Estimating Biomass of Eastern Redcedar (*Juniperus virginiana*) with Key Variables and Understory Analysis

Natural Resources and Environmental Sciences Capstone Project
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Introduction

With increasing awareness of the invasion of Juniperus virginiana, or Eastern Redcedar, across much of the Great Plains (Bragg and Hulbert 1976), it has become more necessary to determine the implications of this population increase. With a large amount of this encroachment happening within the past 30 years (Pierce and Reich 2009) there are many data points which need to be collected to find conclusive results of the growing populations. The areas that are dominated by the Eastern Redcedar are commonly found to be of poor soil nutritional value, steep slope and of a shallow soil profile (Pierce and Reich 2009).

Alternative fuels are in constant demand throughout the world. The possibility of using Eastern Redcedar as a potential biofuel source to supply this demand requires many variables (i.e. logistics, consistent economic demand, and total physical supply) that must be closely analyzed before a conclusion can be found. This group decided to focus on predicting the biomass of Eastern Redcedars within varied tree densities. The goal was to determine the best variables for predicting the biomass of a single redcedar tree, and to also determine what effect this has on the tree's understory.

Literature Review

Eastern Redcedar, *Juniperus virginiana*, has not been abundant in the tallgrass prairie until recent decades. In the past 50 years, some study areas have transitioned from completely treeless to being defined by hardwood growth (Fitch *et al* 2001). This new invasion, mainly of *Juniperus virginiana*, has occurred due to several factors; the practice of fire suppression, the decline of large grazing mammal populations, and change in land use (Norris *et al* 2001). Disruptions in the ecosystem, such as fire, have played an important role in plant associations on the prairie. Fire suppression has allowed the non-native species of Juniper, Eastern Redcedar, to invade. The trees' fire-intolerant seeds have had a significant impact on the prairie community including altering species habitat, soil chemistry, and biodiversity (Pierce and Peter 2008). A wide variety of small mammals are essential to the tallgrass prairie system for adjusting a plant community's composition and structure. Since the invasion of redcedar, the configuration of the understory has changed, showing a decrease in the diversity of these mammals (Horncastle *et al* 2005). Along with the habitat change associated with the encroachment of Eastern Redcedar, the soil chemistry changed dramatically. Tallgrass prairie biomass is concentrated belowground but is highly productive aboveground, with the change to redcedar stands, the biomass is concentrated aboveground, allowing more storage of carbon. With the increase of carbon storage, the tallgrass prairie and its associated plant communities can alter many components such as decay, growth, and productivity (Norris *et al* 2001).

Eastern Redcedar has invaded and established a foot hold in Kansas and across the Midwest over time. For example in Oklahoma, "The Governor's Task Force, in 2002, suggested that some 8 million acres of juniper existed in the state. That same Task Force estimated that Oklahoma is losing almost 300,000 acres per year to juniper encroachment" (McKinley, 2012).

This diagnosis is true across much of the native tallgrass prairie, illustrating an increasing demand for a solution to stopping the spread of Eastern Redcedar. Research has been done on the potential biofuel use of redcedar through field studies and biomass estimates. By collecting field data such as DBH (diameter at breast height), DGL (diameter at ground line), canopy width and tree height, each tree's biomass can be estimated. With this data and an estimate of the total acreage of redcedar in Kansas, one can predict the total potential energy resource available in Kansas. However this in no way implies all the biomass is accessible, available, or economical to harvest, transport, process or utilize for biofuel purposes. This value potentially contained within Eastern Redcedar presents an opportunity. Although Eastern Redcedar has already invaded, recovery of the native ecosystem after removal is viable (Pierce *et al* 2010). This represents a crucial link for this topic. The removal of *Juniperus virginiana* could be both economically and environmentally advantageous. The removal of Eastern Redcedar for its value as biofuel could positively impact the local ecology by helping restore populations of native fauna (Alford *et al* 2012).

This research illustrates both the problems and opportunities associated with Eastern Redcedar invasion. Redcedar has been shown to cause environmental problems, but the environment has also shown resiliency after removal of the species. This resiliency paired with the potential value of the biomass contained in Eastern Redcedar provides an opportunity to restore the local ecosystem. What is needed, however, is more research on the reliability of variables and methods to estimate the amount of biomass available.

Research question and hypothesis

Biomass- Which of the key variables is the best indicator of redcedar biomass?

Understory- There is no relationship between canopy cover and vegetation composition.

Study Area

For this study, an area located 11.5 miles Northwest of Kansas State University on Tuttle Creek Blvd. Figure 1 is a map showing Kansas State University as the starting location (A) and the study area (B) as the final destination point was utilized. Tuttle Creek Reservoir is the large body of water located in the Northeastern portion of the photo.

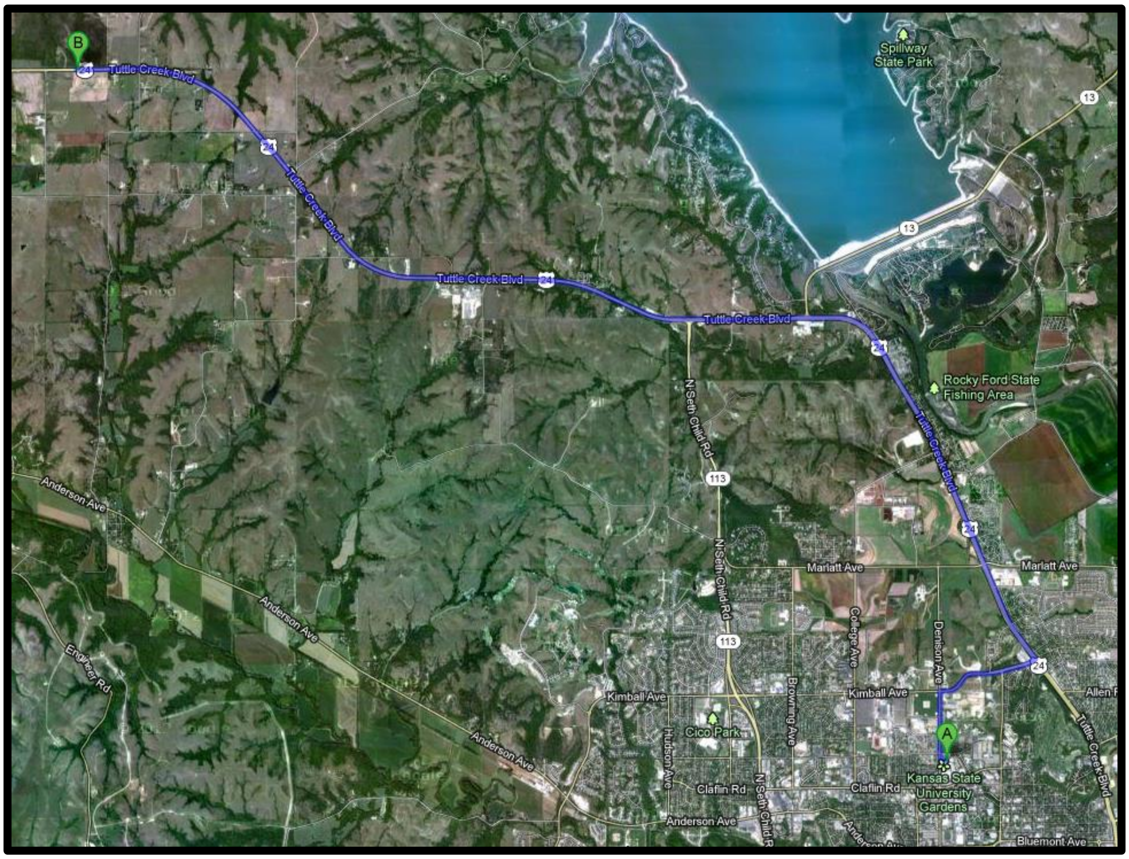


Figure 1: The image above is showing Kansas State University (A) and the study area (B). The blue line shows driving directions.

The name of the study area is The Prairie Rose Ranch owned by Mr. Charles Hall. This ranch has a large population of Eastern Redcedar, and was selected for this reason. Figure 2 is an image showing an aerial view of the entirety of The Prairie Rose Ranch, highlighting the amount of tree cover in the area. This image shows the tree density gradient at the ranch, with areas of low, medium, and high density cover.

Figure 2: The above image is an aerial image showing the entirety of the study area.

Three transects were plotted within the *Juniperus virginiana* forest to study. Each transect was 200 ft. long and was plotted in a specific tree density. Figure 3 shows the three different transects. The pink pins represent the low density forest, yellow pins represent the medium density forest, and the blue pins represent the high density forest.

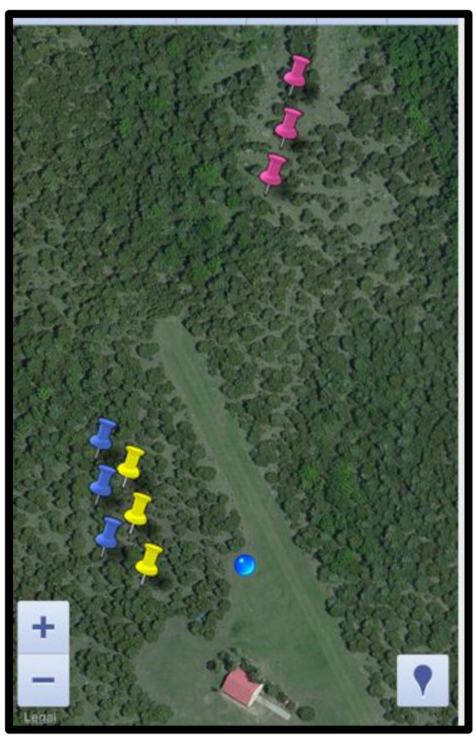


Figure 3: The above image is an aerial image showing the locations of the three transects.

The Prairie Rose Ranch is located in the Flint Hills of Kansas within the tallgrass prairie ecoregion. The Flint Hills are comprised of primarily Permian limestone and shale. The tallgrass prairie is comprised of switchgrass, big bluestem, little bluestem, and Indiangrass. Within the Flint Hills the land use is primarily rangeland for cattle grazing and there are areas of cropland agriculture around river valleys (Hansen, 2012).

Charles Hall bought the area in 1977, mostly because of the trees. He has not done anything to the land since 1977, and there hasn't been farming on the land since 1960. This information has been gathered from a personal interview with Charles Hall himself. Figure 4 is a picture of the study area in 1962, with a much smaller population of trees than at present.

