

Effects of Microclimate on the regeneration
of Quaking Aspens, *Populus tremuloides*

Student: Marco Castaneda

Mentor: Benjamin Blonder

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Abstract:

Populus tremuloides is a keystone species found throughout North America. *P. tremuloides* aids the regeneration of eco systems, however as climate changes, the health of *P. tremuloides* is changing. *P. tremuloides* populations are on the decline in the American southwest, and with time it could affect *P. tremuloides* populations in the Rocky Mountains of Colorado. In this Study the relationship between tree regeneration, tree death, soil temperature and soil moisture, a one hectare plot was tested to show if low soil moisture and higher soil temperatures were causing higher *P. tremuloides* mortality rates and low regeneration rates. The study resulted in no significance between dead trees and soil moisture and soil temperature. However, regenerating trees expressed a decline when soil temperature rises.

Introduction:

Populus tremuloides has a broad geographic and environmental range extending from the high-altitude mountains of Colorado to the mountains of Mexico (Grant and Mitton 1996). *Populus tremuloides* is a keystone species in forests throughout northern and western North America, creating a home for insects and food for ungulates. In short, *P. tremuloides* is an extraordinary “Successful” species (Clair and Lindroth 2013). *P. tremuloides* success is due to its ability to reproduce asexually. *P. tremuloides* uses two reproductive processes. The first one is sexually through pollination, despite the enormous crops of viable seeds *P. tremuloides* seed sprouting is a more common in the most humid forests of New England. The second one is asexually through suckering, which is more prominent in the semi-arid west, where the stem will grow a lateral root and if environmental conditions are right, the root will send out a new stem and generate a new identical tree (Grant and Mitton 1996). as the root spreads and ramets

generate, The Quaking aspen develops a mass network of modified roots creating an immense organism that remains dormant underground until a disturbance (Grant and Mitton 1996).

Through suckering, *P. tremuloides* regenerates ecosystems after wildfires and create new hotspots for native and non-native species (Binkley Stohlgren and Suzuki 1999).

Aspen decline is on the rise (Bartos and Campbell 2000). Forests are changing worldwide due to interacting effects of climate change, invasive species, and land use (Kashian Kaye Kulawoski 2013). Recent studies have showed, Insect parasitism, thaw-freeze events, and fungal pathogens are major factors causing sudden aspen dieoff (Brandt Hogg Michaelian 1998). Sudden aspen decline is thought to ultimately caused by drought and low soil moistures. The less water an aspen has available the more stressed it becomes and the more susceptible to disease and death it becomes as well (Bartos, Roberts 1998). As climates are changing, whole populations are changing as well. Wet climates are becoming dry and dry climates are becoming even more dry (Malhi 2008). Simulations of the future reveal that warming may lead to dryer climates over the next few decades. The finding that aspen forests are sensitive to drought has posed additional concerns. What we do know is that ground water availability plays a major role on stimulating growth or causing dieback (Michaelian Hogg 2011). Climate Change is reaching the most remote places. Colorado not being an exception. In 1995, analyses were performed by a group of researchers of universities and the private sector throughout Colorado and on the Colorado river basin. Tree ring-studies were done and they suggest that droughts of that duration and magnitude were much more serious than the ones before (white and cliff 2001). I hypothesize that *P. tremuloides* are declining in Colorado, due to low soil moisture and warmer temperatures.

Hypothesis:

I predict a higher percentage rate of *P. tremuloides* dying off than regenerating due to higher soil temperatures and low soil moisture. I predict that regeneration rate will be lower because of low soil moisture. I predict its mortality rate will be higher because of high temperatures and low soil moisture.

Methods:

Site location- To test the hypothesis, a one-hectare (10,000m Sq.) plot named DRC-01 Figure 13, located about 1.5 south east of The Rocky Mountain Biological Laboratory research station (Latitude 38.951154, Longitude -106.965180) was chosen for use. The plot itself was chosen due to its proximity and diverse topography. DRC-01 was divided into 25 subplots (400m Sq.) for better accuracy.

Recruitment and mortality census - fifty 4x4 meter regions located at the right bottom and left top corner were chosen for censusing. In both regions of each subplot, measuring tape was laid out to separate the region for the plot. All the dead or dying *P. tremuloides* were counted, tagged using flagging tape, numbered, and their diameter at breast height was recorded. All the *P. tremuloides* ramets between >5cm and <.5cm in diameter were censused the same way as the dead or dying aspen. Using a tree field work protocol provided by Rainfor: The Amazon Forest inventory network, all the *P. tremuloides* were coded accordingly in categories to represent their state of health (I.E how did it die? Is it standing, bended, uprooted?).

