QBS 181 Final Project Aim 2 (Say OK)

Say OK

2024-10-28

Load Libraries

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(ggplot2)
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v forcats   1.0.0     v stringr   1.5.1
## v lubridate 1.9.3     v tibble    3.2.1
## v purrr     1.0.2     v tidyr     1.3.1
## v readr     2.1.5

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(tidyr)
library(readxl)
library(ppcor)
```

```
## Loading required package: MASS
##
## Attaching package: 'MASS'
##
## The following object is masked from 'package:dplyr':
##
##     select
```

```r
library(lme4)
```

```
## Warning: package 'lme4' was built under R version 4.3.3

## Loading required package: Matrix
##
## Attaching package: 'Matrix'
##
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
```

```r
library(knitr)
```

```
## Warning: package 'knitr' was built under R version 4.3.3
```

I. Load and Merge Datasets

1. Load the cleaned agricultural dataset (from Excel worksheet)

Please refer to the excel file for details on data cleaning, calculations, and exploratory steps. We created a sheet named "R", which includes all columns needed for input into R.

```r
# Set working directory ("Session" --> "Set Working Directory")
# Input the sheet named "R" in the Excel file
ag_data <- read_excel("/Users/violet/Documents/QBS Fall 2024/QBS 181/Final Project/Data/Ag_Data_Clean.xl

head(ag_data)
```

```
## # A tibble: 6 x 15
##   State_Fips_Code State_Name Geographic_Region Geographic_Division Total_Acres
##             <dbl> <chr>      <chr>             <chr>                     <dbl>
## 1               1 ALABAMA    South             East South Central      8629101
## 2               2 ALASKA     West              Pacific                  869852
## 3               4 ARIZONA    West              Mountain               25525087
## 4               5 ARKANSAS   South             West South Central     13722525
## 5               6 CALIFORNIA West              Pacific                24190604
## 6               8 COLORADO   West              Mountain               30213899
## # i 10 more variables: Total_Chemical_Expenditure <dbl>,
## #   Chemical_Expenditure_per_Acres <dbl>,
## #   Insecticide_No_Nema_Treatment_Acres <dbl>,
## #   `Insecticide_No_Nema_Treatment_Percentage_(%)` <dbl>,
## #   Insecticide_Nema_Treatment_Acres <dbl>,
## #   `Insecticide_Nema_Treatment_Percentage_(%)` <dbl>,
## #   Herbicide_Treatment_Acres <dbl>, ...
```

```r
dim(ag_data)
```

```
## [1] 50 15
```

2. Load 2022 Parkinson mortality rate data (downloaded from CDC)

Longitudinal data on Parkinson's disease mortality rate over years can be downloaded directly from CDC. All rates are age-adjusted mortality rates and represent the number of deaths per 100,000 total population.

```
# Set working directory ("Session" --> "Set Working Directory")
# Input the sheet named "R" in the Excel file
mortality <- read.csv("/Users/violet/Documents/QBS Fall 2024/QBS 181/Final Project/Data/Parkinson_Morta
# Remove the last column (unnecessary URL)
mortality <- mortality[, -ncol(mortality)]

head(mortality)
```

```
##   YEAR STATE RATE DEATHS
## 1 2022    AL 10.7    696
## 2 2022    AK 10.9     62
## 3 2022    AZ  9.9  1,007
## 4 2022    AR  9.8    382
## 5 2022    CA  9.4  4,289
## 6 2022    CO 10.7    665
```

```
dim(mortality)
```

```
## [1] 501   4
```

Filter to keep 2022

```
# Filter to keep year == 2022
mortality <- mortality %>%
  filter(YEAR == 2022)

dim(mortality)
```

```
## [1] 51  4
```

3. Combine agricultural dataset with 2022 Parkinson mortality rate data

Create a conversion table as state is presented as full name in ag_data whereas it is presented as abbreviation in the mortality.

```
# Create the conversion table as a data frame
state_abbreviations <- data.frame(
  State = toupper(c("Alabama", "Alaska", "Arizona", "Arkansas", "California",
                    "Colorado", "Connecticut", "Delaware", "Florida", "Georgia",
                    "Hawaii", "Idaho", "Illinois", "Indiana", "Iowa", "Kansas",
                    "Kentucky", "Louisiana", "Maine", "Maryland",
                    "Massachusetts", "Michigan", "Minnesota", "Mississippi",
                    "Missouri", "Montana", "Nebraska", "Nevada",
                    "New Hampshire", "New Jersey", "New Mexico", "New York",
                    "North Carolina", "North Dakota", "Ohio", "Oklahoma",
                    "Oregon", "Pennsylvania", "Rhode Island", "South Carolina",
```

```
                     "South Dakota", "Tennessee", "Texas", "Utah", "Vermont",
                     "Virginia", "Washington", "West Virginia", "Wisconsin",
                     "Wyoming")),
  State_Abbrev = c("AL", "AK", "AZ", "AR", "CA", "CO", "CT", "DE", "FL", "GA",
                   "HI", "ID", "IL", "IN", "IA", "KS", "KY", "LA", "ME", "MD",
                   "MA", "MI", "MN", "MS", "MO", "MT", "NE", "NV", "NH", "NJ",
                   "NM", "NY", "NC", "ND", "OH", "OK", "OR", "PA", "RI", "SC",
                   "SD", "TN", "TX", "UT", "VT", "VA", "WA", "WV", "WI", "WY")
)
head(state_abbreviations)
```

```
##        State State_Abbrev
## 1    ALABAMA           AL
## 2     ALASKA           AK
## 3    ARIZONA           AZ
## 4   ARKANSAS           AR
## 5 CALIFORNIA           CA
## 6   COLORADO           CO
```

Merge the datasets

```
ag_data <- merge(ag_data, state_abbreviations, by.x = "State_Name", by.y = "State", all.x = TRUE)
df <- merge(ag_data, mortality, by.x = "State_Abbrev", by.y = "STATE", all.x = TRUE)

head(df)
```

```
##   State_Abbrev State_Name State_Fips_Code Geographic_Region Geographic_Division
## 1           AK     ALASKA               2              West             Pacific
## 2           AL    ALABAMA               1             South  East South Central
## 3           AR   ARKANSAS               5             South  West South Central
## 4           AZ    ARIZONA               4              West            Mountain
## 5           CA CALIFORNIA               6              West             Pacific
## 6           CO   COLORADO               8              West            Mountain
##   Total_Acres Total_Chemical_Expenditure Chemical_Expenditure_per_Acres
## 1      869852                     646000                      0.7426551
## 2     8629101                  188889000                     21.8897658
## 3    13722525                  761692000                     55.5066943
## 4    25525087                  198303000                      7.7689451
## 5    24190604                 2806374000                    116.0109107
## 6    30213899                  229485000                      7.5953454
##   Insecticide_No_Nema_Treatment_Acres
## 1                                 587
## 2                              852151
## 3                             2973520
## 4                              440869
## 5                             4811723
## 6                              864811
##   Insecticide_No_Nema_Treatment_Percentage_(%) Insecticide_Nema_Treatment_Acres
## 1                                   0.06748274                               84
## 2                                   9.87531610                           358745
## 3                                  21.66889840                           546309
## 4                                   1.72719881                           115041
## 5                                  19.89087581                          1316284
```

