Dhirubhai Ambani University

Project Report on

Climate Change Trends Analysis Report

For the fulfillment of the course on
Interactive Data Visualization
(DS612)

By

Group 10

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Submitted to

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Introduction

Long-term changes in temperature and weather patterns are referred to as climate change. Since the 18th century , the biggest cause of climate change is human activity, though natural factors like volcanic eruption and change in solar activity have also contributed. A significantly large amount of greenhouse gases, primarily carbon dioxide, are released into the atmosphere when fossil fuels like coal, oil, and gas are burned. These gases strengthen the greenhouse effect by trapping the heat and causing global temperatures to rise over time.

Different activities are accountable for the emission of greenhouse gases, but energy generation and transport are generally considered to be the primary causes. Production of fertilizers, rice cultivation, animal husbandry, and food processing, packaging, and transportation are some of the activities accountable for agricultural emissions. Apart from the direct emission of carbon dioxide, highly potent greenhouse gases such as methane and nitrous oxide are released from agricultural activities such as ploughing the fields, burning crop residues, and handling manure. Additionally, the expansion of more land for agriculture and urbanization, generally by deforestation, results in deforestation and land use changes, increasing carbon dioxide content in the environment even more.

To gain a clear understanding of climate change, it is important to understand a wide variety of factors that are interconnected. The dataset used in this project spans from 1990 onward and includes key climate-related variables across multiple countries. These variables encompass changes in land cover, temperature variations, incidences of forest and savanna fires, rice cultivation, and the management of agricultural residues. The dataset also consists of other major factors such as CO_2 emissions, food system emission etc. All these factors collectively give an overview of effect of human activity on climate

Objective

The main objective of this project is to understand and examine the key indicators of climate change and how they have evolved over time. This study aims to explore the influence of various factors such as CO_2 emissions, urban and rural population growth, emission due to various industries on global temperature anomalies from the year 1990 onward. By analyzing these indicators, the project seeks to identify meaningful patterns and relationships that contribute to our understanding of climate change thereby emphasizing the importance of sustainable practices and informed decision-making in the face of an evolving climate crisis.

Dataset Description

In this section a detailed discussion about the dataset used is undertaken. This section discusses the original dataset, the additional datasets that are being used and the description of each of the columns in the final merged dataset.

Original dataset:
The original dataset consists of 72 columns and 226 rows. The dataset consists of the following columns:

- Country: The name of the country for which the data is recorded (e.g., Afghanistan, Albania).
- ISO2: The 2-letter ISO country code, a standardized code used internationally to refer to countries (e.g., AF for Afghanistan, AL for Albania).
- ISO3: The 3-letter ISO country code (e.g., AFG for Afghanistan, ALB for Albania).
- Indicator: Describes what the dataset measures. In this case,"Temperature change with respect to a baseline climatology, corresponding to the period 1951–1980", which means each year's temperature value is compared to the average from 1951–1980.
- Unit: The unit of measurement for the data values. Here, it's in Degrees Celsius.
- Source: Sites where the data comes from. This dataset is from Food and Agriculture Organization of the United Nations (FAO), FAOSTAT Climate Change Indicators.It also includes a reference link and license details.
- CTS_Code: A coded reference for categorizing the climate data. In this case, ECCS.
- CTS_Name: A short descriptor of the climate metric. Here, it is "Surface Temperature Change".
- CTS_Full_Descriptor: A detailed classification of the indicator.
- Each column labeled F1961 through F2020 represents the temperature anomaly (change) in that particular year compared to the average temperature from 1951–1980 for that country.

In this dataset we performed a transpose of the columns labelled as F1961-F2020 into a single column labelling it as Year using python so that merging this dataset with other datasets would be easier.

Supplementary datasets used:

In addition to the primary dataset provided, this project incorporates additional data sources to enhance the depth and accuracy of the analysis. These supplementary datasets were selected to provide additional information about the temperature anomalies. Here two datasets are merged with the original dataset. The links to the supplementary dataset are provided below.

- https://www.kaggle.com/code/sasakitetsuya/co2-emission-gap-among-countries-clustering-pca/
- https://www.kaggle.com/code/sasakitetsuya/global-cumulative-co2-emission-gap-analysis/input

The final merged dataset is used for the analysis in this project.This dataset provides a thorough understanding of environmental factors and climate change across various countries from the year 1990 onwards. To provide a comprehensive picture of human influence on climate change, it integrates population data, emissions data (CO_2 and emission from different factors), net forest conversion etc.

This dataset consists of 30 columns and 4240 rows. The columns in this dataset are as following:

- Country: Name of the country to which the data belongs.
- Year: Year for which the data is recorded (starting from 1990).
- Temperature_Change: The annual average temperature deviation from historical norms (in °C). Useful for tracking climate change.
- CO2_emission (Tons): Total carbon dioxide emissions in metric tons, reflecting the country's contribution to greenhouse gases.
- Rural_population: Number of people living in rural areas.
- Urban_population: Number of people living in urban areas.
- Savanna_fires: Emissions from fires in savanna landscapes.
- Forest_fires: Emissions from forest fires, which may result from deforestation or climate-driven dryness.
- Crop_Residues: Emissions from the burning of leftover plant materials after harvesting.
- Rice_Cultivation: Emissions from paddy fields, which produce methane due to anaerobic decomposition.
- Drained_organic_soils (CO2): CO_2 released when organic-rich soils are drained, often for agriculture.
- Pesticides_Manufacturing: Emissions from chemical production used in crop protection.
- Food_Transport: Emissions from transporting food products (logistics, supply chains).
- Forestland: Amount of land covered by forests in the country.
- Net_Forest_conversion: Net change in forest cover — includes deforestation and reforestation.
- Food_Household_Consumption: Emissions related to final consumption of food in households.
- Food_Retail: Emissions from retail food operations including supermarkets and outlets.
- On-farm_Electricity_Use: Electricity consumption on farms (for irrigation, lighting, equipment, etc.).
- Food_Packaging: Emissions generated from food packaging materials and processes.
- Agrifood_Systems_Waste_Disposal: Emissions due to food waste management and disposal.
- Food_Processing: Emissions from converting raw agricultural products into consumable food.
- Fertilizers_Manufacturing: Emissions from producing fertilizers for agriculture.

- IPPU: Industrial Processes and Product Use which indicates emissions from manufacturing (excluding energy).
- Manure_applied_to_Soils: Emissions from applying animal manure to fields as fertilizer.
- Manure_left_on_Pasture: Manure from grazing animals left in open fields, contributing to methane emissions.
- Manure_Management: Emissions from storage and handling of manure on farms.
- Fires_in_organic_soils: Emissions from the burning of peat and other carbon-rich soils.
- Fires_in_humid_tropical_forests: Emissions due to deforestation or natural fires in tropical rainforests.
- On-farm_energy_use: Total energy consumption on farms, including fuel, electricity, etc.

<u>Additional created column</u>:

Coastal_or_Landlocked Indicates whether a country is coastal (has sea access) or landlocked. Useful for comparing climate patterns.

<u>Derived Parameter/Derived field:</u>

- Decade: Grouped ten years together.
- Continent: Grouped the Countries belonging to the same continent together.
- Food System Emission: Using the columns [Food Household Consumption] + [Food Retail] + [Food Packaging] + [Food Processing] + [Food Transport]
- Industrial Emission: [Fertilization Manufacturing]+[Pesticide Manufacturing]+IIPU
- Agriculture_Emission: Using the columns [Crop Residues] + [Rice Cultivation] + [Drained organic soils (CO2)] + [Manure applied to Soils] + [Manure left on Pasture] + [Manure Management]+[On-farm Electricity Use]+[On-farm Energy Use]
- Total Population: [Rural Population]+[Urban Population]
- Urban Ratio: Using the columns [Urban Population]/[Total Population]
- Urban Dominance: using the condition —>If Urban Ratio >0.5 then ‘Urban’ else ‘Rural’

Problem Statement

This project aims to create an in-depth understanding of how various factors such as rural to urban populations, geographic classifications (coastal versus landlocked), and sectoral processes related to industrial and agricultural practices, collectively influence CO_2 emissions. While energy and transport are often spotlighted, this project focuses on the less visible but highly significant impact of agriculture, Food system emission, and urbanization on CO2 emission. These emissions, in turn, are examined for their correlation with temperature anomalies observed globally over time. By exploring these multifaceted relationships, the study seeks to uncover how structural and environmental factors contribute to climate variability at a national level.

We address the following key questions:

Do coastal countries have more temperature deviation compared to landlocked countries?

Are urban countries more responsible for temperature rise due to industrial activity?

Do rural nations contribute more to agricultural emissions?

Does being landlocked or coastal affect the temperature deviation trend?

What activities (e.g., fertilizer use, rice cultivation, food packaging) contribute significantly to CO_2 emissions?

Exploratory Data Visualizations and Interpretations

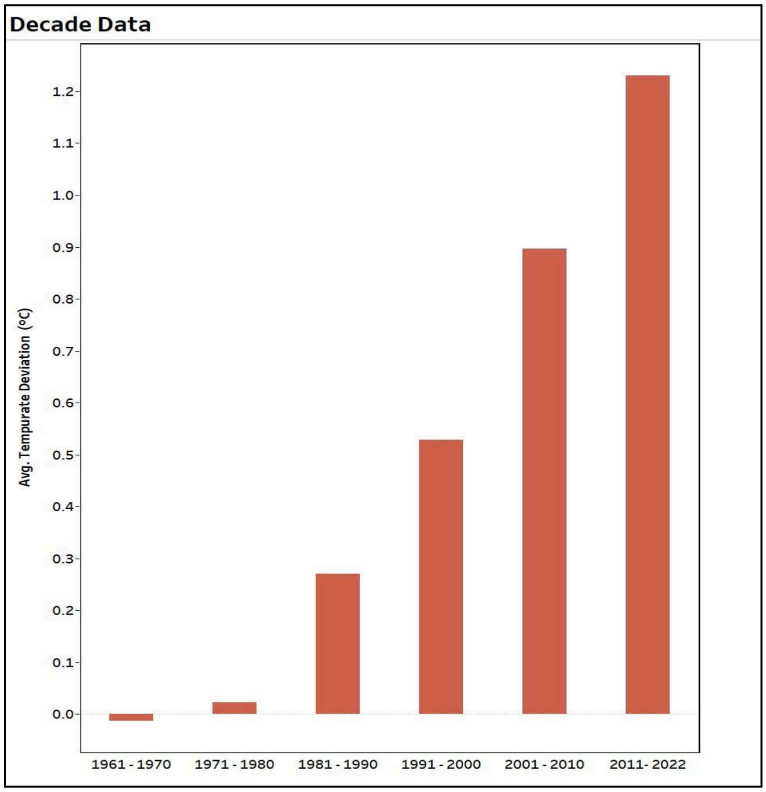
This section offers few data visualizations that reveal trends, abnormalities, and corbetween temperature change and various emissions caused by several human-induced factors like urbanization, and agricultural practices in order to convert the complex data into understandable insights. Concise insights, derived parameters wherever applicable, and justifications of the visualization used to convey the data story are included with every visualization.

