Abstract/Introduction

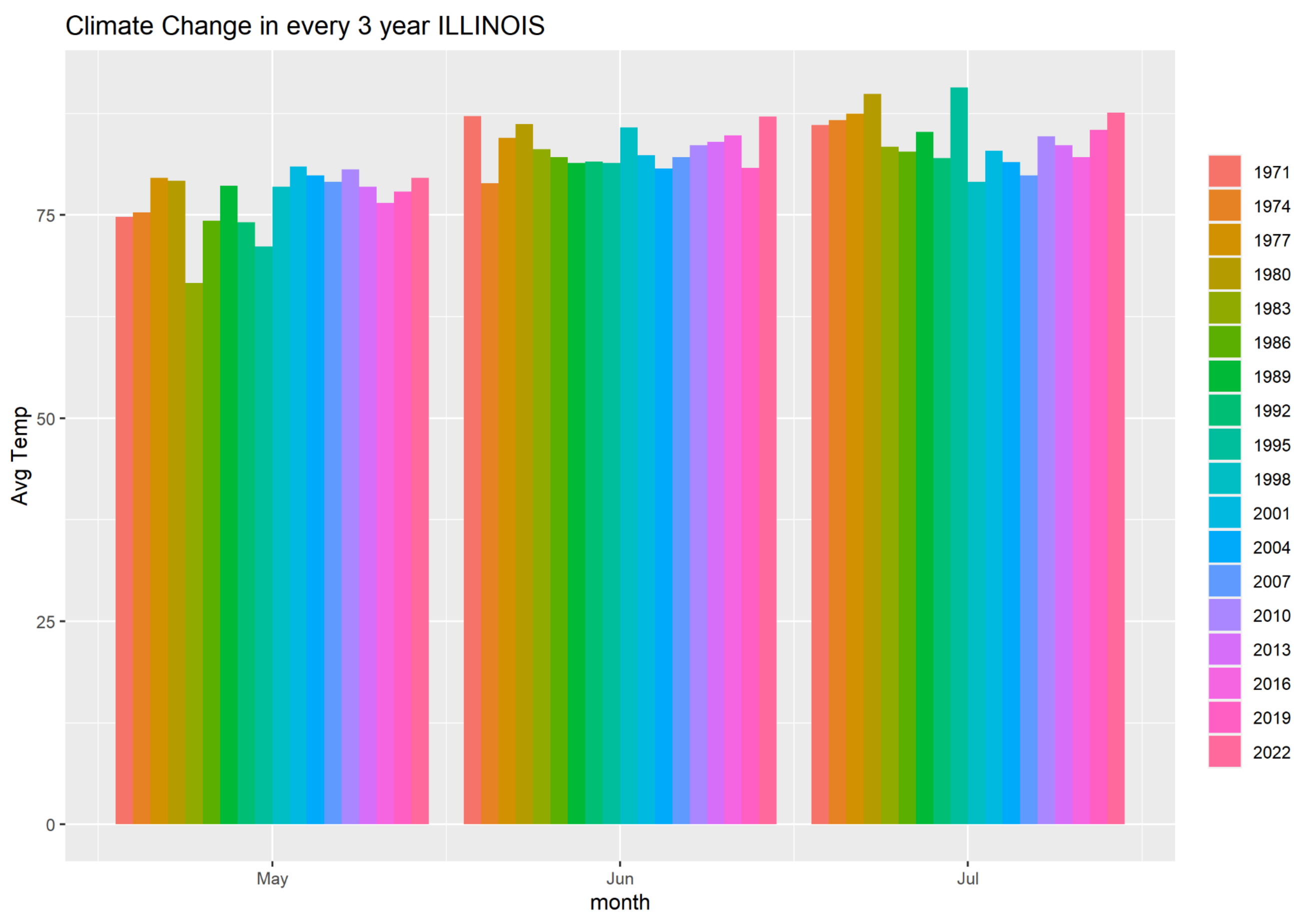
Climate change has emerged as a critical global issue, with profound impacts on agricultural systems worldwide. In the United States, the soybean industry is particularly vulnerable to these climatic changes due to soybeans' sensitivity to temperature and moisture variations. As temperatures rise, weather patterns become more unpredictable, and extreme weather events grow more frequent, the consequences of climate change on U.S. soybean production are becoming increasingly apparent. In this study, I collected data from 1970 to 2020 to analyze and evaluate the effects of changing weather patterns on soybean production in the U.S.