```
## 6                                   2.86229526                              111125
##   Insecticide_Nema_Treatment_Percentage_(%) Herbicide_Treatment_Acres
## 1                               0.009656815                     10424
## 2                               4.157385572                   1967762
## 3                               3.981111348                   6395120
## 4                               0.450697778                    622607
## 5                               5.441302747                   5554203
## 6                               0.367794306                   4647801
##   Herbicide_Treatment_Percentage_(%) Fungicide_Treatment_Acres
## 1                           1.198365                       168
## 2                          22.803789                    289571
## 3                          46.603085                   1671797
## 4                           2.439196                     96524
## 5                          22.960167                   2565494
## 6                          15.382990                    180797
##   Fungicide_Treatment_Percentage_(%) YEAR RATE DEATHS
## 1                         0.01931363 2022 10.9     62
## 2                         3.35574934 2022 10.7    696
## 3                        12.18286722 2022  9.8    382
## 4                         0.37815346 2022  9.9  1,007
## 5                        10.60533255 2022  9.4  4,289
## 6                         0.59839016 2022 10.7    665
```

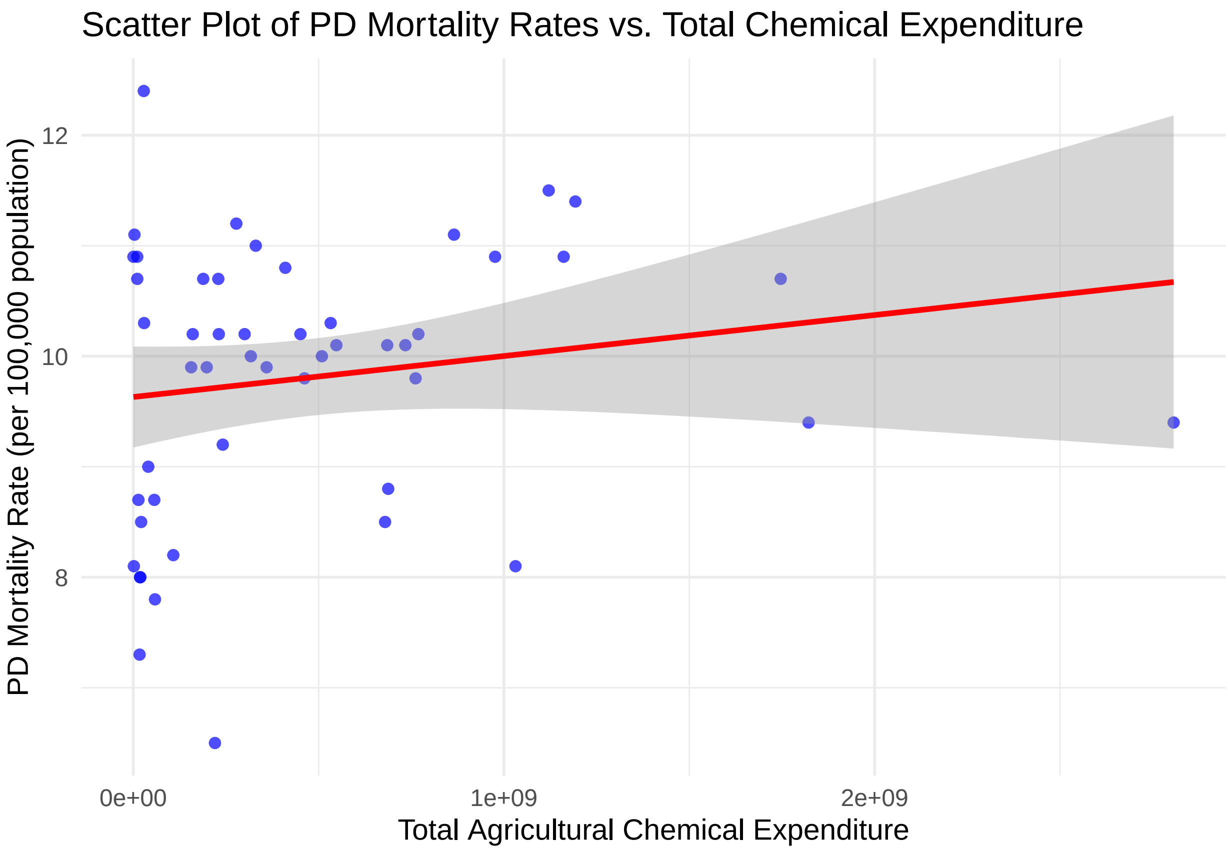
II. Aim 2a: Investigate the relationship between PD mortality rates and total agricultural chemical expenditure per state.

1. PD mortality rates vs. Total agricultural chemical expenditure per state

a. scatter plot visualization

```
ggplot(df, aes(x = Total_Chemical_Expenditure, y = RATE)) +
  geom_point(color = "blue", alpha = 0.7) +
  geom_smooth(method = "lm", color = "red", se = TRUE) +
  labs(title = "Scatter Plot of PD Mortality Rates vs. Total Chemical Expenditure",
       x = "Total Agricultural Chemical Expenditure",
       y = "PD Mortality Rate (per 100,000 population)") +
  theme_minimal()
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



b. Spearman's rank correlation for statistical testing

```
spearman_correlation <- cor(df$Total_Chemical_Expenditure, df$RATE, method = "spearman", use = "complete
spearman_correlation
```

```
## [1] 0.2019572
```

