Correlations between Biophysical Measurements, Tree Stand Density and BTU Potential of Eastern Redcedar in Northeast Kansas

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1.0 - Introduction

Tallgrass prairie ecosystems are rare and ecologically valuable, but they are also diminishing, largely because of the invasion of woody species into these grasslands. In the Great Plains, the expansion of trees onto grasslands has become a huge concern, from both ecological and economic perspectives. From the onset of Euro-American settling of the Great Plains into today, a combination of romantic notions of wooded areas, a desire to use trees as windbreaks, and a lack of knowledge of the needs of prairies have allowed the problem to exacerbate (Rodgers 1984). The elimination of controlled fires is certainly a large contributing factor to this (Briggs et al. 2002; Ganguli et al. 2008; Rodgers 1984). Factors like climate change and intensive grazing likely also play a role (Briggs et al. 2002), although Owensby et al. (1973) reported redcedar seedling establishment was inversely related to grazing intensity. He found that the cattle will eat young tender redcedar trees. Horncastle et al. (2004) have pointed to the role of species consuming and dispersing seeds as a factor leading to tree expansion. Some combination of these components has led to an accelerated rate of grassland ecosystem to woody ecosystem conversion since the time of initial introduction of non-native trees. Of particular concern in Kansas and across the Midwest is the rapid westward expansion of the eastern redcedar tree (Juniperus virginiana).

This species is showing an exponential rate of invasion. From 1981 to 1994, eastern Kansas had a 100% increase in wooded pasture (Price 2012). Estimates from Oklahoma state that the species may be taking over 762 acres per day, and it is not a stretch to say this is the pattern across a broad range of Midwestern states (Price 2012). Indeed, Briggs *et al.* (2002) submit that it could take as little as forty years for tallgrass prairies to be completely converted to closed-canopy forest. If these estimates are accurate across the board, the economic losses from agriculture and livestock revenue due to eastern redcedar could be in the millions each year (Price 2012). The major ecological consequences of ecosystem conversion – a process which can unfold in a few decades – include greatly diminished biodiversity (with differing implications across multiple trophic levels) and herbaceous productivity (Briggs *et al.* 2002; Horncastle *et al.* 2005; Limb *et al.* 2010); the facilitation of invasion by other non-native species (Gehrig & Bragg 1992); altered nutrient cycling, water use, and light penetration (Limb *et al.* 2010); soil erosion (Price 2012); and implications for carbon storage and biogeochemistry (Johnson 2012; Norris *et al.* 2007; Price 2012). To maintain the ecological viability and biodiversity of the tallgrass prairies of the Great Plains, as well as to protect the economic interests of Midwestern states, efforts to research and develop management plans in response to the threat of eastern redcedar expansion need to be undertaken quickly and vigorously.

The conversion of prairie to woodlands is not irreversible and several solutions have been proposed to combat redcedar invasion. Perhaps the easiest and most effective approach is burning the grasslands regularly (Drake & Todd 2002; Owensby *et al.* 1973), but this requires making sure landowners have accurate knowledge about burning procedures and wildfire protection techniques. For instance, the time of year and frequency at which burns are conducted can greatly impact the effectiveness of the burns in suppressing invasion and yielding productive new growth (Briggs *et al.* 2002; Owensby 2012). Without this sort of knowledge, the burning that landowners carry out may not be more effective - or could potentially even be more harmful - than no burning at all. Ultimately, involving landowners more in prescribed burns and giving them incentives to do so may be a critical step. A variety of other direct methods of control could be undertaken as well, including cutting and removal of trees, selective removal of seedlings, use of herbicide granules, and altered stocking rates (Horncastle *et al.* 2004; Owensby *et al.* 1973). Of course, continually promoting further research and increasing public awareness of the problem and possible management options ought to be integral components of any management strategy in order to achieve long-term effectiveness.

More recently there has been speculation over the potential economic value of eastern redcedar. Because of its durability, appearance, fragrance, and insect and natural decay resistance, redcedar can be used to make things like fence posts, furniture, large and small animal bedding, mulch, medicines, and oils (Biles 2012). It can be used as a renewable biofuel resource. Some businesses, hospitals and schools have already converted to biofuel-burning boilers, and have saved thousands of dollars in energy costs by doing so (Biles 2012). Using redcedar as an alternative energy source would decrease the dependence on fossil fuels, and because the amount of carbon released when redcedar is burned only equals the amount the tree had captured during its lifetime, using redcedar would also reduce the overall emission of CO2, the greenhouse gas currently contributing most to global warming (IPCC 2007).

The aim of this study was to further the understanding of the viability of eastern redcedar as a biofuel source. Based on several physical measurements taken in the field, as well as through aerial photography, predictions were made for the BTU (British Thermal Unit) potential at different stand densities. This study's data from medium and high density stands was compiled with data from a previous year's study of low density stands in order to determine which stand density is most ideal for harvest as a source of biofuel.

