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Rationale and Research Questions

This report examines how local conditions affect local air quality, focusing on power plant emissions and precipitation levels. While pollution is often studied at a global level, examining its contribution to climate change and warming temperatures, its affect on communities local to the emissions source is studied less frequently. This analysis considers other factors (precipitation) that may influence air quality and explores how air quality levels vary day-to-day. Texas was chosen as the study area for this analysis because of its number of power plants and counties. This report investigates the following three questions:

- 1) Is there a correlation between county level emission levels from power plants and county air quality in Texas?
- 2) Is there a trend in air quality values and emissions over time in Harris county, Texas?
- 3) Is there a relationship between precipitation and air quality in Harris county Texas?

Dataset Information

This report analyzes three sources of data: EPA Air Quality, Emissions & Generation Resource Integrated Database (eGRID), and *INSERT PRECIPITATION DATA*

EPA Air Quality Data is collected at local monitors across the United States. It can be downloaded by pollutant type, region, and year. This report uses data for Texas between 2018 and 2023 for PM2.5 and Ozone. PM2.5 and Ozone are two criteria pollutants that can cause respiratory issues, especially for people with pre-existing health conditions, children, and seniors. The AQI based on PM2.5 and Ozone are recorded separately and range on a scale from 0-500, with higher values being more dangerous. Values 0-50 indicate "Good" AQ, 50 - 100 "Moderate", and increasingly poor from there. For more information about Air Quality Index and criteria pollutants, visit <https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information>

eGRID data is released annually and contains information for all power plants across the United States. It contains information about generation, age of the plant, fuel type, and emissions, including CO₂ Equivalent emissions. This report uses the eGRID 2018 - 2023 annual reports and focuses only on Texas power plants.

INSERT SOMETHING ABOUT PRECIPITATION DATA

Exploratory Analysis

This report analyzes air quality data from 2019 - 2023 in Texas for both PM2.5 and Ozone. For each year, there are separate PM2.5 and Ozone files, but the structure is the same for all. Below is the structure of the 2019 Texas PM2.5 data.

```
## 'data.frame': 18138 obs. of 22 variables:
##   $ Date                  : chr "03/16/2019" "03/17/2019" "03/18/2019" "03/19/2019" ...
##   $ Source                : chr "AQS" "AQS" "AQS" "AQS" ...
##   $ Site.ID               : int 480271045 480271045 480271045 480271045 480271045 480271045 ...
##   $ POC                   : int 1 1 1 1 1 1 1 1 1 1 ...
##   $ Daily.Mean.PM2.5.Concentration: num 4.4 6.3 7 11.1 12.7 5.6 7.5 8.4 7.7 14.3 ...
##   $ Units                 : chr "ug/m3 LC" "ug/m3 LC" "ug/m3 LC" "ug/m3 LC" ...
##   $ Daily.AQI.Value       : int 24 35 39 55 58 31 42 47 43 61 ...
##   $ Local.Site.Name       : chr "Temple Georgia" "Temple Georgia" "Temple Georgia" "Temple Georgia" ...
##   $ Daily.Obs.Count       : int 1 1 1 1 1 1 1 1 1 1 ...
##   $ Percent.Complete      : num 100 100 100 100 100 100 100 100 100 100 ...
##   $ AQS.Parameter.Code    : int 88101 88101 88101 88101 88101 88101 88101 88101 88101 88101 ...
##   $ AQS.Parameter.Description: chr "PM2.5 - Local Conditions" "PM2.5 - Local Conditions" "PM2.5 - Local Conditions" ...
##   $ Method.Code            : int 209 209 209 209 209 209 209 209 209 209 ...
##   $ Method.Description     : chr "Met One BAM-1022 Mass Monitor w/ VSCC or TE-PM2.5C" "Met One BAM-1022 Mass Monitor w/ VSCC or TE-PM2.5C" ...
##   $ CBSA.Code              : int 28660 28660 28660 28660 28660 28660 28660 28660 28660 28660 ...
##   $ CBSA.Name              : chr "Killeen-Temple, TX" "Killeen-Temple, TX" "Killeen-Temple, TX" ...
##   $ State.FIPS.Code        : int 48 48 48 48 48 48 48 48 48 48 ...
##   $ State                  : chr "Texas" "Texas" "Texas" "Texas" ...
##   $ County.FIPS.Code       : int 27 27 27 27 27 27 27 27 27 27 ...
##   $ County                 : chr "Bell" "Bell" "Bell" "Bell" ...
##   $ Site.Latitude          : num 31.1 31.1 31.1 31.1 31.1 ...
##   $ Site.Longitude         : num -97.4 -97.4 -97.4 -97.4 -97.4 ...
```

Analysis

Question 1: Is there a correlation between county level emission levels from power plants and county air quality?

The eGRID data for each year was adjusted to ensure all numeric columns were imported as numeric for quantitative analysis. The year, state, plant name, county, latitude, longitude, and emissions data for all types of recorded emissions (including CO₂ equivalent emissions) were selected to a new data frame. These data frames were combined and further manipulated to have a data frame with the total county emissions for each year.

Relevant columns were selected for each of the PM2.5 and Ozone data frames, including date AQI, site name, AQ type (PM2.5 or Ozone), State, County, longitude and latitude. This was combined into two dataframes, one for PM2.5 and one for Ozone and further manipulated to have data frames with the average air quality value for each county each year.

The data frames were joined to have a data frame with, for each year and each county, total emissions and average AQI.

How often is emissions data reported?

The following map displays all the plants referenced in at least one of the eGRID reports between 2019 and 2023. Not all plants listed in eGRID report CO₂ equivalence. The plants that reported at some point in the 5 years are in blue. Plants that are listed in at least one of the eGRID reports but never report CO₂ emissions (or have zero emissions) are in black.

How are air quality stations spatially located compared to emissions reporting power plants?

The following map shows how plants and EPA air quality monitors are spatially related. Not all counties have both an air quality monitor and at least one CO₂ equivalence reporting plant. Only counties reporting both at some point between 2019 and 2023 are included in the statistical analysis below.

Are annual county emissions correlated with annual county air quality?

The following graphs and tables show the relationship between total annual county emissions and average annual county air quality. A linear regression was run on the data to determine if the relationship has a significant correlation. Harris County data points are highlighted.

