Son-of-Jack.R

# Load required libraries  
library(tidyverse)

## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──  
## ✔ dplyr 1.1.4 ✔ readr 2.1.5  
## ✔ forcats 1.0.0 ✔ stringr 1.5.1  
## ✔ ggplot2 3.5.1 ✔ tibble 3.2.1  
## ✔ lubridate 1.9.3 ✔ tidyr 1.3.1  
## ✔ purrr 1.0.2   
## ── Conflicts ────────────────────────────────────────── tidyverse\_conflicts() ──  
## ✖ dplyr::filter() masks stats::filter()  
## ✖ dplyr::lag() masks stats::lag()  
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

library(forecast)

## Registered S3 method overwritten by 'quantmod':  
## method from  
## as.zoo.data.frame zoo

library(tseries)  
library(ggplot2)  
library(dplyr)  
  
setwd("C://Users//kelvi//Desktop")  
# Load maize yield data  
maize\_data1 <- read.csv("maize\_updated10k.csv")  
maize\_data <-head(maize\_data1,58)  
maize\_data

## Crop Season State Area Production Annual\_Rainfall Fertilizer  
## 1 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 2 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 3 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 4 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 5 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 6 Maize Whole Year Barisal 35469 130390 1852.9 3375584.7  
## 7 Maize Monsoon Dhaka 19810 13965 2354.4 1957228.0  
## 8 Maize Monsoon Chittagong 450472 1542607 1260.8 44506633.6  
## 9 Maize Winter Chittagong 49922 101605 1260.8 4932293.6  
## 10 Maize Summer Chittagong 11974 27080 1260.8 1183031.2  
## 11 Maize Monsoon Rajshahi 17219 25272 6552.7 1701237.2  
## 12 Maize Monsoon Barisal 38519 121161 2152.5 3805677.2  
## 13 Maize Monsoon Dhaka 19708 14056 2201.8 2091610.0  
## 14 Maize Monsoon Rajshahi 16637 24051 6200.3 1765684.8  
## 15 Maize Monsoon Barisal 35129 69682 2318.1 3728240.8  
## 16 Maize Monsoon Jessore 430544 1107165 935.6 42266504.5  
## 17 Maize Winter Jessore 97123 473602 935.6 9534564.9  
## 18 Maize Monsoon Dhaka 20241 14616 1965.5 1987059.0  
## 19 Maize Monsoon Chittagong 599893 1961879 1213.3 58891495.8  
## 20 Maize Winter Chittagong 57797 142674 1213.3 5673931.5  
## 21 Maize Summer Chittagong 11165 31091 1213.3 1096068.1  
## 22 Maize Monsoon Rajshahi 16906 24250 6258.8 1659662.0  
## 23 Maize Monsoon Barisal 35267 88264 1907.7 3462161.4  
## 24 Maize Monsoon Jessore 337533 986011 928.4 34472245.3  
## 25 Maize Winter Jessore 90752 470744 928.4 9268501.8  
## 26 Maize Monsoon Dhaka 19600 13940 1824.7 2001748.0  
## 27 Maize Monsoon Chittagong 505574 1274858 1002.9 51634272.6  
## 28 Maize Winter Chittagong 65189 152769 1002.9 6657752.6  
## 29 Maize Summer Chittagong 9272 23960 1002.9 946949.4  
## 30 Maize Monsoon Rajshahi 16866 25247 4241.0 1722524.6  
## 31 Maize Monsoon Barisal 33288 86409 1556.6 3399703.4  
## 32 Maize Monsoon Jessore 413659 912047 648.1 39161097.5  
## 33 Maize Winter Jessore 111990 573695 648.1 10602093.3  
## 34 Maize Monsoon Dhaka 19812 14194 1973.6 1875602.0  
## 35 Maize Monsoon Narayanganj 121057 191646 