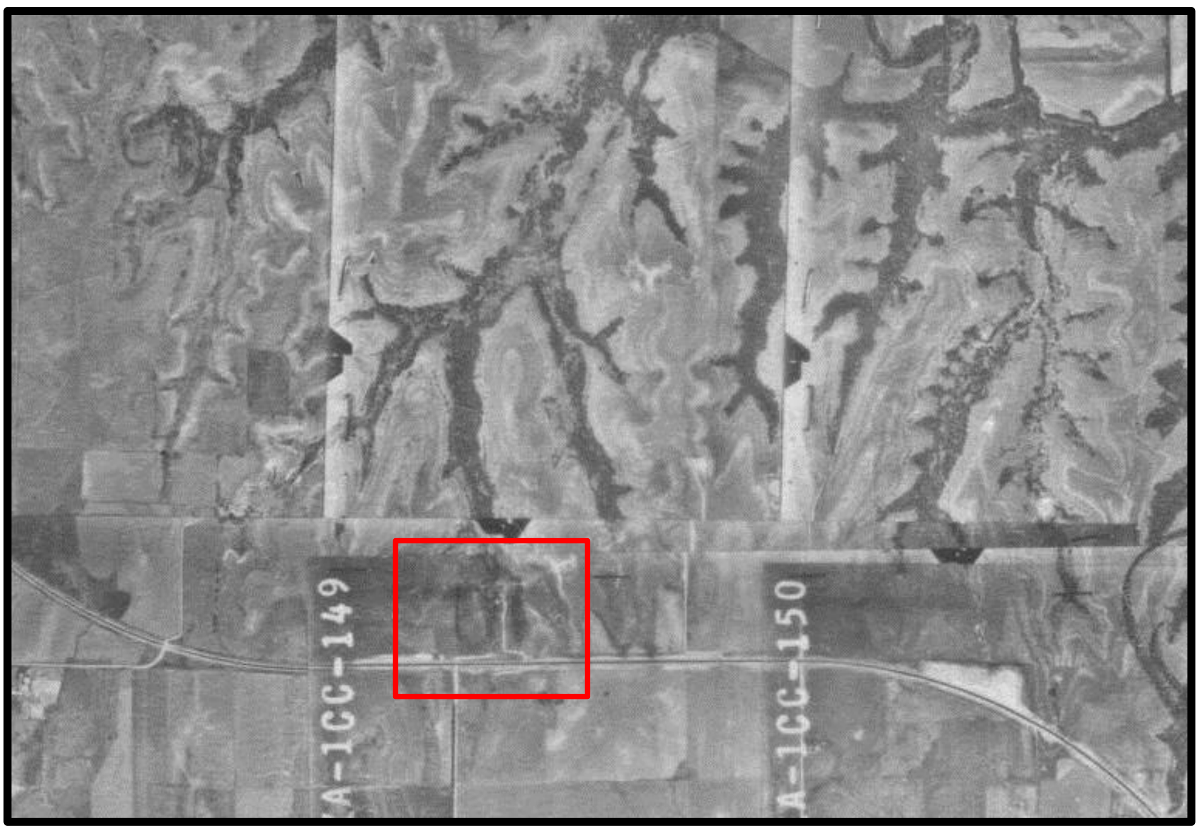


Figure 4: The above image is an aerial image for the study area in 1962. The red box outlines the study area.

Field Methods

Transects

To obtain data from the redcedar trees for the purpose of this study, the placement of three transect was chosen; one each in three different tree densities. The densities were chosen by looking at aerial photos and approximating the densities of trees to match levels of high, medium, and low. Figure 5 shows pictures of the different densities. Once the three densities were found, 60m of rope was laid out for each transect. All three transects ran north to south, with seven points marked on each rope every 10m. In total, 21 points were marked out over three transects. Following the setup of transects, data was then able to be collected. At each point there were four quadrants labeled quadrant one through four. The tree closest to each quadrant was chosen to collect data from. Once a tree was chosen, data was taken from it.

Figure 5: Tree densities (low, medium, high)

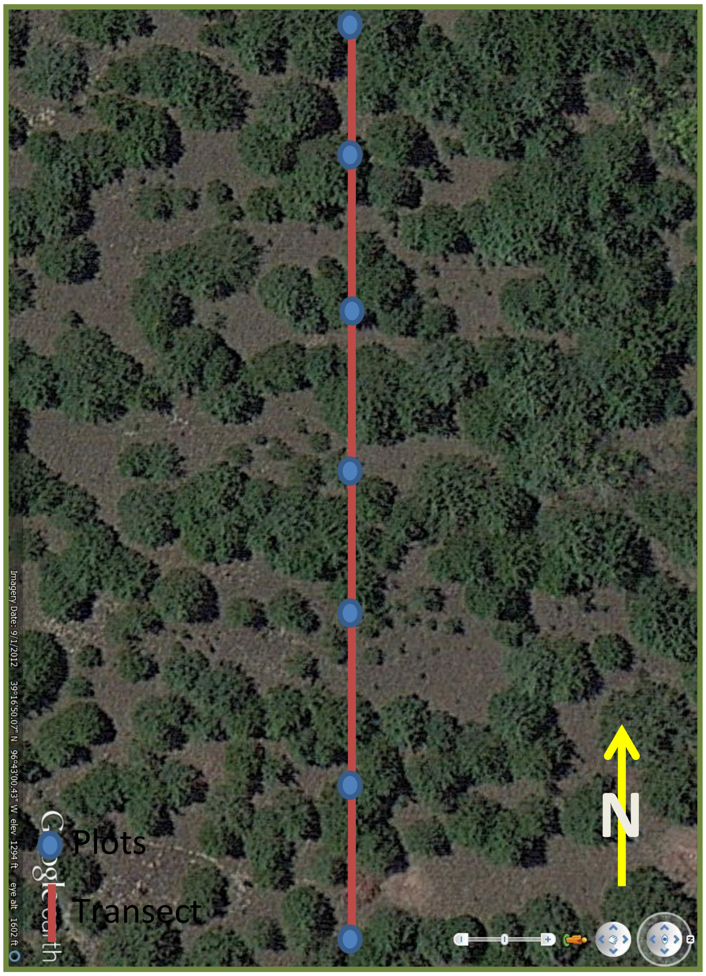
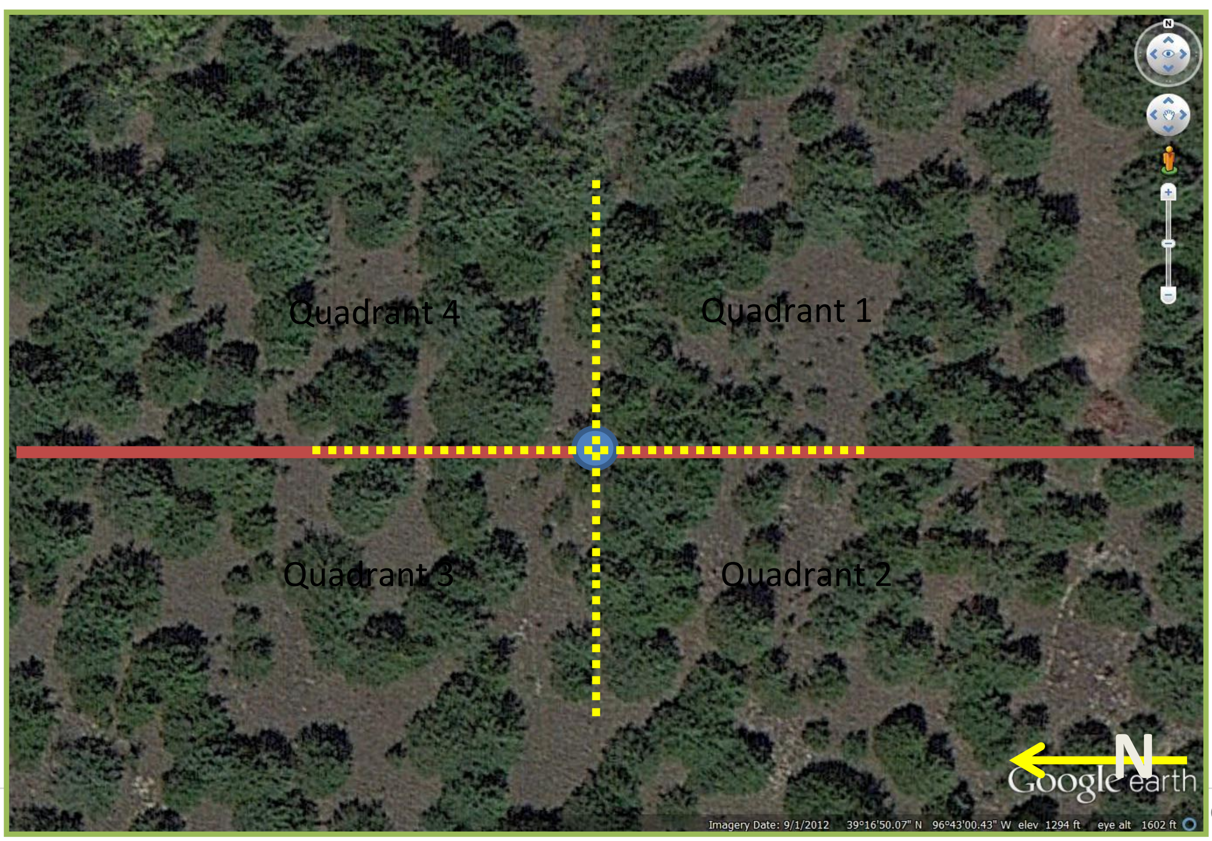


Figure 6. To the left is a diagram of an example of a transect laid out. The red line is a transect and the blue dots represent the plots. Plot number 1 is the furthest north blue dot, plot 7 is the furthest south plot.

Figure 7: The diagram below shows how the quadrants are identified for each of the 21 points.



Biomass

The measurements that were gathered from each tree were diameter at ground line, diameter at breast height, distance from center of plot, canopy width (two directions), and tree height. In addition, some trees were cored and five trees were cut down and weighed. Gathering the data for diameter at ground line (Figure 8), diameter at breast height, canopy width (two directions), and distance from center of plot (Figure 9) was all done with a measuring tape. The tree height was calculated with a Clinometer (Figure 10) and cores were taken with a tree corer. Within the medium tree density transect, five trees were chosen to cut down and weigh; two trees were picked from plot 1, two trees were picked from plot 4, and one tree was picked from plot 7.



Figures 8,9 and 10

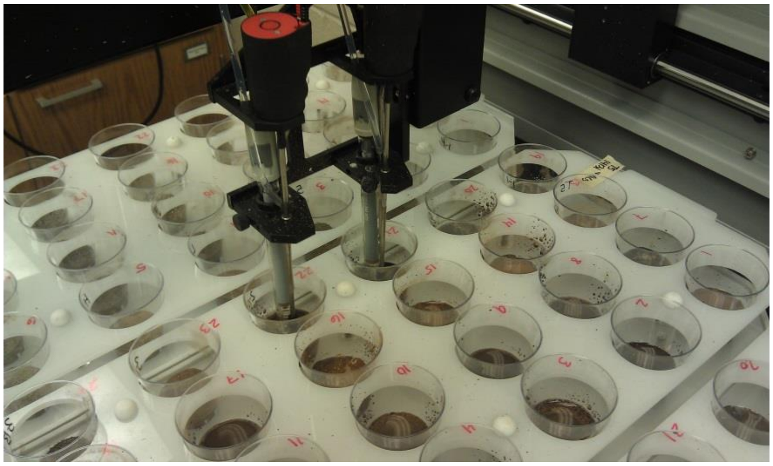
A field form was produced to try and keep data as accurate and consistent as possible. Figure 11 is an example of the field form that was developed for this project. This particular field form was for medium density. In the field it was easier to take the circumference measurements than derive the diameter from the circumference measurements. In the analysis, the diameter was used but it was derived from the circumference.

Transect 2 (Medium Density)						
	Circumference Ground Line	Circumference Breast Height	Distance from Center of Plot	Canopy Width (2 directions)	Tree Height	Age
Plot 1						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 2						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 3						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 4						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 5						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 6						
Quad 1						
Quad 2						
Quad 3						
Quad 4						
Plot 7						
Quad 1						
Quad 2						
Quad 3						
Quad 4						

Figure 11: The table above shows the field form used for medium density.

Soil Sampling

One soil composite sample was taken for each quadrant using a standard hand-held soil probe (Figure 12). Each composite was comprised of three samples taken from 0-3”, sampled equidistant and diagonally from the quadrant origin. The 21 soil samples were placed in an oven at 60 degrees Celsius overnight, then ground and passed through a 2mm sieve. 10 gram samples were then weighed and 10mL of water was added. The pHs were then read using the Kansas State University Soil Testing Laboratory robotic soil probe, the Skalar SP50 (Figure 13).