Census of other plants- Aspen understory was censused. Three abundant species of understory were surveyed *symphoricarpos oreophilus* a dry meadow tolerant shrub native to the state of

Utah (University of Washington 2006). *Festuca Arizonica*, a drought tolerant bunchgrass native to Colorado (An, Liu, and Siegel 1992). *Ligusticum Porteri* a perennial herb found in moist environments throughout the southwestern United States (Kindscher and Yang 2013). These three-abundant species were chosen for censusing because they are possible predictors of *P. tremuloides* regeneration or death due to their abilities to tolerate drought. *S. oreophilus*, *F. Arizonica*, *L. porteri* were first censused by their presence in all 50 regions of the subplot, then using a one to five scale, density was determined. One representing low density and five representing high density.

Microclimate- Soil moisture was collected from the top left corner of each subplot right before the beginning of seasonal rains. Using 48.26 cm soil corer, soil was extracted and stored in pre-labeled bags and taken back to RMBL for soil moisture content. Using a measurement of soil moisture content by gravimetric method protocol provided by KM DeAngelis from the University of California, Berkeley. Soil temperature will be recorded simultaneously with the extraction of a soil sample at each subplot. D519216-FHS Thermotron 4k Buttons thermometers, were labeled, water sealed, and attached to a fluorescent string for easy extraction out of the ground. Each thermometer was programmed to record temperature hourly starting July 10th, 2017 at 10:39AM and ending July 17th, 2017 at 10:39AM, recording one week of soil temperature data. A fluorescent flag was placed for location recognition.

Statistical Analysis- From the beginning of the experiment all the data was collected using pre-typed data sheets, compiled and simplified. Using R studio, linear regression graphs were made to model the relationships between then analyzed using a linear regression graph to model the relationship death rate (y) and soil moisture (x), Death rate (y) soil temperature (x), regeneration rate(y) and soil moisture(x), regeneration rate(y) and soil temperature. Using R-studio, Multiple

regression tables were created to model the relationship between (x) soil temperature, (y) regeneration rate, death rate, understory presence, understory density, and slope. A multiple regression table was also used to test the relationship between (x) soil moisture, (y) regeneration rate, death rate, understory presence, understory density, and slope. All materials from DRC-01 were recollected and disposed of properly.

Results:

Using linear models, the number of alive trees expressed an increase in tree birth regeneration as moisture percentage increases (Figure. 1, lm R-Squared: 2.283%, P-Value: .4709), indicating a weak statistical relationship. Dead trees increased as the percent of soil moisture increased (Figure. 2, lm R-Squared 12.5%, P-value: .08243) indicating a weak statistical relationship. Alive trees declined as average soil temperature increased (Figure. 3, lm R-Squared: 1.0%, P-value: .6294) Number of dead trees dropped as the average temperature increased (Figure. 4, lm, R-Squared 7.1%, P-value: .1958) Fractions of alive trees and fractions of dead trees both declined as soil moisture decreased (Figure 5. Fraction of alive lm, R-squared: .7544%, P-value: .6772) (Figure .6, Fractions of dead trees, R-Squared: .472%, P-value: .7442). Fraction of dead trees and fraction of alive trees expressed declined as soil temperature increased (Figure. 7, lm fraction of alive trees, R-squared: .665%, P-value: .7005) (Figure .8, lm fraction dead trees R-squared: 2.7%, P-value: .4265). Basal area of alive trees and basal area of dead trees decreased as average temperature increased (Figure. 11, basal area alive, lm R-squared: .0596, P-value: 0.2396) (Figure. 12, basal area dead, R-squared: .0596, P-value: 0.2396)

Multiple regression graphs were used to predict the value of variance of average Temperature, Percent moisture, *P. microphyllus* presence and density, *F. Arizonica* presence and density, *L. porteri* presence and density, and slope on alive trees (Table. 1, no significance). Dead trees (Table. 2, no significance). Basal area alive (Table. 3, *L. porteri* density increased as dead trees decreased, $\Pr(>f)$: .08653). Basal area dead (Table. 4, no significance). Fraction of dead trees (Table. 5, no significance). Fraction of alive trees (Table. 6, as temperature increases alive trees decrease, $\Pr(>f)$: .03657). Fraction of dead trees (Table 7, *P. microphyllus* coverage: *P. microphyllus* density, $\Pr(>f)$: .02007). Dead trees (Table 8, *L. porteri* coverage: *L. porteri* density increases $\Pr(>f)$.06647).

