EXPLORATORY DATA ANALYSIS OF AN AGRICULTURAL DATASET IN R

Name: Rhian Manwani
SRN: PES1UG21CS486
Course: Programming with R
Course Code: UE22CS222A

TABLE OF CONTENTS

Abstract

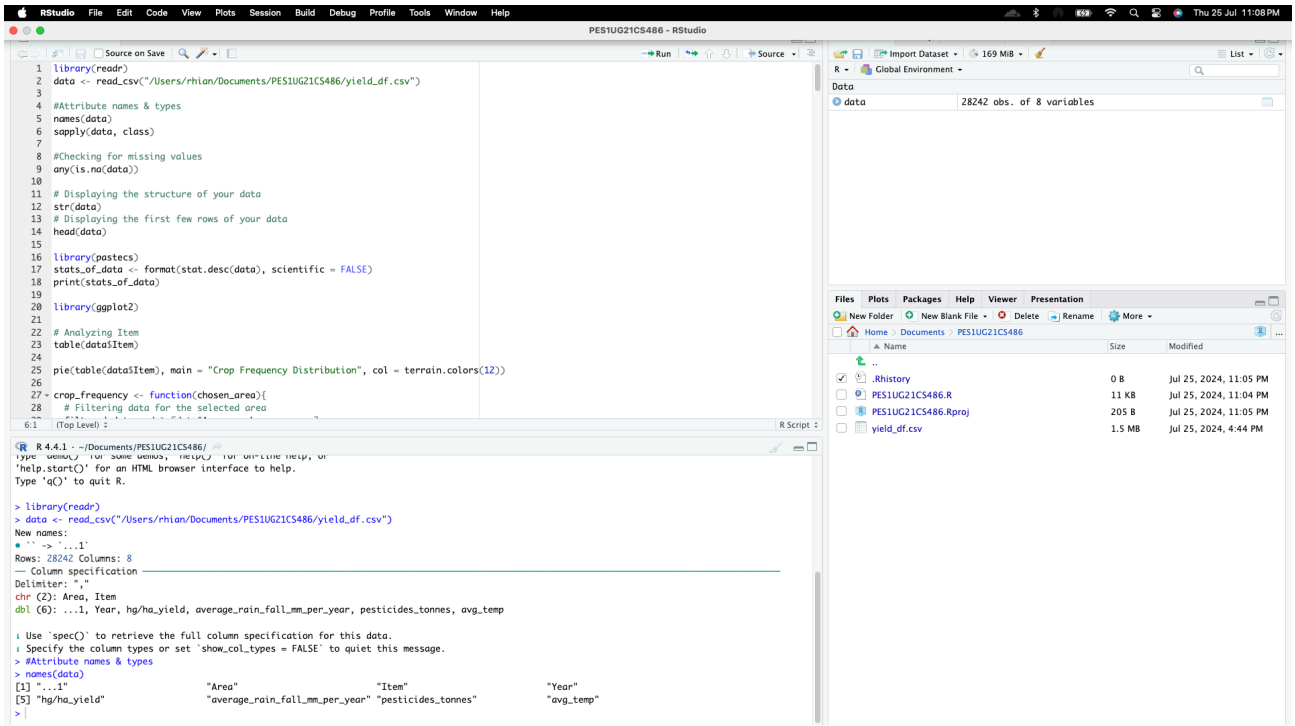
In order to better understand the intricate relationships affecting agricultural productivity, a large dataset comprising information on temperature, pesticide use, rainfall, and crop yield from different locations is analyzed in this study. The study looks at regional variations, temporal trends, and the effects of environmental factors on crop productivity using statistical tools and visualizations. Analysis of correlations is done to find connections between climate factors and yield. The R programming language is used for the entire analysis, and the 'fitdistrplus' tool is used to find the distribution that best fits the yield data. The results emphasize how crucial it is to comprehend how agricultural productivity and climatic conditions are related.

Introduction to Dataset

Key variables like geographic location, crop type, year, yield (in hectograms per hectare), average annual rainfall (in millimetres), pesticide consumption (in tonnes), and average temperature (in degrees Celsius) are all included in the dataset used in this analysis. The dataset, which spans several nations, offers a thorough understanding of how these variables interact and affect agricultural productivity across time. The historical scope of the dataset extends until 1990, making a detailed examination of trends and patterns possible. With an emphasis on staples like potatoes, rice, maize, and sorghum, the dataset makes it easier to comprehend in depth the intricacies present in agricultural systems.

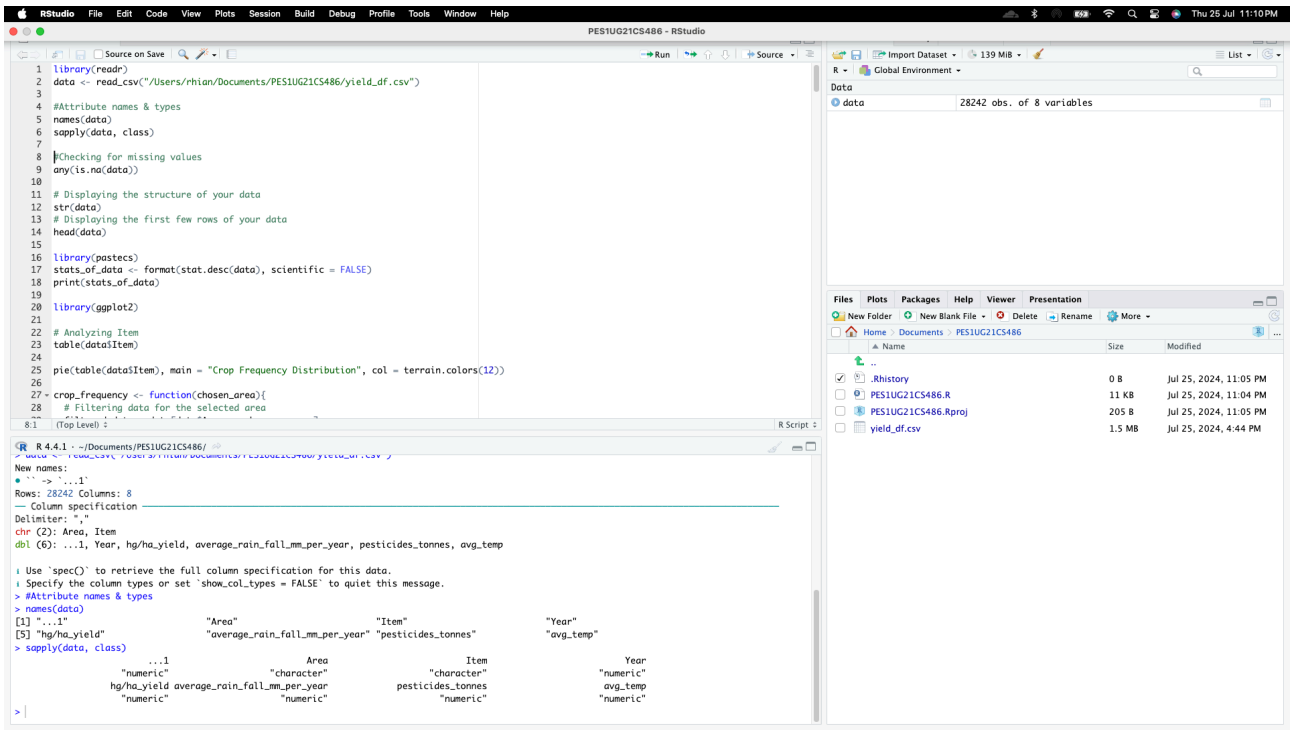
Description of Attributes

The dataset comprises of the following attributes:

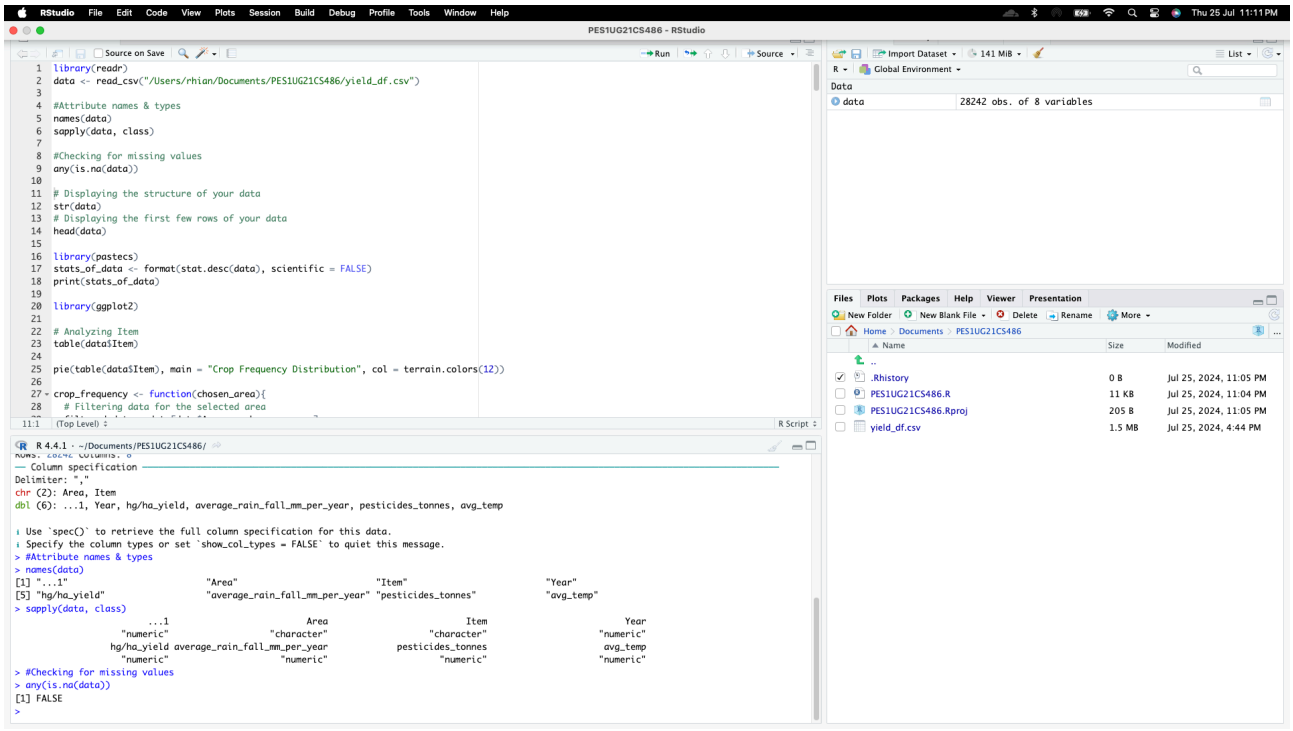


Following is the data type of these attributes:

4



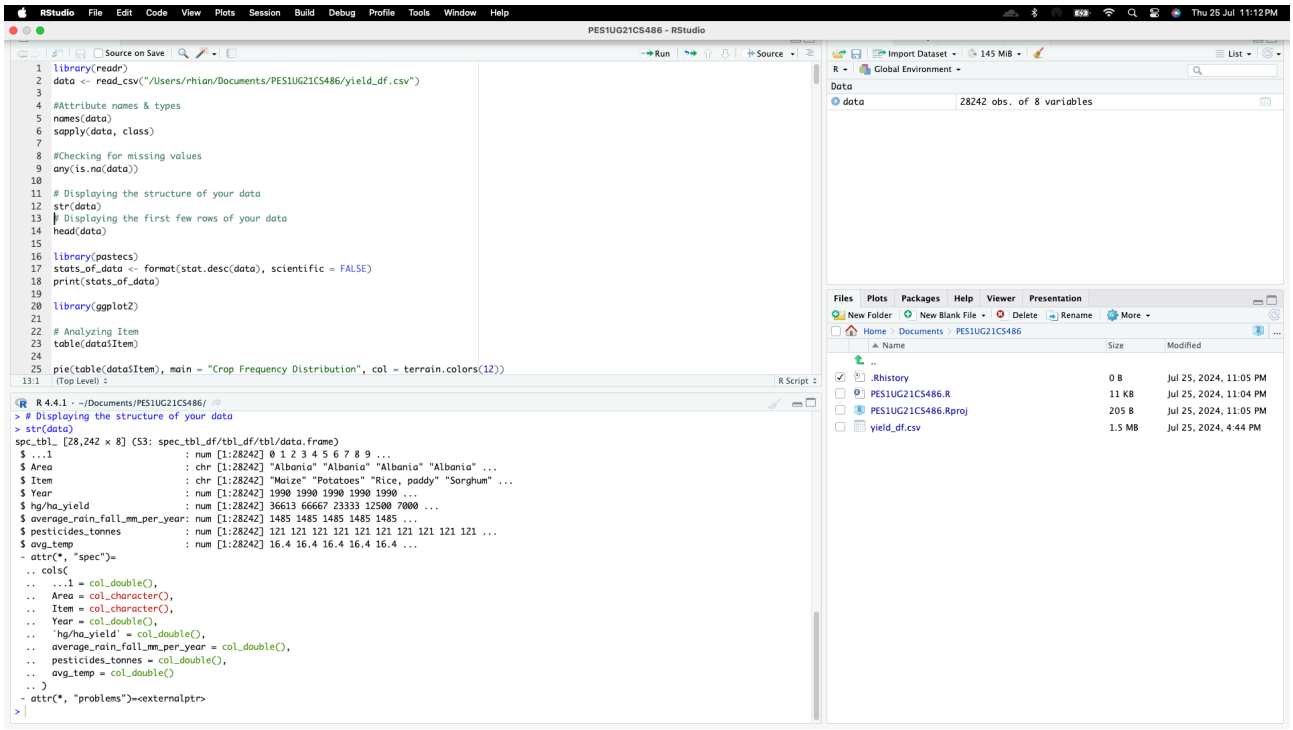
Check for missing values:



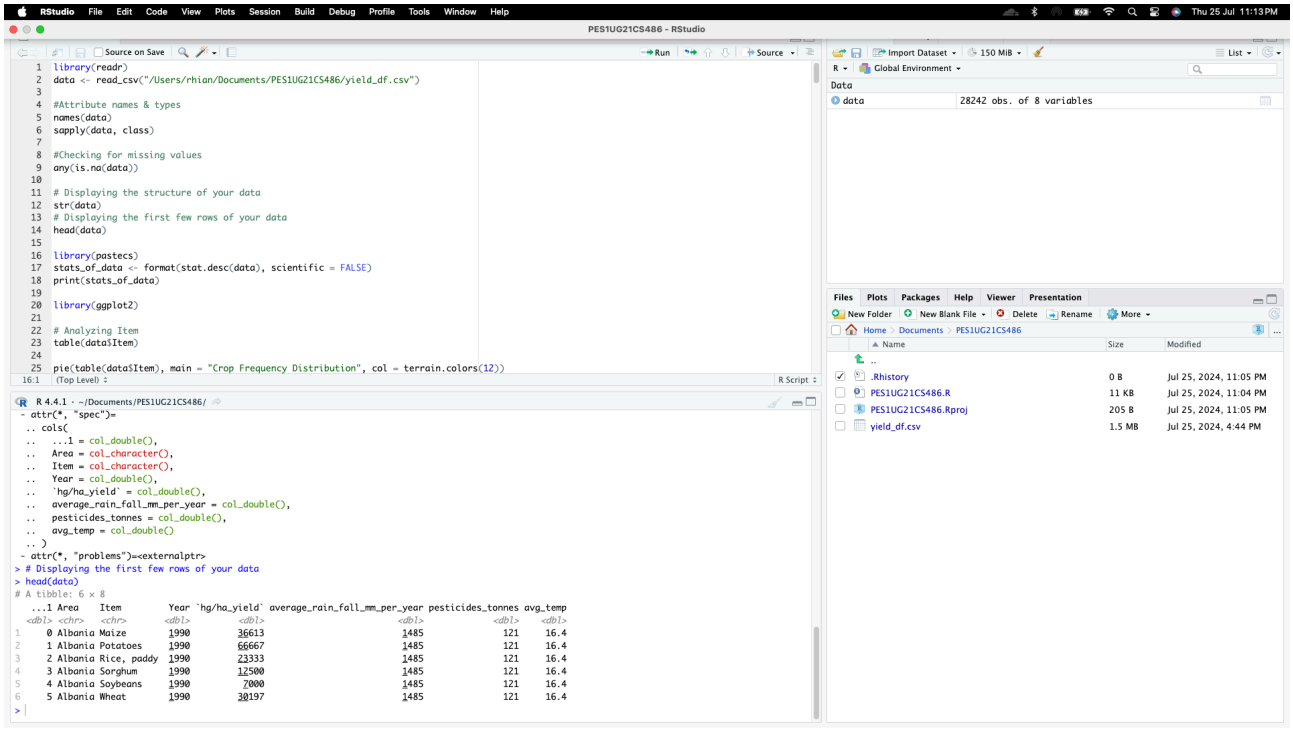
No missing values found in the dataset.

Structure of Dataset

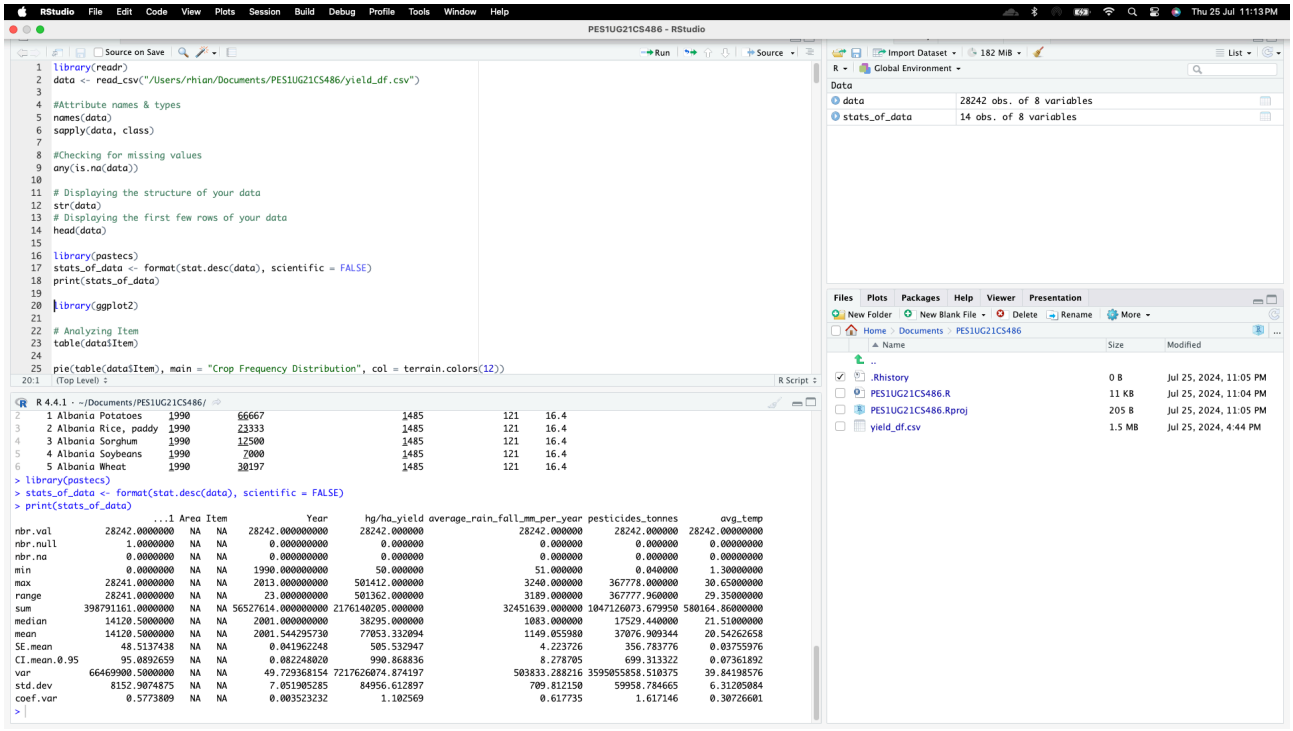
Following is the structure of the dataset



The first few rows of the dataset:

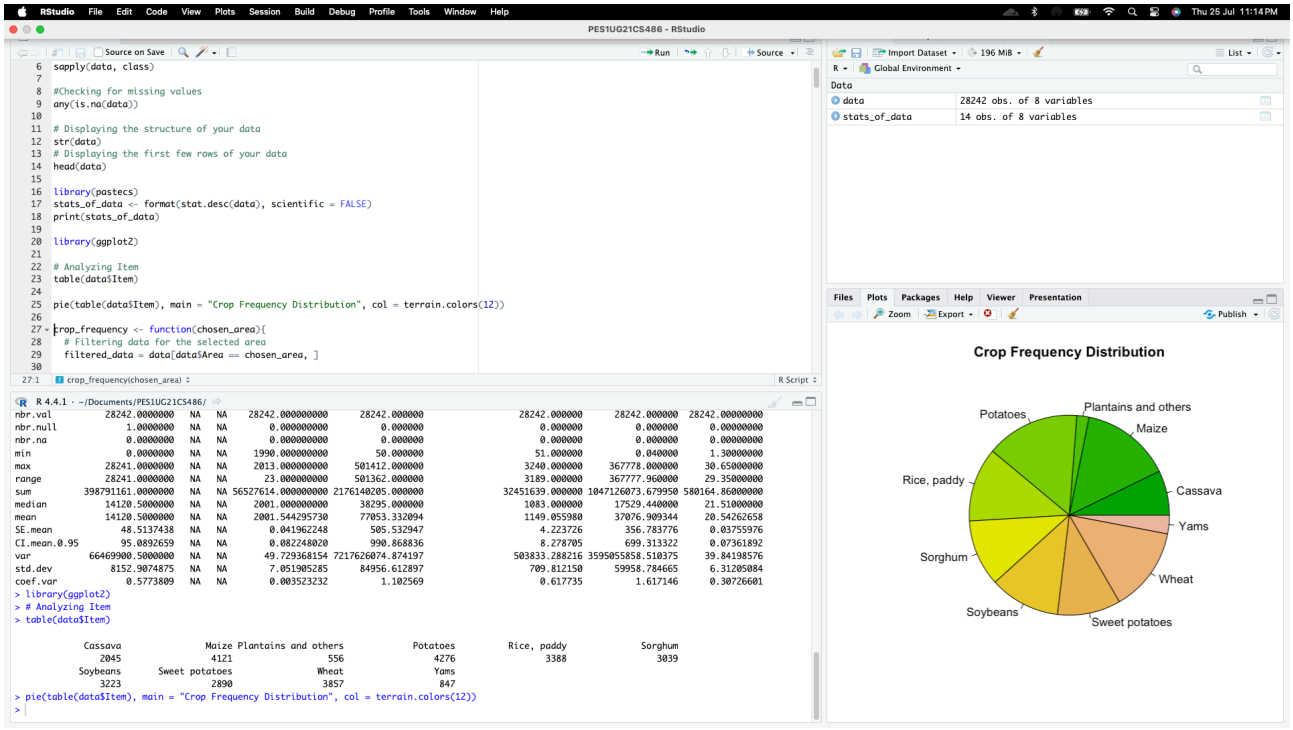


Following is a statistical description of the dataset:

