Montesinho Natural Park Forest Fire Analysis

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ASK: BUSINESS TASK

Gold Coast Conservation Group is a 501(c)(4)concerned with the effects of climate change on campground, parks and lakes in locations with Mediterranean climate. **Gold Coast Conservation Group** endorses, lobbies and provides policy strategies to politicians. **Gold Coast Conservation Group** wants to study *the causes of fires in public lands, the time of year when forest fires occur in high frequency and recommendations to prevent/minimize forest fires.*

BUSINESS QUESTIONS

*What role does weather/climate play in causing fires in public lands?

*What time of year do most fires take place and what is the significance of the time frame?

*What are the soil conditions that cause fires in public lands?

*Provide recommendations to prevent fires in public lands and lakes.

*Can we extrapolate the study and apply the lessons to regions with similar climate conditions to the study?

*Can the findings be used as indicators of long term climate change effects in Santa Barbara county?

Stakeholders and Audience

Gold Coast Conservation Group stakeholders are two conservationists, a former fire department chief and two animal rights activists. The five member panel is concerned with protecting public land and wildlife. The stakeholders will present the findings at fund raising and recruiting events.

Data and Metrics

UC Irvine has a machine learning repository which includes a data set of forest fire data in Montesinho Natural Park in Portugal. The data set is part of research conducted by Paulo Cortez and Anibal Morais. The data set satisfies **Gold Coast Conservation Group's** interest in studying campground, parks and lakes in locations with Mediterranean climate.

The key metrics in the data are weather conditions from 2000-2003 in Montesinho Natural Park, location of forest fires, dates of forest fires and the fire weather index data dealing with fuel index, initial forest fire spread, duff moisture conditions and drought conditions.

PREPARE: DESCRIPTION OF ALL DATA SOURCES

The data was acquired from UC Irvine's Machine Learning Repository. The sources for the data are Paulo Cortez and Anibal Morais from the Department of Information Systems, University of Minho, Portugal. Paulo Cortez and Anibal Morais used the data to create and publish A Data Mining Approach to Predict Forest Fires using Meteorological Data. In this study the focus is on analysis of the data. No machine learning algorithm will be created for this analysis.

Data Credibility

*Reliable: The data was acquired, curated and used to publish data science predictions by universities in Portugal and the United States

*Original: The data comes from observations and calculations from the Canadian Forest Fire Weather Index(FWI) which is used today by Canada, Argentina, and New Zealand. The index is original data acquired from forest fires in Montesinho Natural park between 2000-2003.

*Comprehensive: Data is comprehensive and includes every forest fire, location of forest fire, weather conditions and fuel in various layers in the Montesinho Natural Park.

*Current: The date of the data acquisition is 2000-2003 but it uses variables that are currently used to predict forest fires in various countries throughout the world.

*Cited: A Data Mining Approach to Predict Forest Fires using Meteorological Data and UC Irvine's Machine Learning Repository

The analysis will be done with R. The data is placed in a cloud server and requires a pass code and multiple verification to access the computer and cloud network. The data is public and the results will be published for public consumption but the stakeholder names will not be divulged. Data sourcing will be included in the final report visualizations.

The integrity of the data is verified through the initial study and the location of the data. The data comes from a reputable research university in the United States. Acclimation and to understand the values in the data set required research on the Fire Weather Index that is used by Canada and other countries and the data follows FWI fuel moisture codes.

Sort and Filter Data

```
#Libraries
library(tidyr)
library(dplyr)
library(data.table)
library(formattable)
library(DT)
library(psych)
library(ggplot2)
library(tidyverse)
library(corrplot)
#library(h2o)
#library(lares)
library(weathermetrics)
library(wesanderson)
library(ggalluvial)
library(measurements)
```

```r
#View Structure
str(forest_fire_2)
```

```
## 'data.frame':    517 obs. of  13 variables:
##  $ X    : int  7 7 7 8 8 8 8 8 8 7 ...
##  $ Y    : int  5 4 4 6 6 6 6 6 6 5 ...
##  $ month: chr  "mar" "oct" "oct" "mar" ...
##  $ day  : chr  "fri" "tue" "sat" "fri" ...
##  $ FFMC : num  86.2 90.6 90.6 91.7 89.3 92.3 92.3 91.5 91 92.5 ...
##  $ DMC  : num  26.2 35.4 43.7 33.3 51.3 ...
##  $ DC   : num  94.3 669.1 686.9 77.5 102.2 ...
##  $ ISI  : num  5.1 6.7 6.7 9 9.6 14.7 8.5 10.7 7 7.1 ...
##  $ temp : num  8.2 18 14.6 8.3 11.4 22.2 24.1 8 13.1 22.8 ...
##  $ RH   : int  51 33 33 97 99 29 27 86 63 40 ...
##  $ wind : num  6.7 0.9 1.3 4 1.8 5.4 3.1 2.2 5.4 4 ...
##  $ rain : num  0 0 0 0.2 0 0 0 0 0 0 ...
##  $ area : num  0 0 0 0 0 0 0 0 0 0 ...
```

The data has 517 observations/rows and 13 variables/columns.

Column Names

```r
#Column Names
colnames(forest_fire_2)
```

```
##  [1] "X"     "Y"     "month" "day"   "FFMC"  "DMC"   "DC"    "ISI"   "temp"
## [10] "RH"    "wind"  "rain"  "area"
```

Summary of Data

```r
summary(forest_fire_2)
```

```
##        X               Y           month               day           
##  Min.   :1.000   Min.   :2.0   Length:517         Length:517        
##  1st Qu.:3.000   1st Qu.:4.0   Class :character   Class :character  
##  Median :4.000   Median :4.0   Mode  :character   Mode  :character  
##  Mean   :4.669   Mean   :4.3                                        
##  3rd Qu.:7.000   3rd Qu.:5.0                                        
##  Max.   :9.000   Max.   :9.0                                        
##       FFMC            DMC              DC             ISI        
##  Min.   :18.70   Min.   :  1.1   Min.   :  7.9   Min.   : 0.000  
##  1st Qu.:90.20   1st Qu.: 68.6   1st Qu.:437.7   1st Qu.: 6.500  
##  Median :91.60   Median :108.3   Median :664.2   Median : 8.400  
##  Mean   :90.64   Mean   :110.9   Mean   :547.9   Mean   : 9.022  
##  3rd Qu.:92.90   3rd Qu.:142.4   3rd Qu.:713.9   3rd Qu.:10.800  
##  Max.   :96.20   Max.   :291.3   Max.   :860.6   Max.   :56.100  
##       temp             RH              wind             rain        
##  Min.   : 2.20   Min.   : 15.00   Min.   :0.400   Min.   :0.00000  
```

```
##  1st Qu.:15.50   1st Qu.: 33.00   1st Qu.:2.700   1st Qu.:0.00000
##  Median :19.30   Median : 42.00   Median :4.000   Median :0.00000
##  Mean   :18.89   Mean   : 44.29   Mean   :4.018   Mean   :0.02166
##  3rd Qu.:22.80   3rd Qu.: 53.00   3rd Qu.:4.900   3rd Qu.:0.00000
##  Max.   :33.30   Max.   :100.00   Max.   :9.400   Max.   :6.40000
##       area
##  Min.   :   0.00
##  1st Qu.:   0.00
##  Median :   0.52
##  Mean   :  12.85
##  3rd Qu.:   6.57
##  Max.   :1090.84
```

*The data provides weather and Fire Weather Index values.

*X and Y columns are grids corresponding to the map of Montesinho Natural Park.

*Area provides the amount of area burned in hectares.

The data requires cleaning but from a high level view of the data, it has the requirements needed to provide the required study for **Gold Coast Conservation Group**.

PROCESS: DOCUMENTATION OF ANY CLEANING OR MANIPULATION OF DATA

The data will be cleaned and analyzed with R. Visualizations will be stored in a folder.

CLEANING DATA

Check for NA's.

```
#Verify if Data has NA's

any(is.na(forest_fire_2))
```

```
## [1] FALSE
```

Lower Case Column Names

```
#Lower case column names
forest_fire_2 <- forest_fire_2 %>% rename_with(tolower)

colnames(forest_fire_2)
```

```
##  [1] "x"     "y"     "month" "day"   "ffmc"  "dmc"   "dc"    "isi"   "temp"
## [10] "rh"    "wind"  "rain"  "area"
```

Rename Columns

```
#Rename columns.
#rename rh to relative_humidity
forest_fire_2 <- forest_fire_2 %>% rename(humidity = rh)
colnames(forest_fire_2)
```

```
##  [1] "x"        "y"        "month"    "day"      "ffmc"     "dmc"
##  [7] "dc"       "isi"      "temp"     "humidity" "wind"     "rain"
## [13] "area"
```

Change temperature to Fahrenheit

```
#change temp column to F from C
forest_fire_2$temp <- celsius.to.fahrenheit(forest_fire_2$temp)
summary(forest_fire_2)
```

```
##        x               y           month               day
##  Min.   :1.000   Min.   :2.0   Length:517         Length:517
##  1st Qu.:3.000   1st Qu.:4.0   Class :character   Class :character
##  Median :4.000   Median :4.0   Mode  :character   Mode  :character
##  Mean   :4.669   Mean   :4.3
##  3rd Qu.:7.000   3rd Qu.:5.0
##  Max.   :9.000   Max.   :9.0
##       ffmc            dmc              dc             isi
##  Min.   :18.70   Min.   :  1.1   Min.   :  7.9   Min.   : 0.000
##  1st Qu.:90.20   1st Qu.: 68.6   1st Qu.:437.7   1st Qu.: 6.500
##  Median :91.60   Median :108.3   Median :664.2   Median : 8.400
##  Mean   :90.64   Mean   :110.9   Mean   :547.9   Mean   : 9.022
##  3rd Qu.:92.90   3rd Qu.:142.4   3rd Qu.:713.9   3rd Qu.:10.800
##  Max.   :96.20   Max.   :291.3   Max.   :860.6   Max.   :56.100
##       temp          humidity          wind            rain
##  Min.   :35.96   Min.   : 15.00   Min.   :0.400   Min.   :0.00000
##  1st Qu.:59.90   1st Qu.: 33.00   1st Qu.:2.700   1st Qu.:0.00000
##  Median :66.74   Median : 42.00   Median :4.000   Median :0.00000
##  Mean   :66.00   Mean   : 44.29   Mean   :4.018   Mean   :0.02166
##  3rd Qu.:73.04   3rd Qu.: 53.00   3rd Qu.:4.900   3rd Qu.:0.00000
##  Max.   :91.94   Max.   :100.00   Max.   :9.400   Max.   :6.40000
##       area
##  Min.   :   0.00
##  1st Qu.:   0.00
##  Median :   0.52
##  Mean   :  12.85
##  3rd Qu.:   6.57
##  Max.   :1090.84
```

The temperature column has a high of 91.94 degrees Fahrenheit and a mean of 66.00.

Format and factor the month columns for GGPLOT.

```
#Change month column to date month
format(forest_fire_2$month, format = "%B")
```

```
##   [1] "mar" "oct" "oct" "mar" "mar" "aug" "aug" "aug" "sep" "sep" "sep" "sep"
##  [13] "aug" "sep" "sep" "sep" "mar" "oct" "mar" "apr" "sep" "sep" "jun" "aug"
##  [25] "aug" "aug" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
##  [37] "oct" "oct" "oct" "mar" "jul" "aug" "aug" "sep" "sep" "sep" "sep" "jul"
##  [49] "mar" "mar" "sep" "aug" "aug" "aug" "aug" "sep" "sep" "oct" "feb" "feb"
##  [61] "mar" "mar" "aug" "aug" "aug" "aug" "sep" "sep" "sep" "mar" "mar" "sep"
##  [73] "mar" "aug" "sep" "feb" "feb" "mar" "aug" "aug" "aug" "aug" "aug" "aug"
##  [85] "aug" "sep" "sep" "sep" "sep" "mar" "aug" "mar" "aug" "aug" "aug" "sep"
##  [97] "feb" "mar" "aug" "aug" "aug" "aug" "aug" "sep" "jan" "mar" "mar" "aug"
## [109] "sep" "sep" "mar" "mar" "sep" "sep" "mar" "mar" "mar" "mar" "mar" "aug"
## [121] "aug" "aug" "sep" "sep" "sep" "oct" "mar" "sep" "oct" "oct" "feb" "mar"
## [133] "mar" "sep" "mar" "aug" "sep" "sep" "jul" "sep" "sep" "aug" "aug" "jul"
## [145] "aug" "aug" "mar" "sep" "aug" "sep" "jun" "jul" "jul" "sep" "sep" "aug"
## [157] "sep" "aug" "aug" "sep" "mar" "aug" "mar" "sep" "sep" "mar" "aug" "aug"
## [169] "mar" "aug" "sep" "aug" "aug" "sep" "aug" "aug" "apr" "aug" "sep" "aug"
## [181] "sep" "oct" "feb" "oct" "aug" "sep" "mar" "sep" "mar" "mar" "mar" "aug"
## [193] "aug" "sep" "aug" "aug" "apr" "sep" "sep" "sep" "sep" "mar" "feb" "oct"
## [205] "mar" "sep" "aug" "sep" "sep" "sep" "oct" "aug" "sep" "mar" "mar" "mar"
## [217] "sep" "sep" "sep" "mar" "aug" "sep" "mar" "jul" "sep" "sep" "oct" "aug"
## [229] "sep" "aug" "sep" "sep" "sep" "sep" "sep" "aug" "sep" "sep" "sep" "apr"
## [241] "apr" "apr" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug"
## [253] "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug"
## [265] "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "dec" "dec" "dec"
## [277] "dec" "dec" "dec" "dec" "dec" "dec" "feb" "feb" "feb" "jul" "jul" "jul"
## [289] "jul" "jul" "jul" "jul" "jul" "jul" "jul" "jun" "jun" "jun" "jun" "jun"
## [301] "jun" "jun" "jun" "jun" "may" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
## [313] "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
## [325] "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
## [337] "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
## [349] "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep"
## [361] "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "sep" "jul"
## [373] "aug" "aug" "sep" "sep" "aug" "aug" "mar" "jan" "jul" "aug" "aug" "aug"
## [385] "aug" "aug" "sep" "mar" "aug" "aug" "feb" "sep" "sep" "mar" "feb" "feb"
## [397] "sep" "aug" "aug" "jun" "jun" "sep" "aug" "aug" "sep" "aug" "sep" "feb"
## [409] "sep" "jul" "feb" "feb" "jul" "aug" "aug" "aug" "jul" "mar" "aug" "aug"
## [421] "aug" "aug" "jul" "sep" "aug" "aug" "aug" "aug" "aug" "aug" "sep" "aug"
## [433] "aug" "aug" "aug" "jul" "aug" "aug" "aug" "sep" "sep" "aug" "apr" "jul"
## [445] "sep" "aug" "aug" "mar" "sep" "aug" "aug" "aug" "aug" "aug" "aug" "jul"
## [457] "aug" "aug" "aug" "aug" "aug" "aug" "sep" "feb" "feb" "feb" "mar" "mar"
## [469] "mar" "apr" "apr" "may" "jun" "jun" "jun" "jun" "jul" "jul" "jul" "jul"
## [481] "jul" "jul" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug"
## [493] "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug"
## [505] "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug" "aug"
## [517] "nov"
```

```
#factor months to organize in ggplot
forest_fire_2 <- forest_fire_2 %>% mutate(month = factor(month, levels = c("jan", "feb", "mar", "apr",
```

```r
                                                                         "aug", "sep", "oct", "nov", "dec")

head(forest_fire_2, 2)
```

```
##   x y month day ffmc  dmc    dc isi  temp humidity wind rain area
## 1 7 5   mar fri 86.2 26.2  94.3 5.1 46.76       51  6.7    0    0
## 2 7 4   oct tue 90.6 35.4 669.1 6.7 64.40       33  0.9    0    0
```

Format and factor day column for GGPLOT.

```r
#factor days to organize in plots
forest_fire_2 <- forest_fire_2 %>% mutate(day = factor(day, levels = c("sun", "mon", "tue", "wed", "thu
```

Verified that columns follow same naming conventions. Temperature was changed from Celsius to Fahrenheit. Cleaning process was documented. Additional cleaning might be necessary as we move through the Analyze process.