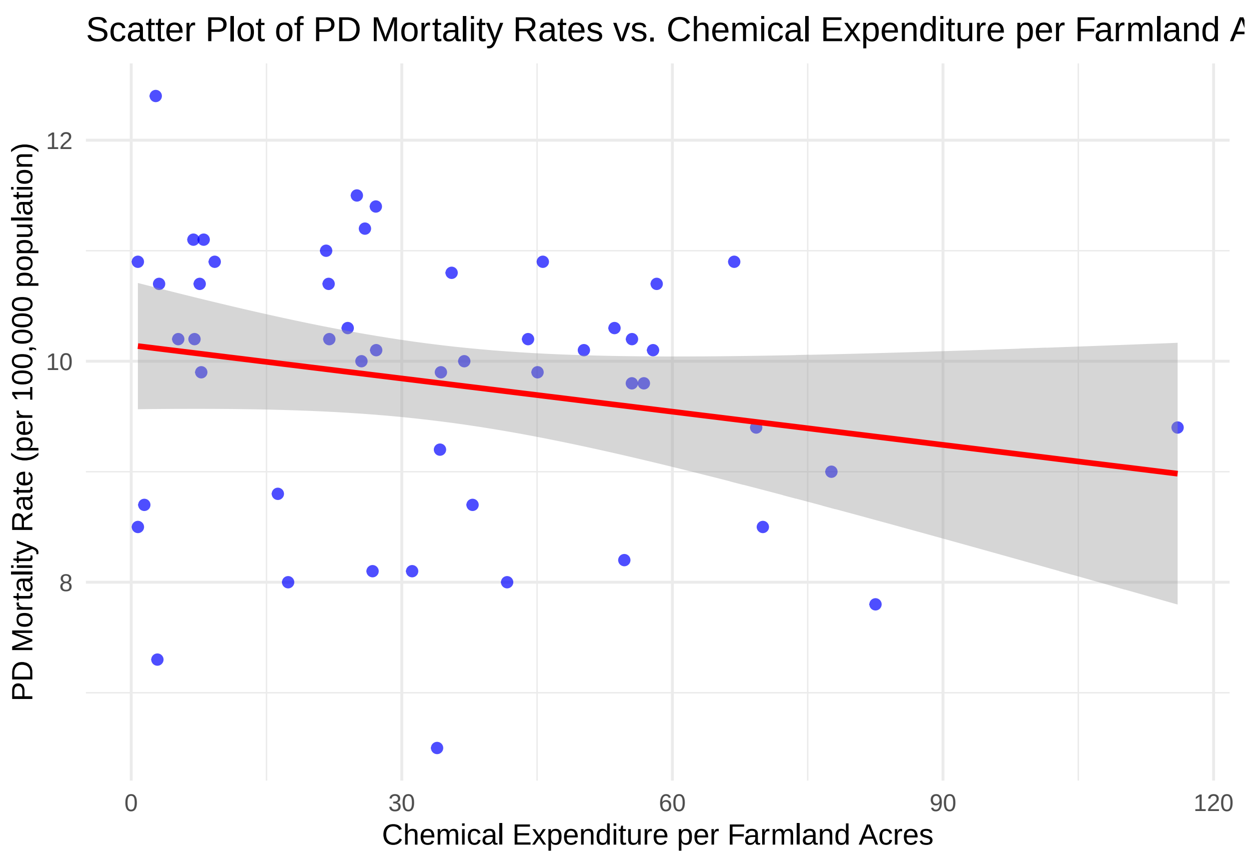
Result: There is a weak positive monotonic relationship between Total Chemical Expenditure and Mortality RATE.

2.PD mortality rates vs. Chemical Expenditure per Farmland Acres per State

a. scatter plot visualization

```
ggplot(df, aes(x = Chemical_Expenditure_per_Acres, y = RATE)) +
  geom_point(color = "blue", alpha = 0.7) +
  geom_smooth(method = "lm", color = "red", se = TRUE) +
  labs(title = "Scatter Plot of PD Mortality Rates vs. Chemical Expenditure per Farmland Acres",
       x = "Chemical Expenditure per Farmland Acres",
       y = "PD Mortality Rate (per 100,000 population)") +
  theme_minimal()
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



b. Spearman's rank correlation for statistical testing