Decadal and Regional Temperature Deviation Patterns

This section highlights temperature deviation over different decades, across different continents and further drills down to the countries in the continent with the highest deviation in temperature. Thus, giving more detailed insights into temperature deviation across time and space.

1. Macroscopic view

a. Decade-wise Global Temperature Deviation



Data Type	Quantitative(Ordered) Attribute: Year Quantitative: Avg Temperature deviation
Marks	1D
Channels	Both Horizontal and Vertical Position (Separable Horizontally aligned Vertically and Order by Quantitative attribute (Avg. Temperature))
Scalability	High (Dozen to Hundreds of levels for bars and Hundreds for Value)
Task	Comparison

Justification:

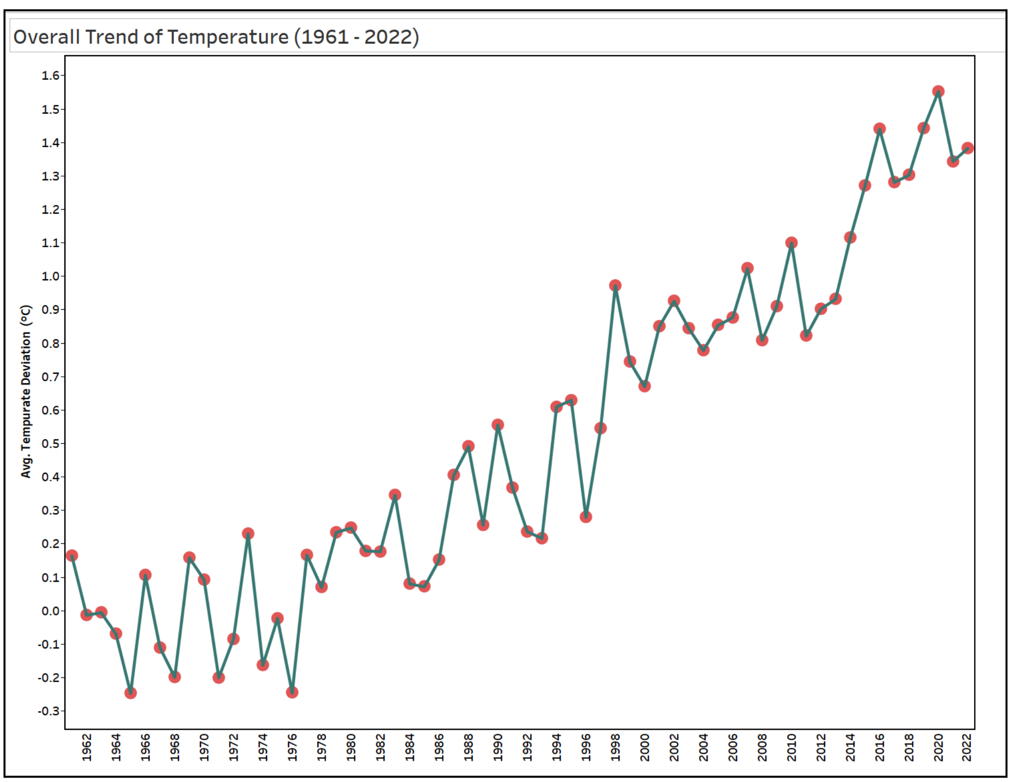
Bar charts are cognitively efficient for comparing magnitudes across categories, as the length of bars provides a direct and intuitive encoding of quantitative value which in our case represents the temperature deviations. This minimizes cognitive load, allowing viewers to grasp the accelerating trend of temperature deviations quickly without additional processing effort. A uniform warm orange-red is used to indicate heat which aligns with intuitive color mapping where these tones represent warming

Insights:

Between 1961 and 2022, the Earth's average temperature deviation increased gradually decade by decade, as seen from this bar chart. Prior to the 1990s, the deviation was small, approximately 0.2°C. From 2000, however, there is a noticeable increase in the deviation, which exceeds the 0.5°C mark and rises far above 1.06°C by the 2011–2022 period which was considered the hottest decade.

This confirms that the rate of global warming has dramatically increased in the twenty-first century. The evidence supports central conclusions in climate science, with evidence for intensified industrial processes, the emissions from the burning of fossil fuels, and increased greenhouse gas concentrations as central drivers. A tipping point is evidenced by the sharp rise observed following 2000, supporting an unprecedented deviation of global temperatures from their historically established natural baselines.

b. Overall trend



Data Type	2 quantitative Attributes: Year (ordered), Average Temperature Deviation
Marks	Points (And Line connection between them)
Channels	Position
Scalability	High
Task	Find Trend (Over the year how Temperature is increase or decrease)

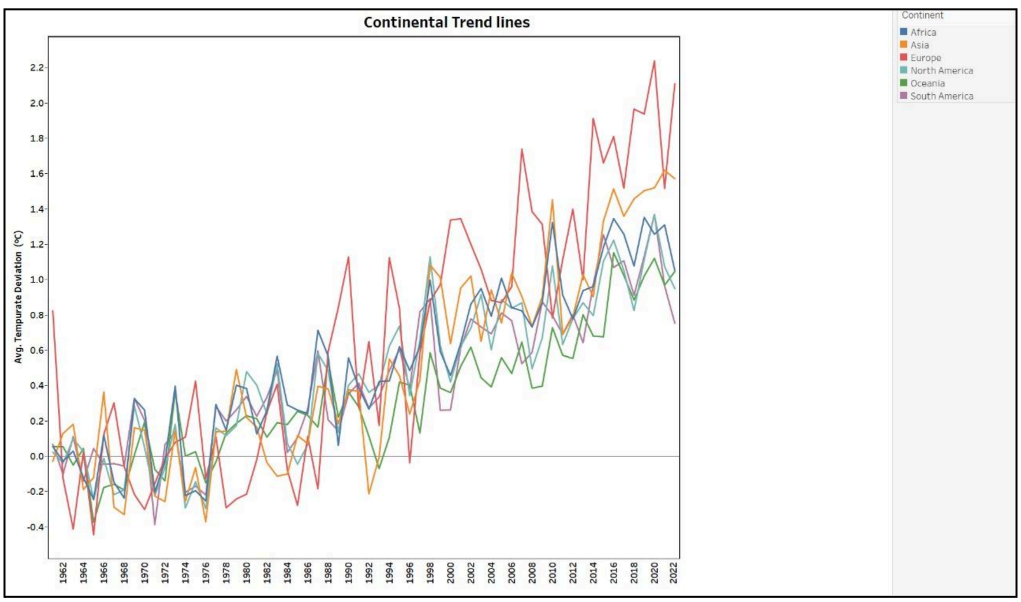
<u>Justification:</u>

Line chart here helps to show an overall trend here it shows temperature deviation over the years helping us to analyze some dips and peaks.

<u>Insights:</u>

Here, as explained, the El Nino effect is observed particularly in the year 1997-1998 which was considered the most powerful El Nino event recorded in history. Most of the insights are described in the text box.

c. <u>Continental Temperature Deviation Trend Lines</u>



Data Type	6 Categorical: Continent Name 2 Quantitative Attributes: Year (Ordered),Avg. Temp Deviation
Marks	Points (0D) (And line connection between them)
Channels	Position, slop (Tilt), Color Hue
Scalability	High
Task	Find Trends

Justification:

A multi-series line chart effectively conveys changes over continuous time while enabling comparative trend analysis across multiple categories, here in this case, continents. This visualization preserves temporal continuity while maintaining low cognitive friction for trend recognition. Line charts excel in showing directionality and volatility, both of which are crucial in climate-related data. Here, each continent is coded with different hues thereby minimizing any confusion.

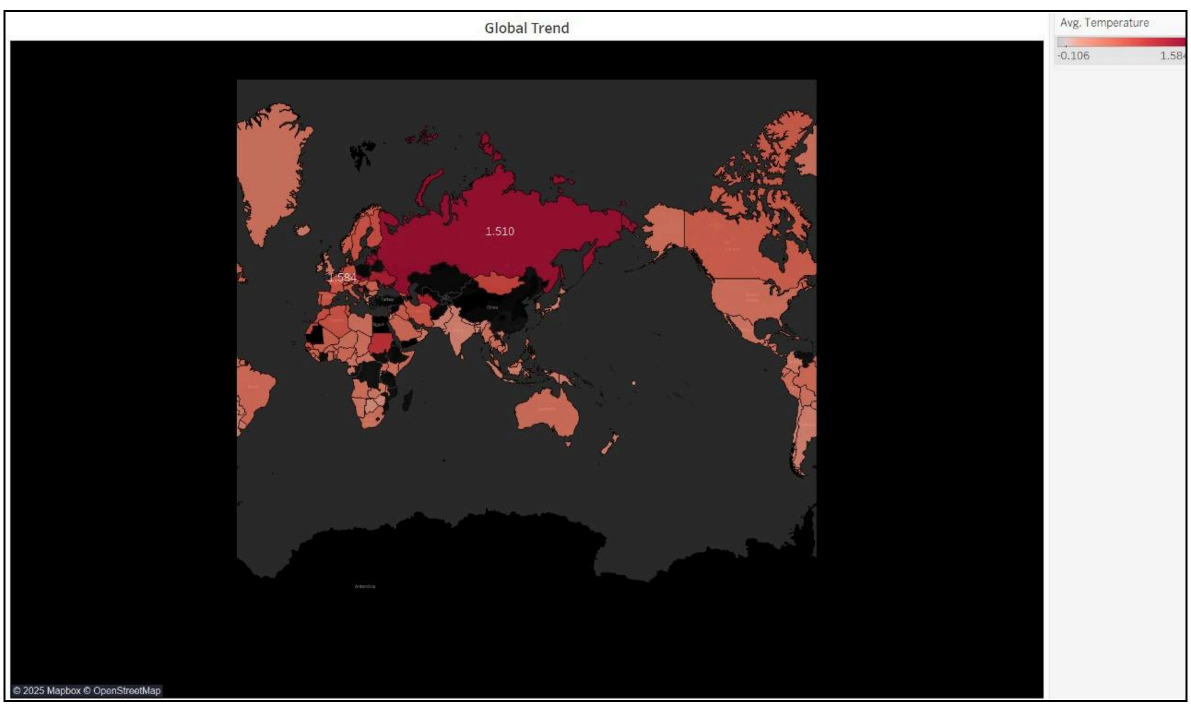
Insights:

This multi-line graph shows the historical temperature variations on several continents. Europe is the continent that warms the fastest in this dataset, showing the highest increase with variances now frequently surpassing 1.5°C.