ANALYZE: SUMMARY OF ANALYSIS

Analyze variable means by month.

```r
#Compare mean of FFMC, DMC, DC, ISI, TEMP AND HUMIDITY, RAIN and AREA by month
forest_fire_2_means <- forest_fire_2 %>% group_by(month) %>%
  summarize(mean_ffmc = mean(ffmc), mean_dmc = mean(dmc), mean_dc = mean(dc),
            mean_isi = mean(isi), mean_temp = mean(temp),mean_wind = mean(wind), mean_humidity = mean(hu


#Change tibble into a dataframe
forest_fire_2_means <- as.data.frame(forest_fire_2_means)

head(forest_fire_2_means, 2)
```

```
##   month mean_ffmc mean_dmc mean_dc mean_isi mean_temp mean_wind mean_humidity
## 1   jan    50.400    2.400   90.35     1.45    41.450     2.000          89.0
## 2   feb    82.905    9.475   54.67     3.35    49.343     3.755          55.7
##   mean_rain mean_area
## 1         0     0.000
## 2         0     6.275
```

Analyze variable standard deviation by month.

```r
#compare standard deviation by month
forest_fire_2_sd <- forest_fire_2 %>% group_by(month) %>%
  summarize(sd_ffmc = sd(ffmc), sd_dmc = sd(dmc), sd_dc = sd(dc),
            sd_isi = sd(isi), sd_temp = sd(temp), sd_humidity = sd(humidity), sd_rain = sd(rain), sd_wi
```

```r
#change tibble into a dataframe
forest_fire_2_sd <- as.data.frame(forest_fire_2_sd)
head(forest_fire_2_sd,2)
```

```
##   month   sd_ffmc   sd_dmc     sd_dc  sd_isi   sd_temp sd_humidity sd_rain
## 1   jan 44.830570 1.838478 114.62201 2.05061 0.1272792    15.55635       0
## 2   feb  4.805531 6.197102  72.73467 1.69969 7.1506327    14.23894       0
##    sd_wind  sd_area
## 1 1.555635  0.00000
## 2 2.345090 12.34251
```

AREA BURNT STANDARD DEVIATION

```r
#Create df to show values of area standard deviation by month
sd_month_area <- forest_fire_2_sd[c("month", "sd_area")]
sd_month_area
```

```
##    month   sd_area
## 1    jan  0.000000
## 2    feb 12.342510
## 3    mar  9.140107
## 4    apr 19.929092
## 5    may 27.209469
## 6    jun 16.884945
## 7    jul 50.849299
## 8    aug 60.364174
## 9    sep 87.648175
## 10   oct 13.699522
## 11   nov        NA
## 12   dec  6.610747
```

*August and September deviate the farthest from the mean of out of all the months from 2000-2003.

FFMC STANDARD DEVIATION

```r
#create df to show values of ffmc standard deviation by month
sd_ffmc_month <- forest_fire_2_sd[c("month", "sd_ffmc")]
sd_ffmc_month
```

```
##    month    sd_ffmc
## 1    jan 44.8305699
## 2    feb  4.8055314
## 3    mar  3.4919134
## 4    apr  3.9307901
## 5    may  3.1819805
## 6    jun  9.4234922
## 7    jul  2.8867030
```

```
## 8    aug  3.3142915
## 9    sep  4.1392866
## 10   oct  2.4011505
## 11   nov         NA
## 12   dec  0.5477226
```

*FFMC in January deviates farthest from the mean from 2000-2003.

DC STANDARD DEVIATION

```r
#create df to show values of dc standard deviation by month
sd_dc_month <- forest_fire_2_sd[c("month", "sd_dc")]
sd_dc_month
```

```
##    month      sd_dc
## 1    jan 114.622009
## 2    feb  72.734666
## 3    mar  24.479253
## 4    apr  28.669980
## 5    may  28.354982
## 6    jun  68.293910
## 7    jul  94.925106
## 8    aug  77.962037
## 9    sep  47.815146
## 10   oct  11.518647
## 11   nov         NA
## 12   dec   1.958387
```

*Drought Code has levels that push the standard deviation far from the mean throughout the year.

*DC and FFMC deviate farthest from the mean the most in January.

RAIN STANDARD DEVIATION

```r
#create df to show values of rain standard deviation by month.
sd_rain_month <- forest_fire_2_sd[c("month", "sd_rain")]
sd_rain_month
```

```
##    month    sd_rain
## 1    jan 0.00000000
## 2    feb 0.00000000
## 3    mar 0.02721655
## 4    apr 0.00000000
## 5    may 0.00000000
## 6    jun 0.00000000
## 7    jul 0.03535534
## 8    aug 0.49437319
## 9    sep 0.00000000
## 10   oct 0.00000000
## 11   nov         NA
## 12   dec 0.00000000
```

*The region gets no rain. The standard deviation does not deviate from the mean throughout the year. There are no instances of heavy rain.

*The natural park went through a severe drought from 2000-2003.

Analyze max in variables by month.

```
#Compare Max of FFMC, DMC, DC, ISI, TEMP, HUMIDITY, RAIN AND AREA BY MONTH

forest_fire_2_max <- forest_fire_2 %>% group_by(month) %>%
  summarize(max_ffmc = max(ffmc), max_dmc = max(dmc), max_dc = max(dc),
            max_isi = max(isi), max_temp = max(temp), max_humidity = max(humidity), max_rain = max(rain

#change forest_fire_max to dataframe
forest_fire_2_max <- as.data.frame(forest_fire_2_max)

#create df to show august and september max area burnt
august_sept_outliers <- forest_fire_2_max[c("month","max_area" )]

#create df to show rain max values by month
rain_outliers <- forest_fire_2_max[c("month", "max_rain")]
august_sept_outliers
```

```
##    month max_area
## 1    jan     0.00
## 2    feb    51.78
## 3    mar    36.85
## 4    apr    61.13
## 5    may    38.48
## 6    jun    70.32
## 7    jul   278.53
## 8    aug   746.28
## 9    sep  1090.84
## 10   oct    49.37
## 11   nov     0.00
## 12   dec    24.77
```

*August and September have two instinces of more than 700 hectares burned.

RAIN MAX VALUES

```
rain_outliers
```

```
##    month max_rain
## 1    jan      0.0
## 2    feb      0.0
## 3    mar      0.2
## 4    apr      0.0
## 5    may      0.0
## 6    jun      0.0
```

```
## 7    jul      0.2
## 8    aug      6.4
## 9    sep      0.0
## 10   oct      0.0
## 11   nov      0.0
## 12   dec      0.0
```

*August gets the most rain at 0.25 mm from 2000-2003.

Create data frames for the months of August and September.

```r
#Create a dataframe out of August and September values
forest_fire_2_aug <- forest_fire_2[forest_fire_2$month == "aug", ]


forest_fire_2_sep <- forest_fire_2[forest_fire_2$month == "sep", ]


forest_fire_2_aug <- as.data.frame(forest_fire_2_aug)
forest_fire_2_sep <- as.data.frame(forest_fire_2_sep)
```

Create data frames from means data frame for dmc to plot in ggplot

```r
#Create data frame from means data frame for dmc to plot in  ggplot
dmc_2_months <- c("Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug",
                "Sep", "Oct", "Nov", "Dec")

dmc_2_values <- c(2.4000, 9.47500, 34.54259, 15.91111, 26.70000, 93.38235, 110.38750, 153.73261,
                120.92267, 41.42000, 3.00000, 26.12222)


dmc_2_means <- data.frame(dmc_2_months, dmc_2_values)

dmc_2_means <- dmc_2_means %>% mutate(dmc_2_months = factor(dmc_2_months, levels = c("Jan", "Feb", "Mar
                                                                      "Aug", "Sep", "Oct", "Nov", "Dec
```

Create data frame from dc means to plot in ggplot

```r
#create dataframe for dc means to plot in ggplot
dc_2_months <- c("Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug",
                "Sep", "Oct", "Nov", "Dec")

dc_2_values <- c(90.35000, 54.67000, 75.94259,  48.55556,  93.75000, 297.70588, 450.60312, 641.07772,
               734.61570, 681.67333, 106.70000, 351.24444)


dc_2_means <- data.frame(dc_2_months, dc_2_values)
```

```
dc_2_means <- dc_2_means %>% mutate(dc_2_months = factor(dc_2_months, levels = c("Jan", "Feb", "Mar", "
                                                                            "Aug", "Sep", "Oct", "Nov"
```

Create data frame from meand data frame for ffmc to plot in ggplot

```
#create data frame from means data frame for ffmc to plot in ggplot

ffmc_2_months <- c("Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug",
               "Sep", "Oct", "Nov", "Dec")

ffmc_2_values <- c(50.40000, 82.90500, 89.44444, 85.78889, 87.35000, 89.42941, 91.32812, 92.33696, 91.2
                 90.45333, 79.50000, 84.96667)


ffmc_2_means <- data.frame(ffmc_2_months, ffmc_2_values)

ffmc_2_means <- ffmc_2_means %>% mutate(ffmc_2_months = factor(ffmc_2_months, levels = c("Jan", "Feb",
                                                                        "Aug", "Sep", "Oct", "Nov", "De
```

Create dataframe from means data frame to plot ISI in ggplot

```
#Creating a dataframe for ISI


isi_2_months <- c("Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug",
                 "Sep", "Oct", "Nov", "Dec")

isi_2_values <- c(1.450000, 3.350000, 7.107407, 5.377778, 4.600000, 11.776471,9.393750, 11.072283,
                8.577326, 7.146667, 1.100000, 3.466667)


isi_2_means <- data.frame(isi_2_months, isi_2_values)

isi_2_means <- isi_2_means %>% mutate(isi_2_months = factor(isi_2_months, levels = c("Jan", "Feb", "Mar
                                                                              "Aug", "Sep", "Oct", "
```

```
#Which sectors have the highest frequency of fires in x?
forest_fire_2_frequency_x <- aggregate(area ~ month + x , forest_fire_2, FUN = "length")
head(forest_fire_2_frequency_x, 2)
```

```
##   month x area
## 1   mar 1    1
## 2   jul 1    3
```

Which sectors have the highest frequency of fires in y?

```
#Which sectors have the highest frequency of fires in y by month?
forest_fire_2_freq_area_y <- aggregate(area ~  y, forest_fire_2, FUN = "length")
forest_fire_2_freq_area_y
```

```
##   y area
## 1 2   44
## 2 3   64
## 3 4  203
## 4 5  125
## 5 6   74
## 6 8    1
## 7 9    6
```

Y runs vertically in the montesinho map. Y has 8 sectors and begins with sector 2. Sectors 4 and 5 are the regions with the highest frequency of fires.

Which sectors have the highest frequency of fires in x?

```
#Which sectors have the highest frequency of fires in x
forest_fire_2_freq_area_x <- aggregate(area ~ x, forest_fire_2, FUN = "length")
forest_fire_2_freq_area_x
```

```
##   x area
## 1 1   48
## 2 2   73
## 3 3   55
## 4 4   91
## 5 5   30
## 6 6   86
## 7 7   60
## 8 8   61
## 9 9   13
```

X has nine sectors and it runs horizontally. Sector 4 has the highest frequency of forest fires followed by sector 6.

```
#aggregate the number of forest fires in sectors x and y
forest_fire_2_xy_area <- aggregate(area ~x +y, forest_fire_2, FUN = "length")
```

```
#aggregate the mean dc and dmc levels by region
forest_fire_2_xy_dmc_dc <- aggregate(dmc ~dc +x +y, forest_fire_2, FUN = "mean")
```

```
#aggregating the mean isi and ffmc levels by region
forest_fire_2ffmc_isi <- aggregate(ffmc~isi +x +y, forest_fire_2, FUN = "mean")
```

DELIVERABLE: SUMMARY OF ANALYSIS

What time of year has the most forest fires?

August and September are the months with the most forest fires. The summer season in Portugal begins in June and ends in September. August is the official summer month in Portugal and people in Portugal vacation the most in August and continue to September. Park visitations by tourists and vacationers may be the reason as to why there are so many forest fires in August in September.

```
#What is the count of fires per month in the dataset?
forest_fire_2_area_count <- aggregate(area ~ month, forest_fire_2, FUN = "length")
forest_fire_2_area_count <- as.data.frame(forest_fire_2_area_count)
forest_fire_2_area_count
```

```
##    month area
## 1    jan    2
## 2    feb   20
## 3    mar   54
## 4    apr    9
## 5    may    2
## 6    jun   17
## 7    jul   32
## 8    aug  184
## 9    sep  172
## 10   oct   15
## 11   nov    1
## 12   dec    9
```

Which days of the week have the most forest fires?

Sunday(95), Friday(85), and Saturday(84) are days of the week when forest fires occur. This supports the conclusion that park visitation is one of the main reasons for forest fires in Montesinho Natural Park since there is a jump in forest fires on the weekend.

```
#What is the count of fires per days of the week?
forest_fire_2_area_day <- aggregate(area ~ day, forest_fire_2, FUN = "length")
forest_fire_2_area_day
```

```
##   day area
## 1 sun   95
## 2 mon   74
## 3 tue   64
## 4 wed   54
## 5 thu   61
## 6 fri   85
## 7 sat   84
```

What is the breakdown for frequency of forest fires in the month of August?