Discussion:

In Figure.1, as the percentage of soil moisture increases, the number of alive quaking aspens increases. In Figure. 3, as average soil temperature increases the number of alive quaking aspens decrease. In Figure 8, as average soil temperature increases fraction of alive aspens increases. In Figure 9, as the percentage of soil moisture increases, the basal area of alive aspen increases. In Figure 11, as average soil temperature increases, basal area of alive aspen increases. The average R-squared value for the five figures is 7.9% and the average P-value is about .7023, making them statistically insignificant. In Figure .2, as percent soil moisture increases, dead aspens increase. In Figure .4, as average soil temperature increases, dead aspens are increasing. In Figure .6, as the percent of soil moisture increases, the fraction of the dead trees is increasing. In Figure.7, as average soil temperature increases, fraction of dead trees decrease. In Figure 10, as the percent soil moisture increases the basal area of dead trees increase. In Figure. 12, as average soil temperature increases basal area of dead aspens increase. In all the dead data sets of

P. tremuloides the average R-squared value for the figures is 6.2% and the average P-value is about .8023. However, all the alive *P. tremuloides* data sets have visual significance since their trendlines indicate a positive or negative relationship between their x & y factors. This visual significance is an indicator for potential. The potential to express statistical significance is possible if the study is replicated under new methods. All the dead *P. tremuloides* data sets did not visually represent the dynamics of the plot. One reason could be that most of the barren plots did not have a presence of dead *P. tremuloides* nor their stumps. The barren plots already have or are starting to be taken over by different vegetation. Also, the barren plots have a significantly lower amount of soil moisture percentage which is unfavorable for the growth rate of *P. tremuloides* ramets.

Multiple regression ANOVAS were ran as an extension of simple linear models. They were used to predict the value of all the alive and dead *P. tremuloides* data sets based on the values of regeneration rate, death rate, understory presence, understory density, and slope. The fraction of alive trees is declining as soil temperature is increasing, according to the multiple regression Table 1-5 did not express any significance. Table.6 (Pr(>f): .03697) As soil temperature increases soil moisture decreases, the more susceptible *P. tremuloides* is to stress, disease and death (Hogg and Brant 2002). Table 7 did not express any significance as well. In Table .8, *S.oreophilus* density and coverage did respond to Number of dead *P. tremuloides*, As the number of dead trees increases, the density of *S.oreophilus* decreases. *S.oreophilus* grows in open areas and on open slopes, and can live in dry soils (University of Washington, 2006). Therefore, the trend is inconsistent with what the actual plot looks like. Overall, the study does have enough evidence to back up the first portion of the hypothesis which is “I predict a higher percentage rate of *P. tremuloides* dying off than regenerating due to higher soil temperatures and

low soil moisture. (Table. 6)” The second and third part of the hypothesis which are, “I predict that regeneration rate will be lower because of low soil moisture. I predict its mortality rate will be higher because of high temperatures and low soil moisture.” Are not supported by any statistical analysis performed. Half of my hypothesis has any significance. Replication if this study in a larger scale would be better for understanding the dynamics of the aspen forests in Gunnison county, Colorado. Incorporating a new study on how aspen understory could be a predictor of regeneration and death would be ideal as well. Overall the survey answered one question and still leaves some questions to be answered with future experiments.

Tables and Figures:

Figure. 1

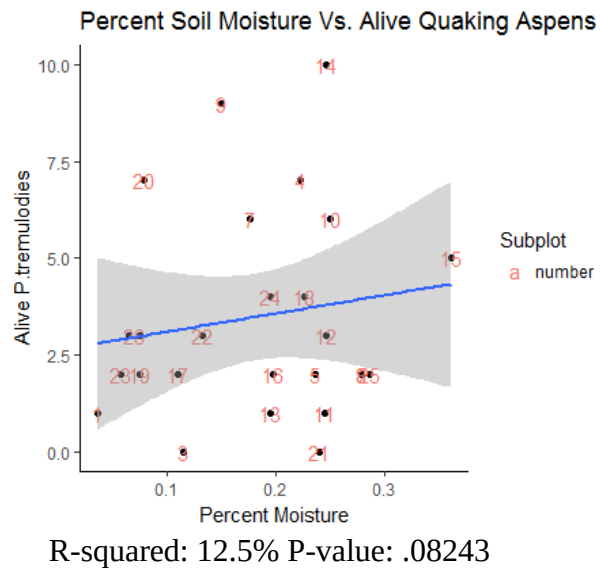


Figure. 2

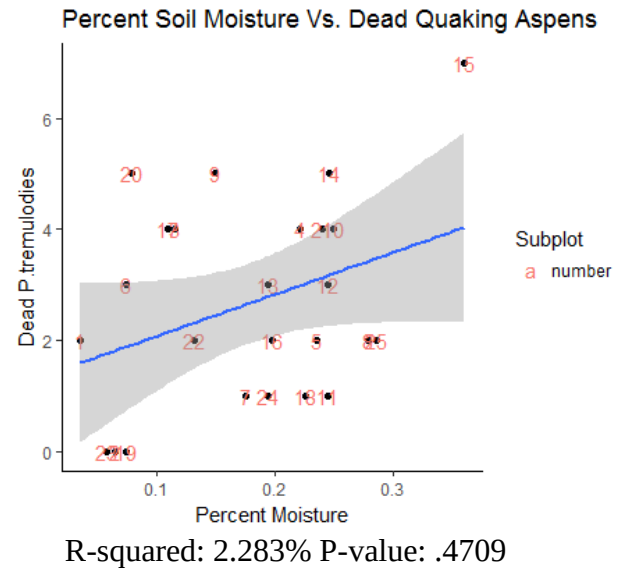


Figure. 3

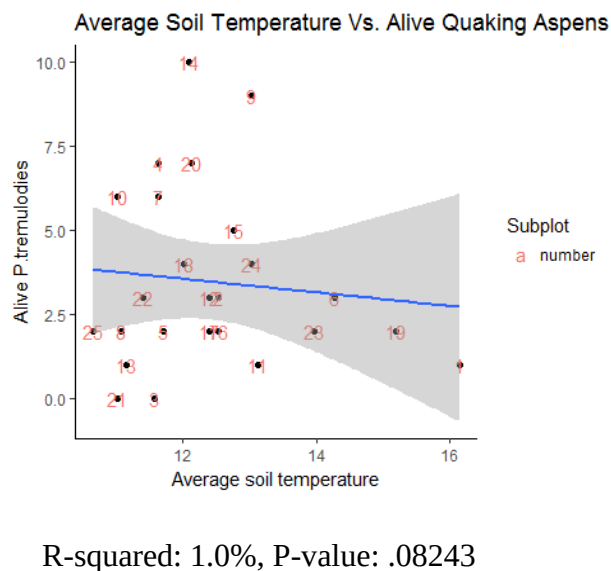


Figure. 4

