GRASS COUNT SURVEY OF THE NORTHERNMOST PLOT IN THE CORNERSTONE PLAZA

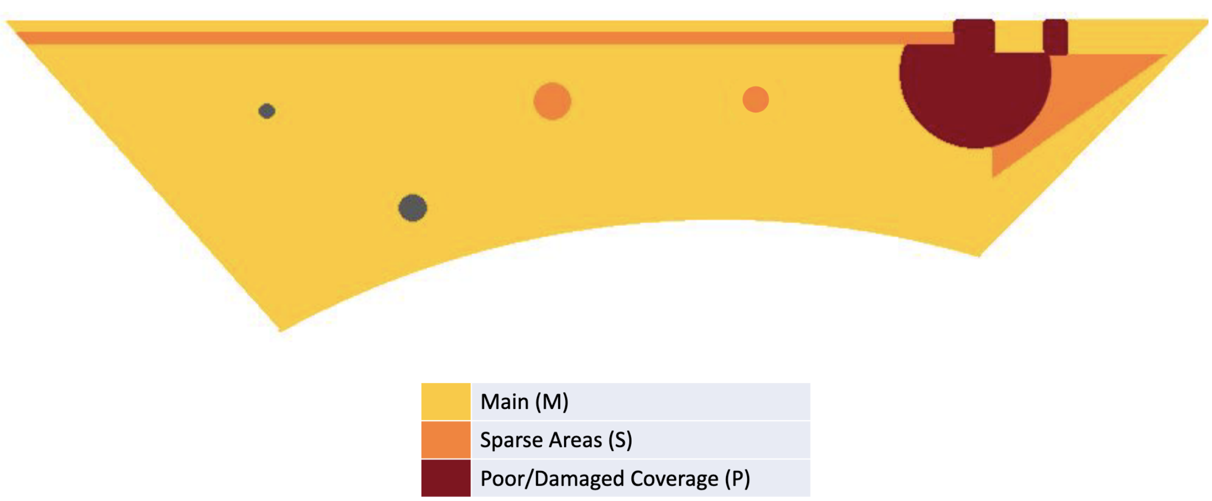
STEFANO FOCHESATTO, BRIA HIEBERT-CRAPE, WILLIAM ODOM

Abstract. Density data was collected from the northernmost plot of grass in the Cornerstone Plaza at UAF during the Fall 2021 semester. The plot was organized into 3 strata with varying amounts of visual 'patchiness' prior to performing sampling. The area of the the plot and each strata was estimated using a combination of field measurements and satellite photography. Our group decided on taking 15 samples total, dividing them between the strata using proportional allocation. Data collection was performed on a sampling unit size of four inches squared, captured with a 4k camera and then counted, by hand, after the fact with photo editing software.

Area Study

Initial Survey. The plot of grass was divided into three different strata with varying degree of visual 'patchiness'. The largest strata was referred to as Main and it exhibited the least amount of 'patchiness' upon visual inspection. The Sparse and Poor strata exhibited a medium and high amount of 'patchiness' respectively. A rough breakdown of the strata is shown below,

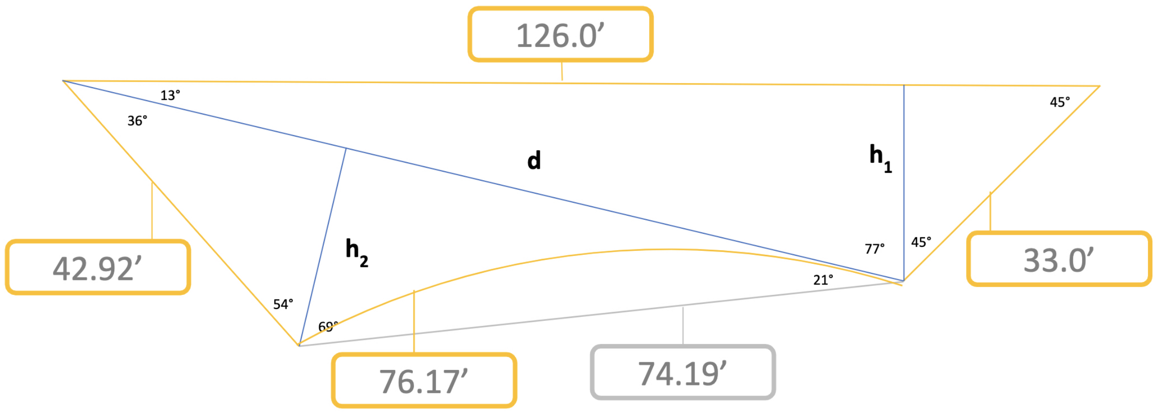
Figure 1. Strata Breakdown



Date: September 23, 2021.

