How Climate Change Affects U.S. Corn and Wheat Yields

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https://github.com/yilongxu-usc/dsci510_fall2025_final_project

Introduction

- Project Goal：To examine how temperature and precipitation relate to corn and wheat yields across different U.S. states from 1970–2024

- Key Questions：
  - Do corn and wheat respond differently to temperature and precipitation?
  - Are climate–yield relationships consistent across states, or highly regional?
  - Which climate variable appears more influential on crop yield?

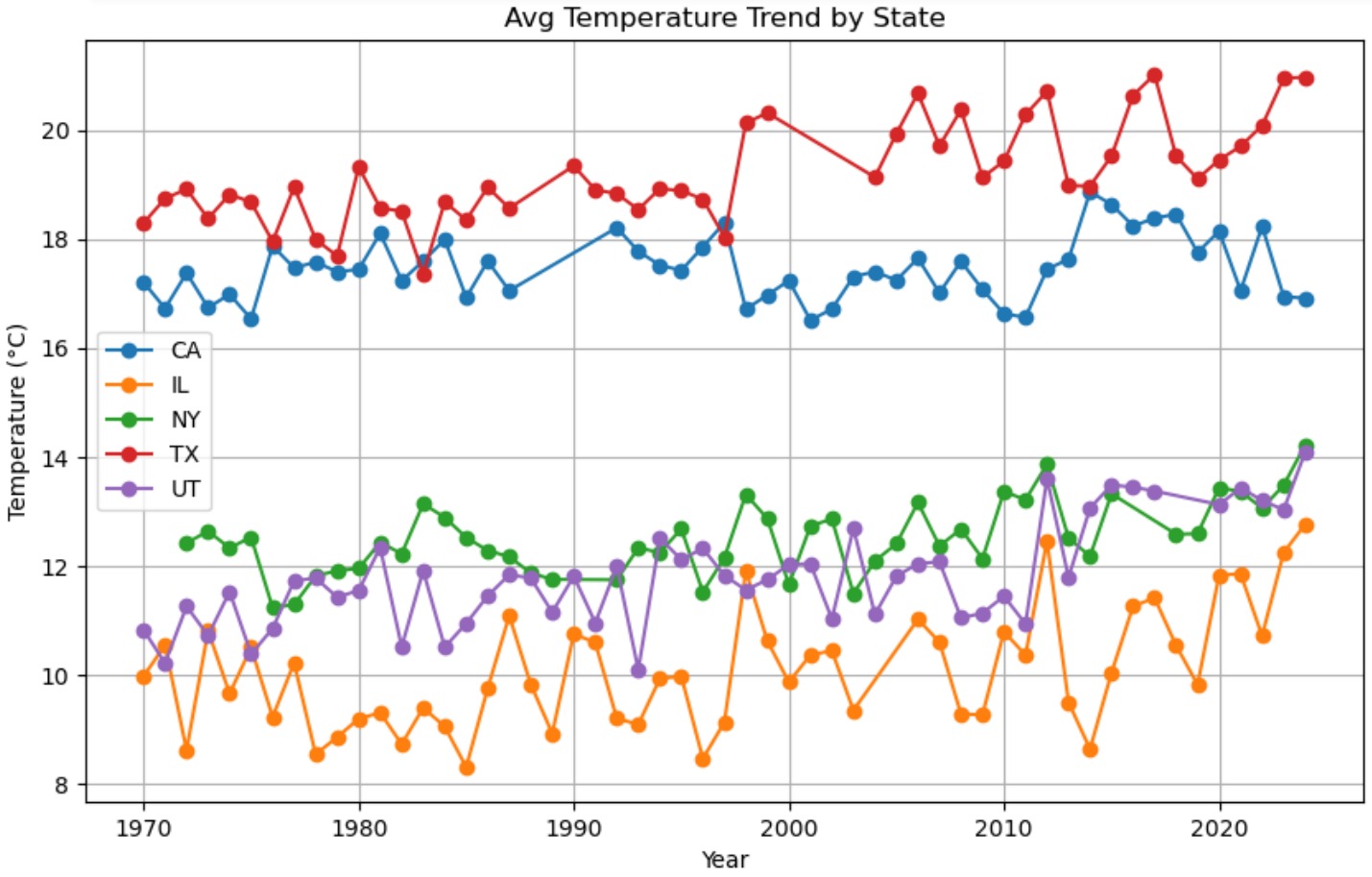
- Approach：Integrating USDA crop yield data with NOAA climate records and apply correlation, regression, and trend analysis at the state level