2.0 - Goals and Hypotheses

The goal of this project was to establish the relationship between BTU output and eastern redcedar tree stand density. In order to do this, the biophysical factors of the eastern redcedar were used to predict BTU output. Additional biophysical factors taken were biomass, incremement bore data for age estimation, crown size, Diameter at breast heigh (DBH) and basal area.

In order to focus the discussion, the group came up with a main hypothesis/objective and two secondary hypotheses to test:

H_1 - There is a relationship between BTU output and eastern redcedar tree stand density.

<u>Secondary objectives:</u>

SH_1 - Biophysical characteristics of the trees can be use to relate to BTU.

- Biomass
- Increment bore data (age)
- Crown size
- Diameter at Breast Height (DBH)
- Height
- Canopy cover
- Basal area

SH_2 - Aerial photography can be used to relate tree stand density to BTU output.

3.0 - Study Sites

Initially, the group was under the impression that multiple sites must be found by traversing the area in order to locate sites with various levels of tree density for analysis, however with the help of the graduate students of KSU's Geography Department and Google Earth; a site was located that had varying degrees of eastern redcedar density. This gradient allowed for multiple sites within walking distance of one another and because of this, the site was chosen. The area is located near Tuttle Creek Reservoir (Figure 1). After researching the landowners in the area via Riley County GIS, it was found that this land was owned by Kansas State University. Permission was obtained to take field measurements and cut down trees for weighing.

All of the plot areas chosen for measurement were first scouted out on Google Earth and high and medium density plots were chosen. From the aerial photographs, redcedar trees could easily be distinguished from other species. Using Google Earth, the time frame was set to the fall season when the redcedars would be green, and other deciduous tree species had dropped their leaves. The study site selected was property owned by Kansas State University and had several stands of redcedar that ranged from low density to very high density stands. From the study site, several waypoints were selected, three medium density and three high density areas of study as seen in figure 1. Once the waypoints were determined, the latitudes and longitudes were programmed into a handheld GPS in order to help find the waypoints and study areas once in the

Figure 1: Study Site located north of Manhattan, KS

field.

4.0 - Methodology

Sampling Red Cedar Trees Using the Point-quarter Method

Since the study area was so large and studying every tree in the area would be physically impossible, it was necessary that a method was utilized that would allow the group to take quality random samples of the area. The method of point-quarter sampling (Figure 2) was chosen for its ease of use and also high effectiveness. This method involves first choosing a sample point within the area in which to be studied; in this case, high or medium density stands of eastern redcedar. Once the point is chosen, one must then divide the area into quadrants, in the group's case with 15 foot axes from the center point. This will give a total of five sample areas for the site; the center point, north, south, east and west points. From each of these points a quadrant is set up for the northeast, southeast, southwest, and northwest corners of the point. In these sections, the closest tree (greater than three inches in diameter) is chosen and sampled with the fore mentioned methods. This process is repeated for every point on the grid (center, north, south, east and west). This process provides a random sample of twenty trees in which to collect data and is much more efficient than the original plan of picking individual trees from aerial photos.

