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MULTI-DECADAL GLOBAL CLIMATE TRENDS: A DESCRIPTIVE ANALYTICS ASSESSMENT

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Abstract
Today, climate change is one of the biggest problems globally. The earth's temperature has increased, rainfall patterns have changed, and floods, heatwaves, and storms have become more common over many years. This study looks at climate factors such as changes in Earth's temperature, extreme weather events, the amount of carbon dioxide CO2 in the air, and rising sea levels from 1980 to 2025. Simple methods for finding trends, average comparisons, and graphs are used to understand the data. The results show that the earth is getting warmer, Greenhouse gases are increasing quickly, and climate conditions are changing in many parts of the world. These findings show that climate change is becoming more serious. This study explains why it is important to make smart plans, use data to create rules and policies, and keep watching climate changes in the future

INTRODUCTION

Climate change means long-term changes in the climate of earth. These changes are happening due to human activities, to burning fossil fuels, factory pollution, and cutting down trees on Earth [1]. Over many years, researchers and scientists have noticed a big change in Earth's temperature, oceans, air around the Earth, and the number of extreme weather events like heatwaves, storms, and floods [2]. Understanding these changes helps us to know how serious it is and how we can reduce its effects and protect the world from this serious issue.

Today, modern technologies, such as remote sensing, satellite, and automatic weather stations, collect a large amount of climate data [3]. This data helps the scientists to study more precisely and clearly. The descriptive method is a simple method to study this by summarizing it and finding the patterns. It helps the researcher and scientist to notice important, unusual events, changes in weather, and long-term trends in the climate.

This study uses descriptive methods to study the climate changes from 1980 to 2025. By studying things like carbon dioxide (CO_2) levels, temperature changes, extreme weather, and rising sea levels. The current study helps us to understand how the Earth's temperature is increasing yearly, why the climate is changing over time, and why it is important to protect the environment from this serious concern.

Problem statement

Although a lot of data on climate change is available today, there is still a need to study long-term climate changes precisely and clearly in an organized way [4]. Many studies show the future climate change trend, or climate change effects, some show simply climate change past data using easy numbers and charts [5]. Because of this, decision-makers, researchers, and environmental planners find it harder to fully understand how climate factors have changed over time. So it is very important to study and summarize global climate data to help everyone understand climate change better.

The primary purpose of this study is to understand how global climate indicators and phenomena are changing over time. Additionally, the study provides an overview of variability (how often an indicator has deviated from its norm) and describes the long-term trends associated with climate indicators using descriptive analyses.

Research Objectives

This study will analyze the global climate data on a long time scale using a descriptive method. The following objectives will be achieved to help achieve this overall purpose:

- To obtain and pre-process a long-term climate database that has been established by known Global Climate Agencies.
- To use descriptive analytic techniques (both graphical and tabular) to characterize the long-term patterns of temperature changes, CO_2 emissions, coastal ocean rise, and natural disasters (extreme weather).
- To evaluate and compare climate data across different geographic areas, identifying geographic areas that are experiencing substantial climate changes.
- To interpret the results of the analyses and provide an overview of their implications for climate policy, adaptation strategies, and direction for future study.

Literature Review

Climate change is the result of long-term changes in the Earth's climate system, which includes changes in Earth's temperature, amount of rainfall, amount of sea level rise, and the frequency/intensity of extreme weather events [6]. The reports from the Intergovernmental Panel on Climate Change (IPCC) have shown that the global climate is warming at a faster rate than before, and most likely because of human activities such as burning fossil fuels, emitting industrial gases, and cutting down forests (deforestation) [7]. The most significant changes occurred after the late twentieth century and particularly after 1980, with global Mean Surface Temperature increasing significantly [8]. These Temperature increases are related to the changes in the atmospheric composition, increased ocean heat content, melting glaciers and ice sheets, and interruption of the natural Ecosystems [9].

An extensive number of studies have been conducted on how significant a role greenhouse gases, particularly carbon dioxide (CO_2), have in driving climate change [10]. Evidence from ice core samples, atmospheric monitoring stations, and long-term observational data has indicated increasing levels of CO_2, which have risen from pre-industrial levels (280 ppm) to levels peaking over 420 ppm [11]. This increase has been largely linked to human activity associated with energy production, transportation, and land-use change. The presence of higher levels of greenhouse gases, such as CO_2, creates a greater greenhouse effect within Earth's atmosphere and, thus, leads to higher levels of heat being trapped and contributing to Global Warming and Climate change-related effects [12].

The global average temperature has consistently risen since the 1980s, based on long-term temperature data from weather stations around the world and satellite observations [13]. The last few decades have been the hottest in recorded history. The warming is not distributed evenly across the globe. Regions within the polar region have experienced a greater rate of warming than other regions [14]. From observational studies, we are seeing evidence of changing weather patterns, including an increase in the frequency and severity of extreme heat events, which will have tremendous consequences on both human health, food production, and energy consumption.

As one of the main components of the climate system, the Ocean absorbs excess energy and carbon dioxide from the atmosphere [15]. Scientific data indicate that at least half of the additional heat generated by Global Warming has been absorbed by the Ocean, resulting in an increase in sea surface temperature and ocean heat content since 1980. As Ocean temperatures increase, ocean volume increases through thermal expansion, and combined with the melting of glaciers and polar ice caps, will contribute to rising sea levels [16]. The changes in Sea Level will be a major issue for Coastal Communities, Marine Ecosystems, and Human settlements.

The relationship of climate change with the frequency and severity of extreme weather events can be understood by reviewing descriptive long-term climate records. In long-term climate records, there is evidence of an increase in both the frequency and severity of heat waves, torrential downpours, flooding, drought, and tropical storms [17]. Although natural variations in climate can affect weather patterns, many of the changes occurring today correlate with the long-term warming trend associated with human-caused climate change. Higher global temperatures have an impact on the global hydrological cycle by creating wet climates in certain areas and dry extremes (drought) in others.

With advancements in the collection of climate data, researchers have gained a much greater understanding of long-term climate change. Remote Sensing, satellite technologies, and automatic meteorological stations have provided continuous, large-scale observations of temperature, precipitation, sea level, Ice Cover, and atmospheric composition [18]. Long-term satellite records from multiple years have been an asset in understanding long-term climate changes and identifying global climate change patterns over time, as they provide researchers with a consistent and clear picture of past and current climate change patterns [17].