Data Sources

Date Range: 1970/01/01- 2024-12-31

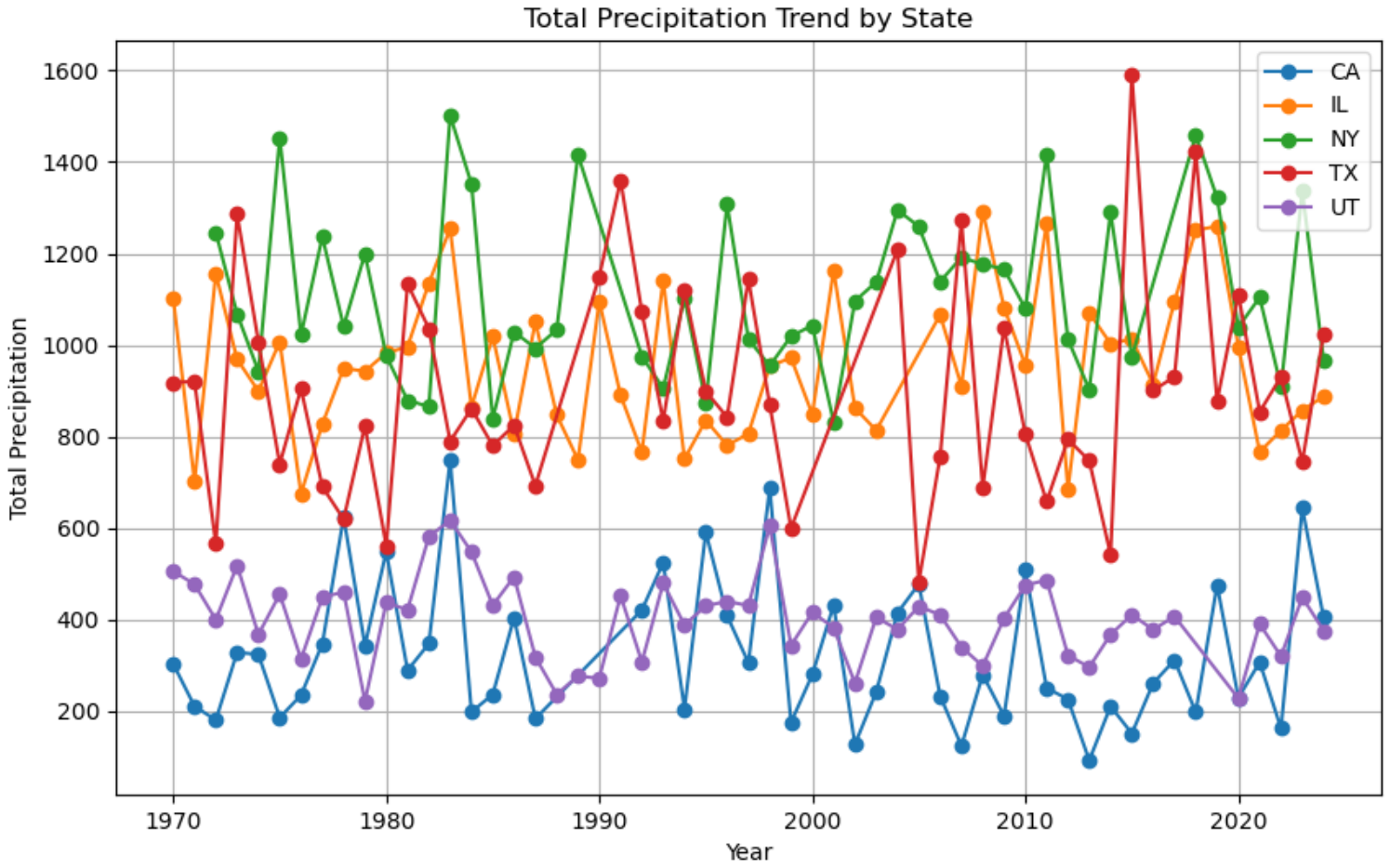
Dataset	Description	Type	Format	Data Size
Corn Yield Data, USDA NASS	• Provides annual corn yield (bushels per acre) for U.S. states. • Shows how corn productivity varies geographically and how yields change over time	API Call	HTML response > json > CSV	13000+ rows, 3 columns
Wheat Yield Data, USDA NASS	• Contains annual wheat yield statistics for U.S. states • Works together with corn yield data to provide two independent agricultural indicators		HTML response > json > CSV	22000+ rows, 3 columns
Monthly temperature and precipitaion	• Provides monthly average temperature (TAVG) and total precipitation (PRCP) for multiple U.S. climate stations • Used to compute annual climate metrics (mean temperature, accumulated precipitation) matched by state		HTML response > json > CSV	6000+ rows, 7 columns

Temperature Trends Across States (1970–2024)



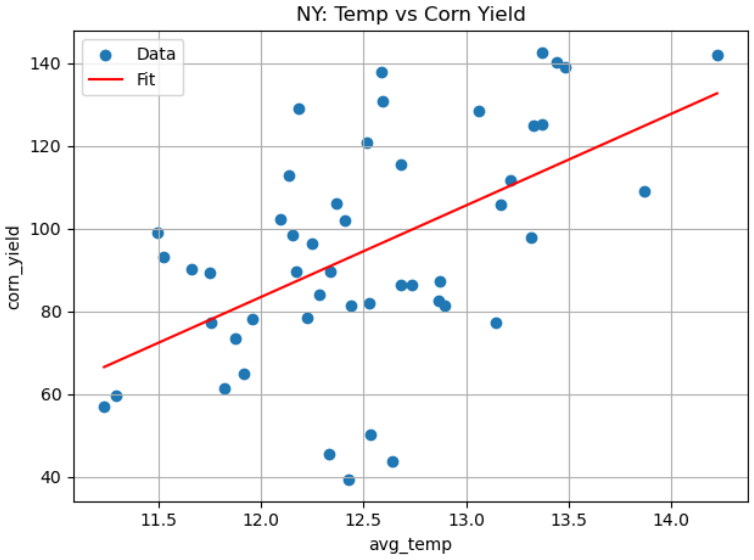
- All five states exhibit a clear long-term warming trend from 1970 to 2024, although the rate and magnitude differ by state.
- Texas consistently records the highest average temperatures, remaining well above other states throughout the entire period and showing a persistent upward trend, especially after the late 1990s
- California also shows sustained warming, with relatively high average temperatures compared to northern states and a noticeable increase since the 1980s, though with some mid-period variability
- Illinois and New York remain cooler overall, but both display gradual warming over time, with more pronounced increases in the most recent decades (post-2000)
- Utah demonstrates the greatest year-to-year variability, with sharper short-term fluctuations around its warming trend, suggesting higher climate variability relative to the other states
- The warming signal becomes more pronounced after 2000, indicating accelerated temperature increases across most states in the last two decades