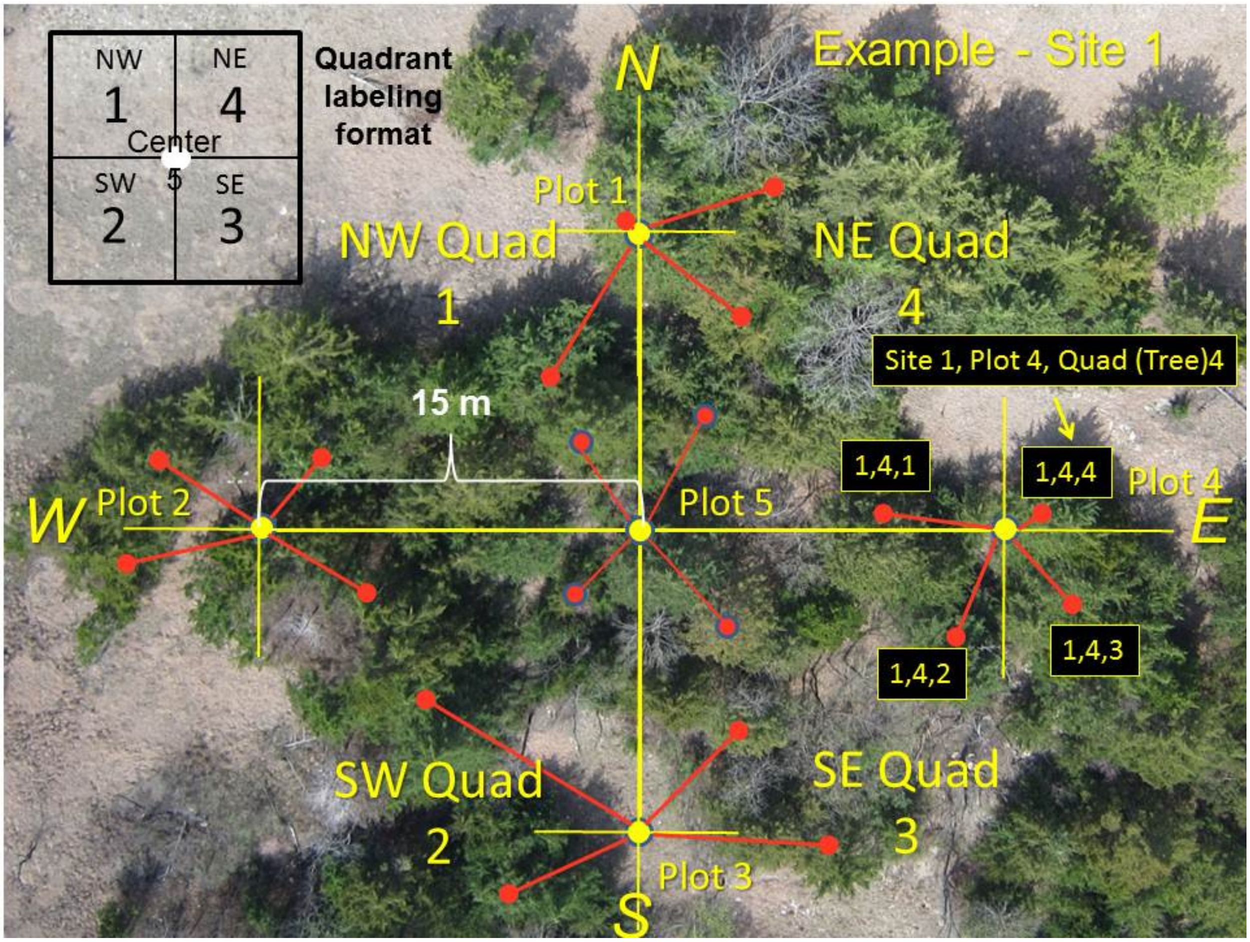

Figure 2: Point Quarter Method Labeling Format

<u>Tree Canopy Cover Measurements (Spherical Densitometer)</u>

Densitometer readings were taken every 5 meters along the transect lines in the same location as the Daubenmire quadrants. The device was held at waist height unless tree cover inhibited by vegetation then the densitometer was held level at ground level in a manner such that the readings were not impeded by the ground cover. Count was taken of the less prominent cover feature in the mirror, tree cover or sky, as if there were four dots in each box in the mirror. To calculate percent tree canopy cover, the count for tree was multiplied by 1.04 cover conversion factor (Lemmon 1956).

Tree Basal Area Measurements (Point Cruise Method)

In order to determine tree trunk basal area, the Point Cruise method was used with a basal area factor of 10 (Figure 3). The JIMGEM® Cruz-All was used throughout all of the sites (Avery and Burkhart 2002). The scores were calculated using the following equation. BA = (Total trees tallied/number of points) BAF

Figure 3: Demonstration of the Point Cruise method

Tree Age Measurements (Core Samples)

Cores data was extracted from six trees (Figure 4). The cores were taken from two small, two medium and two large trees in order to sample across a tree age-class gradient. These six trees were also the trees that were cut down to determine biomass. Cores were taken at breast height except in the case of small trees; these were taken closer to the base. Additional exceptions were made for the large trees, where one had to climb between branches. These samples were taken at slightly higher than breast height. The cores, once extracted, were stored in plastic tubes and refrigerated until they were secured to a board for drying. Tree age was taken as the average age found between the three counters.

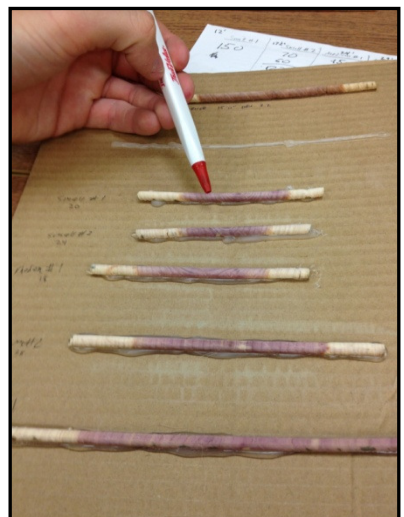

Figure 4: Core Samples

Tree Height Measurement (Clinometers)

Tree height was determined with the use of clinometers. The device is held up to the student's eye and aligned with the top of the tree. After alignment, the percentage on the right side of the dial was read and recorded as demonstrated in figure 5. A measurement from the

Figure 5: Gathering Clinometer Readings

base of the tree to where the measurement was taken is necessary to the computation of tree height. The following equation was used to determine the height:

Tree Height = H + D x Tan(A)

H=Height of Clinometer to floor base

D=Distance of Clinometer to object

A=Angle taken from Clinometer Reading

<u>Biomass (Scale)</u>

With the help of the Kansas Forest Service, six trees were weighed (Figure 6). These six trees were marked by sizes as: two small, two medium, and two large. The trees were then were felled and sectioned up. Trees were placed in a tarp and weighed by hand as noted in figure 6. Height measurements were also taken after trees were felled.