North America and Asia show somewhat lower but comparable patterns, indicating that they are also warming significantly, especially after 1980. However, the warming trend is still noticeable in South America, Africa, and Oceania, where the rise is more moderate.

These differences are significant because they imply that although global warming is a worldwide phenomenon, its effects vary by location and are impacted by urbanization, deforestation and various other factors which will be discussed further in this project.

d. Global Temperature Deviation



Data Type	geographic geometry (Here Country Name), 1 Quantitative Attribute: per region (Temperature change)
Marks	2D
Channels	Color saturation,Position
Scalability	Number of Country
Task	To show Geographic Temperature change

<u>Justification:</u>

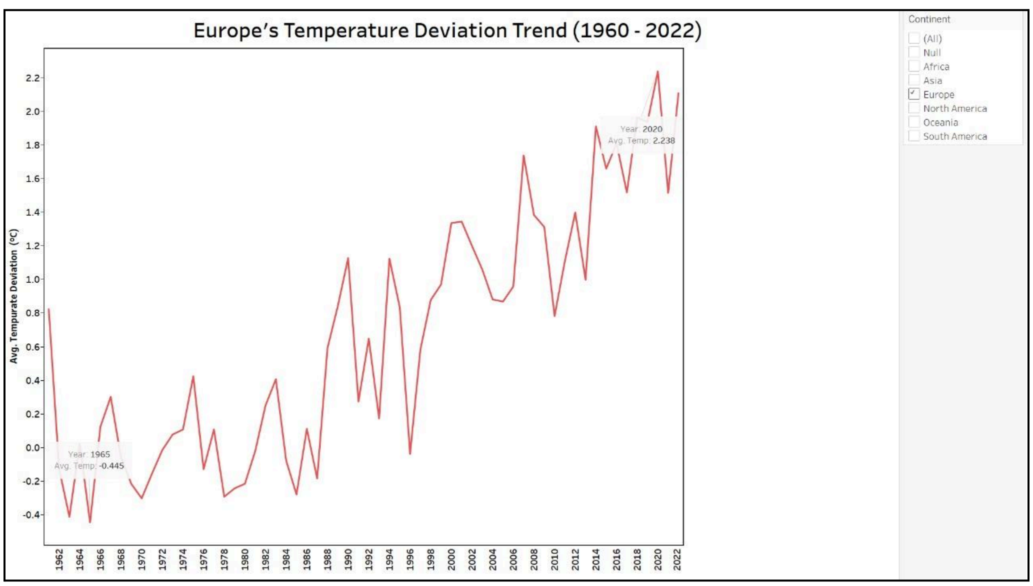
A choropleth map effectively visualizes geographically distributed data, enabling quick identification of patterns and regional disparities, integrating real-world context for intuitive understanding and deeper insights.Here saturation of red hue is used to show the increasing order of temperature deviation where lighter red suggest low temperature deviation and darker red represents the increasing temperature deviation.

<u>Insights:</u>

This graph represents the degree to which each nation has diverged from the average world temperature using color intensity. The nations with the deepest reds, which indicate average variances of more than 1.5°C, include those in Northern Europe, Canada, and Russia. Higher latitudes (those nearer the Arctic) warm more quickly, as this map graphically demonstrates. Countries close to the equator, on the other hand, exhibit lighter hues, indicating less variation in temperature change.

2. Microscopic View

a. <u>Europe’s temperature deviation trend</u>



Data Type	2 Quantitative Attribute: Year (ordered) , Average Temp. Deviation
Marks	0D (Points) and Line connection between them
Channels	Length, Both Horizontal and Vertical Position
Scalability	High
Task	Comparison

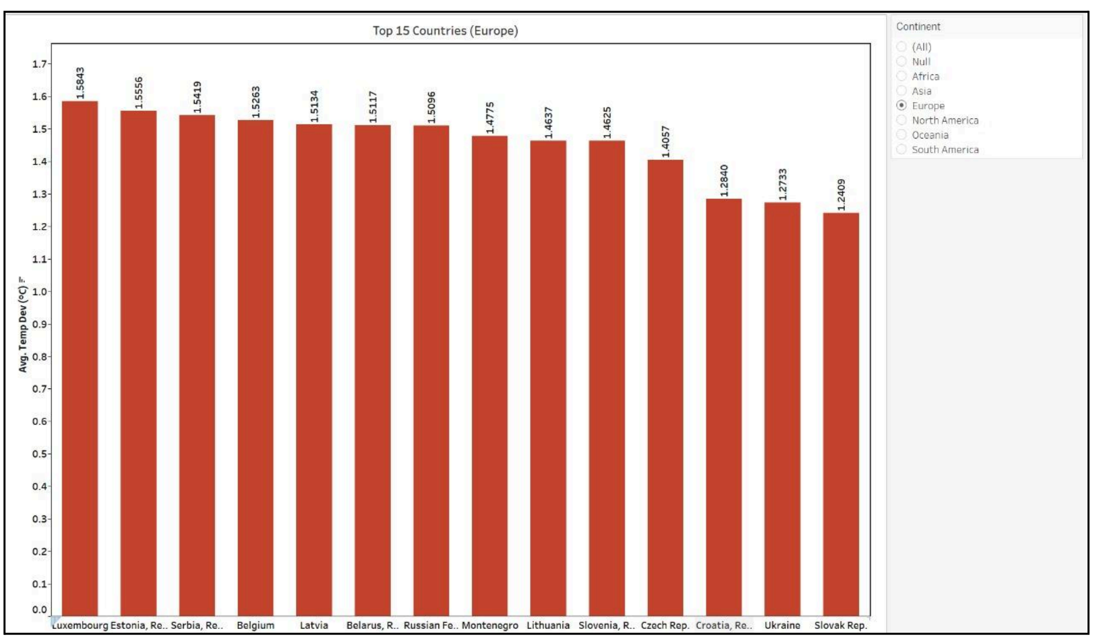
Justification:

Line charts are perfect to depict temporal trends, here we used it for temperature deviation. It depicts continuous changes perfectly tracking progression with lesser cognitive effort.Here, also red hue is selected to continue the theme as repetition of colors leverages brain's ability to process visuals rapidly without much effort.

Insights:

The line graph centered on Europe demonstrates a sharp and steady rise in temperature deviation beginning in the middle of the 1980s. After 2000, the slope was increasingly steeper and it can be observed that by 2022, the most current readings were as high as 2.2°C. This indicates that Europe is warming at an unusually rapid rate, as it is more than twice the global average.Its steady annual gain, devoid of any recent dips, indicates that it will continue to rise throughout the year. At the national and continental levels, this graph acts as a call for immediate adaptation and emission control measures.

b. Top 10 countries in Europe by temperature deviation



Data Type	1 Categorical: Country Name 1 Quantitative: Avg. Temp. Deviation
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position
Scalability	High
Task	Comparison

Justification:

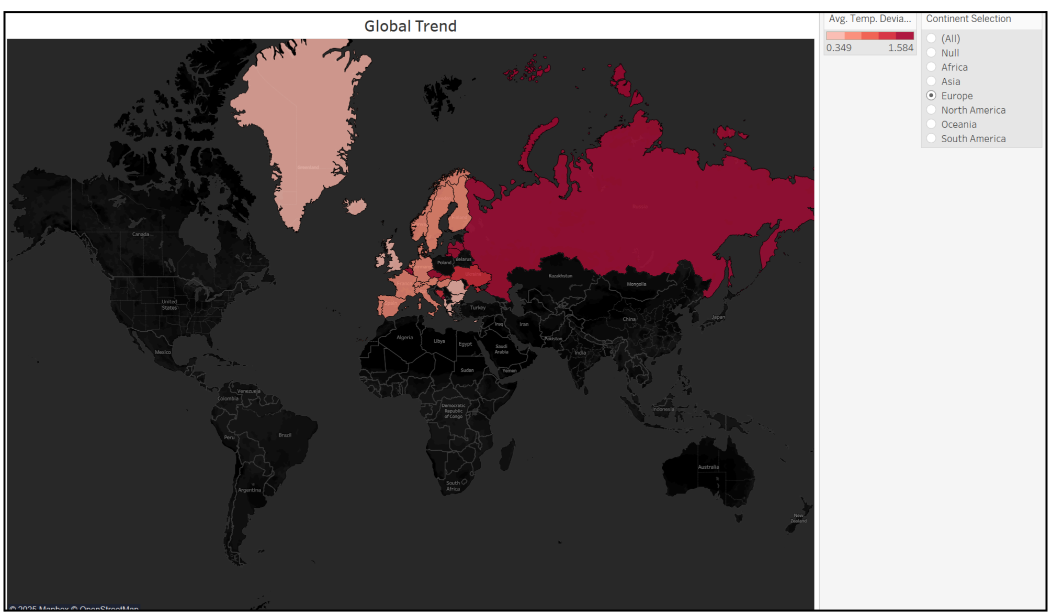
Bar charts are ideal for showing ranking and comparing categories thereby reducing the cognitive load. Here, the values are sorted from highest to lowest and also displaying the values on top of each bar thereby minimizing the cognitive efforts.

Insights:

The line graph centered on Europe demonstrates a sharp and steady rise in temperature deviation beginning in the middle of the 1980s. After 2000, the slope was increasingly steeper; by 2022, the most current readings were as high as 2.2°C. This indicates that Europe is warming at an unusually rapid rate, as it is more than twice the global average.

The tendency is a reflection of the continent's high levels of industrial activity, patterns of energy use, and perhaps feedback mechanisms brought on by shifting land use. Its steady annual gain, devoid of any recent dips, indicates that it will continue to rise throughout the year. At the national and continental levels, this graph acts as a call for immediate adaptation and emission control measures.

c. Focus on Europe's Map



Data Type	geographic geometry (Here Country Name), 1 Quantitative attribute per region (Temperature change)
Marks	2D
Channels	Color saturation, Position
Scalability	Fix as number of Country
Task	To show Geographic Temperature change

Justification:

A choropleth map is ideal for visualizing geographic data where values vary across countries, regions, or districts, in terms of temperature deviation in this case.