Table 1: Linear Regression of Emissions vs. Ozone Air Quality

Item	Value
P-value	0.5239
R-squared	-0.0043
Degrees of Freedom	136

Table 2: Linear Regression of Emissions vs. PM2.5 Air Quality

Item	Value
P-value	0.4074
R-squared	-0.0025

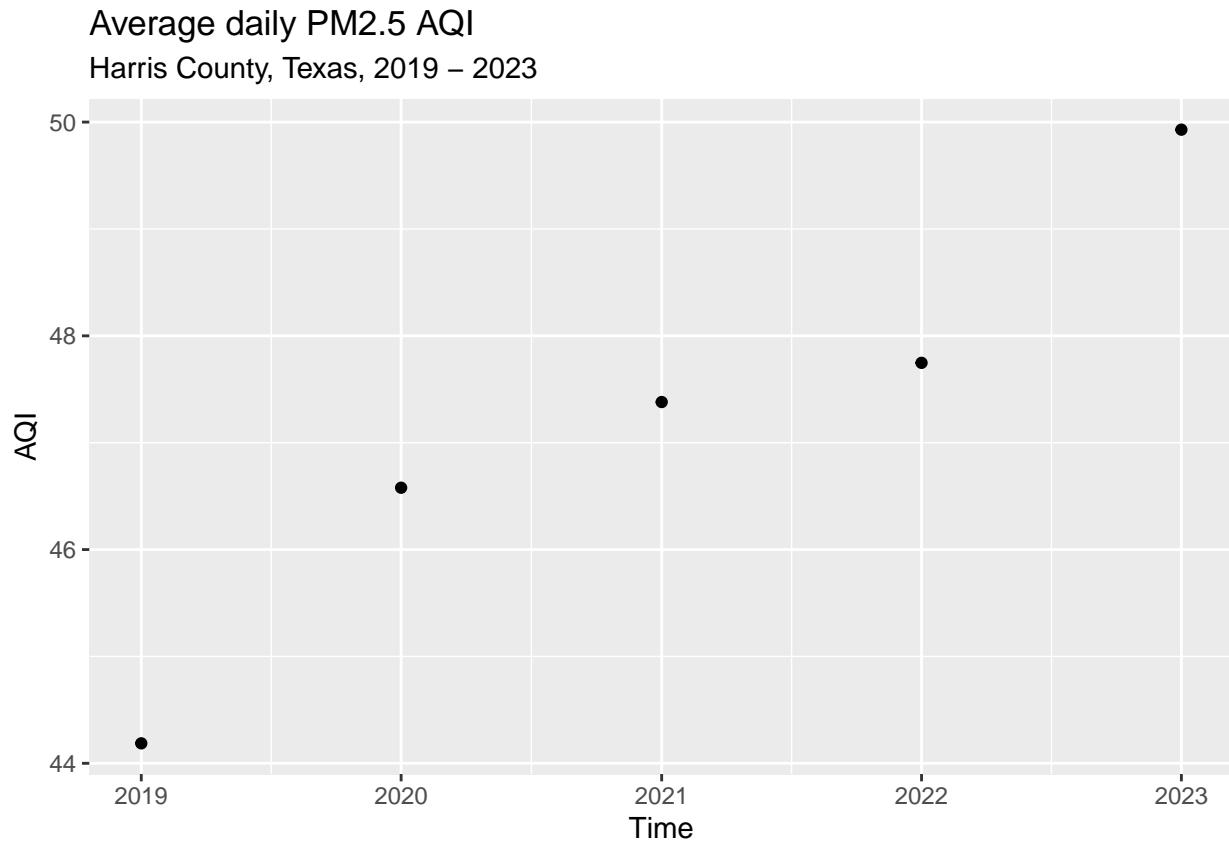
Item	Value
Degrees of Freedom	125

Question 2:

```
## `summarise()` has grouped output by 'Plant.state.abbreviation',
## 'Plant.county.name'. You can override using the '.groups' argument.

## `summarise()` has grouped output by 'Date'. You can override using the
## '.groups' argument.

## `summarise()` has grouped output by 'Date'. You can override using the
## '.groups' argument.
```



Listed and Emissions Reporting Texas Power Plants 2018 – 2023 eGRID Reports

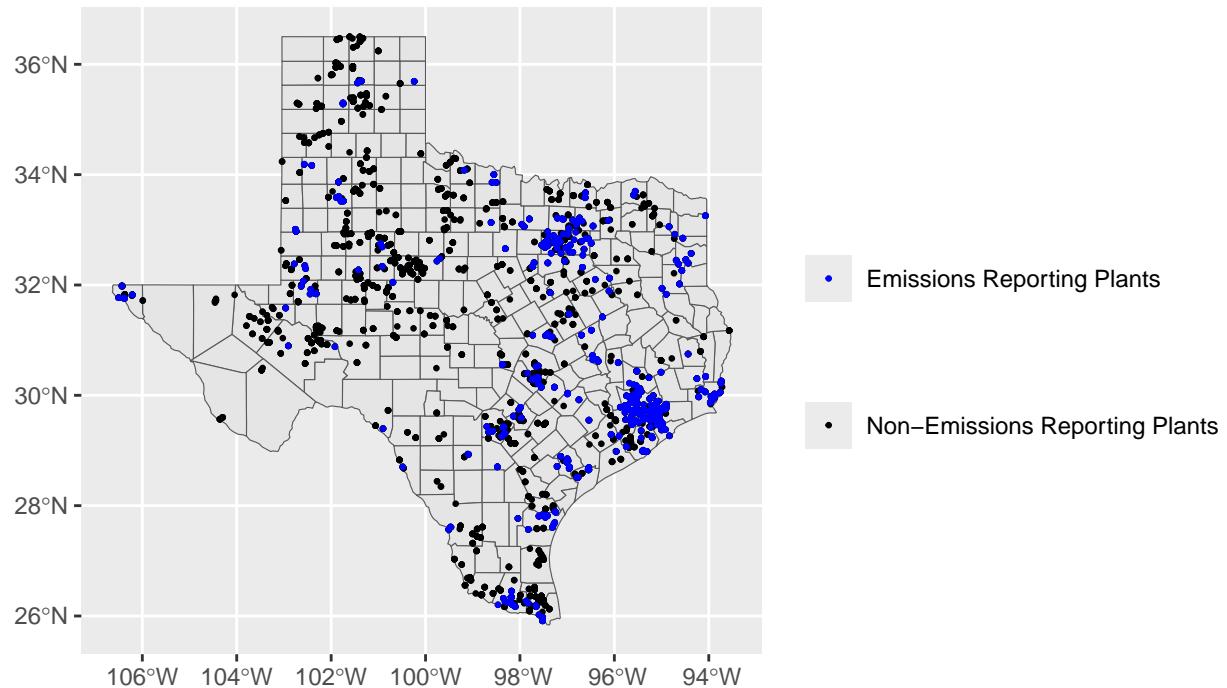


Figure 1: Listed and Emissions Reporting Texas Power Plants

Air Quality Monitors & Annual Emissions from Power Plants and in Texas 2018 – 2023

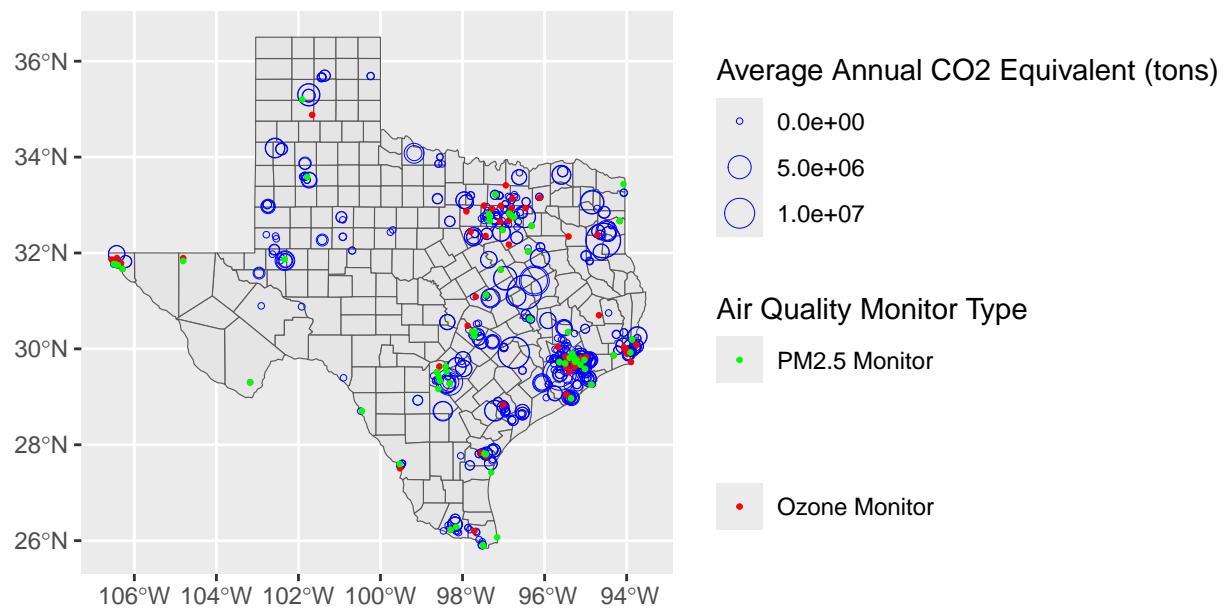


Figure 2: Air Quality Monitors & Annual Emissions from Power Plants and in Texas

Average Daily Ozone AQI Value vs. Annual CO₂ Equivalent Emissions
Per County, Texas, 2019 – 2023