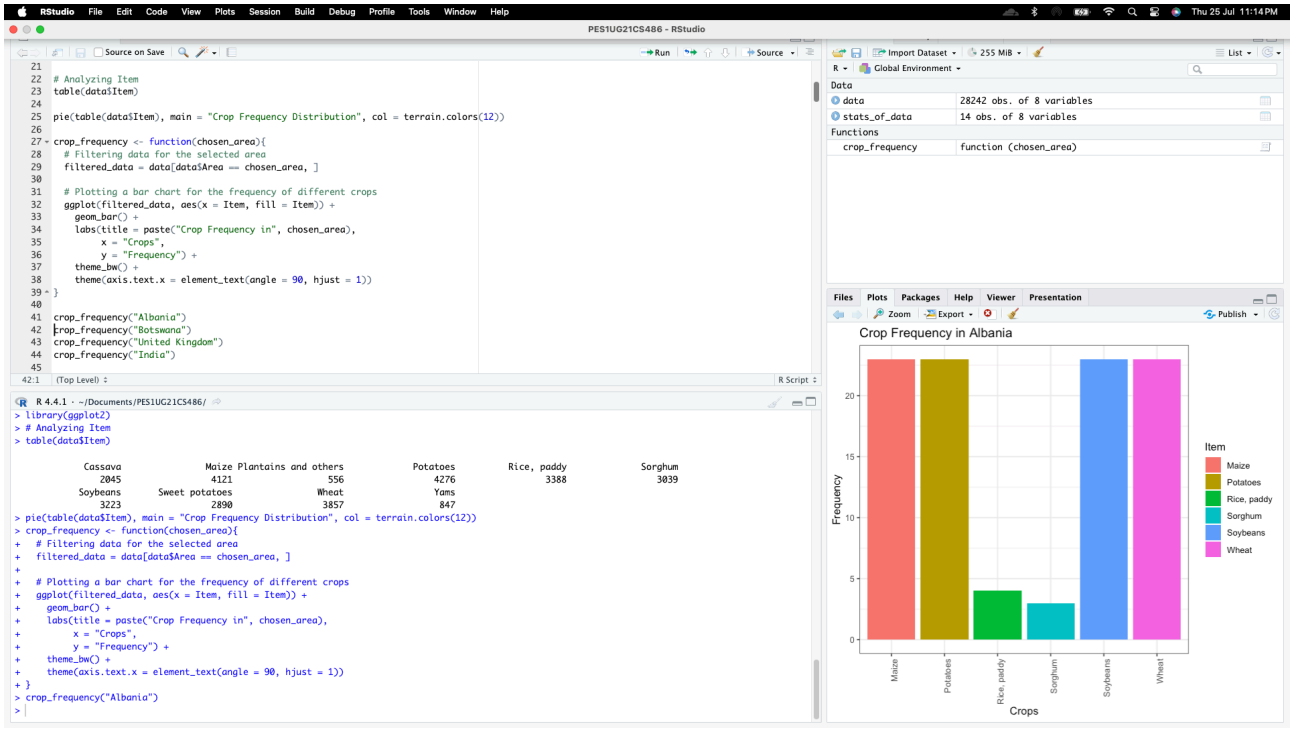


Crop Item Analysis

Frequency of the each crop grown in different regions of the world from 1990-2013 is given by:

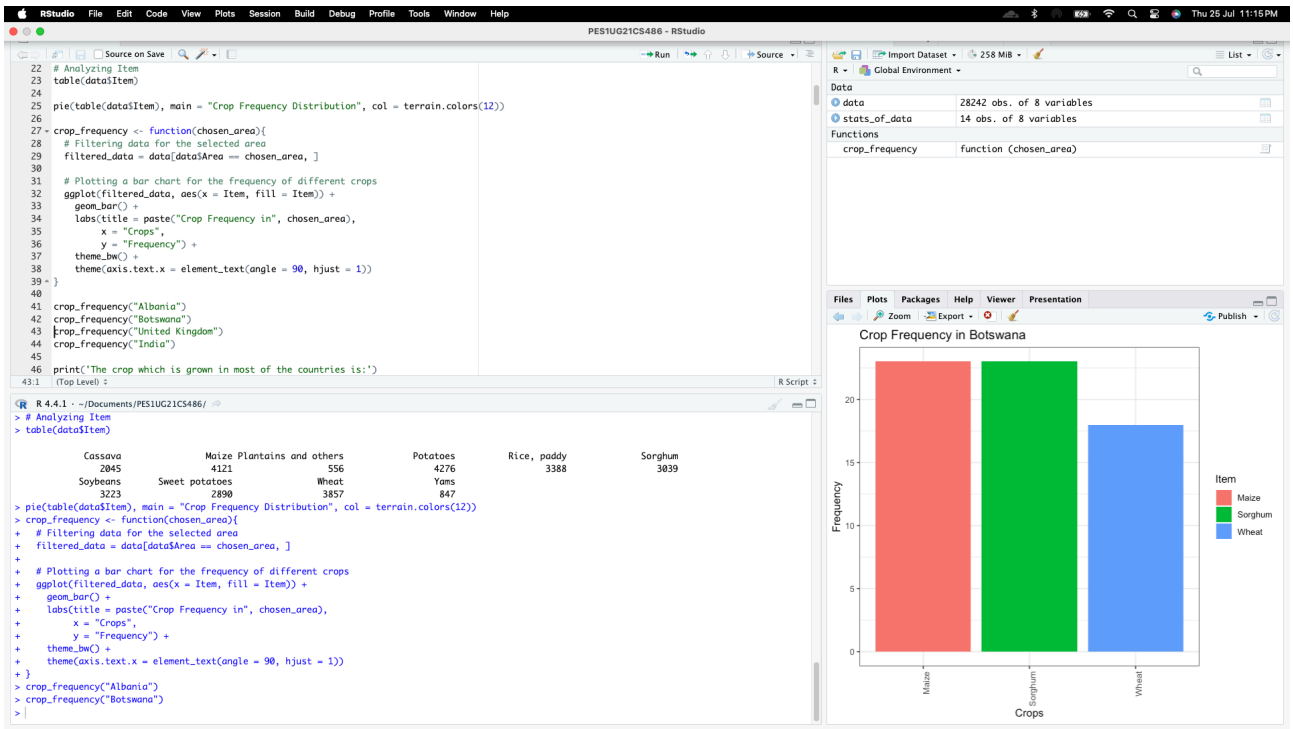


On the right side of the image we can see a pie chart of the crop frequency distribution. Out of all crops, crops like Potatoes, Maize and Wheat are the most preferred crop around the world while Yams, Plantains and others are the least preferred.
Following graph shows for a particular geographical area, the kinds of crops grown and the frequency of each crop item. For example in Albania, we see an equal preference for crops like Maize, Potatoes, Soybeans and Wheat while crops like Rice and Sorghum have an extremely low preference.

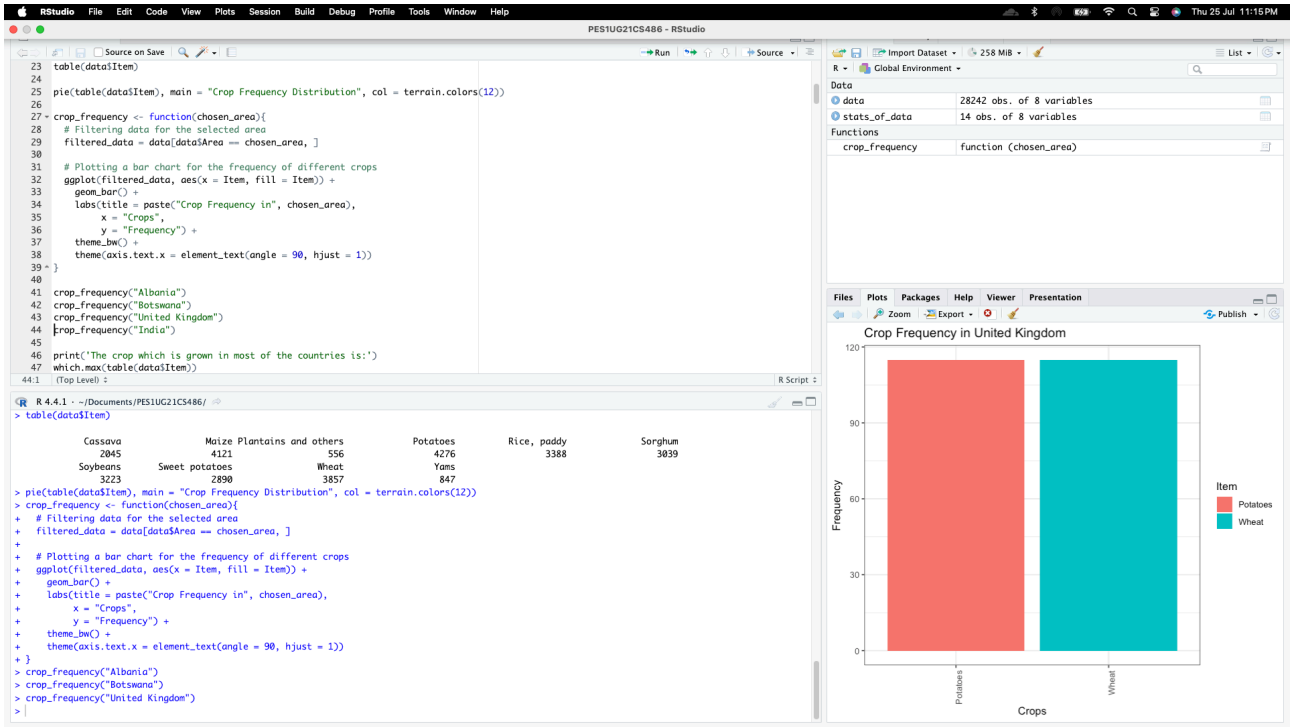


In a similar way we can have barplots for crop preference in different countries, such as United Kingdom, India, Botswana, etc

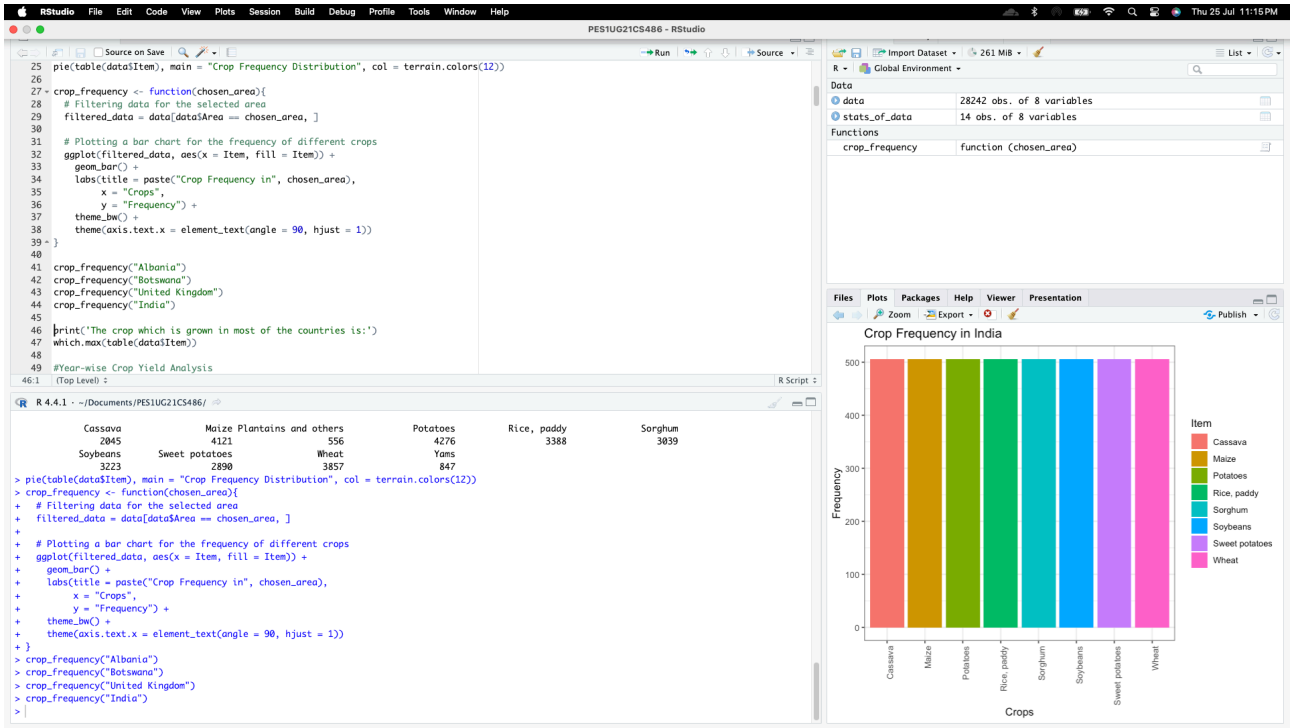
*On exploring further it was observed that i*n Botswana, only Maize, Sorghum and Wheat were grown between 1990-2013, out of which less preference was given to Wheat.



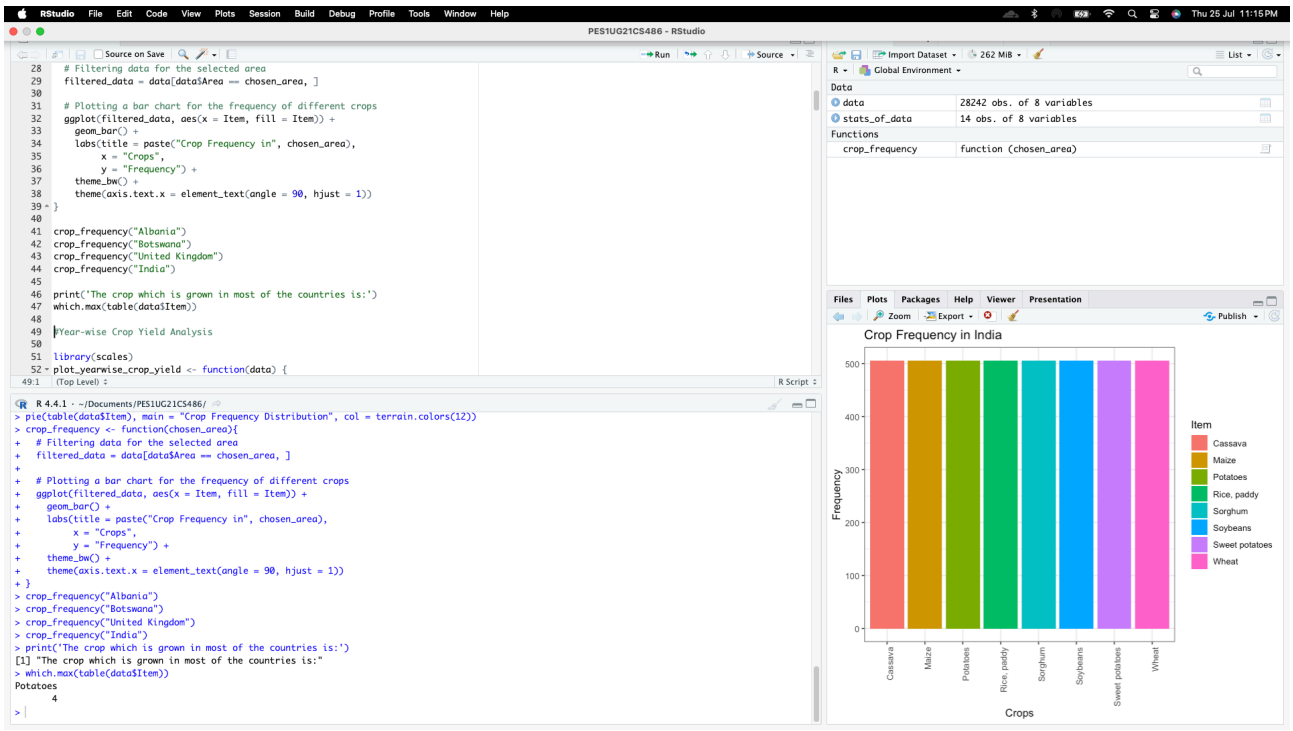
In United Kingdom, Potatoes and Wheat were the most eaten crops between 1990-2013.



In India, an equal preference is given to crops like Cassava, Maize, Potatoes, Rice, Sorghum, Soybeans, Sweet Potatoes and Wheat.

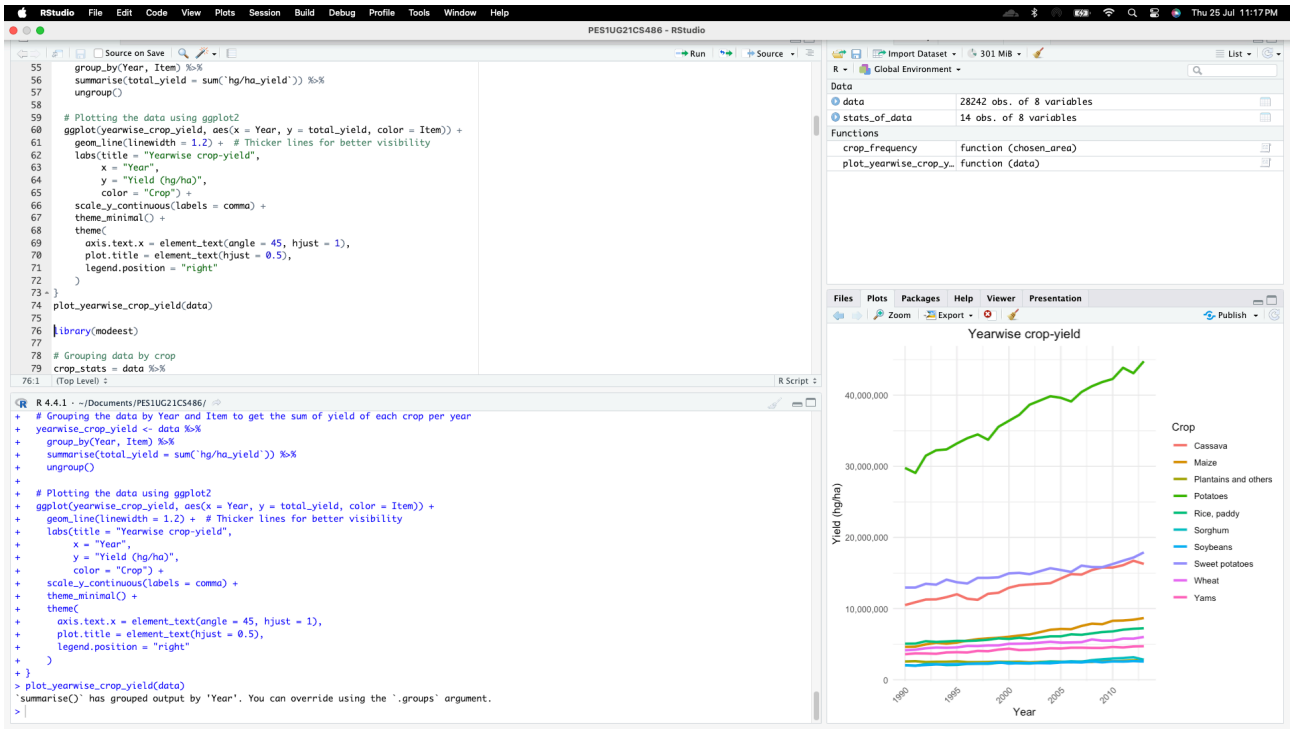


We can also conclude from the dataset that the most grown crop in all the countries in Potato.

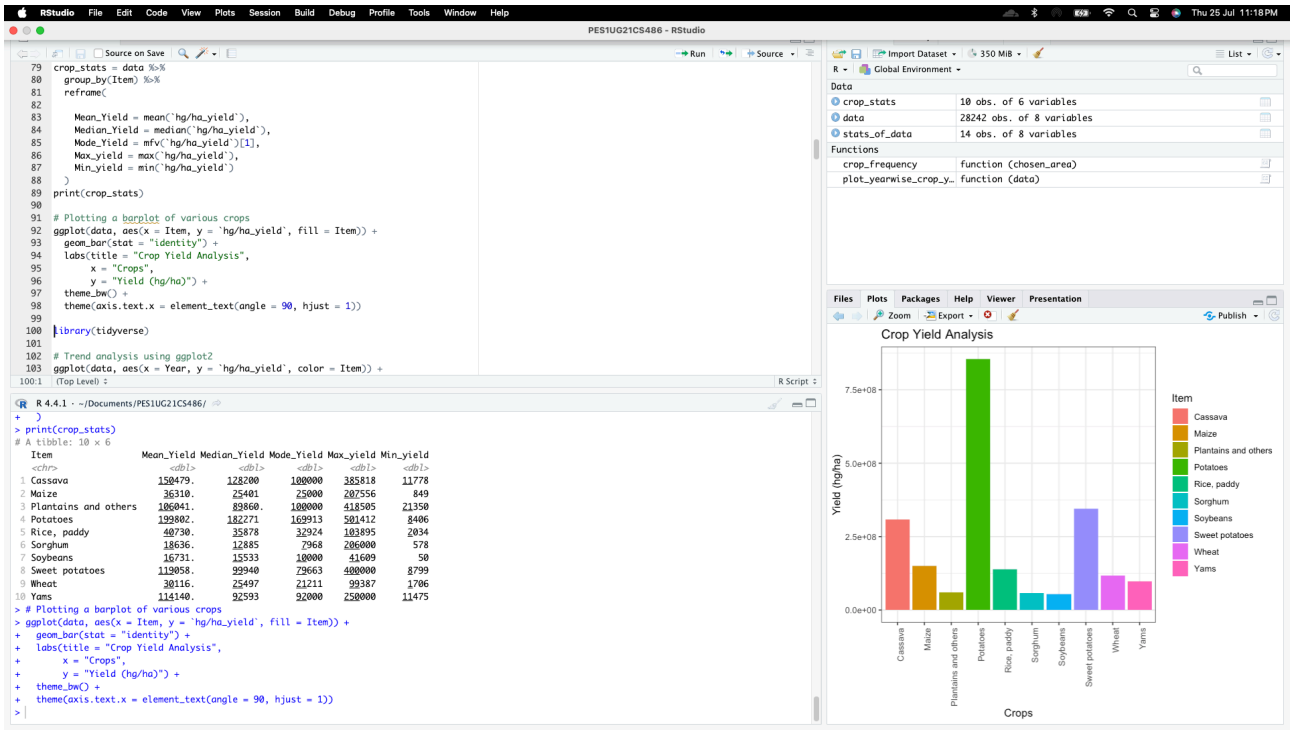


Crop Yield Analysis

Looking closely at the year wise crop-yield we notice that potatoes are the highest by a big margin. We can also observe that sweet potatoes and cassava yields have gotten closer from 1990 to 2013. Crops like Soybean and Sorghum have the lowest yield.