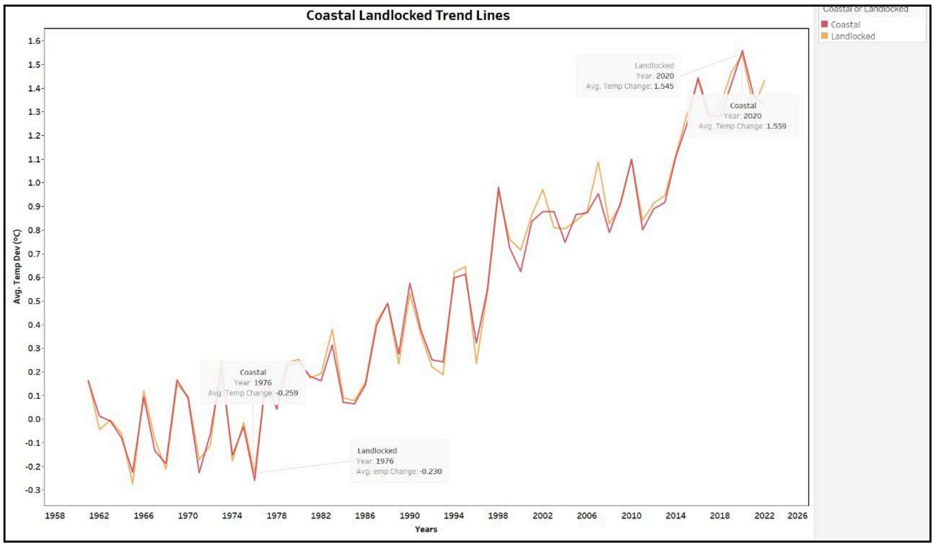
Insights:

This focused map of Europe allows a granular view of how each country is affected. Countries like Luxembourg, Belgium, Switzerland, and Estonia show deviations above 1.5°C, putting them among the most affected. These countries are often small, industrialized, and highly urbanized which are the factors that can accelerate local warming. The color gradient also reveals that even within Europe, warming is not uniform; northern and central countries show higher deviations compared to southern ones.

<u>Hypothesis 1:</u>

Coastal countries should experience lower temperature increases compared to landlocked nations due to oceanic influence as they exhibit more extreme warming trends due to faster land heating.

a. <u>Trend line analysis of coastal countries and landlocked country analysis</u>



Data Type	2 Categorical: Landlocked, Costal, 2 Quantitative: Year (ordered), Average Temp. Deviation
Marks	Points (Line connection between them)
Channels	Position, Color Hue
Scalability	High (hundreds of key levels, hundreds of value levels)
Task	Find Trend (Over the year how Temperature is increase or decrease)

<u>Justification:</u>

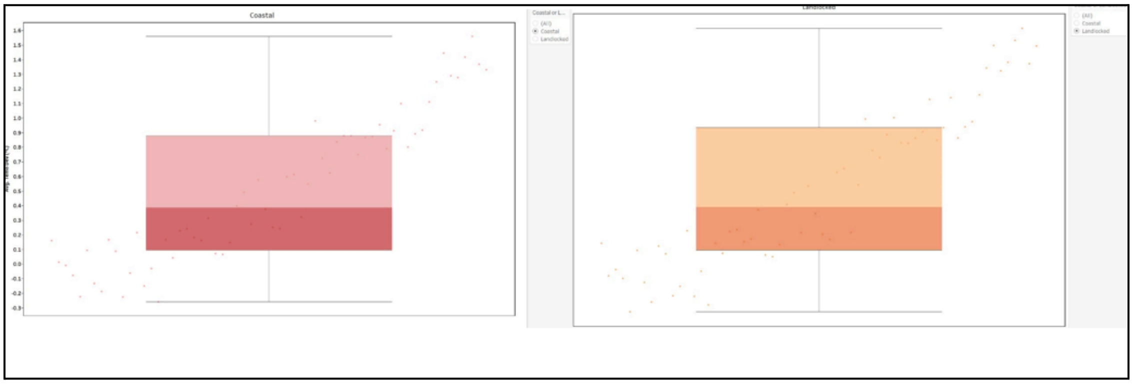
Line chart helps in comparing the overall trend in both coastal and landlocked countries.The different hues helps to minimize the cognitive effort in differentiating the both categories

<u>Insights:</u>

This graph compares temperature deviation trends between coastal and landlocked nations from 1961 to 2022. The results show no significant difference in warming trends, particularly post-1980, where both regions experience an almost identical trajectory. By 2020, the average temperature deviation reached around 1.55°C for both categories.

This suggests that geographic features like proximity to oceans do not offer immunity from global warming, contrary to initial hypotheses. The rejection of the hypothesis emphasizes the universality of climate change impacts.

b. Statistically comparing Coastal and landlocked countries:



Data Type	5 Quantitative (Derived Data)
Marks	1D
Channels	Length , Color Hue (For Landlocked and Coastal Countries Separability)
Scalability	Very High
Task	To Find Distribution.

Justification:

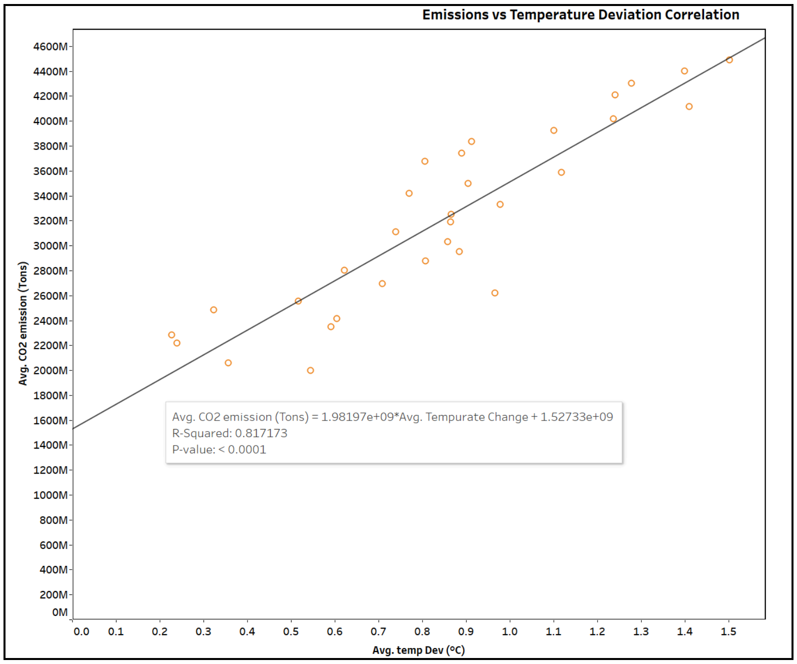
Box plots help in understanding the statistical aspect and to understand the distribution of the data. Thus, here it is used to compare the landlocked and coastal countries at a deeper level.

Insights:

By analyzing the distributions of landlocked and coastal countries' temperature deviations, one can come to a conclusion that both of the categories don't vary much in terms of temperature deviation. Despite the general assumption that coastal regions experience oceanic moderation and thus will warm less rapidly, the data proves otherwise that both groups have the same range and median of temperature deviation. This disproves the hypothesis of gentler warming in coastal countries as a result of ocean buffering, and instead points towards global warming effects being more ubiquitous and less dependent on spatial distance to the oceans.

Effect of Emission on temperature deviation

a. Correlation between emission and temperature deviation



Data Type	2 Quantitative Attribute: Average Temperature change, Average CO2 Emission
Marks	Points (0D)
Channels	Both Horizontal and Vertical Position
Scalability	High
Task	Find Trends and Correlation Between Avg Temp. and CO2 Emission.

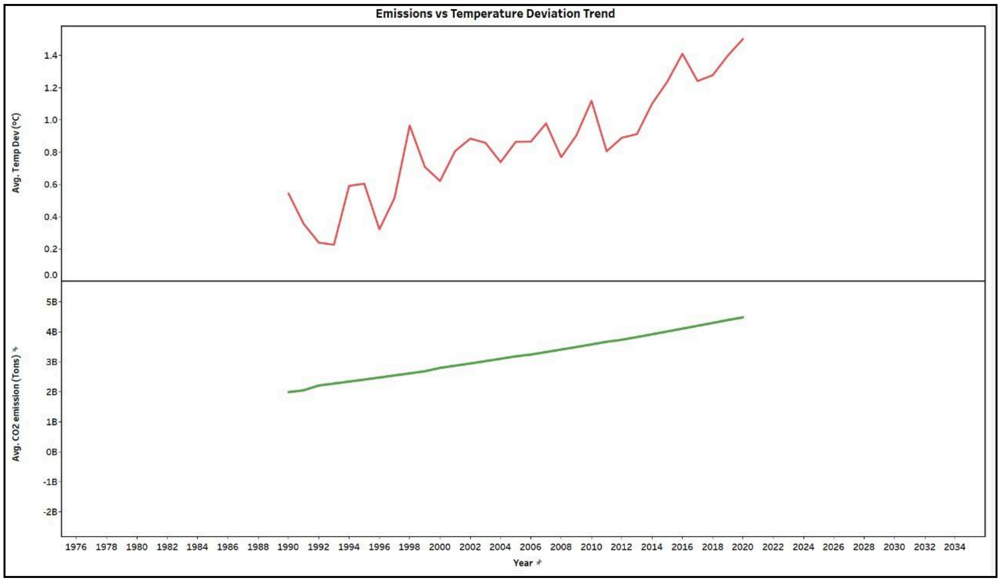
Justification:

The scattterplot is ideal for analyzing the correlation between two

Insights:

This plot shows a clear positive correlation between average temperature deviation and total emissions. As emissions increase, temperature deviation also rises. The scatter points closely follow a linear trend, suggesting a strong relationship between the two variables

b. Trend of Emission and Temperature Deviation Over Time



Data Type	2 Quantitative: Year(ordered), Average Temp. Deviation
Marks	Points (Line connection between them)
Channels	Position, Color Hue
Scalability	High (hundreds of key levels, hundreds of value levels)
Task	Find Trend (Over the year how Temperature is increase or decrease)