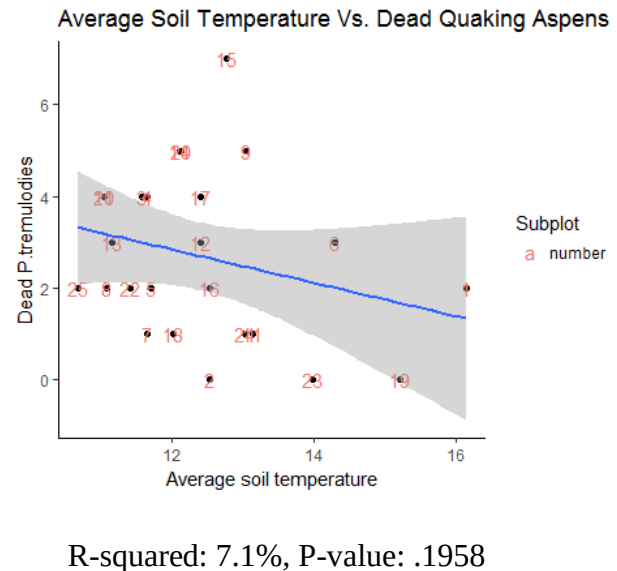
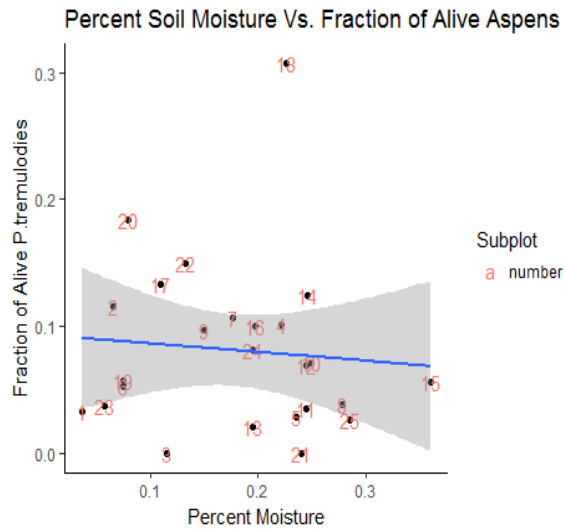
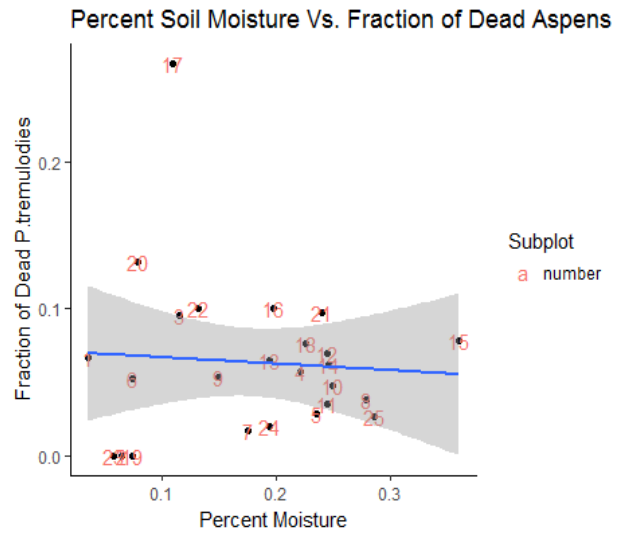
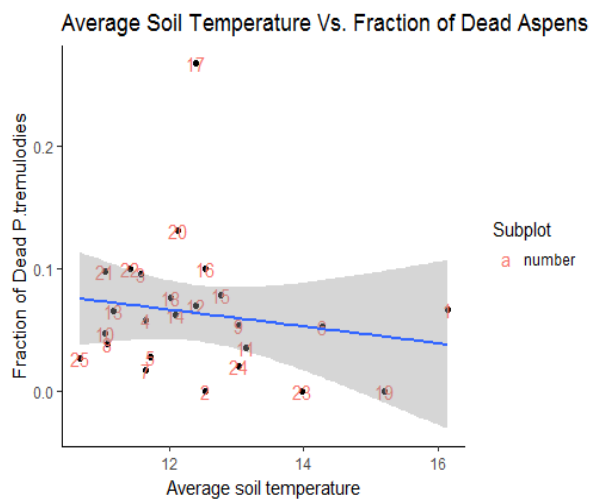


