Heatwave Color Visualization

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2022-05-10

Study Explanation

Background

As climate change progresses, disturbances in forested ecosystems will become a more powerful force of ecosystem change . Heatwaves and droughts will become more prevalent and co-occurring with climate change, yet it is largely unknown how this will impact seedling establishment and forest regeneration. The purpose of this proposal is to develop an experimental design to determine the impact of heatwaves on mortality rates of droughted tree seedlings.

Main Question

- Do Ponderosa Pine tree seedlings show temperature sensitivity to heatwaves under droughted conditions?
- Can plant stress be captured through color change over time using repeat photographs?

Photo Measurements

- *What*: Take photos of each plant, in the same position and with similar lighting
- *When*: weekly
- *Why*: Photos can capture color change over time to determine when a plant has died
- *Limitations*: Requires time to develop a code to take an image of a plant, isolate the needles, and determine pixel color as a measure from green to brown. This is what I explore in the final project!

Treatments

A subset of 10 plants (out of 250) were included in this visualization process, with the goal of refining the workflow of quantifying colors and exploring potential useful visualizations. Photos were taken of these plants every week for 13 weeks, until all plants in the study had died from drought.

These 10 plants were divided into two groups, based on the experimental design.

- Drought (5 plants)
- Drought + heatwave (5 plants)

Pre-vizualization work flow

How can I construct a code to take an image of a plant, isolate the needles, and determine pixel color as a measure from green to brown?

1. From weekly photographs, exclude pixels that are not living tissue using a Gaussian Mixture Model in python (background/foreground)

2. Develop code in R to extract pixels and organize data into a data frame

3. Reduce the data frame and summarize information for analysis

Data

Photo Example

For this visualization, I took a subset of 10 plants, tracked with photographs over 13 weeks (from August 26 2021 to November 19 2021).

Below is a photo of one plant as an example, after the background has been removed using a Gaussian Mixture Model. The goal of this was to leave only plant-tissue pixels in the photo.

```
pic <- "data_raw/final_project/Photos/August 26 2021/Final/PIPO10 Ambient+HW Drought DSC00273_segmented_
pic1 <- image_read(pic)
image_scale(pic1, "500")
```

Pixel Data

Using the processed photos, I then worked with R to extract the plant-tissue pixels and put color information in a data frame.

I have three sets of data, which are summarized to different levels

1. Total

- **tree_rgb_all**: contains all the pixels extracted from my images (~12,000,000 data points)

2. Summarized

- **tree_rgb_sum_all**: summarized into color groups (~12,000 data points)

3. Filtered

- **tree_rgb_sum_filter_all**: filtered to exclude grey colors and pixels with less than 0% color contribution (~6,000 data points)

```
# read in data
#tree_rgb_all is too big to upload to github...see next viz
tree_rgb_sum_all <- read.csv("data_raw/final_project/tree_rgb_sum/tree_rgb_sum_all.csv")
tree_rgb_sum_filter_all <- read.csv("data_raw/final_project/tree_rgb_sum_filter/tree_rgb_sum_filter_all
```

Viz 1

3D (and 2D) scatterplot of total pixel colors plotted on red-green-blue axes

Let's start by looking at the total data.

. . . I couldn't add this file to github because it's too big, but if you'd like to download the data it looks really cool as a 3D plot! Code is below if you download the total data separately, add file to data_raw/final_project

```
#tree_rgb_all <- read.csv("data_raw/final_project/tree_rgb/tree_rgb_all.csv")

# tree_rgb_all %>%
#   filter(SpeciesID == "PIPO10" & Week == 1) %>%
#   plot_colors_3d(sample_size = 5000, marker_size = 2.5, color_space = "RGB")
```

Let's instead look at summarized data, because 12 million data points is a lot!

```
#Summarized data: tree_rgb_sum_all
#to see how I came up with this data, look at 1_naming.R, 2_rgb.R, and 3_rgb_sum.R in the scripts folde
head(tree_rgb_sum_all)
```

```
##   Week       Date Species SpeciesID Treatment_temp Treatment_water red_class
## 1    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 2    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 3    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
```

```
## 4    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 5    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
## 6    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
##   green_class blue_class red green blue col_hex col_freq col_total col_share
## 1        1-32      33-64  31    30   43 #1f1e2b        7   1571147       0.0
## 2       33-64       1-32  28    58    8 #1c3a08      411   1571147       0.0
## 3       33-64      33-64  31    36   39 #1f2427       11   1571147       0.0
## 4       65-96       1-32  29    70    9 #1d4609      195   1571147       0.0
## 5     129-160    129-160 147   151  137 #939789    25074   1571147       1.6
## 6     129-160    161-192 158   158  162 #9e9ea2        5   1571147       0.0
```

```
#Here's a list of all the species available
#PIPO stands for Ponderosa Pine (tree seedling), the number represents an individual out of 50 replicat
tree_rgb_sum_all %>%
  summarize(species = unique(SpeciesID))
```

```
##    species
## 1   PIPO10
## 2   PIPO14
## 3   PIPO23
## 4   PIPO29
## 5   PIPO34
## 6   PIPO39
## 7   PIPO42
## 8   PIPO44
## 9   PIPO45
## 10  PIPO49
```