Area Analysis. Measurement for both the whole plot and each strata where taken using a combination of field measurements and satellite photography. Below are the measurement of the plot used to calculate the area of the plot, including the sector on the bottom.

FIGURE 2. Initial Measurement



Computing the triangulated area with the following,

$$h_1 = 33 * sin(45^o) = 23$$

$$h_2 = 43 * sin(36^o) = 25$$

$$d = (126 - 23)/cos(13^o) = 106$$

$$Triangulated_{area} = \frac{106 * 25}{2} + \frac{126 * 23}{2} = 2774$$

Then we computed the area of the lune shape near the bottom of the plot to subtract off the $Triangualted_{area}$ in order to get our actual area estimate. The radius of the circle which encompasses the lune was measured at $r = 96.15$. Using the radius and our calculation for the arclength of the lune we were able to find the angle θ which subtends the sector,

$$\theta = 2\pi \frac{76.17}{2\pi * 96.15} = .7921rad$$

Now we compute the area of the sector,

$$Sector_{area} = \pi(96.15)^2 \frac{\theta}{2\pi} = 3652$$

Computing the area of the triangle, first we find the height,

$$h_3 = 96.15 * arcos(\theta/2) = 88.7.$$

Finally we get,

$$Triangle_{area} = \frac{74.19 * 88.7}{2} = 3290.$$

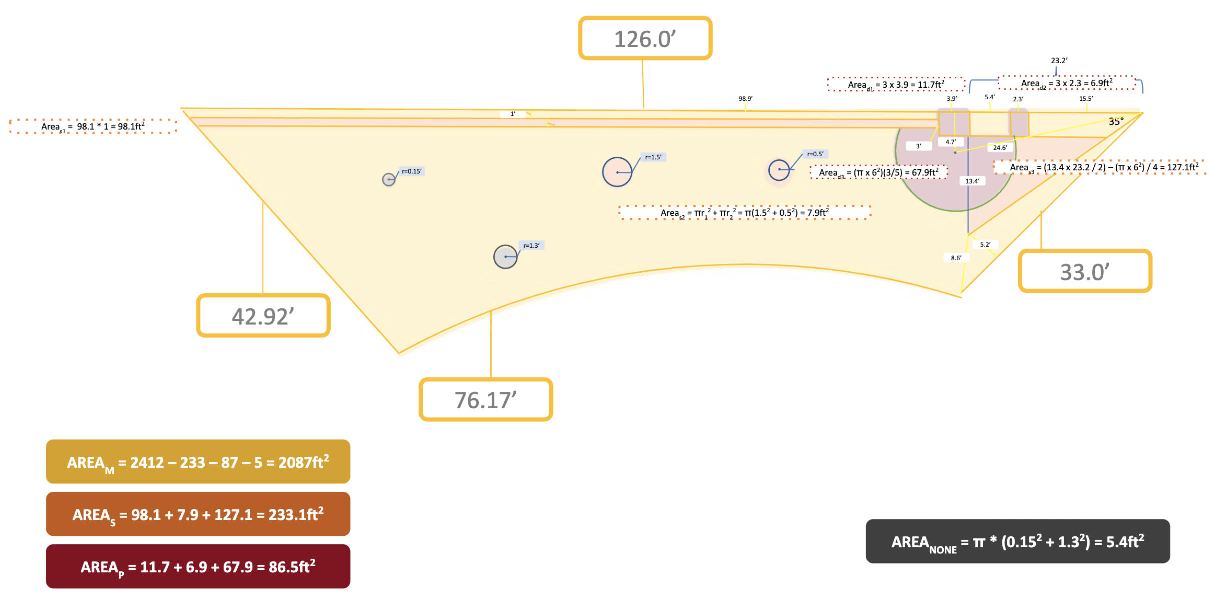
Computing the area of the lune, then the final area,

$$Lune_{area} = Sector_{area} - Triangle_{area} = 3652 - 3290 = 362.$$

$$Total_{area} = Triangulated_{area} - Lune_{area} = 2774 - 362 = 2412.$$

The areas of each strata were computed through a similar analysis that is outlined in the figure below,

