PROJECT

FUTURE PROJECTION OF CLIMATE AT DHAKA CITY OF BANGLADESH

Submitted To

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1.INTRODUCTION

By 2050, the world's population is expected to reach 9.6 billion, with around 66% living in urban areas . This shift is happening rapidly, particularly in developing countries where the majority of people have been living in cities since 2017 . Urban growth, driven by migration from rural to urban areas, has created dense, overburdened cities that are especially vulnerable to the impacts of climate change. In cities with limited infrastructure and management capacity, these risks are compounded, making adaptation essential for protecting urban populations. Without effective adaptation strategies, people in developing countries are expected to face even greater climate challenges in the future.

Dhaka, the capital of Bangladesh, exemplifies these challenges. With a population of approximately 14.6 million people crowded into an area of just 1,530.84 km², Dhaka has an extremely high population density. The city's rapid population growth has outpaced physical expansion, leading to severe strain on essential services. Many residents, particularly those in informal settlements, have limited or no access to safe water, reliable energy, sanitation, waste disposal, healthcare, and education. Dhaka's vulnerability is further exacerbated by weak institutional capacities, limited resources, and inadequate infrastructure, ranking it among the most at-risk cities in the world with regard to climate change.

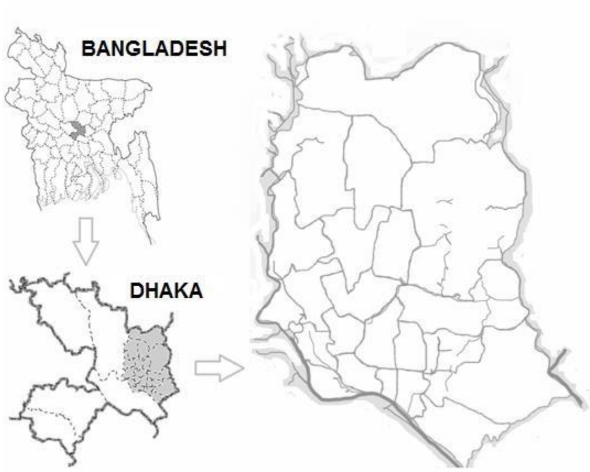
Geographically, Dhaka is located in central Bangladesh on the Ganges Delta, which is prone to seasonal flooding. Dhaka's climate is characterized as wet and humid, with annual rainfall between 2,000 mm and 3,000 mm. Climate projections suggest significant increases in temperature and shifts in rainfall patterns due to global warming, which will likely trigger more frequent extreme weather events in Dhaka]. These changing conditions are expected to further increase the vulnerability of the city's population to climate risks.

Understanding these shifts in Dhaka's climate is essential for planning effective adaptation strategies. This project uses statistical methods to analyze current climate trends and future projections for Dhaka, with the aim of assessing how climate change may impact the city's infrastructure and the lives of its residents. We also explore possible adaptation measures that could help increase Dhaka's resilience to climate change. The results of this study are intended to support policy makers and urban planners in developing the necessary strategies for climate adaptation and mitigation.

2.MATERIALS AND METHODS

2.1 Data and Sources

This study on climate change impacts in Dhaka is based on an analysis of historical data and projections of climate variables and extreme weather events. We used long-term daily rainfall and temperature data (1901–2015) from a meteorological station in Dhaka, sourced from the Bangladesh Meteorological Department. Data quality checks were performed to eliminate errors, such as cases where precipitation was recorded as negative, winter rainfall exceeded 100 mm, or temperature values were anomalously low or high. These steps ensured reliable calculations and trend assessments. A histogram of daily rainfall showed no issues with the data, and both subjective double-mass curves and objective statistical tests confirmed its



homogeneity.

To downscale future climate projections for Dhaka, we sourced predictor variables from the National Center for Environmental Prediction (NCEP) reanalysis dataset. A total of 26 variables typically projected by climate models, including the Hadley Centre Climate Model (HadCM), were analyzed to select relevant predictors. For projecting future rainfall and temperature, we used data from the HadCM3 global circulation model (GCM), enabling detailed downscaling of future climate scenarios for Dhaka.

2.2 Trend Analysis of Climate and Climate-Related Extremes

To analyze trends in climate data and extreme events in Dhaka, we used the non-parametric Mann–Kendall (MK) trend test. This test is suitable for identifying monotonic trends in time series data without requiring it to follow a specific distribution. Additionally, we used Sen's slope method to estimate the rate of change (slope) in the data.