Figure 6: Weighing sections of cedar tree

5.0 - Results and Discussion

As stated above, a sub hypothesis of this project was to find a relationship between biomass and aerial canopy cover, but the group ran into trouble using the aerial photography and was not able to find the exact locations and pinpoint the exact trees that corresponded to measurements using Google Earth. Thus by analyzing the data the group came up with other methods of estimating redcedar biomass. The data was scrutinized from as many different angles as possible and this resulted in countless graphs. Many of the graphs showed very weak correlation or almost no relationship between the variables whatsoever. However, a few were promising. While DBH, distance from center point and height of almost 100 trees were measured, only six were cut down and weighed. Unfortunately, they were all cut down from an area of uniform density and only height, weight and age were recorded. Luckily, the group was able to approximate a DBH for these trees since the core samples had been taken roughly at breast height. This gave two variables, DBH and height, to use as a link between the two data sets. The next step then was to determine which of these variables had a stronger correlation with tree weight. It was found that weight and DBH have a correlation coefficient of 0.82 and weight and height have a correlation coefficient of 0.72. Therefore it was the groups' decision to use DBH to calculate biomass for all the trees that were not weighed.

Figures 7 & 8 show the graphs of weight vs. DBH. Since this is not a linear relationship, the group chose to use a power function trend line that maximized the coefficient of determination (R^2).

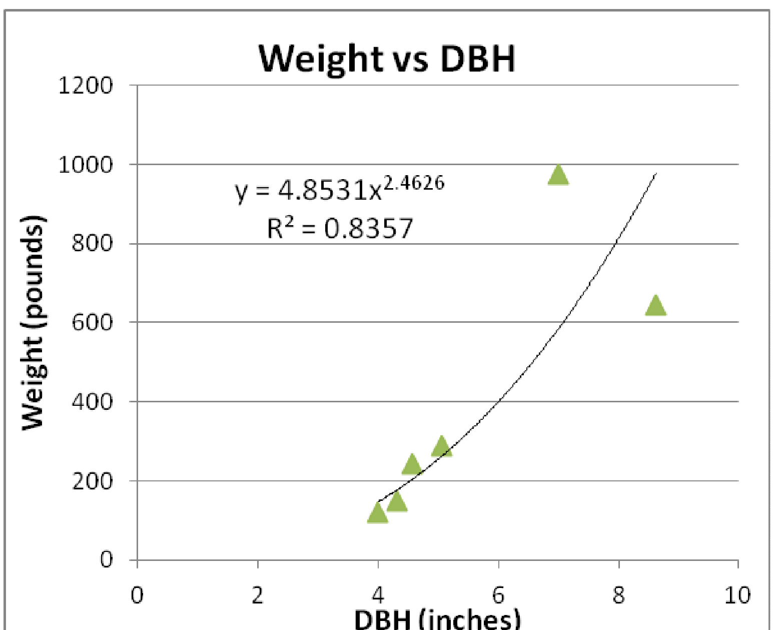

Figure 7: Weight vs. DBH

Considering that six data points are hardly adequate to formulate a trend line, included is a graph of weight vs. DBH for the trees measured in last year's project to demonstrate that a power curve does in fact do a good job relating weight to DBH.

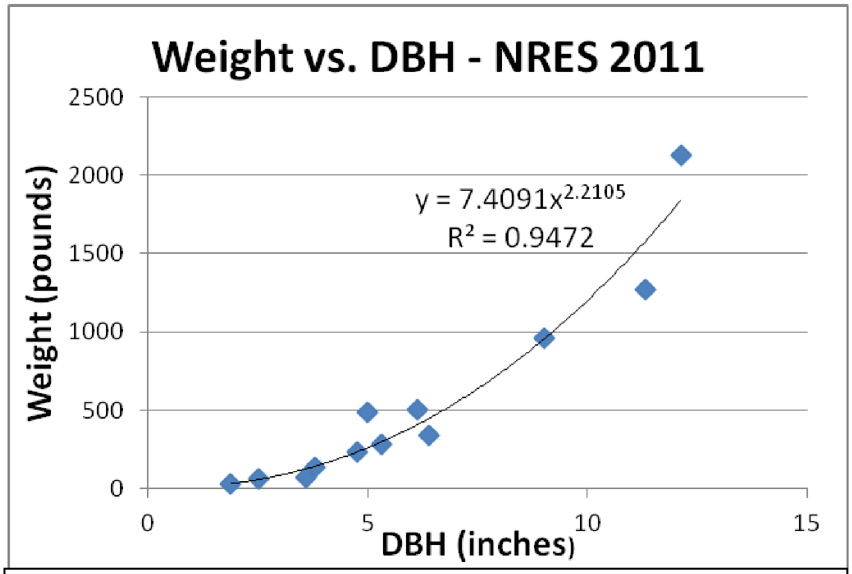

Figure 8: Weight vs. DBH last year's project

With the equation from the trend line, the group was able to calculate the mass of all the trees that where the DBH had been measured. It was found via the internet that there are 3300 lbs/cord and 17.5 million BTUs/cord. This allowed for the conversion of mass (measured or calculated) into BTUs. Figure 9 demonstrates how BTUs relate to DBH using the equation determined above.