FIGURE 3. Strata Area Analysis



1. Sample Allocation and Methods

Following the area analysis we could now begin identifying the allocation of samples among the strata, as well as the exact methods for how we would take our samples i.e. unit size, total samples, and picture vs by-hand counting. Our group decided on a total sample size $N = 15$, allocating the samples between the three strata using proportional allocation,using a proportional variance estimate as weights. Details on how samples were allocated are in the R code below,

Figure 4. Sample Allocation Code:

```
## Importing our Proportional Strata Variances
Var_Strata <- c(1,2,4)


## We have to multiply each value by 9 since our sampling unit is a 4 inch square and
## the area was measured in feet squared. Doesn't affect allocation but is helpful for
## later analysis.

N_Main_Var_Strata = 9*2087
N_Sparse_Var_Strata = 9*233
N_Poor_Var_Strata = 9*87
N_Total_Area = N_Main_Var_Strata + N_Sparse_Var_Strata + N_Poor_Var_Strata

## Vectorizing N_i
N_Strata <- c(N_Main_Var_Strata, N_Sparse_Var_Strata, N_Poor_Var_Strata)

## Computing w_i
Strata_Allocation <- N_Strata*sqrt(Var_Strata)/sum(N_Strata*sqrt(Var_Strata))
Strata_Allocation * 12
[1] 9.6675878 1.5263938 0.8060183
```

Since we wanted samplers to have the same number of samples across each strata we rounded down the Main strata to 9 samples, and had the Sparse and Poor strata at 3 samples.

1.1. The Simple Random Sample.

With the samples allocated, now we need to identify a truly random selection of samples in each strata. To do so we overlayed a grid on our rendition of the plot, numbered each square, and then conducted a simple random sample without replacement on each of the strata in R. Below is the R code that was used to produce the samples, along with the position of the resultant samples.

FIGURE 5. Sample Allocation Code:

```
### Simple Random Sampling within Strata using R

## SRS from each strata
## Population
P_l <- c(1:17882)
P_m <- c(1:1580)
P_h <- c(1:1239)

## Sample Sizes
n_l <- 9
n_m <- 3
n_h <- 3

## SRS
set.seed(28); samp_l <- sample(P_l, n_l, replace = F)
set.seed(31); samp_m <- sample(P_m, n_m, replace = F)
set.seed(14); samp_h <- sample(P_h, n_h, replace = F)

## Randomizing the samples among samplers
set.seed(42); samp_billy <- sample(c(paste(samp_l[1:3], "m"),
                                paste(samp_m[1],"s"),
                                paste(samp_h[1],"p")), 5, replace = F)

set.seed(52); samp_stefano <- sample(c(paste(samp_l[4:6], "m"),
                                  paste(samp_m[2],"s"),
                                  paste(samp_h[2],"p")), 5, replace = F)

set.seed(62); samp_bria <- sample(c(paste(samp_l[7:9], "m"),
                                paste(samp_m[3],"s"),
                                paste(samp_h[3],"p")), 5, replace = F)
```

Figure 6. Sample Location

BILLY

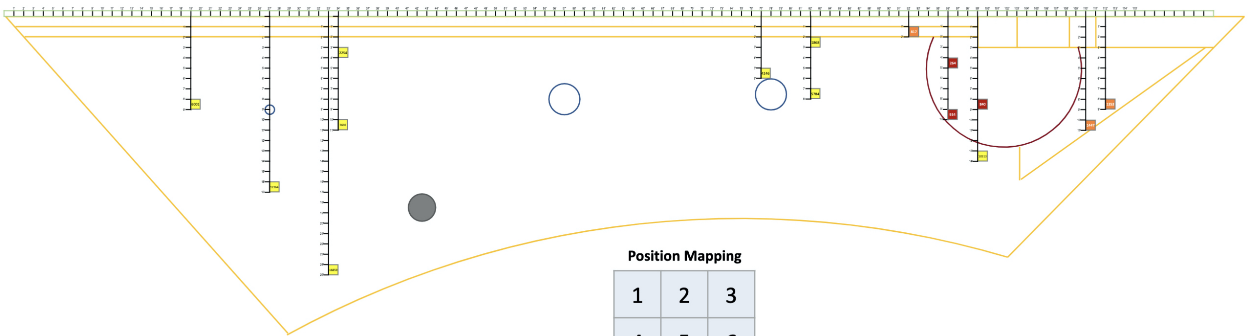
	Sample #	Right (ft)	Down (ft)	Position
1	M1873	82′	3′	6
2	P265	96′	4′	2
3	S1453	110′	10′	7
4	M6001	19′	8′	1
5	M5792	82′	7′	9