315.9 11460466.2  
## 36 Maize Monsoon Barisal 27724 55300 1629.1 2624631.1  
## 37 Maize Monsoon Jessore 557812 1671502 826.0 55212231.8  
## 38 Maize Winter Jessore 162802 805284 826.0 16114142.0  
## 39 Maize Monsoon Dhaka 19569 14051 2213.7 1936939.6  
## 40 Maize Monsoon Chittagong 545546 1066107 867.6 53998143.1  
## 41 Maize Winter Chittagong 64199 123529 867.6 6354417.0  
## 42 Maize Summer Chittagong 8428 20264 867.6 834203.4  
## 43 Maize Monsoon Rajshahi 16900 25929 3321.3 1672762.0  
## 44 Maize Monsoon Narayanganj 160159 250992 345.6 15852537.8  
## 45 Maize Monsoon Barisal 55530 126059 1526.7 5496359.4  
## 46 Maize Monsoon Chittagong 783835 2310082 1117.7 84920683.9  
## 47 Maize Winter Chittagong 57478 171589 1117.7 6227166.5  
## 48 Maize Summer Chittagong 9056 27678 1117.7 981127.0  
## 49 Maize Monsoon Rajshahi 16875 24000 4767.9 1828237.5  
## 50 Maize Monsoon Narayanganj 189893 294717 1034.0 20573007.6  
## 51 Maize Monsoon Jessore 593135 2098190 1075.5 71128749.2  
## 52 Maize Winter Jessore 164827 988711 1075.5 19766053.8  
## 53 Maize Monsoon Dhaka 18969 13745 2184.6 2274762.5  
## 54 Maize Monsoon Chittagong 842243 2486900 1316.2 101001780.6  
## 55 Maize Winter Chittagong 81621 282618 1316.2 9787990.3  
## 56 Maize Summer Chittagong 11990 37005 1316.2 1437840.8  
## 57 Maize Monsoon Rajshahi 16898 24424 3374.4 2026408.2  
## 58 Maize Monsoon Narayanganj 202830 0 1364.1 24323373.6  
## Pesticide Yield  
## 1 5956.96 0.6156522  
## 2 155867.07 2.6877778  
## 3 15141.64 1.9800000  
## 4 3016.30 2.1657143  
## 5 5324.25 1.4442857  
## 6 10995.39 2.6584615  
## 7 5744.90 0.6086957  
## 8 130636.88 3.3660000  
## 9 14477.38 1.9795238  
## 10 3472.46 2.2419048  
## 11 4993.51 1.4571429  
## 12 11170.51 2.6340000  
## 13 5321.16 0.6139130  
## 14 4491.99 1.4485714  
## 15 9484.83 1.9415385  
## 16 111941.44 2.5645455  
## 17 25251.98 5.0195455  
## 18 5262.66 0.6056522  
## 19 155972.18 3.1712000  
## 20 15027.22 2.3973684  
## 21 2902.90 2.7747619  
## 22 4395.56 1.4371429  
## 23 9169.42 2.5685714  
## 24 87758.58 2.8018182  
## 25 23595.52 5.5928571  
## 26 5096.00 0.6086957  
## 27 131449.24 2.6633333  
## 28 16949.14 2.2790000  
## 29 2410.72 2.6265000  
## 30 4385.16 1.4714286  
## 31 8654.88 2.3142857  
## 32 103414.75 1.4913636  
## 33 27997.50 5.6022727  
## 34 4953.00 0.6060870  
## 35 30264.25 1.8069565  
## 36 6931.00 1.8953846  
## 37 133874.88 2.4209091  
## 38 39072.48 5.0818182  
## 39 4696.56 0.6073913  
## 40 130931.04 2.3356000  
## 41 15407.76 1.9434783  
## 42 2022.72 2.4709091  
## 43 4056.00 1.5285714  
## 44 38438.16 1.7856000  
## 45 13327.20 2.1333333  
## 46 164605.35 3.0068000  
## 47 12070.38 2.8482609  
## 48 1901.76 3.0078261  
## 49 3543.75 1.4657143  
## 50 39877.53 1.7588462  
## 51 124558.35 3.8036364  
## 52 34613.67 6.0322727  
## 53 3983.49 0.6359259  
## 54 176871.03 3.1212000  
## 55 17140.41 3.3413043  
## 56 2517.90 3.0966667  
## 57 3548.58 1.4814286  
## 58 42594.30 0.0000000