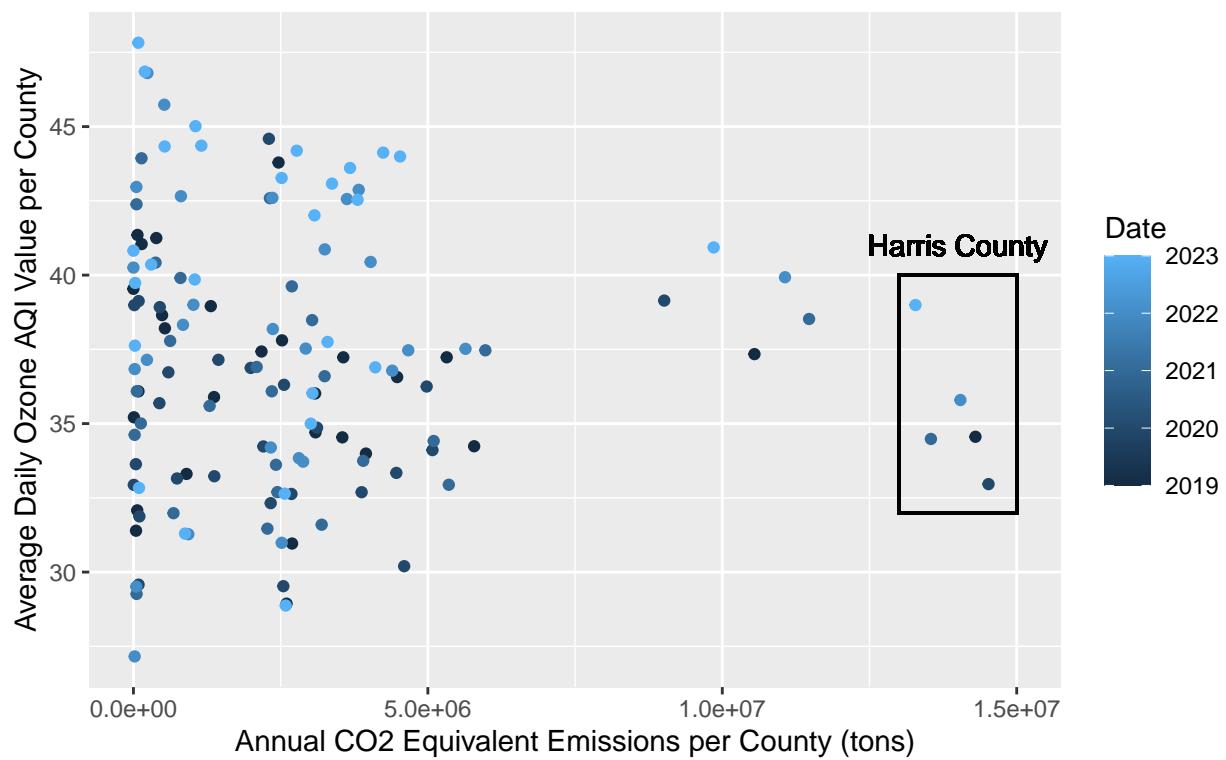


Figure 3: Average Daily Ozone AQI Value vs. Annual CO₂ Equivalent Emissions

Average Daily PM2.5 AQI Value vs. Annual CO2 Equivalent Emissions in Individual Counties in Texas, 2019 – 2023

