Analysis and Visualization of Agricultural Data based on the impact of Climate Change through ETL process.

1. Introduction:

Climate change is increasingly reshaping agricultural landscapes worldwide, posing significant challenges to food security and crop productivity. The effects of rising mean surface temperatures are particularly evident in countries with diverse agricultural practices and climatic conditions. The impact of climate change on crop yield, measured in hectogram per hectare (hg/ha), varies by region. The temperate regions such as Turkey and Germany may initially benefit from warmer temperatures with longer growing seasons. The tropical regions such as Pakistan and Australia are likely to suffer more from increased temperatures, as many crops are already near their optimal temperature range.

For this purpose, the objective of this project is to build an ETL pipeline to assess the impact of climate change on agricultural data and provide necessary valuable insights based on the below project question:

Project Question:

What impact has climate change based on mean surface temperature variation had on crop yield in countries with diverse climates like Pakistan, Germany, Turkey, and Australia in the last years ? Have there been any trends or recurring patterns, in the yields of key crops such as maize, wheat, rice, and grapes?

2. ETL Pipeline and Final Data:

The pipeline generates a merged dataset that integrates crop yield data with mean surface temperature statistics from various countries globally. To maintain consistency, the analysis focuses on the period from 1970 to 2019 and selects comparable countries for examination. To meet the requirements and page limitations of the report, the analysis includes major countries such as Pakistan, Germany, Turkey, and Australia, and focuses on crops of interest: maize, wheat, rice, and grapes. The combined data is shown in table 1.

Table. 1: Overall dataset description

Dataset	License	Data Format	Parameters			
Dataset-1	CC BY-NC-SA	CSV	Different Crops	Yield (Hg/Ha)	1970-2019	Worldwide
Dataset-2	CC0 1.0	CSV	Mean Surface Temperature	°C	1970-2019	Worldwide

Note: This work is purely non-commercial and is used only for semester project of module “MADE” at FAU.

3. Analysis: Impact of Climate Change on Crop Yield in Diverse Climates

To address the question of how climate change, specifically mean surface temperature variations, has impacted crop yields in countries with diverse climates such as Pakistan, Germany, Turkey, and Australia over the period from 1970 to 2019, a comprehensive analysis was conducted. This analysis focused on key crops including carrots, turnips, maize, rice, and grapes. The results of this analysis are presented through time series plots.

3.1 Visualization Results:

Climate change poses significant challenges to global agricultural productivity, impacting crop yields. Efficient data analysis and visualization are crucial for understanding the complex relationship between surface temperature changes and agriculture.

3.1.1 Crop Yield Trends:

Illustrated the crop yield plots for Pakistan, Germany, Turkey, and Australia over the period from 1970 to 2019. The data showed varied trends, as shown in figure 1:

- **Carrots and Turnips:** An overall upward trend in these crop yields is evident, reaching upto 600k hg/ha by 2019 for the countries: Turkey, Germany and Australia. However, there were consistent declines in the yield of carrots and turnips in Pakistan from 1975 to 2019, with the yield remained below 200k hg/ha.

- **Maize and Rice**: Fluctuations in these crop yields with a general upward trend in maize and rice yields. Germany had the highest average maize yield, with 75,972.52 hg/ha over the entire period, despite not producing rice. In contrast, Australia achieved the highest average rice yield at 78,909.78 hg/ha.
- **Grapes:** The production of grapes exhibited significant variability in yields, which were heavily influenced by changes in temperature. This crop was particularly sensitive to fluctuations in climate conditions.