To communicate the impacts of climate change, descriptive analysis provides an approach for collating and describing a large amount of climate data that is simple to understand. Descriptive methods help to show how climate indicators have changed over time by focusing on averages and extreme values, hopes and despair, variations in weather patterns, etc. The findings of the studies conducted through descriptive analysis are most useful to lawmakers, policy experts, environmental planners, and the general public in that descriptive analysis provides an easy-to-understand and reliable means to communicate and interpret the seriousness of climate change.

Methodology

Data for the project are collected through a combination of systematic collection, pre-processing, descriptive statistics, and interpretive analysis.

Data Collection

Data will be obtained from reputable organizations. The data will be obtained from NASA, NOAA, IPCC, and WMO.

The primary variables of interest will be:

- Changes in global surface temperature
- Concentration of atmospheric CO_2
- Sea level rise
- Extreme weather events

Data preprocessing

Datasets Collected will submit to Cleaning (Remove Missing Values and Outliers, Correct Inconsistent Formats) and Normalization/Scaling when warranted; Temporal Alignment (Ensure Consistent Intervals); Create Analytical Format (e.g., CSV table, Time Series) from Raw Data.

Descriptive Analytics

Climate data will be summarized via descriptive methods including mean, median, range, variance, and standard deviation; Annual and Decadal averages; Anomalies; Distribution and Variance Analysis. The following Visualization Techniques will be used: Line plots to present Temporal Trends, Box plots to illustrate

Variance, Correlation Analysis will be illustrated with Heat Maps, and Regional patterns will be displayed using Geographic Maps.

Interpretation and Discussion

The last step of data interpretation includes:

- Recognition of significant climate changes;
- Examination of changes throughout time by decade;
- Identification of areas with large differences in climate;
- Analysis of the effects of climate change on ecological policy and adaptation to climate change.

Future directions for research should consider predictive analytics and uses for machine learning.

Results

Counts Vs Continents Chart

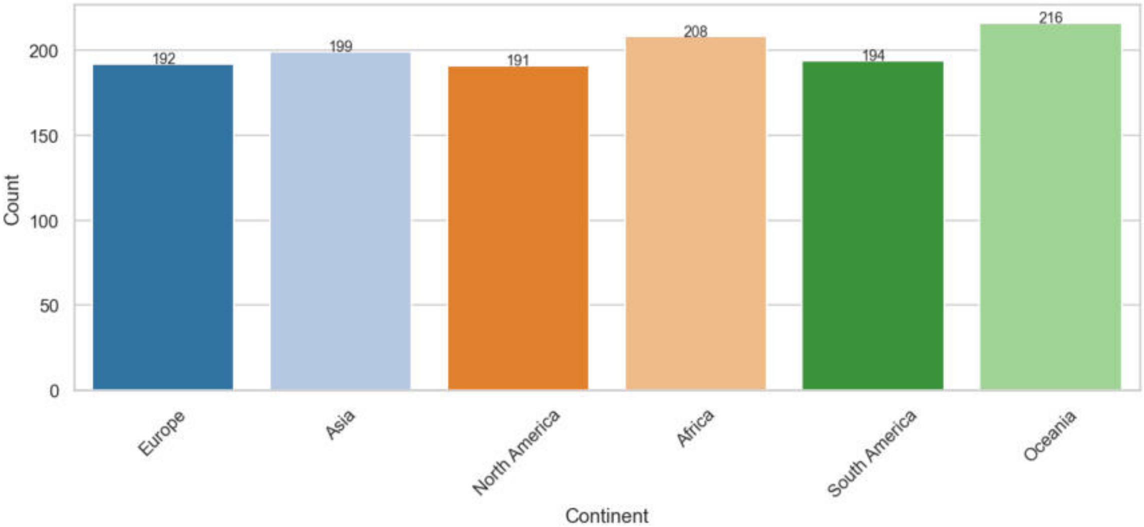

Figure 1: Counts Vs Continents Chart

According to the bar graph in Figure 1, in terms of the number of people counted from the different continents, there is a fairly balanced distribution among the 6 continents. The largest number of people counted came from Oceania, while the second highest number came from Africa. The least number of people were counted from Europe and North America. While there were some variations in the number of people on each continent, the overall difference in the number of counts among all six continents was fairly small; thus, the measured variable has an acceptable balance among the continents, with only minor differences in the amount of measurement taken from each of the continents.