Figures 12 & 13

Understory Cover

Starting from the north end of the transect and moving along in intervals of 30 feet the Daubenmire Quadrat method was used. At each point along the transect, three sticks were used to construct the Daubenmire square, 2 perpendicular from the transect and 1 parallel to the transect that connected the 2 perpendicular sticks. After the Daubenmire quadrat was laid out, visual estimates (in percentages) of certain life forms and features were taken. This includes grasses, forbs, shrubs and vines, bare ground, litter, persistent litter, rock, and moss on a scale of 1 – 5%, 6 – 25%, 26 -50%, 51 - 75%, 76 – 95%, and 96 – 100% (Figure 14). This method was used on all three density transects.

Figure 14

Daubenmire Quadrat Method for estimating understory cover.
Cover Classes:
1 = 1 - 5 (2.5%) **3** = 26 - 50% (37.5%) **5** = 76-95% (85%)
2 = 6 - 25 (15%) **4** = 51 - 75% (62.5%) **6** = 96-100% (97.5%)

Site location:______ **Plot #**______ **Date:** ______**, 2013** **Photo Numbers** **Scribe Name:**

LIFEFORMS plots	1	2	3	4	5	6	7	8	9	10
Grasses And Grasslikes (sedges and rushes)										
Forbs (Herbs/broadleaf non-grasses)										
Shrubs and Vines										
Redcedar (From densitometer average in N,E,S & W)										
Bare ground										
Litter (Ground and Standing)										
Persistent Litter										
Rock										
Moss										
Anything else you decide to include										

Canopy Cover

For this data collection, a Standard Model-C Densiometer (Figure 15) was used to measure the amount of canopy cover at each location. As with many of the other collection methods, each transect was approached with having 7 points, each 10 meters apart. Each point was then split into four quadrants to allow for more accurate density measurements.

Figure 15

Within each quadrant, the general directions on the densiometer were followed (Figure 16). This included holding the tool 12-18 inches in front of the observer's body at elbow height. The operator's body should be just outside of the reflective mirror (Figure 17).

Figures 16 &17

Within each square etched into the mirror, four equi-spaced dots are visualized and the number of dots covered by canopy openings (i.e. open sky) were counted. This final number is then multiplied by 1.04 to account for the lack of four dots on the densiometer. This result is the overhead space not occupied by canopy, so to calculate the canopy cover, find the difference between this overhead space and 100. This process was repeated in all four cardinal directions (North, East, South, and West) and in each of the four quadrants at each point for a total of 16 measurements per point. These methods were continued for each point in all three density transects.

Worm Observations

For this data collection, preparation needed to occur before a visit to the study site. The mixture needed required 1/2 canister of dry mustard to 1 gallon of water (Figures 18 and 19). To simplify this process, one canister of mustard was mixed with water in a glass, then 1/2 the mixture would be poured into 1 gallon nearly full of water. One gallon was created for each point, resulting in 21 different gallons.

Figures 18 & 19

Once in the field, the grass and turf in each southeast quadrant was removed by hand. The soil in this section was then soaked with approximately 1/3 gallon of the mustard mixture (shaken first). Once this amount was soaked into the soil without running off, the actions were repeated until the entire gallon was used (Figure 20).

Figures 20 & 21

Once all of the liquid had been poured on the soil, the number of biotic creatures that appeared was counted immediately. Items such as snails, worms (Figure 21), spider, etc, were all split into separate categories and recorded in the field.

Data and Results

Numerical Data

Figure 22 is the filled out field form for the medium density transect, with no cores taken in the medium density. Figure 23 is the filled out field form for the low density transect.

Transcet 2 (Medium Density)						
	Circumference Ground Line	Circumference Breast Height	Distance from Center of Plot	Canopy Width (2 directions)	Tree Height	Age
Plot 1						
Quad 1	30 in.	20 in.	15 ft.	14 ft. 1in. / 15 ft. 10 in.	6.4m	
Quad 2	17 in.	9 in.	23 ft. 4 in.	7 ft. 10 in. / 8 ft. 5 in.	3.2m	
Quad 3	18 in.	12 in.	35 ft. 10 in.	10 ft. 2in. /	3.6m	
Quad 4	40 in.	27 in.	16 ft. 7 in.	18 ft. / 19 ft. 4 in.	5.6m	
Plot 4						
Quad 1	37 in.	27 in.	11 ft.	14 ft. 3 in. / 12 ft. 6 in.	5.2m	
Quad 2	16 in.	6 in.	8 ft. 11 in.	8 ft. 7 in. / 9 ft. 6 in.	3.6m	
Quad 3	19 in.	11 in.	16 ft.	8 ft. 8in. / 10 ft 9 in.	4.4m	
Quad 4	39 in.	23 in.	22 ft.	13 ft. 9 in. / 11 ft. 11 in.	5.6m	
Plot 7						
Quad 1	41 in.	52 in.	30 ft.	21 ft 3 in. / 25 ft. 7 in.	7.6m	
Quad 2	52 in.	33 in.	15 ft. 9 in.	12 ft 1 in. / 18 ft. 8 in.	7.6m	
Quad 3	22 in.	16 in.	15 ft. 8 in.	8 ft 8 in. / 16 ft. 2 in.	4.8m	
Quad 4	11 in.	20 in.	18 ft. 5 in.	10 ft. 7 in. / 8 ft. 4 in.	3.6m	

Figure 22: The table above is the medium density field form.

Transcet 1 (Low Density)						
	Circumference Ground Line	Circumference Breast Height	Distance from Center of Plot	Canopy Width (2 directions)	Tree Height	Age
Plot 1						
Quad 1	1.43	1.08	7.6	8.25/8.7	6.54	
Quad 2	0.9	0.59	13.65	4.1/4.38	7.23	
Quad 3	0.9	0.8	22.9	7.6/7.65	6.64	
Quad 4	1.22	0.63	5	6.3/6.2	5.7	
Plot 2						
Quad 1	1.35	0.85	10.8	8.4/7.25	6.8	
Quad 2	0.37	0.21	3.47	3.5/3.1	3.3	
Quad 3	0.62	0.4	14	3.5/4.2	4.2	
Quad 4	0.42	0.25	7.2	2.3/3	4.39	
Plot 3						
Quad 1	1.35	1	9	9.9/7.05	6.12	
Quad 2	1.3	0.56	24.23	7.3/7.1	6.54	
Quad 3	0.78	0.53	5.45	4.4/3.5	5.78	
Quad 4	0.82	0.36	5.95	5.8/6	5	

Figure 23: The table above is the low density field form.

ID	pH		
Low 1- North end	7.7		
Low 2	7.9		Low avg pH=7.94
Low 3	8		Med. avg pH=7.94
Low 4 @ red flag	8.1		High avg pH=7.86
Low 5	8		Conclusion: density does not drastically effect soil pH
Low 6	8		
Low 7- South end	7.9		
Medium 1- North end	8		
Medium 2	8		
Medium 3	8		
Medium 4 @ red flag	8		
Medium 5	7.8		
Medium 6	7.9		
Medium 7- South end	7.9		
High 1-North end	7.8		
High 2	8		
High 3	7.8		
HIgh 4 @ red flag	7.9		
High 5	7.8		
HIgh 6	7.8		
High 7- South end	7.9		

Figure 24: The above table shows the pH of the soils from all three transects.

Transect:	Low Density	Reported By: Chelsea Corkins and Terrance Crossland												
4/12/2013		Quadrant												
		NW			NE			SE			SW			
		Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	
Point 1:	N	96	0	0	96	0	0	96	0	0	96	0	0	1.04
Northern Most	E	96	0	0	96	0	0	96	0	0	96	0	0	
	S	90	6	6.24	96	0	0	91	5	5.2	37	59	61.36	
	W	87	9	9.36	90	6	6.24	57	39	40.56	38	58	60.32	
Point 2:	N	86	10	10.4	44	52	54.08	52	44	45.76	95	1	1.04	
	E	50	46	47.84	1	95	98.8	80	16	16.64	88	8	8.32	
	S	96	0	0	82	14	14.56	96	0	0	91	5	5.2	
	W	80	16	16.64	93	3	3.12	96	0	0	91	5	5.2	
Point 3:	N	96	0	0	10	86	89.44	27	69	71.76	91	5	5.2	
	E	56	40	41.6	0	96	99.84	76	20	20.8	79	17	17.68	
	S	92	4	4.16	72	24	24.96	79	17	17.68	94	2	2.08	
	W	96	0	0	94	2	2.08	96	0	0	96	0	0	
Point 4:	N	88	8	8.32	96	0	0	96	0	0	90	6	6.24	
	E	96	0	0	75	21	21.84	96	0	0	96	0	0	
	S	96	0	0	96	0	0	79	17	17.68	96	0	0	
	W	96	0	0	96	0	0	96	0	0	96	0	0	
Point 5:	N	96	0	0	62	34	35.36	92	4	4.16	96	0	0	
	E	84	12	12.48	80	16	16.64	64	32	33.28	79	17	17.68	
	S	80	16	16.64	96	0	0	96	0	0	31	65	67.6	
	W	81	15	15.6	91	5	5.2	56	40	41.6	12	84	87.36	
Point 6:	N	96	0	0	92	4	4.16	96	0	0	96	0	0	
	E	96	0	0	96	0	0	95	1	1.04	96	0	0	
	S	96	0	0	96	0	0	96	0	0	96	0	0	
	W	96	0	0	96	0	0	94	2	2.08	96	0	0	
Point 7:	N	3	93	96.72	3	93	96.72	86	10	10.4	1	95	98.8	
Southern Most	E	12	84	87.36	12	84	87.36	84	12	12.48	85	11	11.44	
	S	0	96	99.84	0	96	99.84	96	0	0	10	86	89.44	
	W	0	96	99.84	0	96	99.84	76	20	20.8	77	19	19.76	

Figure 25: Canopy Cover Percentage along Low Density Transect.

Transect:	Medium Density	Reported By: Chelsea Corkins and Terrance Crossland												
4/12/2013		Quadrant												
		NW			NE			SE			SW			
		Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	
Point 1:	N	96	0	0	87	9	9.36	96	0	0	96	0	0	1.04
Northern Most	E	91	5	5.2	78	18	18.72	87	9	9.36	96	0	0	
	S	96	0	0	96	0	0	92	4	4.16	96	0	0	
	W	96	0	0	96	0	0	96	0	0	96	0	0	
Point 2:	N	88	8	8.32	32	64	66.56	12	84	87.36	95	1	1.04	
	E	14	82	85.28	0	96	99.84	11	85	88.4	77	19	19.76	
	S	92	4	4.16	0	96	99.84	66	30	31.2	96	0	0	
	W	77	19	19.76	12	84	87.36	95	1	1.04	96	0	0	
Point 3:	N	0	96	99.84	1	95	98.8	52	44	45.76	6	90	93.6	
	E	17	79	82.16	12	84	87.36	50	46	47.84	67	29	30.16	
	S	13	83	86.32	48	48	49.92	11	85	88.4	68	28	29.12	
	W	0	96	99.84	0	96	99.84	40	56	58.24	10	86	89.44	
Point 4:	N	96	0	0	96	0	0	96	0	0	96	0	0	
	E	96	0	0	95	1	1.04	6	90	93.6	50	46	47.84	
	S	94	2	2.08	77	19	19.76	54	42	43.68	17	79	82.16	
	W	96	0	0	96	0	0	96	0	0	96	0	0	
Point 5:	N	5	91	94.64	32	64	66.56	90	6	6.24	12	84	87.36	
	E	14	82	85.28	94	2	2.08	34	62	64.48	59	37	38.48	
	S	15	81	84.24	96	0	0	0	96	99.84	16	80	83.2	
	W	0	96	99.84	0	96	99.84	19	77	80.08	9	87	90.48	
Point 6:	N	88	8	8.32	69	27	28.08	95	1	1.04	92	4	4.16	
	E	77	19	19.76	49	47	48.88	29	67	69.68	84	12	12.48	
	S	94	2	2.08	93	3	3.12	84	12	12.48	72	24	24.96	
	W	70	26	27.04	91	5	5.2	92	4	4.16	69	27	28.08	
Point 7:	N	92	4	4.16	72	24	24.96	75	21	21.84	92	4	4.16	
Southern Most	E	86	10	10.4	82	14	14.56	80	16	16.64	35	61	63.44	
	S	12	84	87.36	8	88	91.52	7	89	92.56	5	91	94.64	
	W	36	60	62.4	58	38	39.52	22	74	76.96	11	85	88.4	

Figure 26: Canopy Cover Percentage along Medium Density Transect.