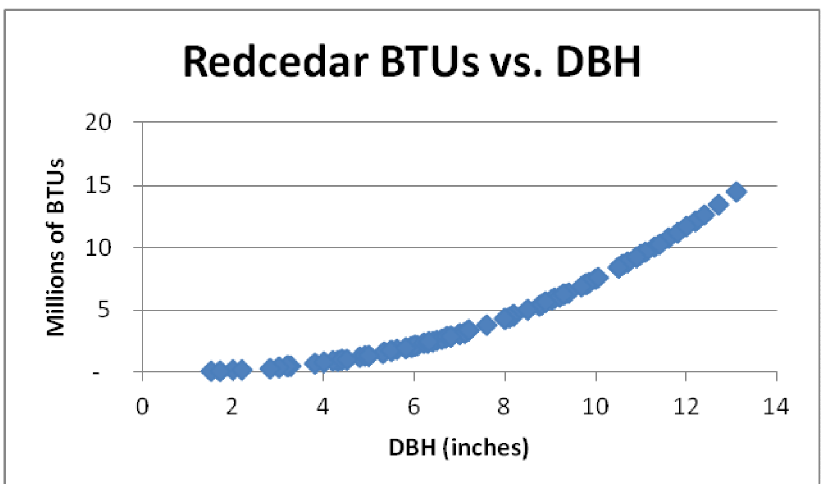

Figure 9: Redcedar BTUs vs. DBH using trend line equation

To further analyze the data, it was entered into an online point-quarter method calculator that gave an output of average DBH, mean basal area, absolute density, mean distance and total cover. Most of the numbers that came from this did not yield well correlated graphs, but they are included.

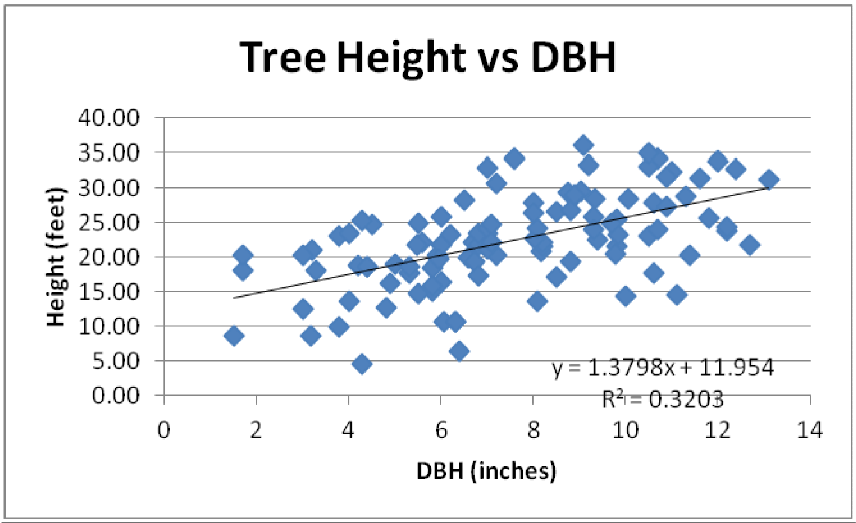

Figure 10: Tree Height vs. DBH

It was the groups' expectation that tree height would increase with DBH, which it slightly does. However most statisticians would not consider an R2 of 0.32 to be “sound".

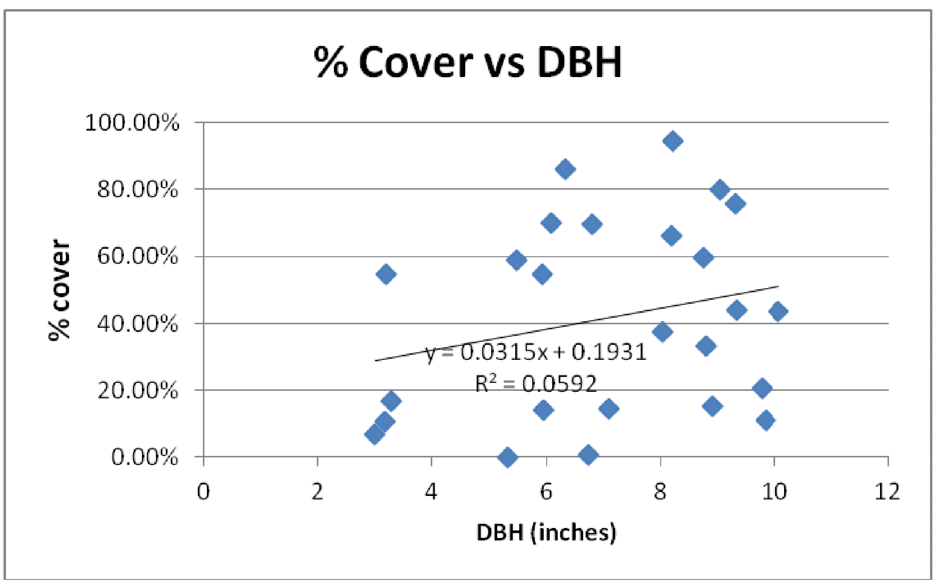

Figure 11: % Cover vs. DBH

This data comparison has two possible trend lines. One of them is that with higher cover, there would be lower DBHs due to high-density plots. The other possible scenario would be a logarithmic relationship, with % cover increasing along with DBH to the site threshold. This second scenario would be possible from a few mature, dominant trees taking up the majority of % cover.