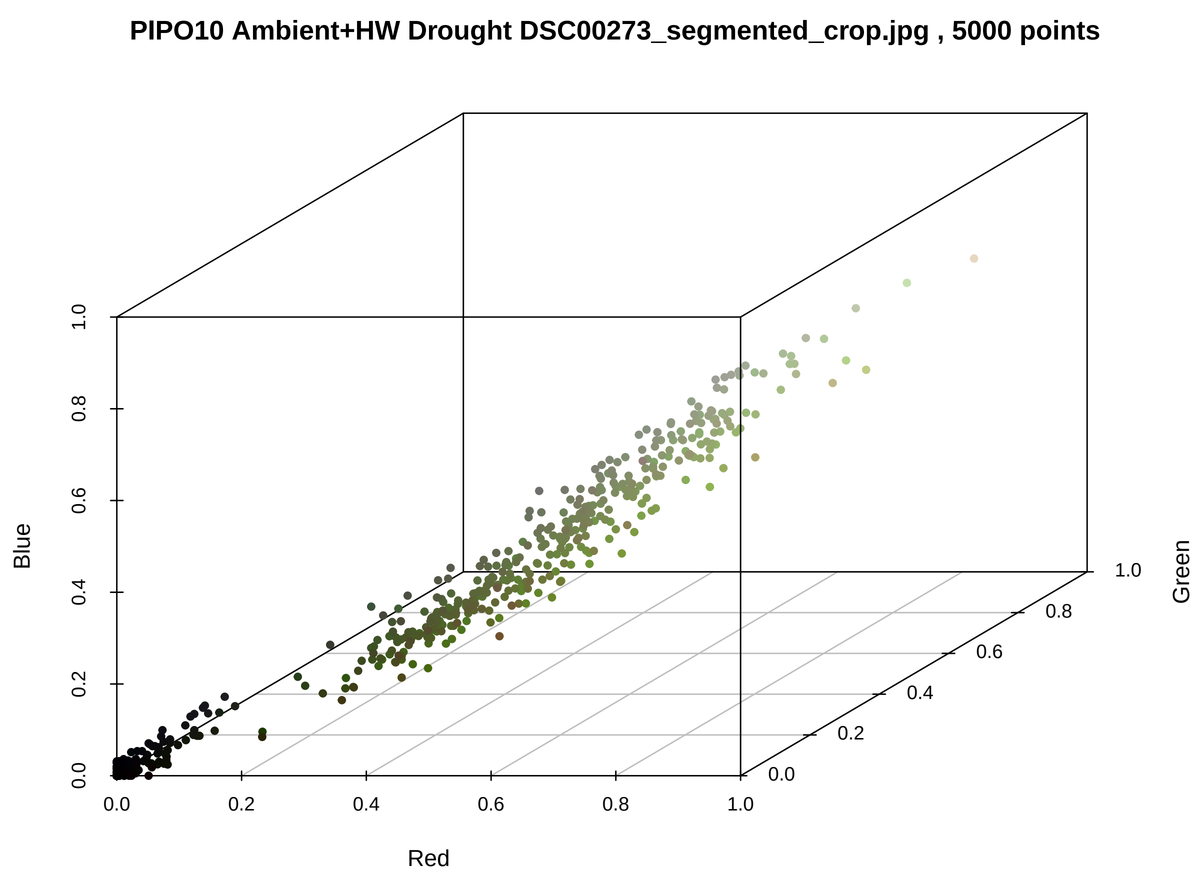
```
#Here's a list of all dates available
tree_rgb_sum_all %>%
  summarize(dates = unique(Date), week = unique(Week)) %>%
  arrange(week)
```

```
##         dates week
## 1  2021-08-26    1
## 2  2021-09-02    2
## 3  2021-09-09    3
## 4  2021-09-16    4
## 5  2021-09-24    5
## 6  2021-09-30    6
## 7  2021-10-07    7
## 8  2021-10-15    8
## 9  2021-10-21    9
## 10 2021-10-29   10
## 11 2021-11-05   11
## 12 2021-11-11   12
## 13 2021-11-19   13
```

```
#Take a look at this 3D color graph
#Feel free to change the species and week to explore colors
#I tried to do this on Shiny to be more interactive, but was unsuccessful and ran out of time.... perha
tree_rgb_sum_all %>%
```

```r
  filter(SpeciesID == "PIPO10" & Week == 1) %>%
  plot_colors_3d(sample_size = 5000, marker_size = 2.5, color_space = "RGB")
```

```r
#If this doesn't work (could need computer installations), look at this 2D color graph
pic <- "data_raw/final_project/Photos/August 26 2021/Final/PIPO10 Ambient+HW Drought DSC00273_segmented_
colordistance::plotPixels(pic, lower = NULL, upper = NULL, n = 5000)
```