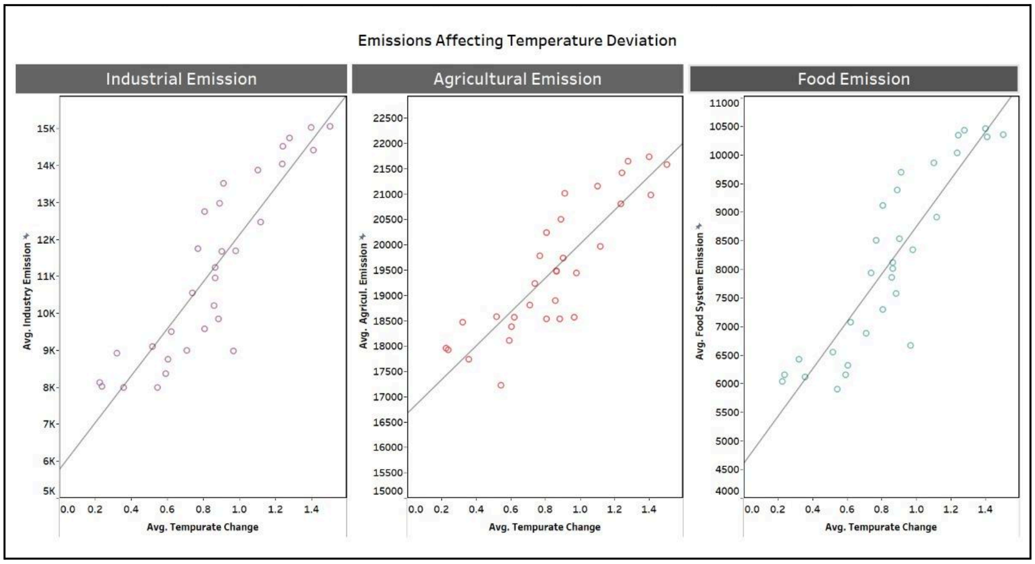
Justification:

The two-line times series graph is a way in which one can understand the change in temperature deviation and CO2 emissions over time. By having each variable presented on separate subplots along the same timeline, it is easily comparable without the complications of scale distortion. It is easily identifiable from the graph that there is a clear trend of increase in both variables, and it also suggests a correlation between increasing emissions and global warming. This approach is an easy yet effective method of presenting trends in climate change over time.

Insights

This line graph tracks how average temperature deviation has changed from 1990 to 2020. The upward trend indicates a steady increase in temperature over time, with slight year-to-year fluctuations. This plot was chosen to highlight the temporal progression of climate change, allowing us to see how warming has unfolded over the years.

c. <u>Correlation between emission and temperature deviation</u>



Data Type	2 Quantitative Attribute
Marks	Points (0D)
Channels	Horizontal and Vertical Position
Scalability	Very High
Task	To Find Correlation and Trend

<u>Justification:</u>

Here scatterplot has been used along with a regression line making it the most suitable graphical tool to visually evaluate the strength and character of the relationship between two continuous variables in this case, different types of emissions and temperature deviation. This graphical tool not only displays individual data points but also quantifies the correlation in R^2 and p-value, so it is very suitable for the statistical confirmation of the relationship.

<u>Insights:</u>

1). **<u>Industrial Emission vs Temperature Deviation</u>** shows trend and correlation between Average Temperature change and Average Industry Emission. (These are two Quantitative Attributes)

Industrial emissions exhibit a strong positive correlation with temperature deviations. Regions or periods with higher industrial emissions show a steeper rise in temperature deviations. This is likely due to urbanization and increased reliance on heavy industries.The graphs highlight how countries with industrial expansion experience disproportionately high warming.

2). **Agriculture Emission vs Temperature Deviation** shows trend and correlation between Average temperature change and Average Agriculture Emission. (These are two Quantitative Attributes).

Agricultural emissions show a moderate correlation with temperature deviations. The variability suggests some regions manage agricultural emissions better than others.Rural-dominant regions likely experience higher agricultural emissions due to reliance on traditional farming methods and less regulation of livestock and soil practices. The graphs underscore the need for sustainable agriculture, such as no-till farming, controlled grazing, and optimized fertilizer application.

3). **Food emission vs Temperature Deviation** Shows Trend and Correlation between Average Temperature change and Average Food System Emission. (These are two Quantitative Attributes).

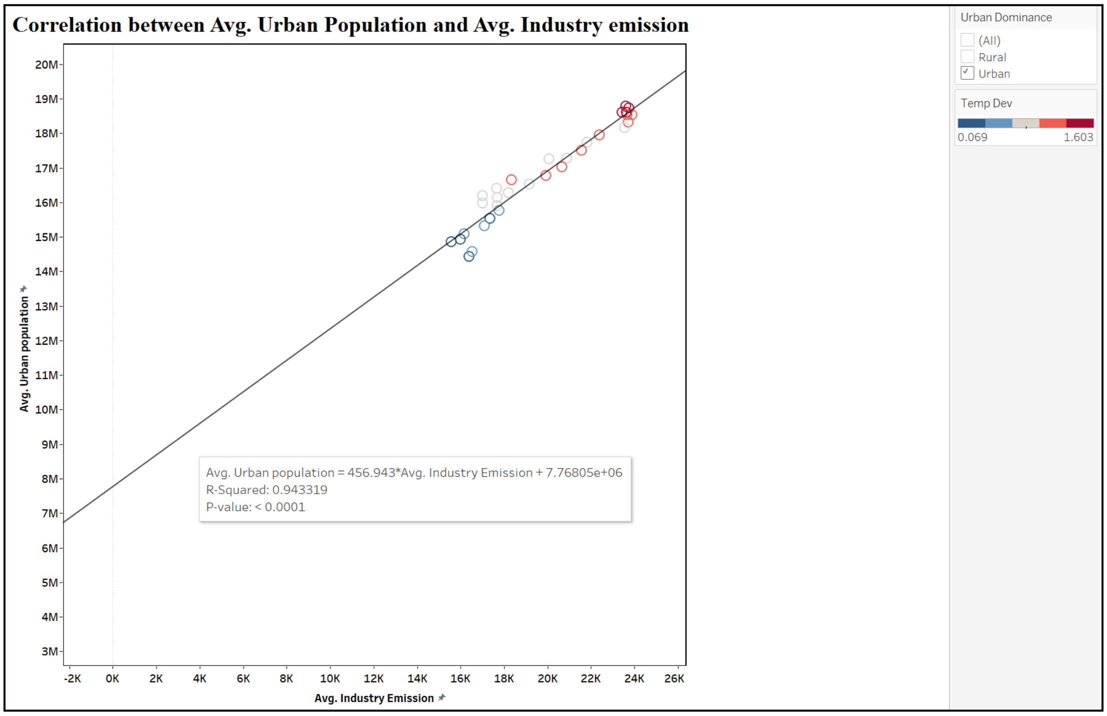
Food emissions correlate positively with temperature deviations, though the impact is less steep compared to industrial emissions. This indicates food-related activities are significant but secondary contributors to warming.Urban-dominant regions likely display higher food emissions due to lifestyle patterns, reliance on packaged foods, and long-distance transportation. The graphs suggest targeted interventions like reducing food waste, local sourcing, and energy-efficient retailing can significantly mitigate emissions.

Industrial emissions drive the largest temperature deviations due to their scale and persistence.Food emissions, while secondary, are rising rapidly, indicating a growing environmental footprint from modern food systems.Agricultural emissions remain a localized but critical factor in climate dynamics, particularly in rural economies.

Hypothesis 2:

Urban-dominant countries have significantly higher industrial and IPPU emissions compared to rural-dominant ones.

- Scatter Plot: Correlation between Avg. Urban Population and Avg. Industry emission



Data Type	3 Quantitative Attribute: Avg.Temp Deviation,Avg Urban Population,Avg Industry Emission.
Marks	Points (0D)
Channels	Horizontal and Vertical Position, Color Hue (Bidirectional)
Scalability	Very High
Task	To Find Correlation and Trend

Justification:

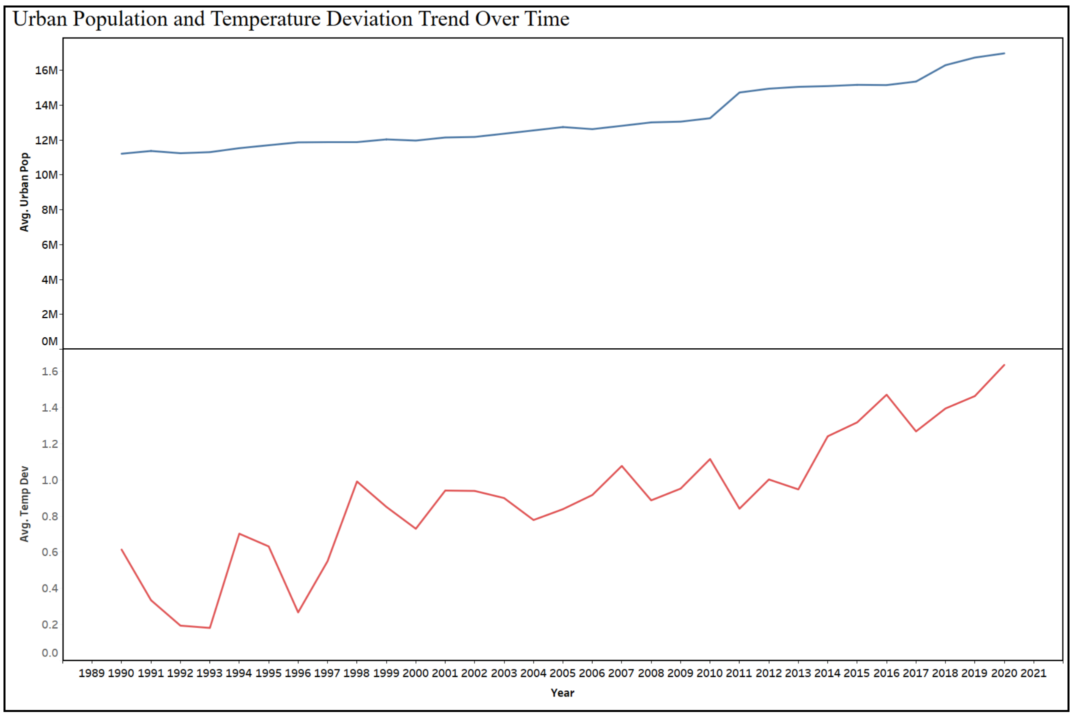
Here also scatterplot along with a regression line so as to show the correlation between the two continuous variables.

Insights:

Scatter plot shows steady increase in the urban population from 1990 to 2022, reaching approximately 15 million. The consistent rise reflects rapid urbanization, which fuels industrial activities and emissions.