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Count Vs Country Charts

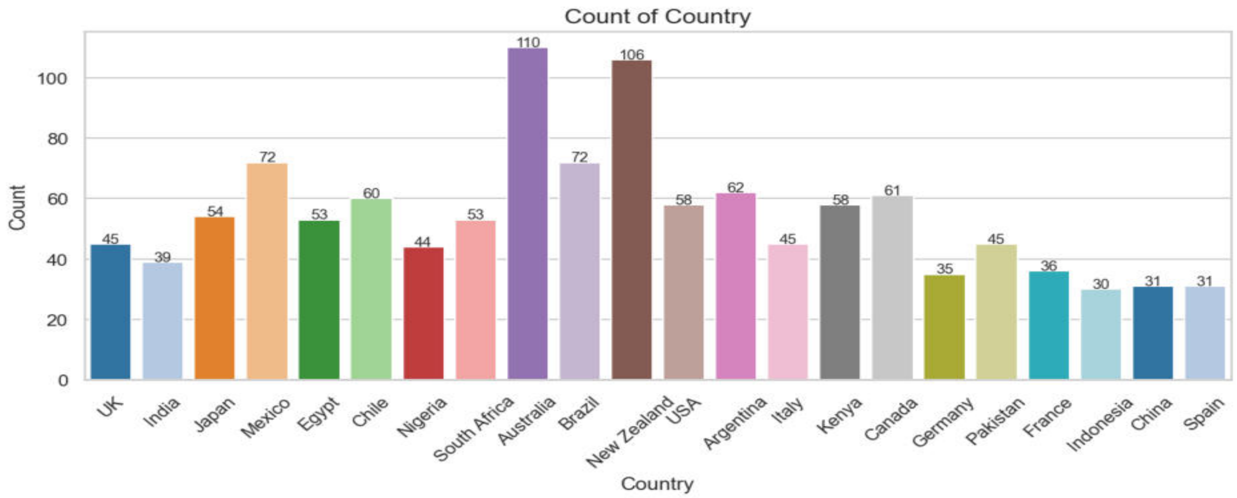
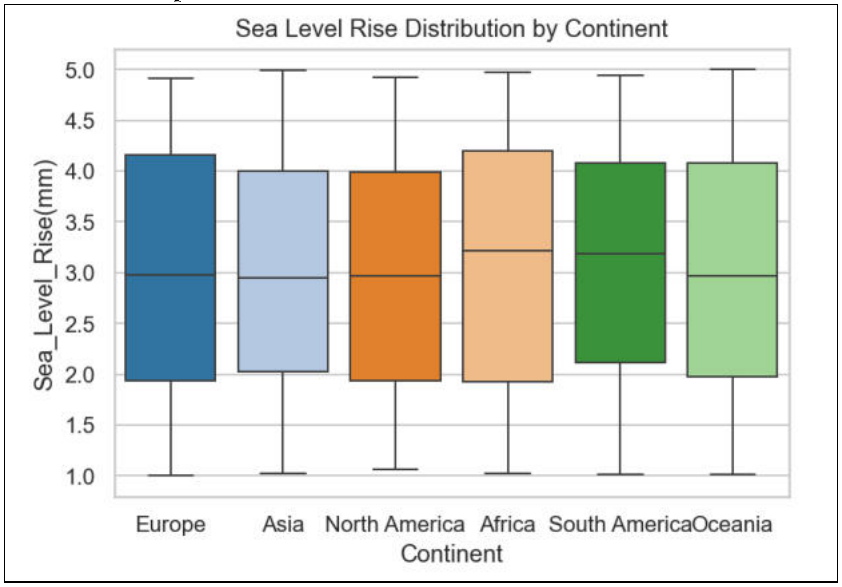


Figure 2:Count Vs Country Charts

This graph in Figure 2 contains information about counts associated with countries collected from more than one continent. The graph identifies Australia having the maximum count (110), followed closely by New Zealand (106), which indicates that there is a robust level of participation occurring from these nations within the Oceanic region. Mexico and Brazil are identified as having a moderate count between them (72 each). The other nations, such as Argentina, Canada, Chile, the USA, Kenya, Japan, Egypt, and South Africa, have counts along the midpoint of this scale. The count levels of countries within these regions are identified as having very low counts. Three of the four lowest count levels belong to countries located in either Europe or Asia: Indonesia (30), China (31), and Spain (31). Therefore, the overall count level for this study ranged from 30 to 110, demonstrating this region is significantly more active than others, and the countries from the Asian and European regions have lower participation levels than Oceania.

Sea Level Rise Distribution Graphs



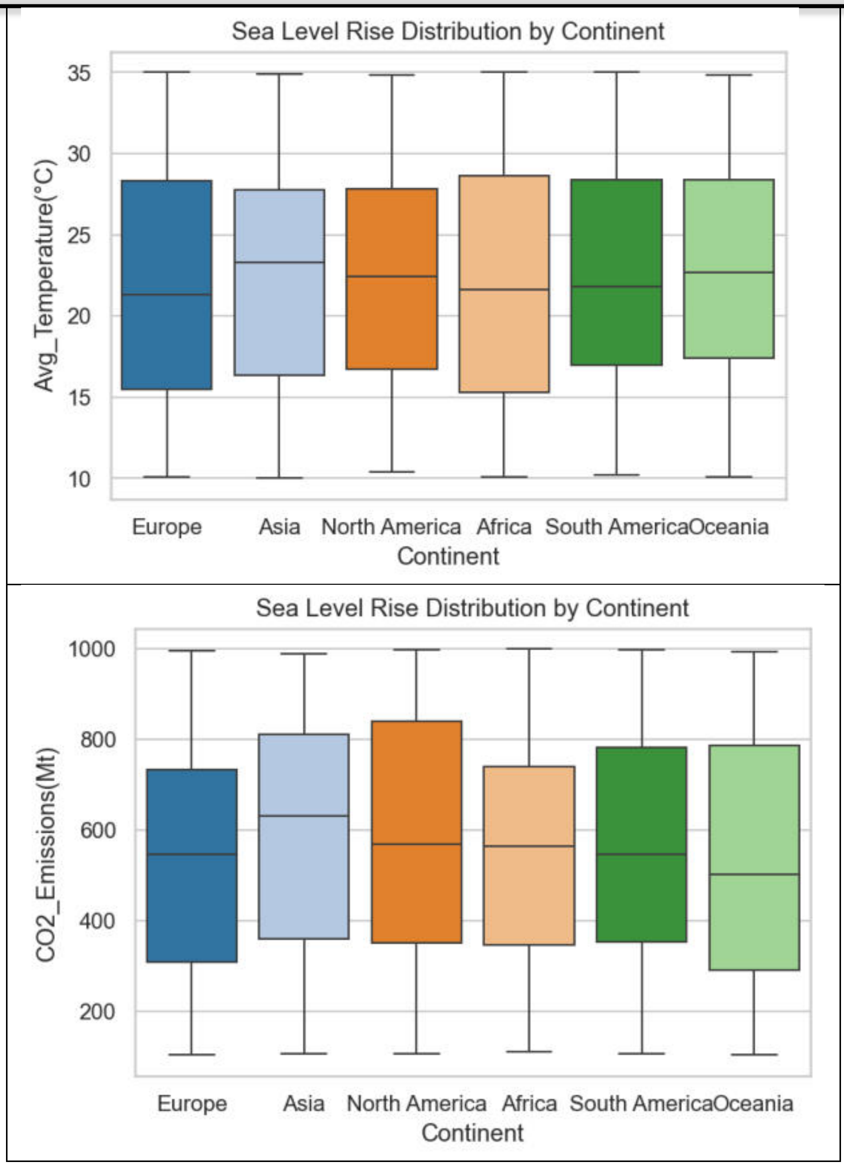


Figure 3:Sea Level Rise Distribution Graphs

In Figure 3, the combination of the three separate Boxplot Visuals provides an overview of the Variability and Magnitude of important Climate Indicators for Each Continent, as well as similarities that exist globally. Sea Level Rise exhibits a Mostly Normal Distribution Across Continents; therefore, it can be considered a Global Issue. Average Temperature demonstrates Wide Ranges on Every Continent, and these Diverse Climate Conditions are related to Where Each Continent is located (Geography) and its Topography. The Median Values of Average Temperature Show Little Difference. On the Other Hand, CO_2 Emissions Are Highly Dispersed Between Continents, and They Exhibit Wide Variations and Extremely High Values on Several Continents; This is Due to Industrialization, Population, and the Type of Economic Activity That is Present on Some Continents Versus Others. These Three Boxplot Visuals Provide an Overall Overview of Climate Trends Globally, as Well as Common Environmental Pressures and Regionally Based Environmental Factors.

