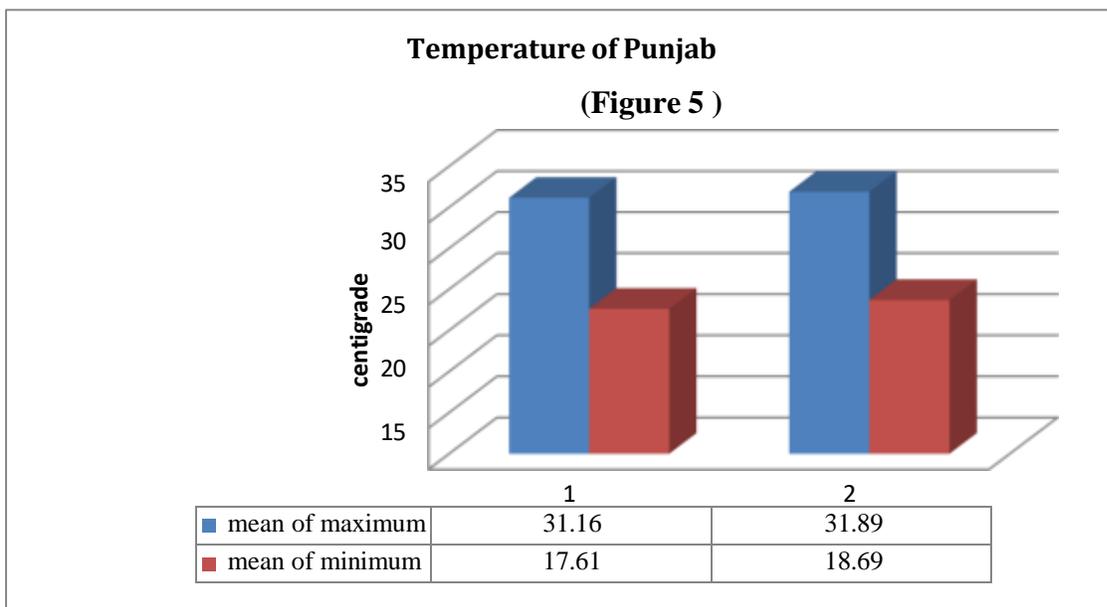


Source Emission inventory of Punjab 2022

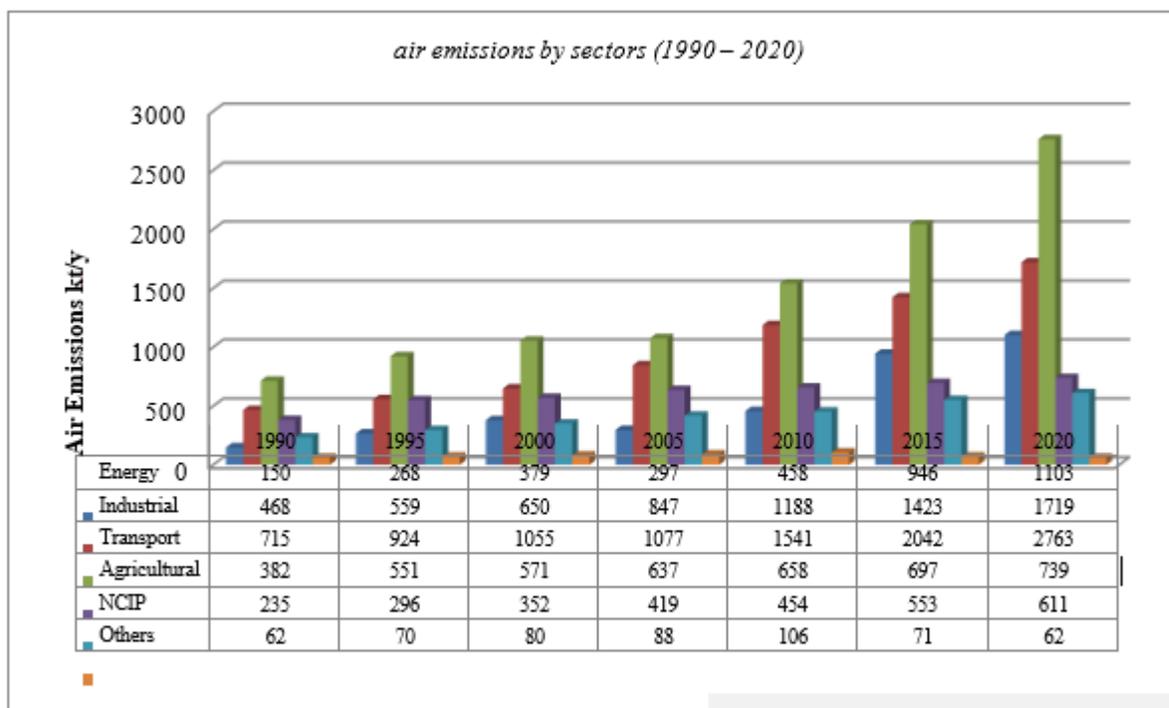
Pollution is another outcome of haphazard and unplanned urbanization. The study revealed that rapid urbanization is creating environmental issues in the urban areas such as air pollution, poor water quality, Sanitation and wastewater treatment, Increase the temperature of Earth, increasing slums areas (Gao, J., & Bukovsky, M. S. 2023). (Li, Y., & Gao, K. 2022). (Avtar, R. et al. 2019). Human instinct has always been an important factor in shifting land usage and environmental damage. The primary cause of land use changes is a shift in social goals and increased demand for human necessities (Turner. E. et al,