In August, Sunday jumps is the day with the most number of forest fires. Saturday comes in second.

```r
# aggregate burned by day of week in aug and sep
forest_fire_2_aug_count <- aggregate(area ~ day, forest_fire_2_aug, FUN = "length")
forest_fire_2_aug_count <- as.data.frame(forest_fire_2_aug_count)
forest_fire_2_aug_count
```

```
##   day area
## 1 sun   40
## 2 mon   15
## 3 tue   28
## 4 wed   25
## 5 thu   26
## 6 fri   21
## 7 sat   29
```

What is the breakdown for frequency of forest fires in the month of September?

In September Friday has a significant number of fires compared with the rest of the week. Sunday ranks third behind Monday and Saturday is fourth.

```r
#september
forest_fire_2_sep_count <- aggregate(area ~ day, forest_fire_2_sep, FUN = "length")
forest_fire_2_sep_count <- as.data.frame(forest_fire_2_sep_count)
forest_fire_2_sep_count
```

```
##   day area
## 1 sun   27
## 2 mon   28
## 3 tue   19
## 4 wed   14
## 5 thu   21
## 6 fri   38
## 7 sat   25
```

What role did climate play in causing forest fires in Montesinho Natural Park from 2000-2003?

September has the highest mean for humidity. The region is not getting rain. August has the highest mean for rain but it's less than an inch. July and August are the hottest months of the year but the average temperature is less than 72 degrees Fahrenheit. The region averages winds of 2 mph for most of the year. The main takeaway from the climate is the lack of rain the natural park received from 2000 - 2003. The climate caused a severe drought from 2000-2003.

How combustible is the soil by August and September?

FFMC averages above 80 starting in January. FFMC is most accurate above 80 and the severe humidity in January combined with the lack of rain creates brush, needles, grass that is primed to burn.

DC measures drought and the index rapidly climbs in June. Throughout the summer months and into October, the drought index is high and represents drying deep into the soil which impacts Duff Moisture Code(DMC) which is a fuel index of decomposed organic material underneath litter. DMC rapidly climbs in June and stays high into September.

According to the FWI Fuel Moisture Codes, the soil, brush, needles in mid to deep layers indicate dry conditions that are at their highest in August and September.

What is the total number of Hectares burnt from 2000-2003?

```
#What is the total number of hecters burnt from 2000-2003?
hectares_burnt <- sum(forest_fire_2$area)
hectares_burnt
```

```
## [1] 6642.05
```

What Regions in the park have the most forest fires?

The regions that have the most number of forest fires are section 4 on the Y axis and intersecting regions 1 to 5 and 7 on the X axis.

Note: The plot resembles how the forest fire map is laid out and explains the purpose of x and y columns. The plot is inversed with the x axis at the top and the y axis descending on the left. To clarify which regions burn more frequently, a legend is added. The legend identifies the areas with the most forest fires by coloring them in a darker red and by assigning a plot with a bigger area. The objective of the plot is to place it on top of the map. The transformation will be carried out on Adobe Illustrator.

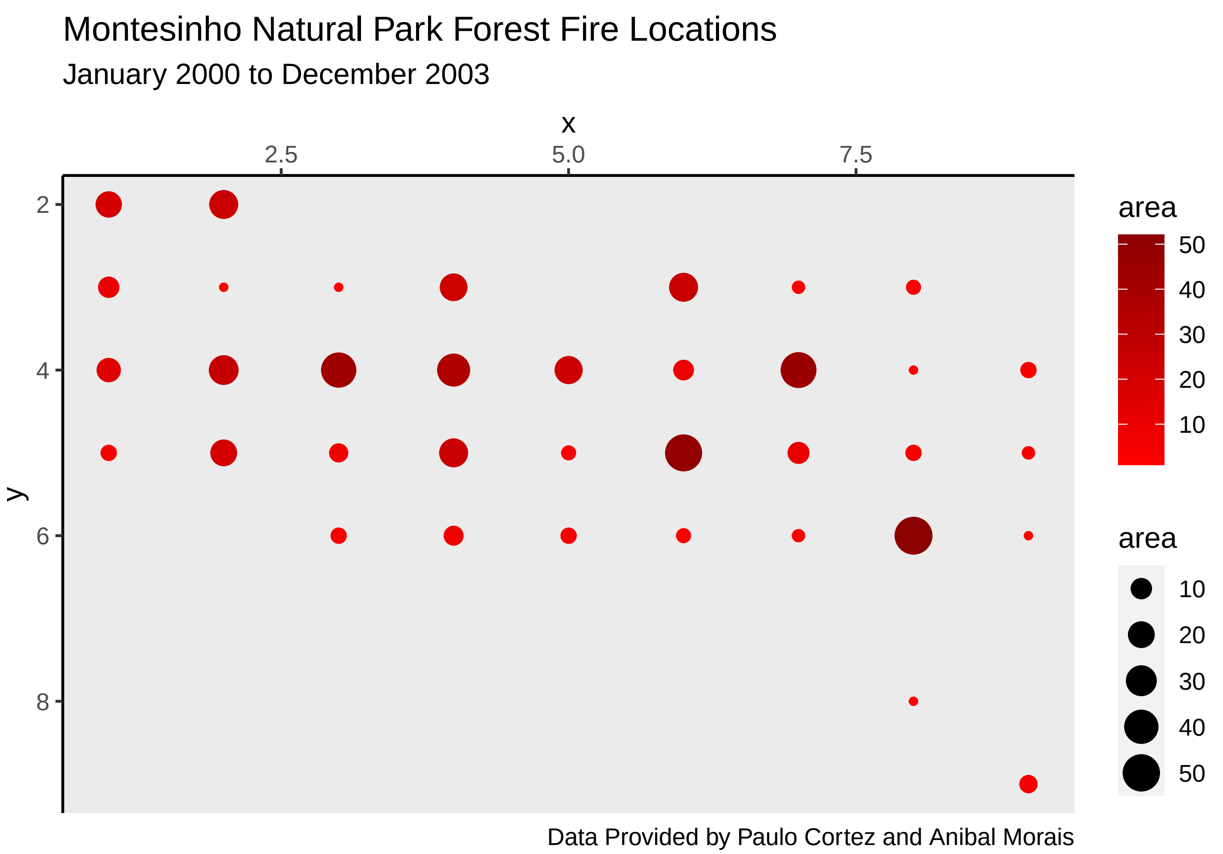
```
#Plot forest_fire_xy_area
#Create color pallete
fun_color_range <- colorRampPalette(c("red", "darkred"))
my_colors <- fun_color_range(100)

#plot fire locations flip x and y axis to top and include labels
ggp <- ggplot(forest_fire_2_xy_area, aes(x = x, y = y, color = area, size = area)) + geom_point()+ scal
  scale_y_continuous(breaks = scales::pretty_breaks(n = 10))+ scale_y_reverse()+scale_x_continuous(posi
```

```
## Scale for 'y' is already present. Adding another scale for 'y', which will
## replace the existing scale.
```

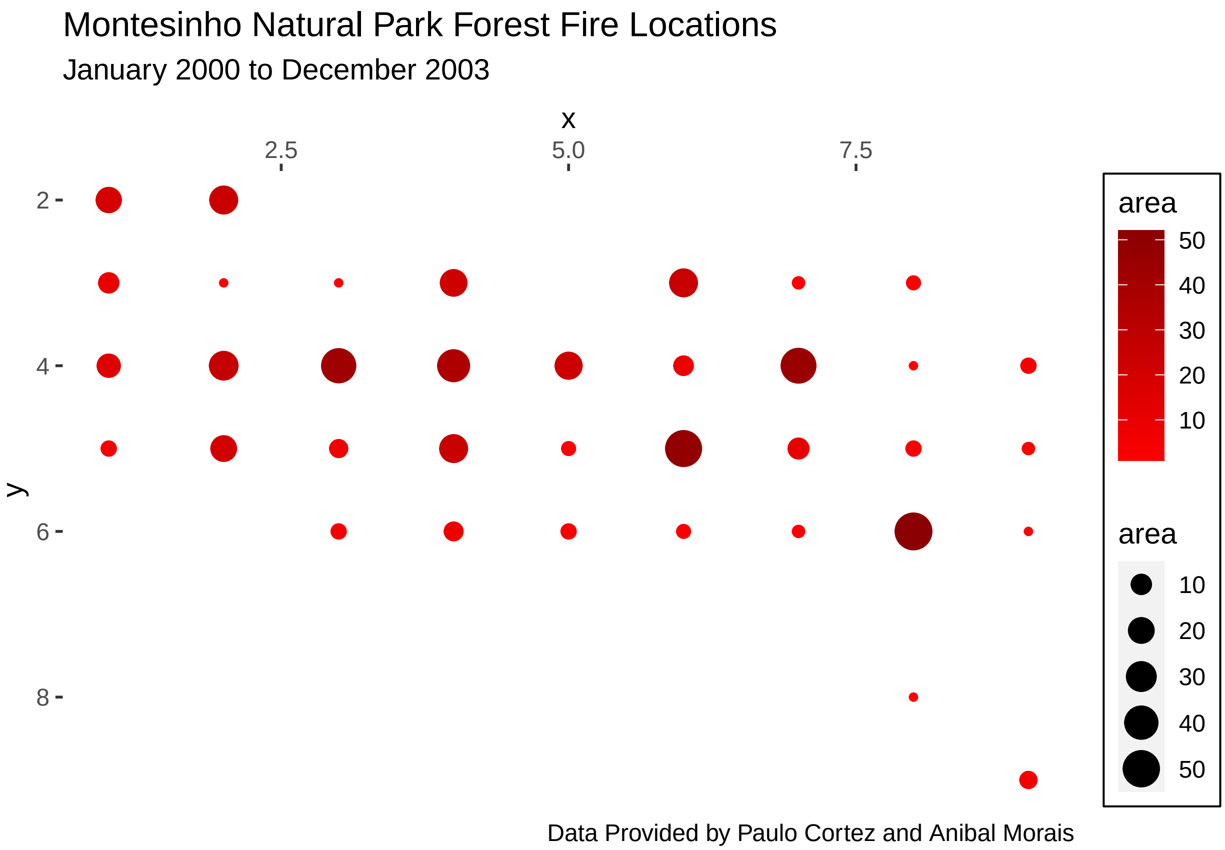
```
## Scale for 'x' is already present. Adding another scale for 'x', which will
## replace the existing scale.
```

```
#change color to red scale and remove ggplot grid lines
ggp + scale_colour_gradientn(colors = my_colors) +theme(
  # Hide panel borders and remove grid lines
  panel.border = element_blank(),
  panel.grid.major = element_blank(),
```

```
  panel.grid.minor = element_blank(),
  # Change axis line
  axis.line = element_line(colour = "black"))
```




```
#remove gridlines in background of plot
ggp + scale_colour_gradientn(colors = my_colors) + theme(
  panel.background = element_rect(fill='transparent'),
  plot.background = element_rect(fill='transparent', color=NA),
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  legend.background = element_rect(fill='transparent'),
  legend.box.background = element_rect(fill='transparent')
)
```



What is the relationship between fuel index levels and forest fire locations?

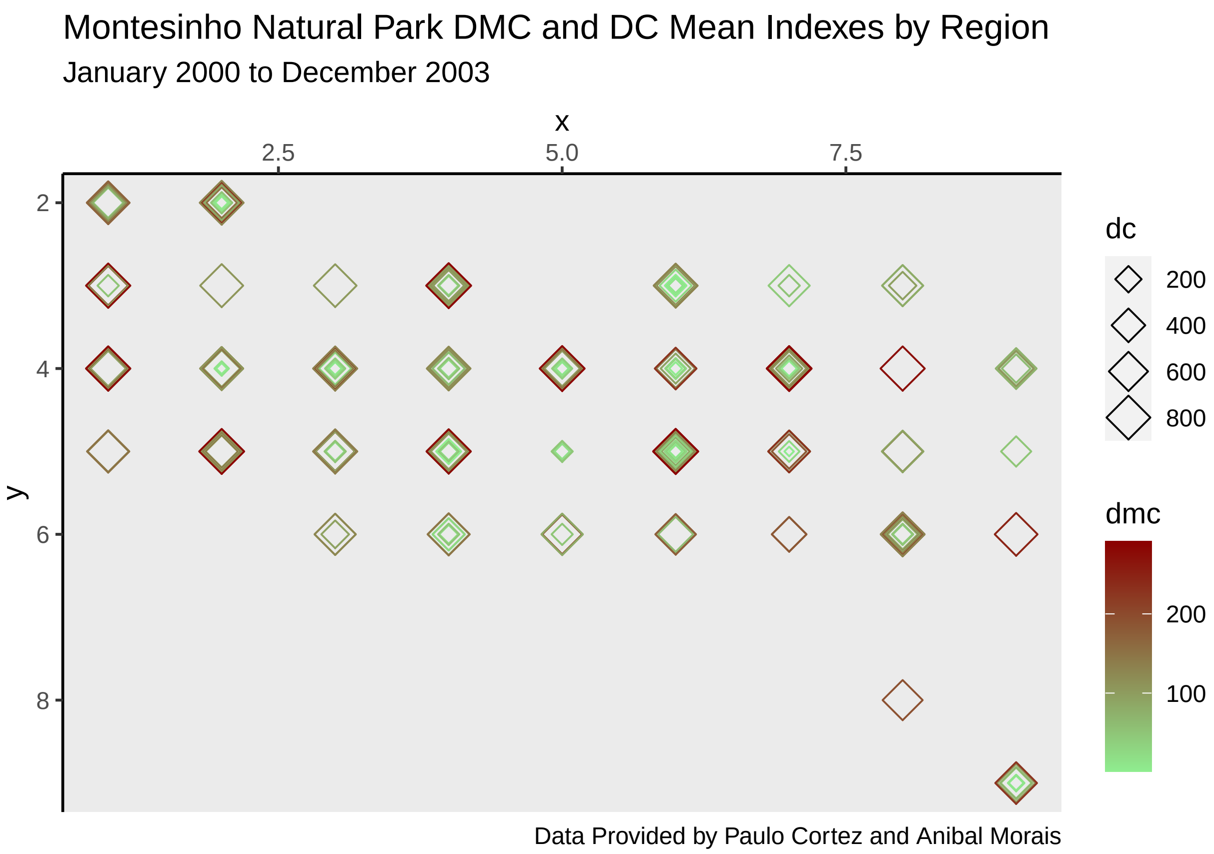
DC levels are high all throughout the park. The DMC hot zones are in the middle of the park along region 4 in the y axis and intersecting regions 1 and 3-6 on the x-axis. There are other surrounding hot spots in region 3 and 5 on the y axis. The DC and DMC hot zones correspond with the pattern of the most frequent forest fire locations.

```
#Create green color pallete
fun_color_range2 <- colorRampPalette(c("lightgreen", "darkred"))
my_colors2 <- fun_color_range2(100)

#plot data
ggp2 <- ggplot(forest_fire_2_xy_dmc_dc, aes(x = x, y = y, color = dmc, size = dc)) + geom_point(shape =
  scale_y_continuous(breaks = scales::pretty_breaks(n = 10))+ scale_y_reverse()+scale_x_continuous(posi
```