Confusion Metric

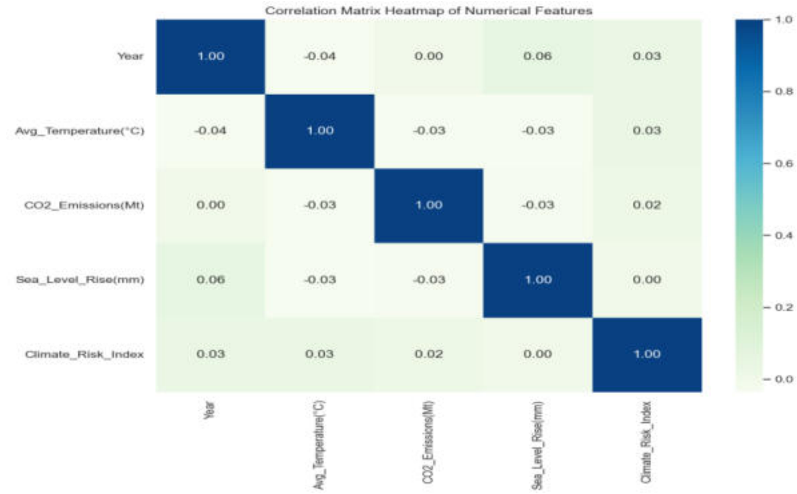


Figure 4: Correlation Matrix heat map of Numerical features

In Figure 4, the five climate variables, Year, Average Temperature, CO_2 Emissions, Sea Level Rise, and Climate Risk Index, have very weak to negligible linear correlations with each other based on the correlation heat-map. Aside from the self-correlations (which are naturally all perfect on the diagonal), all other correlations are situated in proximity to zero. In addition, CO_2 emissions, Average Temperature, and Climate Risk have no meaningful or substantive linear relationship with each other. In summary, the correlation heat-map demonstrates the inherent complexity of climate systems; that simple linear correlations are inadequate to develop a sufficient understanding of climate systems; and that a more robust approach (e.g., analytical, machine learning) will reveal deeper relationships between climate variables.