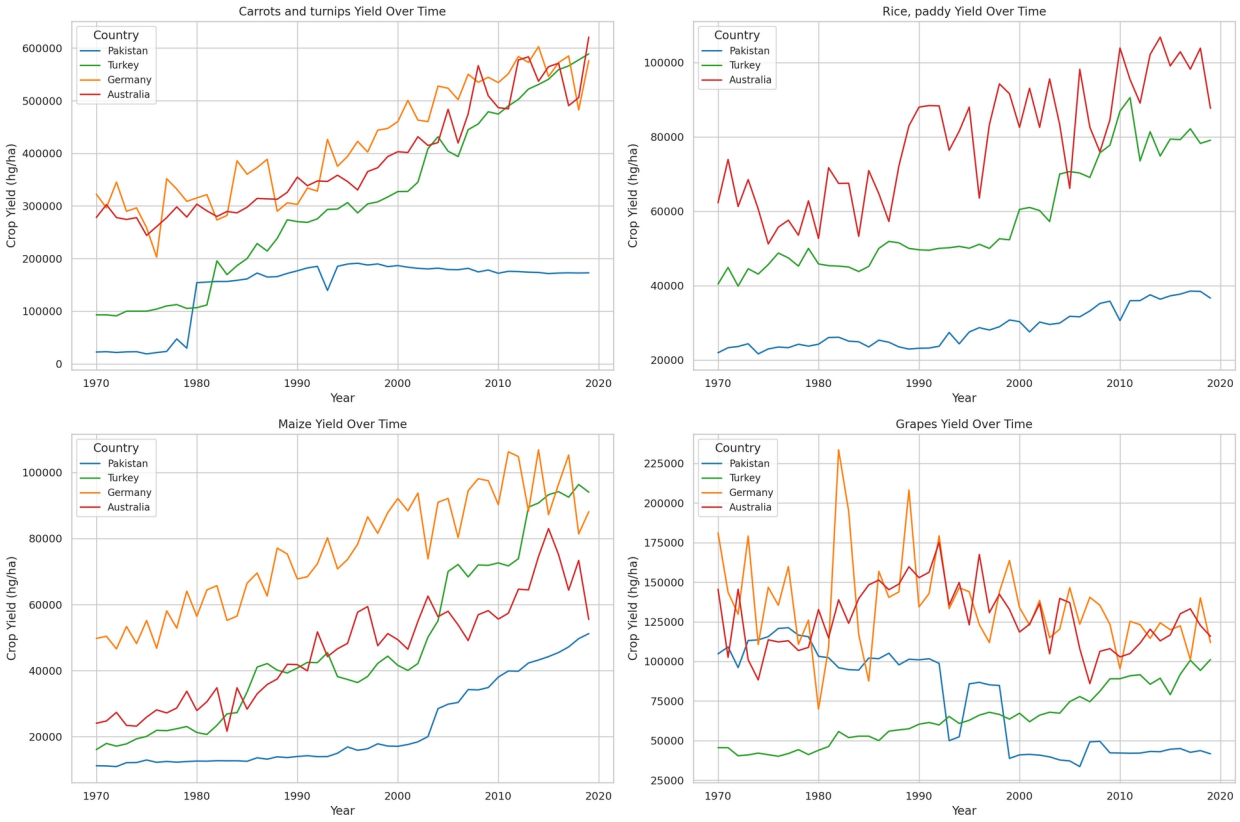

Fig. 1: Crop yield over specific period from 1970 to 2019.

3.1.2 Maximum Mean Surface Temperature:

Displayed the maximum mean surface temperature recorded among several countries from 1970 to 2019. This graph provided an overview of the temperature trends and highlighted the years of significant temperature changes. The plot as shown in figure 2, revealed a clear upward trend in mean surface temperatures across the countries. Notable peaks in temperature were observed for Canada in certain years, indicating periods of significant climatic changes as upto 2.93 °C temperature.

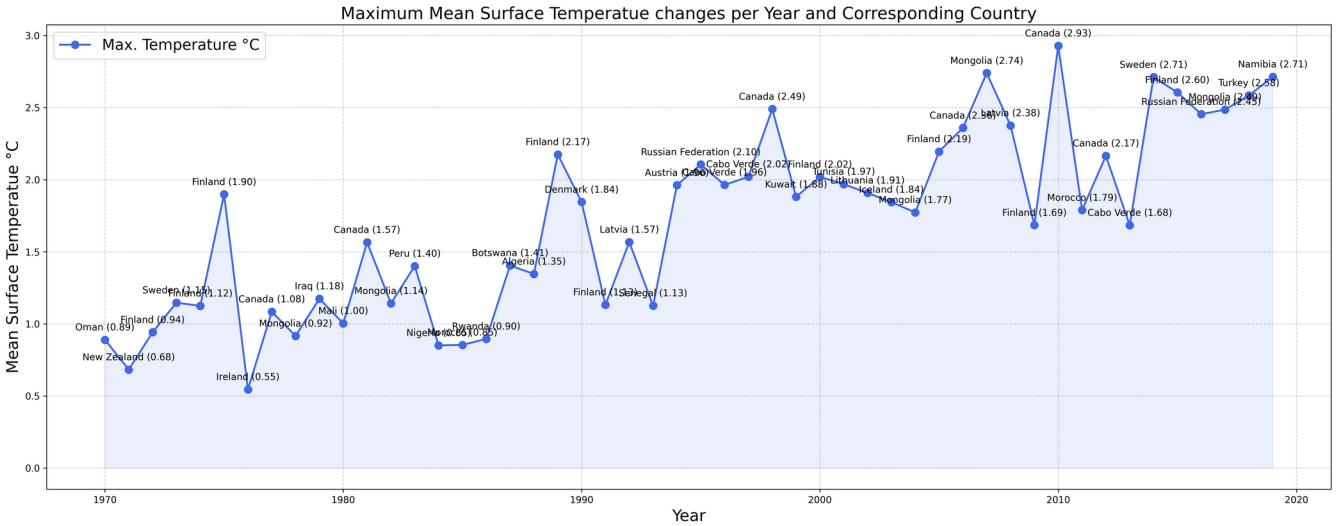

Fig. 2: Overall trend of maximum mean surface temperature change with corresponding country over time

3.1.3 Correlation Between Crop Yield and Temperature Change:

Showed the correlation between crop yields and mean surface temperature changes for the aforementioned countries and crops. From 1970 to 2019, the crop yields in Pakistan, Germany, Turkey, and Australia exhibited diverse trends influenced by rising mean surface temperatures, which increased by approximately between 1-2 °C across these regions. This section aimed to reveal any direct relationships between temperature variations and crop yield.