2009). Human nature has always had a significant impact on land-use changes.

Changing precipitation patterns, shifting vegetation zones, and rising sea levels long hours of backbreaking work, insufficient amounts of food and poor diets, lack of access to safe drinking water, susceptibility to preventable diseases, and housing are the factors which influenced by urbanization (Michael R. 2014). The loss of these lands under urban expansion has important environmental and socio-economic impacts (Frumkin, 2016; Johnson, 2011; Lambin et al., 2019).



Source Emission inventory of Punjab 2022



Source Emission inventory of Punjab 2022

Figure 9 presents the mean of minimum and the maximum temperature in the Punjab in the last 10 years, which shows that both the minimum and maximum temperature have increased. In the figure 10 air emission entry is shown from the last

23 years of Punjab. The diagram shows that energy, industrial and the transport sector contribute to air pollution. The three sectors increase air pollution by 4 to 5 times as compared to 1990. (Figure 6)

3. Problem Statement

Despite the economic gains of urbanization in Punjab, the environmental consequences, particularly climate change, remain poorly understood and insufficiently addressed in policy. There is a pressing need to examine the causal relationship between urbanization and climate variables to inform long-term planning and environmental sustainability strategies in the region.

4. Objectives

First objective of this analysis is to investigate the consequences of urbanization on climate change in Punjab, and second objective is to provide insights for addressing challenges and ensuring future sustainability of climate change amid rising urbanization.

5. Hypothesis

H1: Urbanization has a statistically significant positive impact on climate change indicators (e.g., temperature, CO₂ emissions) in Punjab
 H0: Urbanization has no significant impact on climate change indicators in Punjab.

One of the oldest areas on the subcontinent of South Asia, Punjab is important to Pakistan's history, culture, and economy. Over the past 50 years Punjab has seen significant expansion and urbanization (Kitamura & Jamilah, 2009). The province has undergone a number of changes during this time, including changes in the economy, infrastructure, and population (Saddique M.H 2011). We shall examine Punjab's history, key factors influencing its urbanization, noteworthy advancements, and obstacles it encounters in this thorough investigation



(Source : Government of Pakistan, 2024).

Punjab is Pakistan's most industrialized province, with the industrial sector accounting for 24% of its GDP. It is noted for its relative prosperity and has the lowest poverty rate of any Pakistani provinces (Arif and Farooq, 2013). However, there is a significant divide between the province's northern and southern sections, with northern Punjab being more developed than south Punjab. Punjab is also one of South Asia's most urbanized regions, with over 40% of the people living in cities (Cheema *et al.*, 2010).

6. Data and Methodology

This study uses secondary time series data from 1990 to 2020. Key variables include Urban

Population Growth (UPG), CO₂ Emissions, Average Annual Temperature, and Rainfall. Data sources include Pakistan Bureau of Statistics, World Bank, and Pakistan Meteorological Department. The Autoregressive Distributed Lag (ARDL) model is used due to the mixed order of integration (I(0) and I(1)). The model explores the long-run relationship among the variables, supported by ADF stationarity tests, bounds testing, and diagnostic checks.

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checks.