Transect:	High Dens	Reported By: Chelsea Corkins and Terrance Crossland												
4/12/2013		Quadrant												
		NW			NE			SE			SW			
		Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	Clear Sky	Tree	Tree Adj	
Point 1:	N	94	2	2.08	96	0	0	73	23	23.92	93	3	3.12	1.04
Northern Most	E	74	22	22.88	8	88	91.52	2	94	97.76	17	79	82.16	
	S	77	19	19.76	15	81	84.24	0	96	99.84	18	78	81.12	
	W	83	13	13.52	91	5	5.2	75	21	21.84	96	0	0	
Point 2:	N	1	95	98.8	0	96	99.84	1	95	98.8	16	80	83.2	
	E	0	96	99.84	0	96	99.84	24	72	74.88	33	63	65.52	
	S	6	90	93.6	1	95	98.8	96	0	0	7	89	92.56	
	W	13	83	86.32	8	88	91.52	18	78	81.12	6	90	93.6	
Point 3:	N	0	96	99.84	56	40	41.6	14	82	85.28	9	87	90.48	
	E	25	71	73.84	72	24	24.96	10	86	89.44	45	51	53.04	
	S	1	95	98.8	21	75	78	5	91	94.64	18	78	81.12	
	W	1	95	98.8	30	66	68.64	1	95	98.8	0	96	99.84	
Point 4:	N	0	96	99.84	0	96	99.84	0	96	99.84	4	92	95.68	
	E	4	92	95.68	0	96	99.84	3	93	96.72	4	92	95.68	
	S	8	88	91.52	0	96	99.84	10	86	89.44	0	96	99.84	
	W	0	96	99.84	5	91	94.64	3	93	96.72	6	90	93.6	
Point 5:	N	4	92	95.68	0	96	99.84	6	90	93.6	23	73	75.92	
	E	0	96	99.84	0	96	99.84	6	90	93.6	2	94	97.76	
	S	0	96	99.84	0	96	99.84	1	95	98.8	0	96	99.84	
	W	26	70	72.8	3	93	96.72	7	89	92.56	11	85	88.4	
Point 6:	N	23	73	75.92	0	96	99.84	19	77	80.08	76	20	20.8	
	E	0	96	99.84	0	96	99.84	15	81	84.24	31	65	67.6	
	S	81	15	15.6	85	11	11.44	66	30	31.2	51	45	46.8	
	W	0	96	99.84	7	89	92.56	25	71	73.84	13	83	86.32	
Point 7:	N	0	96	99.84	0	96	99.84	3	93	96.72	6	90	93.6	
Southern Most	E	6	90	93.6	0	96	99.84	1	95	98.8	0	96	99.84	
	S	16	80	83.2	1	95	98.8	5	91	94.64	5	91	94.64	
	W	1	95	98.8	32	64	66.56	36	60	62.4	50	46	47.84	

Figure 27: Canopy Cover Percentage along High Density Transect.

Averages were calculated from the raw data collected in the field at each point (Figure 28). To do this, the north, east, south, and west facing readings in each quadrant were averaged together. Then, the four quadrants that make up each point were averaged. The values for each point in each of the three densities were than averaged for comparison to other variables as well as a total average for the entirety of each transect.

	Low Density (%)	Medium Density (%)	High Density (%)
Point 1	11.83	2.93	40.56
Point 2	20.48	43.75	84.89
Point 3	24.83	74.17	79.82
Point 4	3.38	18.14	96.79
Point 5	22.10	67.67	94.06
Point 6	0.46	18.72	67.86
Point 7	64.42	49.60	89.31
Total Average	21.07	39.28	73.25

Figure 28: Canopy Cover Percentage averages for each point throughout study site.

From the numerical results of the averages, it can be interpreted that as the density of the redcedar increased, so did the canopy cover. As a result, this variable became the deterministic variable that can potentially be used to predict other biotic and abiotic traits of the forested area.

Daubenmire Quadrat Method for estimating understory cover.

***Cover Classes*:**

1 = 1 - 5 (2.5%) **3** = 26 - 50% (37.5%) **5** = 76-95% (85%)
2 = 6 - 25 (15%) **4** = 51 - 75% (62.5%) **6** = 96-100% (97.5%)

Site location: 7100 Tuttle Creek Blvd, Manhattan Plot # Low Density Date: 4/20/13 Photo Numbers
Scribe Name: Debbie Mildfelt
Start time: 4:45pm End time: 6:05pm Temp: 65 degrees and overcast
Technique for worm collection: ½ canister of dry mustard to 1 gallon of water. Remove grass/turf by hand of lower right quarter of quadrat then soak soil with mustard mixture

LIFEFORMS plots	**North 1**	**2**	**3**	**4**	**5**	**6**	**South 7**
Grasses And Grasslikes (sedges and rushes)	5	5	4	5	5	3	3
Forbs (Herbs/broadleaf non-grasses)				1	1	1	
Shrubs and Vines			1				1
Redcedar (From densitometer average in N,E,S & W**)**							
Bare ground	1	2	2	2	1	3	
Litter (Ground and Standing)					1	1	1
Persistent Litter	2					1	3
Rock							1
Moss			1		1	1	1
Anything else you decide to include							
# of Ants						1	
# of Teenie tiny snails						16	7
# of Worms		1			1		1
Sunny/shady?	Very shady	Sunn y	Part sun	Most ly sunn	Part sun	Part sun	Most ly sunn
Notes: The grass/turf was easily removed at quadrats 2, 5, 7 (the only locations where worms were detected). Teenie tiny snails were detected by accident at quadrats 6, 7 so were counted. These quadrats (6,7) were close to dead trees. One ant detected at 6 so counted that in data too. The soil was damp and quite cool, probably too cool for worms to be active at surface.							

Figure 29: Shows results from mustard dilution study at Low Density

Daubenmire Quadrat Method for estimating understory cover.
***Cover Classes*:**
1 = 1 - 5 (2.5%) **3** = 26 - 50% (37.5%) **5** = 76-95% (85%)
2 = 6 - 25 (15%) **4** = 51 - 75% (62.5%) **6** = 96-100% (97.5%)

Site location: 7100 Tuttle Creek Blvd, Manhattan Plot # Medium Density Date: 4/25/13 Photo Numbers
Scribe Name: Debbie Mildfelt
Start time: 3:05pm End time: 4:45pm Temp: 70 degrees and sunny/windy
Technique for worm collection: ½ canister of dry mustard to 1 gallon of water. Remove grass/turf by hand of lower right quarter of quadrat then soak soil with mustard

LIFEFORMS plots	**North 1**	**2**	**3**	**4**	**5**	**6**	**South 7**
Grasses And Grasslikes (sedges and rushes)	3	2	1	2	1	1	2
Forbs (Herbs/broadleaf non-grasses)				1	1	1	1
Shrubs and Vines	1				1		
Redcedar (From densitometer average in N,E,S & W**)**							
Bare ground	3		2		3	2	
Litter (Ground and Standing)	1	1	3	4	1	1	2
Persistent Litter		3	2			1	2
Rock	2	2			3	4	
Moss	1		1	1	1	1	
Anything else you decide to include							
# of Spider	1						
# of Teenie tiny snails	8		11	9		7	4
# of Worms						1	1
Sunny/shady?	Sunny	Very Shady	Very Shady	Part sun	Part sun	Mostly sunn	Mostly shade
Notes: Quadrat 2 had 2 inches of persistent pine needles on soil. Normally, 1/3 gallon of mixture would be poured at a time to allow liquid to soak into soils but this quadrat was so dry, it took the entire gallon without pooling and soaked in immediately. The soil at this quadrat was extremely dry. It also had a live juniper branch touching the soil. Quadrat 4 had grass clumps that were smashed into the soil. Vegetation at quadrat 5 was difficult to remove. Quadrat 6 was very rocky.							

Figure 30: Shows results from mustard dilution study at Medium Density

Daubenmire Quadrat Method for estimating understory cover.
***Cover Classes*:**
1 = 1 - 5 (2.5%) **3** = 26 - 50% (37.5%) **5** = 76-95% (85%)
2 = 6 - 25 (15%) **4** = 51 - 75% (62.5%) **6** = 96-100% (97.5%)

Site location: 7100 Tuttle Creek Blvd, Manhattan Plot # High Density Date: 4/28/13 Photo Numbers
Scribe Name: Debbie Mildfelt
Start time: 9:35am End time: 10:45am Temp: 60 degrees and sunny
Technique for worm collection: ½ canister of dry mustard to 1 gallon of water. Remove grass/turf by hand of lower right quarter of quadrat then soak soil with mustard

LIFEFORMS **plots**	**North** **1**	**2**	**3**	**4**	**5**	**6**	**South** **7**
Grasses And Grasslikes (sedges and rushes)		2	1		2	3	2
Forbs (Herbs/broadleaf non-grasses)				1		1	1
Shrubs and Vines	1	1	1		1	1	
Redcedar (From densitometer average in N,E,S & W**)**							
Bare ground	1			3			2
Litter (Ground and Standing)	1	2	1	1	1	1	1
Persistent Litter	5		5	2	4	2	1
Rock		1	1	1		1	1
Moss		1		1			2
Anything else you decide to include							
# of Teenie tiny snails		4			5	1	1
# of Worms			3	3		1	
Sunny/shady?	Very Shady	Mostl y Shad	Very Shad y	Most ly Shad	Most ly Shad	Most ly Shad	Most ly Shad

Notes: Quadrats 1, 3, 6 had pine needles 2 inches thick on the ground. Quadrat 5 had a live juniper limb touching ground. Quadrats 3 and 4 had 3 good sized worms come to the surface almost immediately.

Figure 31: Shows results from mustard dilution study at High Density

Canopy Cover and Understory Analysis

In order to analyze the data collected by those involved with the undercover and canopy cover study, each variable was compared externally in a basic scatter plot. The data collected regarding canopy cover was used as the independent variable for each graph as the transects were divided depending on the team’s visual prediction of density. As mentioned above, the canopy cover correlated in a positive linear direction as the density increased, suggesting that in any spot at the study site, if the density increases, the canopy cover will increase. In order to further predict any other trends relating to undercover and canopy cover, the following comparisons were made and analyzed: canopy vs living matter, canopy vs dead matter, canopy vs worms, canopy vs insects, canopy vs pH.