In the MK test, data points are evaluated as an ordered time series. Let x1,x2,x3,…,xix_1, x_2, x_3, \dots, x_ix1,x2,x3,…,xi represent a sequence of nnn data points, where xjx_jxj is the data value at time jjj. The Mann-Kendall statistic S is

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

Where: $sing(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_j > 0 \\ 0 & if\ x_j - x_j = 0 \\ -1 & if\ x_j - x_j < 0 \end{cases}$

Normalized test statistic Z is computed as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAS(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAS(S)}} & if\ S < 0 \end{cases}$$

computed as:

The null hypothesis of no trend is rejected at p=0.01, if 575 . 2 > Z ; and at p=0.05, if 96 . 1 > Z . Sen's method proceeds by calculating the slope as a change in measurement per change in time,

Where, $Q/$ is slope between data points / t x and t x ; / t x is data measurement at time / t , and t x is the data measurement at time t. Sen's es

$$Q = \begin{cases} Q'_{[\frac{n+1}{2}]} & if\ N\ is\ odd \\ \left(Q'_{[\frac{N}{2}]} + Q'_{[\frac{n+1}{2}]}\right)/2 & if\ N\ is\ even \end{cases}$$

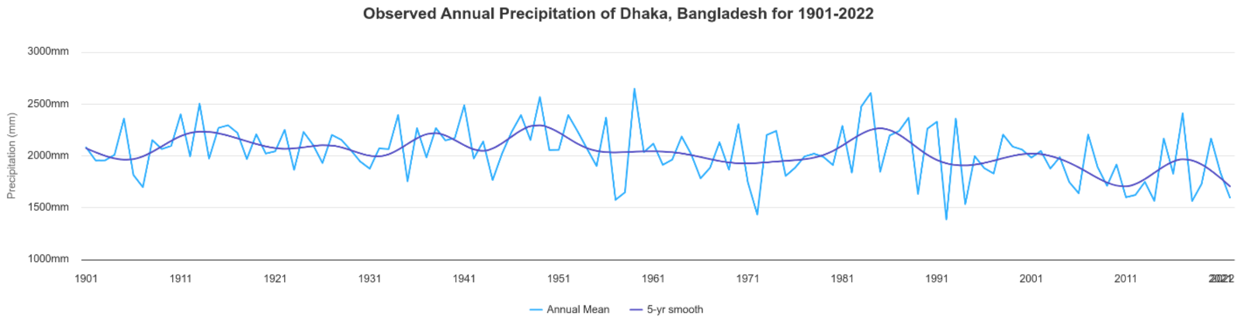
Where, N is the number of calculated slopes. Confidence levels of 90%, 95% and 99% were set as thresholds for determining significant temperature trends. A number rainfall and temperature-related extreme indices were estimated some of which were based on thresholds defined as percentiles. The percentiles were calculated from the reference period 1961-1990, which is considered the "current climate normal period" by the World Meteorological Organization

. The indices include

i. days with rainfall more than 20 mm;
ii. days having rainfall more than 95 percentile of the rainfall in reference period;
iii. continuously dry days in a year;
iv. continuously wet days in a year;
v. days having maximum temperature more than 32°C;
vi. days having minimum temperature more than 25°C.

2.3 Statistical Downscaling Model

Statistical Downscaling Model (SDSM) was used to project future change in rainfall and temperature at Dhaka city. SDMS is a widely used downscaling tool developed by Wilby and Wigley. SDSM uses multiple linear regression technique for the development of downscaling model. It develops the model by establishing the statistical relationship between the predict and predictors in the first step and then simulate the future series of predict and by using the predicted data from GCMs. SDSM uses two separate sub-models to determine the occurrence and the amount of conditional meteorological variables (or discrete variables) such as precipitation. Therefore, SDSM can be classified as a conditional weather generator in which regression equations are used to estimate the parameters of daily precipitation occurrence and amount, separately. Therefore, it is more sophisticated than a straightforward regression model. In this study, climate projections by HadCM3 model under B2 scenario were used to projection climate change in future at Dhaka city.



3. Data Processing and Analysis

3.1 Tools Utilized

NumPy

Building on the power of Python, I utilized NumPy to handle numerical calculations efficiently. NumPy is renowned for its ability to perform array-based operations, allowing for fast and efficient processing of large datasets.. Its ability to perform complex mathematical computations with ease significantly sped up the analytical process, enabling deeper insights into the data.

Pandas

For data manipulation, Pandas was my go-to library. It transformed the way I worked with the seismic dataset by providing powerful data structures, specifically DataFrames, which are ideal for handling tabular data. With Pandas, I could effortlessly load the dataset, clean it by addressing missing values, and reorganize it to prepare for analysis. The library's intuitive functions made it easy to filter data, group it by specific attributes, and perform operations that would have been cumbersome with basic Python alone.