Continent Sea Level Rise Charts

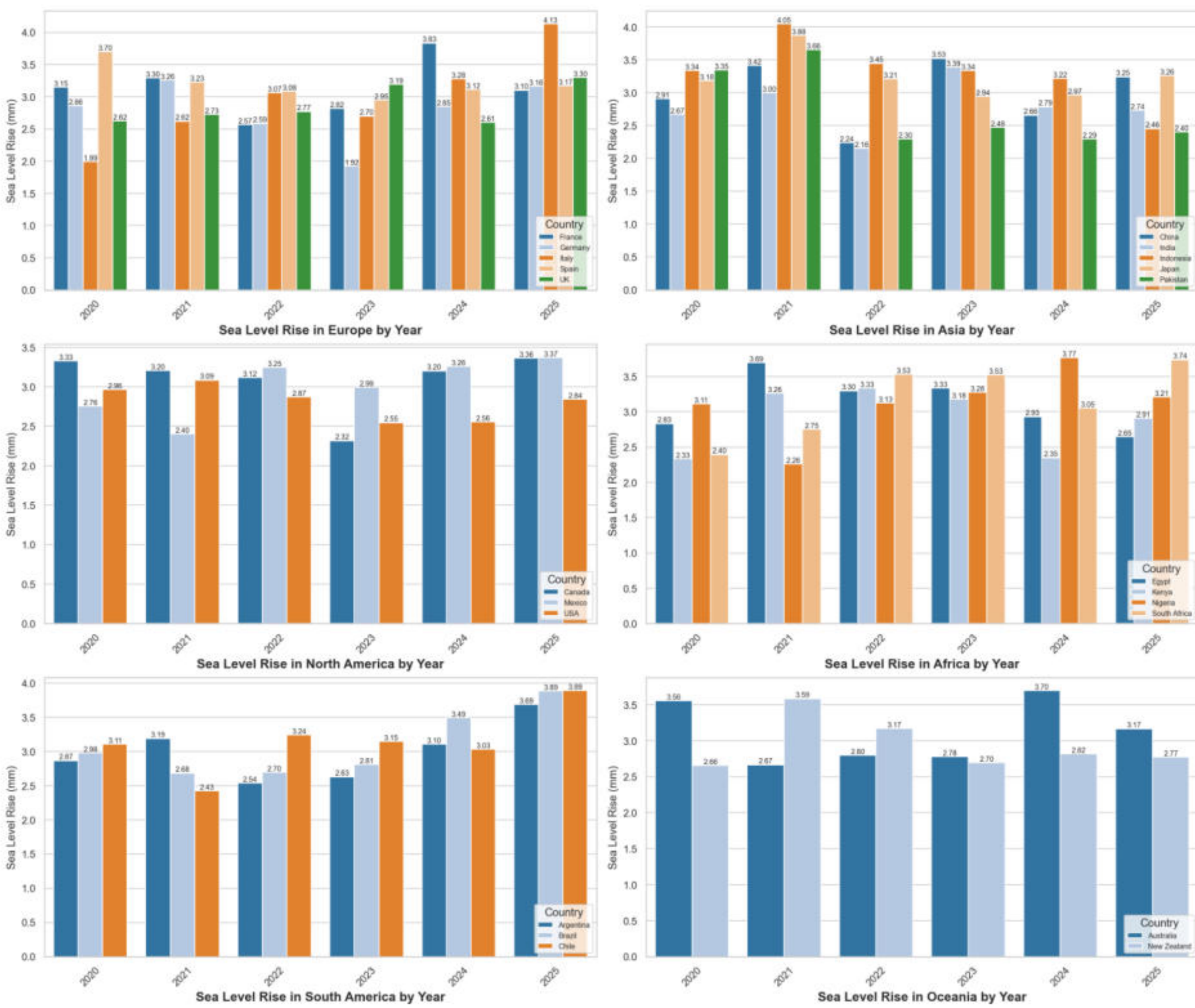


Figure 5: Continental Sea Level Rise Charts

The multi-subplot plot in Figure 5 indicates a continuing upward trend in sea level growth from 2020 until 2025 for all six continents of the world and therefore demonstrates the globality of the sea level rise. All continents are seeing upward trends and therefore, a consistent rise, although each country is experiencing this at different rates and sizes. Europe and Asia have generally moderate sea level trends, with some countries showing higher rates of increase in later years as compared to earlier. North America seems to follow a more consistent upward trend than most other continents, especially the USA. Countries in Africa show gradual increases over time; however, by the end of the study period, a number of countries are experiencing much larger increases. In terms of maximum sea level readings, South America appears to be home to some of the largest increasing sea levels, specifically Brazil and Chile, while Oceania appears to have both Australia and New Zealand increasing their average sea levels in a consistent upward trend. The chart shows how in many regions of the world, sea levels are increasing at different speeds and at different rates.

Continent Temperature Rise Graphs

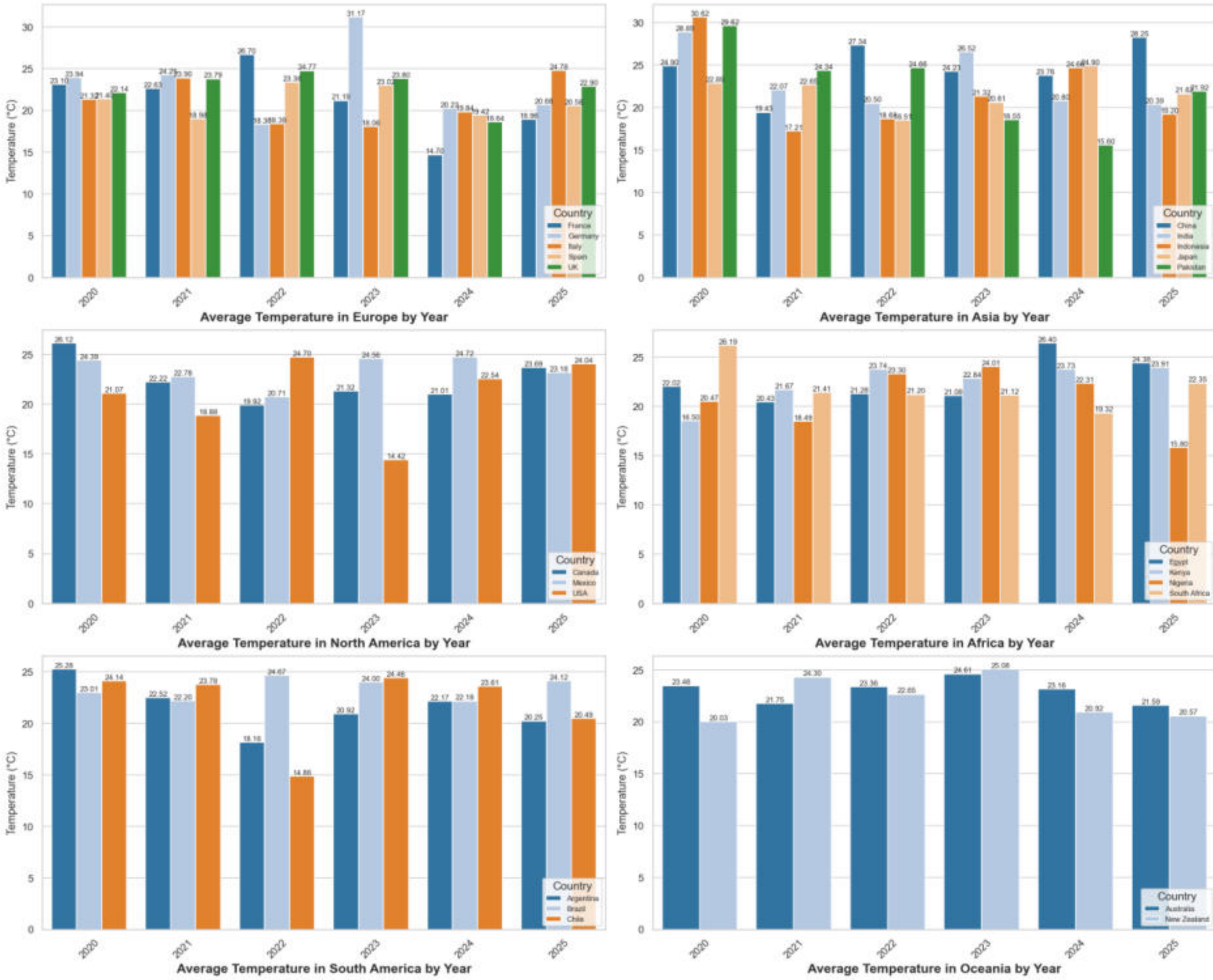


Figure 5:Continent Temperature Rise Graphs

In Figure 6, the annual average temperature trend chart for six continents between 2020-2025 contains multiple subplots to show how countries within each region have responded differently to global climate change. In terms of temperature fluctuation, there was moderate fluctuation recorded within the continent of Europe, with Italy experiencing its greatest spike (Year = 2023). As for Asia, it has the highest variability; Japan and Indonesia both show high variability, while India and China show lower levels of variability. In addition, temperature trends present inconsistently across North America; the United States has remained relatively level over this period, while Mexico has continued to see temperature peaks increase over the same timeframe. Temperature records for Africa indicate gradual warming trends through both Years = 2023 and 2025, whereas South American countries (through Brazil and Chile) saw significant increases post-2022. In Oceania, the temperature trend across Australia has fluctuated somewhat consistently with lower and mid-level temperature spikes than have been experienced in New Zealand. Thus, while the data on the chart suggest an overall temperature increase throughout most geographical regions of the world (which seems to be attributable to changing climate conditions), there are examples of specific geographical areas continuing to experience dramatic variances over those 5 years.