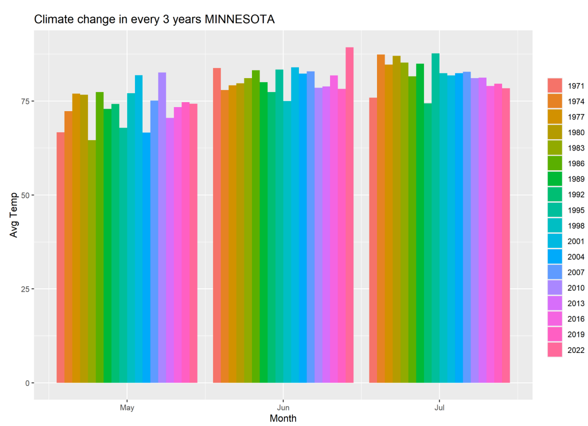
Methods and Materials

This research focused on soybean yield and climate data spanning from 1970 to 2022 for three U.S. states: Illinois, Nebraska, and Minnesota. After gathering the necessary data, I researched soybean planting fundamentals, including soil selection, planting timing, and water management practices. The primary tools used for data processing were online resources and R programming. R enabled comprehensive data cleaning, exploratory data analysis, hypothesis testing, and the application of advanced statistical techniques. Additionally, R Studio's powerful visualization tools facilitated the creation of charts, graphs, and plots to effectively communicate findings.

Results and Discussion

Figure 1: This figure displays the average temperature for each state over three-month intervals, combined every three years. The data reveal a steady temperature increase in Illinois and Minnesota from 1995 to 1998, while Nebraska recorded temperatures exceeding 90 degrees in 1974.


Climate Change in every 3 year ILLINOIS
Avg Temp
0
25
50
75
May
Jun
Jul
month
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
2019
2022


Climate change in every 3 years MINNESOTA
Avg Temp
0
25
50
75
May
Jun
Jul
Month
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
2019
2022

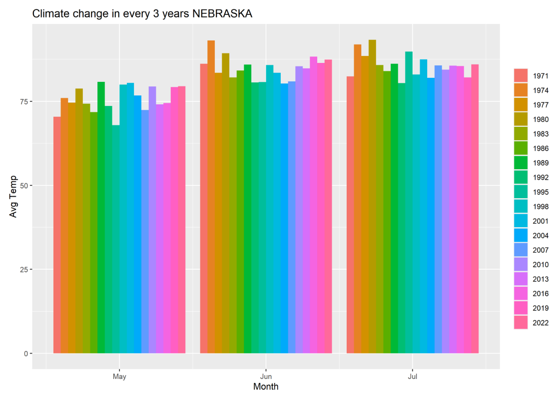
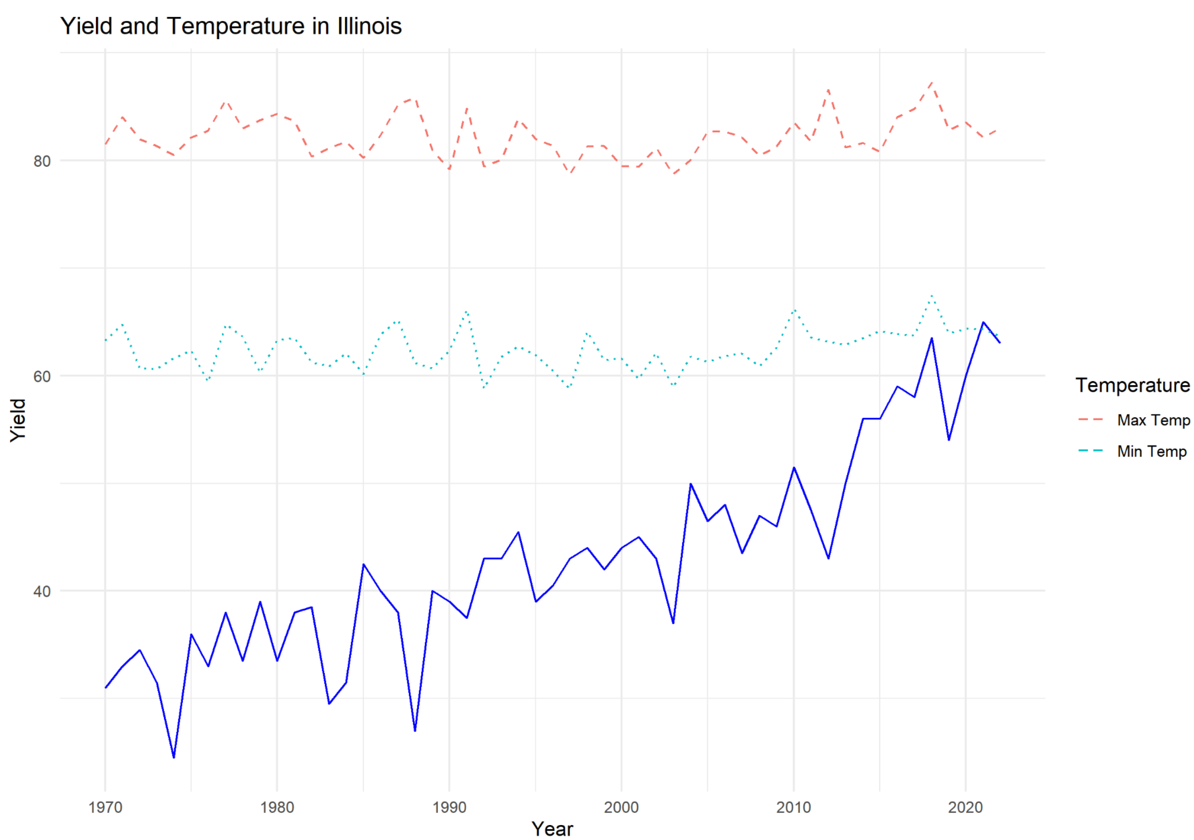
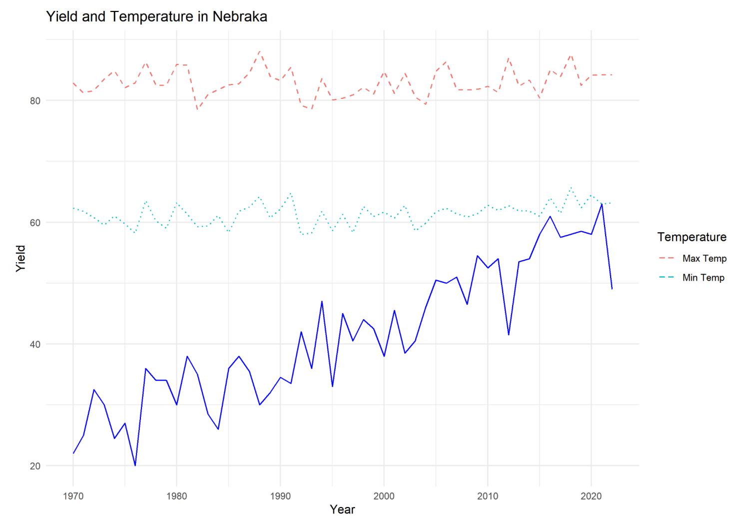