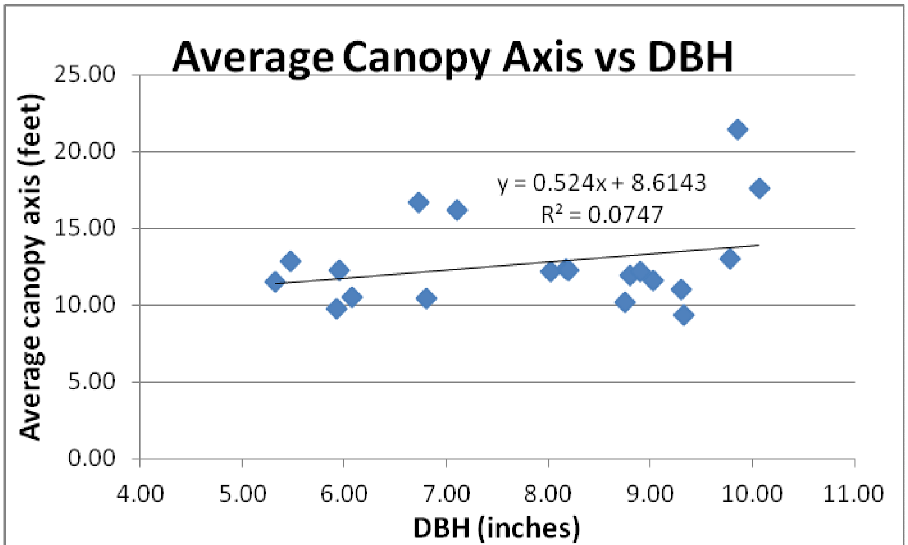

Figure 12: Average Canopy Axis vs. DBH

The group expected a positive correlation here with larger canopy sizes equating to larger DBHs, due to the idea of larger trees having larger canopies. This small set of data hints at this relationship, but does not show the threshold curve or show tight correlation.

Figure 13 shows the expected relationship with DBH increasing with age. One would expect the logarithmic correlation to hit the species' growth threshold and stabilize.