```
spearman_correlation <- cor(df$Chemical_Expenditure_per_Acres, df$RATE,
                            method = "spearman", use = "complete.obs")
spearman_correlation
```

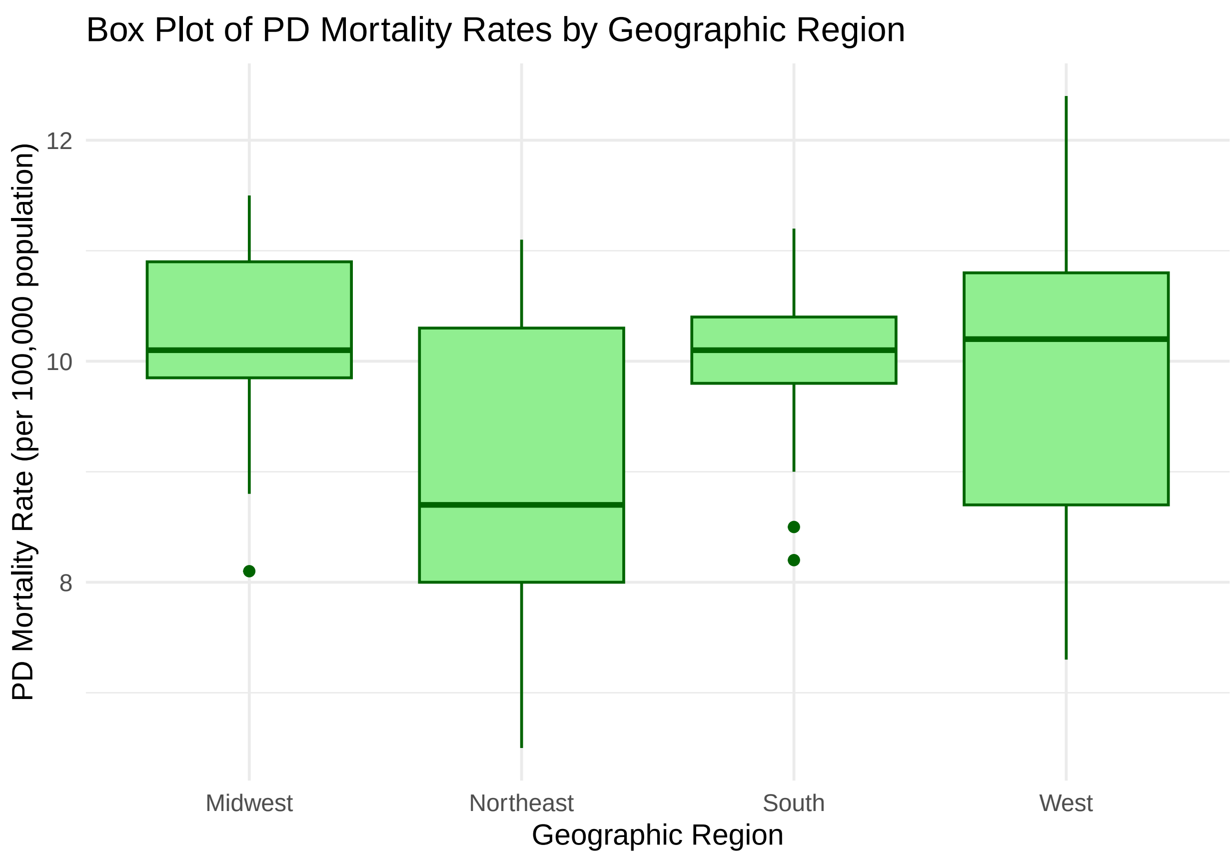
```
## [1] -0.2528793
```

Result: There is a weak inverse relationship, meaning that as agricultural chemical expenditure rises, Parkinson's mortality rate slightly decreases.

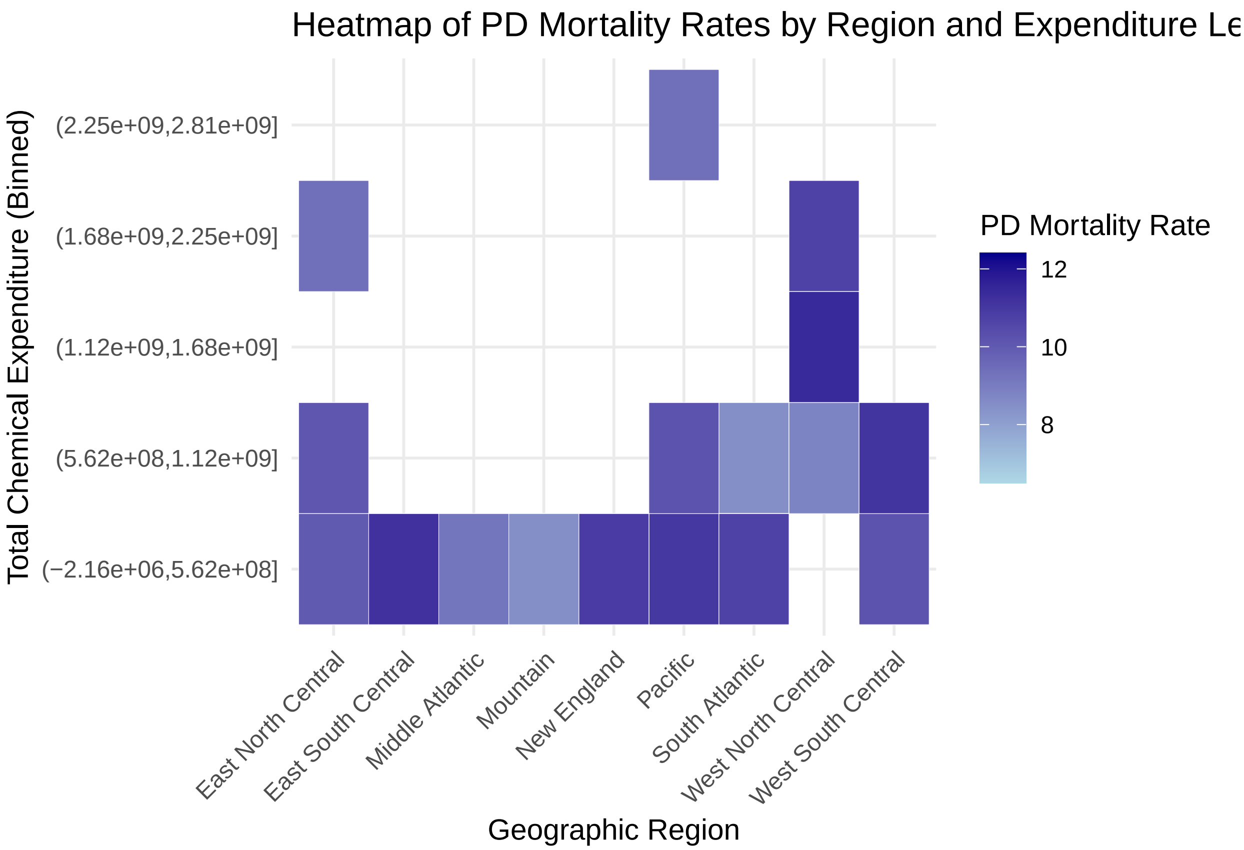
3. PD mortality rates vs. Total Chemical Expenditure Considering Geographic Regions

a. boxplot and heatmap

```
# Box Plot: PD mortality rates by Geographic Region
ggplot(df, aes(x = Geographic_Region, y = RATE)) +
  geom_boxplot(fill = "lightgreen", color = "darkgreen") +
  labs(title = "Box Plot of PD Mortality Rates by Geographic Region",
       x = "Geographic Region",
       y = "PD Mortality Rate (per 100,000 population)") +
  theme_minimal()
```




```
# Heatmap: PD mortality rate by Geographic Divisions and Total Chemical Expenditures
## Divide the Chemical_Expenditure_per_Acres into quintile
df <- df %>%
  mutate(Expenditure_Bin = cut(Total_Chemical_Expenditure, breaks = 5))
## Plot
ggplot(df, aes(x = Geographic_Division, y = Expenditure_Bin, fill = RATE)) +
  geom_tile(color = "white") +
  scale_fill_gradient(low = "lightblue", high = "darkblue") +
  labs(title = "Heatmap of PD Mortality Rates by Region and Expenditure Levels",
       x = "Geographic Region",
       y = "Total Chemical Expenditure (Binned)",
       fill = "PD Mortality Rate") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))
```



b. Fit the mixed-effects model Since the Geographic Region is a higher-level above State, we can use a mixed-effects model to show a more accurate relationship

```
# Fit the mixed-effects model
# Assuming RATE is the dependent variable
# and Total_Chemical_Expenditure is the main predictor
model <- lmer(RATE ~ Total_Chemical_Expenditure + (1 | Geographic_Region)
              , data = df)
```

```
## Warning: Some predictor variables are on very different scales: consider
## rescaling
```