Continent Carbon dioxide rise Graphs

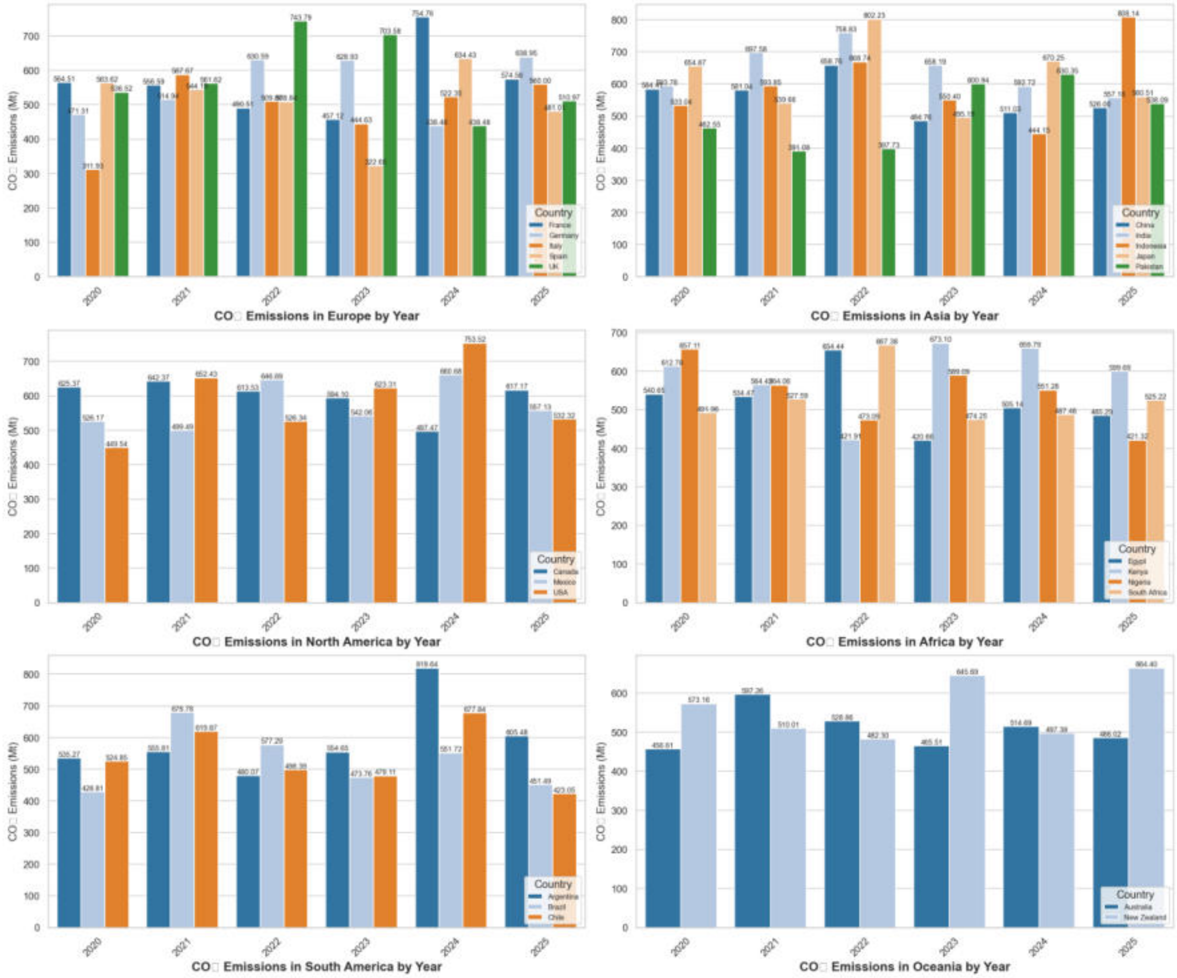


Figure 6:Continent Carbon dioxide rise Graphs

The multi-subplot chart in Figure 7 shows how much CO2 emissions throughout six Continents have increased annually between the years 2020 and 2025 for each nation. The trend of CO2 emissions in Europe was characterized by its constant growth, but only moderately, with Germany and Italy having the two highest levels, while Asia shows the highest overall amount of CO2 emissions; this can be attributed to India & China, both of which are expected to create the highest CO2 emissions globally during the year 2023/2025. North America has also experienced a steady increase, especially for the United States, with high CO2 emissions over the years; although, Canada & Mexico have increased slightly but don't follow the same clear pattern as the U.S.A. South African nations continue on a moderate upward trend of CO2 emissions, with South Africa showing the most significant amount of CO2 emissions. The trend in CO2 emissions in South America has increased yearly since the year 2020, with Brazil being the highest emitter of CO2 and peaking during 2023/2025. Oceania exhibits a slow but continual rise in CO2 emissions, with Australia ahead of New Zealand in CO2 emissions. In summary: The graphic provides reliable data about the world's overall increase in CO2 emissions in almost every continent's region, and this will make it more challenging for industries to deal with their ability to manage and reduce greenhouse gas emissions globally.