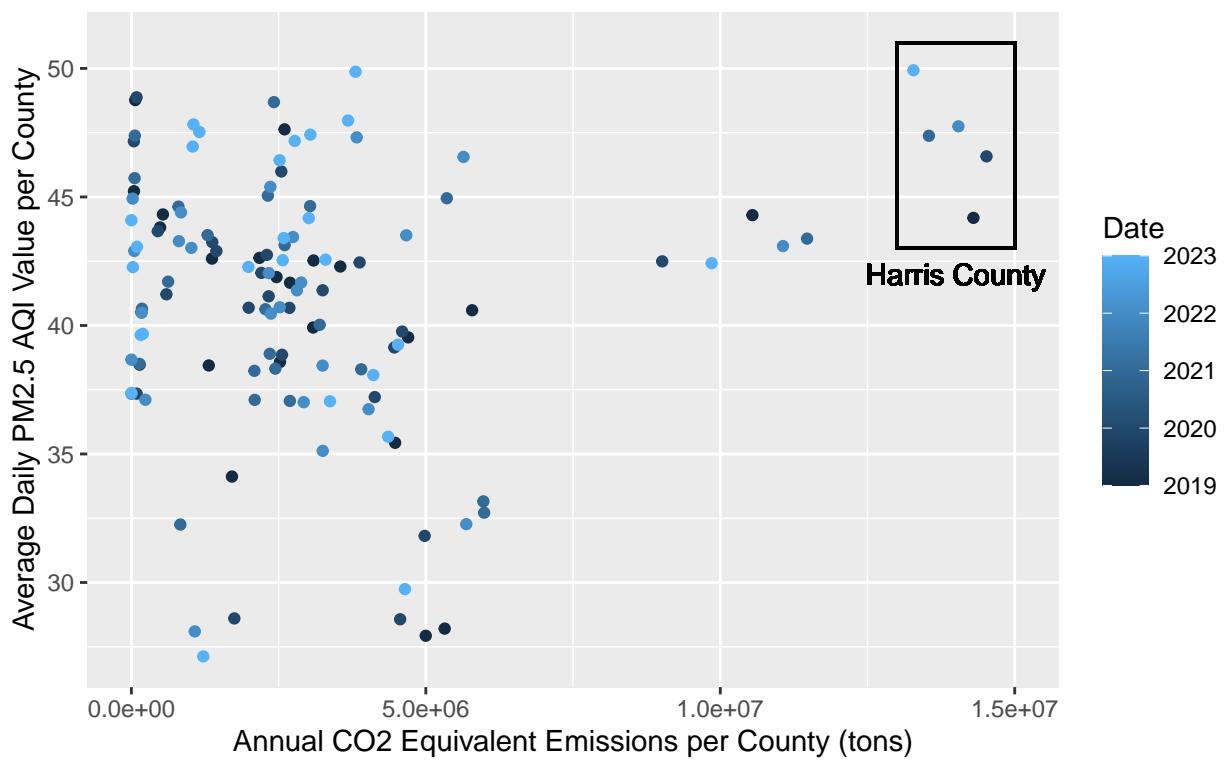
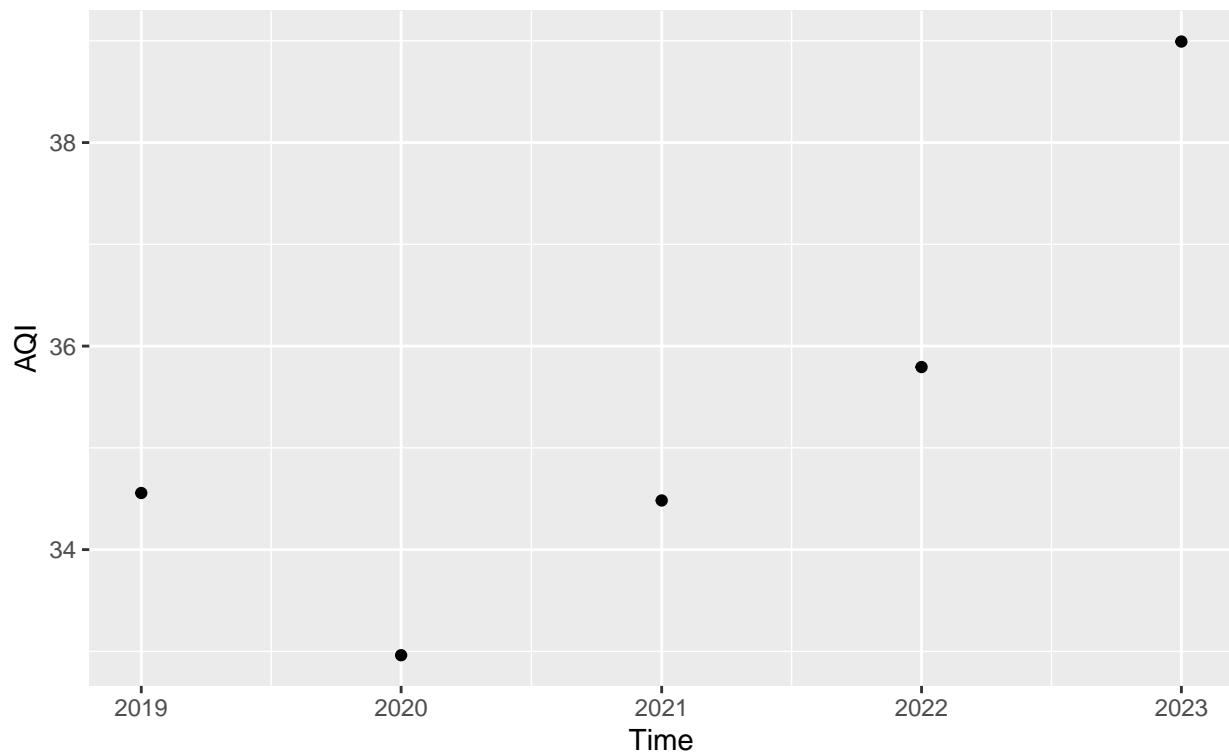
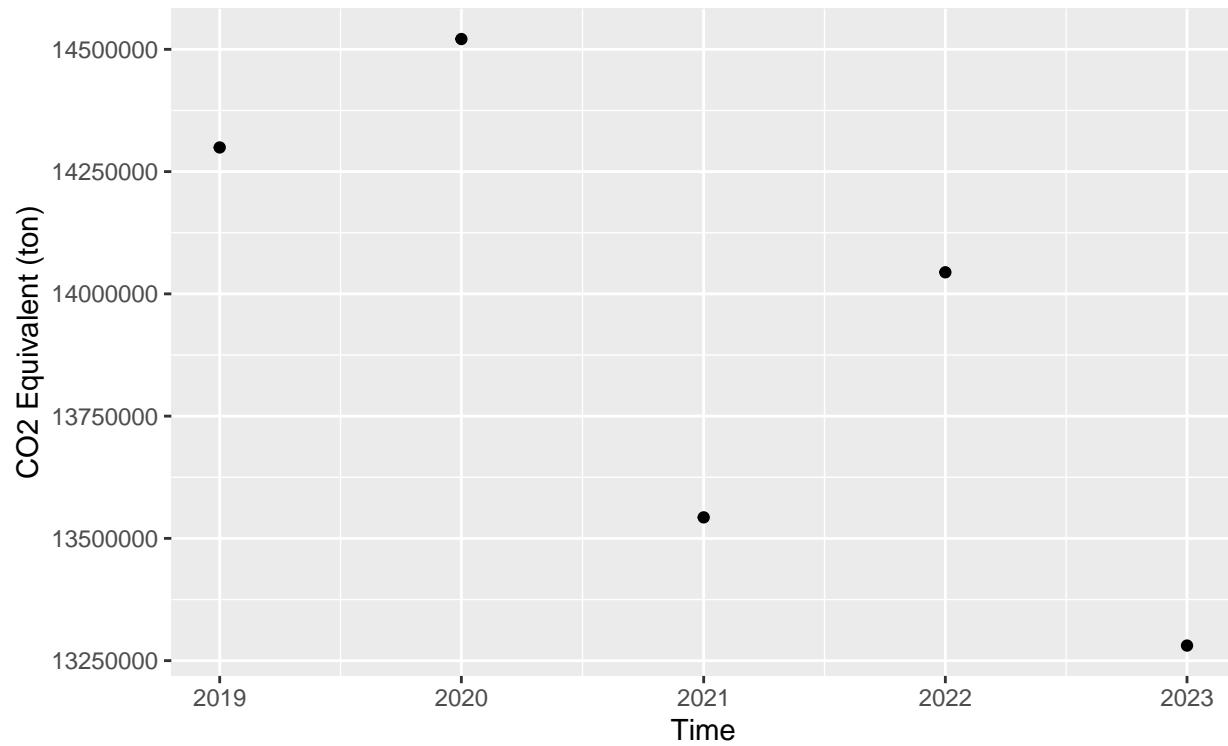


Figure 4: Average Daily PM2.5 AQI Value vs. Annual CO2 Equivalent Emissions in Individual Counties

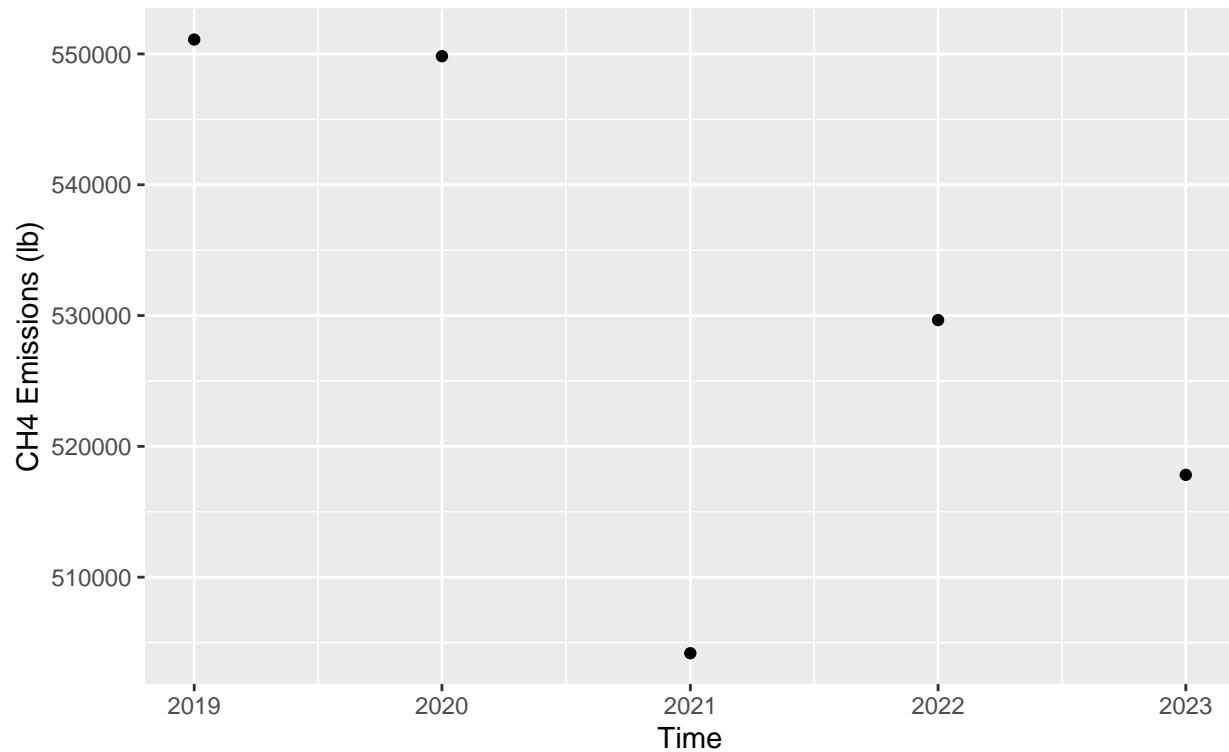
Average daily ozone AQI
Harris County, Texas, 2019 – 2023