# Add 'Year' column to the maize data  
maize\_data$Year <- seq(2019, 2023, by = 1)[1:nrow(maize\_data)]  
  
# Load weather data  
weather <- read.csv("bangladesh\_weather\_dataset.csv")  
  
# Filter weather data to 2019-2023  
weather\_data <- weather %>%  
 filter(Year >= 2019 & Year <= 2023)  
  
# Merge the maize and weather data based on the 'Year' column  
combined\_data1 <- merge(maize\_data, weather\_data, by = "Year", all.x = TRUE)  
  
# Display the combined data  
combined\_data<-head(combined\_data1,58)  
combined\_data

## Year Crop Season State Area Production Annual\_Rainfall Fertilizer  
## 1 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 2 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 3 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 4 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 5 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 6 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 7 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 8 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 9 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 10 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 11 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 12 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 13 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 14 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 15 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 16 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 17 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 18 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 19 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 20 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 21 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 22 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 23 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 24 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 25 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 26 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 27 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 28 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 29 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 30 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 31 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 32 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 33 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 34 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 35 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 36 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 37 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 38 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 39 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 40 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 41 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 42 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 43 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 44 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 45 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 46 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 47 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 48 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 49 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 50 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 51 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 52 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 53 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 54 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 55 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 56 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 57 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 58 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## Pesticide Yield tem Month rain  
## 1 5956.96 0.6156522 17.83806 1 6.183647  
## 2 5956.96 0.6156522 20.59750 2 19.344405  
## 3 5956.96 0.6156522 24.24290 3 48.393848  
## 4 5956.96 0.6156522 27.63233 4 176.648228  
## 5 5956.96 0.6156522 28.55032 5 203.718416  
## 6 5956.96 0.6156522 28.82267 6 295.239817  
## 7 5956.96 0.6156522 28.51968 7 576.679324  
## 8 5956.96 0.6156522 28.99581 8 458.843633  
## 9 5956.96 0.6156522 28.02333 9 313.252394  
## 10 5956.96 0.6156522 26.07742 10 212.489937  
## 11 5956.96 0.6156522 22.79900 11 87.720679  
## 12 5956.96 0.6156522 17.79290 12 7.071553  
## 13 155867.07 2.6877778 16.56097 1 23.144846  
## 14 155867.07 2.6877778 18.84966 2 12.156942  
## 15 155867.07 2.6877778 24.55710 3 29.130981  
## 16 155867.07 2.6877778 27.41267 4 95.935772  
## 17 155867.07 2.6877778 27.98742 5 251.969403  
## 18 155867.07 2.6877778 28.03467 6 423.505012  
## 19 155867.07 2.6877778 28.39000 7 454.518013  
## 20 155867.07 2.6877778 28.50871 8 400.628665  
## 21 155867.07 2.6877778 28.28267 9 368.930497  
## 22 155867.07 2.6877778 27.60581 10 306.973893  
## 23 155867.07 2.6877778 22.96567 11 119.180611  
## 24 155867.07 2.6877778 17.90968 12 8.097426  
## 25 15141.64 1.9800000 17.17032 1 4.931574  
## 26 15141.64 1.9800000 20.16000 2 6.809095  
## 27 15141.64 1.9800000 25.93742 3 20.896596  
## 28 15141.64 1.9800000 28.20333 4 39.386048  
## 29 15141.64 1.9800000 28.14226 5 186.031686  
## 30 15141.64 1.9800000 28.03000 6 432.248367  
## 31 15141.64 1.9800000 28.60774 7 414.554922  
## 32 15141.64 1.9800000 28.20226 8 469.075914  
## 33 15141.64 1.9800000 28.23667 9 336.511954  
## 34 15141.64 1.9800000 26.67871 10 252.313705  
## 35 15141.64 1.9800000 21.25333 11 71.932057  
## 36 15141.64 1.9800000 18.85452 12 29.214461  
## 37 3016.30 2.1657143 17.26161 1 10.740734  
## 38 3016.30 2.1657143 18.04786 2 27.998292  
## 39 3016.30 2.1657143 25.85097 3 23.930848  
## 40 3016.30 2.1657143 28.13133 4 59.572921  
## 41 3016.30 2.1657143 28.11935 5 191.440239  
## 42 3016.30 2.1657143 27.54600 6 397.114455  
## 43 3016.30 2.1657143 28.72032 7 270.494697  
## 44 3016.30 2.1657143 28.85903 8 296.771929  
## 45 3016.30 2.1657143 27.84533 9 318.433222  
## 46 3016.30 2.1657143 26.13452 10 265.741351  
## 47 3016.30 2.1657143 22.46567 11 120.230027  
## 48 3016.30 2.1657143 20.12516 12 5.163592  
## 49 5324.25 1.4442857 18.63355 1 5.678513  
## 50 5324.25 1.4442857 22.14071 2 6.811323  
## 51 5324.25 1.4442857 24.52000 3 58.797578  
## 52 5324.25 1.4442857 28.31500 4 76.420277  
## 53 5324.25 1.4442857 28.72950 5 124.202106  
## 54 5324.25 1.4442857 28.58639 6 299.915166  
## 55 5324.25 1.4442857 28.53309 7 353.399033  
## 56 5324.25 1.4442857 28.45193 8 421.058714  
## 57 5324.25 1.4442857 27.73721 9 306.090925  
## 58 5324.25 1.4442857 26.01552 10 320.779073