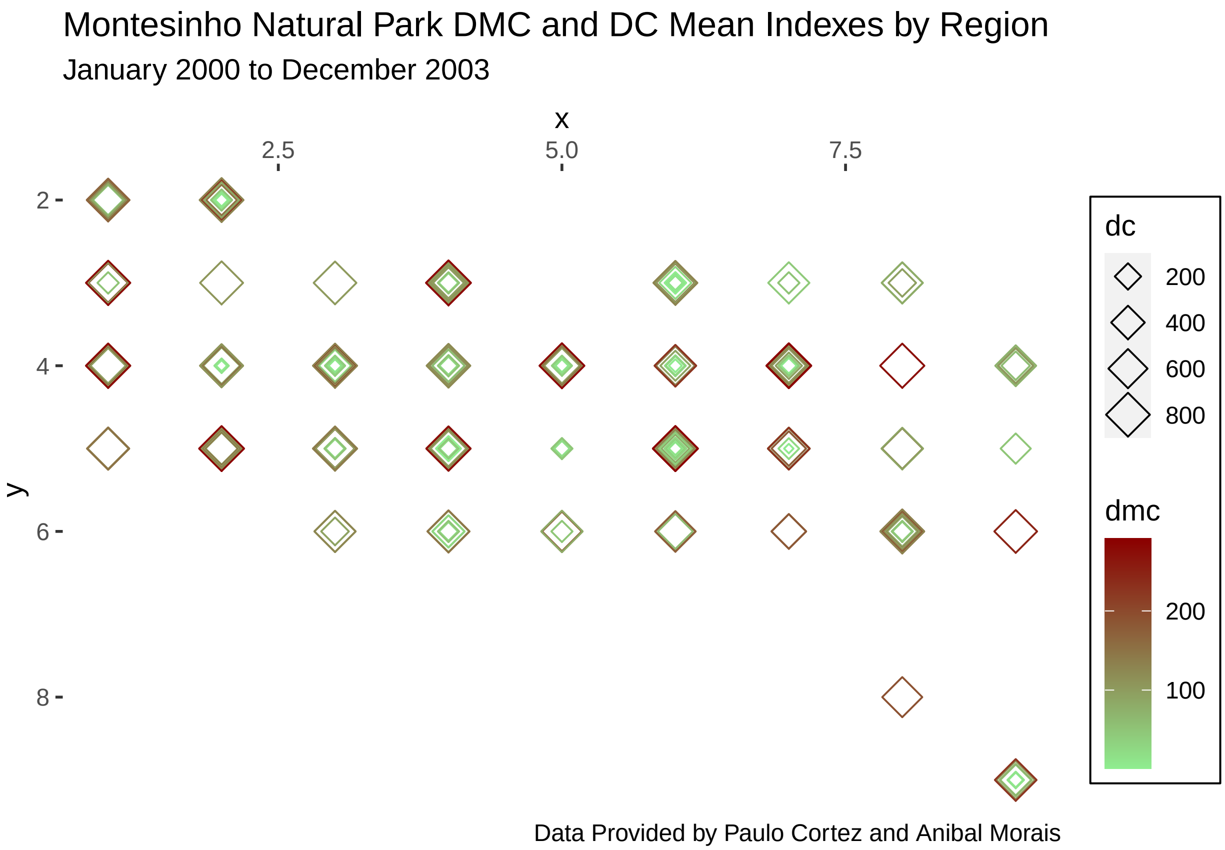
```
## Scale for 'y' is already present. Adding another scale for 'y', which will
## replace the existing scale.
```

```
## Scale for 'x' is already present. Adding another scale for 'x', which will
## replace the existing scale.
```

```r
ggp2 + scale_colour_gradientn(colors = my_colors2) +theme(
  # Hide panel borders and remove grid lines
  panel.border = element_blank(),
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  # Change axis line
  axis.line = element_line(colour = "black"))
```




```r
#make transparent background
#remove grid lines in background of plot
ggp2 + scale_colour_gradientn(colors = my_colors2) + theme(
  panel.background = element_rect(fill='transparent'),
  plot.background = element_rect(fill='transparent', color=NA),
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  legend.background = element_rect(fill='transparent'),
  legend.box.background = element_rect(fill='transparent')
)
```



FFMC and ISI in the Park

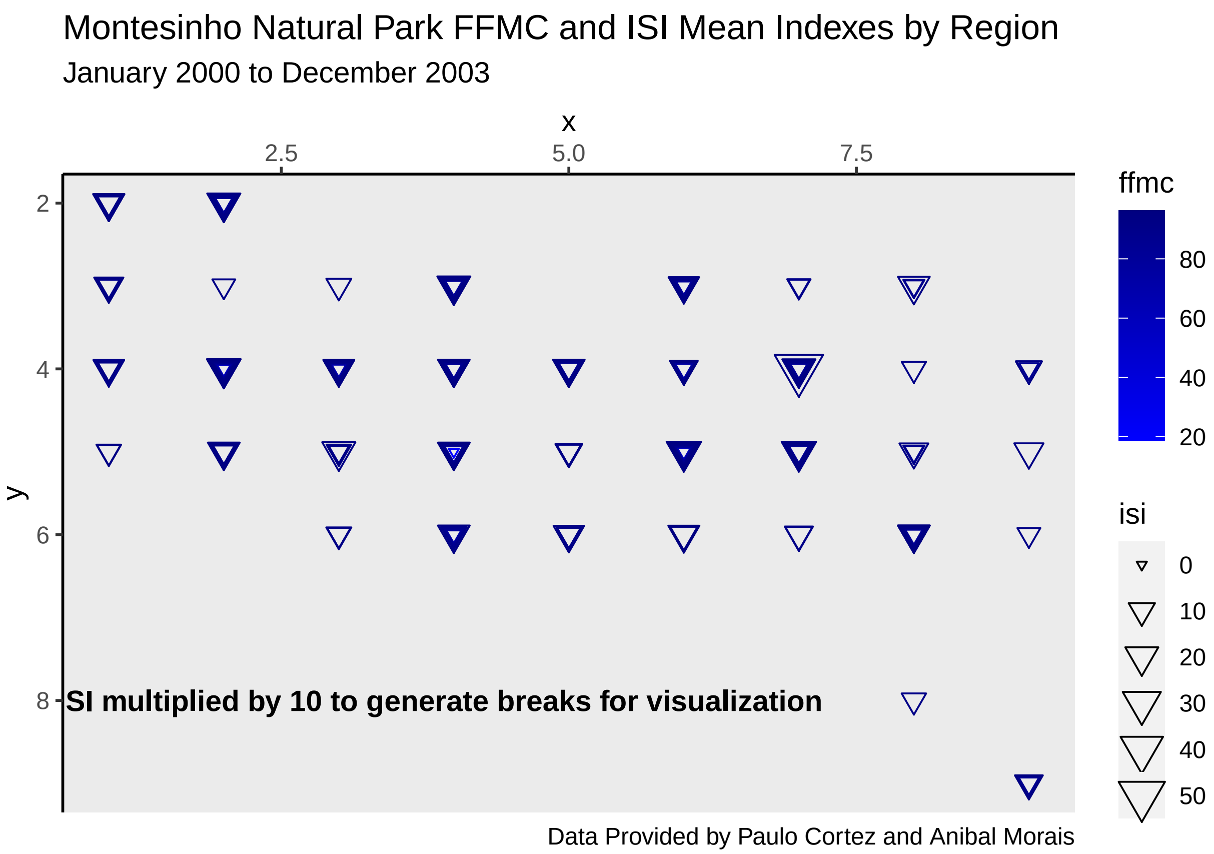
FFMC and ISI have the same pattern as DC/DMC and the regions with the most forest fires. Region 4 on the y axis and intersecting regions 1 -7 on the x axis.

```
#create blue color palette
fun_colorrange3 <- colorRampPalette(c("blue", "navy"))
mycolors3 <- fun_colorrange3(20)

#plot data
ggp3 <- ggplot(forest_fire_2ffmc_isi, aes(x = x, y = y, color = ffmc, size = isi)) + geom_point(shape =
  scale_y_continuous(breaks = scales::pretty_breaks(n = 1))+ scale_y_reverse()+scale_x_continuous(posit
```

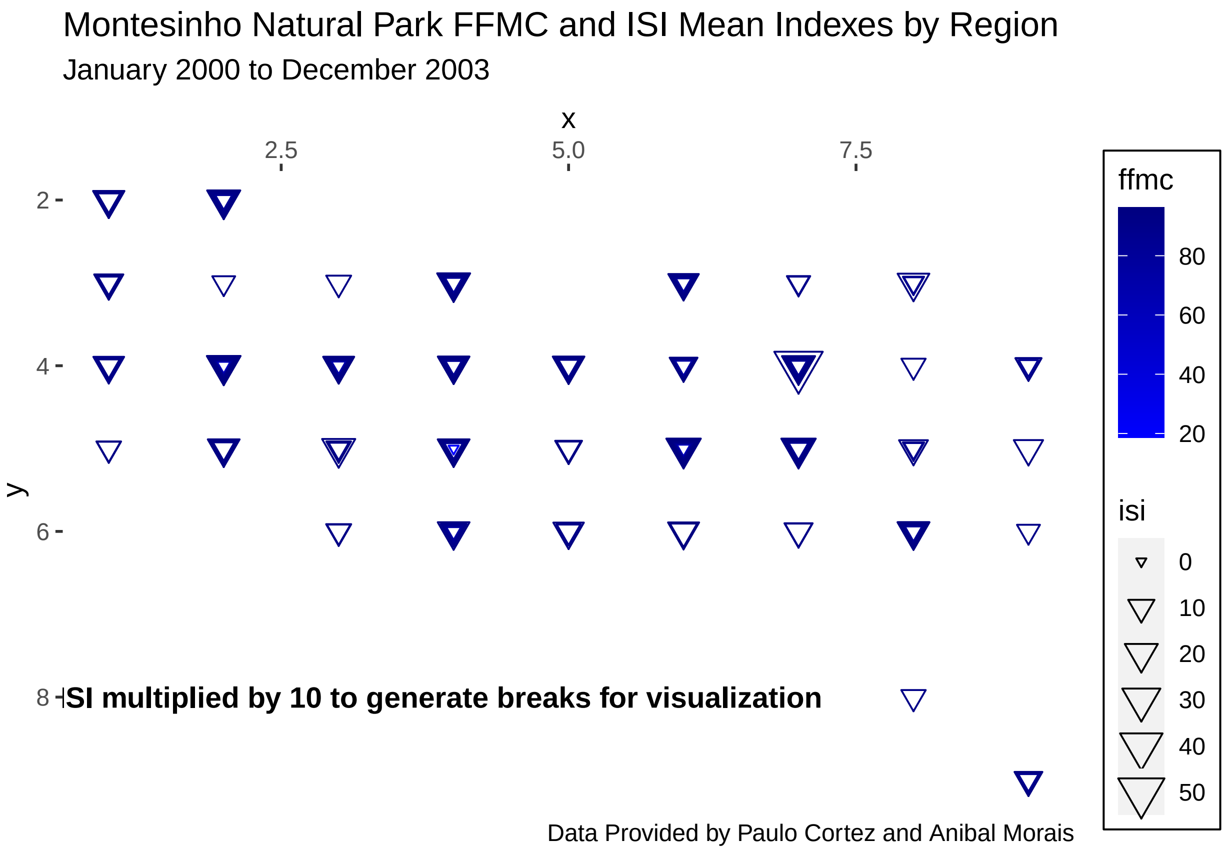
```
## Scale for 'y' is already present. Adding another scale for 'y', which will
## replace the existing scale.

## Scale for 'x' is already present. Adding another scale for 'x', which will
## replace the existing scale.
```

```
#flip axis and insert size and color schemes
ggp3 + scale_colour_gradientn(colors = mycolors3) +theme(
  # Hide panel borders and remove grid lines
  panel.border = element_blank(),
```

```
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  # Change axis line
  axis.line = element_line(colour = "black"))
```



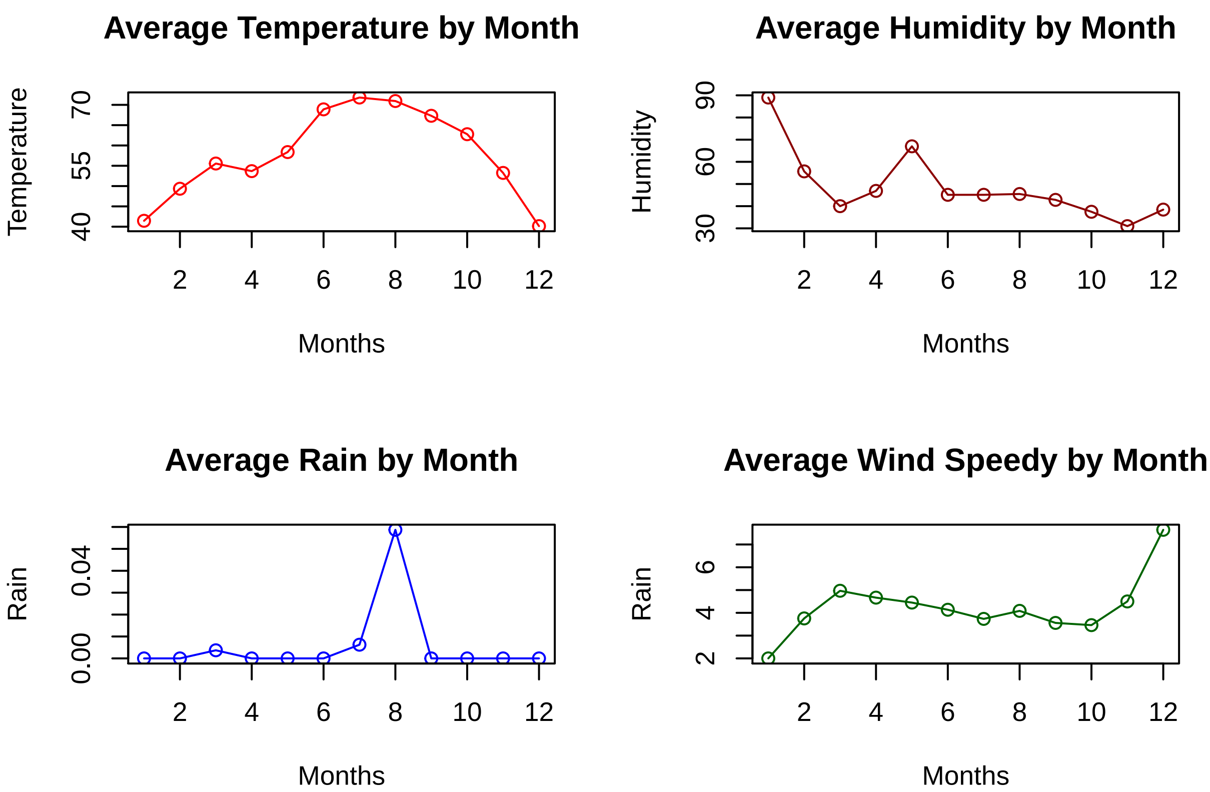

```
#change background to transparent
ggp3 + scale_colour_gradientn(colors = mycolors3) + theme(
  panel.background = element_rect(fill='transparent'),
  plot.background = element_rect(fill='transparent', color=NA),
  panel.grid.major = element_blank(),
  panel.grid.minor = element_blank(),
  legend.background = element_rect(fill='transparent'),
  legend.box.background = element_rect(fill='transparent')
)
```