```
# Summary of the model
summary(model)
```

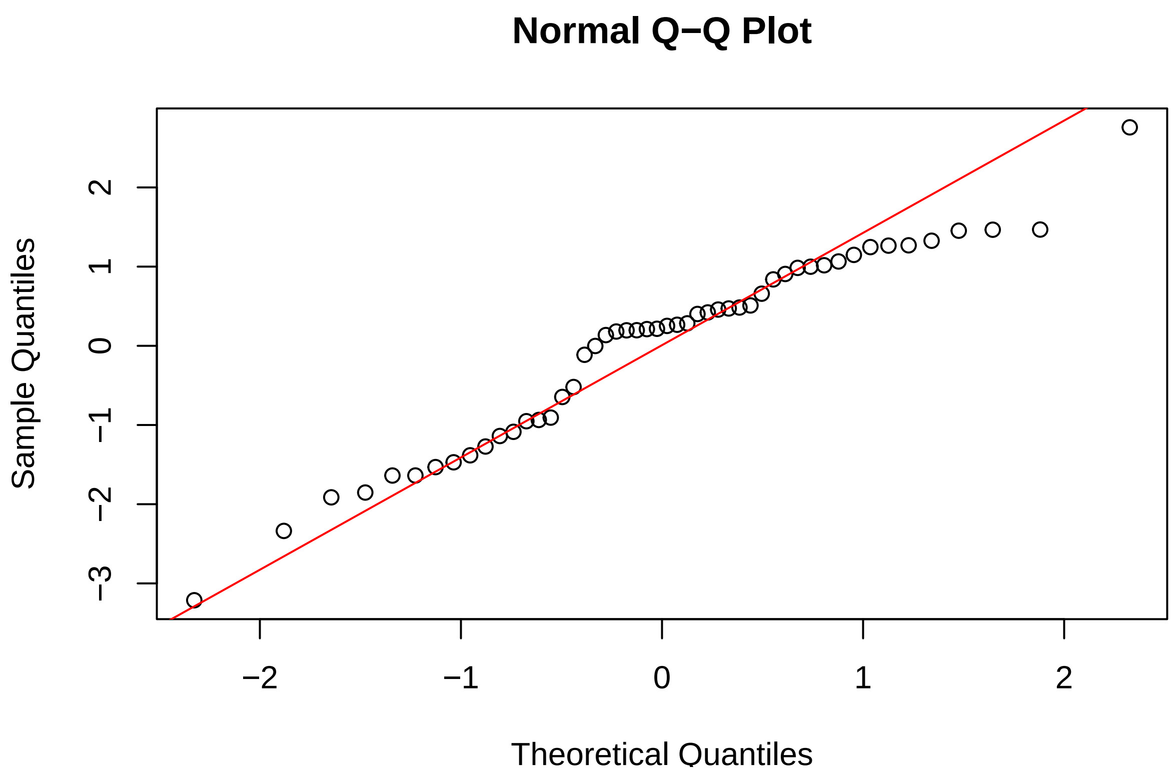
```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RATE ~ Total_Chemical_Expenditure + (1 | Geographic_Region)
##    Data: df
##
## REML criterion at convergence: 203.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5440 -0.7841  0.1603  0.7648  2.2556
##
```

```
## Random effects:
##  Groups            Name        Variance Std.Dev.
##  Geographic_Region (Intercept) 0.03491  0.1868
##  Residual                      1.47136  1.2130
## Number of obs: 50, groups:  Geographic_Region, 4
##
## Fixed effects:
##                              Estimate Std. Error t value
## (Intercept)                 9.636e+00  2.479e-01  38.875
## Total_Chemical_Expenditure 3.323e-10  3.222e-10   1.031
##
## Correlation of Fixed Effects:
##             (Intr)
## Ttl_Chmcl_E -0.612
## fit warnings:
## Some predictor variables are on very different scales: consider rescaling
```

```
# Check normality of residuals of the dependent variable
## Fit a simple linear regression model
model <- lm(RATE ~ Total_Chemical_Expenditure, data = df)
summary(model)
```

```
##
## Call:
## lm(formula = RATE ~ Total_Chemical_Expenditure, data = df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.2127 -0.9480  0.2332  0.9647  2.7585
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 9.631e+00  2.273e-01  42.379   <2e-16 ***
## Total_Chemical_Expenditure 3.709e-10  3.125e-10   1.187    0.241
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.222 on 48 degrees of freedom
## Multiple R-squared:  0.02851,    Adjusted R-squared:  0.008274
## F-statistic: 1.409 on 1 and 48 DF,  p-value: 0.2411
```

```
## Extract residuals
residuals <- resid(model)
qqnorm(residuals)
qqline(residuals, col = "red")
```



Interpretation: The coefficient indicates that for each dollar increase in Total Chemical Expenditure, the RATE (PD mortality rate) is expected to increase by 3.709e-10 per 100,000 person. In other word, for each billion-dollar increase in Total Chemical Expenditure, the RATE (PD mortality rate) is expected to increase by 0.3709 deaths per 100,000 people. The p-value for Total_Chemical_Expenditure is 0.241, which is above the significance level (0.05). This means the effect of Total Chemical Expenditure on PD mortality rate is not statistically significant in this model.

III. Aim 2b: Evaluate the association between the amount of acreage treated with three types of pesticides and PD mortality rates.

Look at totals and averages

```
# create a summary table of the total acreage of treated farmland
# for different types of pesticides and the mortality rate
summary_table <- df %>%
  summarise(
    Insecticide_No_Nema_Sum_Acres =
      sum(Insecticide_No_Nema_Treatment_Acres, na.rm = TRUE),
    Insecticide_No_Nema_Avg_Percentage =
      mean(`Insecticide_No_Nema_Treatment_Percentage_(%)`, na.rm = TRUE),
    Insecticide_No_Nema_SD_Percentage =
      sd(`Insecticide_No_Nema_Treatment_Percentage_(%)`, na.rm = TRUE),

    Insecticide_Nema_Sum_Acres =
      sum(Insecticide_Nema_Treatment_Acres, na.rm = TRUE),
    Insecticide_Nema_Avg_Percentage =
```

```r
      mean(`Insecticide_Nema_Treatment_Percentage_(%)`, na.rm = TRUE),
    Insecticide_Nema_SD_Percentage =
      sd(`Insecticide_Nema_Treatment_Percentage_(%)`, na.rm = TRUE),

    Herbicide_Sum_Acres =
      sum(Herbicide_Treatment_Acres, na.rm = TRUE),
    Herbicide_Avg_Percentage =
      mean(`Herbicide_Treatment_Percentage_(%)`, na.rm = TRUE),
    Herbicide_SD_Percentage =
      sd(`Herbicide_Treatment_Percentage_(%)`, na.rm = TRUE),