Continental Average Temperature Trends from 2020 To 2025

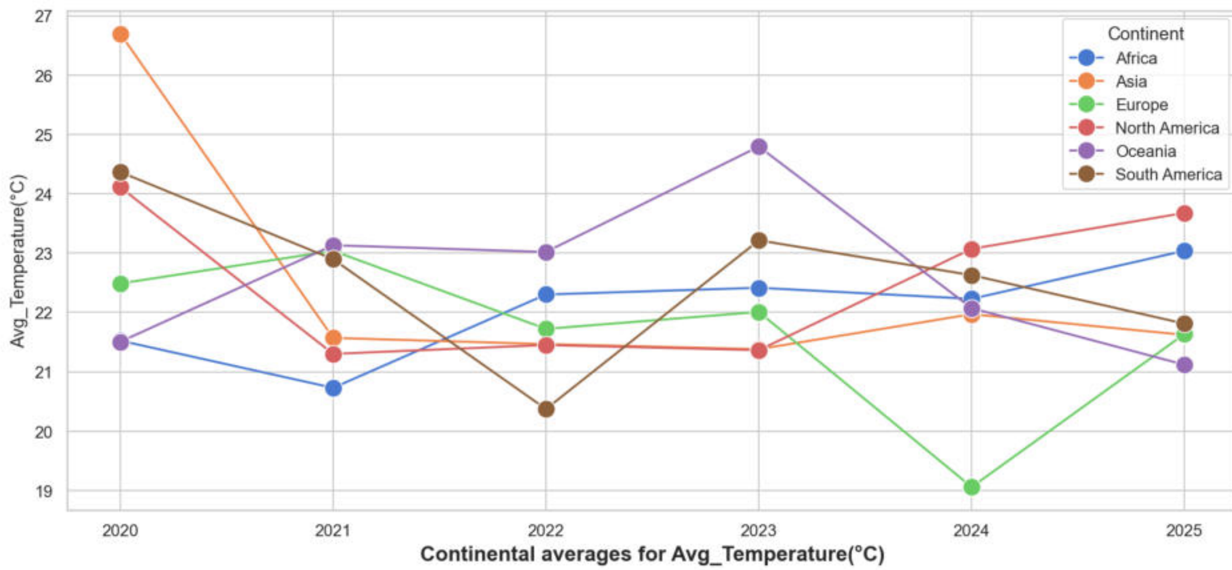


Figure 7:Continental Average Temperature Trends from 2020 To 2025

According to the data presented on the line chart as shown in Figure 8, average temperature trends were across the six continents between 2023 thru 2025. For instance, in 2020, Asia was the warmest continent, while Europe was the coldest. The average temperatures for all of the world were roughly equal across all continents by the end of 2021; however, in 2022, South America had a significant drop in its average temperature. In 2023, Oceania and South America had both begun to show signs of warming, while both Africa and Europe were experiencing continued gradual increases in their average temperatures. Europe saw a dramatic decline in average temperature by the end of 2024, whereas North America experienced steady growth in its average temperature throughout that period. Average temperatures throughout 2025 increased moderately throughout Africa, North America, and Europe, but slightly declined in Asia and Oceania. While the line chart ultimately illustrates the fluctuations in average temperature experienced across the six continents from 2020-25 are generally representative of broad global warming trends, it also suggests that the degree of temperature fluctuation is determined by many regional factors as well as overall climate change globally.

Continent average CO_2 emissions

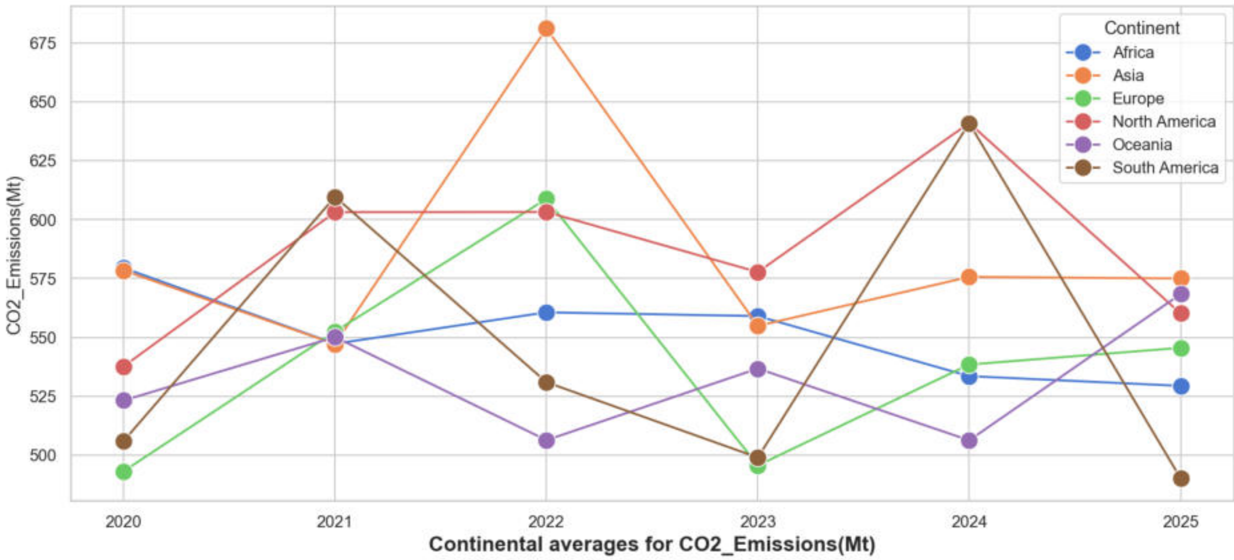


Figure 8:Continent average CO_2 emissions

The graph in Figure 9 displays average CO_2 emissions per continent between 2020-2025(6), indicating the largest degree of volatility over this period is shown by Asia, which reaches its maximum in 2022 and then decreases to a minimum in 2023. Europe displays an upward trend until 2022 and then decreases significantly over the course of 2023, although it begins to show some recovery in subsequent years; whereas North America maintains consistently higher levels of emissions throughout (with a maximum reached in 2021-2022 and again after an upward spike occurs in 2024). On the other hand, Asia/Africa are relatively stable through most of the timeline, with only marginal increases seen earlier, with an overall decrease noted by the end year (2025). Conversely, Oceania shows moderate variability within the data with a dip noted during Year 2022 and another increase beginning between 2023-2025. South America, although experiencing the least stable trend overall, exhibits the greatest variability, with peaks noted in the Year 2024, followed by the steepest drops. In summary, trends on the chart provide evidence to support the increasing variances between continents and from year to year among and between continents as a result of varying economic activity levels and energy consumption practices, as well as local policies and procedures unique to their respective regions.