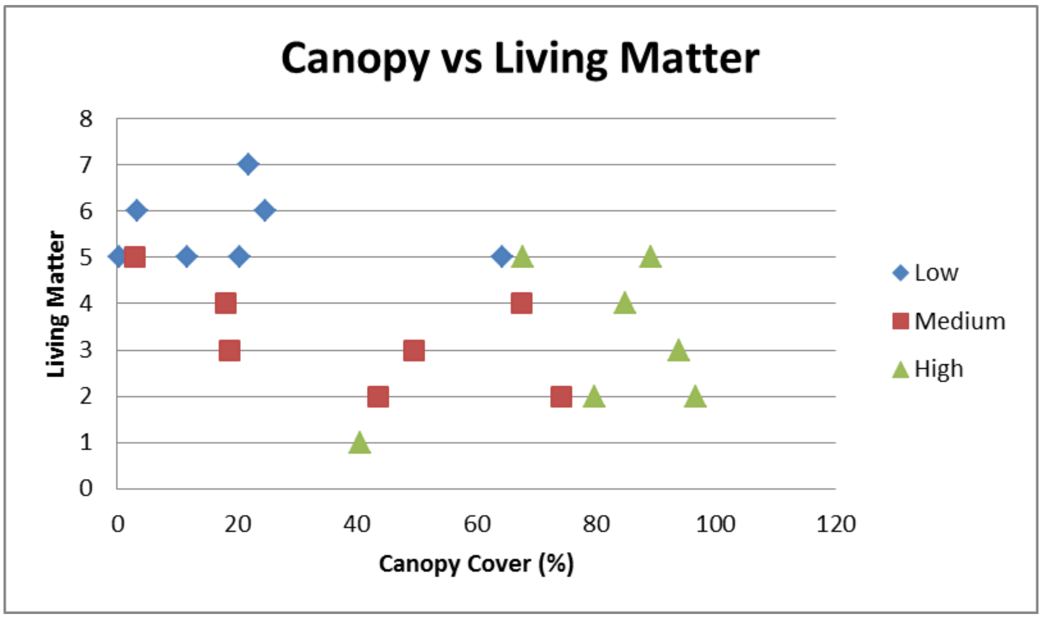


Figure 32: Canopy vs Living Matter scatterplot

From the above graph (Figure 32), three clusters can be generally identified relating to low, medium, and high density. Some overlap does clearly exist, suggesting that there will not be an absolutely true linear relationship between these two variables. Nonetheless, this point by point analysis of canopy cover and living matter does support there being a significant difference between the three densities and living matter.

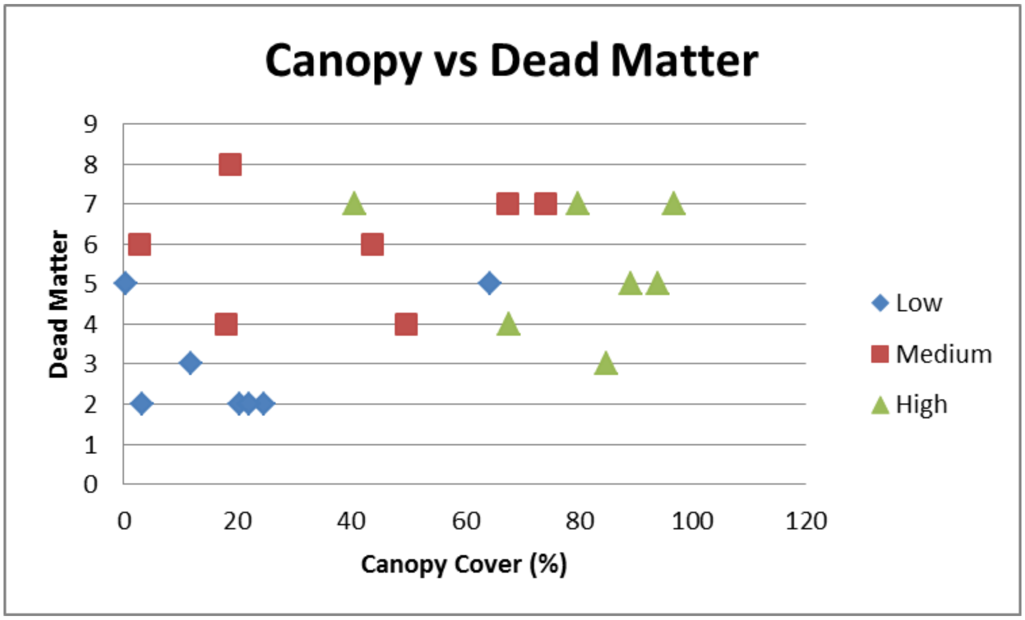


Figure 33: Canopy vs Dead Matter scatterplot

In the above graph (Figure 33), similar trends that group dead matter into three distinct groups exist, but are not as clearly clustered as the previous figure. Much more overlap occurred between the 40-60% range, suggesting that is a random point in the study site with canopy cover in that section was selected, there would not be a strong likelihood of correctly predicting the dead matter.

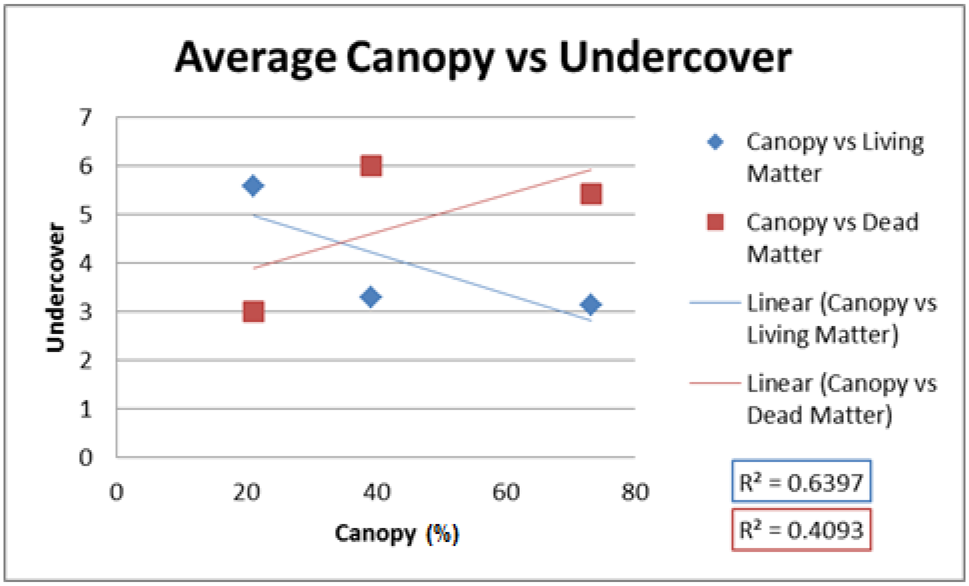


Figure 34: Average Canopy vs Average Undercover scatterplot

To better understand any possible relationship between canopy cover and undercover, the average values for these two categories were plotted against each other. As seen from Figure 34, dead mater generally increased as canopy cover increased (R^2 = 0.4093) while living matter generally decreased as canopy cover increased (R^2 = 0.6397). These two relationships make sense in the idea that as canopy cover increases, less light will be able to penetrate to the ground level and more litter will be produced by the surrounding plants. This data should be interpreted with caution, however, as only three transects were used. If more data sites could have been used, a better prediction of undercover may be determined based on canopy cover.

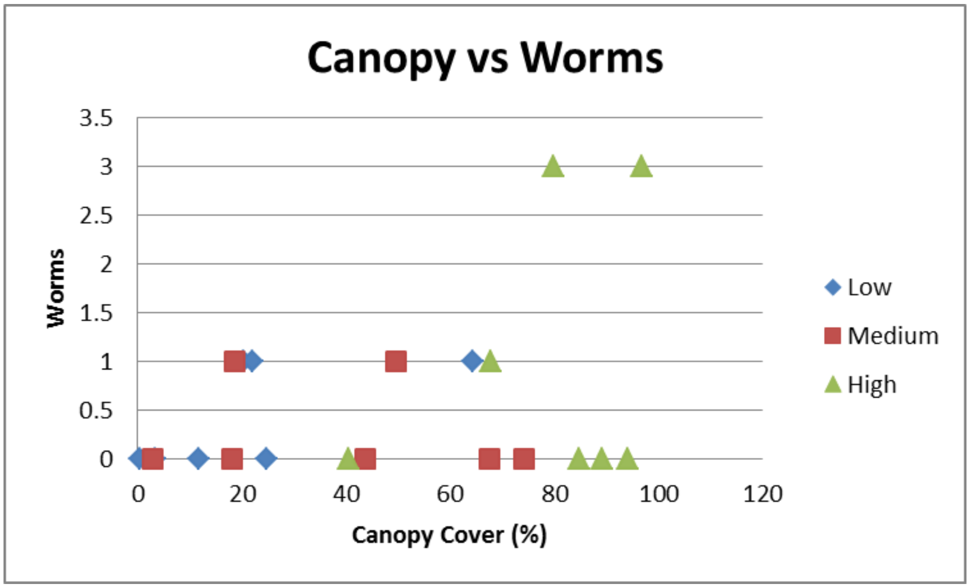


Figure 35: Canopy vs Worm Count scatterplot

Generally speaking, it is difficult to interpret whether or not a linear correlation exists between canopy cover and worms from the above graph (Figure 35).

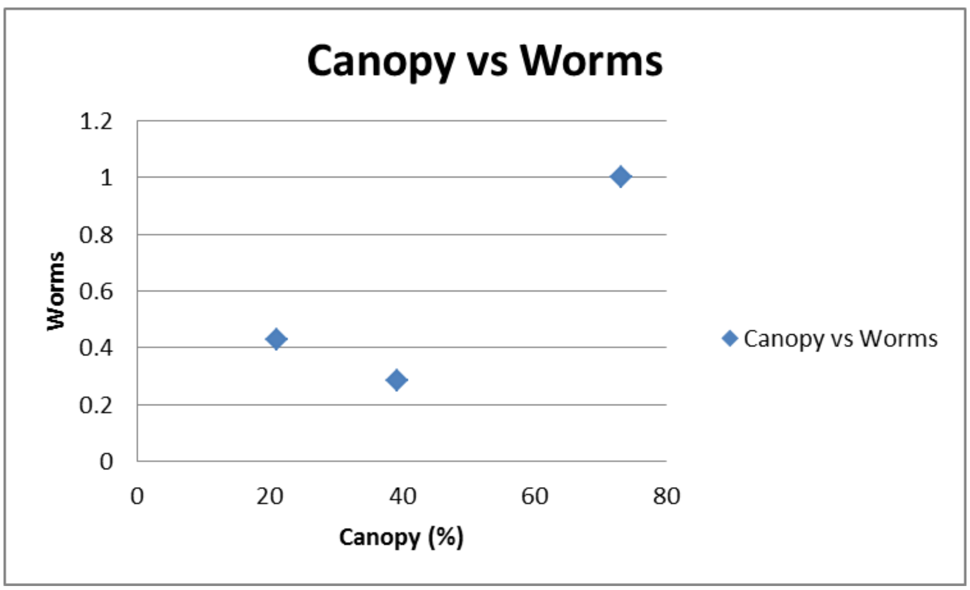


Figure 36: Average Canopy vs Average Worm count scatterplot

Once the averages were considered in Figure 36, it appears that the medium density did not follow the established linear relationship for the study site. There does tend to be a possible parabolic relationship between the three points, but without an increase in data sites, such a thought is not conclusive.