    Fungicide_Sum_Acres =
      sum(Fungicide_Treatment_Acres, na.rm = TRUE),
    Fungicide_Avg_Percentage =
      mean(`Fungicide_Treatment_Percentage_(%)`, na.rm = TRUE),
    Fungicide_SD_Percentage =
      sd(`Fungicide_Treatment_Percentage_(%)`, na.rm = TRUE),

    Mortality_Sum_Rate = sum(RATE, na.rm = TRUE),
    Mortality_Avg_Rate = mean(RATE, na.rm = TRUE),
    Mortality_SD_Rate = sd(RATE, na.rm = TRUE)
  )

print(summary_table)
```

```
##   Insecticide_No_Nema_Sum_Acres Insecticide_No_Nema_Avg_Percentage
## 1                      82860848                           11.33876
##   Insecticide_No_Nema_SD_Percentage Insecticide_Nema_Sum_Acres
## 1                          9.365526                   21210813
##   Insecticide_Nema_Avg_Percentage Insecticide_Nema_SD_Percentage
## 1                        2.873056                       2.998834
##   Herbicide_Sum_Acres Herbicide_Avg_Percentage Herbicide_SD_Percentage
## 1           264177083                 30.04337                 22.3878
##   Fungicide_Sum_Acres Fungicide_Avg_Percentage Fungicide_SD_Percentage
## 1            40710631                 5.666355                4.813071
##   Mortality_Sum_Rate Mortality_Avg_Rate Mortality_SD_Rate
## 1              490.3              9.806          1.227476
```

```r
(correlations <- data.frame(
  Treatment_Type = c("Insecticide No Nema Acres",
                     "Insecticide No Nema Percentage",
                     "Insecticide Nema Acres",
                     "Insecticide Nema Percentage",
                     "Herbicide Acres",
                     "Herbicide Percentage",
                     "Fungicide Acres",
                     "Fungicide Percentage"),
  Spearman_Correlation_with_Mortality = c(
    cor(df$Insecticide_No_Nema_Treatment_Acres, df$RATE,
        method = "spearman", use = "complete.obs"),
    cor(df$`Insecticide_No_Nema_Treatment_Percentage_(%)`,
        df$RATE, method = "spearman", use = "complete.obs"),
```

```
    cor(df$Insecticide_Nema_Treatment_Acres, df$RATE,
        method = "spearman", use = "complete.obs"),
    cor(df$`Insecticide_Nema_Treatment_Percentage_(%)`,
        df$RATE, method = "spearman", use = "complete.obs"),

    cor(df$Herbicide_Treatment_Acres, df$RATE,
        method = "spearman", use = "complete.obs"),
    cor(df$`Herbicide_Treatment_Percentage_(%)`, df$RATE,
        method = "spearman", use = "complete.obs"),

    cor(df$Fungicide_Treatment_Acres, df$RATE,
        method = "spearman", use = "complete.obs"),
    cor(df$`Fungicide_Treatment_Percentage_(%)`,
        df$RATE, method = "spearman", use = "complete.obs")
  )
))
```

```
##                   Treatment_Type Spearman_Correlation_with_Mortality
## 1      Insecticide No Nema Acres                          0.22484574
## 2 Insecticide No Nema Percentage                         -0.13829263
## 3         Insecticide Nema Acres                          0.22114319
## 4    Insecticide Nema Percentage                         -0.09285225
## 5                Herbicide Acres                          0.27677760
## 6           Herbicide Percentage                          0.00778978
## 7                Fungicide Acres                          0.18844535
## 8           Fungicide Percentage                         -0.15233347
```

```
kable(correlations, caption = "Spearman Correlation Matrix")
```

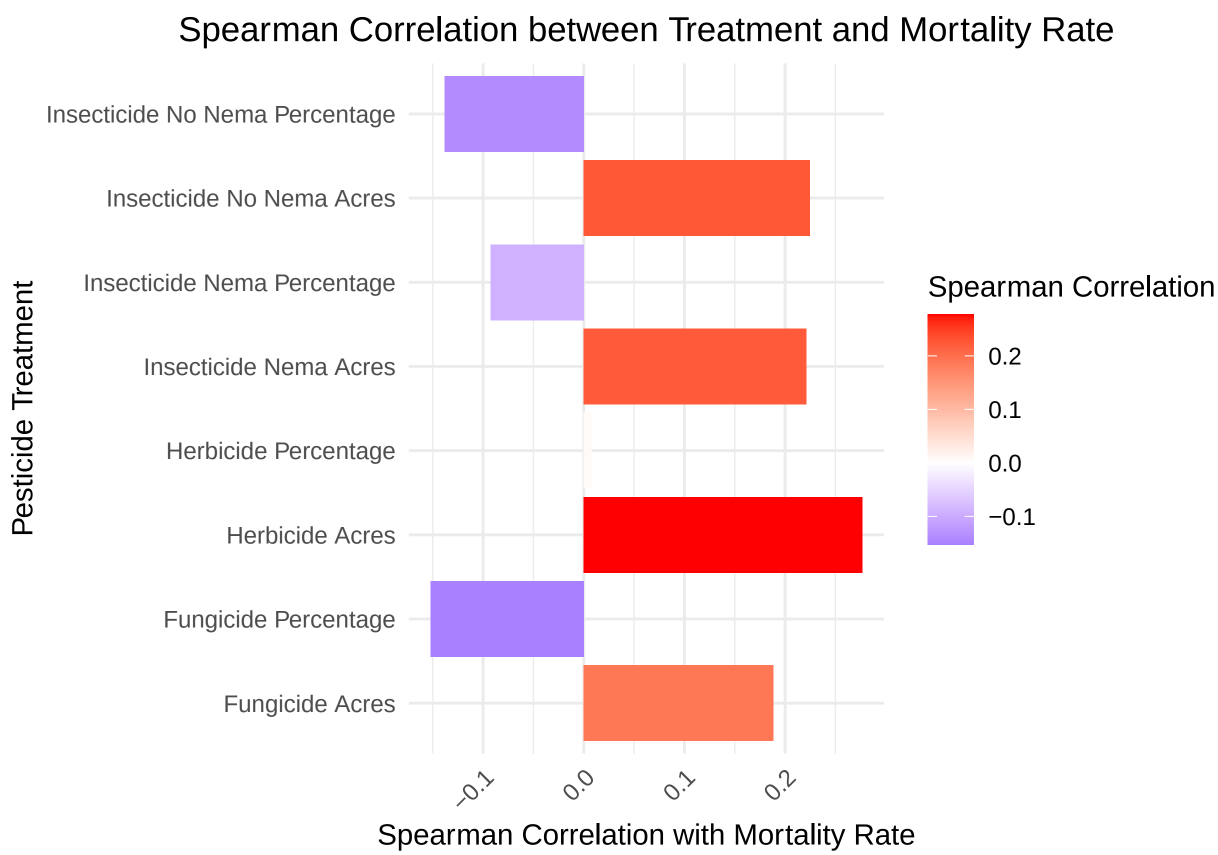
Table 1: Spearman Correlation Matrix

Treatment_Type	Spearman_Correlation_with_Mortality
Insecticide No Nema Acres	0.2248457
Insecticide No Nema Percentage	-0.1382926
Insecticide Nema Acres	0.2211432
Insecticide Nema Percentage	-0.0928522
Herbicide Acres	0.2767776
Herbicide Percentage	0.0077898
Fungicide Acres	0.1884453
Fungicide Percentage	-0.1523335