- **Carrots and Turnips Yield vs Temperature changes:**

In Germany and Turkey, the moderate increase in temperature in these temperate regions positively correlated with extended growing seasons, significantly boosting yields to around 580,000 hg/ha and 590,000 hg/ha respectively by 2019, indicating potential adaptability to gradual climate change. In Australia, similar temperature increases improved growing conditions, pushing yields to over 500,000 hg/ha. However, in Pakistan, despite a similar temperature rise, yields remained relatively low as below 200,000 hg/ha, due to increased heat stress and water scarcity typical of its tropical climate. Figure 3 illustrates these trends.

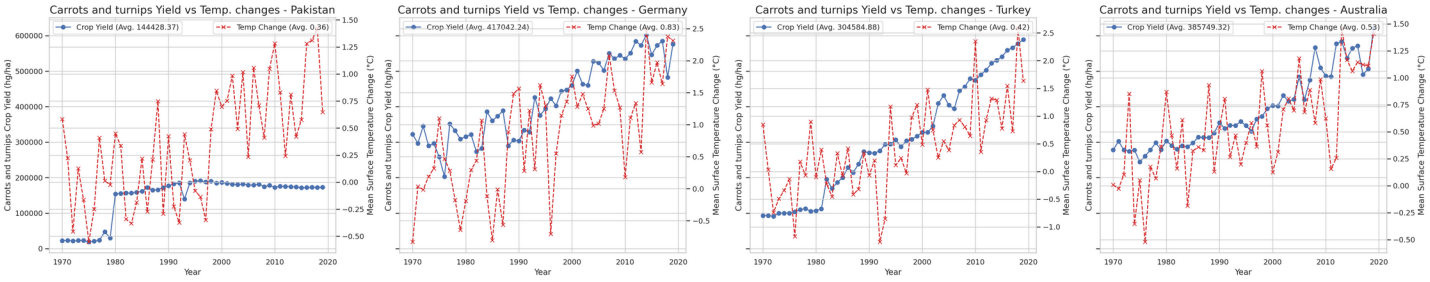

Fig. 3: Carrots and Turnips yield vs temperature changes over time.

- **Grapes Yield vs Temperature changes:**

Germany emerged as a leading producer in yields, averaging around 135,726 hg/ha, benefiting from fluctuating temperature increases that extended the growing season. Turkey as a temperate region also saw notable improvements in relatively stable yields showing positive correlation with an increase in temperature, averaging about 64,450 hg/ha, leveraging favorable climatic conditions. In contrast, Pakistan as a tropical region displayed mixed results, with some negative correlations in periods of extreme temperature changes, having average yield 75,068 hg/ha, due to increased heat stress and variable climatic conditions. Australia's grape yields showed resilience to temperature changes, maintaining steady increase in yield till 1994, but downfall in grape yield can be seen in later years caused by high temperature variations, having average around 126,958 hg/ha. The graph is shown in figure 4.

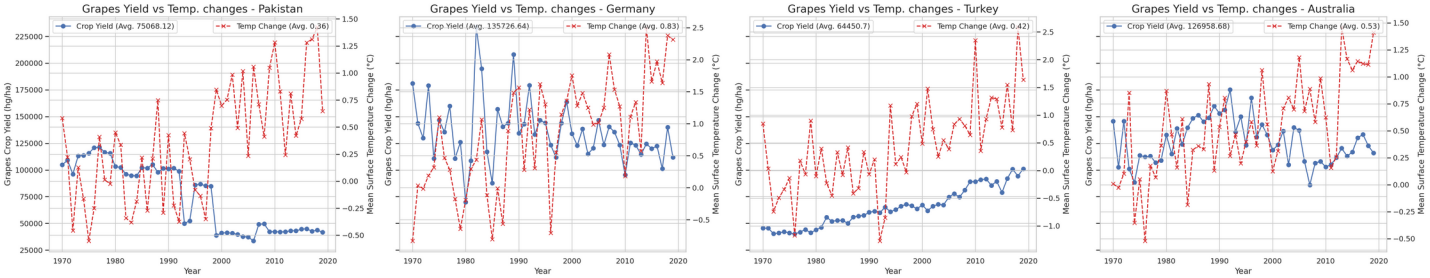

Fig. 4: Grapes yield vs temperature changes over time.