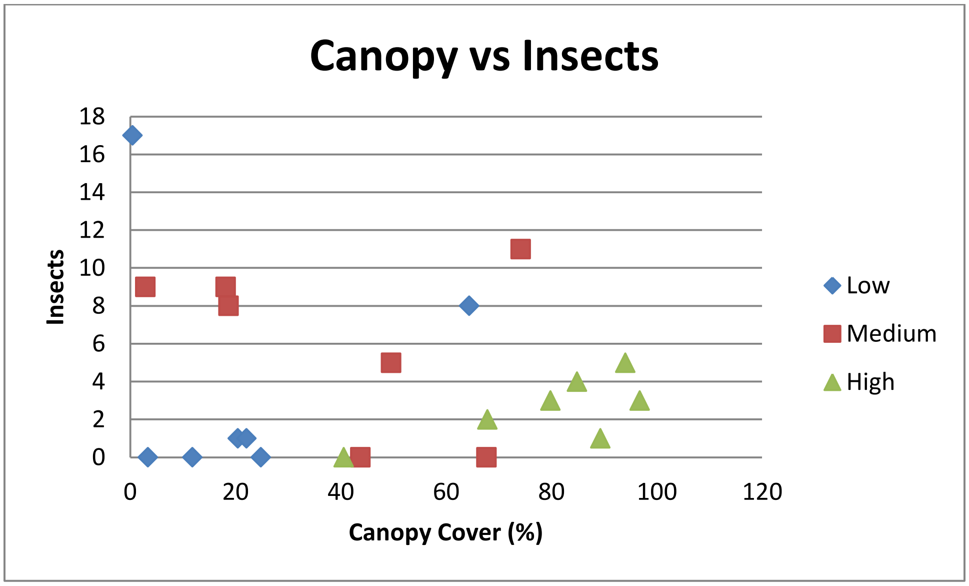


Figure 37: Canopy vs Insect Count scatterplot

Figure 37 above again shows a lack of clustering – particularly in the medium density range. From this chart alone, the high density did seem to produce the lowest amount of insects at each point, but the low density also seemed to provide this trend.

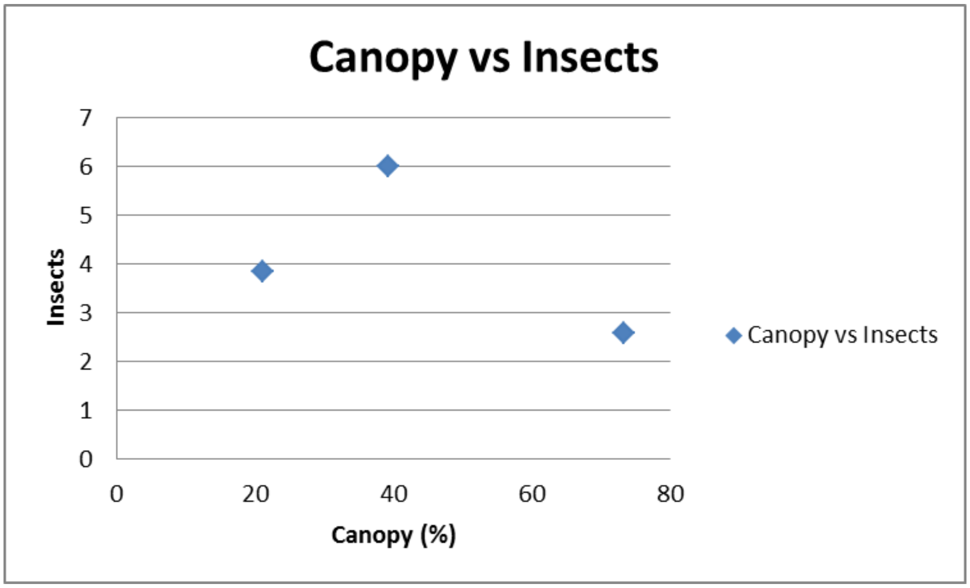


Figure 38: Average Canopy vs Average Insect Count scatterplot

From Figure 38 above, the thought that little correlation exists is confirmed. There is not a linear relationship between insects and canopy cover, suggesting that if the canopy cover is known for a given spot, the number of insects present cannot be predicted.

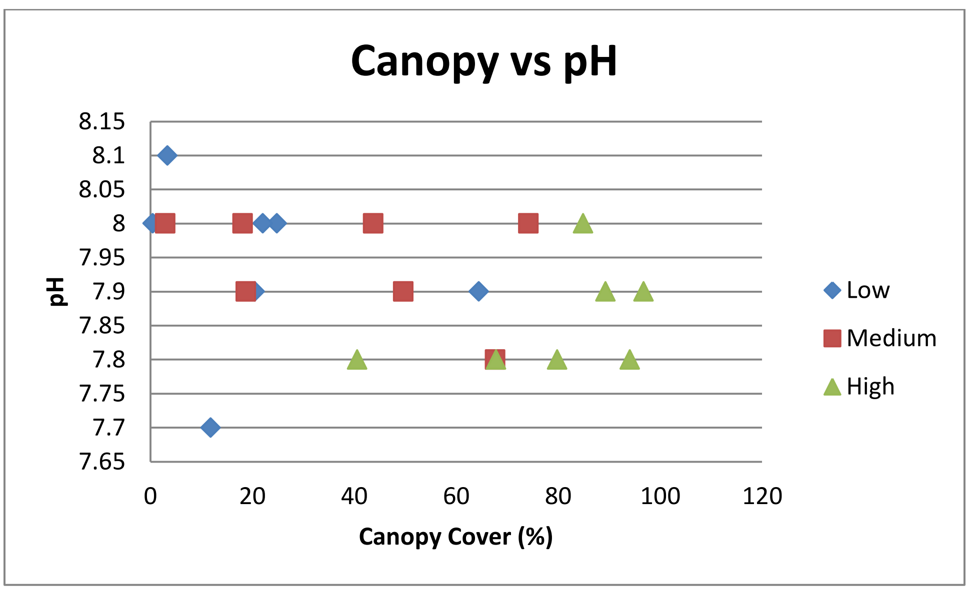


Figure 39: Canopy vs pH scatterplot

No major results can be interpreted from the above figure (Figure 39) as no significant clustering or regression seems to occur within any of the three densities. Of the later variables analyzed in the study however, pH may be of interest for further statistical analysis. While this study focused on the three different densities, it might be more accurate to ignore initial density identification and instead solely consider canopy cover at each point. Doing so may reveal a general decrease in pH as canopy cover increases, but this idea was outside of this study's scope of work.

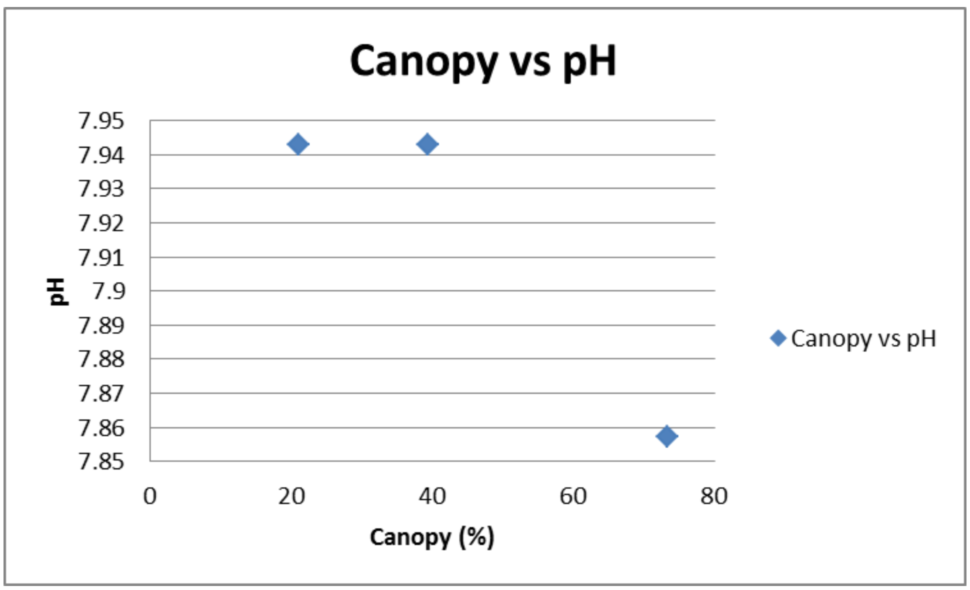


Figure 40: Average Canopy vs Average pH scatterplot

Figure 40 above proves that a linear relationship between canopy cover and pH does not exist. However, one idea does seem to present them from the above graph. There may be a threshold at which the pH drops in the soil depending on the canopy percentage. This idea would likely be supported or rejected if the above mentioned analysis would be completed regardless of initial density identification.

Biomass Analysis

Linear regression analysis was used to examine the relationships between the key variables and redcedar biomass. Because the different groups recorded the data using different units of measurement, conversion of some measurements had to occur to ensure uniformity in order to run an accurate regression model. This table is shown below.

Density/ Plot/Quad	Circumference Ground Line (m)	Circumference Breast Height (m)	Distance from Center of Plot (m)	Canopy Width (m)	Tree Height (m)	Weight (lbs)
Medp1q1	0.762	0.51	4.57	4.4	6.4	128
Medp1q2	0.432	0.23	7.13	2.5	3.2	
Medp1q3	0.457	0.31	10.9	3	3.6	
Medp1q4	1.02	0.69	5.03	5.7	5.6	615
Medp4q1	0.94	0.686	3.35	4.1	5.2	522
Medp4q2	0.41	0.152	2.74	2.7	3.6	
Medp4q3	0.483	0.28	4.88	2.9	4.4	142
Medp4q4	0.991	0.584	6.71	3.9	5.6	
Medp7q1	1.041	1.321	9.14	7.1	7.6	
Medp7q2	1.321	0.838	4.82	4.7	7.6	
Medp7q3	0.56	0.406	4.8	3.8	4.8	247
Medp7q4	0.28	0.508	5.61	2.9	3.6	
Lowp1q1	1.43	1.08	7.6	8.48	6.54	
Lowp1q2	0.9	0.59	13.65	4.24	7.23	
Lowp1q3	0.9	0.8	22.9	7.63	6.64	
Lowp1q4	1.22	0.63	5	6.25	5.7	

Lowp2q1	1.35	0.85	10.8	7.83	6.8
Lowp2q2	0.37	0.21	3.47	3.3	3.3
Lowp2q3	0.62	0.4	14	3.85	4.2
Lowp2q4	0.42	0.25	7.2	2.65	4.39
Lowp3q1	1.35	1	9	8.48	6.12
Lowp3q2	1.3	0.56	24.23	7.2	6.54
Lowp3q3	0.78	0.53	5.45	3.95	5.78
Lowp3q4	0.82	0.36	5.95	5.9	5

After this, two summary tables were produced; one showing the means of the measurements by plot, the other showing the means of the measurements by transect (Figures 40 and 41, respectively), and a chart was produced showing the means of the variables for the two transects in which the measurements were taken (Figure 42).

	Mean CGL (m)	Mean CBH (m)	Mean Distance from Center (m)	Mean Canopy Width (m)	Mean Tree Height (m)
Medium Density					
Plot 1 (Med)	0.66775	0.435	6.9075	3.9	4.7
Plot 4 (Med)	0.706	0.4255	4.42	3.4	4.7
Plot 7 (Med)	0.8005	0.76825	6.0925	4.625	5.9
Low Density					
Plot 1 (Low)	1.1125	0.775	12.2875	6.65	6.5275
Plot 2 (Low)	0.69	0.4275	8.8675	4.4075	4.6725
Plot 3 (Low)	1.0625	0.6125	11.1575	6.3825	5.86

Figure 40 (above) shows the means of the key variables by plot; while figure 33 (below) summarizes the means of the key variables by transect.