With a R-square value of 0.94, this scatter plot reveals a clear positive correlation between urban population size and average industrial emissions. Countries with larger urban populations tend to emit more industrial emissions, driven by the concentration of manufacturing plants, energy consumption, and transportation needs in urban areas. The color gradient shows that higher emissions are closely linked to greater temperature deviations, reinforcing the role of urban emissions in driving climate change.

- <u>Line Chart: Urban Population and Temperature Deviation Trend Over Time</u>



Data Type	2 Quantitative Attribute: Year (ordered), Average Temp. Deviation
Marks	Points (Line connection between them)
Channels	Position, Color Hue
Scalability	High (hundreds of key levels, hundreds of value levels)
Task	Find Trend (Over the year how Temperature is increase or decrease)

<u>Justification</u>:

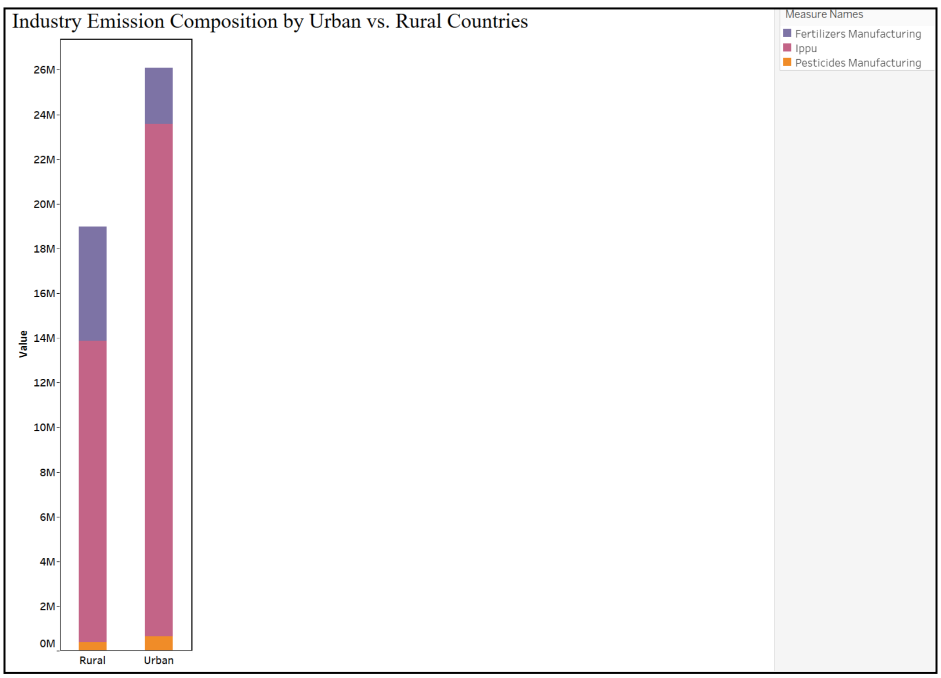
Here the line chart is used to show temporal trends for both urban population and temperature deviation for various urban countries.

Insights:

Urban Population Over Time: The line chart displays the trend of average urban population from 1988 to 2022. It shows a consistent upward trajectory, indicating steady urban growth over the years. The sharp rise after the early 2000s suggests accelerating urbanization. This visual provides insight into the demographic shift towards cities, which may align with industrial expansion and related emission patterns.

Average Temperature Deviation Over Time : This line chart shows the average temperature deviation over time, which gradually increases from 1988 to 2022. The trend indicates a progressive rise in temperature variation, with the most noticeable increase occurring after the mid-1990s. The chart offers a time-based perspective on how temperature deviation has evolved, which can be examined in relation to emission and population trends.

- Stack Bar Chart: Industry Emission Composition by Urban vs. Rural Countries

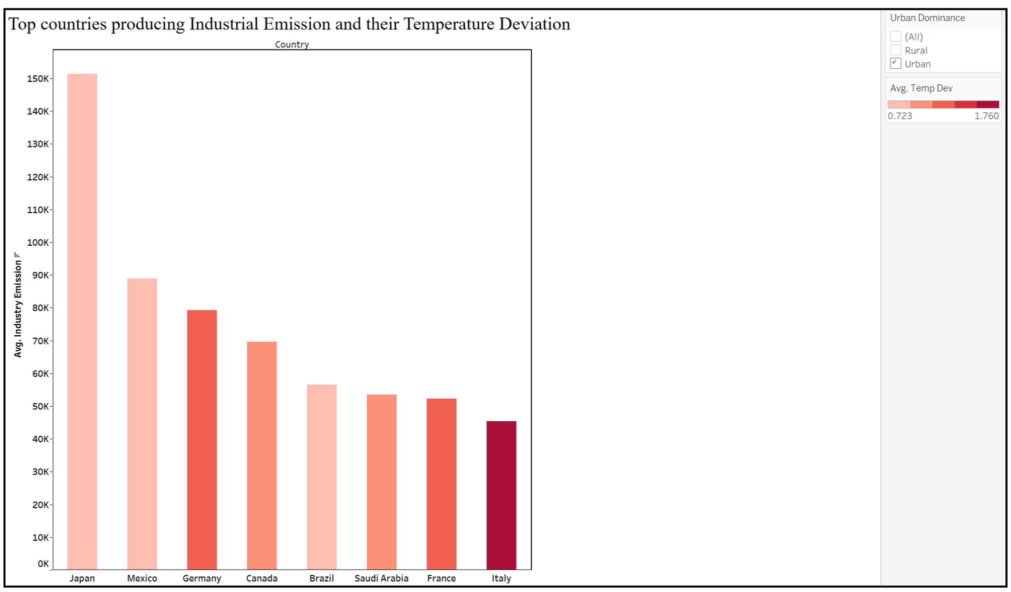


Data Type	2 Categorical: Country type(Urban or Rural dominant) 1 Quantitative: Value 2 Categorical: Country type , Component that give total emission
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position, Color Hue
Scalability	High
Task	Part to whole relationship (Rural and Urban)

Insights:

Stack Bar chart contrasts industrial emissions between rural and urban areas, broken down into three key components: IPPU (Industrial Processes and Product Use), Fertilizer Manufacturing, and Pesticides Manufacturing.
This bar chart compares the emission contributions of rural and urban areas across three industrial sources: fertilizers manufacturing, IPPU (Industrial Processes and Product Use), and pesticides manufacturing. It is evident that urban areas emit significantly more across all categories.
IPPU dominates urban emissions, suggesting that city-based industries are central to heavy industrial activities. Rural areas, while contributing less overall, still show measurable emissions, particularly from fertilizers

- Bar Chart: Top countries producing Industrial Emission and their Temperature Deviation



Data Type	1 Categorical : Country Name 2 Quantitative: Avg. Temp. Deviation,Avg. Industry Emission
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position, Color Saturation
Scalability	High
Task	Comparison

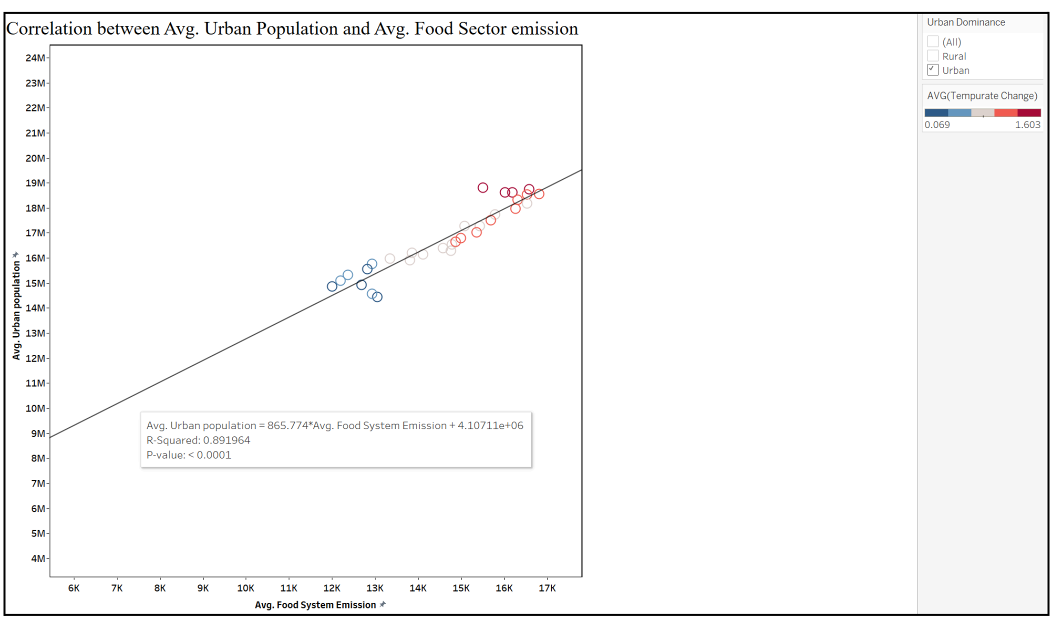
Insights:

This chart compares the average industrial emissions across countries, highlighting Japan, Mexico, and Germany as the highest contributors. These countries exhibit advanced industrialization, which directly correlates with higher temperature deviations. The contrast between nations emphasizes the disproportionate climate impact of industrialized economies.

Hypothesis 3:

Urban-dominant nations exhibit greater food processing, packaging, and household consumption emissions due to centralized supply chains and higher per capita consumption.

- Scatter Plot: Correlation between Avg. Urban Population and Avg. Food Sector emission

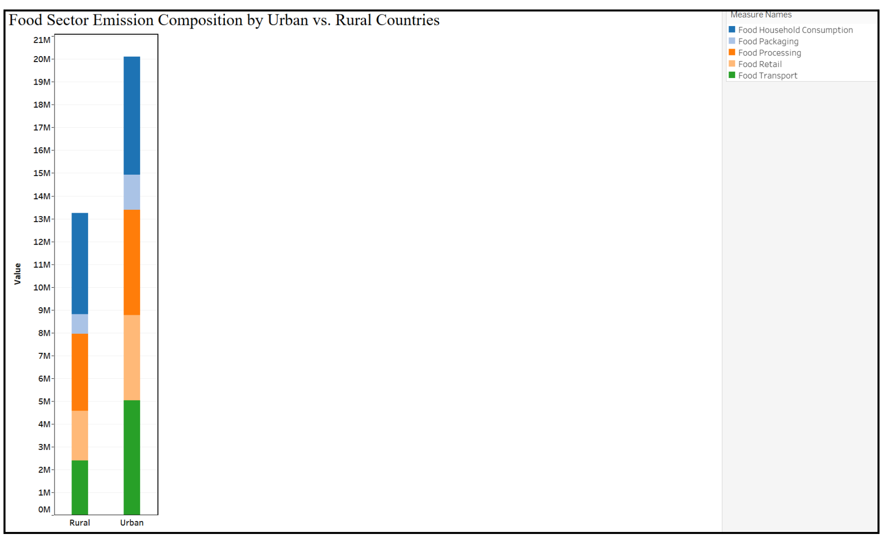


Data Type	3 Quantitative Attribute: Avg. food system emission, Avg. Urban Population, Avg. temp deviation
Marks	Points (0D)
Channels	Horizontal and Vertical Position, Color Hue (Bidirectional)
Scalability	Very High
Task	To Find Correlation and Trend

Insights:

This scatter plot visualizes the relationship between average urban population and average food system emissions. With a R-square value of 0.89, a strong positive trend is observed—countries with larger urban populations tend to have higher food sector emissions. The temperature deviation is represented by color, providing additional insight into how emissions scale with urban density and affect environmental conditions.