Annual CO₂equivalent
Harris County, Texas, 2019 – 2023



Annual methane emissions
Harris County, Texas, 2019 – 2023



Question 3:

```
#r setup, include=FALSE} #library(tidyverse);library(lubridate);library(here);library(cowplot);library(dplyr)
#here() #
```

```
#TX only PM2.5
TXPM2523_SB <- read.csv(here("Data/TXPM2523.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "County.GeoID")

TXPM2522_SB <- read.csv(here("Data/TXPM2522.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "County.GeoID")

TXPM2521_SB <- read.csv(here("Data/TXPM2521.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "County.GeoID")

TXPM2520_SB <- read.csv(here("Data/TXPM2520.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "County.GeoID")

TXPM2519_SB <- read.csv(here("Data/TXPM2519.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "County.GeoID")
```

```

#All Texas PM2.5 2018 - 2023 by County
TXPM25_SB <- rbind(TXPM2519_SB, TXPM2520_SB, TXPM2521_SB, TXPM2522_SB, TXPM2523_SB)

#TX only Ozone
TX0zone23_SB <- read.csv(here("Data/TX0zone23.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "CountyName")

TX0zone22_SB <- read.csv(here("Data/TX0zone22.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "CountyName")

TX0zone21_SB <- read.csv(here("Data/TX0zone21.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "CountyName")

TX0zone20_SB <- read.csv(here("Data/TX0zone20.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "CountyName")

TX0zone19_SB <- read.csv(here("Data/TX0zone19.csv")) %>%
  mutate(Date=mdy(Date)) %>%
  select("Date", "Daily.AQI.Value", "Local.Site.Name", "AQS.Parameter.Description", "State", "County", "CountyName")

#All Texas Ozone 2018 - 2023 by County
TX0zone_SB <- rbind(TX0zone19_SB, TX0zone20_SB, TX0zone21_SB, TX0zone22_SB, TX0zone23_SB)

TX0zoneHarris <- TX0zone_SB %>%
  filter(County == 'Harris')%>%
  group_by(Date) %>%
  summarise(Avg_AQI_Ozone = mean(Daily.AQI.Value), County='Harris')

TXPM25Harris <- TXPM25_SB %>%
  filter(County == 'Harris')%>%
  group_by(Date) %>%
  summarise(Avg_AQI_PM = mean(Daily.AQI.Value), County='Harris')

HarrisCoRain <- read.csv(here("Data/HarrisCoRain.csv"))%>%
  na.omit(PRCP)%>%
  group_by(DATE) %>%
  summarise(Avg_Rain = mean(PRCP))%>%
  mutate(Date=mdy(DATE))%>%
  select("Date", "Avg_Rain")

HarrisCoRain_AQ1 <- left_join(TX0zoneHarris, HarrisCoRain)

## Joining with `by = join_by(Date)`
  by = c("Date")

HarrisCoRain_AQ <- left_join(HarrisCoRain_AQ1, TXPM25Harris)

## Joining with `by = join_by(Date, County)`

```

```

by = c("Date")

HarrisRainOzone.regression <- lm(
  data = HarrisCoRain_AQ,
  Avg_Rain ~ Avg_AQI_Ozone)
summary(HarrisRainOzone.regression)

##
## Call:
## lm(formula = Avg_Rain ~ Avg_AQI_Ozone, data = HarrisCoRain_AQ)
##
## Residuals:
##    Min      1Q  Median      3Q     Max
## -0.2110 -0.1475 -0.1149 -0.0268  4.6236
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.2297631  0.0195389 11.759 < 2e-16 ***
## Avg_AQI_Ozone -0.0025731  0.0004974 -5.173 2.56e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3642 on 1819 degrees of freedom
## Multiple R-squared:  0.0145, Adjusted R-squared:  0.01396
## F-statistic: 26.76 on 1 and 1819 DF,  p-value: 2.557e-07

HarrisRainPM.regression <- lm(
  data = HarrisCoRain_AQ,
  Avg_Rain ~ Avg_AQI_PM)
summary(HarrisRainPM.regression)

##
## Call:
## lm(formula = Avg_Rain ~ Avg_AQI_PM, data = HarrisCoRain_AQ)
##
## Residuals:
##    Min      1Q  Median      3Q     Max
## -0.3520 -0.1483 -0.0873 -0.0071  4.4733
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.4599711  0.0306523 15.01 <2e-16 ***
## Avg_AQI_PM -0.0068218  0.0006266 -10.89 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3555 on 1819 degrees of freedom
## Multiple R-squared:  0.06117, Adjusted R-squared:  0.06065
## F-statistic: 118.5 on 1 and 1819 DF,  p-value: < 2.2e-16

TXOzoneDallas <- TXOzone_SB %>%
  filter(County == 'Dallas')%>%

```

```

group_by(Date) %>%
  summarise(Avg_AQI_Ozone = mean(Daily.AQI.Value), County='Dallas')

TXPM25Dallas <- TXPM25_SB %>%
  filter(County == 'Dallas')%>%
  group_by(Date) %>%
  summarise(Avg_AQI_PM = mean(Daily.AQI.Value), County='Dallas')

DallasCoRain <- read.csv(here("Data/DallasCoRain.csv"))%>%
  na.omit(PRCP)%>%
  group_by(DATE) %>%
  summarise(Avg_Rain = mean(PRCP))%>%
  mutate(Date=ymd(DATE))%>%
  select("Date", "Avg_Rain")

DallasCoRain_AQ1 <- left_join(TXOzoneDallas, DallasCoRain)

## Joining with `by = join_by(Date)`

by = c("Date")

DallasCoRain_AQ <- left_join(DallasCoRain_AQ1, TXPM25Dallas)

## Joining with `by = join_by(Date, County)`

by = c("Date")

DallasRainOzone.regression <- lm(
  data = DallasCoRain_AQ,
  Avg_Rain ~ Avg_AQI_Ozone)
summary(DallasRainOzone.regression)

## 
## Call:
## lm(formula = Avg_Rain ~ Avg_AQI_Ozone, data = DallasCoRain_AQ)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -0.1785 -0.1261 -0.1016 -0.0335  4.1741 
## 
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 0.2017347  0.0187384 10.766 < 2e-16 ***
## Avg_AQI_Ozone -0.0022472  0.0004366 -5.147 2.93e-07 ***
## ---      
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 0.3328 on 1818 degrees of freedom
## Multiple R-squared:  0.01436,    Adjusted R-squared:  0.01382 
## F-statistic: 26.49 on 1 and 1818 DF,  p-value: 2.933e-07

```

```

DallasRainPM.regression <- lm(
  data = DallasCoRain_AQ,
  Avg_Rain ~ Avg_AQI_PM)
summary(DallasRainPM.regression)

## 
## Call:
## lm(formula = Avg_Rain ~ Avg_AQI_PM, data = DallasCoRain_AQ)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -0.3467 -0.1386 -0.0574  0.0102  4.0097 
## 
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 0.3813303  0.0219118 17.40   <2e-16 ***
## Avg_AQI_PM -0.0061621  0.0004734 -13.02   <2e-16 ***  
## ---      
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 0.3164 on 1778 degrees of freedom
##   (40 observations deleted due to missingness)
## Multiple R-squared:  0.08701,    Adjusted R-squared:  0.0865 
## F-statistic: 169.5 on 1 and 1778 DF,  p-value: < 2.2e-16