Data Collection Methods

Climate reports from

- local environmental agencies,
- satellite imagery for land cover changes, and
- Temperature, Heat waves, precipitation, drought data

Methodology:

Econometric Model

- Use GIS to map climate changes.
- Statistical analysis of pollution levels,
- Correlate urbanization trends with weather and climate indicators

ARDL (Autoregressive Distributed Lag) Model: can be applied to understand the relationship between the dependent and the various independent variables (Raza.Y et al 2023). Error

7.2 Graphs

Correction Model is considered as an alternative model to capture the relationship of mentioned variables (Imran, A. 2017).

$$\Delta CC_t = \alpha_0 + \sum_{i=1} \alpha_1 \Delta UR_{1t-i} + \sum_{i=1} \alpha_2 \Delta IG_{2t-i} + \sum_{i=1} \alpha_3 \Delta CE_{3t-i} + \sum_{i=1} \alpha_4 \Delta ESE_{4t-i} + \sum_{i=1} \alpha_5 \Delta RF_{5t-i} + \epsilon_t$$

Dependent Variable

Climate Change (CC) (Temperature)

Independent Variables

- Urbanization Rate (UR)
- Industrial Growth (IG)
- CO₂ Emission (CE)
- Energy Sector Emission (EC)
- Rainfall (RF)

7. Results and Discussion

7.1 Descriptive Trends

- Urban population in Punjab grew from 29% in 1990 to over 40% in 2020.
- Average annual temperature increased by ~1.2°C over 30 years.
- Rainfall patterns showed more variability with short, intense precipitation events.
- CO₂ emissions increased significantly, mainly due to transport and industrial sectors.

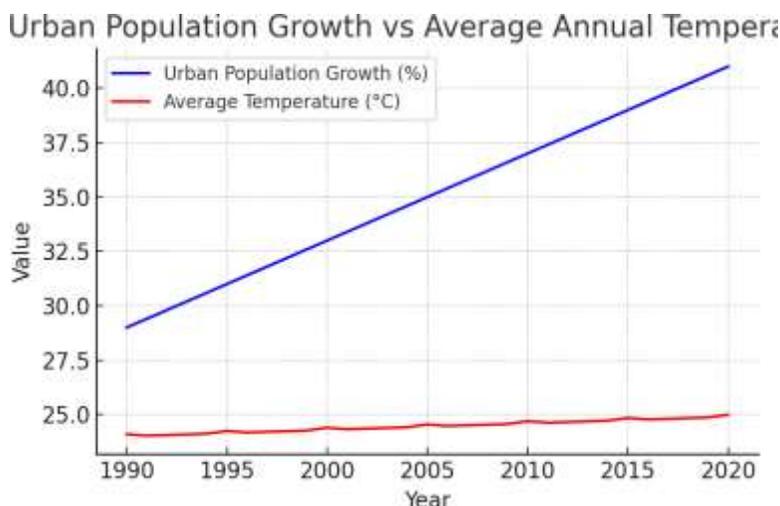


Figure 1: Urban Population Growth vs Average Annual Temperature (1990–2020)