SHARE:SUPPORTING VISUALIZATIONS AND KEY FINDINGS

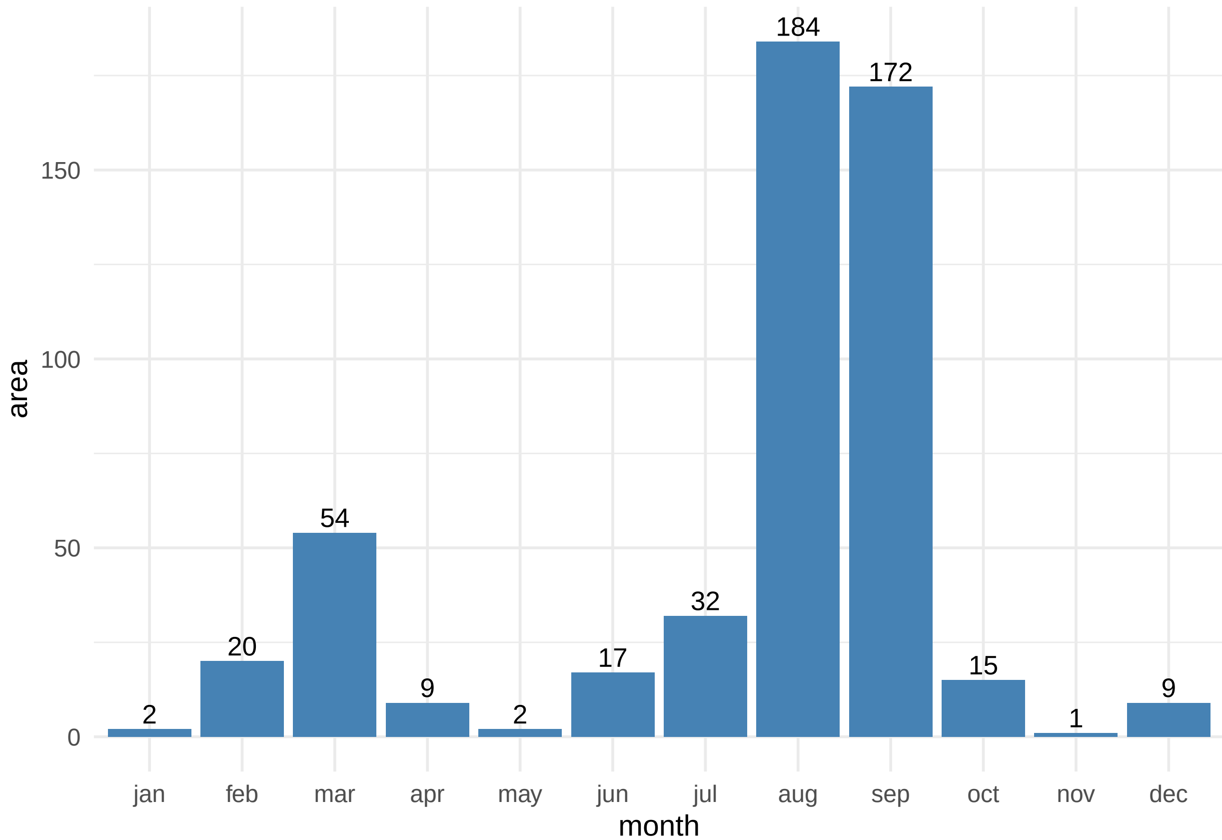
WAS THERE A DROUGHT FROM 2000 - 2003?

```
par(mfrow = c(2,2))
m5 <- tapply(forest_fire_2$temp, list(forest_fire_2$month), mean)
plot(m5, main = "Average Temperature by Month", type = "o", xlab = "Months", ylab = "Temperature", col =

m6 <- tapply(forest_fire_2$humidity, list(forest_fire_2$month), mean)
plot(m6, main = "Average Humidity by Month", type = "o", xlab = "Months", ylab = "Humidity", col = "dar

m7 <- tapply(forest_fire_2$rain, list(forest_fire_2$month), mean)
plot(m7, main = "Average Rain by Month", type = "o", xlab = "Months", ylab = "Rain", col = "blue")

m8 <- tapply(forest_fire_2$wind, list(forest_fire_2$month), mean)
plot(m8, main = "Average Wind Speedy by Month", type = "o", xlab = "Months", ylab = "Rain", col = "dark
```

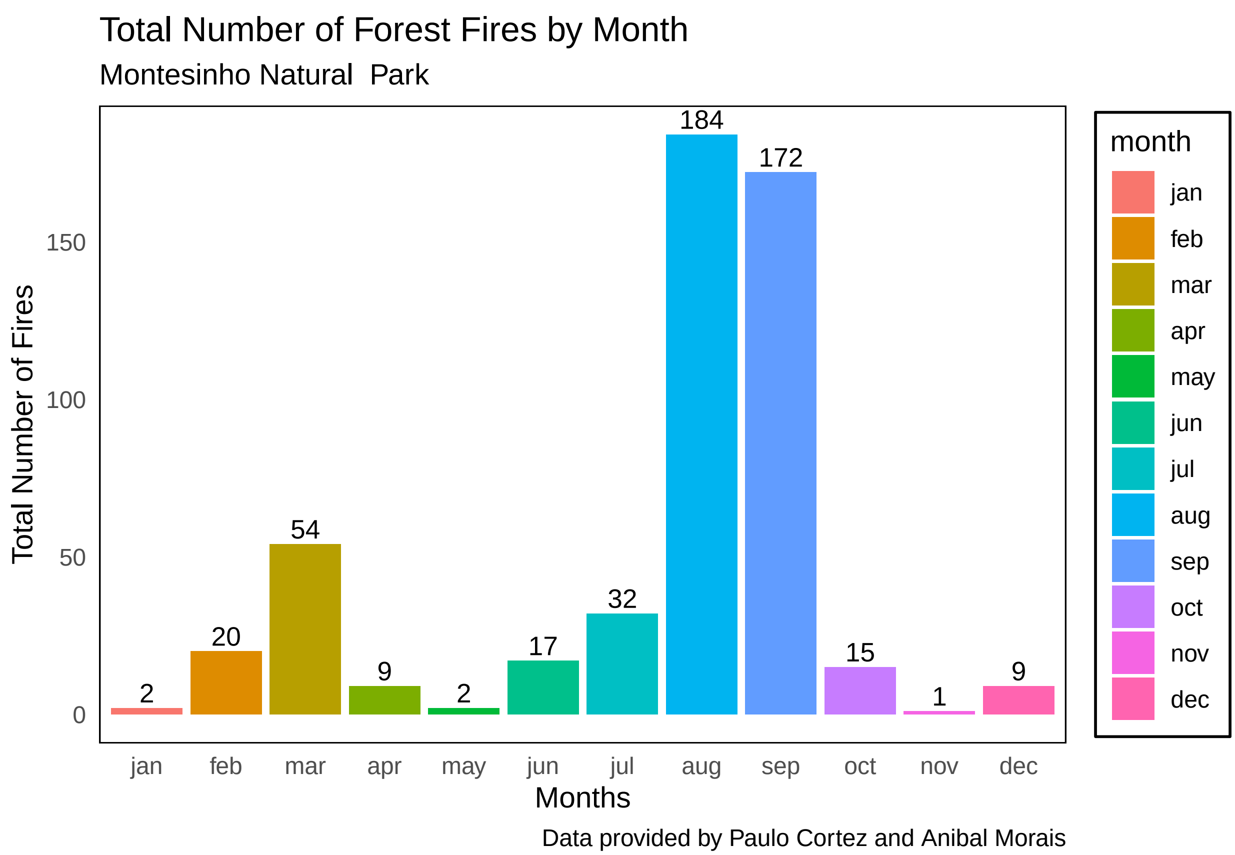


ARE VISITORS THE CAUSE OF FOREST FIRES?

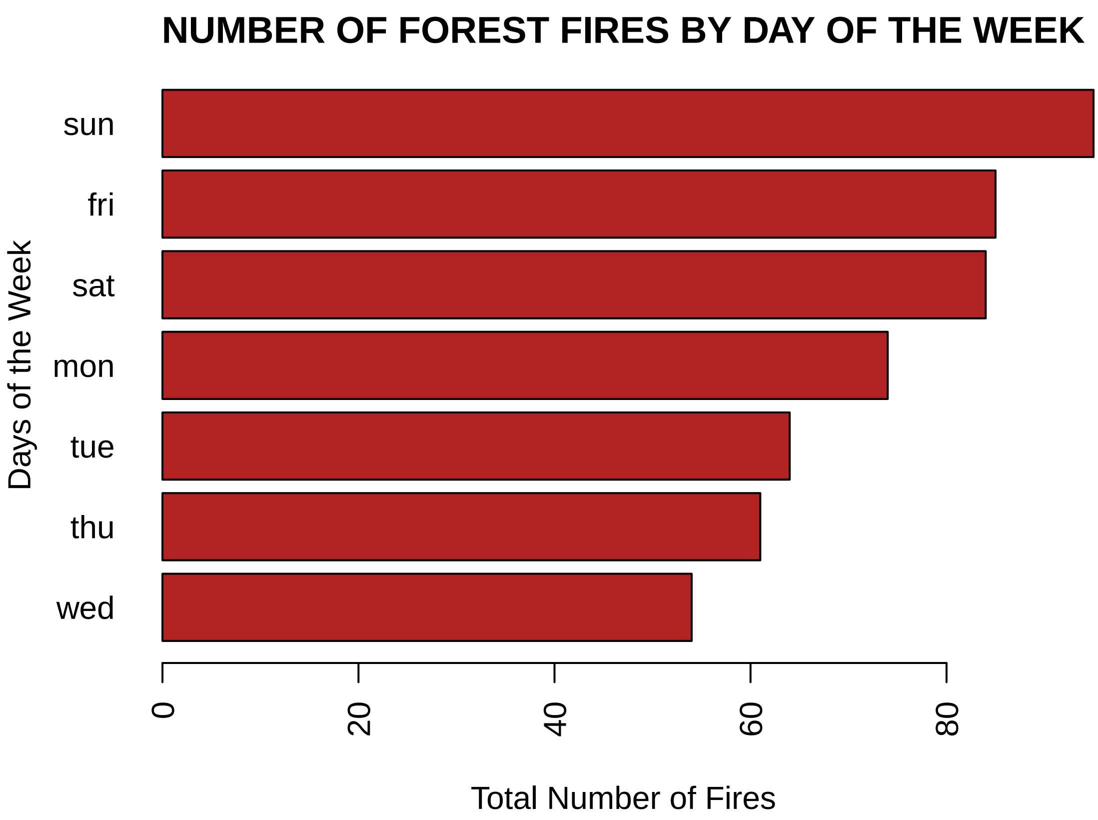
```r
#Plotting number of forest fires by month
fm <- ggplot(forest_fire_2_area_count, aes(x = month, y = area))
fm + geom_bar(stat = "identity", fill = "steelblue") +
  geom_text(aes(label = area), vjust = -0.3, size = 3.5) +
  theme_minimal()
```




```
fm + geom_bar(aes(fill = month), stat = "identity") +
  geom_text(aes(label = area), vjust = -0.3, size = 3.5) +
  theme_minimal() +
  labs(y = "Total Number of Fires", x = "Months", title = "Total Number of Forest Fires by Month", subt
  theme(
    panel.background = element_rect(fill='transparent'),
    plot.background = element_rect(fill='transparent', color=NA),
    panel.grid.major = element_blank(),
    panel.grid.minor = element_blank(),
    legend.background = element_rect(fill='transparent'),
    legend.box.background = element_rect(fill='transparent')
  )
```