```

```
HarrisDallas <- rbind(HarrisCoRain_AQ, DallasCoRain_AQ)
```

```
HarrisDallasRain.anova <- aov(data = HarrisDallas, Avg_Rain ~ County)
summary(HarrisDallasRain.anova)
```

```
##           Df Sum Sq Mean Sq F value Pr(>F)    
## County       1   0.6   0.5598  4.536 0.0333 *  
## Residuals 3639 449.1   0.1234                
## ---      
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
HarrisDallasOzone.anova <- aov(data = HarrisDallas, Avg_AQI_Ozone ~ County)
summary(HarrisDallasOzone.anova)
```

```
##           Df Sum Sq Mean Sq F value Pr(>F)    
## County       1 12377 12377   40.31 2.43e-10 ***
## Residuals 3639 1117149     307                
## ---      
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
HarrisDallasPM.anova <- aov(data = HarrisDallas, Avg_AQI_PM ~ County)
summary(HarrisDallasPM.anova)
```

```
##           Df Sum Sq Mean Sq F value Pr(>F)    
## County       1 11549 11549   54.07 2.38e-13 ***
## Residuals 3599 768715     214                
## ---
```

```

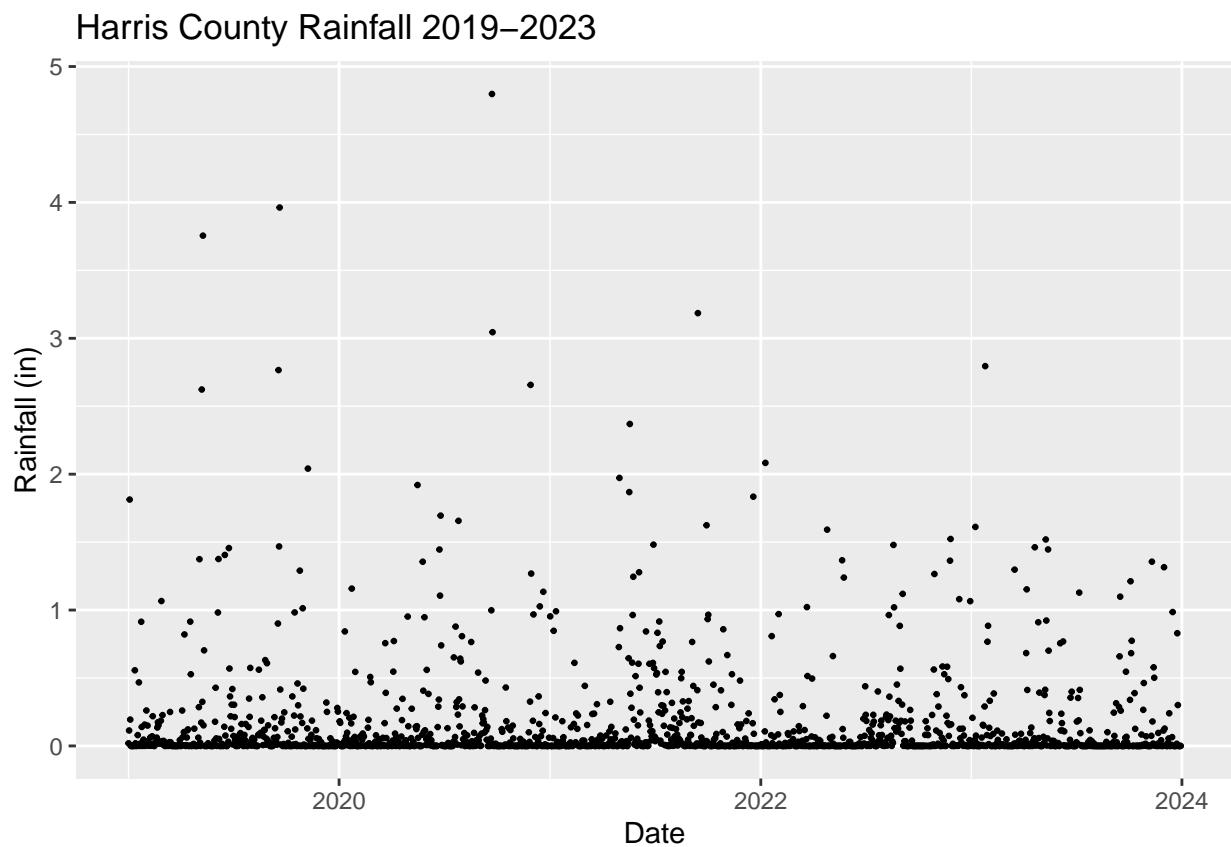
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 40 observations deleted due to missingness

```

```

Rainplot<-HarrisCoRain_AQ%>%
  ggplot(aes(
    x=Date,
    y=Avg_Rain))+
  labs(
    x="Date",
    y="Rainfall (in)")+
  geom_point(size=0.5)+
  ggtitle('Harris County Rainfall 2019–2023')
print(Rainplot)