Viz 2

Bar chart showing plant color variation over time (as plants die)

Let's look again at summarized data.

For ease of visualization, I display only 4 plants over time (2 with heatwave treatment and 2 without)

```r
#Summarized data: tree_rgb_sum_all
#to see how I came up with this data, look at 3_rgb_sum.R in the scripts folder
head(tree_rgb_sum_all)
```

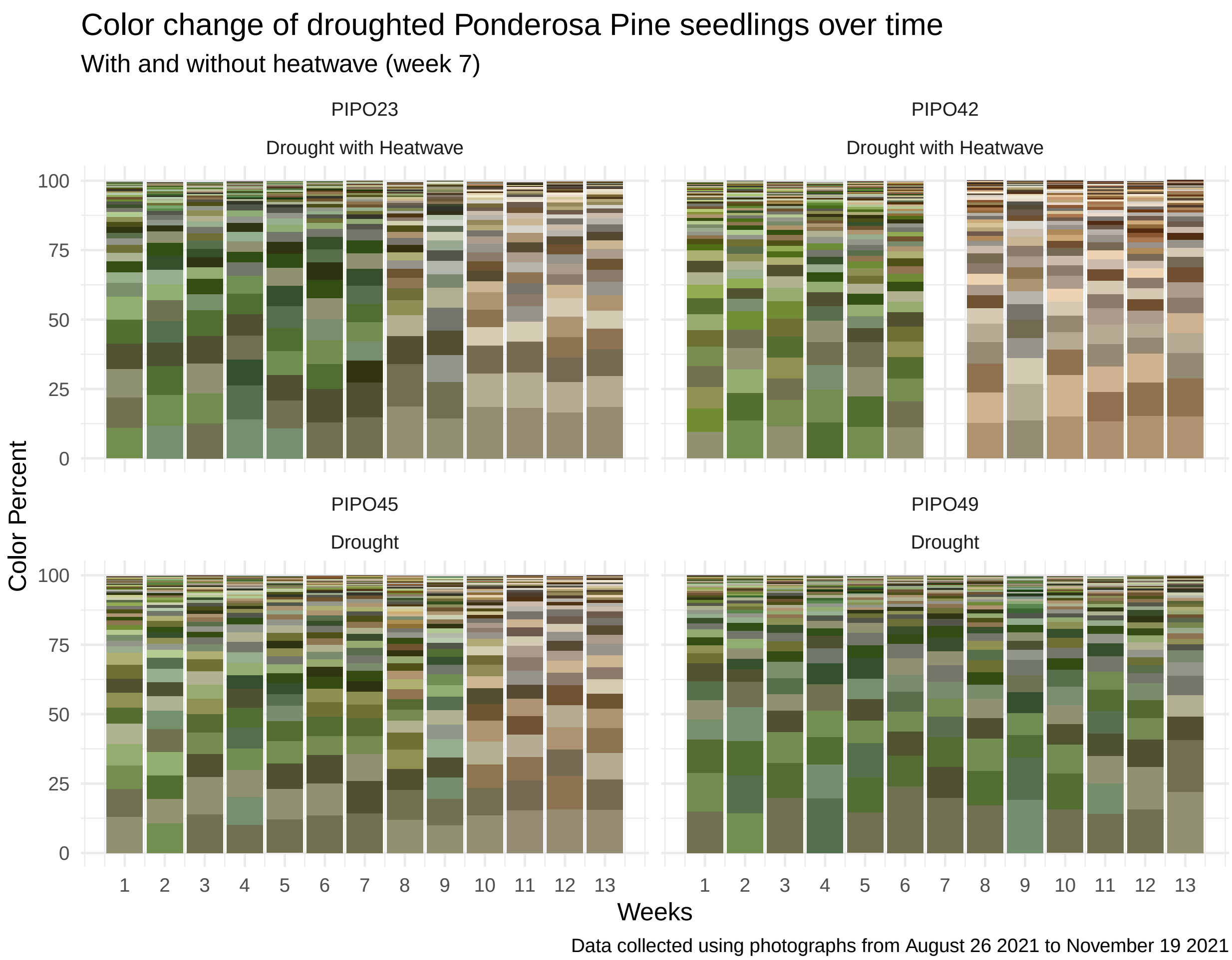
```
##   Week       Date Species SpeciesID Treatment_temp Treatment_water red_class
```

```
## 1     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 2     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 3     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 4     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought      1-32
## 5     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
## 6     1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
##   green_class blue_class red green blue col_hex col_freq col_total col_share
## 1        1-32      33-64  31    30   43 #1f1e2b        7   1571147       0.0
## 2       33-64       1-32  28    58    8 #1c3a08      411   1571147       0.0
## 3       33-64      33-64  31    36   39 #1f2427       11   1571147       0.0
## 4       65-96       1-32  29    70    9 #1d4609      195   1571147       0.0
## 5     129-160    129-160 147   151  137 #939789    25074   1571147       1.6
## 6     129-160    161-192 158   158  162 #9e9ea2        5   1571147       0.0
```

```r
tree_rgb_sum_viz <- tree_rgb_sum_all %>%
  filter(SpeciesID %in% c("PIPO23","PIPO42","PIPO45","PIPO49")) %>%
  arrange(SpeciesID, Date, desc(col_share))

colors1 <- tree_rgb_sum_viz$col_hex

tree_rgb_sum_viz %>%
  mutate(Treatment = ifelse(Treatment_temp == "Ambient+HW", "Drought with Heatwave", "Drought")) %>%
  ggplot(aes(x = Week,
             y = col_share,
             fill = colors1)) +
  geom_col(fill = colors1) +
  facet_wrap(~SpeciesID + Treatment) +
  #facet_grid(rows = vars(SpeciesID)) +
  scale_x_continuous(breaks = 1:13) +
  ylab("Color Percent") +
  xlab("Weeks") +
  labs(title = "Color change of droughted Ponderosa Pine seedlings over time",
       subtitle = "With and without heatwave (week 7)",
       caption = "Data collected using photographs from August 26 2021 to November 19 2021") +
  theme_minimal(base_size = 13)
```