Figure 2: This plot illustrates the maximum and minimum temperatures using dotted and dashed lines, respectively, with an additional line representing the total soybean yield per year. By comparing Figures 1 and 2, we can estimate the years with the lowest and highest soybean production and examine how they align with monthly climate variations.





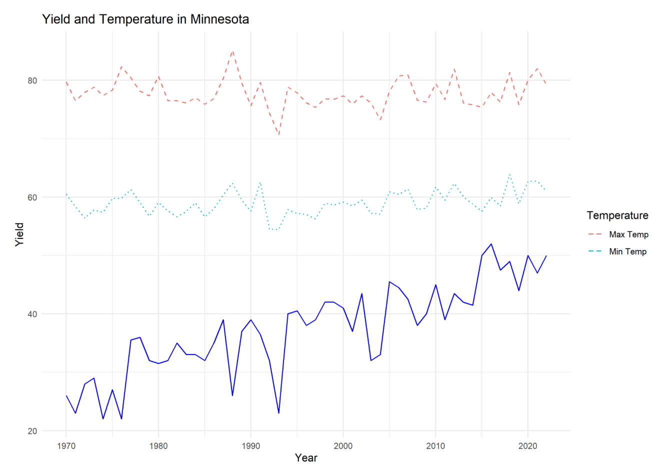


Figure 3: This figure assesses temperature thresholds set between 68 and 86 degrees to categorize the combined state averages as low, high, or normal relative to this range. Calculating the average yield values based on this threshold helps determine the extent to which climate changes have impacted soybean production.

```
illinois_yield <- soybean_yield[soybean_yield$State == "ILLINOIS", c("Year",
"Yield")]
illinois_avg_temp <- aggregate(cbind(temp, tempmax, tempmin) ~
format(datetime, "%Y"), data = filtered_illinois,  FUN  = mean)

colnames(illinois_avg_temp)[1] <- "Year"
illinois_yield <- merge(illinois_yield, illinois_avg_temp, by = "Year", all.x = TRUE)
head(illinois_yield)

temperature_high_threshold <- 86
temperature_low_threshold <- 68

illinois_yield$Temperature_Abnormal <- ifelse(illinois_yield$temp >
temperature_high_threshold, "High", ifelse(illinois_yield$temp <
temperature_low_threshold, "Low", "Normal"))

illinois_yield_summary <- aggregate(Yield ~ Temperature_Abnormal, data =
illinois_yield, FUN = mean)
minnesota_yield_summary <- aggregate(Yield ~ Temperature_Abnormal, data =
minnesota_yield, FUN = mean)
nebraska_yield_summary <- aggregate(Yield ~ Temperature_Abnormal, data =
nebraska_yield, FUN = mean)

illinois_yield_summary
minnesota_yield_summary
nebraska_yield_summary
```

Conclusion

In Figure 2, soybean production in Nebraska dropped to 20 in 1976, coinciding with maximum temperatures exceeding 95 degrees, marking the lowest yield recorded over the past 50 years. Figure 3 enables easy visualization of deviations using R and shows the power of combining columns and measuring numeric values for better analysis. The results reveal that Minnesota's yield average falls below the threshold due to temperature anomalies, contributing to a decline in total yield.

References

https://www.visualcrossing.com/weather/weather-data-services#

https://www.usda.gov/

soybean yield.xlsx

ILLINOIS 1970-01-01 to 2023-01-01 (version 1).xlsb

MINNESOTA 1970-01-01 to 2023-01-01.xlsx

NEBRASKA 1970-01-01 to 2023-01-01 (version 1).xlsb