- Stack Bar Chart: Food Sector Emission Composition by Urban vs. Rural Countries



Data Type	2 Categorical: Country type, Component within stack bar which give total value 1 Quantitative: Value
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position, Color Hue
Scalability	High

Task	Part to whole relationship (Rural and Urban)

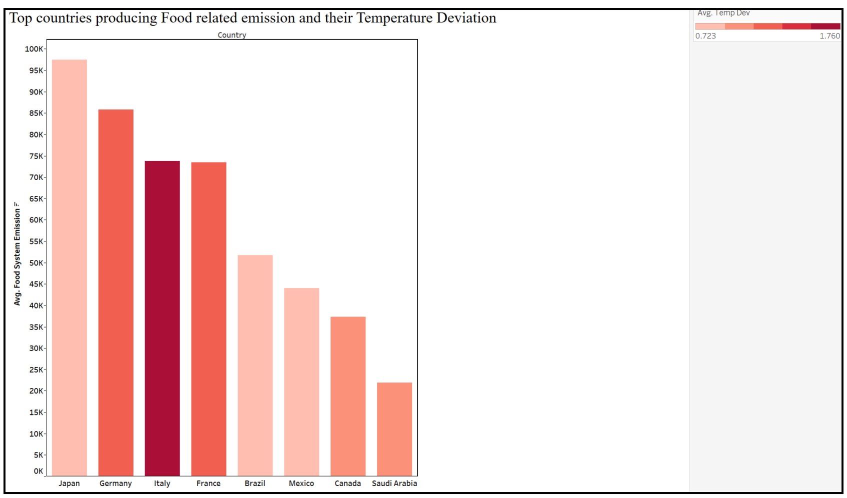
Justification:

A stacked bar chart is appropriate for comparing both total food system emissions and their internal composition across urban and rural areas. This visualization efficiently shows differences not just in magnitude but also in category-specific contributions, which would be harder to interpret in separate plots.

Insights:

The stacked bar chart compares rural and urban food sector emissions across components such as Crop Residues, Drained Organic Soils (CO_2), Manure Application, On-Farm Energy Use, and Rice Cultivation. Rural areas account for the majority of emissions, particularly in categories like rice cultivation and manure application. Urban areas contribute less overall but still register emissions from on-farm electricity and energy use. The chart highlights the spatial distribution of food sector emissions and which sources dominate within rural and urban settings.

- Bar Chart: Top countries producing Food related emission and their Temperature Deviation



Data Type	1 Categorical:Country name 2 Quantitative: Avg. Temp. Deviation, Avg. food Emission
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position, Color Saturation
Scalability	High
Task	Comparison

Justification:

This bar chart ranks countries by food emission system emission levels while incorporating a temperature deviation gradient to encode a second variable. This dual encoding allows for a clear, immediate comparison across nations, making it easy to spot which high-emission countries also experience significant warming.

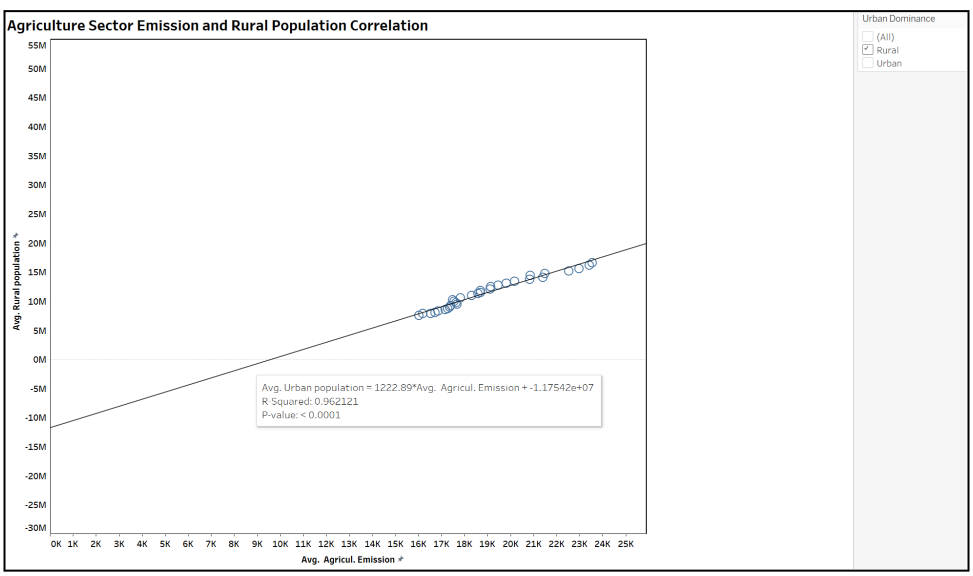
Insights:

The bar chart displays average food system emissions for several countries, with bars shaded to indicate the corresponding average temperature deviation. Japan, Germany, and Italy are among the top emitters. The variation in color helps identify how emission intensity may relate to climate variation, offering insight into how food systems impact environmental conditions across different regions.

Hypothesis 4:

Rural nations contribute more to agricultural and manure-based emissions due to higher dependency on agriculture.

- Scatter Plot: Correlation between Avg. Rural Population and Avg. Agriculture Sector emission



Data Type	2 Quantitative Attribute:
Marks	Points (0D)
Channels	Horizontal and Vertical Position
Scalability	Very High
Task	To Find Correlation and Trend

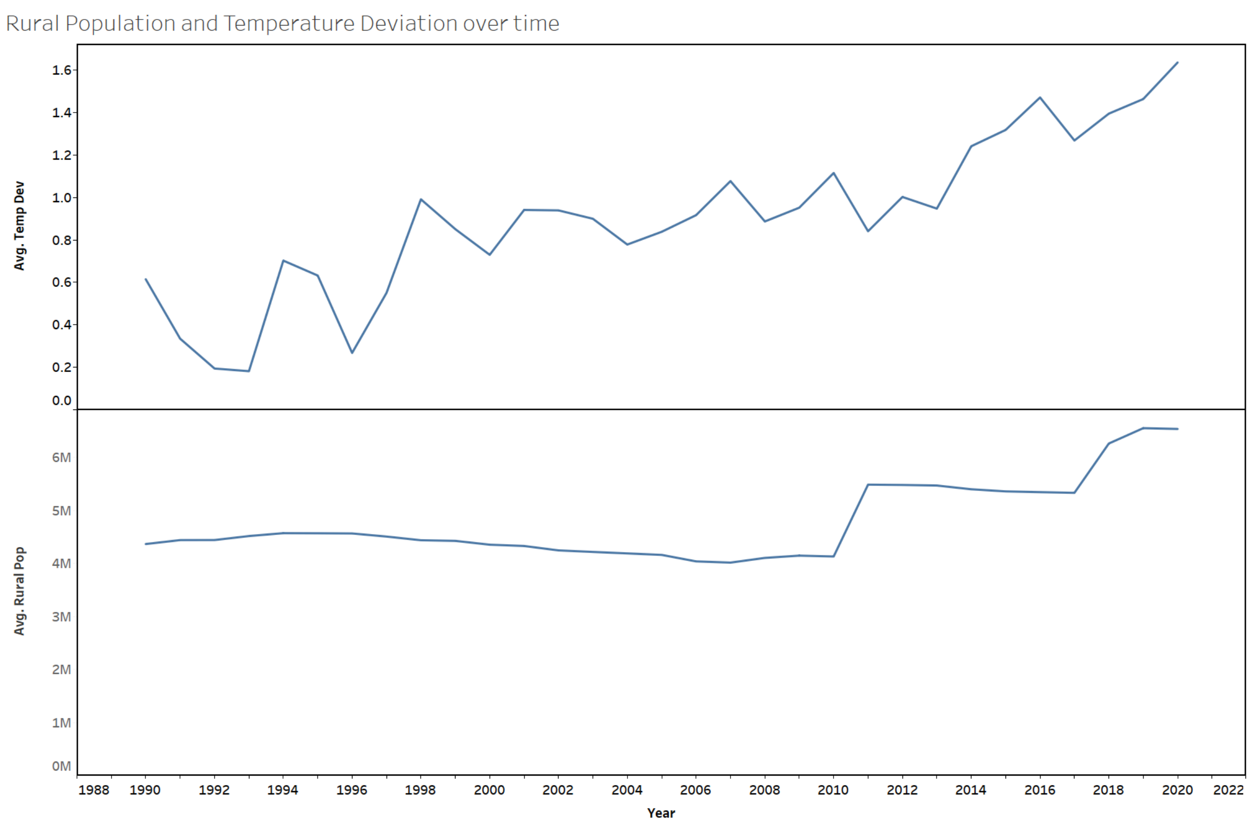
Justification:

Scatter plot displays the correlation between agricultural emissions and urban population, useful for spotting patterns or anomalies.

Insights:

The scatter plot demonstrates a very strong positive correlation ($R^2 = 0.96$, $p < 0.0001$) between average agricultural emissions and average rural population. This implies that countries with larger rural populations tend to generate higher emissions from the agriculture sector. The pattern reinforces the direct link between rural livelihoods and agricultural activity, emphasizing how population density in rural areas can significantly drive emission levels from food production.