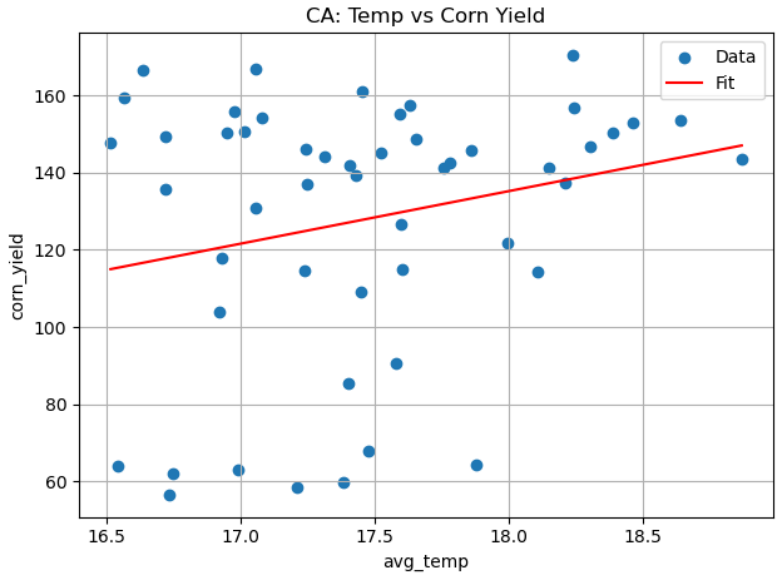
Precipitation Trends (1970–2024)



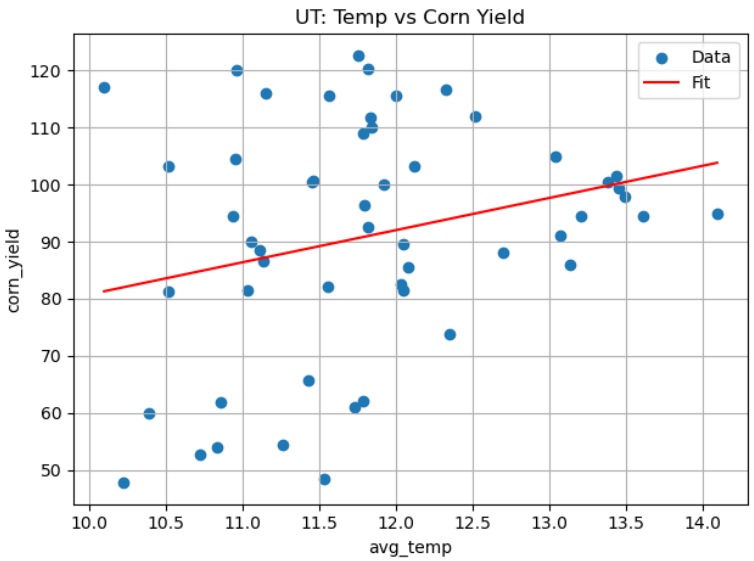
- Total precipitation exhibits substantial year-to-year variability across all five states, with no smooth or uniform long-term trend comparable to temperature
- New York and Texas generally experience higher annual precipitation totals, frequently exceeding other states, but both also show pronounced fluctuations, including occasional extreme wet years.
- Illinois displays moderate precipitation levels with noticeable interannual variability, but without a clear long-term increasing or decreasing trend across the full period
- California remains consistently the driest state, with lower total precipitation values throughout the time series and sharp fluctuations that highlight its sensitivity to wet and dry years
- Utah records relatively low to moderate precipitation, with pronounced variability but no persistent long-term trend, suggesting precipitation changes are dominated by short-term climate variability rather than gradual shifts
- Compared to temperature trends, precipitation patterns are more irregular and episodic, indicating weaker long-term signals and stronger influence of year-specific climate conditions

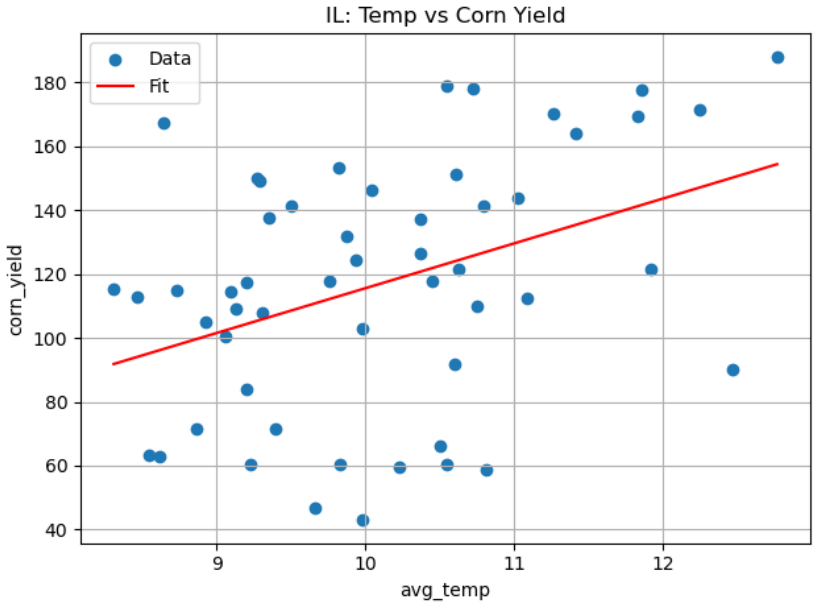
Effect of Temperature on Corn Yields (per state)