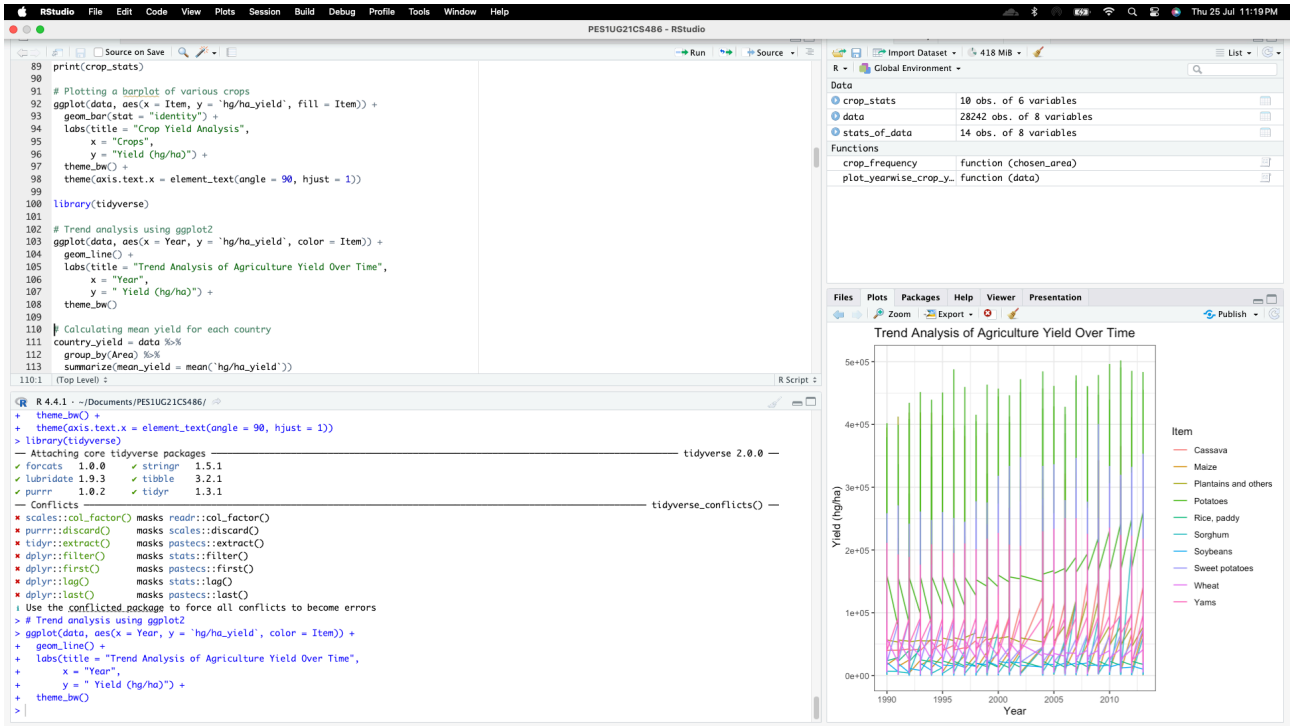


Descriptive statistics of yield for different crop item and the adjacent barplot compares yield of different crops grown in different areas of the world:

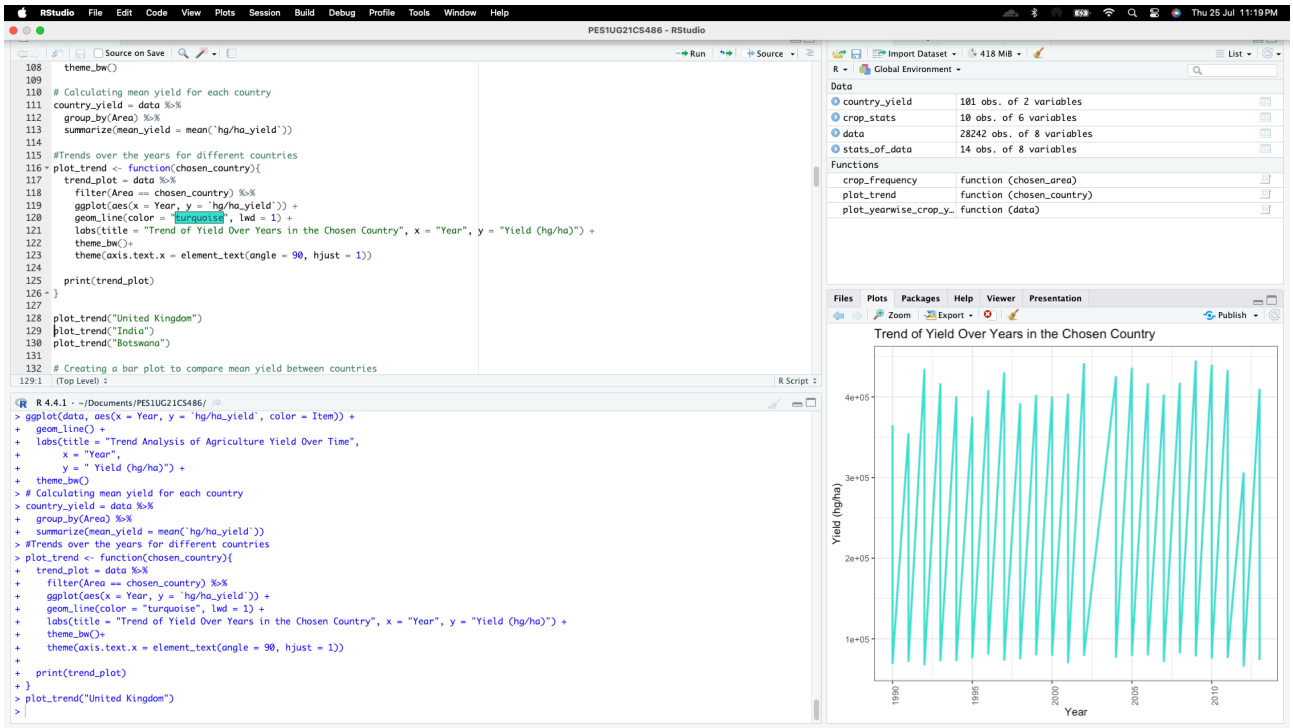


Clearly visible from the above graph, potatoes have been the most popular crop globally, with a maximum yield of 501412 hg/ha. Conversely, there are crops such as soybeans, sorghum, and plantains whose maximum output was constant.

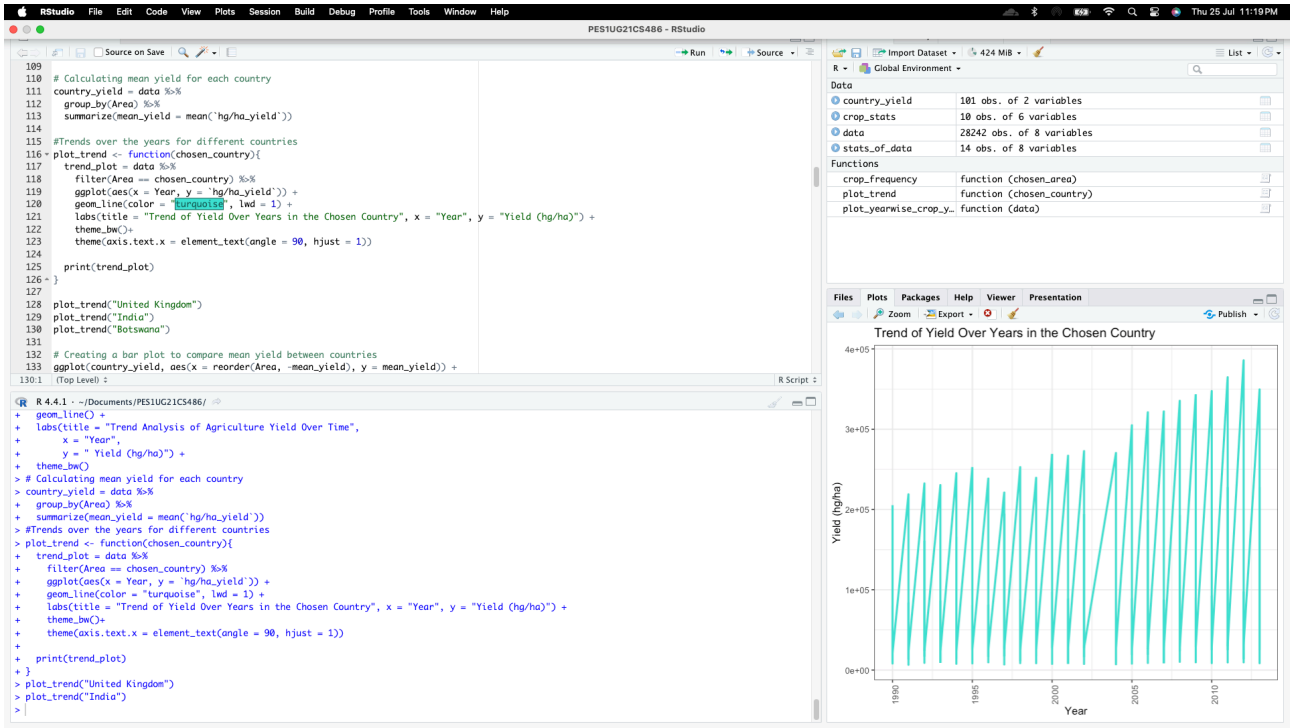
The agricultural yield trends for various crop varieties have changed throughout time in the following ways:



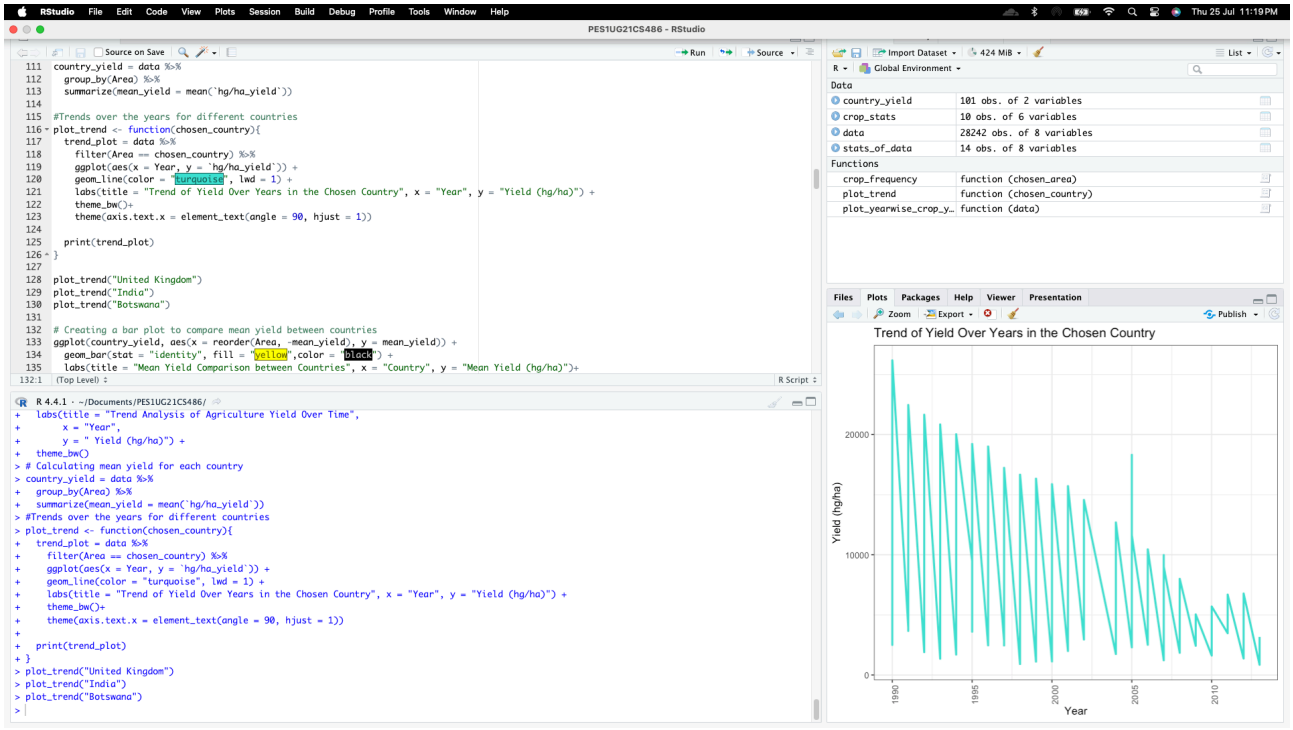
The following plot shows the trends over the years for different countries. This graph helps in visualizing how agricultural yield has evolved over time in the specified country, highlighting both long-term trends and year-to-year variations. The following plot is of the United Kingdoms and the graph shows that United Kingdom has the highest value of mean yield over the time period of 1990 to 2013.



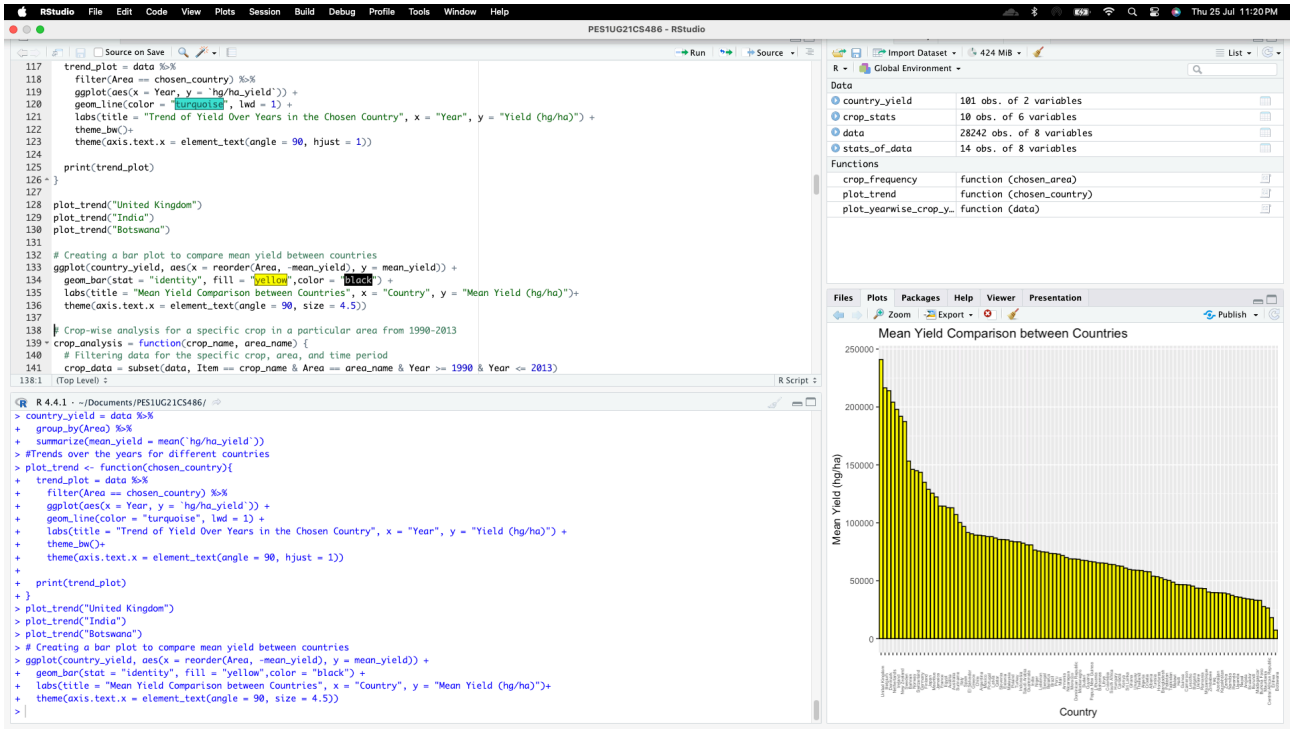
We can also observe that from 2005, the mean yield in India has constantly been rising emphasising on the fact that agriculture in India is advancing due to various factors.



From, the following graph, we can observe that in Botswana the crop yield has significantly decreased from 1990 to 2013.



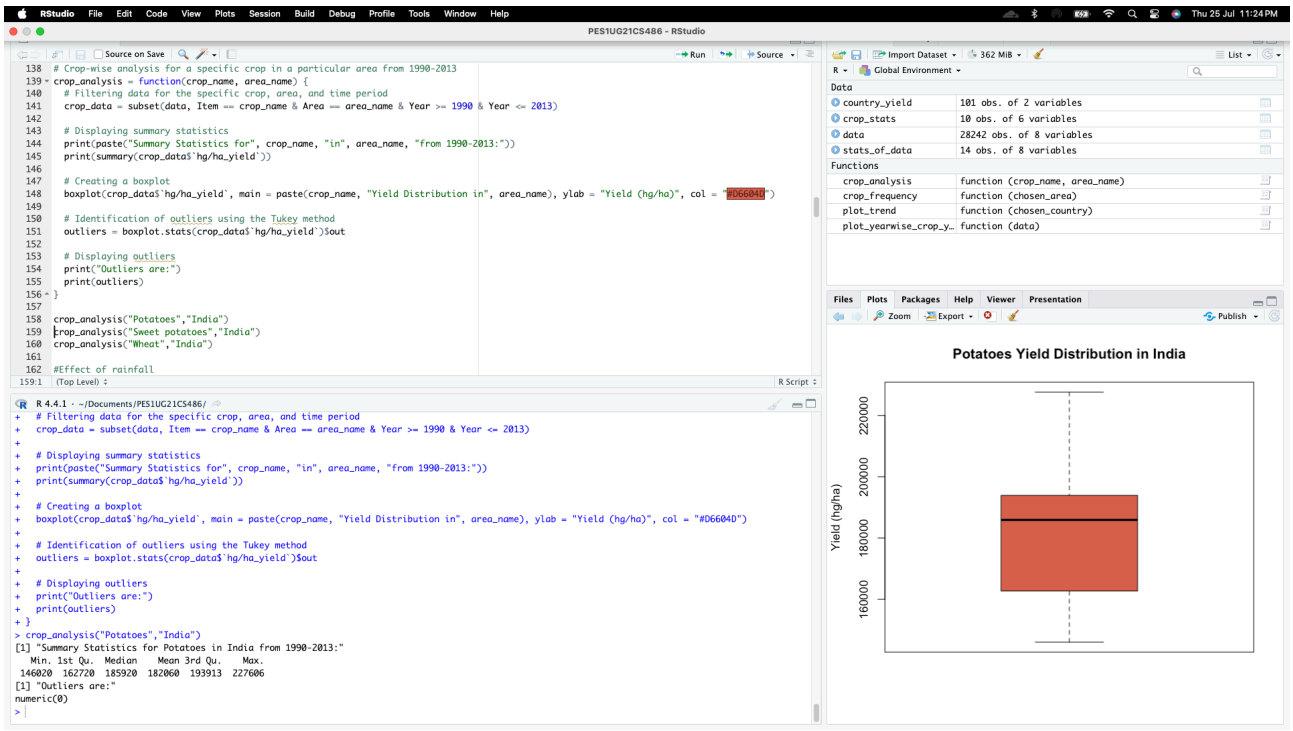
The following graph illustrates the average yield for all crops grown in various areas:

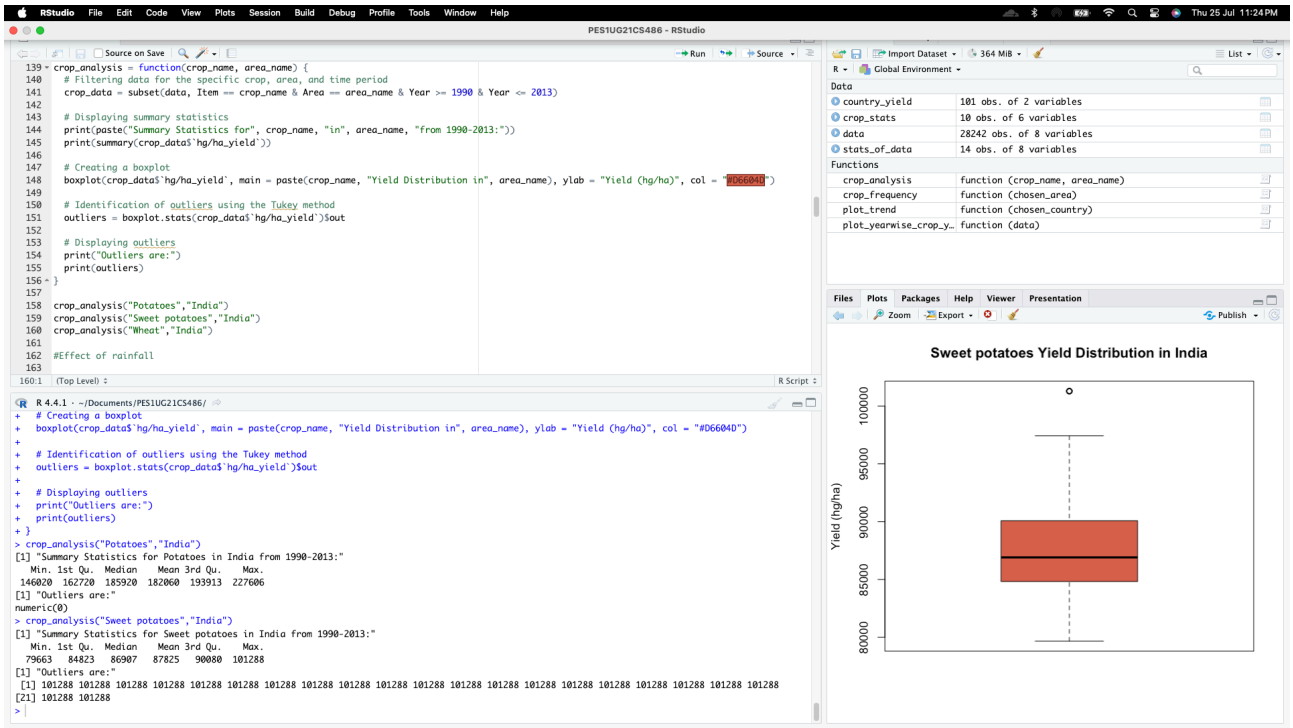


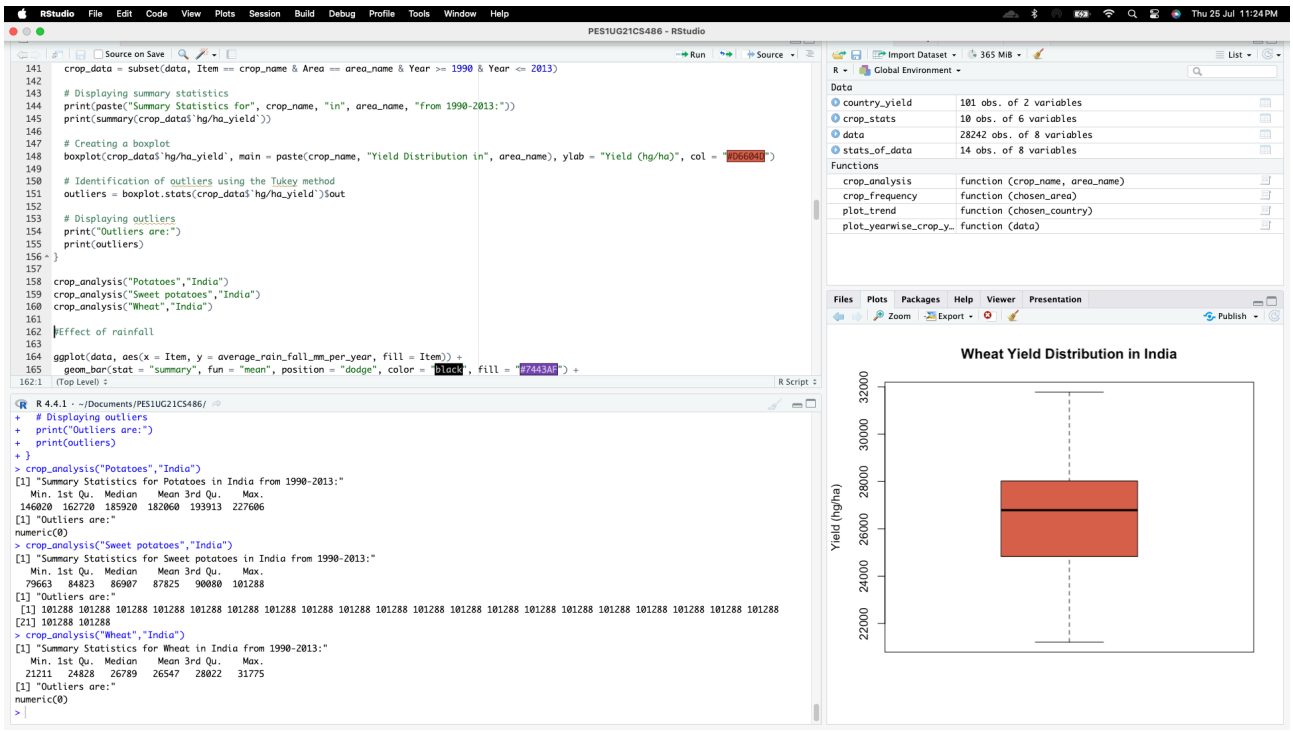
Outlier Detection:

It is also possible to determine the net yield outlier values (in hectograms per hectare) for a certain crop in a nation like India by utilising a boxplot.

The yield outlier value (in hectograms per hectare) for a few crops is provided by:

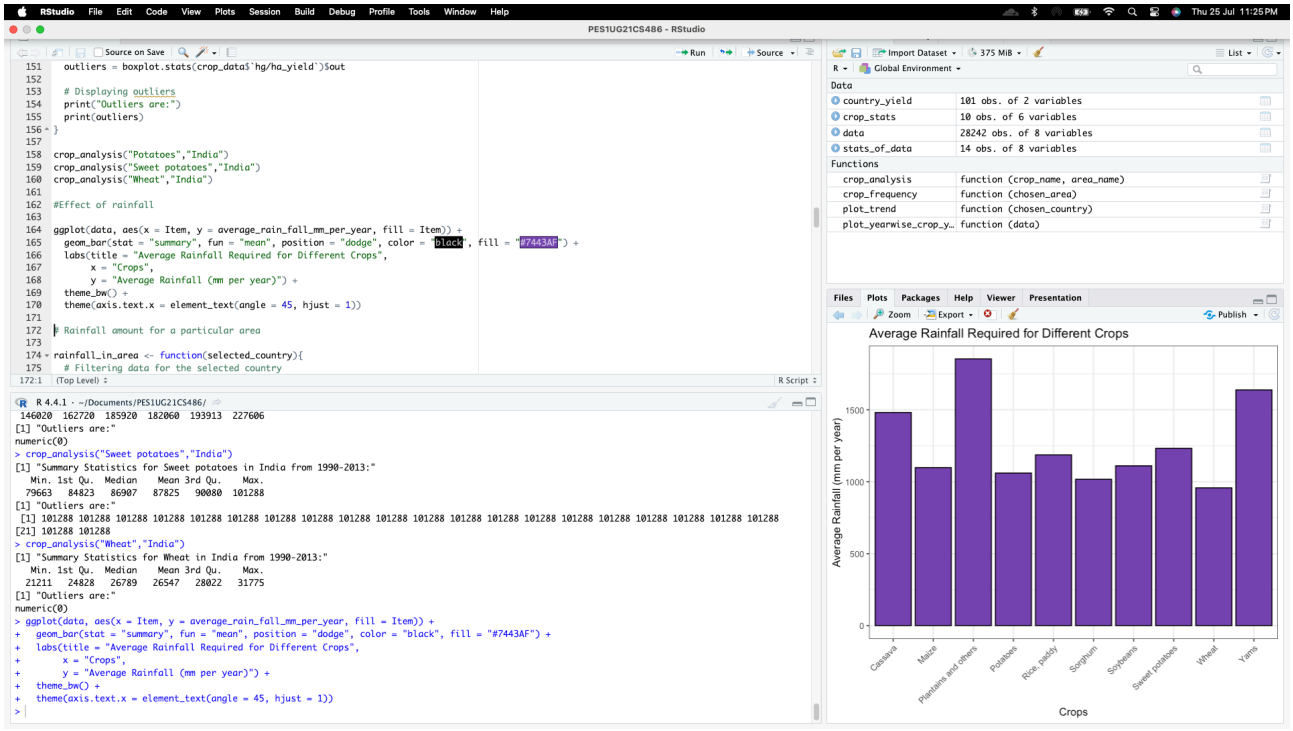

RStudio File Edit Code View Plots Session Build Debug Profile Tools Window Help
Thu 25 Jul 11:24 PM
PES1UG21CS486 - RStudio
Source on Save
Run
Source
# Crop-wise analysis for a specific crop in a particular area from 1990-2013
crop_analysis = function(crop_name, area_name) {
# Filtering data for the specific crop, area, and time period
crop_data = subset(data, Item == crop_name & Area == area_name & Year >= 1990 & Year <= 2013)
# Displaying summary statistics
print(paste("Summary Statistics for", crop_name, "in", area_name, "from 1990-2013:"))
print(summary(crop_data$`hg/ha_yield`))
# Creating a boxplot
boxplot(crop_data$`hg/ha_yield`, main = paste(crop_name, "Yield Distribution in", area_name), ylab = "Yield (hg/ha)", col = "#D6604D")
# Identification of outliers using the Tukey method
outliers = boxplot.stats(crop_data$`hg/ha_yield`)$out
# Displaying outliers
print("Outliers are:")
print(outliers)
}
crop_analysis("Potatoes","India")
crop_analysis("Sweet potatoes","India")
crop_analysis("Wheat","India")
#Effect of rainfall
159:1 (Top Level)
R Script
R 4.4.1 · ~/Documents/PES1UG21CS486/
> crop_analysis("Potatoes","India")
[1] "Summary Statistics for Potatoes in India from 1990-2013:"
Min. 1st Qu. Median Mean 3rd Qu. Max.
146020 162720 185920 182060 193913 227606
[1] "Outliers are:"
numeric(0)
Import Dataset
362 MiB
List
Global Environment
Data
country_yield 101 obs. of 2 variables
crop_stats 10 obs. of 6 variables
data 28242 obs. of 8 variables
stats_of_data 14 obs. of 8 variables
Functions
crop_analysis function (crop_name, area_name)
crop_frequency function (chosen_area)
plot_trend function (chosen_country)
plot_yearwise_crop_y… function (data)
Files Plots Packages Help Viewer Presentation
Zoom
Export
Publish
Potatoes Yield Distribution in India
Yield (hg/ha)
160000
180000
200000
220000


RStudio File Edit Code View Plots Session Build Debug Profile Tools Window Help
Thu 25 Jul 11:24 PM
PES1UG21CS486 - RStudio
Source on Save
Run
Source
crop_analysis = function(crop_name, area_name) {
# Filtering data for the specific crop, area, and time period
crop_data = subset(data, Item == crop_name & Area == area_name & Year >= 1990 & Year <= 2013)
# Displaying summary statistics
print(paste("Summary Statistics for", crop_name, "in", area_name, "from 1990-2013:"))
print(summary(crop_data$`hg/ha_yield`))
# Creating a boxplot
boxplot(crop_data$`hg/ha_yield`, main = paste(crop_name, "Yield Distribution in", area_name), ylab = "Yield (hg/ha)", col = "#D6604D")
# Identification of outliers using the Tukey method
outliers = boxplot.stats(crop_data$`hg/ha_yield`)$out
# Displaying outliers
print("Outliers are:")
print(outliers)
}
crop_analysis("Potatoes","India")
crop_analysis("Sweet potatoes","India")
crop_analysis("Wheat","India")
#Effect of rainfall
160:1 (Top Level)
R Script
R 4.4.1 · ~/Documents/PES1UG21CS486/
> crop_analysis("Potatoes","India")
[1] "Summary Statistics for Potatoes in India from 1990-2013:"
Min. 1st Qu. Median Mean 3rd Qu. Max.
146020 162720 185920 182060 193913 227606
[1] "Outliers are:"
numeric(0)
> crop_analysis("Sweet potatoes","India")
[1] "Summary Statistics for Sweet potatoes in India from 1990-2013:"
Min. 1st Qu. Median Mean 3rd Qu. Max.
79663 84823 86907 87825 90080 101288
[1] "Outliers are:"
[1] 101288
[21] 101288 101288
Import Dataset
364 MiB
List
Global Environment
Data
country_yield 101 obs. of 2 variables
crop_stats 10 obs. of 6 variables
data 28242 obs. of 8 variables
stats_of_data 14 obs. of 8 variables
Functions
crop_analysis function (crop_name, area_name)
crop_frequency function (chosen_area)
plot_trend function (chosen_country)
plot_yearwise_crop_y… function (data)
Files Plots Packages Help Viewer Presentation
Zoom
Export
Publish
Sweet potatoes Yield Distribution in India
Yield (hg/ha)
80000
85000
90000
95000
100000



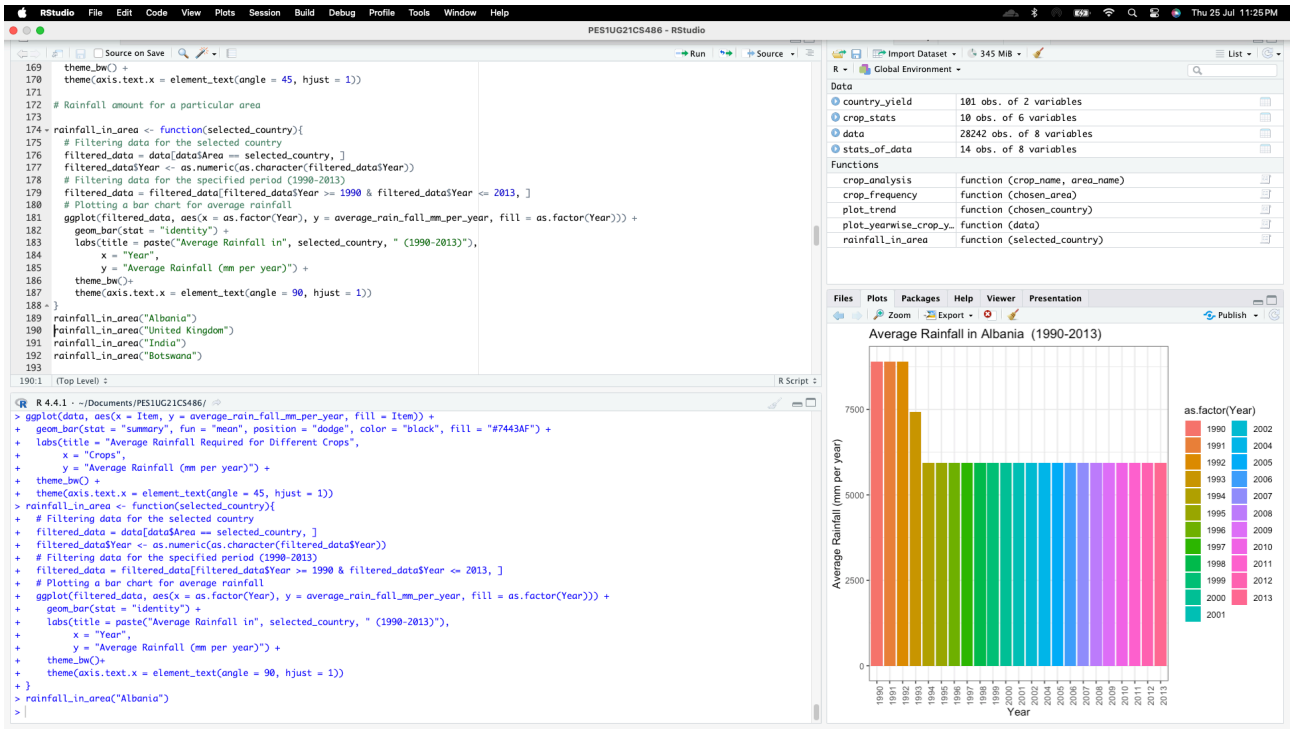
Effect of Rainfall

The quantity of rainfall required annually by various crop kinds can be determined using the bar chart below:

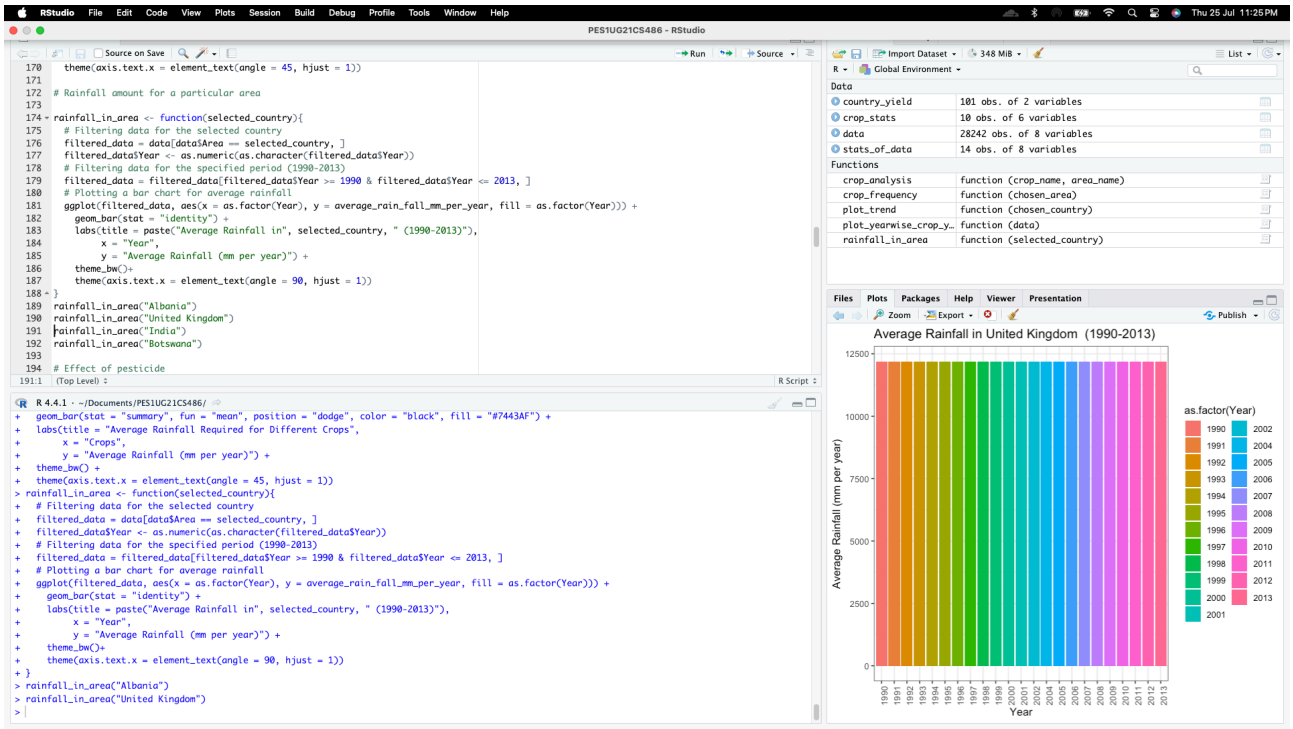


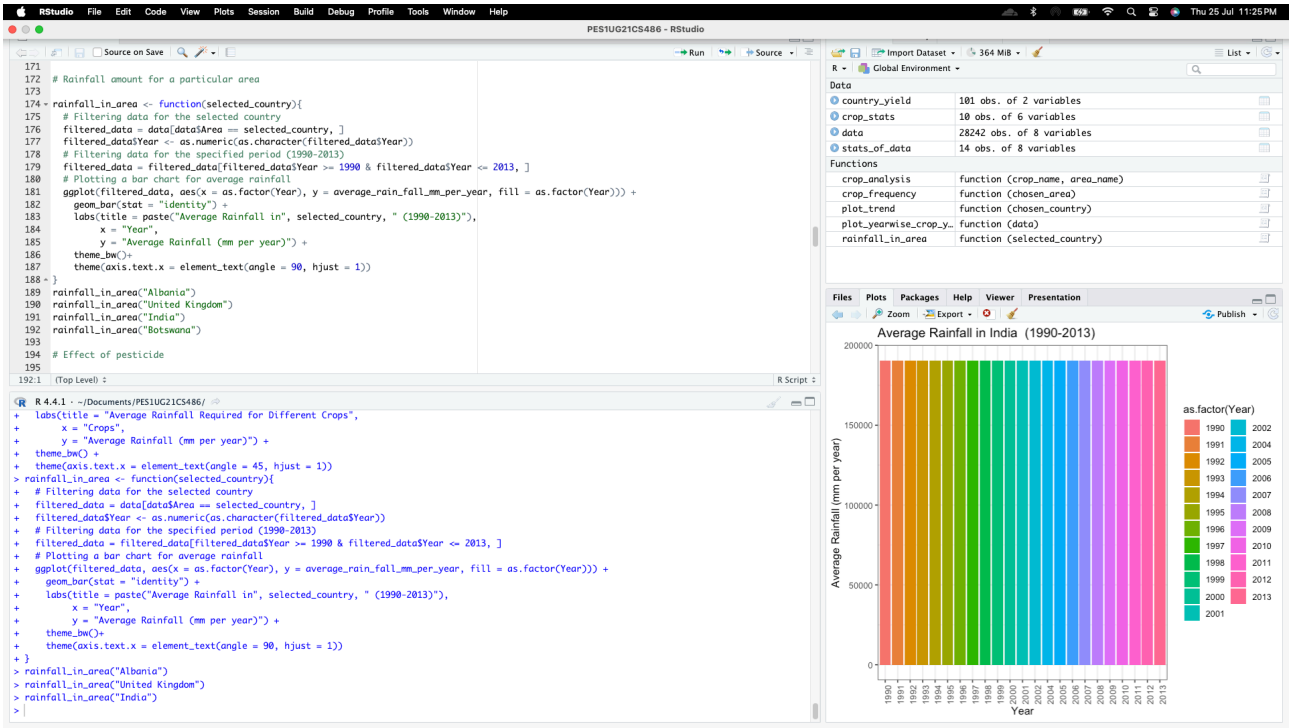
Additionally, throughout time, the average amount of rainfall in a given area varies. It is evident that whereas crops like maize, potatoes, sorghum, and wheat require nearly the same quantity of rainfall, plants and yellows require a significant amount of it. The graphs also illustrates patterns in rainfall for nations including Albania, the United Kingdom, and Botswana from 1990 to 2013.