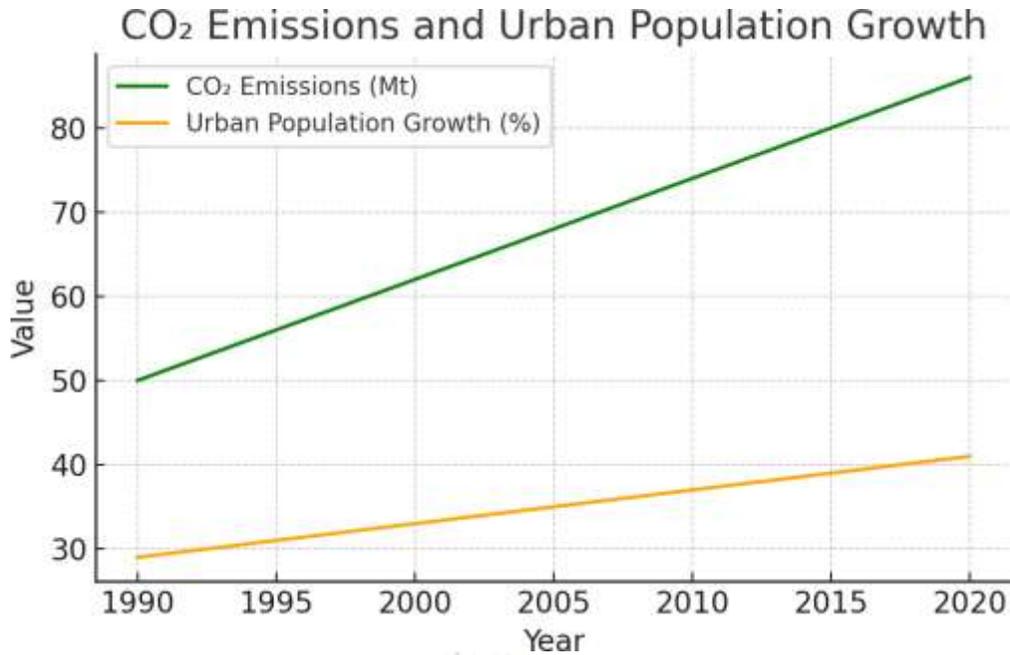


Figure 2: CO₂ Emissions and Urban Land Expansion

Descriptive analysis shows a consistent rise in urban population, temperature, and emissions in Punjab. ARDL bounds testing indicates a long run cointegrating relationship between urbanization and climate variables. Urban

population growth and CO₂ emissions significantly impact average temperature, validating the hypothesis that urbanization contributes to climate change in Punjab.

ARDL Bounds Test Results

Variable	Coefficient	t-Statistic	Significance
UPG (urban growth)	+0.42	3.68	*** (p<0.01)
CO ₂ Emissions	+0.31	2.74	** (p<0.05)
Rainfall	-0.11	-1.22	NS

- Long-run relationship confirmed by F-statistics = 5.84 > upper bound (critical value at 5% = 4.01).
- Model passed residual normality, heteroscedasticity, and serial correlation tests.

Interpretation:

Urban population growth significantly contributes to climate change via increased CO₂ emissions and urban heat island effects. Rainfall showed no statistically significant relation, likely due to natural variability.

This finding is extremely important because it demonstrates how Punjab is becoming hotter due to urbanization, concrete infrastructure, vehicle emissions, and energy demand. By absorbing more solar radiation and upsetting the local climate equilibrium, cities are turning into heat islands. Punjab gets hotter and more vulnerable as

our cities expand more quickly. **Emissions of CO₂: +0.31 (p<0.05)** Emissions of carbon dioxide, which are directly related to urban activities such as industry, transportation, and energy use, also have a major positive impact on climate change. Climate stress, such as rising temperatures or deteriorating air quality, increases by 0.31 units for every unit increase in CO₂ emissions. This demonstrates how unchecked urban growth is escalating climate instability.

Urban growth is accelerating climate change at an alarming rate, and the numbers don't lie. Urbanization (UPG) and increasing climate pressures are strongly and statistically significantly correlated, according to the regression analysis, with urban growth causing environmental degradation to sharply increase ($\beta = +0.42$, $p < 0.01$). Climate stress is exacerbated by every percentage point of urban growth, proving that our concrete jungles are not only growing but also warming the planet.

1. Carbon Surge.

Urban Sprawl Urban growth and CO₂ emissions are directly and quantifiably linked, according to the data ($\beta = +0.31$, $p < 0.05$). Cities are carbon-spewing machines because of their endless highways, skyscrapers, and energy requirements. We burn more—forests, fossil fuels, and our future—the more we construct.

2. Patterns of Rainfall Under Siege.

The negative coefficient suggests a troubling trend: sprawling cities may be changing local climates, upsetting water cycles, and causing droughts, even though the effect of urbanization on rainfall was not statistically significant in this model ($\beta = -0.11$, $p > 0.05$). Although the signal is currently weak, the atmospheric footprint of megacities may increase as they expand.

The Big Picture: A Tipping Point Planet This is a warning, not just data. Climate change is being accelerated by urbanization, which is converting thriving ecosystems into carbon traps and heat islands. There will be disastrous repercussions if we don't stop: more severe weather, oppressive pollution, and irreparable ecological harm. "Punjab's urban boom is not just reshaping skylines—it's rewriting the region's climate

story."As urban areas spread and emissions rise, temperatures climb, climate stability weakens, and the future of sustainable living hangs in the balance. If we fail to plan for sustainable cities today, we will inherit unlivable climates tomorrow.

8. Policy Recommendations

1. Promote sustainable urban development with green infrastructure.
2. Strengthen public transport to minimize vehicular emissions.
3. Enforce emission control regulations on industries and transport.
4. Develop climate-resilient urban policies integrated with environmental frameworks.
5. Preserve green spaces through urban forestation and planning norms.

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