Viz 3

Line graph showing leaf area change over time

Let's look at filtered data now.

```
#Filtered data: tree_rgb_sum_filter_all
#to see how I came up with this data, look at 4_rgb_sum_filter.R in the scripts folder
head(tree_rgb_sum_filter_all)
```

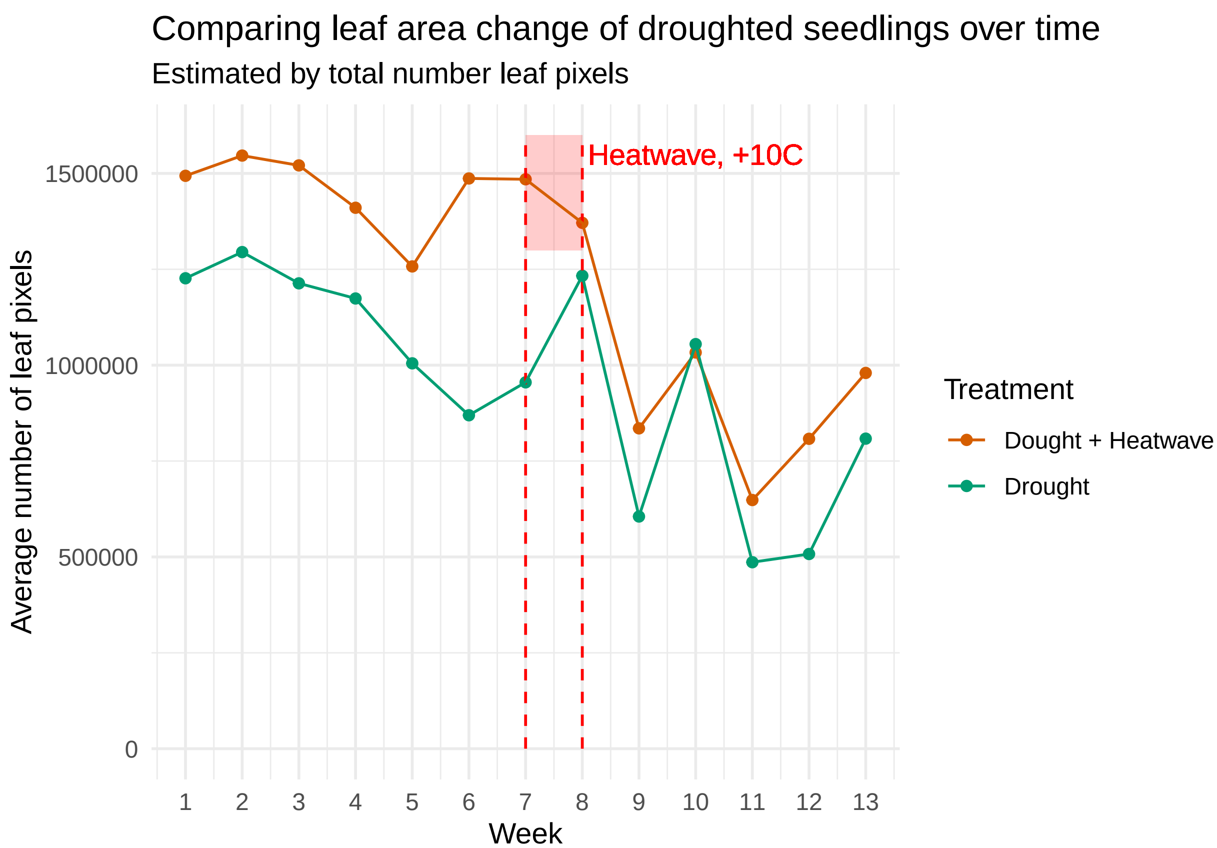
```
##   Week       Date Species SpeciesID Treatment_temp Treatment_water red_class
## 1    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought    97-128
## 2    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought     65-96
## 3    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought     65-96
## 4    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
## 5    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought    97-128
## 6    1 2021-08-26    PIPO    PIPO10     Ambient+HW         Drought   129-160
##   green_class blue_class red green blue col_hex col_freq col_total col_share
## 1      97-128      65-96 112   113   80 #707150   185219   1493285      12.4
## 2      97-128      33-64  84   111   47 #546f2f   181620   1493285      12.2
```

```
## 3       65-96      33-64  80    81    48 #505130    171061    1493285       11.5
## 4      129-160     97-128 142   146   112 #8e9270    155850    1493285       10.4
## 5      129-160      65-96 116   142    79 #748e4f    147858    1493285        9.9
## 6      161-192     97-128 148   174   112 #94ae70    103899    1493285        7.0
```

```
tree_rgb_sum_filter_viz <- tree_rgb_sum_filter_all %>%