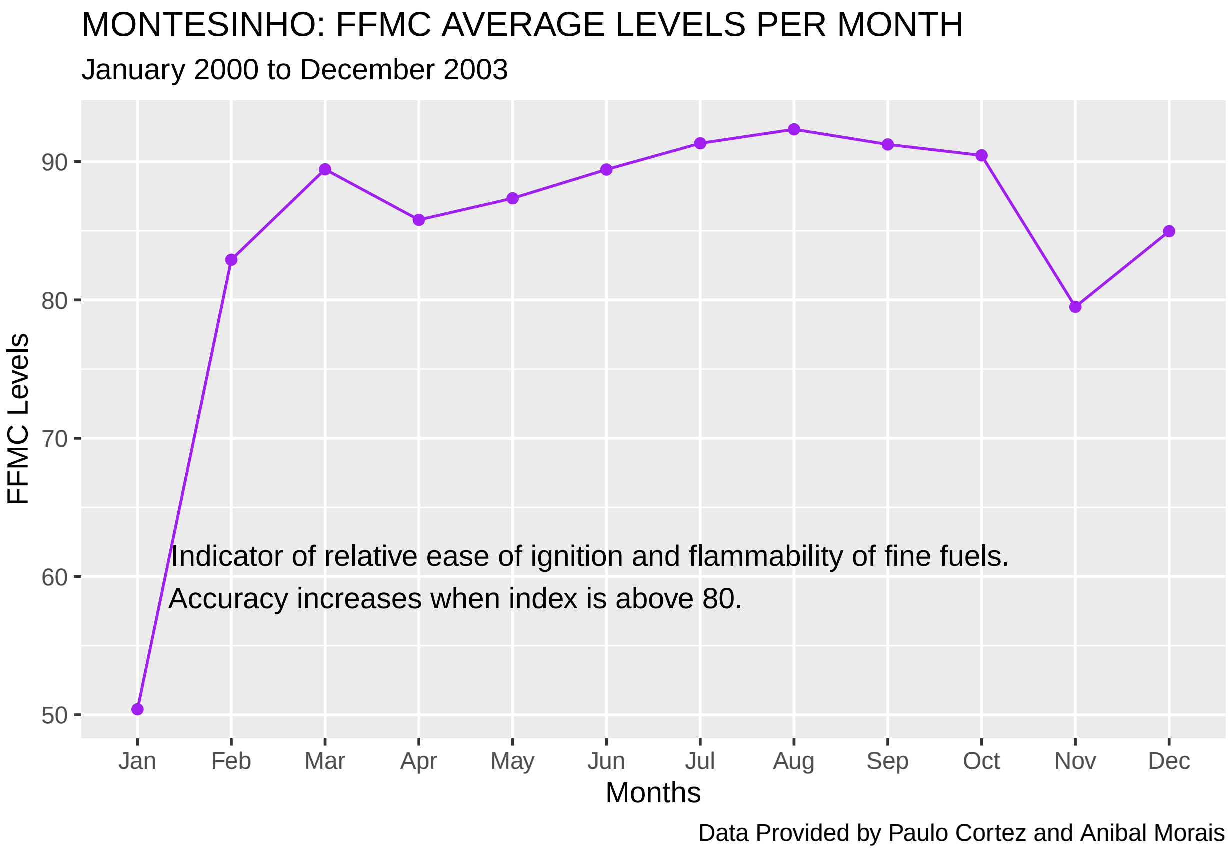



```
fire_desc_2 <- forest_fire_2_area_day[order(forest_fire_2_area_day$area, decreasing=FALSE),]
par(mar=c(5, 6, 2, 2))
barplot(fire_desc_2$area, names.arg=fire_desc_2$day, las = 2,
        horiz = TRUE, cex.names=1, cex.axis=1, col = "#b22222", xlab = "Total Number of Fires",
        ylab = "Days of the Week", main = "NUMBER OF FOREST FIRES BY DAY OF THE WEEK")
```

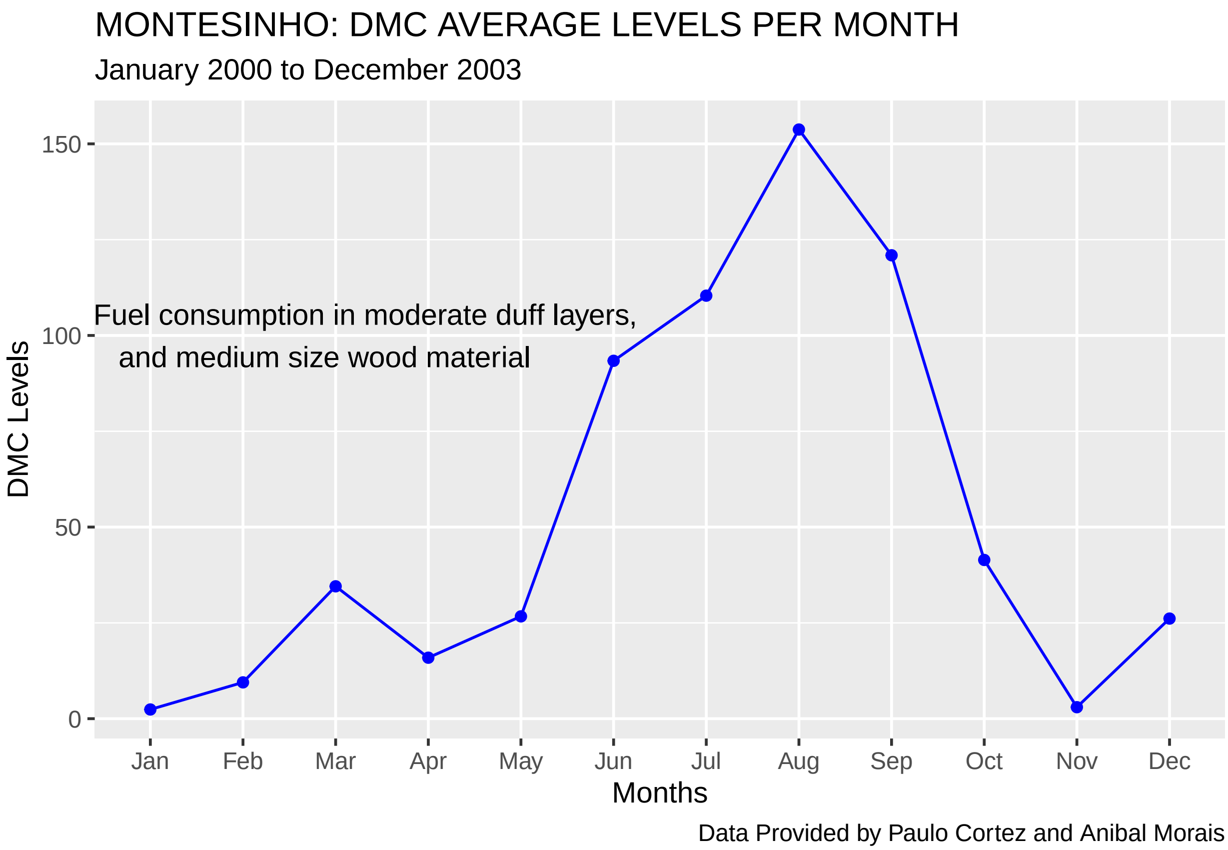


HOW COMBUSTIBLE IS THE SOIL BY AUGUST AND SEPTEMBER?

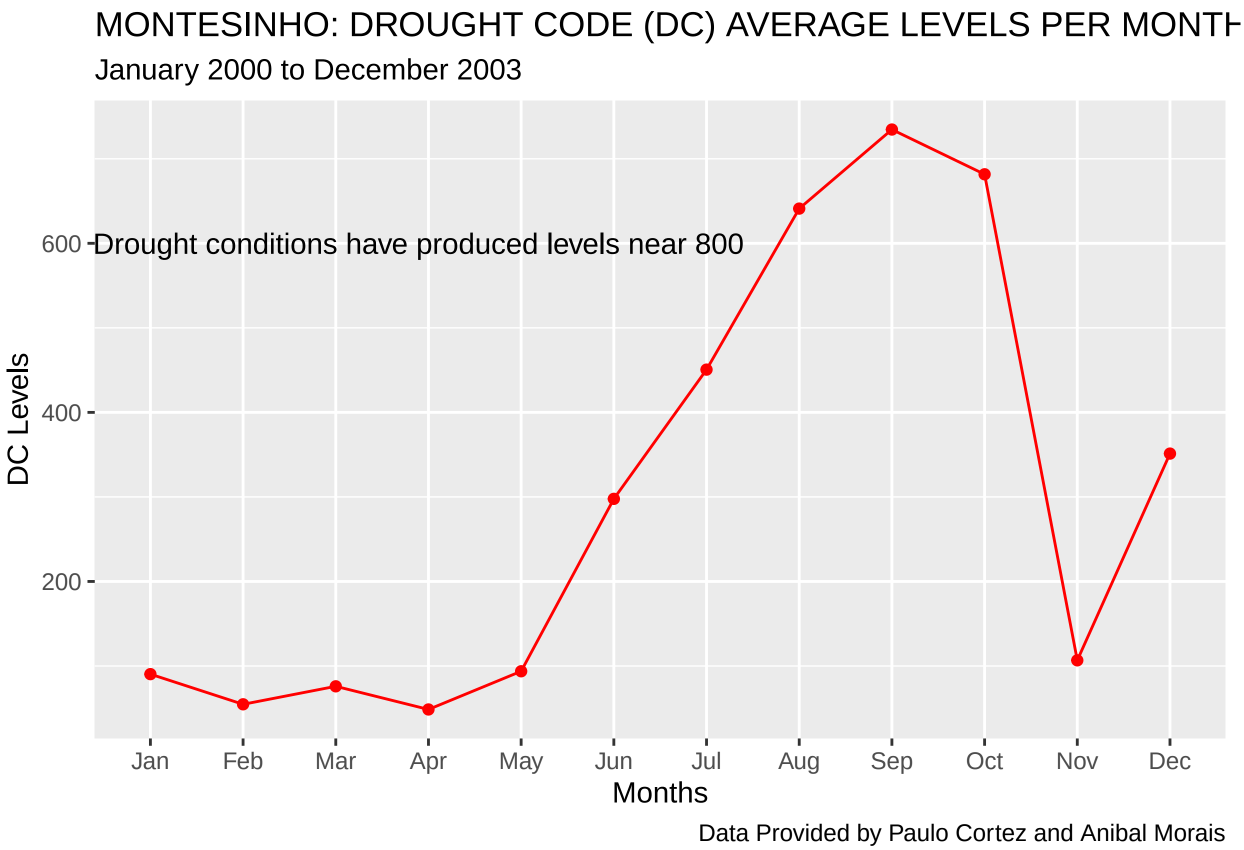
```
ffmc_gplot <- ggplot(ffmc_2_means, aes(x = ffmc_2_months, y = ffmc_2_values, group = 1)) +
  geom_line(color = "purple") +
  geom_point(color = "purple") + labs(y = "FFMC Levels", x = "Months", title = "MONTESINHO: FFMC AVERAG
                                   subtitle = "January 2000 to December 2003",
                                   caption = "Data Provided by Paulo Cortez and Anibal Morais")

ffmc_gplot + annotate("text", x= 2, y = 60, label = "
                                                       Accuracy increases when index is above 80.")
```



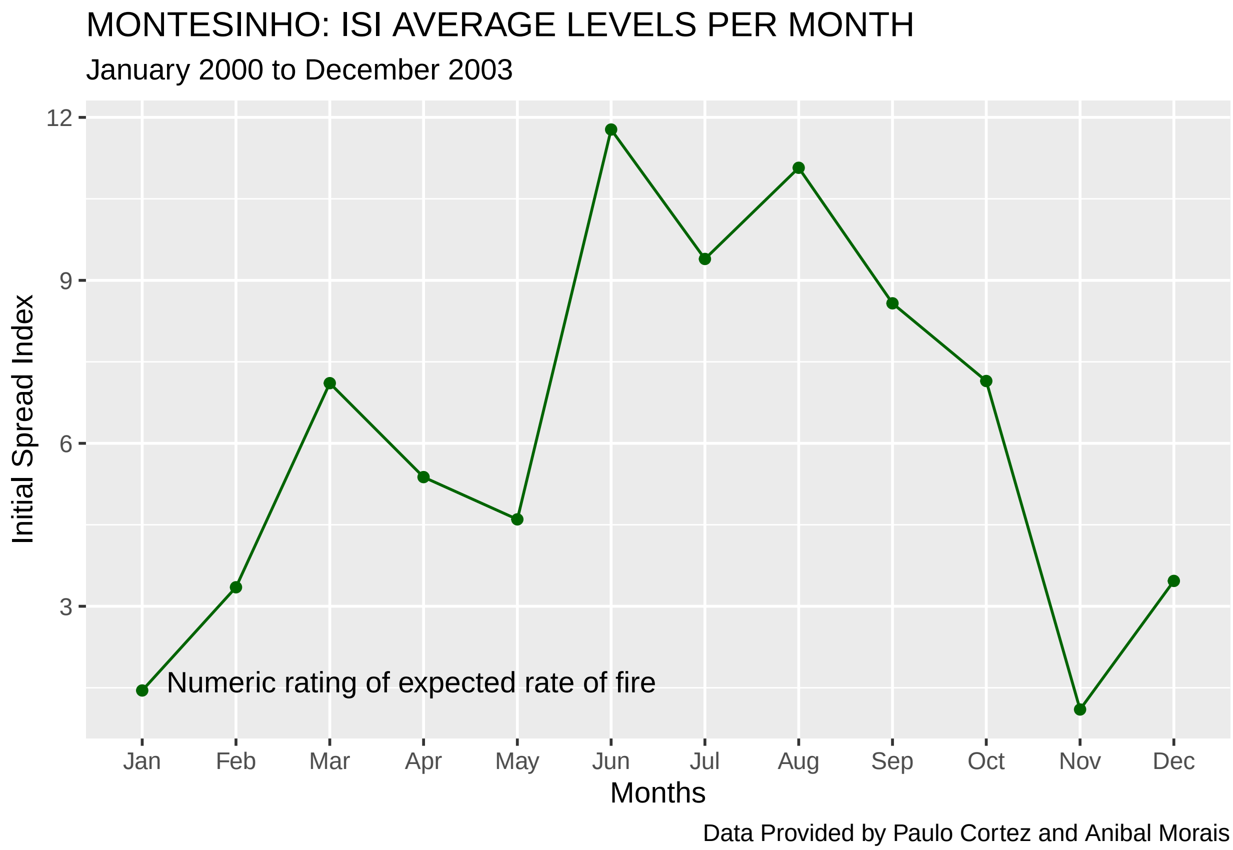

```
dmc_gplot <- ggplot(dmc_2_means, aes(x = dmc_2_months, y = dmc_2_values, group = 1)) +
  geom_line(color = "blue") +
  geom_point(color = "blue") + labs(y = "DMC Levels", x = "Months", title = "MONTESINHO: DMC AVERAGE LE
                                    subtitle = "January 2000 to December 2003",
                                    caption = "Data Provided by Paulo Cortez and Anibal Morais")

dmc_gplot + annotate("text", x= 2, y = 100, label = "                              Fuel consumption in m
                    and medium size wood material")
```




```
dc_gplot <- ggplot(dc_2_means, aes(x = dc_2_months, y = dc_2_values, group = 1)) +
  geom_line(color = "red") +
  geom_point(color = "red") + labs(y = "DC Levels", x = "Months", title = "MONTESINHO: DROUGHT CODE (DC
                                    subtitle = "January 2000 to December 2003",
                                    caption = "Data Provided by Paulo Cortez and Anibal Morais")

dc_gplot + annotate("text", x= 2, y = 600, label = "                                           Drought
```




```
isi_gplot <- ggplot(isi_2_means, aes(x = isi_2_months, y = isi_2_values, group = 1)) +
  geom_line(color = "darkgreen") +
  geom_point(color = "darkgreen") + labs(y = "Initial Spread Index", x = "Months", title = "MONTESINHO:
                                      subtitle = "January 2000 to December 2003",
                                      caption = "Data Provided by Paulo Cortez and Anibal Morais")

isi_gplot + annotate("text", x= 2, y = 2, label = "
                                           Numeric rating of expected rate of fire")
```



ACT:CONCLUSIONS

What role does weather/climate play in causing fires in public lands?