	Mean CGL (m)	Mean CBH (m)	Mean Distance from Center (m)	Mean Canopy Width (m)	Mean Tree Height (m)
Medium Density	0.72475	0.542916667	5.806666667	3.975	5.1
Low Density	0.955	0.605	10.77083333	5.813333333	5.686666667

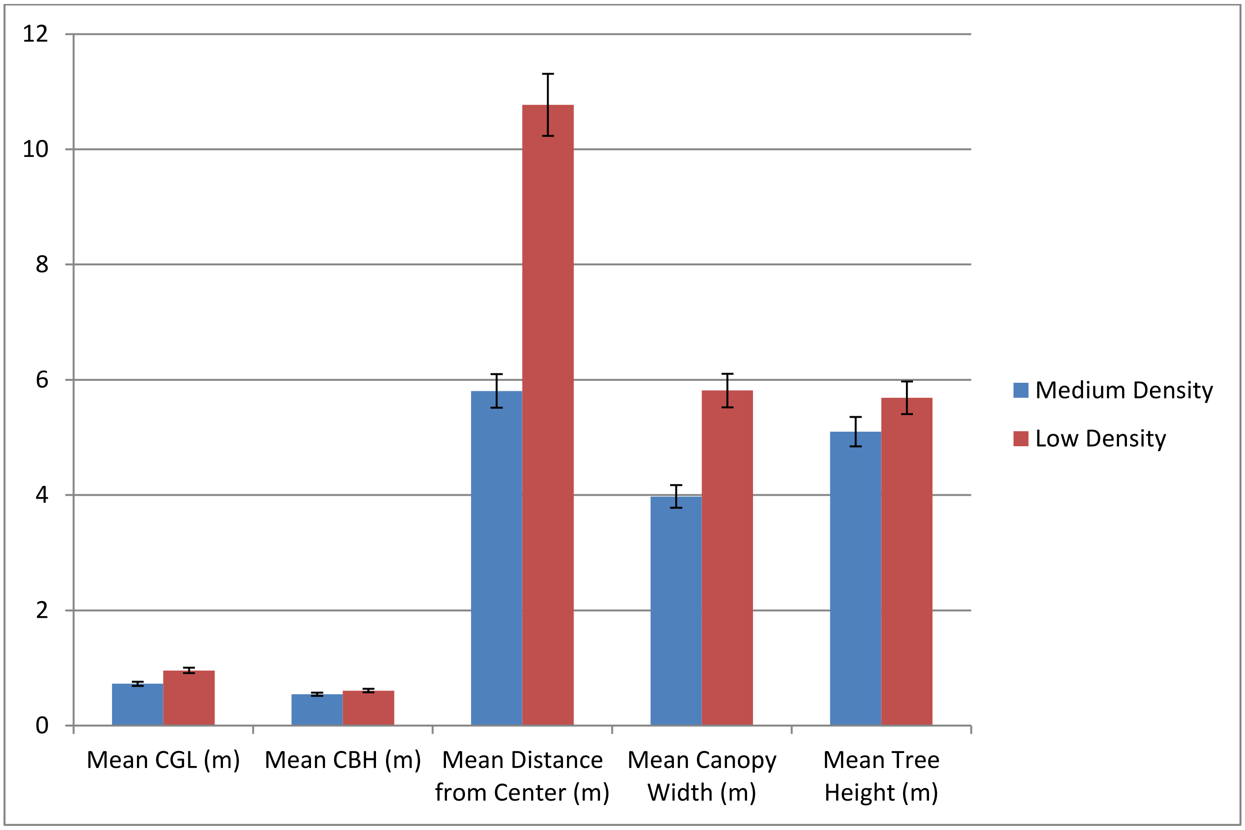


Figure 42 (above) is a chart that displays the means of the key variables in a manner which makes it easy to compare the differences between the medium and low transects. The variables distance from center plot, canopy width, and tree height show the greatest difference.

Before running the regression, the data needed to be checked for multicollinearity. It was expect that a high level of multicollinearity would be observed due to the nature of the variables, most of which are inherently related to one another. A correlation matrix was produced in order to test the chosen variables for multicollinearity, shown below. All variables were included in the matrix.

```
                                 Canopy.Width..Average..m. Circumference.Breast.Height..m.
Canopy.Width..Average..m.                        1.0000000                       0.8176431
Circumference.Breast.Height..m.                  0.8176431                       1.0000000
Circumference.Ground.Line..m.                    0.8566684                       0.9839217
Tree.Height..m.                                  0.6534611                       0.5394763
Weight..lbs.                                     0.7068057                       0.8568924
                                 Circumference.Ground.Line..m. Tree.Height..m. Weight..lbs.
Canopy.Width..Average..m.                            0.8566684      0.65346108   0.70680570
Circumference.Breast.Height..m.                      0.9839217      0.53947633   0.85689244
Circumference.Ground.Line..m.                        1.0000000      0.57374996   0.84806188
Tree.Height..m.                                      0.5737500      1.00000000   0.07952297
Weight..lbs.                                         0.8480619      0.07952297   1.00000000
```

Figure 42: Multicollinearity matrix

As can be seen in the correlation matrix above, there was indeed a very high level of multicollinearity among most of the variables. Because of this, it was determined to not run a multivariate regression model, but rather to test each key variable individually to see which variables are the best predictors of biomass. To do this, a series of simple bivariate regression models were run, testing each key variable as the explanatory variable against the response variable of tree weight.

Variable	R-squared value
Circumference Ground Line (m)	0.719
Circumference Breast Height (m)	0.7343
Canopy Width (Average)(m)	0.4996
Tree Height (m)	0.0063