In Albania, we see a high amount of rainfall from 1990-1992 but a substantial fall in 1992. From 1994-2013, the average amount of rainfall stayed the same.

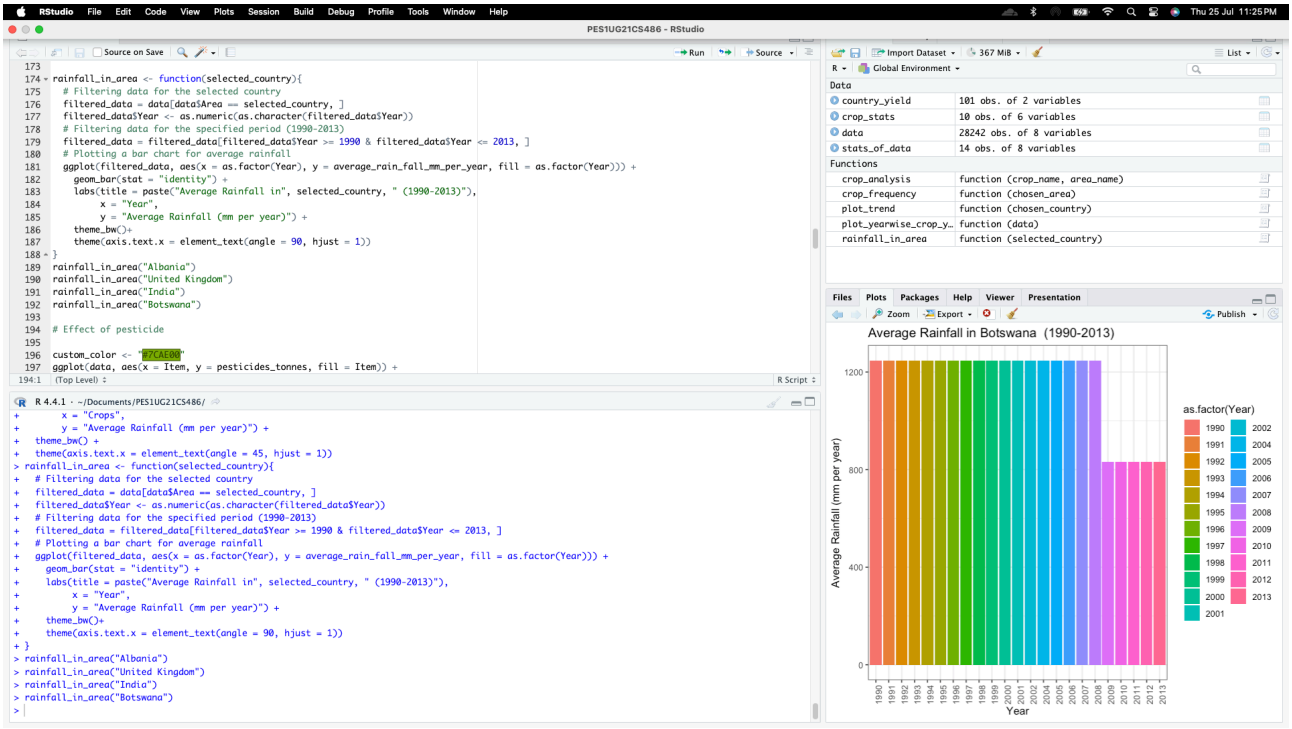


For all the years from 1990 -2013, the average amount of rainfall in regions like The United Kingdom and India stood at the same level.



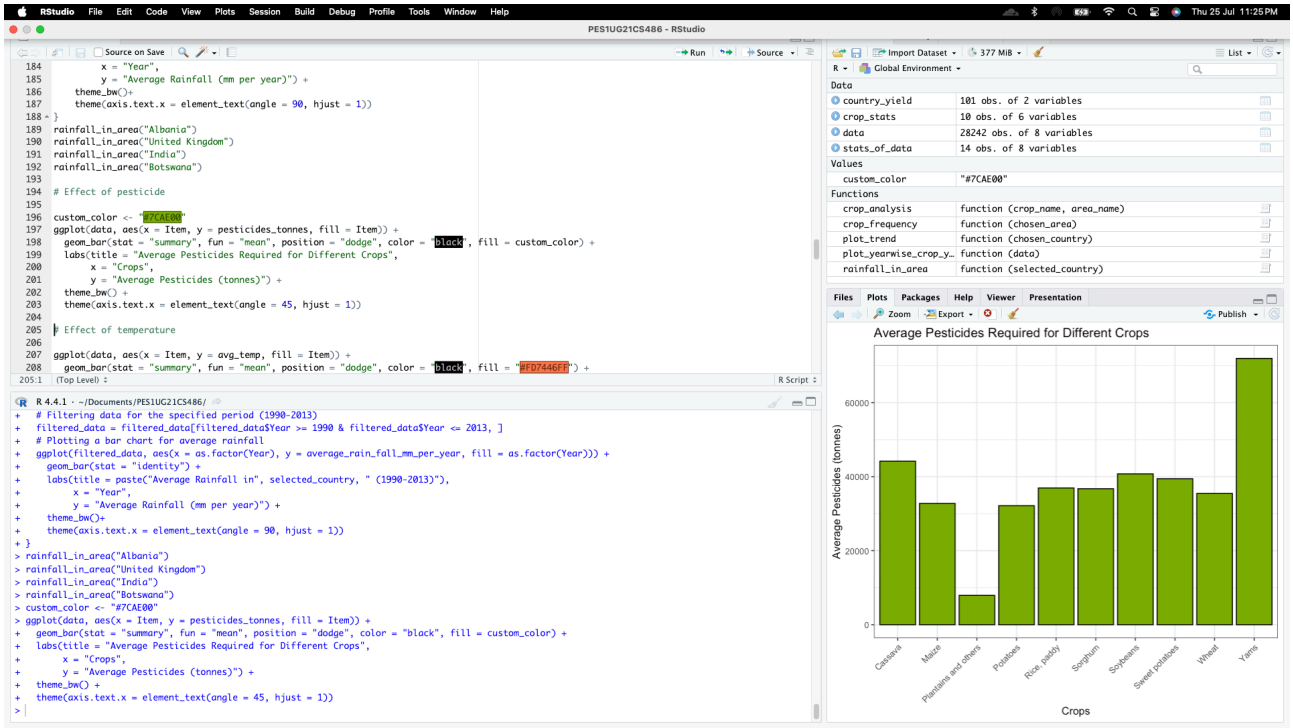


In Botswana there was a sudden drop in rainfall pattern after 2008 and remained the same till 2013.



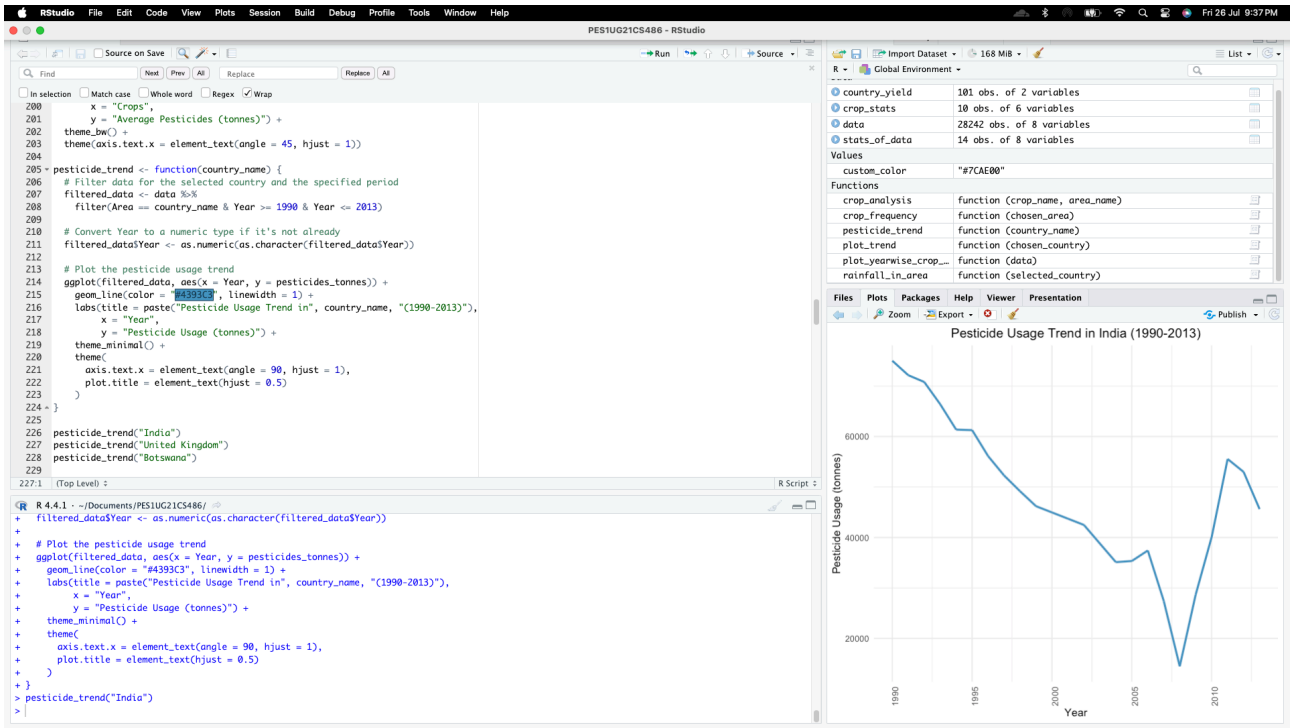
Effect of Pesticides

The following bar chart can be used to estimate the amount of pesticides that different crop kinds require for growth:

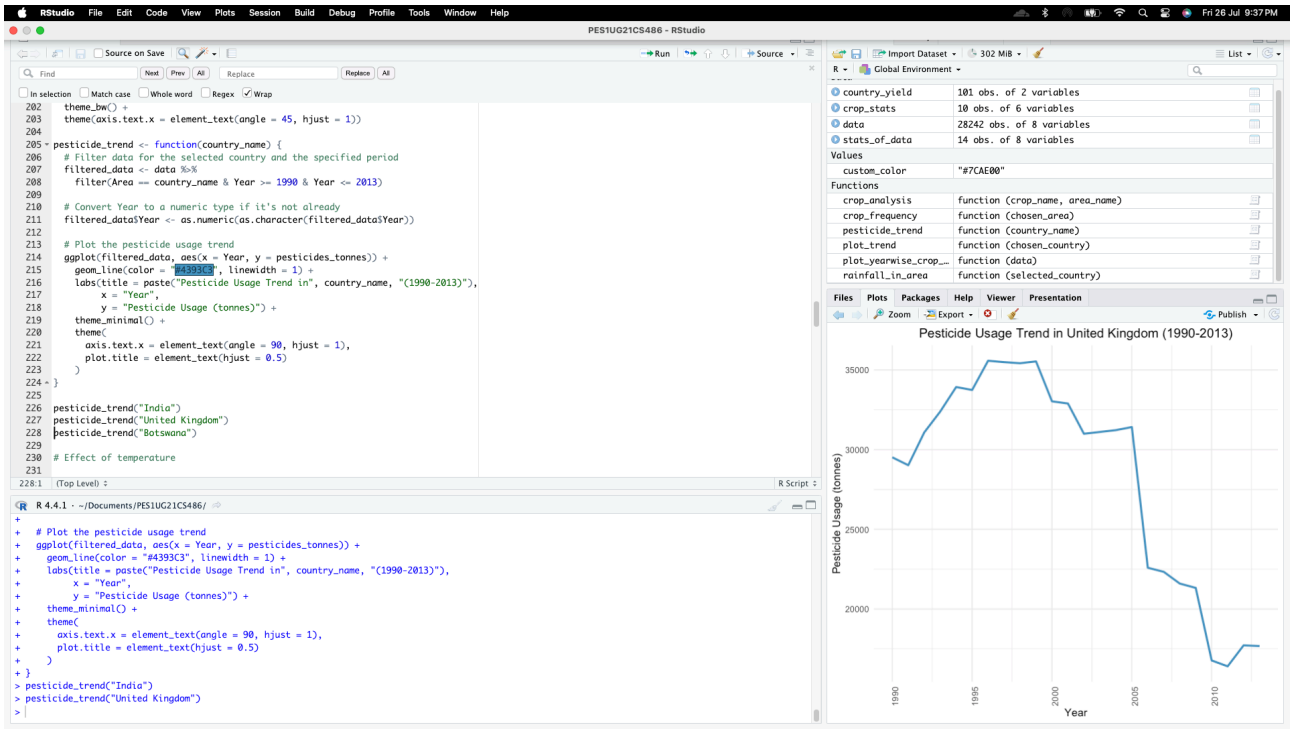


Some observations we can make are that the only crop that needs an excessive number of insecticides is Yams. Given how costly to raise, this could be the reason it is among the least popular crops worldwide. Conversely, the least amount of pesticides is needed for plantains to grow.

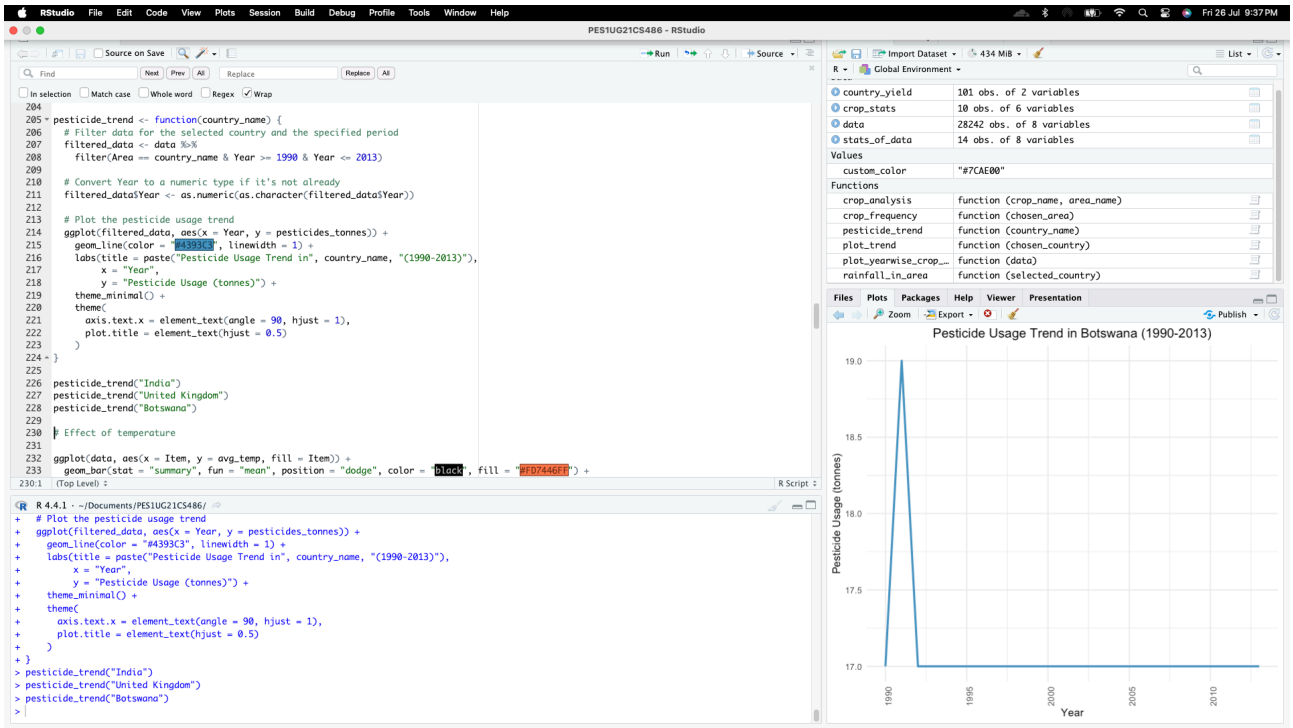
To study the effect of pesticides further, we plot the trends of pesticides over the years in operate countries to study how changes in pesticide usage have affected the yield of the crop. This experiment were conducted on United Kingdom which has the highest mean crop yield , India and Botswana which has the lowest mean yield.



From the above graph we can we that the use of pesticides in India from 2007 onwards has been increased which is an indication that it has been a factor in the increasing mean yield as we saw from our analysis earlier.



Conversely, we also saw a big fall in the mean yield of the United Kingdom post 2010 which further tells us that decreased pesticide usage in the United Kingdom had a big role to play.

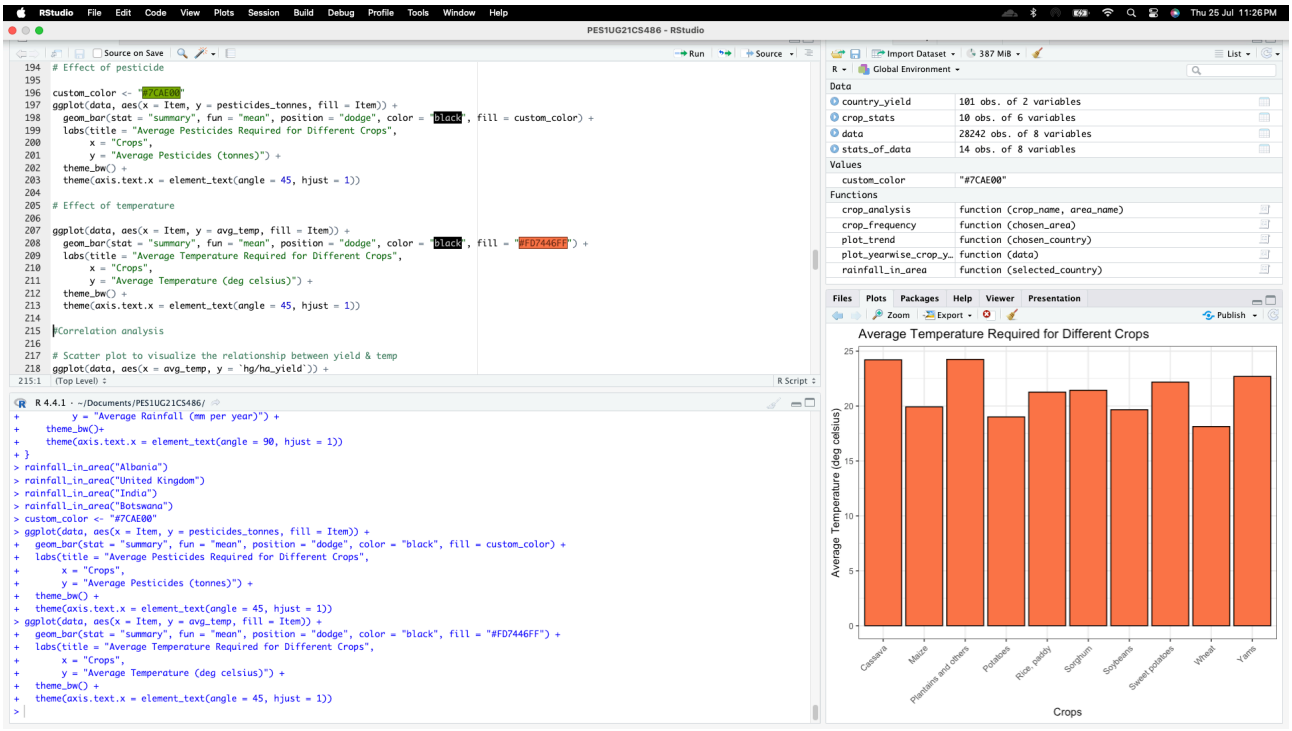


We also saw Botswana having the lowest mean yield and the graph of pesticide usage further confirms our hypothesis that the amount of pesticides used is directly affects the mean yield of a country.

Note: It was interesting to compare the amount of pesticide used in Botswana with any other country, however it could be a human error of recoding incorrect values in the dataset.