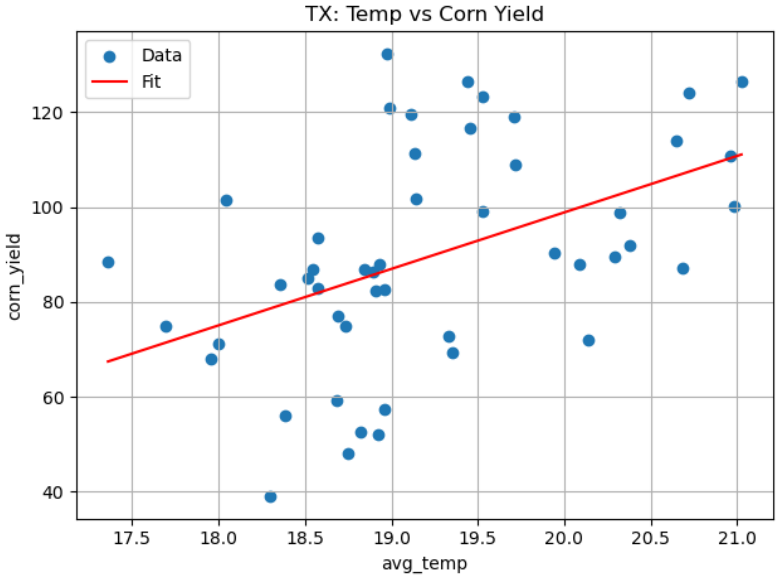




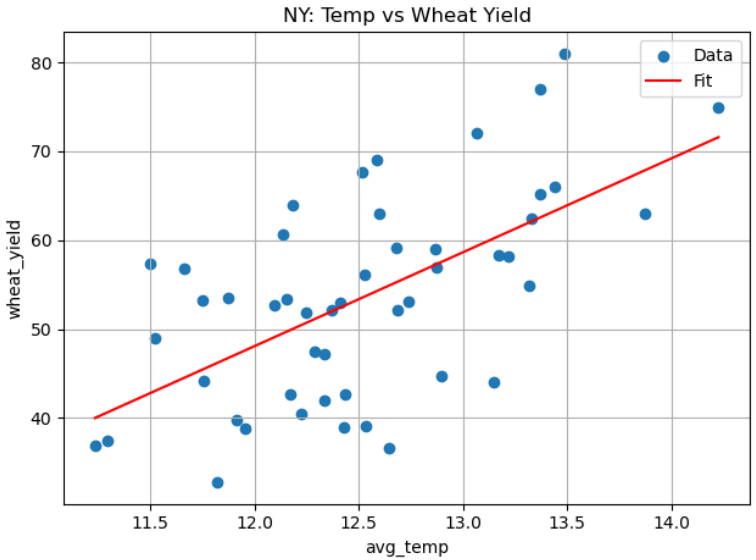
Each point represents a state-level annual observation, pairing average temperature with corn yield for that year

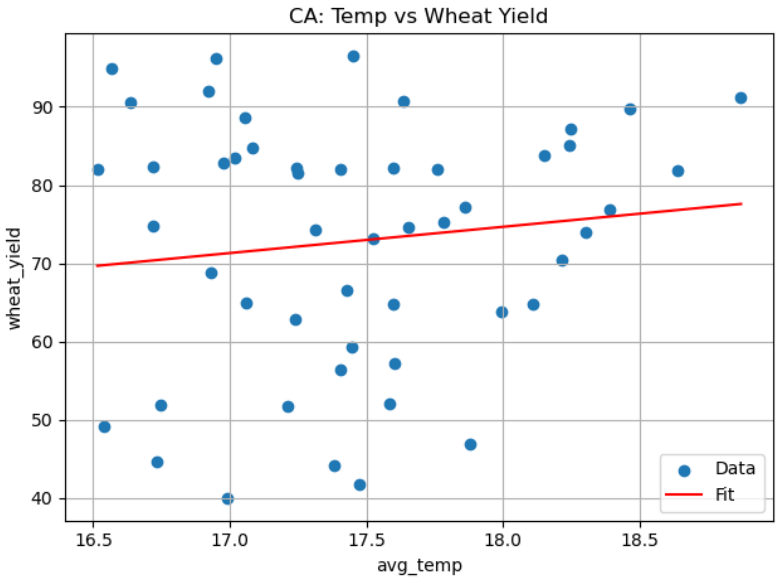




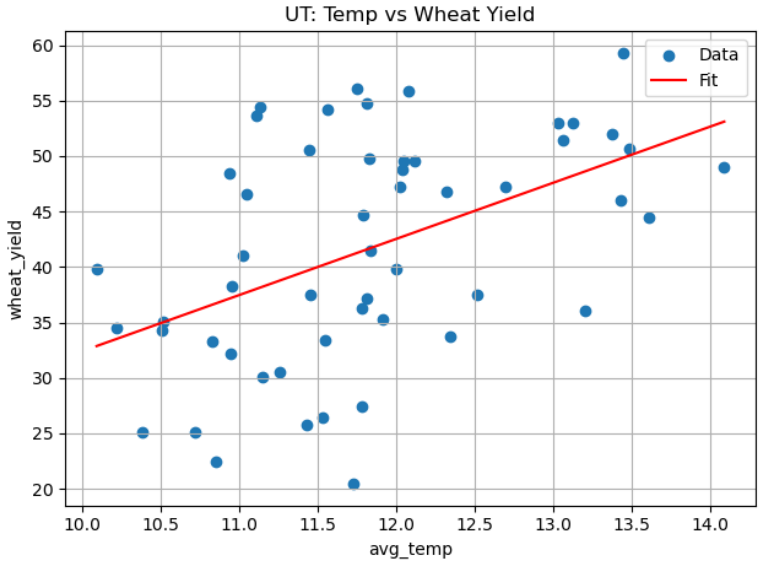


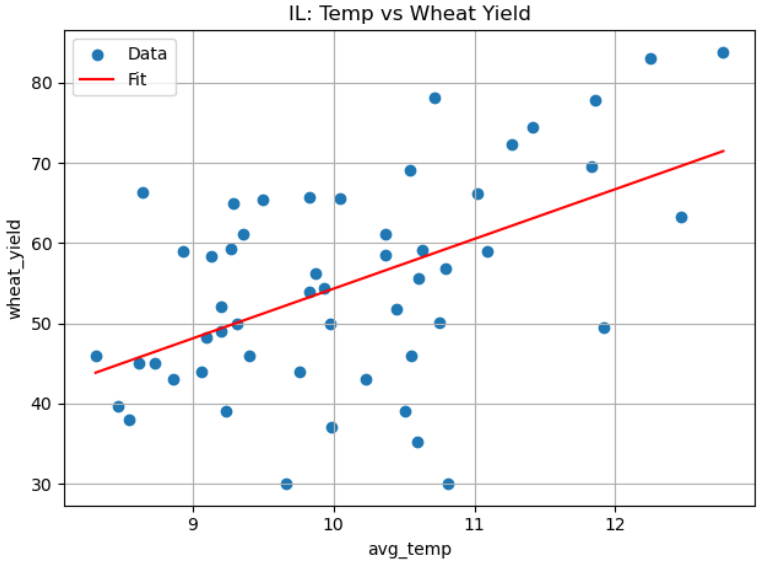
Effect of Temperature on Wheat Yields (per state)