# Check structure and duplicates  
str(maize\_data)

## 'data.frame': 58 obs. of 10 variables:  
## $ Crop : chr "Maize" "Maize" "Maize" "Maize" ...  
## $ Season : chr "Monsoon" "Monsoon" "Winter" "Summer" ...  
## $ State : chr "Dhaka" "Chittagong" "Chittagong" "Chittagong" ...  
## $ Area : num 19216 502797 48844 9730 17175 ...  
## $ Production : int 14721 1391132 98932 20893 24878 130390 13965 1542607 101605 27080 ...  
## $ Annual\_Rainfall: num 2051 1267 1267 1267 3818 ...  
## $ Fertilizer : num 1828787 47851190 4648483 926004 1634545 ...  
## $ Pesticide : num 5957 155867 15142 3016 5324 ...  
## $ Yield : num 0.616 2.688 1.98 2.166 1.444 ...  
## $ Year : num 2019 2020 2021 2022 2023 ...

str(weather\_data)

## 'data.frame': 58 obs. of 4 variables:  
## $ tem : num 17.8 20.6 24.2 27.6 28.6 ...  
## $ Month: int 1 2 3 4 5 6 7 8 9 10 ...  
## $ Year : int 2019 2019 2019 2019 2019 2019 2019 2019 2019 2019 ...  
## $ rain : num 6.18 19.34 48.39 176.65 203.72 ...

sum(duplicated(maize\_data$Year))

## [1] 52

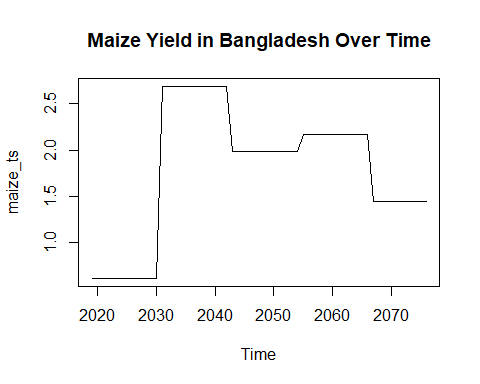
sum(duplicated(weather\_data$Year))