Image edited on Adobe Illustrator.

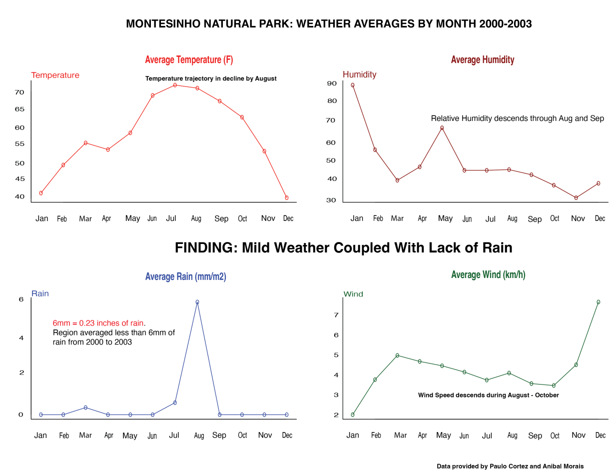


Figure 1: Climate Means By Month 2000-2003

The lack of rain from 2000-2003 created a drought in Montesinho Natural Park. January averaged relative humidity of 90%. The humidity and the lack of rain dried up soil layers throughout the park.

What time of year do most fires take place and what is the significance of the time frame?

Final Images Edited on Adobe Illustrator

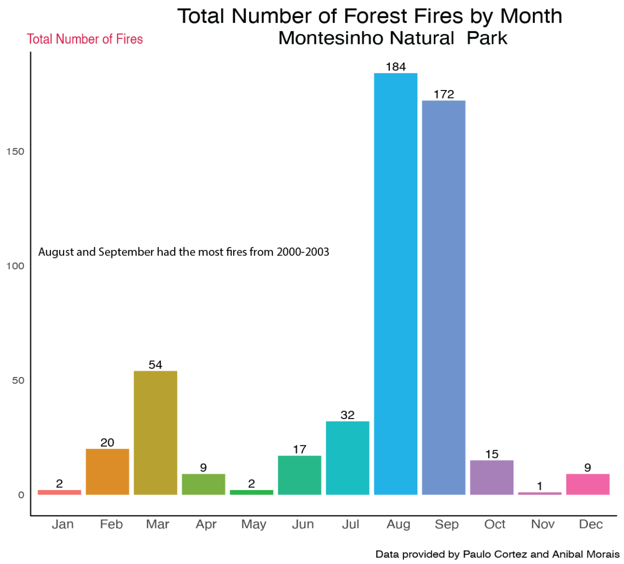


Figure 2: Total Forest Fires by Month 2000-2003

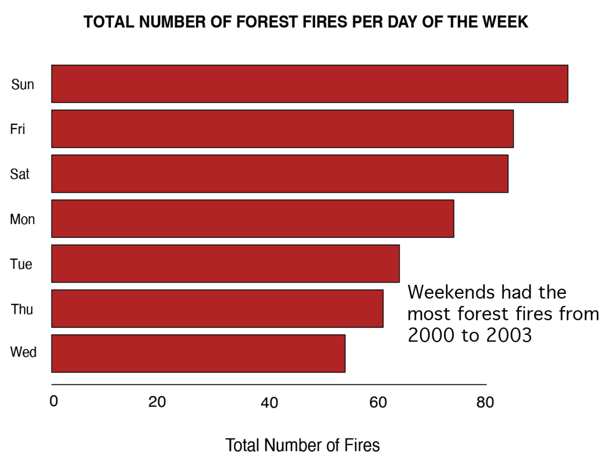
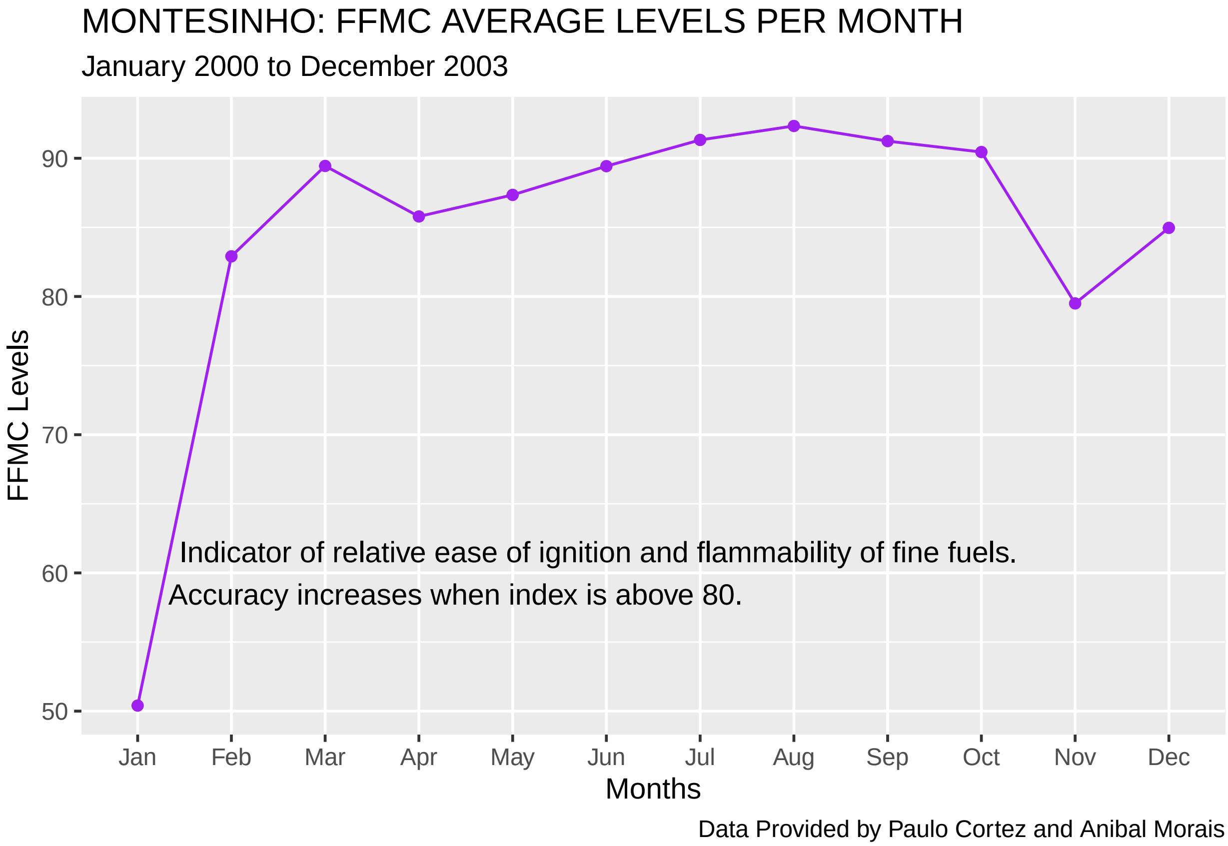


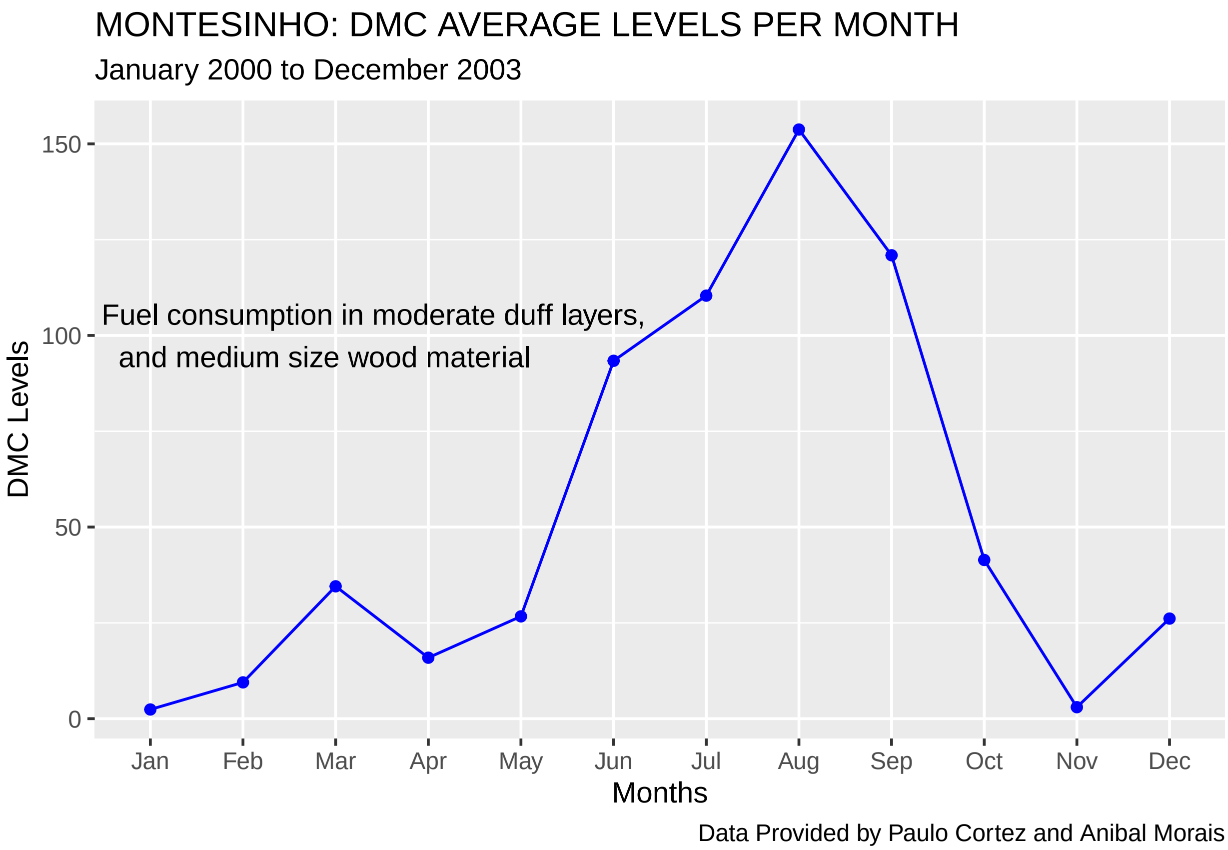
Figure 3: Total Forest Fires by Day of Week 2000-2003

The frequency of forest fires drastically increases in August and September. From 2000-20003, Friday, Saturday and Sunday were the days with most forest fires. Summers in Portugal last from June to September. August is the official summer month of Portugal. There is a correlation between visitor attendance and forest fire frequency. Data pertaining to visitor attendance is needed to clearly link visitor attendance as a prominent cause of forest fires.

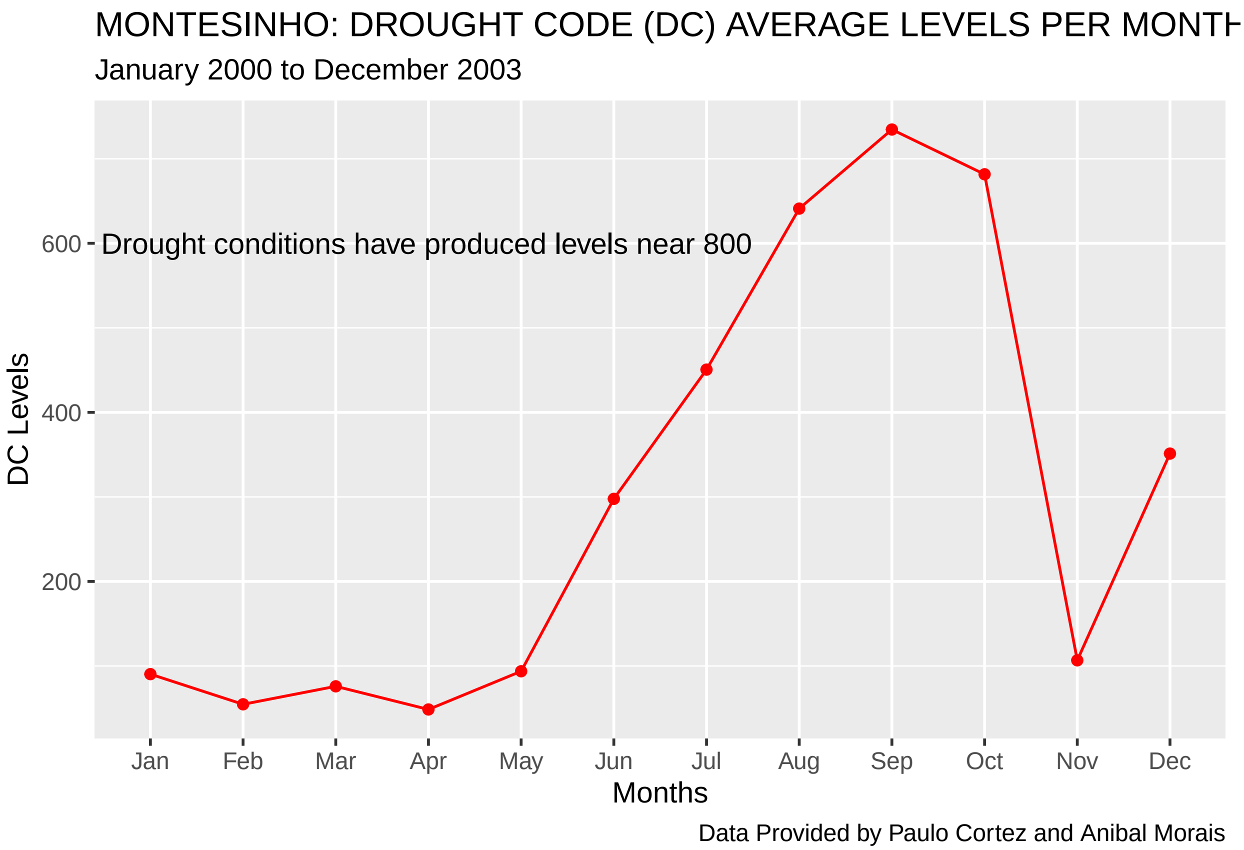
What are the soil conditions that cause fires in public lands?