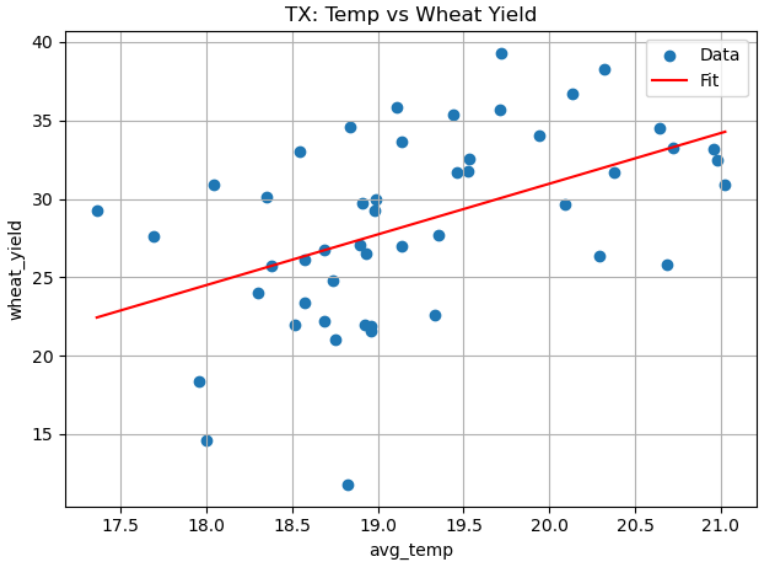




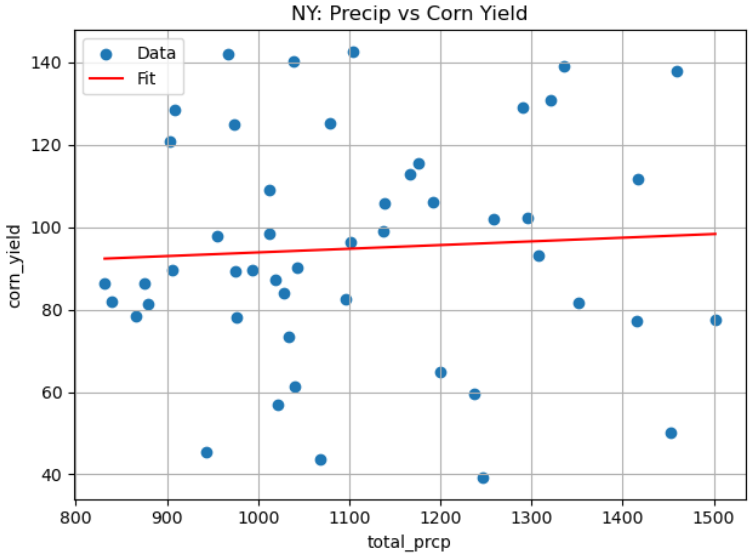
Each point represents a state-level annual observation, pairing average temperature with wheat yield for that year