Figure. 5

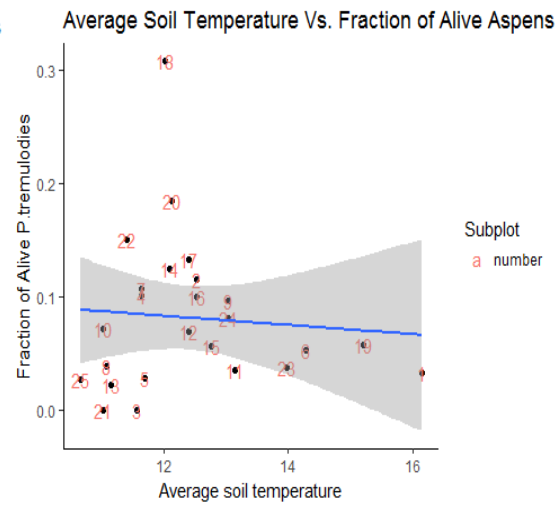
R-squared: .7544%, P-value: .6797

Figure. 6

R-squared: .472%, P-value: .7442

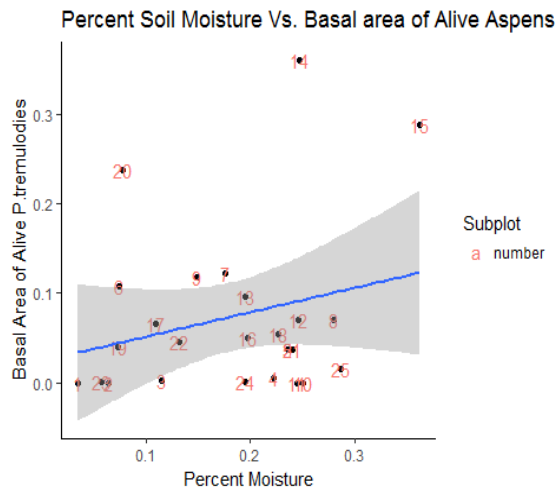
Figure. 7

R-squared: .655%, P-value: .7005

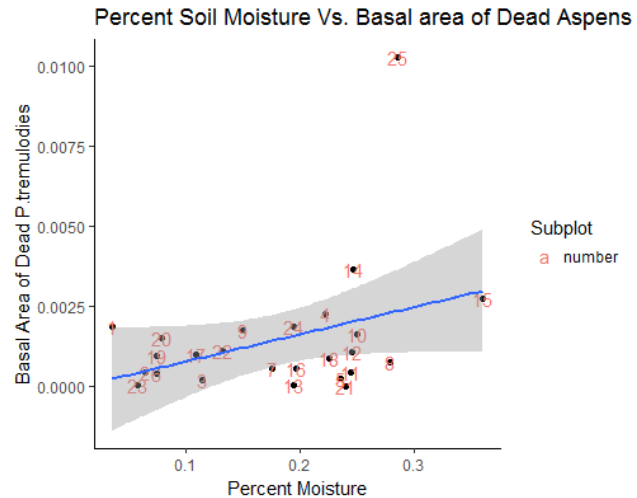
Figure. 8

R-squared: 2.7%, P-value: .4265

Figure. 9**Figure. 10**

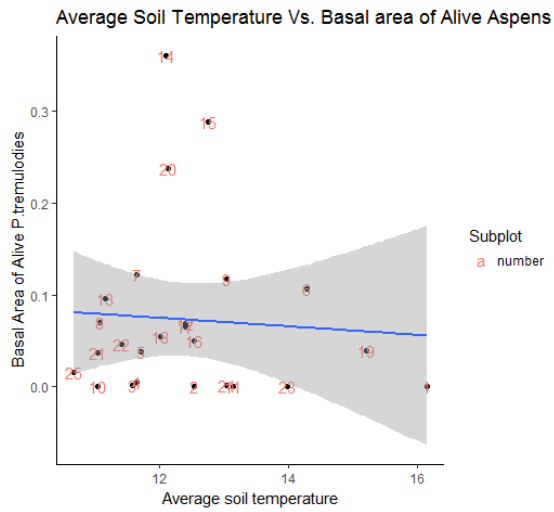


R-squared: 13.9%, P-value: .0663



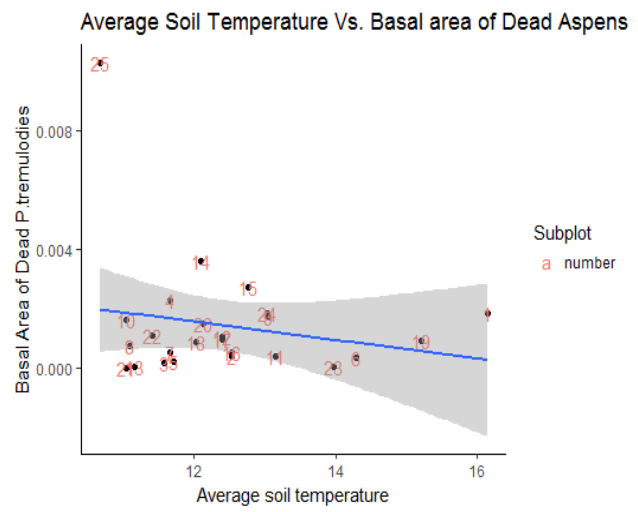
R-squared: 5.9%, P-value: .2396

Figure. 11



R-squared: .395%, P-value: .7652

Figure. 12



R-squared: .0596%, P-value: .2396

Tables:

Table. 1

Anova Table (Type II tests)				
Rensponse: alive trees	Sum Sq	Df	F value	Pr(>F)
Average Temperature	5.643	1	0.7298	0.4064
Percent Moisture	7.278	1	0.9412	0.3473
<i>P. microphyllus</i> Covearge	5.878	1	0.7601	0.3970
<i>P. microphyllus</i> Density	1.687	1	0.2170	0.6480
<i>F. Arizonica</i> Coverage	6.75	1	0.8729	0.3650
<i>F. Arizonica</i> Density	2.842	1	0.3675	0.5535
<i>L. porteri</i> Coverage	1.05	1	0.1357	0.7177
<i>L. porteri</i> Density	20.43	1	2.6420	0.1249
Slope	0.006	1	0.0007	0.9788
Residuals	115.991	15		