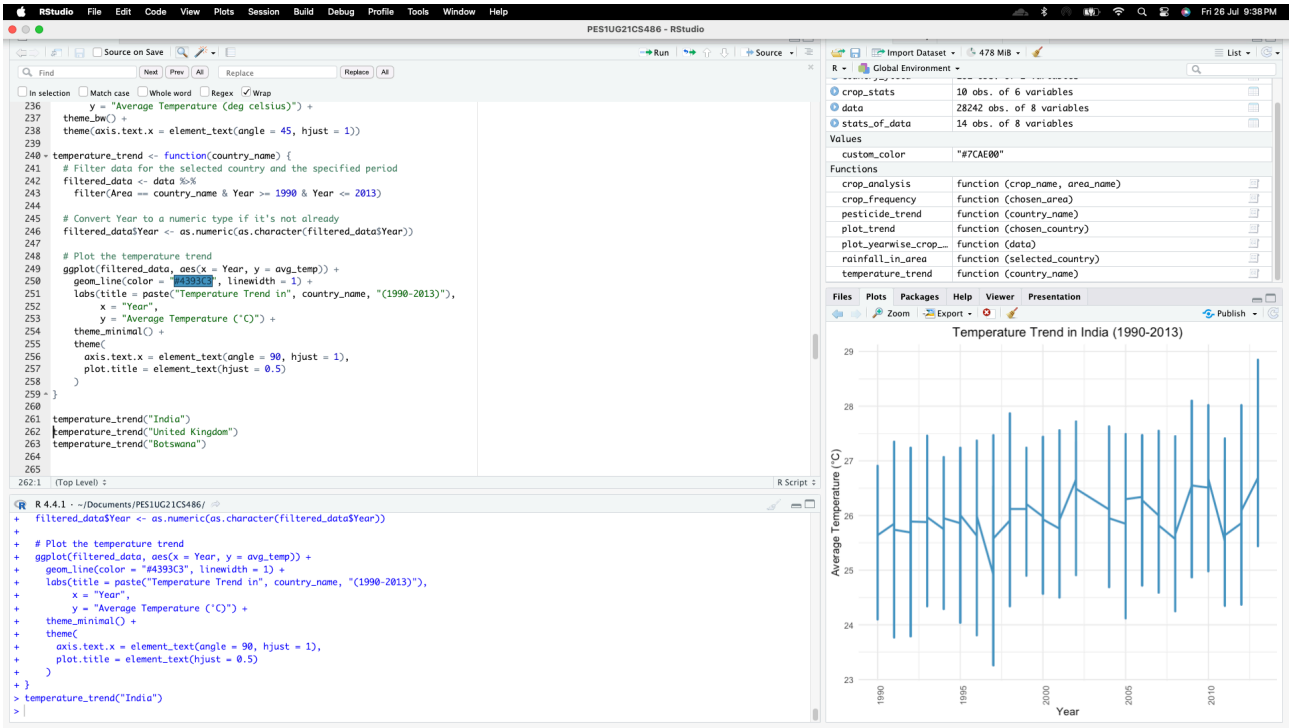
Effect of Temperature

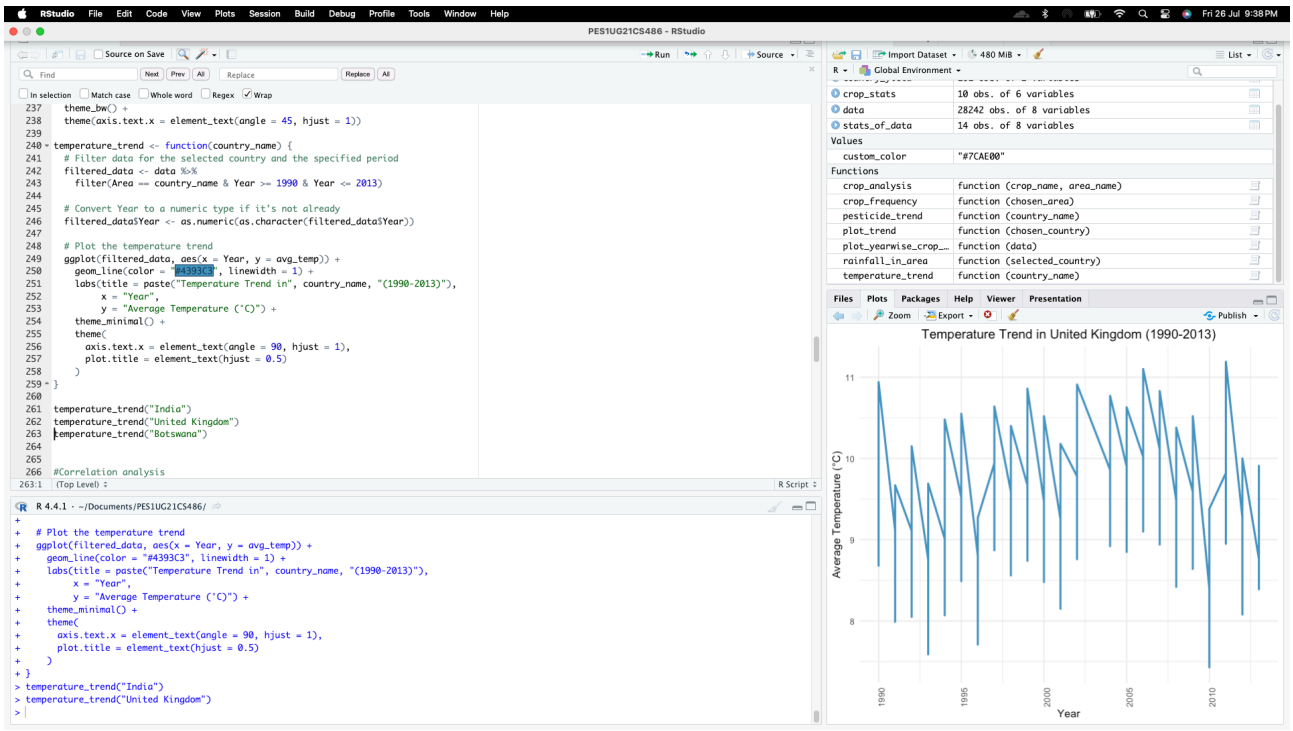
Crop varieties vary in the climates in which they grow. The following bar chart can be used to estimate how temperature affects crops:

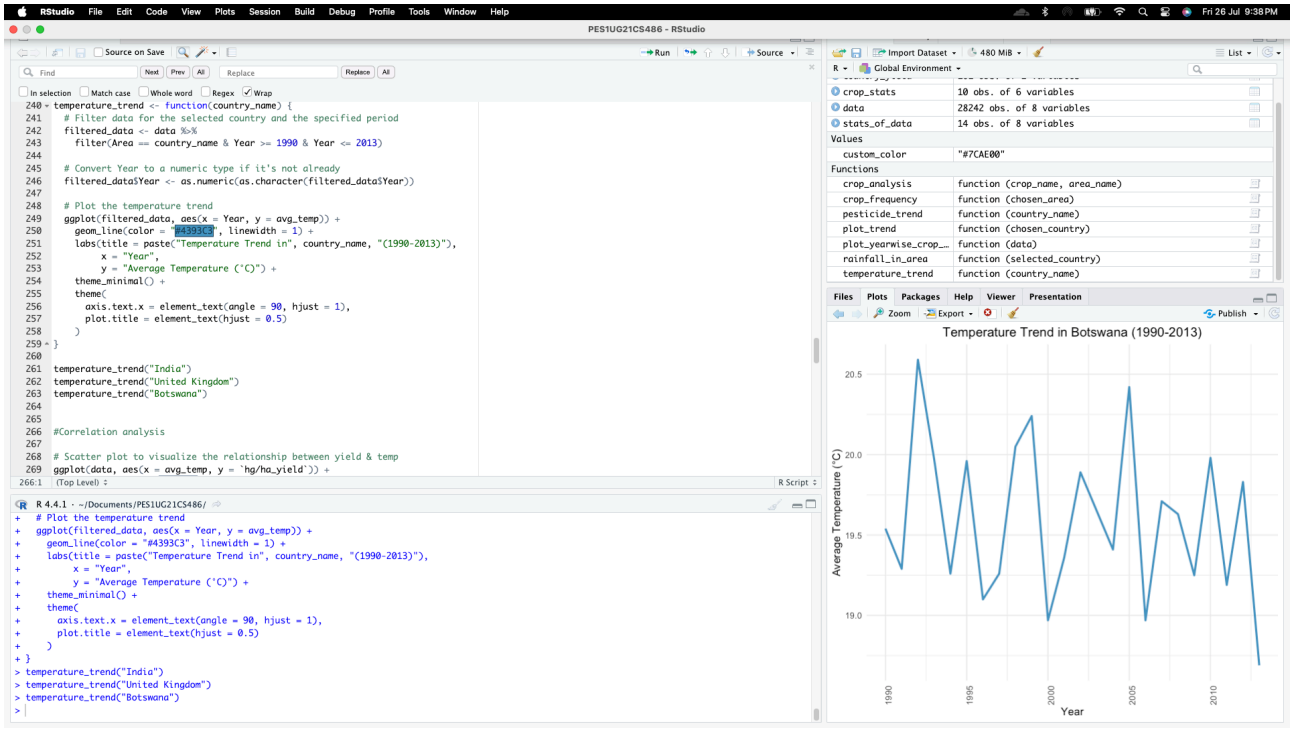


The above figure shows that yams, plantains, cassava, and sweet potatoes flourish in arid regions whereas crops like Maize, Potatoes, Soybeans and Wheat flourish in more favourable weather conditions and hence could attribute to their higher yield statistics.

On doing a trend analysis similar to pesticide trends, I want to see if there have been any unfavourable weather conditions that lead to an impact on yield of a country. Here also I have plotted the trends for United Kingdom, India and Botswana



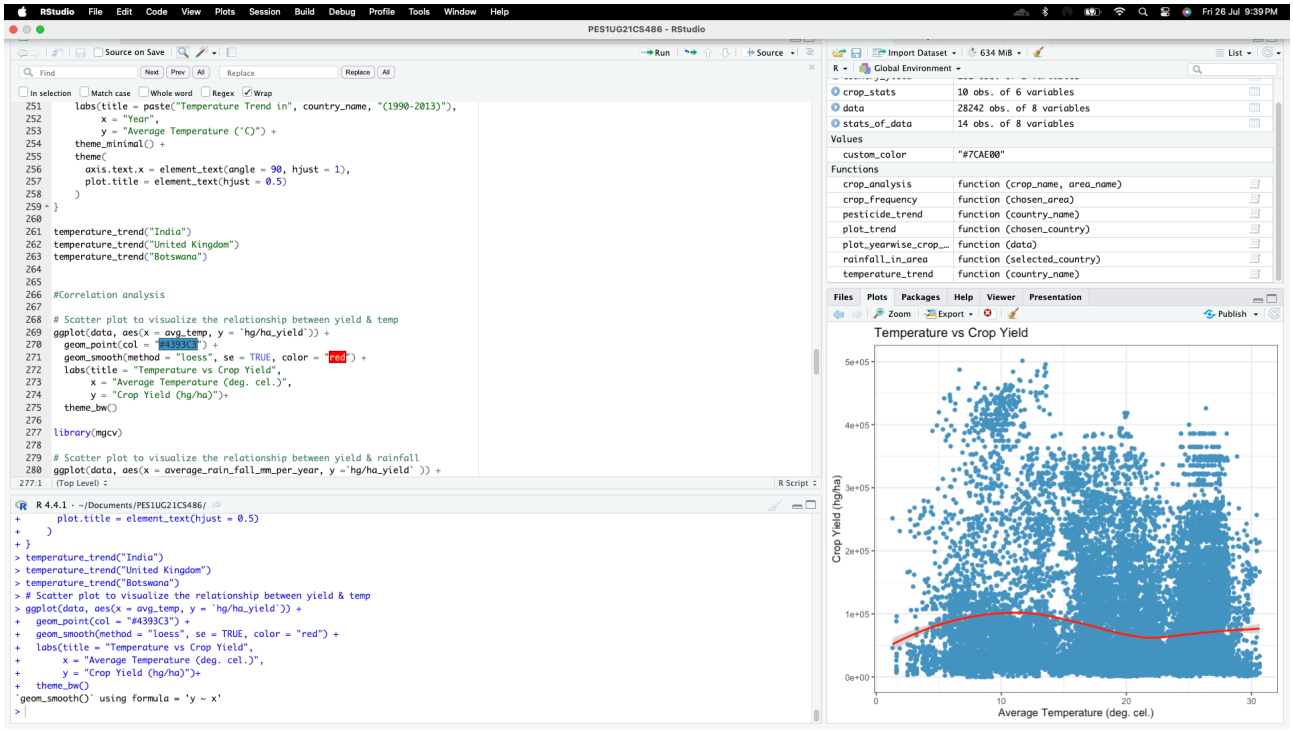


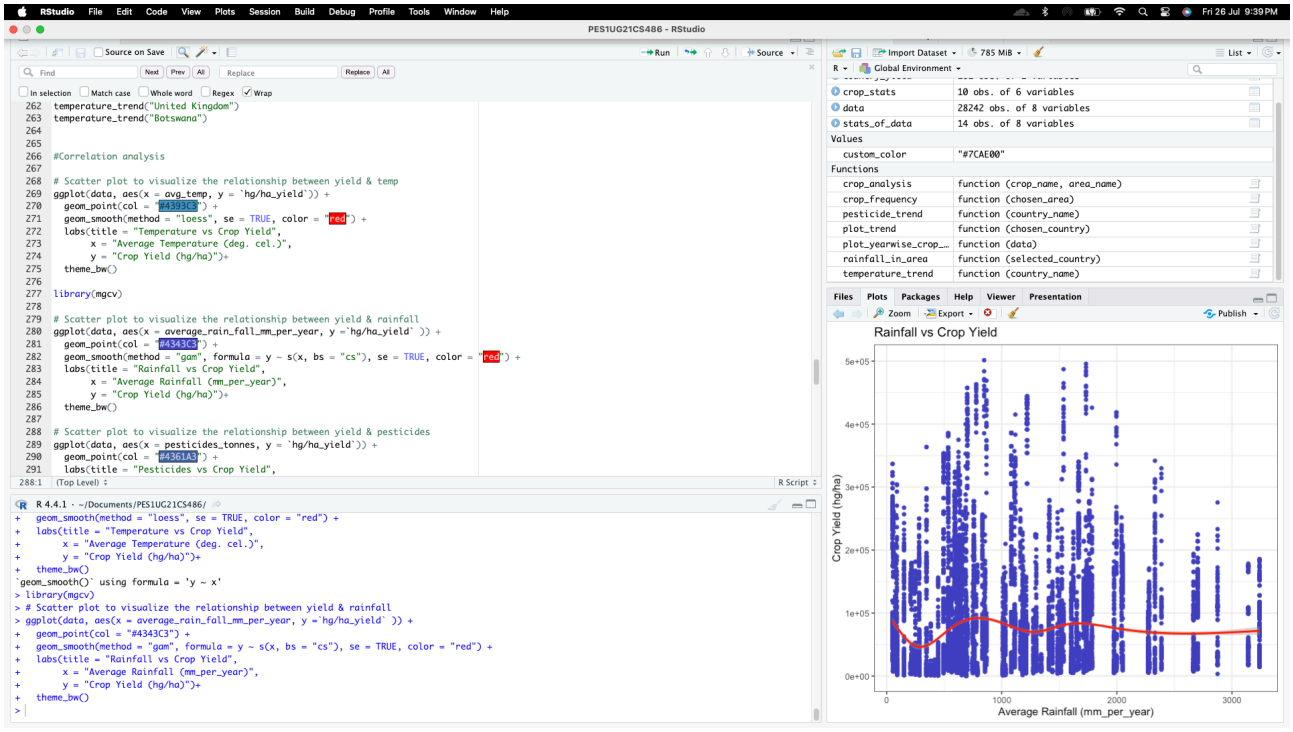


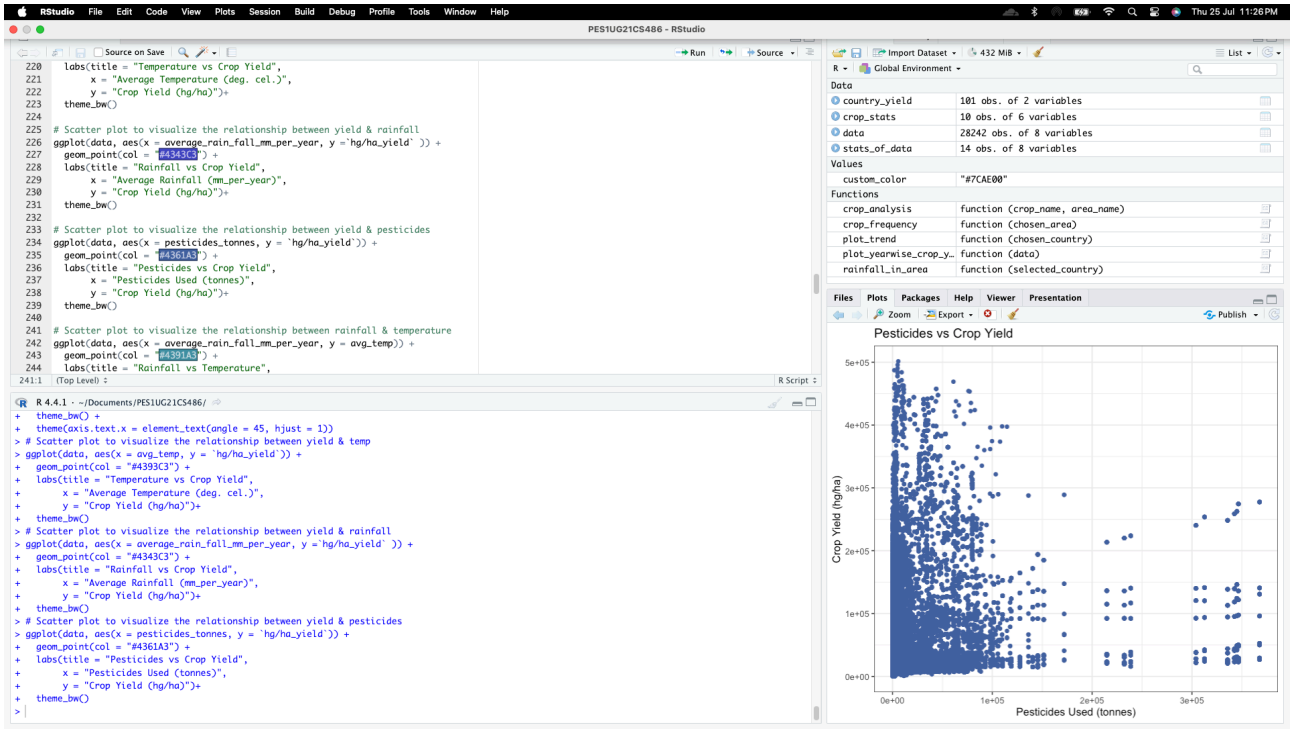
From these graphs, we can observe something very interesting. While countries like India and United Kingdom experience rising temperatures Botswana on the other hand has seen lowering temperatures. This makes me to believe that there is a bit of a negative correlation between temperature and mean yield. However temperature is not the sole factor in deciding the yield.

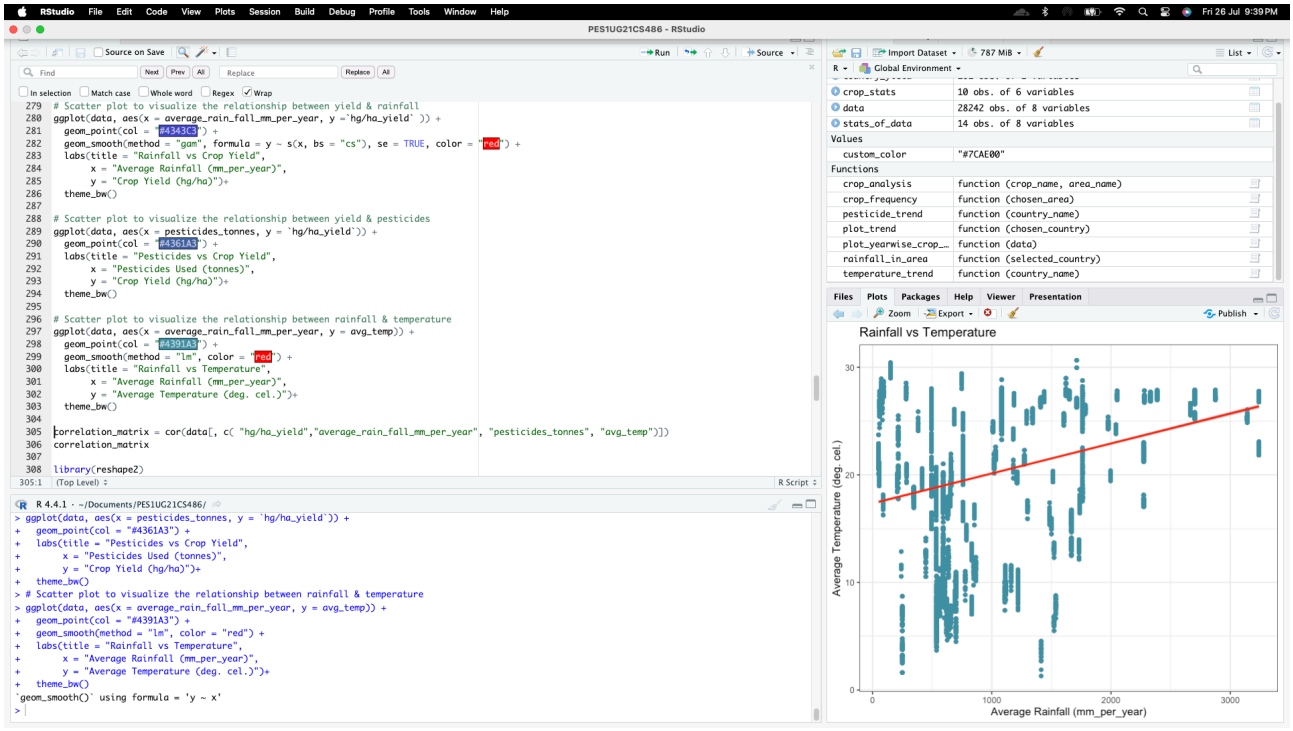
Correlation Analysis

Using scatter plots, we can see how temperature, precipitation, and pesticide use affect yield:

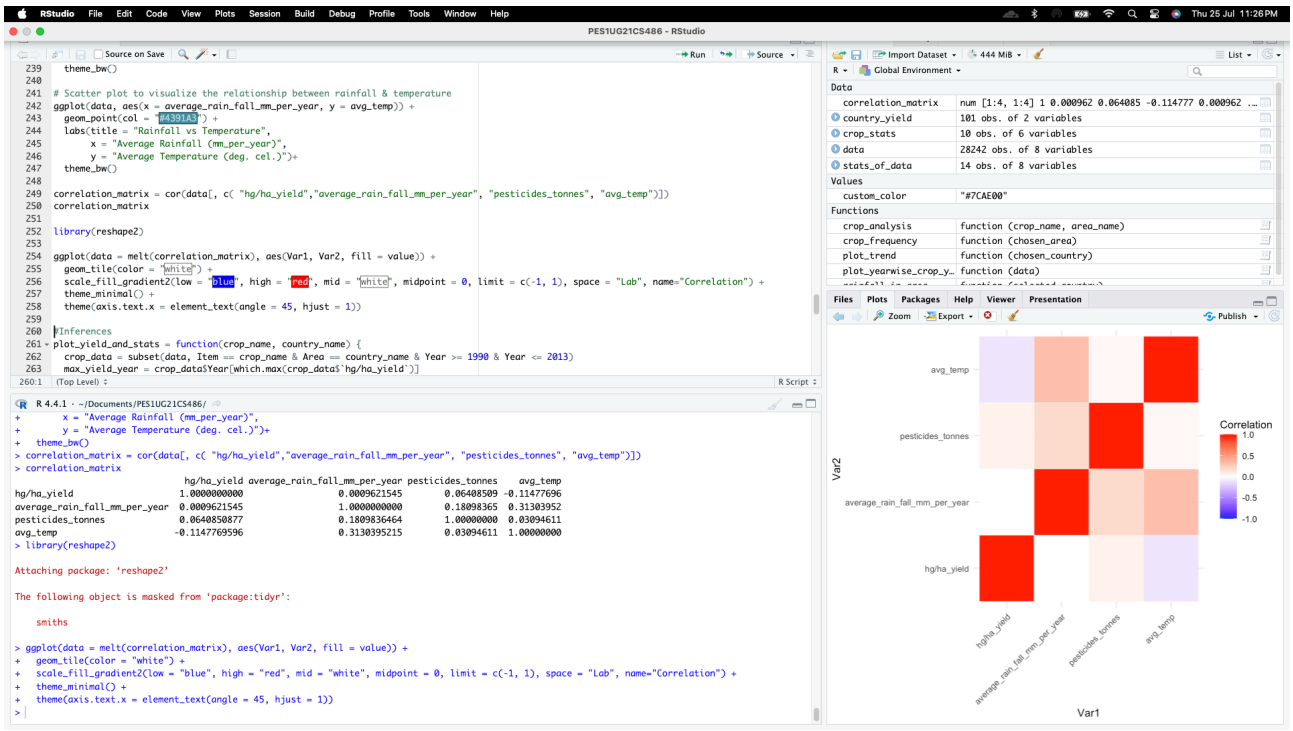








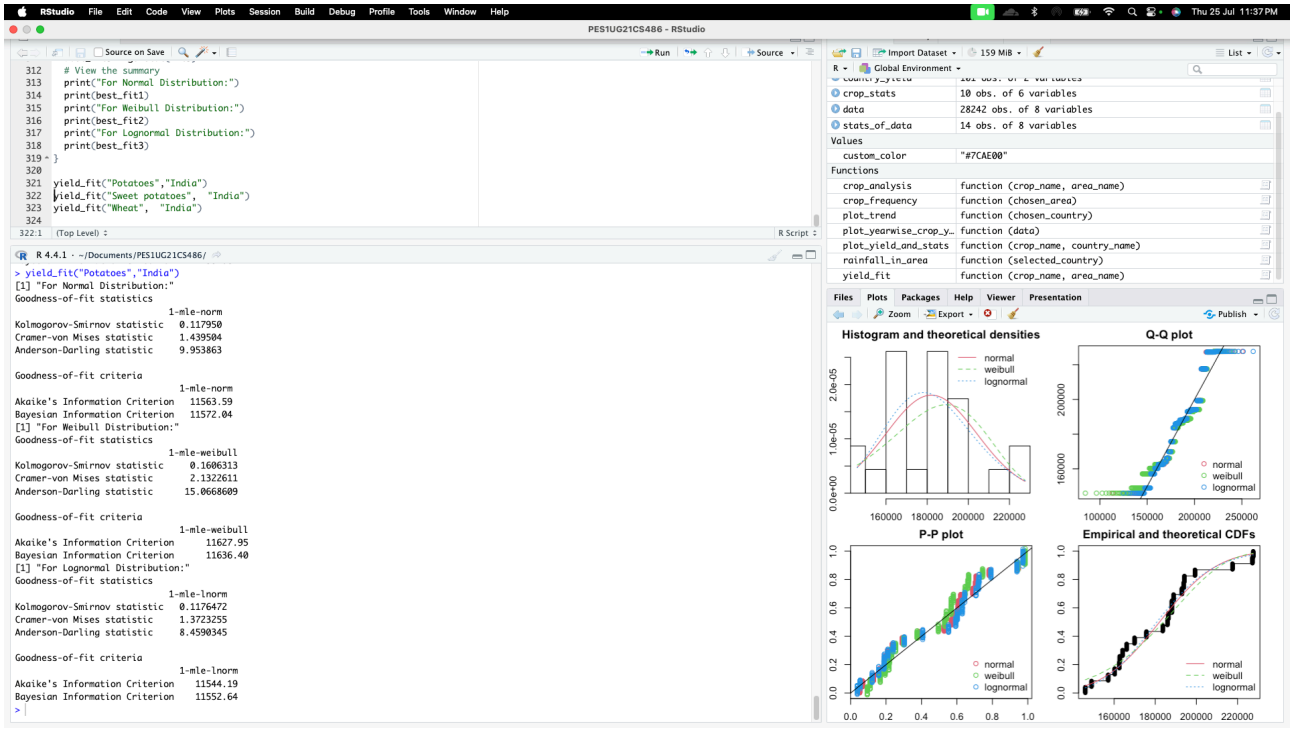
We can now make a correlation Matrix for above relationships and is presented below along with a heat map visualisation for the same:



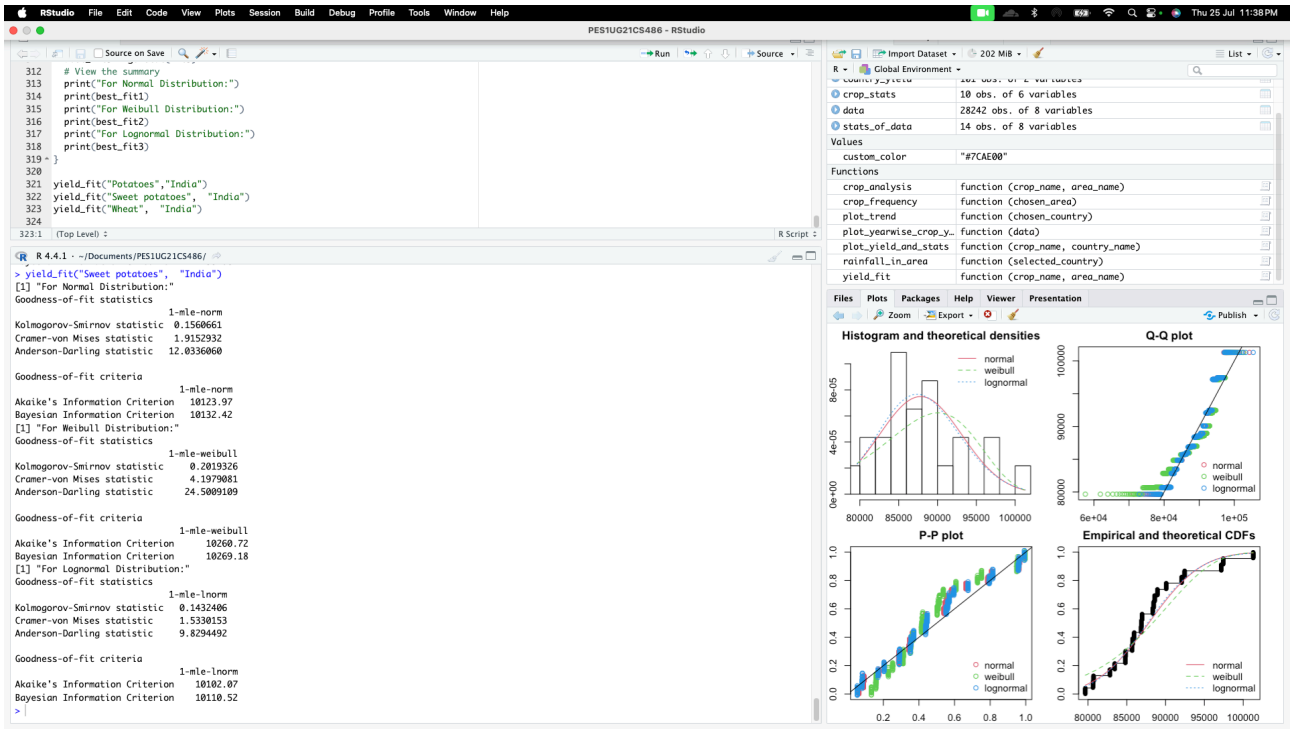
We see that yield is very less correlated with rainfall but more correlated with the amount of pesticides used. Also there is a negative correlation between yield and temperature. A strong positive correlation can also be seen between rainfall and temperature.

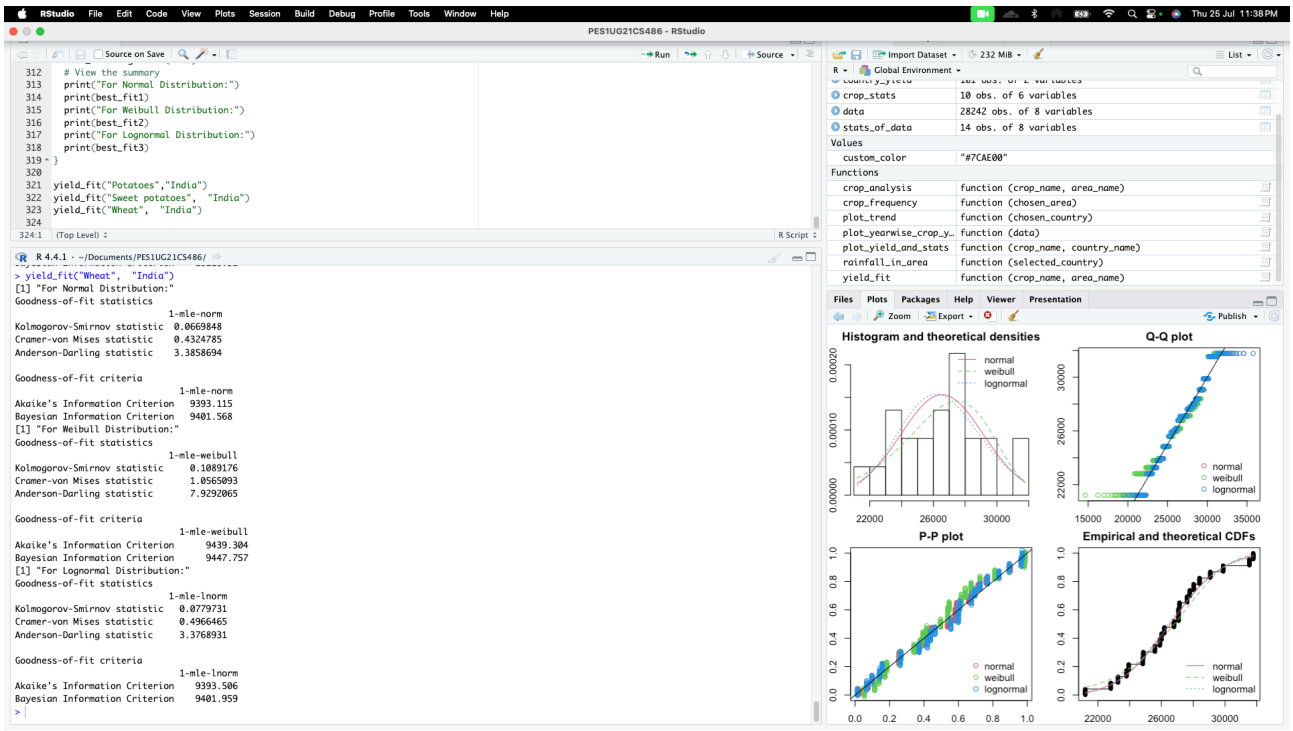
Additional Statistics: Fitting Distributions

Now we can attempt to fit a few distributions to the yield of certain crops produced in India using the “fitdistrplus” package.



From the above information we can conclude that lognormal distribution fits the best for the yield of Potatoes in India. (low KS, AIC and BIC).In a similar fashion we can do so for other crops and countries too.





- Statistics like the AIC (Akaike information criterion), which estimates prediction error and, consequently, the relative quality of statistical models for a given set of data, are obtained through the fitting of distributions.Among a finite collection of models, the Bayesian information criterion (BIC) or Schwarz information criterion (also known as SIC, SBC, or SBIC) is a criterion for model selection; models with lower BIC are typically chosen.) Furthermore, the KS (Kolmogorov–Smirnov test, also known as the K–S test or KS test) is a nonparametric test of the

equality of continuous (or discontinuous), one-dimensional probability distributions. It can be used to compare two samples (the two-sample K–S test) or one sample with a reference probability distribution (the one-sample K–S test).

• Lower AIC and BIC values indicate a better fit. The KS statistic measures the maximum difference between the empirical distribution function of your data and the theoretical distribution. Smaller KS values suggest a better fit.

Benefits of Fitting Distributions

It is beneficial to fit a probability distribution for a country's crop yield over a certain time period for a number of reasons.

1) **Risk Assessment:** The risk connected to various yield levels can be evaluated with the use of probability distributions. Farmers and policymakers can more effectively evaluate and manage the risks involved in crop production by taking preemptive steps to reduce potential losses by knowing the distribution of possible outcomes.

2) **Decision Support:** The foundation for decision support is provided by fitted probability distributions. The distribution can help farmers make well-informed choices on how to allocate resources, manage their crops, and reduce risks. For example, the distribution of predicted yields can help determine decisions about planting schedules, crop insurance, and resource investments.

3) **Supply Chain Management:** Organisations and parties involved in the farming supply chain can forecast and prepare for changes in crop yield by using probability distributions. Pricing tactics, supply chain optimisation, and general market strategy all depend on this.

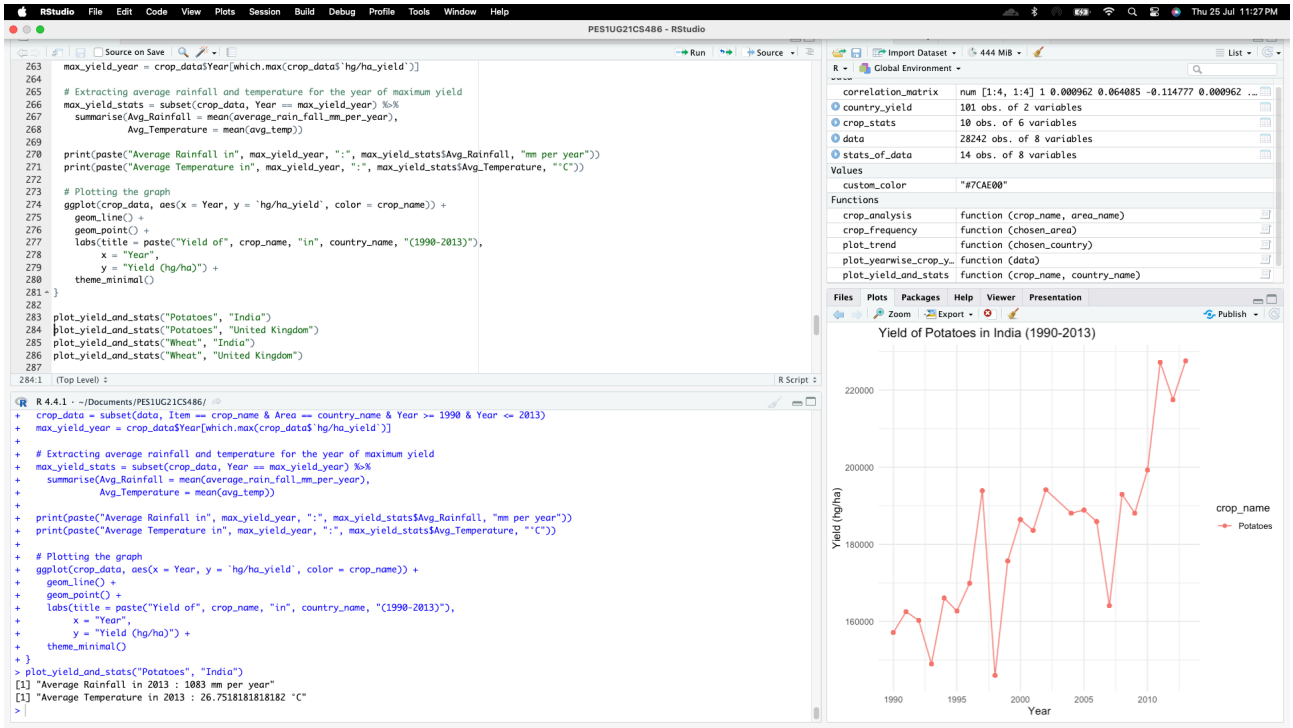
4) **Early Warning Systems:** For catastrophic occurrences like droughts or floods, early warning systems might include probability distributions. Authorities are able to promptly respond to and provide support systems for impacted regions by keeping an eye on deviations from planned yield distributions.

To summarise, the process of fitting a probability distribution to data on crop yields offers a strong foundation for agricultural decision-making, risk evaluation, and resource optimisation. It improves the capacity to foresee and adjust to changing circumstances, which eventually helps to create agricultural methods that are more robust and sustainable.

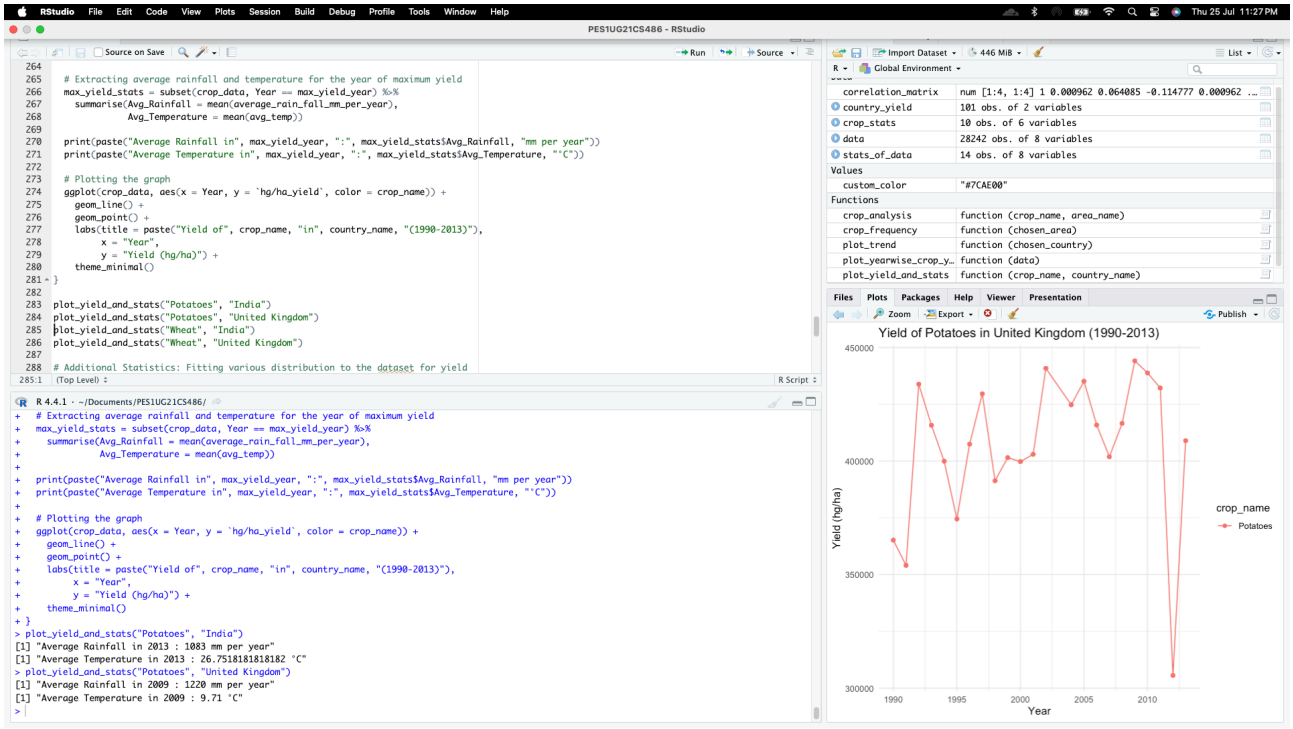
Conclusion

Examining the agricultural yield graph over time in connection to meteorological variables like temperature and rainfall which applicable to any crop and nation:

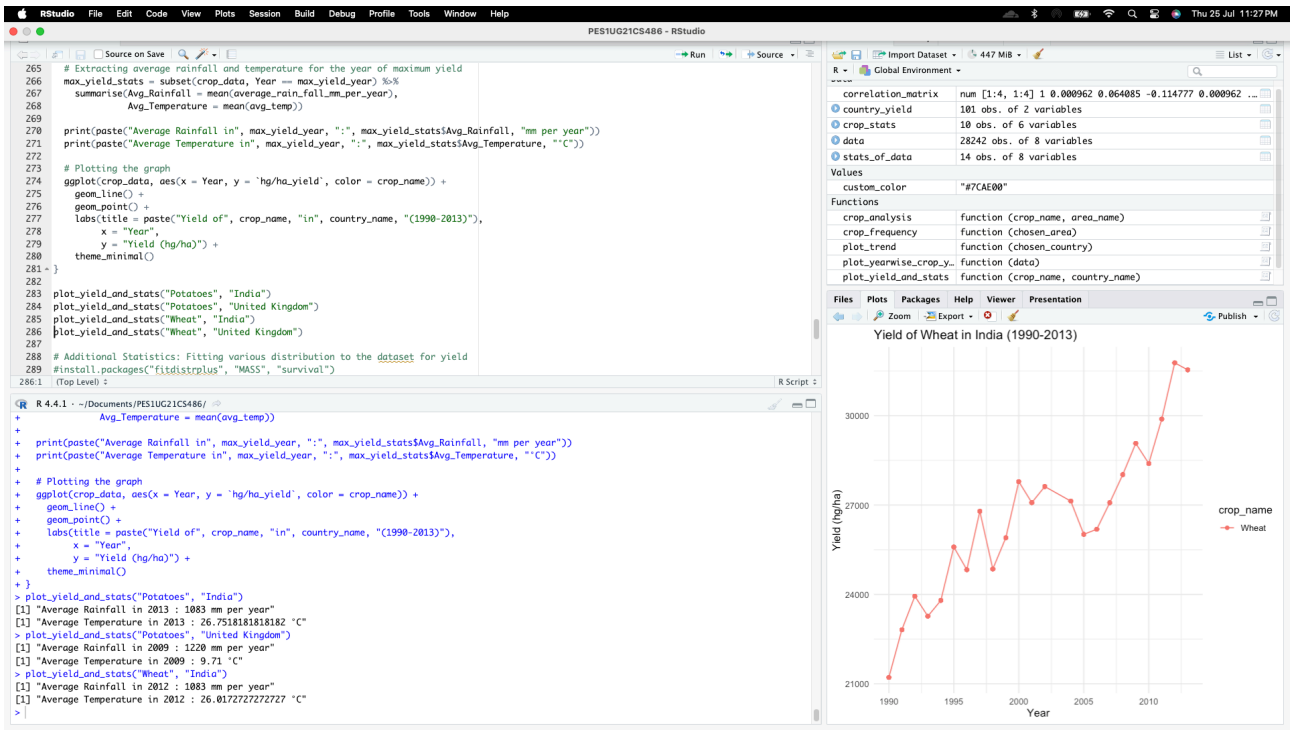
From the following graph we can conclude that following the trends seen everywhere in the world, India’s yield of potatoes has increased significantly from 1990 to 2013 and it remains to be the highest yield crop in India.