```
correlations_long <- correlations %>%
  pivot_longer(cols = Spearman_Correlation_with_Mortality,
               names_to = "Correlation_Type", values_to = "Correlation_Value")

ggplot(correlations_long, aes(x = Treatment_Type, y = Correlation_Value,
                              fill = Correlation_Value)) +
  geom_bar(stat = "identity") +
  coord_flip() +
  scale_fill_gradient2(low = "blue", high = "red", mid = "white",
                       midpoint = 0, name = "Spearman Correlation") +
```

```
  labs(
    title = "Spearman Correlation between Treatment and Mortality Rate",
    x = "Pesticide Treatment",
    y = "Spearman Correlation with Mortality Rate"
  ) +
  theme_minimal() +
  theme(
    axis.text.x = element_text(angle = 45, hjust = 1),
    plot.title = element_text(hjust = 0.5)
  )
```



Interpretation: There is no clear association between these pesticide treatments (measured as total acreage and percentage of farmland treated) with PD mortality rate.

```
cor_data <- df %>%
  dplyr::select(
    Total_Acres,
    Insecticide_No_Nema_Treatment_Acres,
    `Insecticide_No_Nema_Treatment_Percentage_(%)`,
    Insecticide_Nema_Treatment_Acres,
    `Insecticide_Nema_Treatment_Percentage_(%)`,
    Herbicide_Treatment_Acres,
```

```r
    `Herbicide_Treatment_Percentage_(%)`,
    Fungicide_Treatment_Acres,
    `Fungicide_Treatment_Percentage_(%)`,
    DEATHS
  )

cor_data <- cor_data %>% mutate(across(everything(), as.numeric))
```

```
## Warning: There was 1 warning in ‘mutate()‘.
## i In argument: ‘across(everything(), as.numeric)‘.
## Caused by warning:
## ! NAs introduced by coercion
```

```r
# Compute Spearman correlation matrix
cor_matrix <- cor(cor_data, method = "spearman", use = "complete.obs")

# Display the correlation matrix
print(cor_matrix)
```

```
##                                               Total_Acres
## Total_Acres                                    1.00000000
## Insecticide_No_Nema_Treatment_Acres            0.73016741
## Insecticide_No_Nema_Treatment_Percentage_(%) -0.01827333
## Insecticide_Nema_Treatment_Acres               0.65882482
## Insecticide_Nema_Treatment_Percentage_(%)    -0.05022431
## Herbicide_Treatment_Acres                      0.85687712
## Herbicide_Treatment_Percentage_(%)             0.26578400
## Fungicide_Treatment_Acres                      0.65794945
## Fungicide_Treatment_Percentage_(%)            -0.07429697
## DEATHS                                         0.04847357
##                                              Insecticide_No_Nema_Treatment_Acres
## Total_Acres                                                            0.7301674
## Insecticide_No_Nema_Treatment_Acres                                    1.0000000
## Insecticide_No_Nema_Treatment_Percentage_(%)                           0.6124302
## Insecticide_Nema_Treatment_Acres                                       0.9501040
## Insecticide_Nema_Treatment_Percentage_(%)                              0.5452457
## Herbicide_Treatment_Acres                                              0.9536054
## Herbicide_Treatment_Percentage_(%)                                     0.7724040
## Fungicide_Treatment_Acres                                              0.9610461
## Fungicide_Treatment_Percentage_(%)                                     0.5194223
## DEATHS                                                                 0.3373454
##                                              Insecticide_No_Nema_Treatment_Percentage_(%)
## Total_Acres                                                                   -0.01827333
## Insecticide_No_Nema_Treatment_Acres                                            0.61243024
## Insecticide_No_Nema_Treatment_Percentage_(%)                                   1.00000000
## Insecticide_Nema_Treatment_Acres                                               0.65072765
## Insecticide_Nema_Treatment_Percentage_(%)                                      0.94594595
## Herbicide_Treatment_Acres                                                      0.43669986
## Herbicide_Treatment_Percentage_(%)                                             0.91180654
## Fungicide_Treatment_Acres                                                      0.66976693
## Fungicide_Treatment_Percentage_(%)                                             0.94857205
## DEATHS                                                                         0.45201882
```