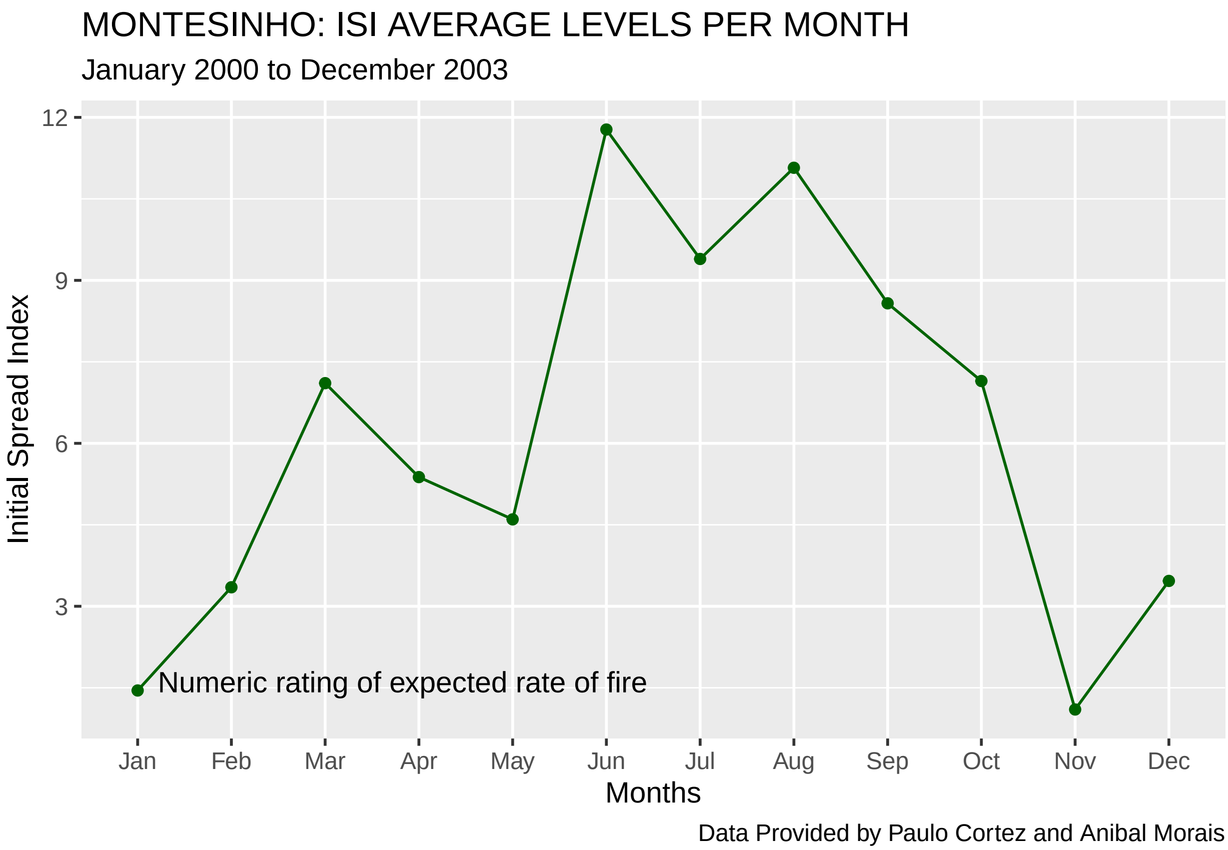
Humidity and lack of rain are reasons for the high index levels. FFMC is affected by humidity, temperature, rain, and wind. The extreme humidity in January and the lack of rain are the causes for the high indicator of relative ease of ignition of fine fuels of loosely compacted layers at moderate depth and deep compact layers.



Duff Moisture Code reaches it's apex in August. DMC impacts medium size wood material.



Drought Conditions are at their highest from August to October. The conditions have been rapidly climbing since May.



ISI is impacted by FFMC and Wind. Layers at mid and deep levels are filled with fine fuel ready to spark. ISI is at it's second highest point in August and descends into September.

The region of the park that burned most frequently is sector 4 on the y axis and intersects with sectors 1-7 on the x axis. The same region has the highest FFMC, DMC, DC and ISI index levels. Loose layers, tightly compacted, moderate wood, and deep decomposing organic layers are extremely dry by August and September.

RECOMMENDATIONS TO PREVENT FIRES IN PUBLIC LANDS AND LAKES

Recommendations are dependent on weather and FWI fuel moisture codes. If weather conditions and fuel moisture codes follow the pattern of the study we recommend the following throughout the year and especially in August and September:

*Limit visitor accessibility to regions with high FFMC, DMC, DC and ISI index levels.

*Increase frequency of patrol of high fuel moisture code regions by park rangers and natural park employees.

*If possible, provide regions with water to decrease fuel moisture indexes.

Extrapolation of study to regions with similar climate conditions to the study

Each region has varying conditions even if the climate conditions are similar. Additional data may be necessary to convince legislators and bureaucrats to take the steps recommended. Similar climate conditions and fuel moisture codes require an increased interest in the region.

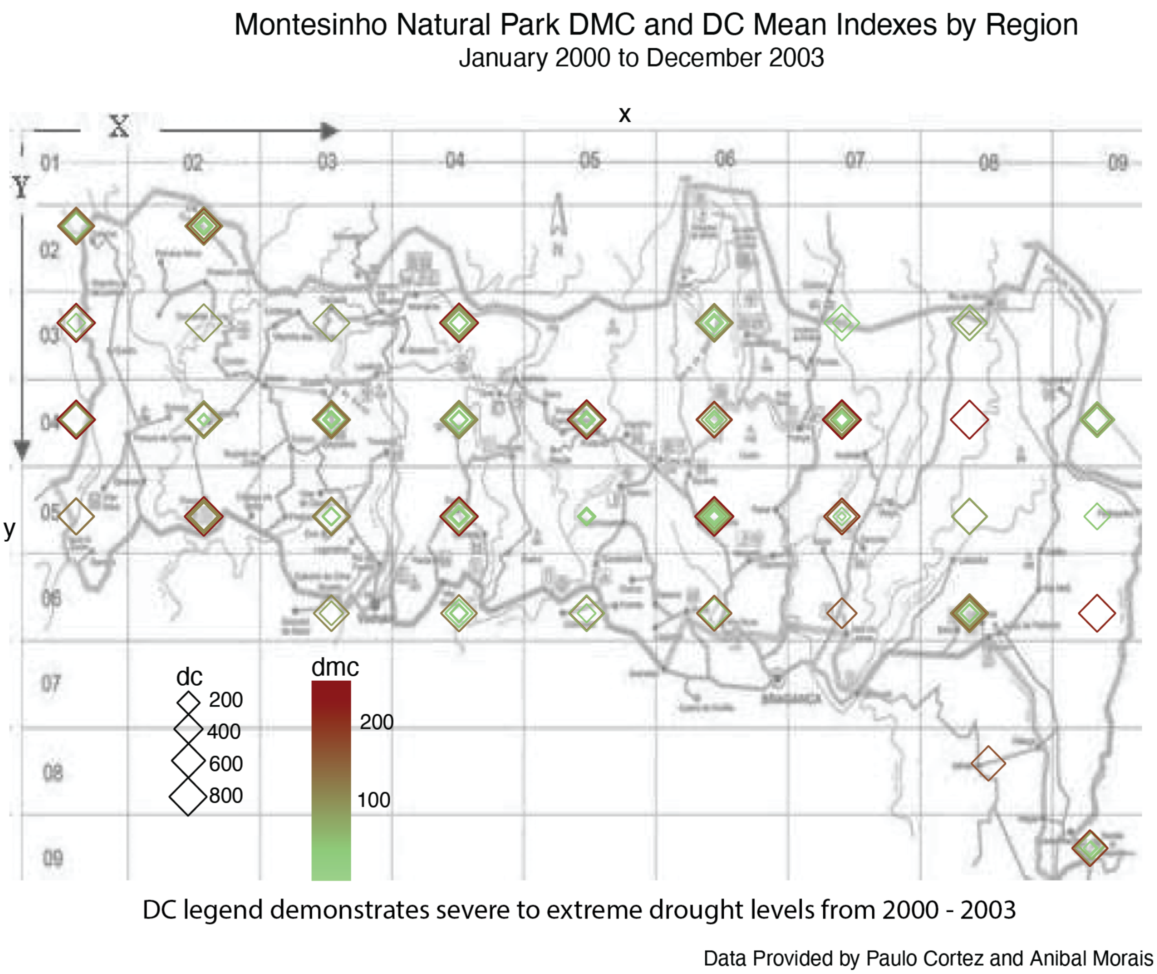


Figure 4: DMC AND DC MEAN INDEXES BY REGION

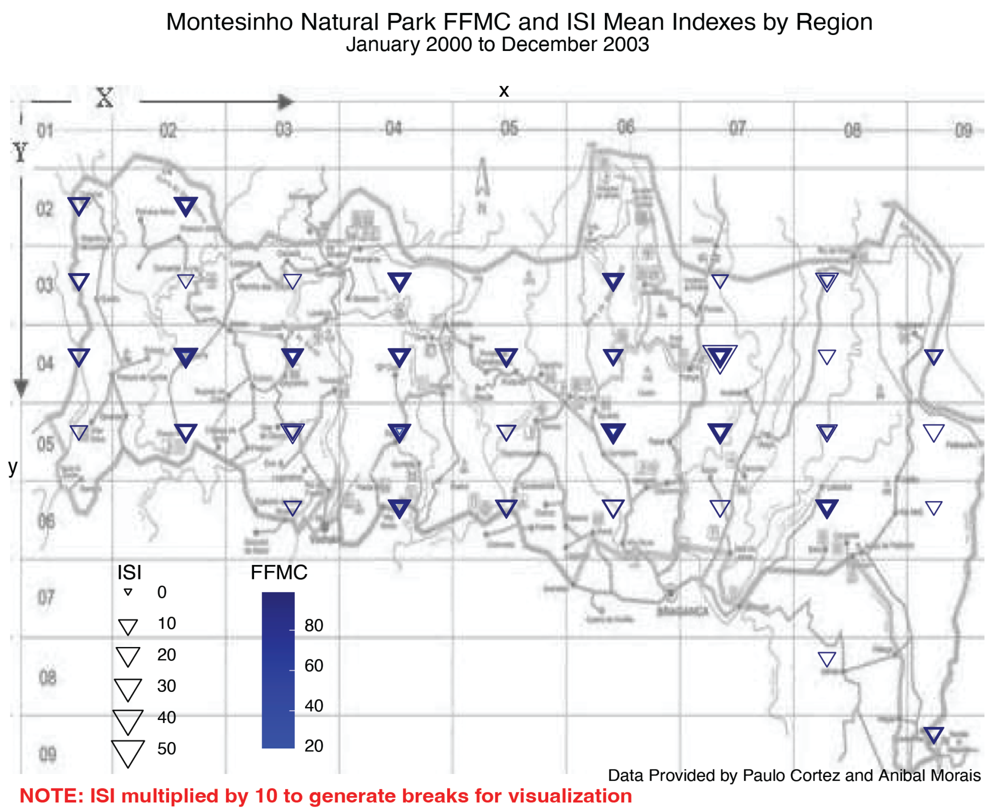


Figure 5: FFMC AND ISI MEAN INDEXES BY REGION

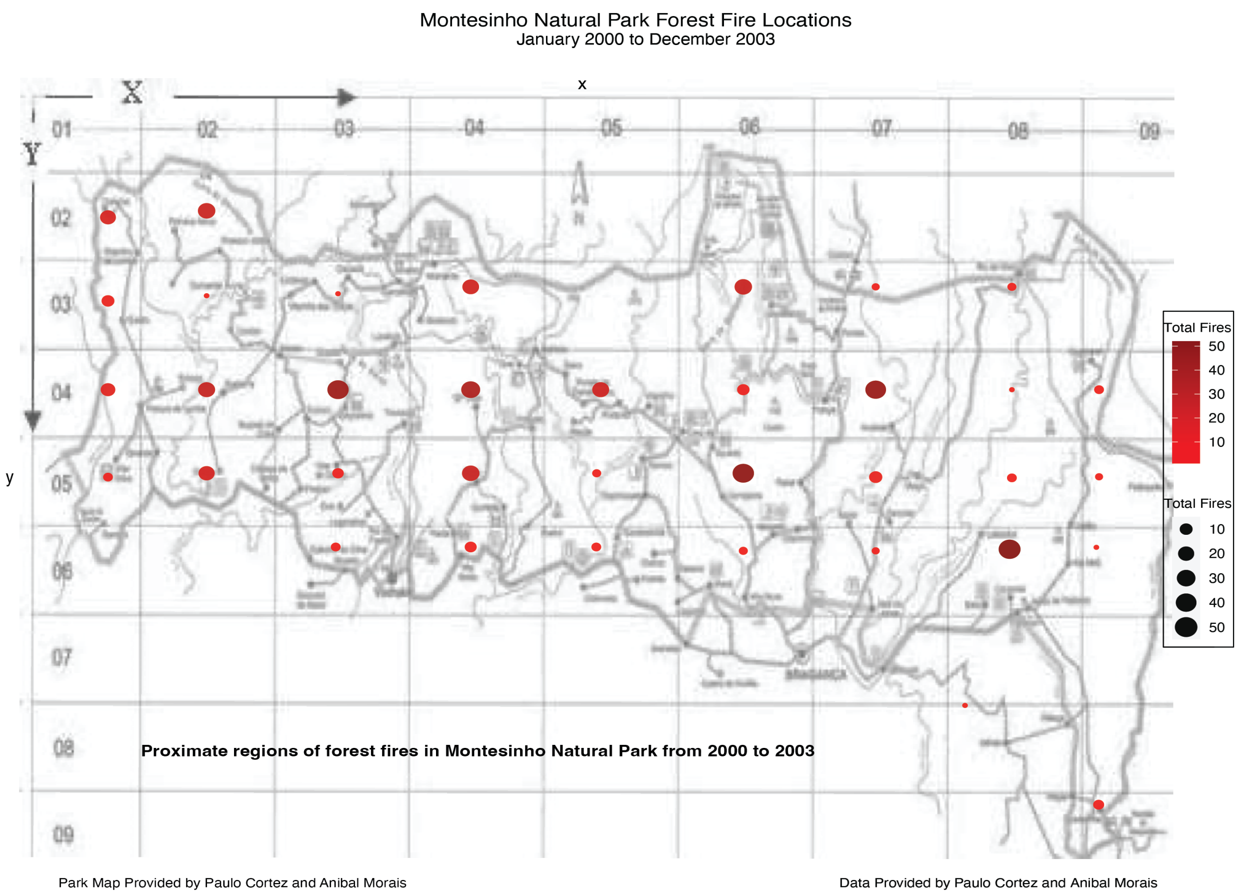


Figure 6: Forest Fire Locations

Can the findings be used as indicators of long term climate change effects in Santa Barbara county?

More data is required.

ADDITIONAL DELIVERABLES NEEDED?

To make a definite conclusion on the role visitors play in causing forest fires, data on park attendance is needed.