Table. 2

Anova Table (Type II tests)				
Rensponse: Dead Trees	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.001	1	0.0004	0.9835
Percent Moisture	0.001	1	0.0004	0.9834
<i>P. microphyllus</i> Covearge	1.976	1	0.6334	0.4385
<i>P. microphyllus</i> Density	1.250	1	0.4006	0.5363
<i>F. Arizonica</i> Coverage	1.297	1	0.416	0.5287
<i>F. Arizonica</i> Density	1.566	1	0.502	0.4895
<i>L. porteri</i> Coverage	1.296	1	0.4153	0.5290
<i>L. porteri</i> Density	5.084	1	1.6299	0.2211
Slope	7.095	1	2.2746	0.1523
Residuals	46.788	15		

Table. 3

Anova Table (Type II tests)				
Rensponse: Basal area alive	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.00428	1	0.4823	0.49800
Percent Moisture	0.001892	1	0.2133	0.65085
<i>P. microphyllus</i> Covearge	0.019148	1	2.1578	0.16251
<i>P. microphyllus</i> Density	0.001435	1	0.1617	0.69329
<i>F. Arizona</i> Coverage	0.001363	1	0.1536	0.70067
<i>F. Arizona</i> Density	0.004752	1	0.5355	0.47557
<i>L. porteri</i> Coverage	0.005612	1	0.6325	0.438866
<i>L. porteri</i> Density	0.029856	1	3.3645	0.08653
Slope	0.000665	1	0.075	0.78795
Residuals	0.133108	15		

Table. 4

Anova Table (Type II tests)				
Rensponse: Basal area dead	Sum Sq	Df	F value	Pr(>F)
Average Temperature	1.54E-06	1	0.2909	0.5975
Percent Moisture	1.07E-05	1	2.0202	0.1767
<i>P. microphyllus</i> Covearge	5.88E-06	1	1.1119	0.3084
<i>P. microphyllus</i> Density	3.41E-07	1	0.0645	0.803
<i>F. Arizona</i> Coverage	6.00E-09	1	0.0012	0.9731
<i>F. Arizona</i> Density	3.80E-07	1	0.0719	0.7922
<i>L. porteri</i> Coverage	3.45E-06	1	0.6531	0.4316
<i>L. porteri</i> Density	3.22E-07	1	0.0609	0.8084
Slope	5.01E-07	1	0.0947	0.7625
Residuals	5.01E-07	15		

Table. 5

Anova Table (Type II tests)				
Response: Basal area dead	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.00094	1	0.2875	0.5997
Percent Moisture	0.000489	1	0.1498	0.7042
<i>P. microphyllus</i> Covearge	0.007145	1	2.1865	0.1599
<i>P. microphyllus</i> Density	0.000048	1	0.0147	0.9052
<i>F. Arizona</i> Coverage	0.001659	1	0.5076	0.4871
<i>F. Arizona</i> Density	0.000011	1	0.0033	0.9551
<i>L. porteri</i> Coverage	0.001574	1	0.4818	0.4982
<i>L. porteri</i> Density	0.000934	1	0.2857	0.6008
Slope	0.000334	1	0.1023	0.7534
Residuals	0.049016	15		

Table. 6

Anova Table (Type II tests)				
Response: Fraction of alive trees	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.025561	1	5.2418	0.03697
Percent Moisture	0.006152	1	1.2617	0.27899
<i>P. microphyllus</i> Covearge	0.011427	1	2.3434	0.14663
<i>P. microphyllus</i> Density	0.0013	1	0.2666	0.61315
<i>F. Arizona</i> Coverage	0.00899	1	1.8436	0.19461
<i>F. Arizona</i> Density	0.000531	1	0.1088	0.74605
<i>L. porteri</i> Coverage	0.007209	1	1.4783	0.23283
<i>L. porteri</i> Density	0.000254	1	0.052	0.82264
Slope	0.005671	1	1.1631	0.29787
Residuals	0.073144	15		