Matplotlib

To visualize the patterns and trends emerging from the dataset, I turned to Matplotlib, one of the most widely used libraries for data visualization in Python. Matplotlib allowed me to create a variety of static, animated, and interactive plots, bringing the data to life in a visual format. I used it to generate basic plots that illustrated key findings, such as frequency distributions of the temperature and rainfall.

3.2 Data Processing

At first load the dataset in in python:

	tem	Month	Year	rain
0	16.9760	1	1901	18.5356
1	19.9026	2	1901	16.2548
2	24.3158	3	1901	70.7981
3	28.1834	4	1901	66.1616
4	27.8892	5	1901	267.2150

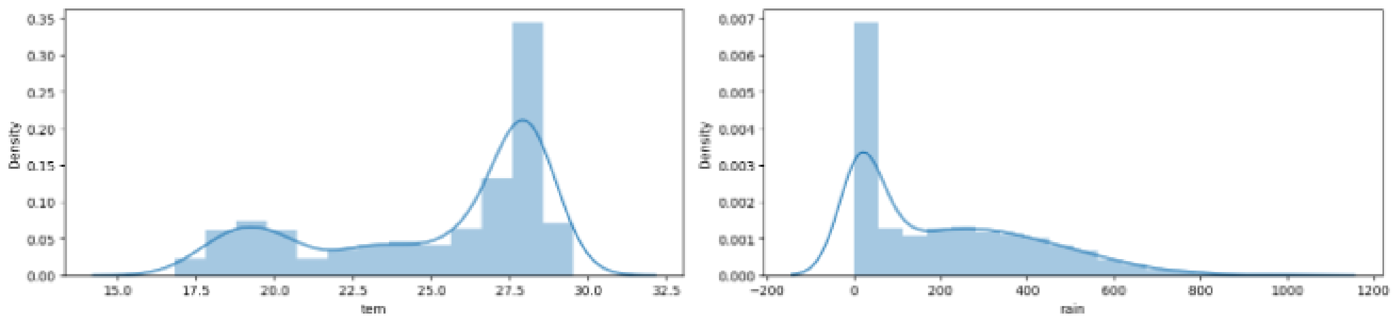
Check which column of the dataset contains which type of data:

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1380 entries, 0 to 1379
Data columns (total 4 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   tem     1380 non-null   float64
 1   Month   1380 non-null   int64  
 2   Year    1380 non-null   int64  
 3   rain    1380 non-null   float64
dtypes: float64(2), int64(2)
memory usage: 43.2 KB
```

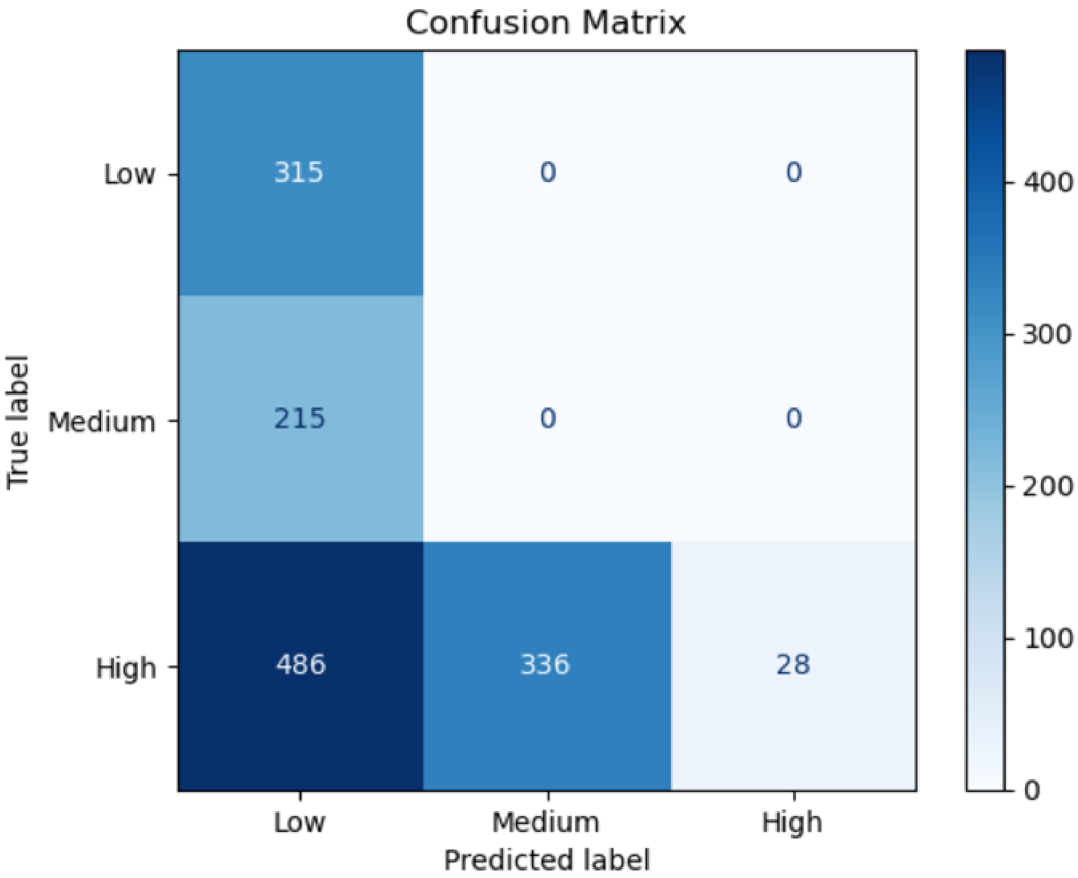
Finding the null value and cleaning process and also remove the unnecessary data from the data set.

	count	mean	std	min	25%	50%	75%	max
tem	1380.0	25.066213	3.682411	16.8006	22.114125	27.01295	28.00785	29.526
Month	1380.0	6.500000	3.453304	1.0000	3.750000	6.50000	9.25000	12.000
Year	1380.0	1958.000000	33.208420	1901.0000	1929.000000	1958.00000	1987.00000	2015.000
rain	1380.0	203.275431	202.730898	0.0000	18.498850	145.08600	347.63950	1012.020

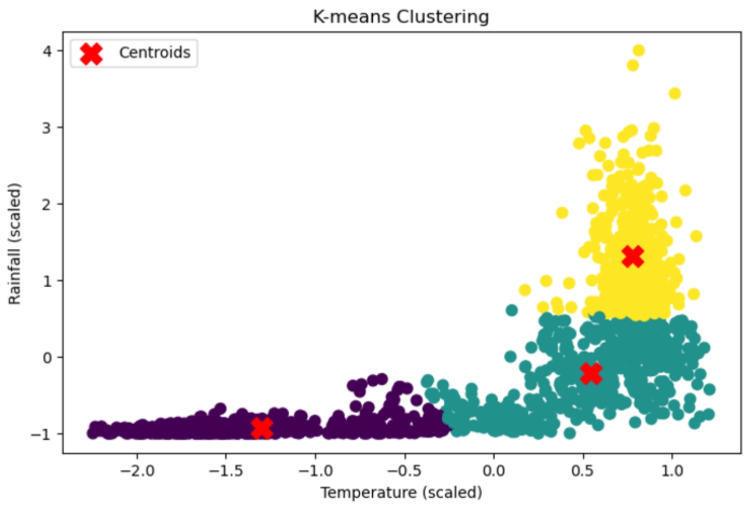
Now find the result of the temperature variation and rainfall variation

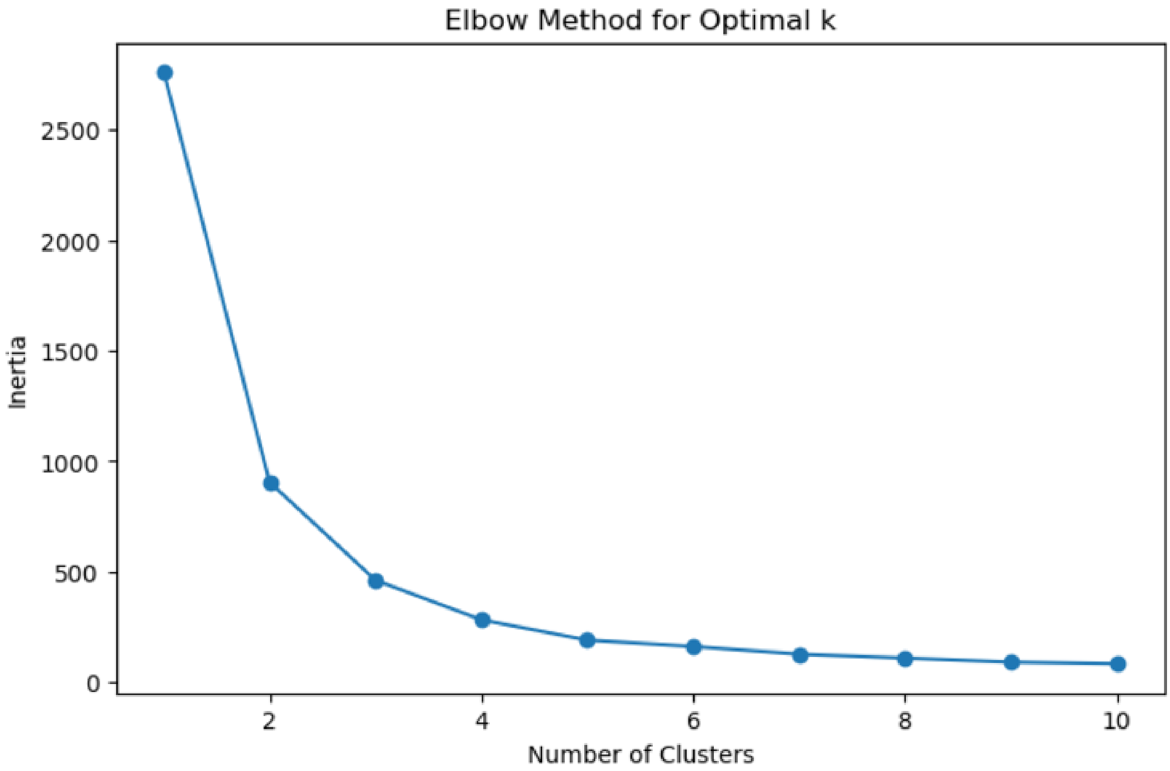


By using confusing matrix we can be defile the maximum and the low value and can be calculate the value from the dataset.



We can also calculate the **K-means clustering value** for measuring the centroids value for accuracy





4.0 POSSIBLE IMPACTS AND ADAPTATION OF CLIMATE CHANGE IN DHAKA

CITY From the above studies, it can be summarized that significant increase of temperature and temperature related extreme events, but almost no change in rainfall and rainfall related extreme events in Dhaka city in last fifty years. Increased temperature in Dhaka city is mostly due to the effect of urban heat island effect. Future projection of climate at Dhaka city by SDSM reveals continuous increase of temperature in Dhaka city. The vulnerability of climate change on urban population of Bangladesh is measured by considering certainty and timing of impact. Certainly of impact uses available knowledge of climate change to assess the likelihood of impacts and the timing implies whether they are likely to manifest themselves in the first or the second half of this century. The present study shows that the urban areas of Bangladesh are already facing an increased daily temperature and related extreme events. Though an increase of rainfall in Bangladesh has been predicted by most of the climate models, it is still not significantly visible in Bangladesh. Therefore, it can be concluded that imminent impacts of climate change in Bangladesh will be due to the higher daily temperature and