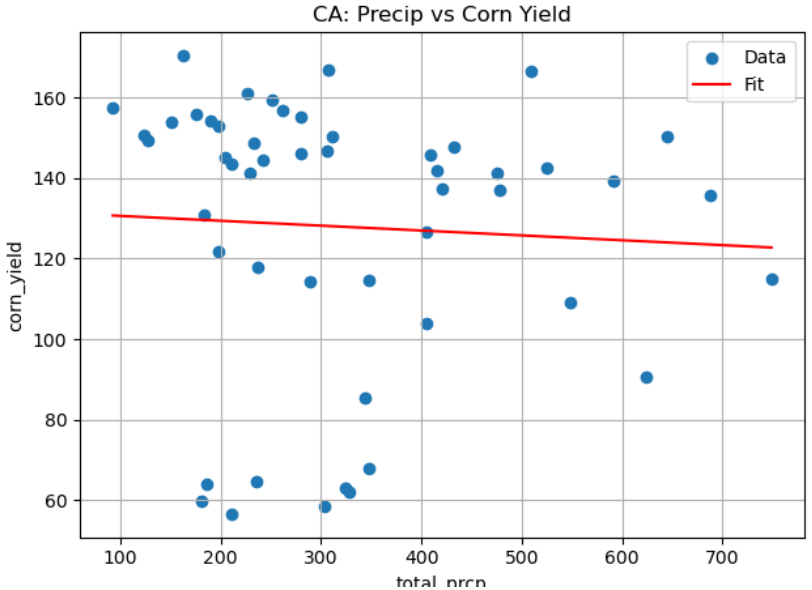




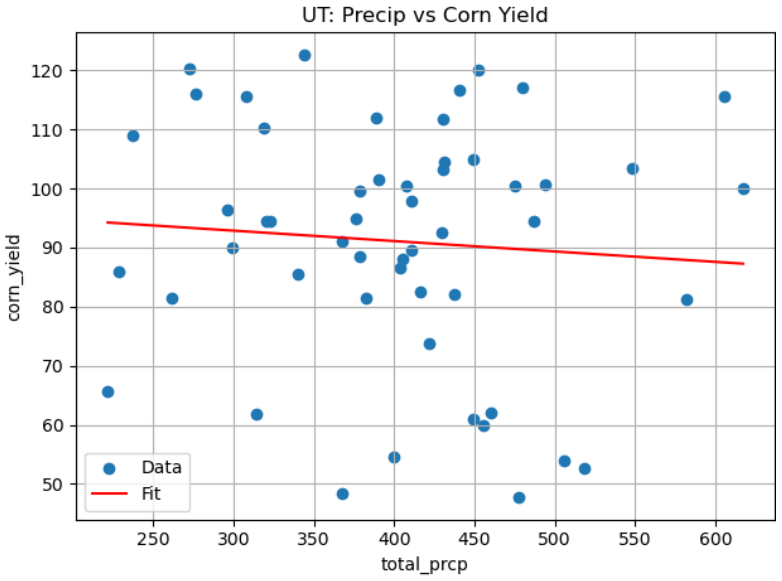


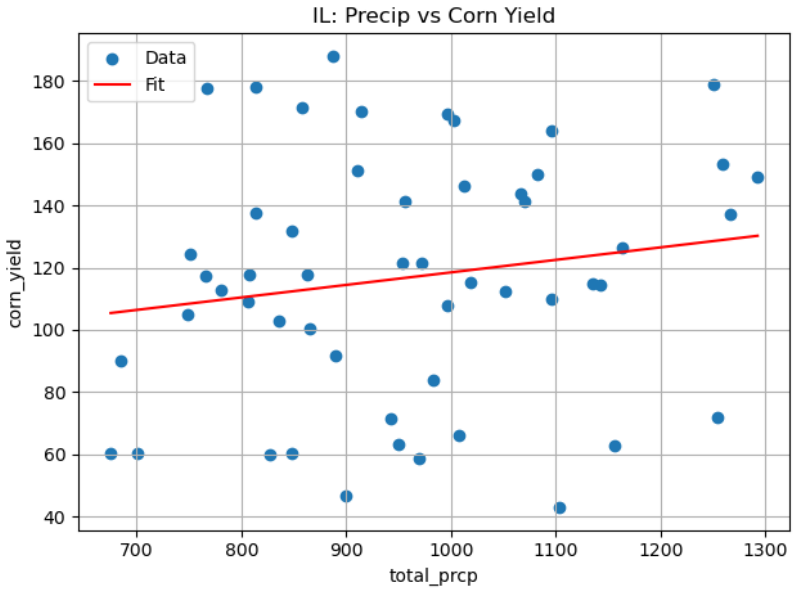
Effect of Precipitation on Corn Yields (per state)

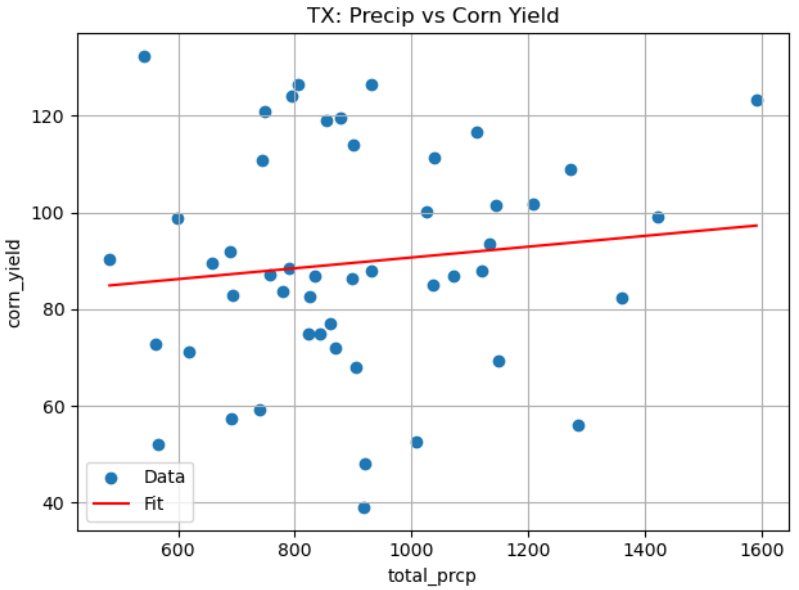




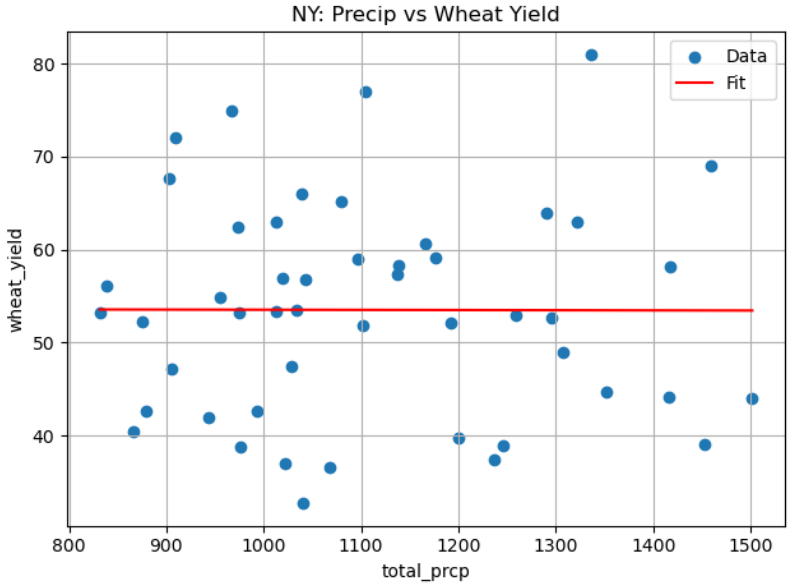
Each point represents a state-level annual observation, pairing average precipitation with corn yield for that year