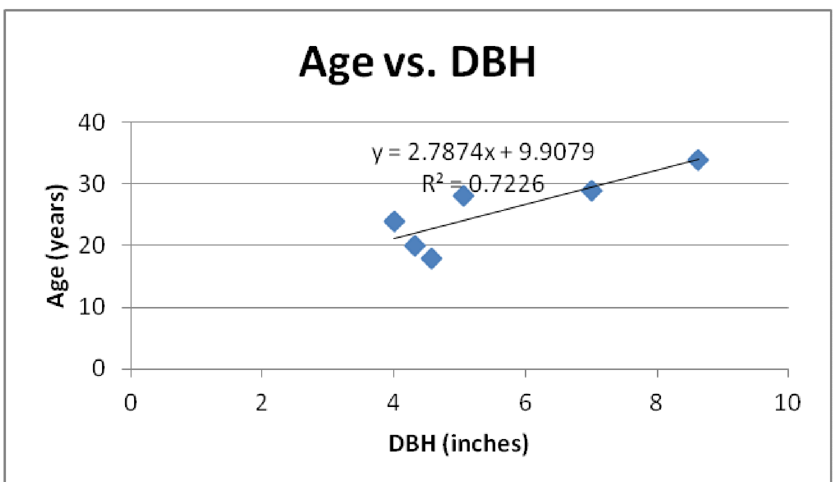

Figure 13: Age of Redcedar vs. DBH

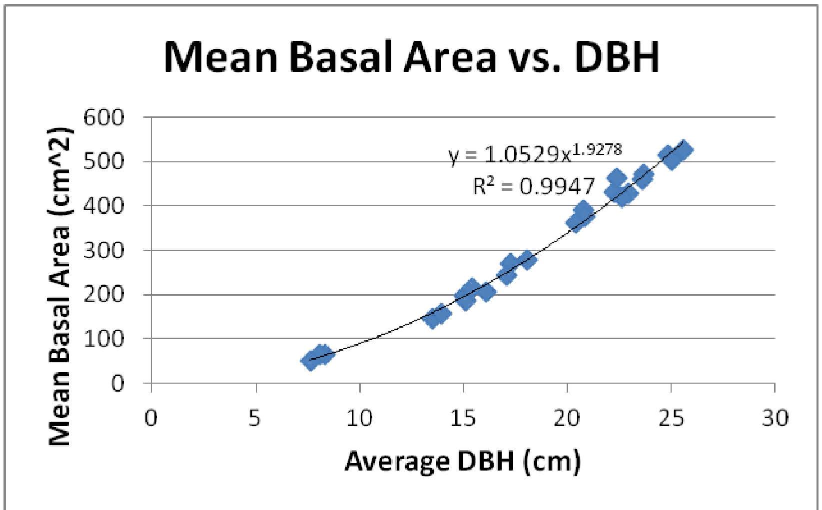

Figure 14: Mean Basal Area vs. DBH

Figure 14 shows positive allometry, with larger basal area correlated with higher average DBH. One would expect the data to hit the carrying capacity threshold and stabilize were more data collected.

This comparison was expected to show a logarithmic correlation, with higher basal area signifying higher Redcedar cover, until it would hit the site threshold and stabilize.

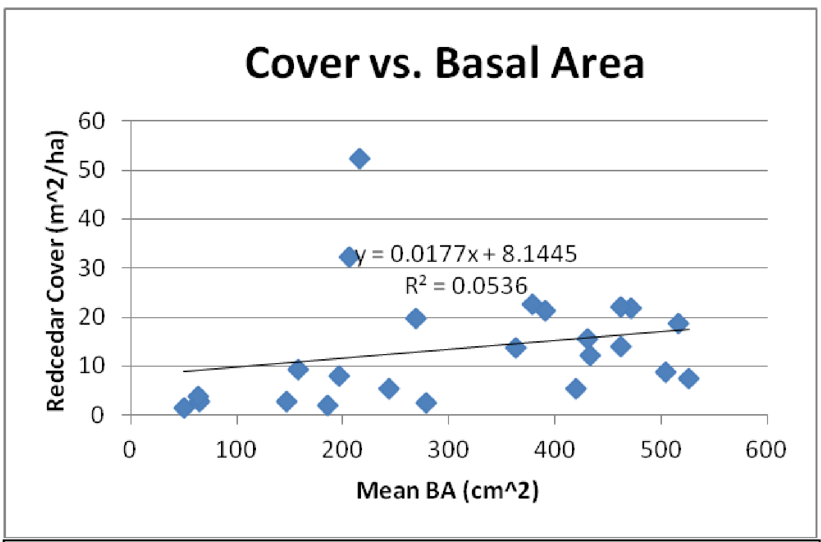

Figure 15: Redcedar Cover vs. Basal Area

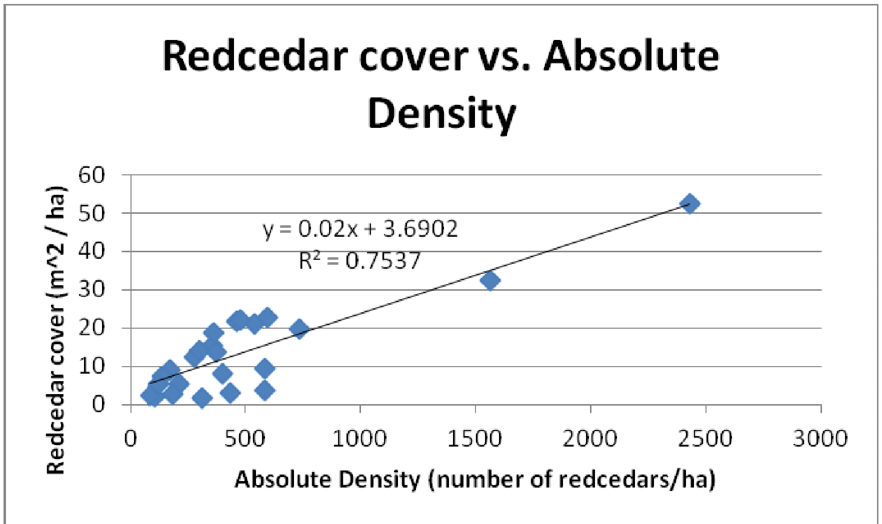

Figure 16: Redcedar cover vs. Density

Table 1 shows the average biomass and energy content of the trees measured in each plot along with the energy equivalent in various fuel sources. It shows the amount of fuel for oil, coal, natural gas, LP gas, and electric heat will be needed to produce the same amount of BTU's that a specific plot can produce. One can see that as weight increases so does the amount of BTU's produced.