STEFANO

	Sample #	Right (ft)	Down (ft)	Position
1	M4235	77′	5′	9
2	M2254	34′	3′	1
3	P841	99′	8′	2
4	M16866	33′	24′	8
5	S817	92′	1′	1

BRIA

	Sample #	Right (ft)	Down (ft)	Position
1	S1355	112′	8′	3
2	M10521	99′	13′	9
3	M7616	34′	10′	9
4	M13267	27′	16′	4
5	P939	96′	9′	6



Position Mapping

1	2	3
4	5	6
7	8	9

1.2. **Sampling Method.** The samples were taken by laying down a template with a 4 inch square cut out, then taking a high quality photograph of the grass. Doing so allowed our group to count comfortably and with higher accuracy as each individual blade of grass would then be marked during counting using photo editing software. Below is an example of how one of the samples was taken.

Figure 7. Uncounted Sample

Figure 8. Counted Sample

2. Results

With the collected data we were able to construct an estimate of the total number of grass blades in the plot. We found that there were approximately $5,623,940$ blades of grass with a

95% confidence interval of $\pm 1,090,437$. Below is the R analysis that produced our estimator and confidence interval,

FIGURE 9. Estimator Analysis Code:

```
#Importing Data
Strata_df <- read.csv('SamplingProject.csv')

## Variance estimate for each strata.
s_squared <- c(var(na.omit(Strata_df$Main_Var_Strata)),
               var(na.omit(Strata_df$Sparse_Var_Strata)),
               var(na.omit(Strata_df$Poor_Var_Strata)))

## Mean estimate for each strata.
xbar_strata <- c(mean(na.omit(Strata_df$Main_Var_Strata)),
                 mean(na.omit(Strata_df$Sparse_Var_Strata)),
                 mean(na.omit(Strata_df$Poor_Var_Strata)))

## Pulling length of each strata.
n_strata <- c(length(na.omit(Strata_df$Main_Var_Strata)),
              length(na.omit(Strata_df$Sparse_Var_Strata)),
              length(na.omit(Strata_df$Poor_Var_Strata)))

## Total Number of samples in each Strata
N_Main_Var_Strata = 9*2087
N_Sparse_Var_Strata = 9*233
N_Poor_Var_Strata = 9*87
N_Total_Area = N_Main_Var_Strata + N_Sparse_Var_Strata + N_Poor_Var_Strata

## Vectorizing N_i
N_Strata <- c(N_Main_Var_Strata, N_Sparse_Var_Strata, N_Poor_Var_Strata)

## Computing Total Population Estimator.
Total_estimator = sum(N_Strata*xbar_strata)
[1] 5623940

## Computing 95% CI interval.
Margin_of_error = 2*sqrt(sum(N_Strata*(N_Strata - n_strata)*(s_squared/n_strata)))
[1] 1090437
CI = c(Total_estimator + Margin_of_error, Total_estimator - Margin_of_error)
[1] 6714377 4533503
```

The following table is our raw data samples, which can also be found linked in the caption.

FIGURE 10. Raw Data

Main	Sparse	Poor
n = 9	*n = 3*	*n = 3*
293	297	128
232	181	73
299	418	228
135		
140		
217		
367		
330		
328		

3. Conclusion

In general I think this project proved to be a great learning experience in how stratified sampling is actually done. I think our group might have done a poor job at splitting up the strata, mainly because we found that in the Poor and Sparse stratas where we expected the count to be lower, there was actually a lot of smaller blades of grass that made the section as a whole appear less dense. In the future I think it's very important to spend more time thinking about how the criteria for splitting into strata is related to the measurement that we are making. I also want to give credit to Bria Hiebert-Crape for making all the area plots and figuring out the SRS grid system that we used for this project.