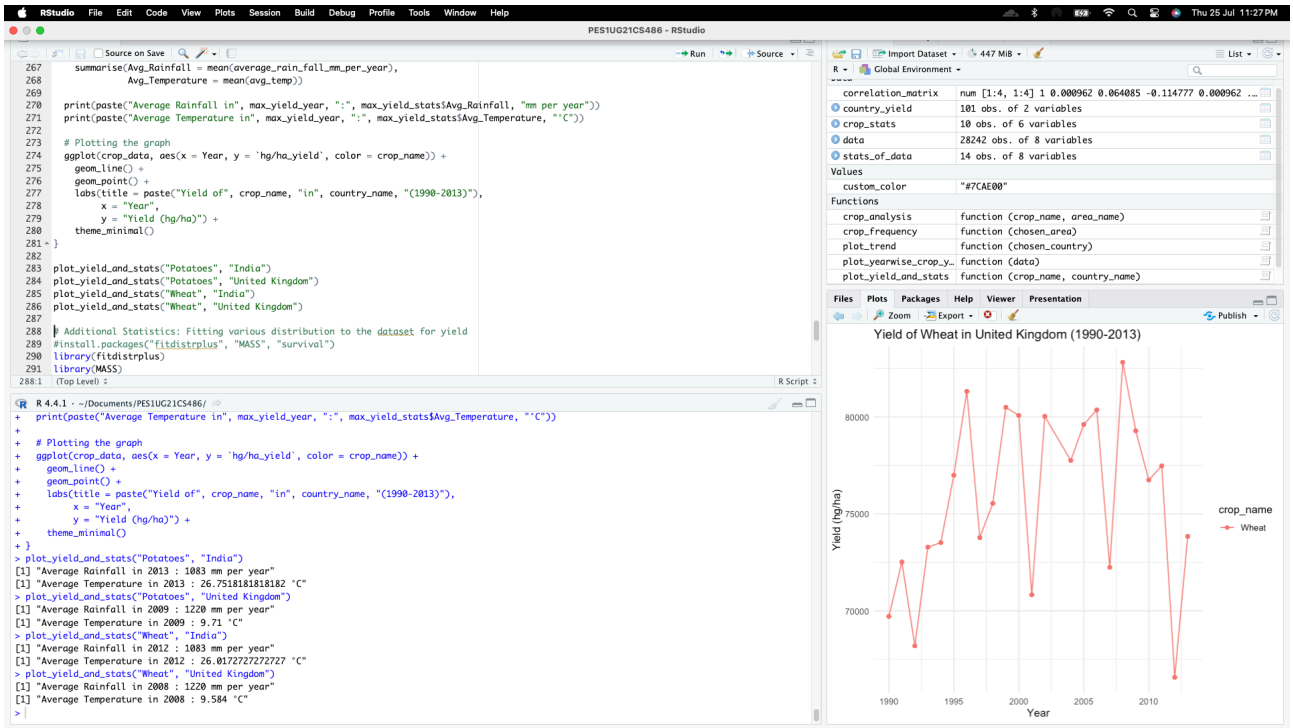
Analysing the trends of yield of potatoes in United Kingdom we see a sudden drop in 2012 which shows that in 2012 the yields in potatoes took a massive hit which could have been a result of several factors like bad harvest season, poor quality of pesticides or unfavourable weather conditions.



We can also see from the below grasp that yields of other crops, in this case Wheat has also significantly increased in India depicting good agricultural practices, favourable weather conditions etc.



Following graph showing Wheat yield also confirms our hypothesis of unfavourable conditions in United Kingdom in the year 2012 which also affected the yield of wheat significantly. We see a slight rise in 2013 just like the potatoes yield, however we can still see a significant decline in yield in United Kingdom from the 1990's.



Findings

1. **Effect of Pesticides:**
   - The analysis shows that increased use of pesticides in India from 2007 onwards has been associated with a rise in mean crop yield.
   - A significant decrease in the mean yield of the United Kingdom post-2010 correlates with reduced pesticide usage.
   - Botswana, with the lowest mean yield, also shows minimal pesticide usage, supporting the hypothesis that pesticide use directly affects crop yield.

2. **Effect of Temperature:**
   - The trend analysis indicates that countries like India and the United Kingdom have experienced rising temperatures, while Botswana has seen a decrease in temperatures.
   - There is a negative correlation between temperature and mean yield, suggesting that higher temperatures are generally associated with lower yields. However, temperature is not the sole factor influencing yield.

3. **Effect of Rainfall:**
   - Rainfall patterns were analyzed to determine their impact on crop yield. In Albania, there was high rainfall from 1990-1992 but a significant drop in 1992. From 1994-2013, rainfall levels remained stable.
   - The United Kingdom and India experienced consistent rainfall levels from 1990-2013, whereas Botswana saw a sudden drop in rainfall after 2008, which remained consistent until 2013.
   - The average rainfall required for different crops was analyzed, showing varying needs. The analysis highlighted how rainfall impacts crop yield in different regions.

4. **Outlier Detection:**
   - Outlier detection was conducted to identify outliers in crop yield data for different countries and crops. This method helps in understanding the anomalies and ensuring the accuracy of data analysis.
   - For example, in the crop yield analysis for India, outliers were identified in the yield distributions of sweet potatoes whereas no outliers potatoes, and wheat from 1990-2013

5. **Correlation Analysis**:
   - A correlation matrix and heat map reveal that yield has a low correlation with rainfall but a stronger correlation with pesticide usage.
   - There is a negative correlation between yield and temperature, and a strong positive correlation between rainfall and temperature.

6. **Fitting Distributions**:
   - The analysis fitted various statistical distributions to crop yield data, finding that the lognormal distribution fits best for potato yields in India. This method can be extended to other crops and countries to support agricultural decision-making and risk assessment.

Here are some insights that can be gained:

1) **Identification of Optimal Conditions:** To determine the ideal growth conditions for a given crop, it is helpful to look at the times of maximum yield and the environmental variables that go along with it. The timing of planting and harvesting can be determined using this information.

2) **Identification of Critical Periods:** Targeted interventions are made possible by pinpointing the times during the crop growth cycle when environmental factors have a significant impact on production. For instance, farmers can put plans in place to lessen any negative effects during a growth stage that is susceptible to temperature fluctuations.

3) **Risk management:** Identifying years with reduced yields and looking at the related environmental factors aid in risk assessment and management. Based on past performance, farmers might employ risk-reduction techniques including crop diversification and resilient variety purchases.

4) **Precision Agriculture:** The application of precision agriculture methods can be guided by the analysis's conclusions. Farmers are able to apply precision irrigation, fertilisation, and pest control tactics that are customised to certain regions of their fields by utilising data on past production changes and related variables.

5) **Crop Rotation and Diversification:** Strategic crop rotation and diversification are made possible by an understanding of how environmental factors affect certain crops. Crop combinations that compliment one another and are resistant to various environmental stresses might be chosen by farmers.

References

- Dataset -> https://www.kaggle.com/datasets/patelris/crop-yield-prediction-dataset?select=yield_df.csv
- https://www.kaggle.com/datasets/patelris/crop-yield-prediction-dataset/discussion/436426
- https://www.kaggle.com/code/noujoudgabed/eda-crop-yield
- https://eos.com/blog/crop-yield-increase
- https://www.intechopen.com/chapters/70658

Appendix (R Program)

```
library(readr)
data <- read_csv("/Users/rhian/Documents/PES1UG21CS486/
yield_df.csv")

#Attribute names & types
names(data)
sapply(data, class)

#Checking for missing values
any(is.na(data))

# Displaying the structure of your data
str(data)
# Displaying the first few rows of your data
head(data)

library(pastecs)
stats_of_data <- format(stat.desc(data), scientific = FALSE)
print(stats_of_data)

library(ggplot2)

# Analyzing Item
table(data$Item)

pie(table(data$Item), main = "Crop Frequency Distribution", col =
terrain.colors(12))

crop_frequency <- function(chosen_area){
  # Filtering data for the selected area
  filtered_data = data[data$Area == chosen_area, ]

  # Plotting a bar chart for the frequency of different crops
  ggplot(filtered_data, aes(x = Item, fill = Item)) +
    geom_bar() +
    labs(title = paste("Crop Frequency in", chosen_area),
         x = "Crops",
         y = "Frequency") +
    theme_bw() +
    theme(axis.text.x = element_text(angle = 90, hjust = 1))
}

crop_frequency("Albania")
crop_frequency("Botswana")
crop_frequency("United Kingdom")
crop_frequency("India")

print('The crop which is grown in most of the countries is:')
which.max(table(data$Item))
```

```r
#Year-wise Crop Yield Analysis
library(dplyr)
library(scales)
plot_yearwise_crop_yield <- function(data) {
  # Grouping the data by Year and Item to get the sum of yield of
each crop per year
  yearwise_crop_yield <- data %>%
    group_by(Year, Item) %>%
    summarise(total_yield = sum(`hg/ha_yield`)) %>%
    ungroup()

  # Plotting the data using ggplot2
  ggplot(yearwise_crop_yield, aes(x = Year, y = total_yield, color
= Item)) +
    geom_line(linewidth = 1.2) +  # Thicker lines for better
visibility
    labs(title = "Yearwise crop-yield",
         x = "Year",
         y = "Yield (hg/ha)",
         color = "Crop") +
    scale_y_continuous(labels = comma) +
    theme_minimal() +
    theme(
      axis.text.x = element_text(angle = 45, hjust = 1),
      plot.title = element_text(hjust = 0.5),
      legend.position = "right"
    )
}
plot_yearwise_crop_yield(data)

library(modeest)

# Grouping data by crop
crop_stats = data %>%
  group_by(Item) %>%
  reframe(

    Mean_Yield = mean(`hg/ha_yield`),
    Median_Yield = median(`hg/ha_yield`),
    Mode_Yield = mfv(`hg/ha_yield`)[1],
    Max_yield = max(`hg/ha_yield`),
    Min_yield = min(`hg/ha_yield`)
  )
print(crop_stats)

# Plotting a barplot of various crops
ggplot(data, aes(x = Item, y = `hg/ha_yield`, fill = Item)) +
  geom_bar(stat = "identity") +
  labs(title = "Crop Yield Analysis",
       x = "Crops",
       y = "Yield (hg/ha)") +
  theme_bw() +
```

```
  theme(axis.text.x = element_text(angle = 90, hjust = 1))

library(tidyverse)

# Trend analysis using ggplot2
ggplot(data, aes(x = Year, y = `hg/ha_yield`, color = Item)) +
  geom_line() +
  labs(title = "Trend Analysis of Agriculture Yield Over Time",
       x = "Year",
       y = " Yield (hg/ha)") +
  theme_bw()

# Calculating mean yield for each country
country_yield = data %>%
  group_by(Area) %>%
  summarize(mean_yield = mean(`hg/ha_yield`))

#Trends over the years for different countries
plot_trend <- function(chosen_country){
  trend_plot = data %>%
    filter(Area == chosen_country) %>%
    ggplot(aes(x = Year, y = `hg/ha_yield`)) +
    geom_line(color = "turquoise", lwd = 1) +
    labs(title = "Trend of Yield Over Years in the Chosen
Country", x = "Year", y = "Yield (hg/ha)") +
    theme_bw()+
    theme(axis.text.x = element_text(angle = 90, hjust = 1))

  print(trend_plot)
}

plot_trend("United Kingdom")
plot_trend("India")
plot_trend("Botswana")

# Creating a bar plot to compare mean yield between countries
ggplot(country_yield, aes(x = reorder(Area, -mean_yield), y =
mean_yield)) +
  geom_bar(stat = "identity", fill = "yellow",color = "black") +
  labs(title = "Mean Yield Comparison between Countries", x =
"Country", y = "Mean Yield (hg/ha)")+
  theme(axis.text.x = element_text(angle = 90, size = 4.5))

# Crop-wise analysis for a specific crop in a particular area from
1990-2013
crop_analysis = function(crop_name, area_name) {
  # Filtering data for the specific crop, area, and time period
  crop_data = subset(data, Item == crop_name & Area == area_name &
Year >= 1990 & Year <= 2013)

  # Displaying summary statistics
```

```
  print(paste("Summary Statistics for", crop_name, "in",
area_name, "from 1990-2013:"))
  print(summary(crop_data$`hg/ha_yield`))

  # Creating a boxplot
  boxplot(crop_data$`hg/ha_yield`, main = paste(crop_name, "Yield
Distribution in", area_name), ylab = "Yield (hg/ha)", col =
"#D6604D")

  # Identification of outliers using the Tukey method
  outliers = boxplot.stats(crop_data$`hg/ha_yield`)$out

  # Displaying outliers
  print("Outliers are:")
  print(outliers)
}

crop_analysis("Potatoes","India")
crop_analysis("Sweet potatoes","India")
crop_analysis("Wheat","India")

#Effect of rainfall

ggplot(data, aes(x = Item, y = average_rain_fall_mm_per_year, fill
= Item)) +
  geom_bar(stat = "summary", fun = "mean", position = "dodge",
color = "black", fill = "#7443AF") +
  labs(title = "Average Rainfall Required for Different Crops",
       x = "Crops",
       y = "Average Rainfall (mm per year)") +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

# Rainfall amount for a particular area

rainfall_in_area <- function(selected_country){
  # Filtering data for the selected country
  filtered_data = data[data$Area == selected_country, ]
  filtered_data$Year <-
as.numeric(as.character(filtered_data$Year))
  # Filtering data for the specified period (1990-2013)
  filtered_data = filtered_data[filtered_data$Year >= 1990 &
filtered_data$Year <= 2013, ]
  # Plotting a bar chart for average rainfall
  ggplot(filtered_data, aes(x = as.factor(Year), y =
average_rain_fall_mm_per_year, fill = as.factor(Year))) +
    geom_bar(stat = "identity") +
    labs(title = paste("Average Rainfall in", selected_country, "
(1990-2013)"),
         x = "Year",
         y = "Average Rainfall (mm per year)") +
    theme_bw()+
```

```
    theme(axis.text.x = element_text(angle = 90, hjust = 1))
}
rainfall_in_area("Albania")
rainfall_in_area("United Kingdom")
rainfall_in_area("India")
rainfall_in_area("Botswana")

# Effect of pesticide

custom_color <- "#7CAE00"
ggplot(data, aes(x = Item, y = pesticides_tonnes, fill = Item)) +
  geom_bar(stat = "summary", fun = "mean", position = "dodge",
color = "black", fill = custom_color) +
  labs(title = "Average Pesticides Required for Different Crops",
       x = "Crops",
       y = "Average Pesticides (tonnes)") +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

pesticide_trend <- function(country_name) {
  # Filter data for the selected country and the specified period
  filtered_data <- data %>%
    filter(Area == country_name & Year >= 1990 & Year <= 2013)

  # Convert Year to a numeric type if it's not already
  filtered_data$Year <-
as.numeric(as.character(filtered_data$Year))

  # Plot the pesticide usage trend
  ggplot(filtered_data, aes(x = Year, y = pesticides_tonnes)) +
    geom_line(color = "#4393C3", linewidth = 1) +
    labs(title = paste("Pesticide Usage Trend in", country_name,
"(1990-2013)"),
         x = "Year",
         y = "Pesticide Usage (tonnes)") +
    theme_minimal() +
    theme(
      axis.text.x = element_text(angle = 90, hjust = 1),
      plot.title = element_text(hjust = 0.5)
    )
}

pesticide_trend("India")
pesticide_trend("United Kingdom")
pesticide_trend("Botswana")

# Effect of temperature

ggplot(data, aes(x = Item, y = avg_temp, fill = Item)) +
  geom_bar(stat = "summary", fun = "mean", position = "dodge",
color = "black", fill = "#FD7446FF") +
  labs(title = "Average Temperature Required for Different Crops",
```

```
       x = "Crops",
       y = "Average Temperature (deg celsius)") +
  theme_bw() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

temperature_trend <- function(country_name) {
  # Filter data for the selected country and the specified period
  filtered_data <- data %>%
    filter(Area == country_name & Year >= 1990 & Year <= 2013)

  # Convert Year to a numeric type if it's not already
  filtered_data$Year <-
as.numeric(as.character(filtered_data$Year))

  # Plot the temperature trend
  ggplot(filtered_data, aes(x = Year, y = avg_temp)) +
    geom_line(color = "#4393C3", linewidth = 1) +
    labs(title = paste("Temperature Trend in", country_name,
"(1990-2013)"),
         x = "Year",
         y = "Average Temperature (°C)") +
    theme_minimal() +
    theme(
      axis.text.x = element_text(angle = 90, hjust = 1),
      plot.title = element_text(hjust = 0.5)
    )
}

temperature_trend("India")
temperature_trend("United Kingdom")
temperature_trend("Botswana")


#Correlation analysis

# Scatter plot to visualize the relationship between yield & temp
ggplot(data, aes(x = avg_temp, y = `hg/ha_yield`)) +
  geom_point(col = "#4393C3") +
  geom_smooth(method = "loess", se = TRUE, color = "red") +
  labs(title = "Temperature vs Crop Yield",
       x = "Average Temperature (deg. cel.)",
       y = "Crop Yield (hg/ha)")+
  theme_bw()

library(mgcv)

# Scatter plot to visualize the relationship between yield &
rainfall
ggplot(data, aes(x = average_rain_fall_mm_per_year, y =`hg/
ha_yield` )) +
  geom_point(col = "#4343C3") +
```

```
  geom_smooth(method = "gam", formula = y ~ s(x, bs = "cs"), se =
TRUE, color = "red") +
  labs(title = "Rainfall vs Crop Yield",
       x = "Average Rainfall (mm_per_year)",
       y = "Crop Yield (hg/ha)")+
  theme_bw()

# Scatter plot to visualize the relationship between yield &
pesticides
ggplot(data, aes(x = pesticides_tonnes, y = `hg/ha_yield`)) +
  geom_point(col = "#4361A3") +
  labs(title = "Pesticides vs Crop Yield",
       x = "Pesticides Used (tonnes)",
       y = "Crop Yield (hg/ha)")+
  theme_bw()

# Scatter plot to visualize the relationship between rainfall &
temperature
ggplot(data, aes(x = average_rain_fall_mm_per_year, y = avg_temp))
+
  geom_point(col = "#4391A3") +
  geom_smooth(method = "lm", color = "red") +
  labs(title = "Rainfall vs Temperature",
       x = "Average Rainfall (mm_per_year)",
       y = "Average Temperature (deg. cel.)")+
  theme_bw()

correlation_matrix = cor(data[, c( "hg/
ha_yield","average_rain_fall_mm_per_year", "pesticides_tonnes",
"avg_temp")])
correlation_matrix

library(reshape2)

ggplot(data = melt(correlation_matrix), aes(Var1, Var2, fill =
value)) +
  geom_tile(color = "white") +
  scale_fill_gradient2(low = "blue", high = "red", mid = "white",
midpoint = 0, limit = c(-1, 1), space = "Lab", name="Correlation")
+
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

#Inferences
plot_yield_and_stats = function(crop_name, country_name) {
  crop_data = subset(data, Item == crop_name & Area ==
country_name & Year >= 1990 & Year <= 2013)
  max_yield_year = crop_data$Year[which.max(crop_data$`hg/
ha_yield`)]

  # Extracting average rainfall and temperature for the year of
maximum yield
```

```
  max_yield_stats = subset(crop_data, Year == max_yield_year) %>%
    summarise(Avg_Rainfall = mean(average_rain_fall_mm_per_year),
              Avg_Temperature = mean(avg_temp))

  print(paste("Average Rainfall in", max_yield_year, ":",
max_yield_stats$Avg_Rainfall, "mm per year"))
  print(paste("Average Temperature in", max_yield_year, ":",
max_yield_stats$Avg_Temperature, "°C"))

  # Plotting the graph
  ggplot(crop_data, aes(x = Year, y = `hg/ha_yield`, color =
crop_name)) +
    geom_line() +
    geom_point() +
    labs(title = paste("Yield of", crop_name, "in", country_name,
"(1990-2013)"),
         x = "Year",
         y = "Yield (hg/ha)") +
    theme_minimal()
}

plot_yield_and_stats("Potatoes", "India")
plot_yield_and_stats("Potatoes", "United Kingdom")
plot_yield_and_stats("Wheat", "India")
plot_yield_and_stats("Wheat", "United Kingdom")
plot_yield_and_stats("Wheat", "Botswana")

# Additional Statistics: Fitting various distribution to the
dataset for yield
#install.packages("fitdistrplus", "MASS", "survival")
library(fitdistrplus)
library(MASS)
library(survival)

yield_fit <- function(crop_name, area_name) {
  crop_data = subset(data, Item == crop_name & Area == area_name &
Year >= 1990 & Year <= 2013)
  datatoplot = crop_data$`hg/ha_yield`
  # Fit Poisson distribution (or other discrete distribution) and
compare
  fit1 = fitdist(datatoplot, "norm")
  fit2 = fitdist(datatoplot, "weibull")
  fit3 = fitdist(datatoplot, "lnorm")
  par(mfrow = c(2,2))
  plot.legend = c("normal","weibull", "lognormal")
  par(mar = c(2,2,2,2))
  denscomp(list(fit1,fit2,fit3), legendtext = plot.legend)
  qqcomp(list(fit1,fit2,fit3), legendtext = plot.legend)
  ppcomp(list(fit1,fit2,fit3), legendtext = plot.legend)
  cdfcomp(list(fit1,fit2,fit3), legendtext = plot.legend)
  # Summary of the best fit
  best_fit1 = gofstat(fit1)
```

```
  best_fit2 = gofstat(fit2)
  best_fit3 = gofstat(fit3)
  # View the summary
  print("For Normal Distribution:")
  print(best_fit1)
  print("For Weibull Distribution:")
  print(best_fit2)
  print("For Lognormal Distribution:")
  print(best_fit3)
}

yield_fit("Potatoes","India")
yield_fit("Sweet potatoes",  "India")
yield_fit("Wheat",  "India")
```