## [1] 53

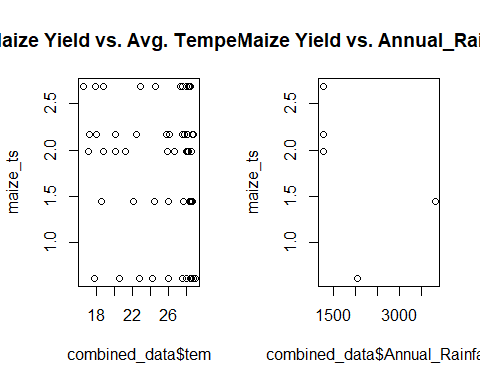
# Aggregate weather data to yearly averages  
weather\_yearly <- weather\_data %>%  
 group\_by(Year) %>%  
 summarise(  
 avg\_temp = mean(tem, na.rm = TRUE),  
 total\_rain = sum(rain, na.rm = TRUE)  
 )  
  
# Remove duplicates from maize data if any  
maize\_data <- maize\_data[!duplicated(maize\_data$Year), ]  
  
# Merge datasets based on year  
combined\_data <- merge(maize\_data, weather\_data, by = "Year")  
combined\_data

## Year Crop Season State Area Production Annual\_Rainfall Fertilizer  
## 1 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 2 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 3 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 4 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 5 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 6 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 7 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 8 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 9 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 10 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 11 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 12 2019 Maize Monsoon Dhaka 19216 14721 2051.4 1828786.7  
## 13 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 14 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 15 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 16 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 17 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 18 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 19 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 20 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 21 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 22 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 23 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 24 2020 Maize Monsoon Chittagong 502797 1391132 1266.7 47851190.5  
## 25 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 26 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 27 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 28 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 29 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 30 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 31 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 32 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 33 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 34 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 35 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 36 2021 Maize Winter Chittagong 48844 98932 1266.7 4648483.5  
## 37 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 38 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 39 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 40 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 41 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 42 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 43 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 44 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 45 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 46 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 47 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 48 2022 Maize Summer Chittagong 9730 20893 1266.7 926004.1  
## 49 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 50 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 51 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 52 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 53 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
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## 57 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## 58 2023 Maize Monsoon Rajshahi 17175 24878 3818.2 1634544.8  
## Pesticide Yield tem Month rain  
## 1 5956.96 0.6156522 17.83806 1 6.183647  
## 2 5956.96 0.6156522 20.59750 2 19.344405  
## 3 5956.96 0.6156522 24.24290 3 48.393848  
## 4 5956.96 0.6156522 27.63233 4 176.648228  
## 5 5956.96 0.6156522 28.55032 5 203.718416  
## 6 5956.96 0.6156522 28.82267 6 295.239817  
## 7 5956.96 0.6156522 28.51968 7 576.679324  
## 8 5956.96 0.6156522 28.99581 8 458.843633  
## 9 5956.96 0.6156522 28.02333 9 313.252394  
## 10 5956.96 0.6156522 26.07742 10 212.489937  
## 11 5956.96 0.6156522 22.79900 11 87.720679  
## 12 5956.96 0.6156522 17.79290 12 7.071553  
## 13 155867.07 2.6877778 16.56097 1 23.144846  
## 14 155867.07 2.6877778 18.84966 2 12.156942  
## 15 155867.07 2.6877778 24.55710 3 29.130981  
## 16 155867.07 2.6877778 27.41267 4 95.935772  
## 17 155867.07 2.6877778 27.98742 5 251.969403  
## 18 155867.07 2.6877778 28.03467 6 423.505012  
## 19 155867.07 2.6877778 28.39000 7 454.518013  
## 20 155867.07 2.6877778 28.50871 8 400.628665  
## 21 155867.07 2.6877778 28.28267 9 368.930497  
## 22 155867.07 2.6877778 27.60581 10 306.973893  
## 23 155867.07 2.6877778 22.96567 11 119.180611  
## 24 155867.07 2.6877778 17.90968 12 8.097426  
## 25 15141.64 1.9800000 17.17032 1 4.931574  
## 26 15141.64 1.9800000 20.16000 2 6.809095  
## 27 15141.64 1.9800000 25.93742 3 20.896596  
## 28 15141.64 1.9800000 28.20333 4 39.386048  
## 29 15141.64 1.9800000 28.14226 5 186.031686  
## 30 15141.64 1.9800000 28.03000 6 432.248367  
## 31 15141.64 1.9800000 28.60774 7 414.554922  
## 32 15141.64 1.9800000 28.20226 8 469.075914  
## 33 15141.64 1.9800000 28.23667 9 336.511954  
## 34 15141.64 1.9800000 26.67871 10 252.313705  
## 35 15141.64 1.9800000 21.25333 11 71.932057  
## 36 15141.64 1.9800000 18.85452 12 29.214461  
## 37 3016.30 2.1657143 17.26161 1 10.740734  
## 38 3016.30 2.1657143 18.04786 2 27.998292  
## 39 3016.30 2.1657143 25.85097 3 23.930848  
## 40 3016.30 2.1657143 28.13133 4 59.572921  
## 41 3016.30 2.1657143 28.11935 5 191.440239  
## 42 3016.30 2.1657143 27.54600 6 397.114455  
## 43 3016.30 2.1657143 28.72032 7 270.494697  
## 44 3016.30 2.1657143 28.85903 8 296.771929  
## 45 3016.30 2.1657143 27.84533 9 318.433222  
## 46 3016.30 2.1657143 26.13452 10 265.741351  
## 47 3016.30 2.1657143 22.46567 11 120.230027  
## 48 3016.30 2.1657143 20.12516 12 5.163592  
## 49 5324.25 1.4442857 18.63355 1 5.678513  
## 50 5324.25 1.4442857 22.14071 2 6.811323  
## 51 5324.25 1.4442857 24.52000 3 58.797578  
## 52 5324.25 1.4442857 28.31500 4 76.420277  
## 53 5324.25 1.4442857 28.72950 5 124.202106  
## 54 5324.25 1.4442857 28.58639 6 299.915166  
## 55 5324.25 1.4442857 28.53309 7 353.399033  
## 56 5324.25 1.4442857 28.45193 8 421.058714  
## 57 5324.25 1.4442857 27.73721 9 306.090925  
## 58 5324.25 1.4442857 26.01552 10 320.779073