Table. 7

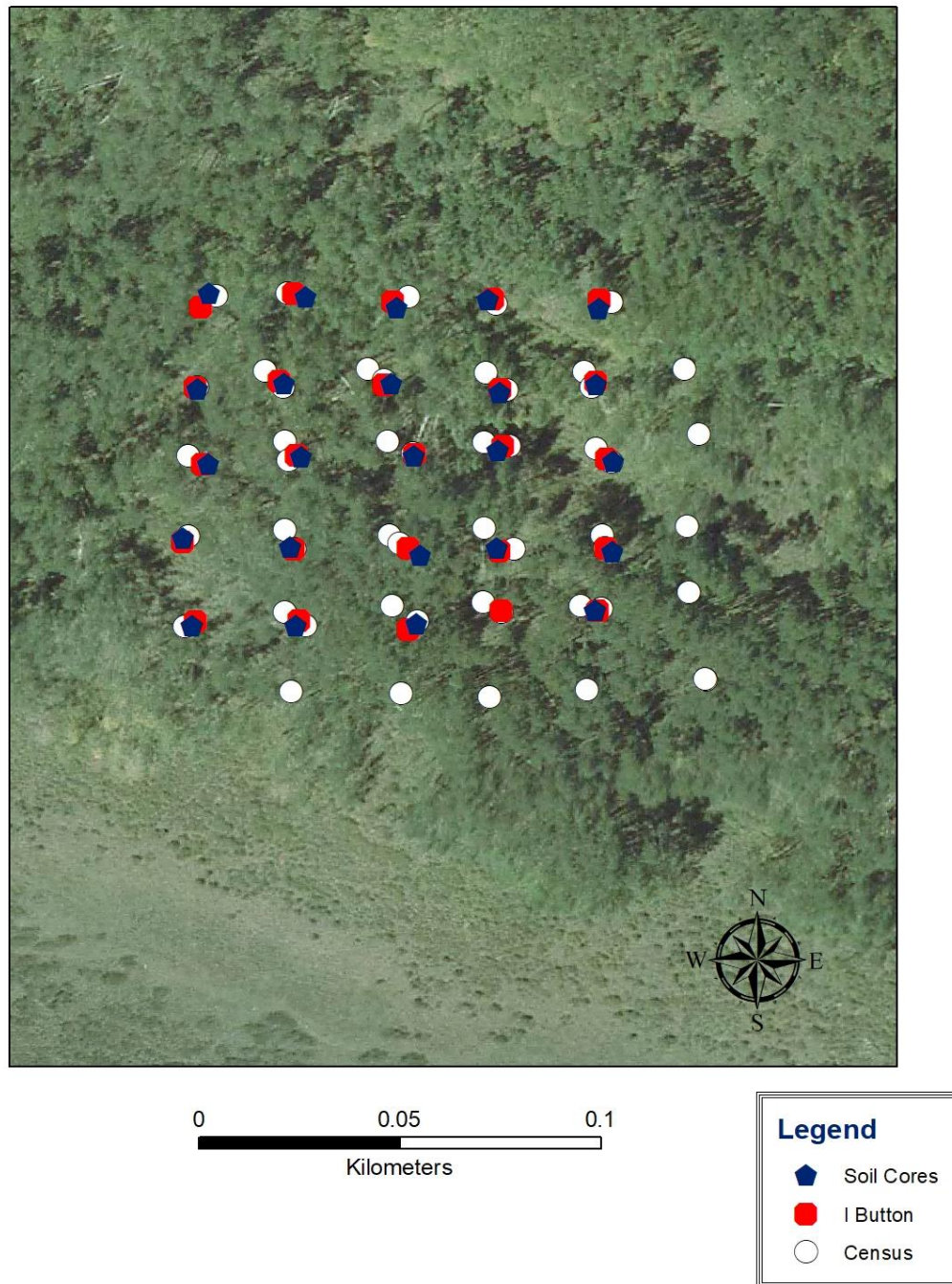
Anova Table (Type II tests)				
Rensponse: Dead trees	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.269	1	0.1224	0.73133
Percent Moisture	0.156	1	0.071	0.7935
Slope	5.279	1	2.4054	0.14176
<i>P. microphyllus</i> Covearge: <i>P. microphyllus</i> Density	10.588	2	2.4122	0.12351
<i>F. Arizonica</i> Density : <i>F. Arizonica</i> Density	0.835	2	0.1903	0.82866
<i>L. porteri</i> Coverage : <i>L. porteri</i> Density	14.334	2	3.2657	0.06647
Residuals	32.919	15		

Table. 8

Anova Table (Type II tests)				
Rensponse: Dead trees	Sum Sq	Df	F value	Pr(>F)
Average Temperature	0.004001	1	1.6877	0.21352
Percent Moisture	0.001237	1	0.5218	0.4812
Slope	0.001247	1	0.5259	0.47949
<i>P. microphyllus</i> Covearge: <i>P. microphyllus</i> Density	0.024321	2	5.1292	0.02007
<i>F. Arizonica</i> Density : <i>F. Arizonica</i> Density	0.00288	2	0.6073	0.55769
<i>L. porteri</i> Coverage : <i>L. porteri</i> Density	0.007991	2	1.6859	0.21867
Residuals	0.035563	15		

Figure 13. Research site.

Marco's Research Site: DCR-01



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