```

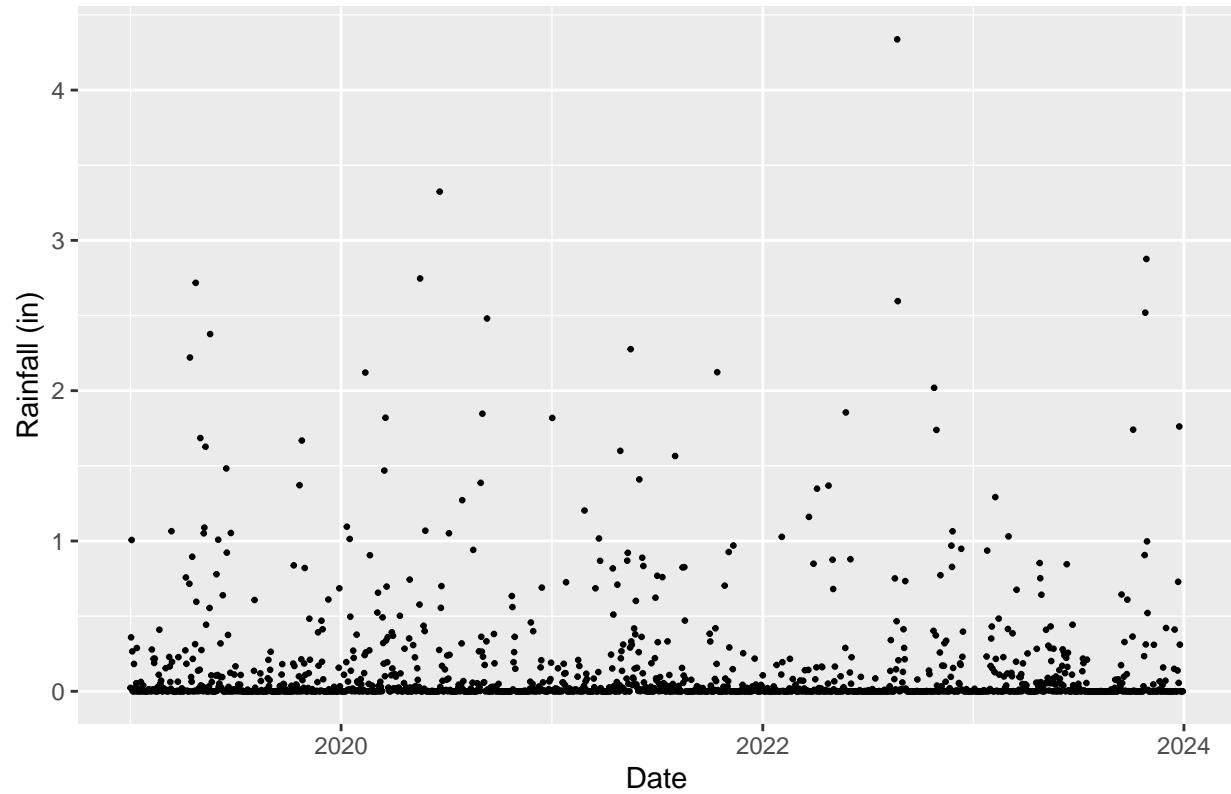


```

Rainplot2<-DallasCoRain_AQ%>%
  ggplot(aes(
    x=Date,
    y=Avg_Rain))+
  labs(
    x="Date",
    y="Rainfall (in)")+
  geom_point(size=0.5)+
  ggtitle('Dallas County Rainfall 2019–2023')
print(Rainplot2)

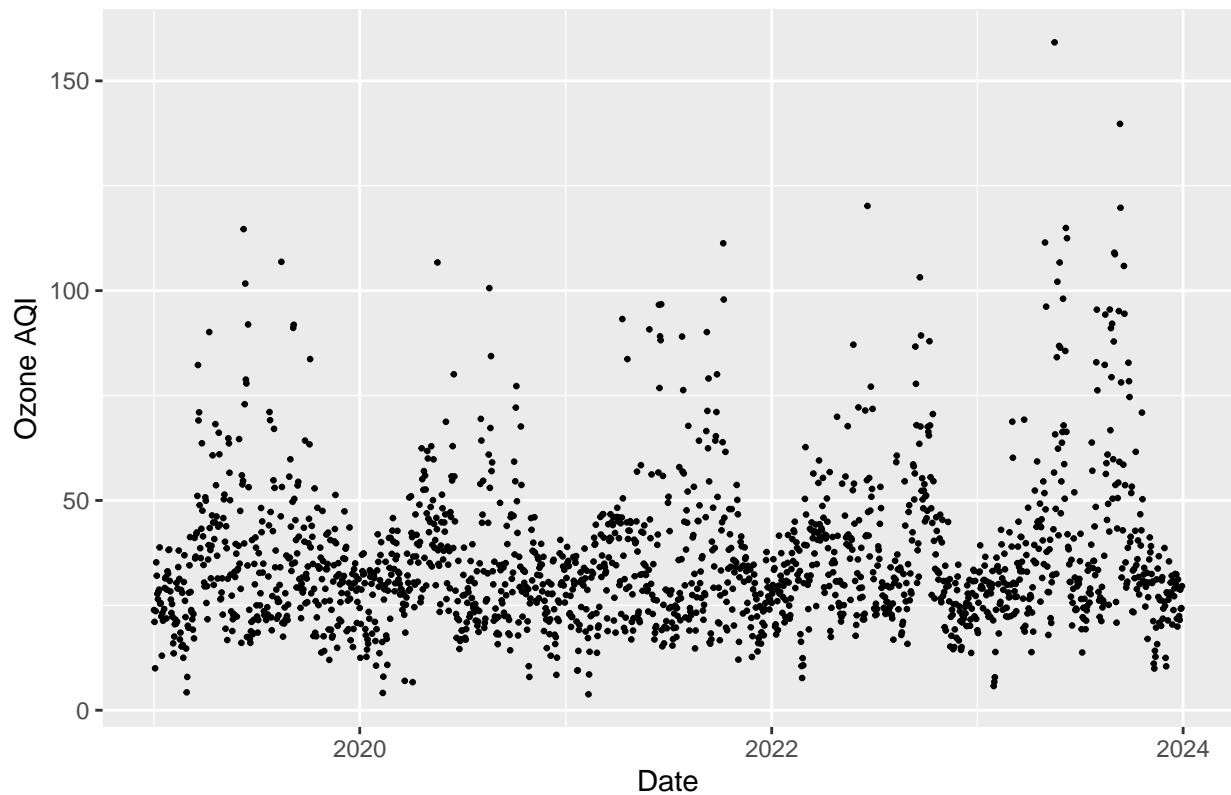
```

Dallas County Rainfall 2019–2023



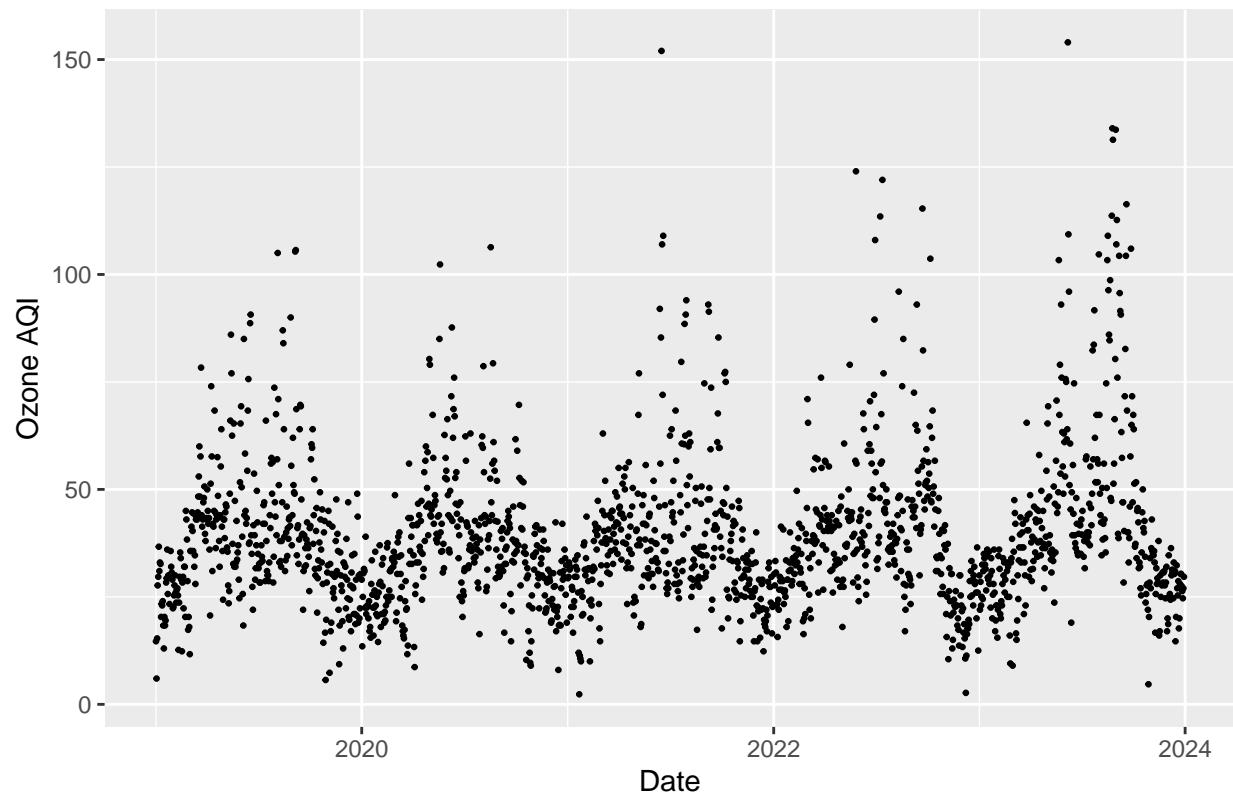
```
Ozoneplot<-HarrisCoRain_AQ%>%
  ggplot(aes(
    x=Date,
    y=Avg_AQI_Ozone))+
  labs(
    x="Date",
    y="Ozone AQI")+
  geom_point(size=0.5)+
  ggtitle('Harris County Ozone 2019-2023')
print(Ozoneplot)
```