- **Maize Yield vs Temperature changes:**

Germany consistently led in maize production, achieving average yields of around 75,972 hg/ha, benefiting from favorable climatic conditions. Turkey also showed robust maize yields, averaging approximately 47,472 hg/ha, favoring the increase in temperature. Pakistan and Australia experienced steady increase in maize yield, averaging about 22,240 hg/ha and 45,897 hg/ha, respectively, with occasional fluctuations influenced by regional climate variations. The graph is shown in figure 5.

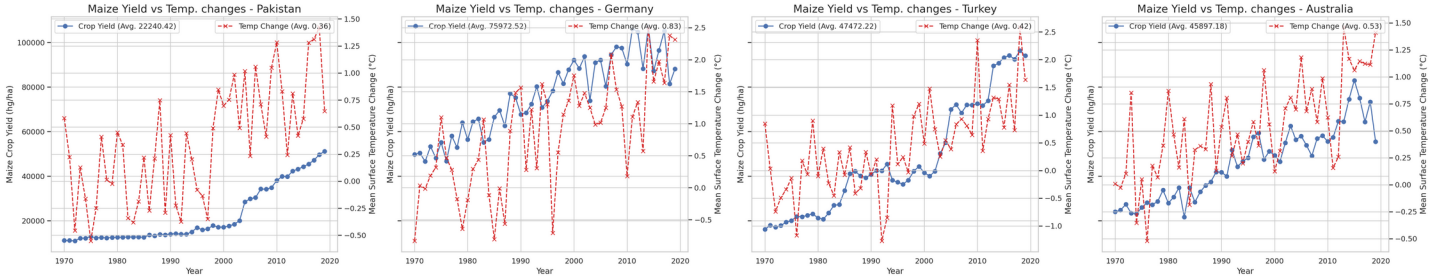

Fig. 5: Maize yield vs temperature changes over time.

- **Rice (Paddy) Yield vs Temperature changes:**

Germany did not produce rice, focusing instead on other crops. Turkey demonstrated consistent rice yields, averaging around 58,150 hg/ha, supported by favorable temperature changes. Australia experienced fluctuations in rice yields but still achieved a highest average yield of approximately 78,909 hg/ha. In contrast, Pakistan's rice yield showed a steady increase, averaging about 28,490 hg/ha, benefiting from moderate temperature increases. The graph is shown in Figure 6.

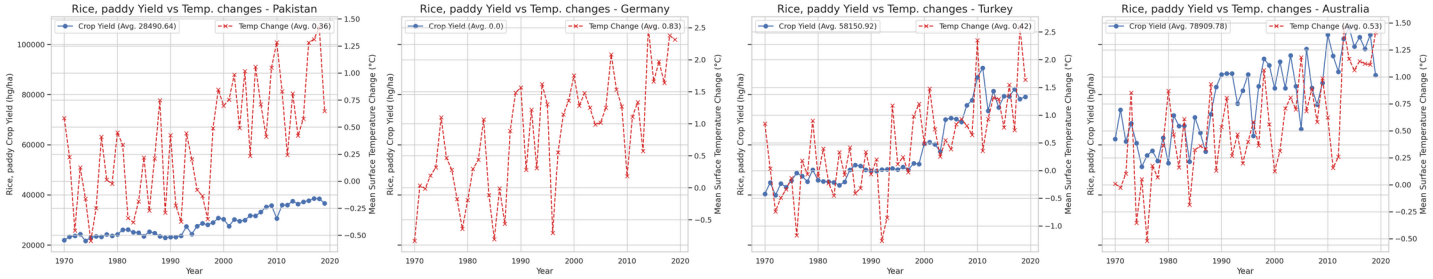

Fig. 6: Rice yield vs temperature changes over time.

4. Discussion and Conclusion:

The analysis of crop yields in Pakistan, Germany, Turkey, and Australia from 1970 to 2019 reveals that rising mean surface temperatures significantly impacted yields of maize, wheat, rice, and grapes. While rice and maize showed adaptability to gradual temperature increases and crops like carrots, turnips, and grapes were more affected by extreme temperature variations. Countries with strong agricultural practices, like Germany and Turkey, managed to sustain and even increase yields despite these climatic changes.

This ETL framework and analysis highlights the need for continued improvements in climate-resilient agricultural practices to ensure food security during global climate changes, empowering policymakers and researchers with informed decision-making capabilities.

4.1 Limitations:

- **Data Scope:** The analysis did not include other climatic factors like precipitation and extreme weather.
- **Regional Variability:** Local agricultural practices and policies were not accounted for, which could also influence yields.
- **Ongoing Changes:** The findings are based on historical data; future trends may differ with continuing climate change.