temperature related extreme events. The impacts will certainly be very much diverse from public health to urban water system and energy demand. However, public health and urban infrastructures viz. water supply and power supply would be the most imminent affected sectors of climate change in the city.Analysis of climate change impacts on various urban sectors suggest that development of climate resilient infrastructure is essential for Dhaka city, which should include up gradation or retrofication of poor structures, replacement of vulnerable infrastructure, redesigning of urban flood control infrastructure, development of resilient water and sanitation systems, planning energy efficient construction, etc. It is necessary to incorporate climate change issues into every planning, design, construction, operation and maintenance of urban infrastructure. The structural measures to adapt with climate change will certainly cause huge financial burden for Bangladesh.

5.0 CONCLUSION

Historical rainfall and temperature data of Dhaka city was analyzed to assess the recent changes in the climate of Dhaka. SDSM was also used to downscale future projections of climate at Dhaka city. The study revealed that the climate change would cause continuous increase of rainfall, temperature and weather related extreme events in Dhaka. However, the most imminent impacts of climate change in Dhaka will be due to the rise of temperature and related extremes, such as, frequent outbreak of tropical diseases, scarcity of water, increased demand of power, etc. It is necessary to incorporate climate change adaptation guidelines into all planning, design, construction, operation and maintenance of urban infrastructure of Dhaka city. It is expected that the finding of present study will help to enhance the knowledge on ongoing changes in the climate and climate related extreme events, possible future scenarios of climate, impacts of climate change on different sectors of Dhaka city according to their certainty and timing. It will also help to identify the possible adaptation measures to mitigate the negative impacts of climate change in Dhaka, which is the political and financial center of the country. Appropriate strategies based on the climate information presented in this paper will reduce the vulnerability of urban livelihoods and infrastructures to future climate change and contributes to achieve sustainability in resources.

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