```
##                                             Insecticide_Nema_Treatment_Acres
## Total_Acres                                                        0.6588248
## Insecticide_No_Nema_Treatment_Acres                                0.9501040
## Insecticide_No_Nema_Treatment_Percentage_(%)                       0.6507277
## Insecticide_Nema_Treatment_Acres                                   1.0000000
## Insecticide_Nema_Treatment_Percentage_(%)                          0.6577306
## Herbicide_Treatment_Acres                                          0.9087428
## Herbicide_Treatment_Percentage_(%)                                 0.7824707
## Fungicide_Treatment_Acres                                          0.9610461
## Fungicide_Treatment_Percentage_(%)                                 0.5721633
## DEATHS                                                             0.4688697
##                                             Insecticide_Nema_Treatment_Percentage_(%)
## Total_Acres                                                               -0.05022431
## Insecticide_No_Nema_Treatment_Acres                                        0.54524565
## Insecticide_No_Nema_Treatment_Percentage_(%)                               0.94594595
## Insecticide_Nema_Treatment_Acres                                           0.65773061
## Insecticide_Nema_Treatment_Percentage_(%)                                  1.00000000
## Herbicide_Treatment_Acres                                                  0.38220812
## Herbicide_Treatment_Percentage_(%)                                         0.83608710
## Fungicide_Treatment_Acres                                                  0.61855783
## Fungicide_Treatment_Percentage_(%)                                         0.89232958
## DEATHS                                                                     0.55049787
##                                             Herbicide_Treatment_Acres
## Total_Acres                                                 0.8568771
## Insecticide_No_Nema_Treatment_Acres                         0.9536054
## Insecticide_No_Nema_Treatment_Percentage_(%)                0.4366999
## Insecticide_Nema_Treatment_Acres                            0.9087428
## Insecticide_Nema_Treatment_Percentage_(%)                   0.3822081
## Herbicide_Treatment_Acres                                   1.0000000
## Herbicide_Treatment_Percentage_(%)                          0.6874932
## Fungicide_Treatment_Acres                                   0.9067732
## Fungicide_Treatment_Percentage_(%)                          0.3557282
## DEATHS                                                      0.2951089
##                                             Herbicide_Treatment_Percentage_(%)
## Total_Acres                                                          0.2657840
## Insecticide_No_Nema_Treatment_Acres                                  0.7724040
## Insecticide_No_Nema_Treatment_Percentage_(%)                         0.9118065
## Insecticide_Nema_Treatment_Acres                                     0.7824707
## Insecticide_Nema_Treatment_Percentage_(%)                            0.8360871
## Herbicide_Treatment_Acres                                            0.6874932
## Herbicide_Treatment_Percentage_(%)                                   1.0000000
## Fungicide_Treatment_Acres                                            0.7951636
## Fungicide_Treatment_Percentage_(%)                                   0.8441843
## DEATHS                                                               0.4561768
##                                             Fungicide_Treatment_Acres
## Total_Acres                                                 0.6579494
## Insecticide_No_Nema_Treatment_Acres                         0.9610461
## Insecticide_No_Nema_Treatment_Percentage_(%)                0.6697669
## Insecticide_Nema_Treatment_Acres                            0.9610461
## Insecticide_Nema_Treatment_Percentage_(%)                   0.6185578
## Herbicide_Treatment_Acres                                   0.9067732
## Herbicide_Treatment_Percentage_(%)                          0.7951636
## Fungicide_Treatment_Acres                                   1.0000000
## Fungicide_Treatment_Percentage_(%)                          0.6319072
```

```
## DEATHS                                                                  0.4049677
##                                                Fungicide_Treatment_Percentage_(%)
## Total_Acres                                                           -0.07429697
## Insecticide_No_Nema_Treatment_Acres                                    0.51942226
## Insecticide_No_Nema_Treatment_Percentage_(%)                           0.94857205
## Insecticide_Nema_Treatment_Acres                                       0.57216326
## Insecticide_Nema_Treatment_Percentage_(%)                              0.89232958
## Herbicide_Treatment_Acres                                              0.35572820
## Herbicide_Treatment_Percentage_(%)                                     0.84418427
## Fungicide_Treatment_Acres                                              0.63190721
## Fungicide_Treatment_Percentage_(%)                                     1.00000000
## DEATHS                                                                 0.39205602
##                                                  DEATHS
## Total_Acres                                  0.04847357
## Insecticide_No_Nema_Treatment_Acres          0.33734544
## Insecticide_No_Nema_Treatment_Percentage_(%) 0.45201882
## Insecticide_Nema_Treatment_Acres             0.46886968
## Insecticide_Nema_Treatment_Percentage_(%)    0.55049787
## Herbicide_Treatment_Acres                    0.29510887
## Herbicide_Treatment_Percentage_(%)           0.45617682
## Fungicide_Treatment_Acres                    0.40496772
## Fungicide_Treatment_Percentage_(%)           0.39205602
## DEATHS                                       1.00000000
```

```r
colnames(cor_matrix) <- c(
  "Total Acres", "Insect No Nema Acres", "Insect No Nema %",
  "Insect Nema Acres", "Insect Nema %", "Herb Acres", "Herb %",
  "Fung Acres", "Fung %", "Deaths"
)
rownames(cor_matrix) <- c(
  "Total Acres", "Insect No Nema Acres", "Insect No Nema %",
  "Insect Nema Acres", "Insect Nema %", "Herb Acres", "Herb %",
  "Fung Acres", "Fung %", "Deaths"
)
kable(cor_matrix, caption = "Spearman Correlation Matrix")
```

Table 2: Spearman Correlation Matrix

	Total Acres	Insect No Nema Acres	Insect No Nema %	Insect Nema Acres	Insect Nema %	Herb Acres	Herb %	Fung Acres	Fung %	Deaths
Total Acres	1.0000000	0.7301674	-0.0182733	0.6588248	-0.0502243	0.8568770	0.2657840	0.6579494	-0.0742970	0.0484736
Insect No Nema Acres	0.7301674	1.0000000	0.6124302	0.9501040	0.5452457	0.9536050	0.7724040	0.9610460	0.5194223	0.3373454
Insect No Nema %	-0.0182733	0.6124302	1.0000000	0.6507277	0.9459459	0.4366990	0.9118060	0.5669766	0.9485721	0.4520188
Insect Nema Acres	0.6588248	0.9501040	0.6507277	1.0000000	0.6577306	0.9087428	0.7824707	0.7961046	0.5721633	0.4688697
Insect Nema %	-0.0502243	0.5452457	0.9459459	0.6577306	1.0000000	0.3822080	0.8360870	0.6185570	0.8923296	0.5504979

	Total Acres	Insect No Nema Acres	Insect No Nema %	Insect Nema Acres	Insect Nema %	Herb Acres	Herb %	Fung Acres	Fung %	Deaths
Herb Acres	0.8568771	0.9536054	0.4366999	0.9087428	0.3822081	1.0000000	0.6874932	0.9067732	0.3557282	0.2951089
Herb %	0.2657840	0.7724040	0.9118065	0.7824707	0.8360871	0.6874932	1.0000000	0.7951636	0.8441843	0.4561768
Fung Acres	0.6579494	0.9610461	0.6697669	0.9610461	0.6185578	0.9067732	0.7951636	1.0000000	0.6319072	0.4049677
Fung %	-0.0742970	0.5194223	0.9485721	0.5721633	0.8923296	0.3557282	0.8441843	0.6319072	1.0000000	0.3920560
Deaths	0.0484736	0.3373454	0.4520188	0.4688697	0.5504979	0.2951089	0.4561768	0.4049677	0.3920560	1.0000000

very weak to weak correlation of some treatment measurements and PD mortality