Figure 43: R-squared values for biomass variables

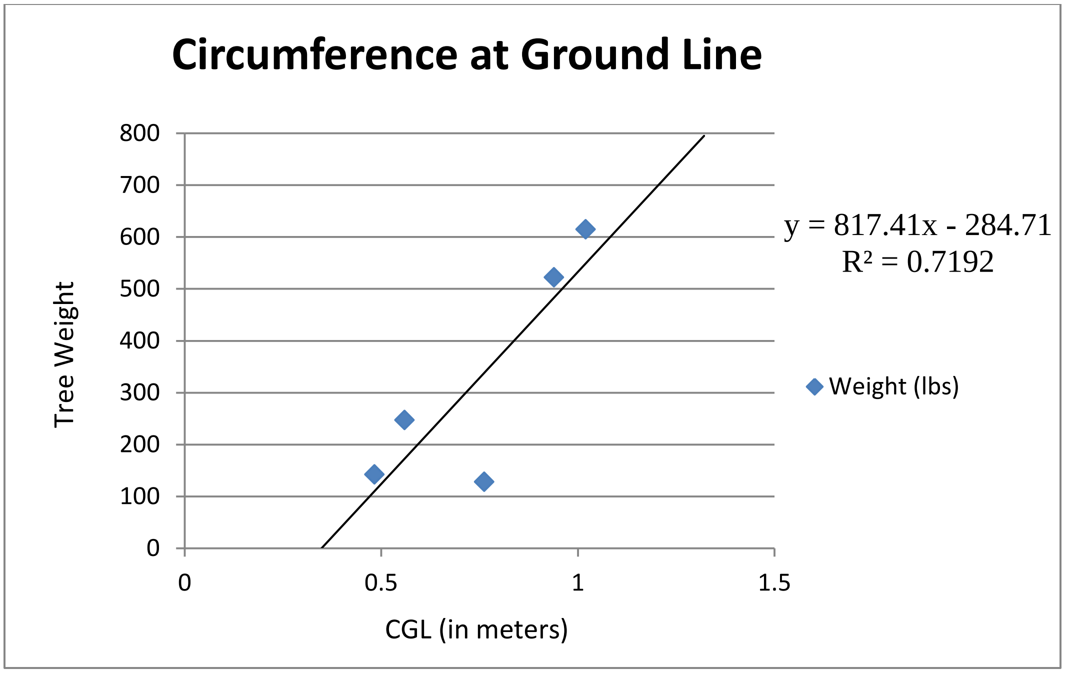


Figure 44: Circumference at ground level vs Tree Weight scatterplot

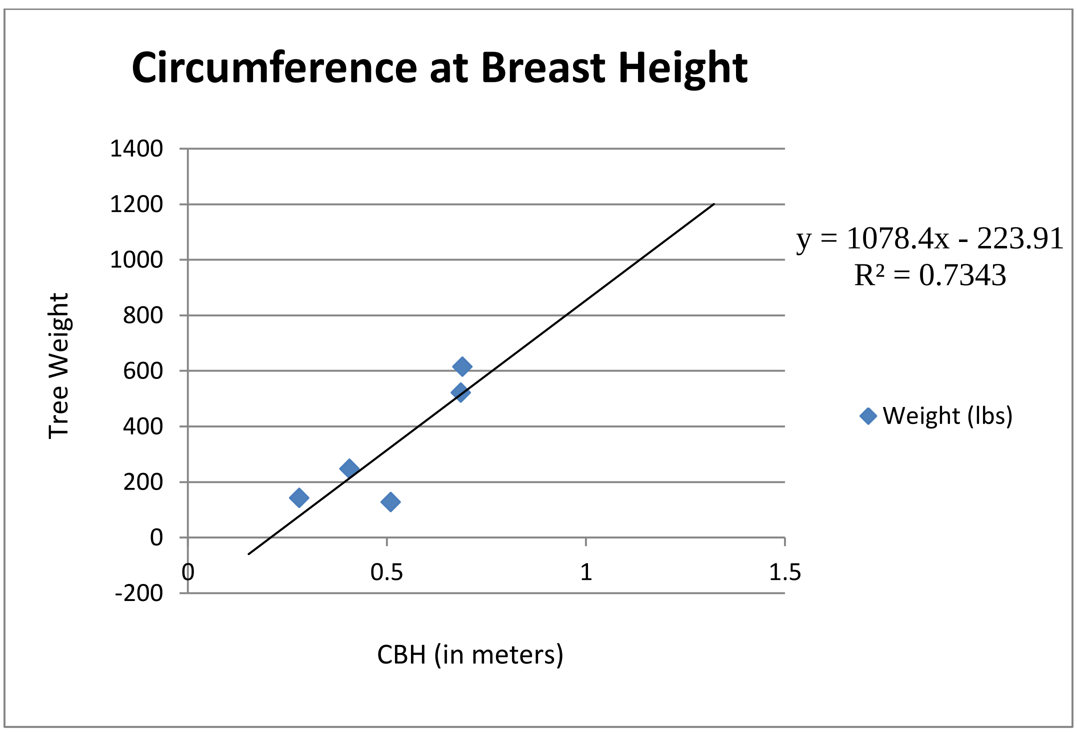


Figure 45: Circumference at Breast Height vs Tree Weight scatterplot

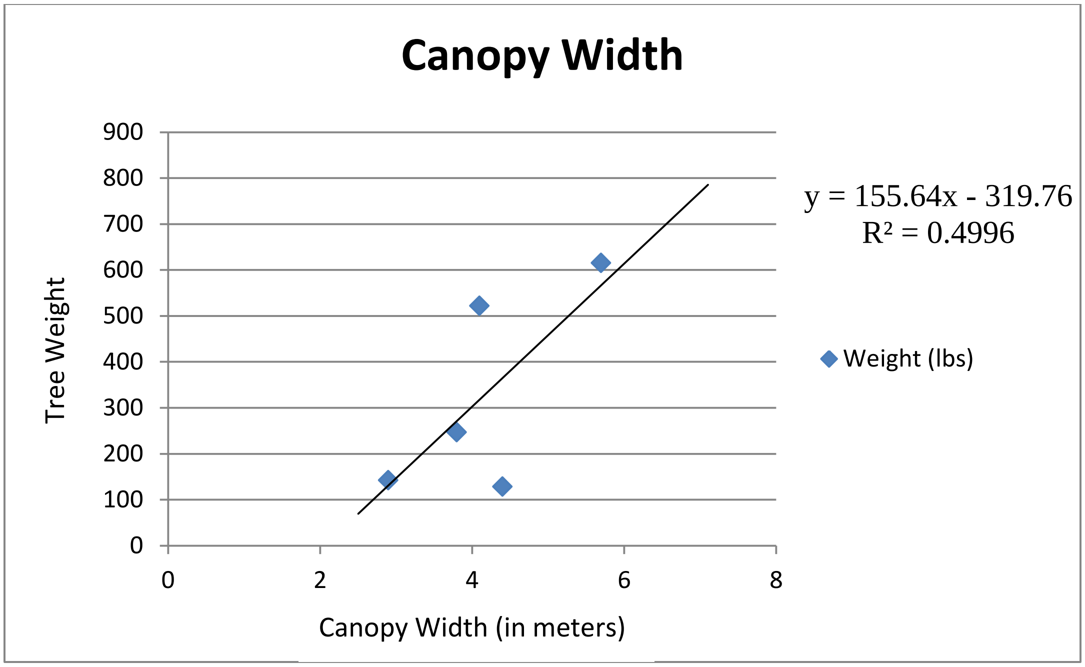


Figure 46: Canopy Width vs Tree Weight scatterplot

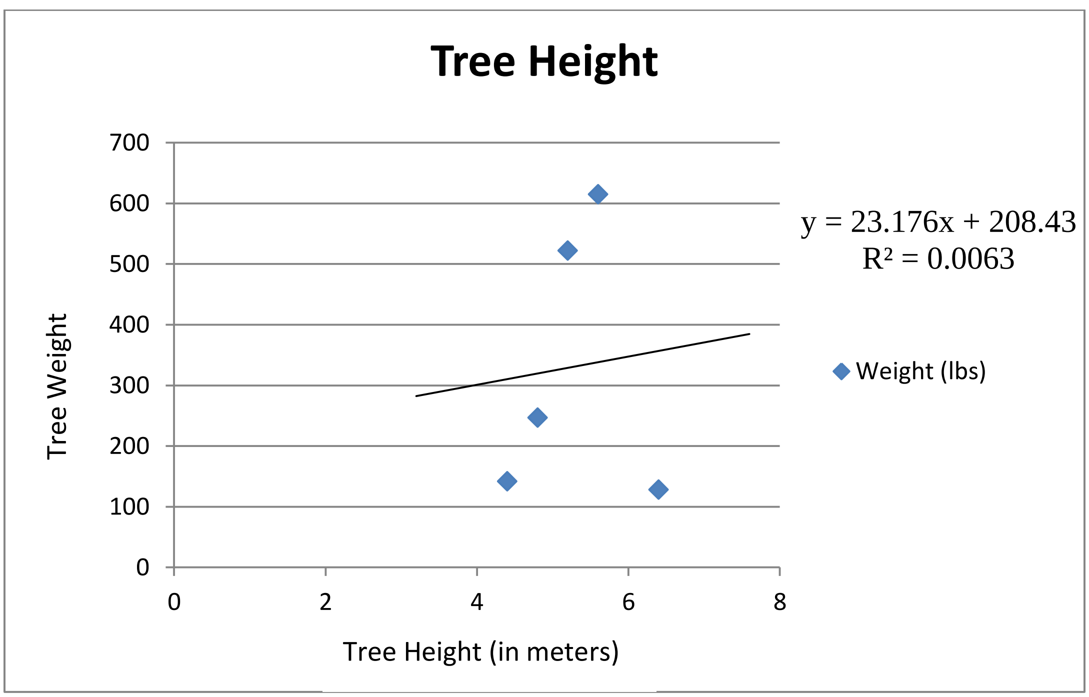


Figure 47: Tree Height vs Tree Weight scatterplot

As can be seen from the table and graphs above, there was a wide range of r-squared values, with circumference at breast height (CBH) being the highest and tree height the lowest.

In other words, CBH is the best predictor of redcedar biomass, followed by circumference at ground line (CGL), canopy width, and tree height being the worst predictor. Given the small sample size (only five tree weights were used), there was some worry about the accuracy of these results. To better ensure accuracy, it was desired to test the results using a model with a larger sample size. To do this, data recorded from a similar study in a previous NRES capstone class was utilized. This data is shown below. Again, some measurement units needed to be converted for uniformity purposes.

Diameter at Breast Height (in)	Weight
5	490
3.6	70
6.4	340
5.3	280
9	960
3.8	135
11.3	1271
2.5	62
6.13	505
1.88	32
4.75	235
12.13	2130
6.29	128
8.64	615
8.59	522
3.5	142
5.079	247

Figure 48: Diameter at Breast Height and Weight table

Because the 2013 group and the group from the previous study took different measurements, only the variable diameter at breast height (the measurements were converted from circumference to diameter) was used, because it was common to both studies and it yielded the greatest correlation to biomass in this study.

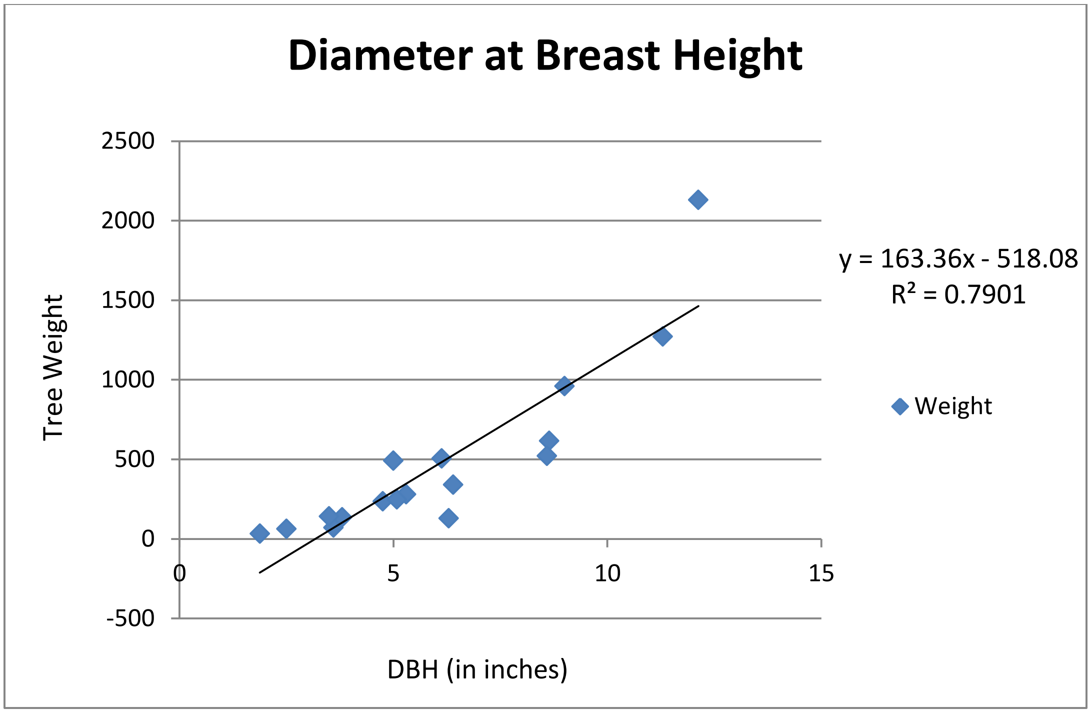


Figure 49: Diameter at Breast Height vs Tree Weight scatterplot

As expected, with the increased sample size of 17, the r-squared value increased, going from 0.7343 to 0.7901. These results led us to conclude there is a fairly strong correlation between diameter/circumference at breast height and biomass in Eastern Redcedar trees.

Further Study

Further study shows the by-products from Eastern Redcedar can be marketed for profit by landowners, businesses and communities. The abundance of *Juniperus virginiana* across much of the Great Plains has sparked interest in many individuals and organizations to find a way to maximize the economic value of harvesting this tree. One interest is to process the redcedar into ethanol bio-fuel which could then be used as an alternative renewable energy source. While this proposal sounds promising, there are concerns on how to effectively harvest, transport, and process these trees in a way to make a steady profit. One processing technique is to heat redcedar chips to extract the cedar oils and then convert the remaining biomass into either jet fuel or diesel (McNutt 2012). Residue, after extraction can be used as boiler fuel for regenerating the steam for the oil process and as space heating in the winter (Gold et al. 2005). According to (McNutt 2012) 200 gallons of jet fuel can be produced per one ton of dry biomass and the cedar oils extracted can be sold for approximately $45 per gallon. As a result, nationwide, Eastern Redcedar is an estimated $60 million dollar per year industry (Gold et al. 2005).

The developing research is to locate a practical area in which an industrial plant can be constructed to process the oil and fuel from huge volumes of redcedar stands. Estimating the biomass of these stands is going to be essential in deciding where to harvest. The ground-based sampling method used in this study shows that there are associations to estimate above ground biomass. Although, large-area inventory of redcedar mass can only be practically addressed via aircraft or satellite remote sensing, because it is too costly, time consuming, and labor intensive to produce such inventories via ground-based sampling (Starks et al. 2011). Satellite and aerial imagery can be used more effectively to determine which tree density has the maximum biomass yield; low, medium or high.

Conclusion

From the data collect at the study site and the analysis completed throughout this report, multiple conclusions can be made regarding Red Cedar biomass and canopy/understory cover.

First, trends were identified between canopy cover and initially identified density. As the densities of the transects increased, so did the canopy cover. This relationship, while possibly elementary, is a key component in further research relating to the Red Cedar.

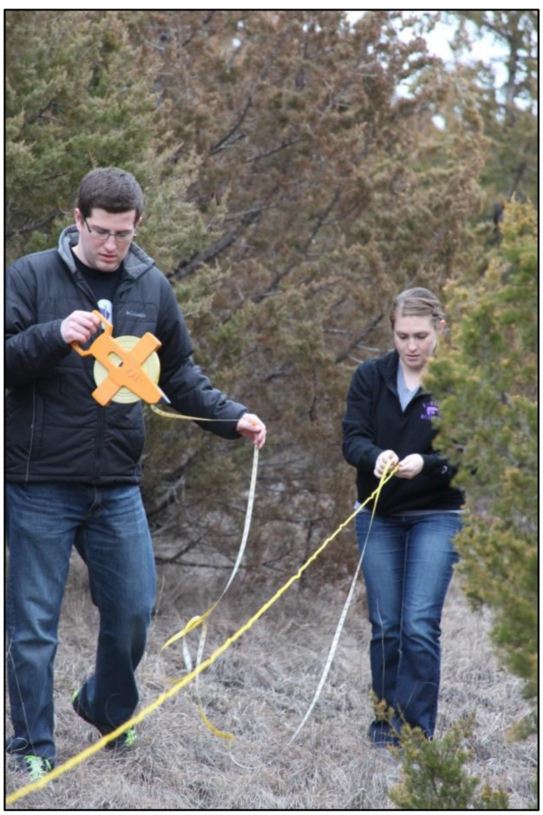
Second, as canopy cover increased, the living matter in the understory decreased while the dead matter in the understory increased. This trend was concluded with an R^2 of 0.6397 and 0.4093 for living and dead matter, respectively. As a result, if a point has a known canopy cover percentage, the understory composition can be predicted with accuracy between 40-63% in this study site.

Third, no significant relationships existed between soil pH, worm, or insect content and density. Whether the density was low, medium, or high, these three dependent variables did not show significant change. Possible regression analysis could be conducted to further solidify this conclusion.

Lastly, it can be concluded that the best predictor of Red Cedar biomass among the key variables is circumference at breast height. Circumference at ground line, with an r-squared value of 0.7192, also has a decently strong correlation. Canopy width, at 0.4996, has a weak correlation; and tree height, at 0.0063, has virtually no correlation to biomass.

Additional Images

Figure 50: The above image shows the two groups setting up the medium density transect.
Figure 51: The below image on the left is showing to group members laying out the low density transect.
Figure 52: The below image on the right is showing a group member taping out 30 ft. plots on a transect.



Figures 53-56 display the weighing process for Redcedars conducted in this study

Figure 57: The above image showls a team member getting ready to pour a mustard mixture on the ground and wait for worms to surface.

Figure 58: The below image shows team member clearing ground cover to check for worms.

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