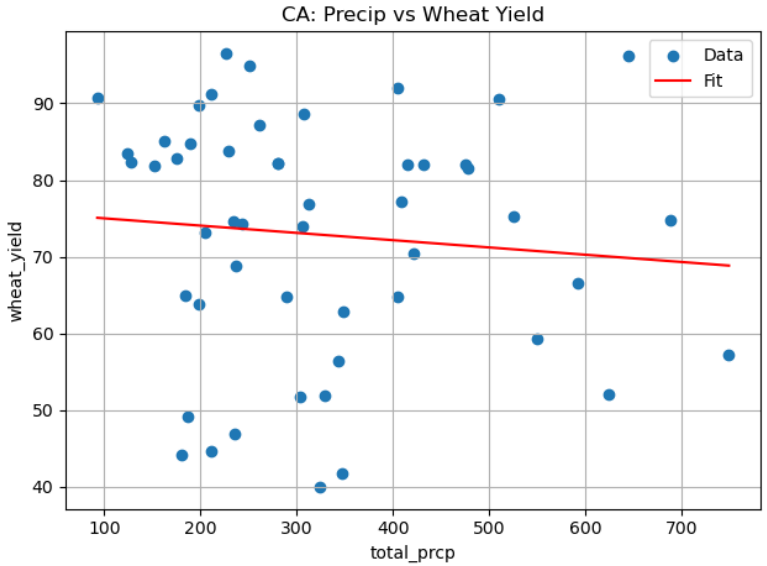




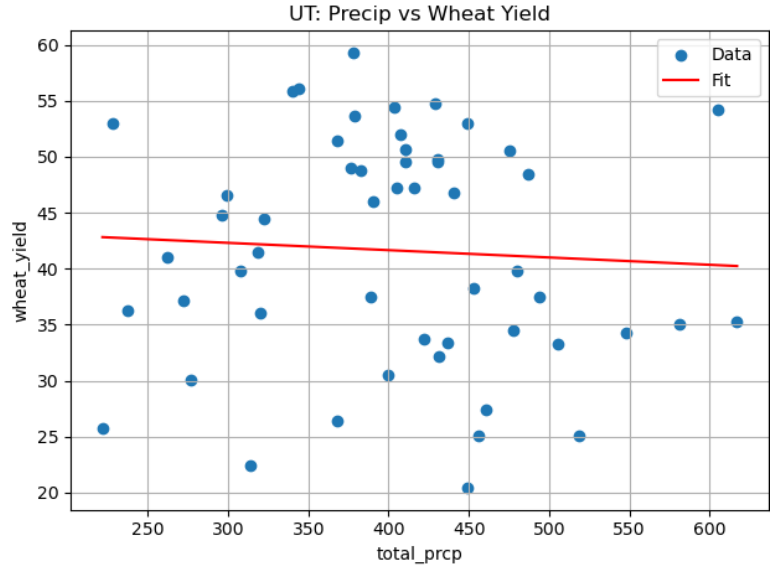


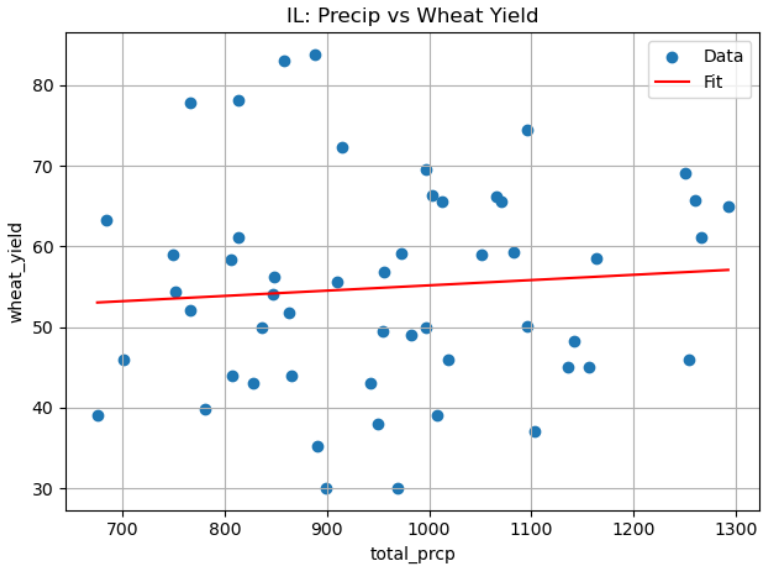
Effect of Precipitation on Wheat Yields (per state)

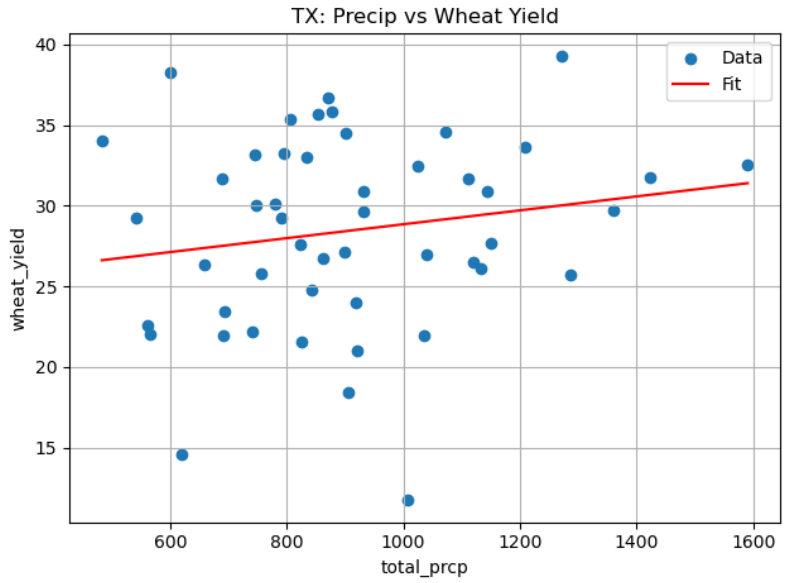




Each point represents a state-level annual observation, pairing average precipitation with corn wheat for that year