Harris County Ozone 2019–2023



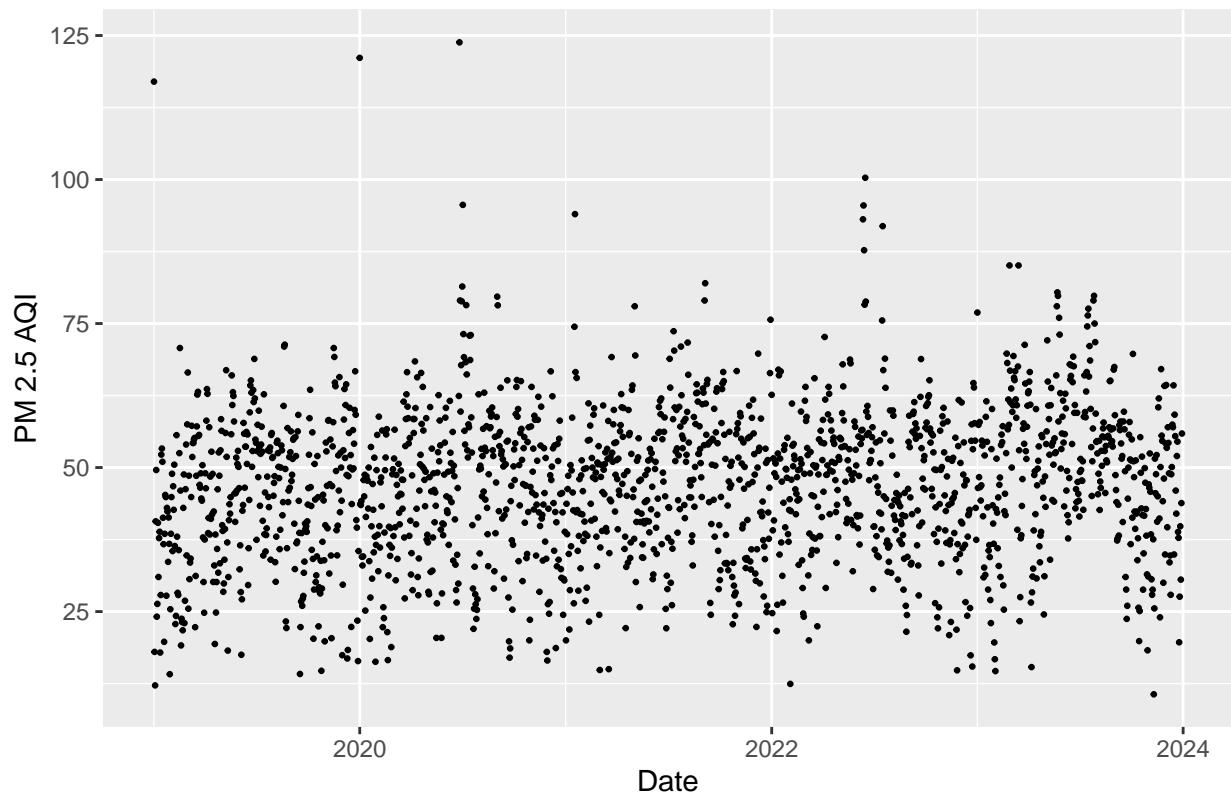
```
Ozoneplot2<-DallasCoRain_AQ%>%
ggplot(aes(
  x=Date,
  y=Avg_AQI_Ozone))+ 
  labs(
    x="Date",
    y="Ozone AQI")+
  geom_point(size=0.5)+
  ggtitle('Dallas County Ozone 2019-2023')
print(Ozoneplot2)
```

Dallas County Ozone 2019–2023



```
PMplot<-HarrisCoRain_AQ%>%
  ggplot(aes(
    x=Date,
    y=Avg_AQI_PM))+ 
  labs(
    x="Date",
    y="PM 2.5 AQI")+
  geom_point(size=0.5)+ 
  ggtitle('Harris County PM 2.5 2019-2023')
print(PMplot)
```

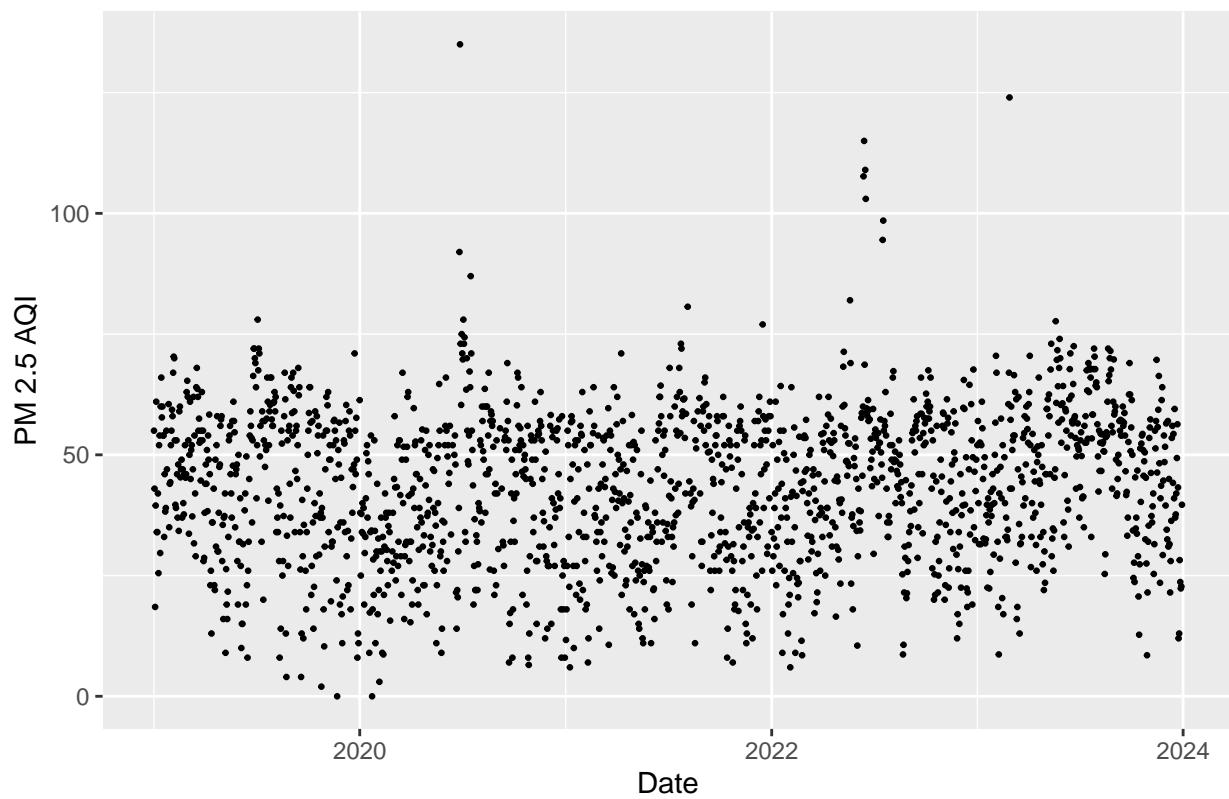
Harris County PM 2.5 2019–2023



```
PMplot2<-DallasCoRain_AQ%>%
  ggplot(aes(
    x=Date,
    y=Avg_AQI_PM))+ 
  labs(
    x="Date",
    y="PM 2.5 AQI")+
  geom_point(size=0.5)+ 
  ggtitle('Dallas County PM 2.5 2019-2023')
print(PMplot2)
```

```
## Warning: Removed 40 rows containing missing values or values outside the scale range
## ('geom_point()').
```

Dallas County PM 2.5 2019–2023



Summary and Conclusions

The analysis of correlation between air quality and emissions at the county level per year did not result in significant results. There is not a significant correlation between annual county emission from power plants and average annual county AQI score from Ozone or PM2.5. Additionally, no county on average saw any poor or unsafe Air Quality Index levels. There are two potential factors influencing this lack of correlation. One is that air quality and emissions cannot be studied at localized scale. Likely emissions disperse out of the county it is in based on local weather patterns. Conducting analysis of local air quality based on power plant emissions might be more accurate if wind patterns were taken into consideration to estimate where emissions may be concentrating. Another reason there may not be a correlation is because there are not enough data points in this analysis to see a trend. All plants do not report emissions and there are not air quality stations in all counties. To perform this analysis more accurately, data should be looked at country wide and there should be better standards for ensuring all active power plants report their emissions.

References

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