# Create time series object for maize yield  
maize\_ts <- ts(combined\_data$Yield, start = min(combined\_data$Year), frequency = 1)  
  
# 2. Exploratory Data Analysis  
  
# Plot the time series  
plot(maize\_ts, main = "Maize Yield in Bangladesh Over Time")



# Scatterplots of maize yield vs. weather variables  
par(mfrow=c(1,2))  
plot(combined\_data$tem, maize\_ts, main="Maize Yield vs. Avg. Temperature")  
plot(combined\_data$Annual\_Rainfall, maize\_ts, main="Maize Yield vs. Annual\_Rainfall")



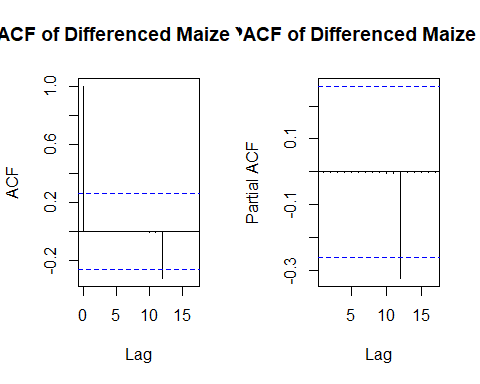
# 3. Check for stationarity  
  
# Perform ADF test  
adf\_test <- adf.test(maize\_ts)  
print(adf\_test)

##   
## Augmented Dickey-Fuller Test  
##   
## data: maize\_ts  
## Dickey-Fuller = -1.938, Lag order = 3, p-value = 0.5997  
## alternative hypothesis: stationary

# If non-stationary, difference the series  
if (adf\_test$p.value > 0.05) {  
 d\_maize\_ts <- diff(maize\_ts)  
 adf\_test\_diff <- adf.test(d\_maize\_ts)  
 print(adf\_test\_diff)  
} else {  
 d\_maize\_ts <- maize\_ts  
}

##   
## Augmented Dickey-Fuller Test  
##   
## data: d\_maize\_ts  
## Dickey-Fuller = -3.7576, Lag order = 3, p-value = 0.02786  
## alternative hypothesis: stationary