- Line Chart: Rural Population and Temperature Deviation Over Time



Data Type	2 Quantitative: Year (ordered), Average Temp. Deviation
Marks	Points (Line connection between them)
Channels	Position, Color Hue
Scalability	High (hundreds of key levels, hundreds of value levels)
Task	Find Trend (Over the year how Temperature is increase or decrease)

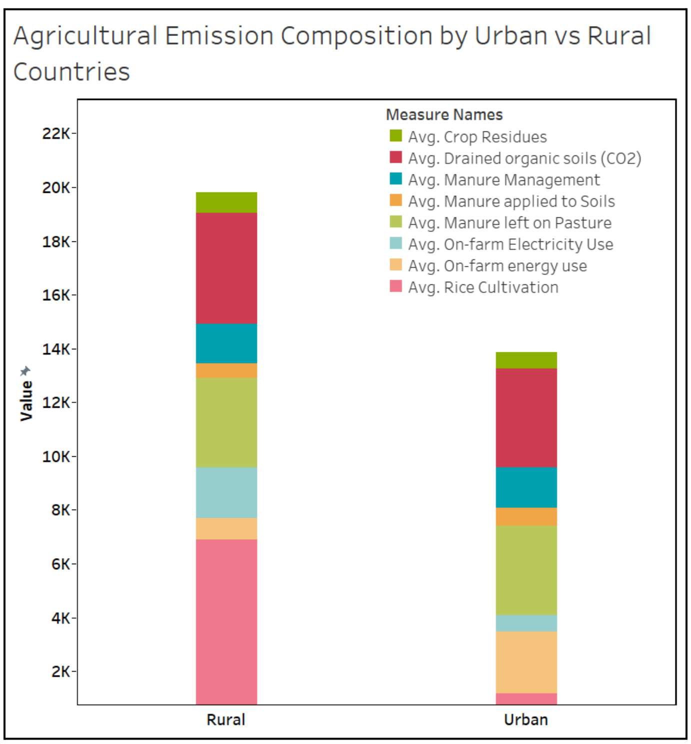
Justification:

Line charts effectively show trends over time, revealing how temperature deviation and rural population evolve.

Insights:

The line chart shows the trend in average temperature deviation from 1988 to 2022. A gradual increase is observed, especially post-2005, indicating a rise in temperature anomalies. This time series provides a contextual backdrop for analyzing how agricultural emissions may align with temperature trends over decades.

- Stack Bar Chart: Agricultural Emission Composition by Urban vs. Rural Countries



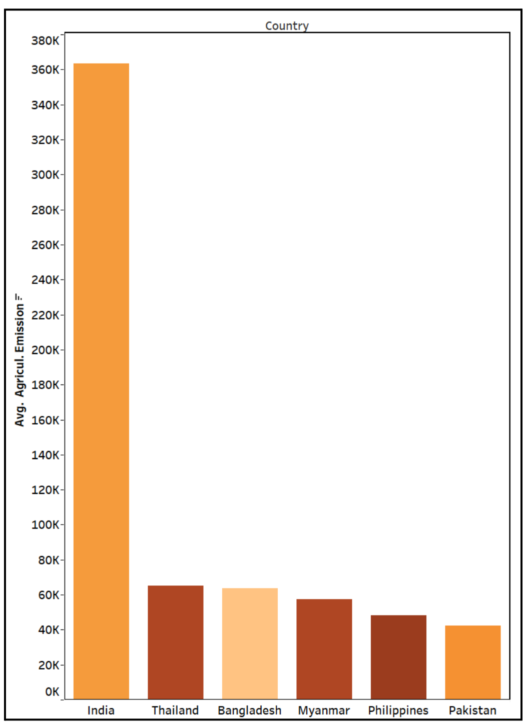
Data Type	2 Categorical: → Country type(Rural dominant or Urban Dominant),within bar Component Quantitative: Values
Marks	Line (1D)

Channels	Length, Both Horizontal and Vertical Position, Color Hue
Scalability	High
Task	Part to whole relationship (Rural and Urban)

Justification**:**Stacked bar chart shows category-wise distribution in rural and urban sectors, helping with analyzing part to whole relation as well.

Insights: The stacked bar chart compares rural and urban agricultural emissions, categorized by key components such as Crop Residues, Drained Organic Soils (CO_2), Manure Applied to Soils, Manure Left on Pasture, On-Farm Electricity and Energy Use, and Rice Cultivation. The chart clearly shows that rural areas contribute a significantly larger share of emissions across nearly all categories. Emissions from field-intensive practices like manure application, crop residue management, and rice cultivation are especially high in rural regions. Urban areas show comparatively lower emissions but still register noticeable values in energy use and manure management. The chart provides how emissions are distributed spatially, highlighting that rural agricultural activities are the dominant source across most emission categories. It also indicates which practices contribute the most within each area, helping to identify which sources are most prevalent depending on the location

- Bar Chart: Top countries producing Agriculture related emission and their Temperature deviation



Data Type	1 Categorical:Country name 2 Quantitative: Avg. Temp. Deviation, Avg
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position, Color Saturation
Scalability	High
Task	Comparison

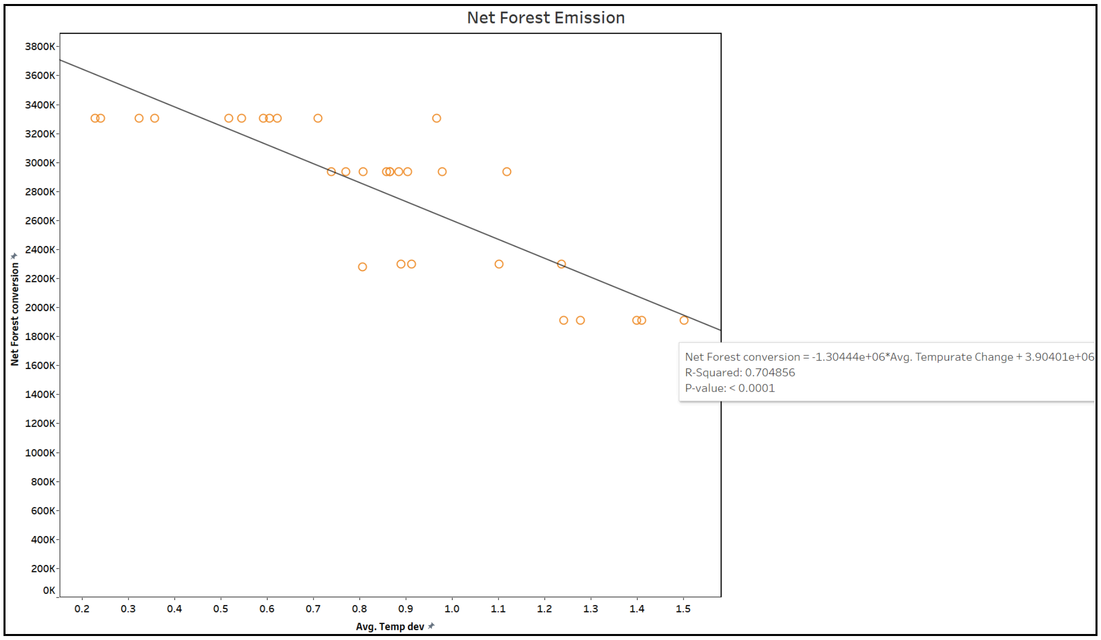
Justification**:** Bar chart is ideal for comparing average emissions across countries, highlighting top contributors visually.

Insights: This bar chart ranks countries by their average agricultural emissions, using color to reflect average temperature deviation. Indonesia leads with the highest emissions, followed by Brazil and Canada. The variation in color and emission level provides insight into which countries have the largest agricultural outputs and how these outputs may correspond to shifts in temperature.

Hypothesis 5:

Net forest conversion is more in rural countries compared to urban dominated countries.

- Net Forest Area vs Temperature Deviation:



Data Type	Quantitative Attribute: Avg Temperature Change, Net Forest Conversion
Marks	Points (0D)
Channels	Horizontal and Vertical Position
Scalability	Very High
Task	To Find Trend and Correlation Between Average Temperature Change and Net Forest Conversion

Justification:

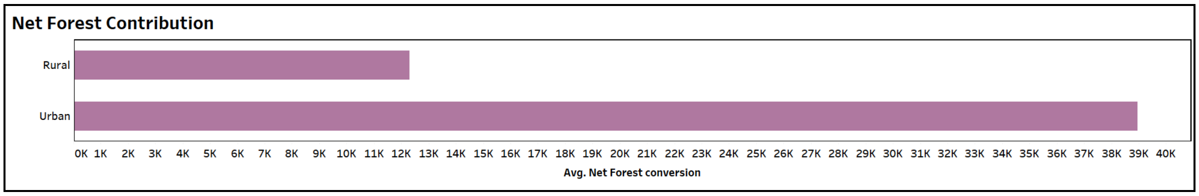
The scatter plot along with regression line is ideal for showing the amount of correlation between the two continuous variable

Insights:

There is a moderate negative correlation between temperature deviation and net forest conversion. As average temperature deviation rises, net forest conversion (in K hectares) tends to decrease.This suggests that rising temperatures may be associated with a decline in forest cover, possibly due to increased deforestation, wildfires, and land-use changes.

Forests play a vital role as carbon sinks; therefore, this trend highlights the urgent need for afforestation and conservation policies to counterbalance temperature rise and ecosystem degradation.

- Comparing Urban and Rural countries based on average net forest conversion.



Data Type	Categorical: Type of Country Urban and Rural Quantitative: Net forest Conversion
Marks	Line (1D)
Channels	Length, Both Horizontal and Vertical Position
Scalability	High
Task	Comparison

Justification:

Helps in easily describing the contribution of each category to net forest conversion.

Insights:

The bar graph illustrates how both rural and urban areas contribute to net forest conversion. The value is far higher in urban-dominant areas than in rural ones, suggesting that urban areas account for a far greater proportion of the change in total forest area. The significant and substantial net forest conversion in this area suggests that urbanization is a primary cause of net forest loss, most likely as a result of deforestation for infrastructure, industrial development, and building. Rural regions, on the other hand, make up a much smaller portion of the total forest conversion, indicating a more balanced land use or comparatively less influence. This realization highlights the strain urbanization is placing on the ecosystem and bolsters the argument for sustainable urban design.

Conclusion

The research, led mainly by industrial processes and the global food system, typically illustrates a strong correlation between rising CO_2 emissions and high temperature anomalies. The environmental importance of food systems today lies in the fact that emissions from the agricultural and food production system account for a considerable share of total emissions. It is also interesting to note that landlocked and coastal nations both follow the same pattern of warming, implying that the impact of climate change is widespread and not geographically limited. The implications of the findings point towards the imperative need for international efforts to curb emissions, especially in the industrial and food system domains.