Continent Average Sea-Level Rise

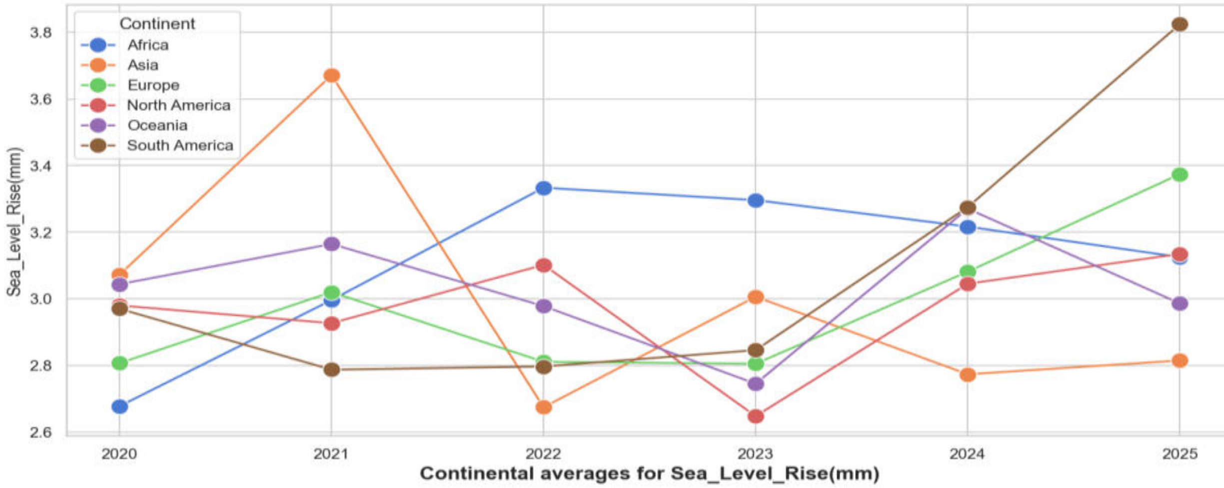


Figure 9:Continent Average Sea-Level Rise

According to the line diagram as shown in Figure 10, there were increases in average sea level rise from 2022 up until 2025, although the amount increased at different rates across all continents. In general, Africa and Europe experienced continued upward trends throughout the History of human civilization, changing slowly. However, Asia had much variability in the sea level in the History of human civilization and had sharp increases/decreases in sea levels in the years 2020-2025. North America remained rather consistent in its increase in sea level with gradual increases towards 2020-2025. Oceania's sea level would have fluctuated around the same time, but many years had peaks or valleys, and ultimately would stabilise. South America had the greatest amount of change between the time periods, having decreased in sea level first, then increased, and would ultimately reach its highest levels in the year 2025. Thus, while a global phenomenon, the rate of sea-level increase and its characteristics can differ between regions.

Continent Average Climate Risk Index

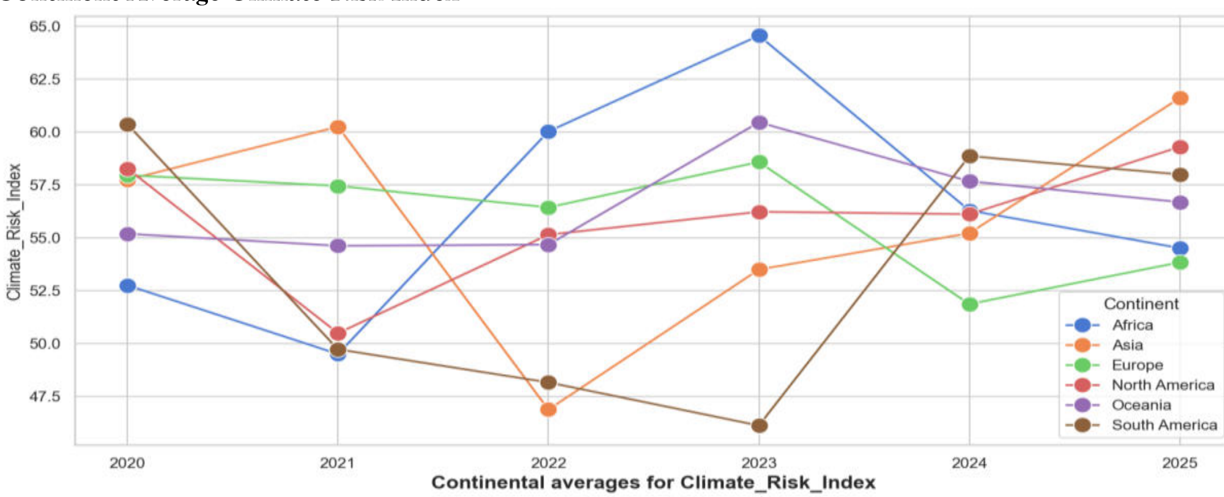


Figure 10:Continent Average Climate Risk Index

While there is a global trend toward increasing climate risk due to global warming, there are significant differences among continents, as shown in Figure 11. The level of climate risk varies greatly depending on which continent you are looking at. For example, Asia and South America experienced high levels of climate risk throughout this period, while Africa and Oceania had low levels in terms of climate risk. In 2023, there was a large spike in climate risk for Africa, suggesting that the African continent's vulnerability to climate change will increase over time. Europe maintained a steady level of risk throughout this period, except for an extremely large drop off between 2024 and 2025. North America had moderate levels of risk throughout the period but began seeing moderate increases from 2023 into 2024. The end of the period showed that Asia, South America, and North America are at the greatest risk for climate change because the level of vulnerability to climate change differs across all regions due to a variety of environmental and socioeconomic factors.

Conclusion

This descriptive research project aimed to analyze and interpret changes in important Climate Indicators over time, including: Global Surface temperatures, Extreme Weather Events, atmospheric CO_2 Concentrations, and Sea Level Rise. This study used summary statistics, average comparisons, and graphs to illustrate how Climate Indicators developed from 1980-2025, but it did not perform any causal modelling.

The Descriptive Analysis of Climate Indicators clearly shows that Global Temperatures have steadily risen, that Greenhouse Gas Concentrations rose rapidly, and some areas of our Planet have undergone drastic Climate Change. Furthermore, with an increase in the Frequency of Extreme Weather Events such as Floods, Heat Waves, and Storms, it is evident that the Intensity of Climate Change is becoming more severe and widespread, and that Climate Change is occurring globally.

Overall, the findings of this study highlight how important it is for policymakers, scientists, and others working on Climate Change to use Descriptive Data Analysis as the basis for understanding and Communicating Climate Change Trends to the Public. This study further emphasizes the need for both Short and Long-Term Planning that uses Best Practices and Evidence-Based Climate Policies, as well as Through Continued Monitoring of Climate Indicators, to facilitate Future Research and Develop Long-Term Management Strategies for Climate Change.

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