  arrange(SpeciesID, Date, desc(col_share))

colors3 <- tree_rgb_sum_filter_viz$col_hex


tree_rgb_sum_filter_viz %>%
  mutate(Treatment = ifelse(Treatment_temp == "Ambient", "Drought", "Dought + Heatwave")) %>%
  group_by(Week, Treatment) %>%
  summarize(mean_pixels = mean(col_total, na.rm = TRUE)) %>%
  ggplot(aes(x = Week,
             y = mean_pixels,
             color = Treatment)) +
  geom_point() +
    annotate("segment",
           x = 7, xend = 7,
           y = 0, yend = 1600000,
           color = "red",
           linetype = "dashed") +
  annotate("segment",
           x = 8, xend = 8,
           y = 0, yend = 1600000,
           color = "red",
           linetype = "dashed") +
  annotate("rect",
           xmin = 7, xmax = 8,
           ymin = 1300000, ymax = 1600000,
           fill = "red",
           alpha = .2) +
  geom_text(label = "Heatwave, +10C",
            x = 10, y = 1550000, color = "red") +
  geom_line() +
  scale_color_manual(values = c("#D55E00", "#009E73")) +
  scale_x_continuous(breaks = 1:13) +
  ylab("Average number of leaf pixels") +
  labs(title = "Comparing leaf area change of droughted seedlings over time",
      subtitle = "Estimated by total number leaf pixels") +
  theme_minimal()
```


Comparing leaf area change of droughted seedlings over time
Estimated by total number leaf pixels
Heatwave, +10C
Average number of leaf pixels
1500000
1000000
500000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Week
Treatment
Dought + Heatwave
Drought