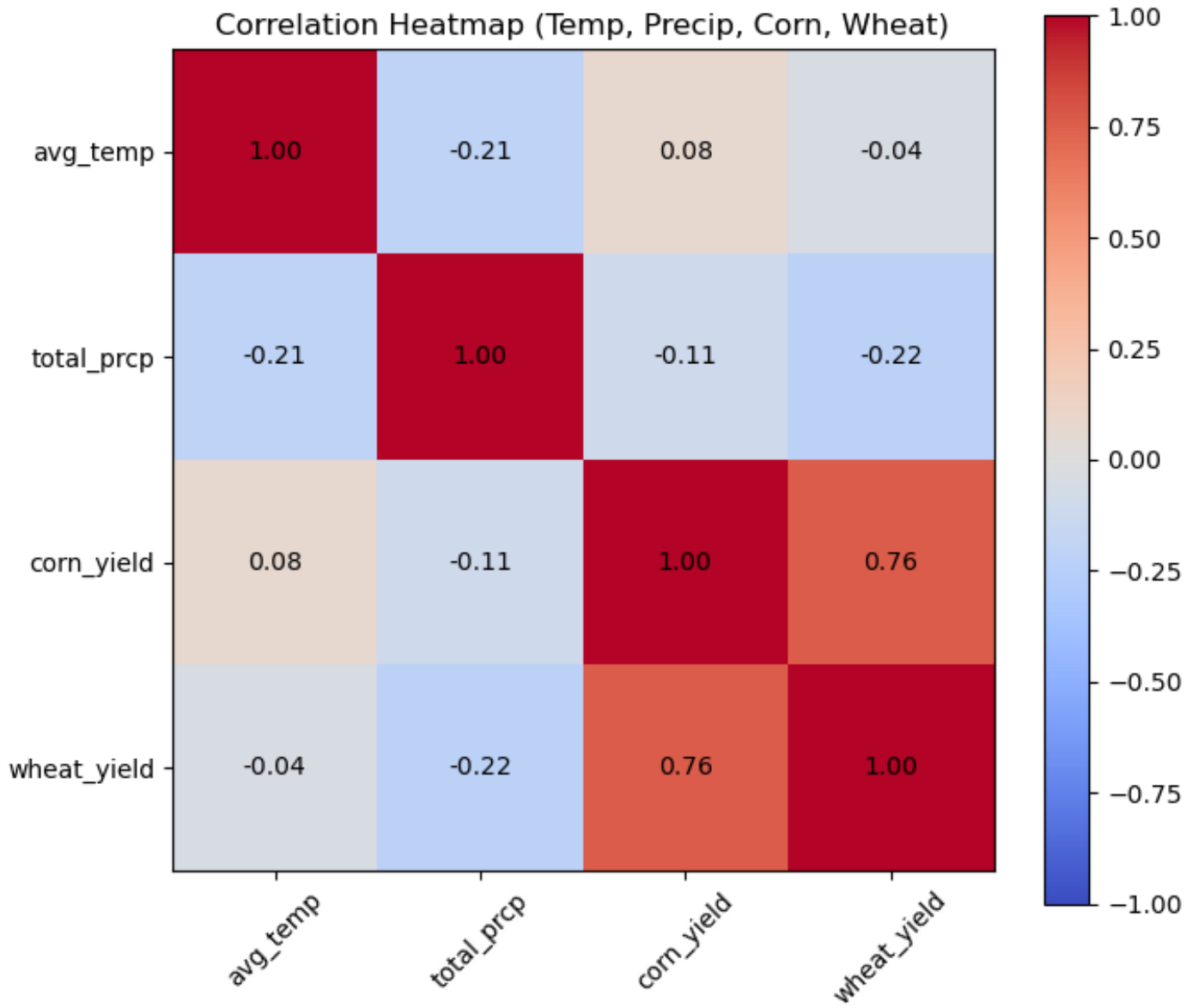






Heatmap

- Corn and wheat yields are strongly positively correlated (r ≈ 0.76), indicating that years with higher corn yields tend to also have higher wheat yields across states.
- Average temperature shows very weak correlations with both corn (r ≈ 0.08) and wheat yields (r ≈ −0.04), suggesting no strong linear relationship between temperature and crop yields at this aggregated scale.
- Total precipitation is weakly negatively correlated with both corn (r ≈ −0.11) and wheat yields (r ≈ −0.22), indicating a slight tendency for higher precipitation to coincide with lower yields, though the relationship is modest.
- Temperature and precipitation are weakly negatively correlated (r ≈ −0.21), implying that warmer years tend to be slightly drier, but the relationship is not strong
- Overall, neither temperature nor precipitation alone is a strong predictor of crop yield, highlighting that crop performance is influenced by more complex interactions beyond simple annual climate averages



Challenges

- Getting reliable climate data from the NOAA API
- Frequent 400 (Bad Request) Errors
- NOAA API Limitations Not Documented Clearly

- Instead of trying to download all climate data at once, I rewrote the function, so it requests each station individually, catching failures without stopping the whole program

```
Traceback (most recent call last):
  File "c:\Users\yilon\dsci510_fall2025_final_project\src\main.py", line 7, in <module>
    temp_df = get_noaa_climate_data()
  File "c:\Users\yilon\dsci510_fall2025_final_project\src\data_retrieval.py", line 72, in get_noaa_climate_data
    response.raise_for_status()
    ~~~~~~~~~~~~~~~~~~~~~~~~~^^
  File "C:\Users\yilon\anaconda3\envs\SSCI586_Fall2025_v3137\Lib\site-packages\requests\models.py", line 1026, in raise_for_status
    raise HTTPError(http_error_msg, response=self)
requests.exceptions.HTTPError: 400 Client Error:  for url: https://www.ncei.noaa.gov/cdo-web/api/v2/data?datasetid=GHCND&datatypeid=
023174&startdate=2010-01-01&enddate=2024-12-31&units=metric&limit=1000&offset=1
```

```python
for name, (label, station_id) in stations.items():
    print(f"  Fetching station {station_id} ({name})...")

    params = {
        "datasetid": dataset,
        "datatypeid": datatype,
        "stationid": station_id,
        "startdate": start,
        "enddate": end,
        "limit": 1000
    }
```

Thank you & Questions