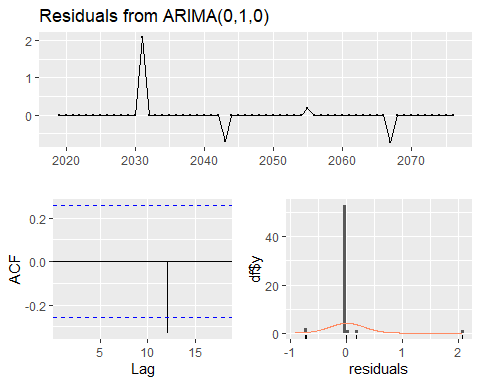
# 4. ACF and PACF plots  
  
acf(d\_maize\_ts, main = "ACF of Differenced Maize Yield")  
pacf(d\_maize\_ts, main = "PACF of Differenced Maize Yield")



# 5. Model Identification and Estimation  
  
# Automatic ARIMA model selection  
auto\_arima <- auto.arima(maize\_ts, seasonal = FALSE)  
summary(auto\_arima)

## Series: maize\_ts   
## ARIMA(0,1,0)   
##   
## sigma^2 = 0.09385: log likelihood = -13.45  
## AIC=28.9 AICc=28.97 BIC=30.94  
##   
## Training set error measures:  
## ME RMSE MAE MPE MAPE MASE  
## Training set 0.0142974 0.3037014 0.06358038 0.001253121 2.956319 0.9829227  
## ACF1  
## Training set -0.002257829

# 6. Diagnostic Checking  
  
# Residual analysis  
checkresiduals(auto\_arima)



##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(0,1,0)  
## Q\* = 0.0049539, df = 10, p-value = 1  
##   
## Model df: 0. Total lags used: 10

# Ljung-Box test  
Box.test(residuals(auto\_arima), type = "Ljung-Box")

##   
## Box-Ljung test  
##   
## data: residuals(auto\_arima)  
## X-squared = 0.00031123, df = 1, p-value = 0.9859

# 7. Forecasting  
  
# Generate forecasts  
forecasts <- forecast(auto\_arima, h = 5) # Forecast 5 years ahead  
plot(forecasts)  
  
# 8. Model Evaluation  
  
# Split data into training and testing sets  
train\_size <- floor(0.8 \* length(maize\_ts))  
train\_ts <- window(maize\_ts, end = c(min(combined\_data$Year) + train\_size - 1))  
test\_ts <- window(maize\_ts, start = c(min(combined\_data$Year) + train\_size))  
  
# Fit model on training data  
train\_model <- auto.arima(train\_ts, seasonal = FALSE)  
  
# Make predictions on test data  
predictions <- forecast(train\_model, h = length(test\_ts))  
  
# Calculate error metrics  
mae <- mean(abs(predictions$mean - test\_ts))  
rmse <- sqrt(mean((predictions$mean - test\_ts)^2))  
mape <- mean(abs((predictions$mean - test\_ts) / test\_ts)) \* 100  
  
cat("MAE:", mae, "\n")

## MAE: 0.6011905

cat("RMSE:", rmse, "\n")

## RMSE: 0.6585712

cat("MAPE:", mape, "%\n")

## MAPE: 41.62545 %

# 9. Visualize Results  
  
ggplot() +  
 geom\_line(aes(x = time(maize\_ts), y = maize\_ts), color = "blue") +  
 geom\_line(aes(x = time(forecasts$mean), y = forecasts$mean), color = "red") +  
 geom\_ribbon(aes(x = time(forecasts$mean),   
 ymin = forecasts$lower[,2],   
 ymax = forecasts$upper[,2]),   
 fill = "pink", alpha = 0.3) +  
 labs(title = "Maize Yield Forecast",   
 x = "Year",   
 y = "Yield") +  
 theme\_minimal()

## Don't know how to automatically pick scale for object of type <ts>. Defaulting  
## to continuous.  
## Don't know how to automatically pick scale for object of type <ts>. Defaulting  
## to continuous.