Table 1: Energy and biomass of redcedars and their fuel equivalents

Energy Produced by Eastern Redcedar						Required amount needed of other fuel sources to produce the same amount energy				
	DBH (in)	Height (ft)	Weight (lb)	BTUs	Cords	Fuel Oil (gallons)	Anthracite Coal (lbs)	Natural gas (ft^3)	LP gas (gallons)	Electric heat (kW)
High #0	8.92	26.84	1220	6,470,054	0.370	55.80	650	7812	85.84	2297.70
Plot 1	8.18	20.87	1090	5,781,456	0.330	49.86	581	6981	76.7	2053
Plot 2	8.75	29.39	1219	6,462,283	0.369	55.73	649	7803	85.7	2295
Plot 3	9.33	28.48	1328	7,041,986	0.402	60.73	707	8503	93.4	2501
Plot 4	9.03	29.56	1173	6,220,559	0.355	53.65	625	7511	82.5	2209
Plot 5	9.30	25.89	1291	6,843,987	0.391	59.02	687	8263	90.8	2430
High # 2	7.01	19.52	738	3,915,332	0.224	33.77	393	4727	51.95	1390
Plot 1	5.93	20.29	458	2,430,526	0.139	20.96	244	2935	32.2	863
Plot 2	8.20	22.22	1026	5,438,414	0.311	46.90	546	6566	72.2	1931
Plot 3	6.80	21.80	696	3,689,615	0.211	31.82	371	4455	49.0	1310
Plot 4	6.08	10.58	529	2,804,010	0.160	24.18	282	3386	37.2	996
Plot 5	8.03	22.70	983	5,214,094	0.298	44.97	524	6296	69.2	1852
Med # 1	7.53	20.10	842	4,467,472	0.255	38.53	449	5394	59.27	1587
Plot 1	6.73	19.30	591	3,135,360	0.179	27.04	315	3786	41.6	1113
Plot 2	9.78	20.52	1484	7,868,470	0.450	67.86	790	9500	104.4	2794
Plot 3	9.85	23.33	1411	7,484,864	0.428	64.55	752	9037	99.3	2658
Plot 4	5.95	19.73	416	2,206,244	0.126	19.03	222	2664	29.3	784
Plot 5	5.33	17.64	310	1,642,420	0.094	14.16	165	1983	21.8	583
Med # 6	8.07	25.66	984	5,218,438	0.298	45.01	524	6301	69.24	1853
Plot 1	10.07	28.51	1485	7,876,713	0.450	67.93	791	9510	104.5	2797
Plot 2	7.10	22.13	606	3,213,332	0.184	27.71	323	3880	42.6	1141
Plot 3	5.48	21.74	341	1,808,066	0.103	15.59	182	2183	24.0	642
Plot 4	8.80	26.85	1344	7,128,195	0.407	61.48	716	8607	94.6	2531
Plot 5	8.90	29.09	1144	6,065,882	0.347	52.31	609	7324	80.5	2154
Form 1	3.80	14.42	178	942,525	0.054	8.13	95	1138	12.51	335
Plot 1	3.20		85	451,363	0.026	3.89	45	545	6.0	160
Plot 2	3.28	18.10	122	645,096	0.037	5.56	65	779	8.6	229
Plot 3	6.33	10.70	470	2,490,414	0.142	21.48	250	3007	33.0	884
Plot 4	3.18	8.60	125	663,242	0.038	5.72	67	801	8.8	236
Plot 5	3.00	20.28	87	462,512	0.026	3.99	46	558	6.1	164

It was also found that if the basal area of a tree is known, BTU is able to be calculated. Figure 17 shows the high relationship between BTU's & Basal Area.

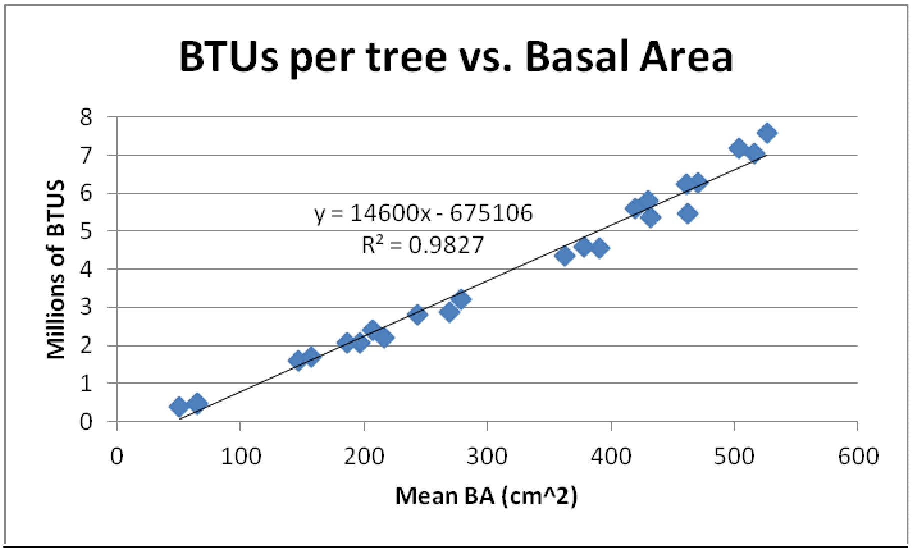

Figure 17: BTUs vs. Basal Area

It was found that the age of the trees would not be a good method of predicting the BTU output of an area. The R square value for this method is .45. The graph below shows the relationship between BTU and age.

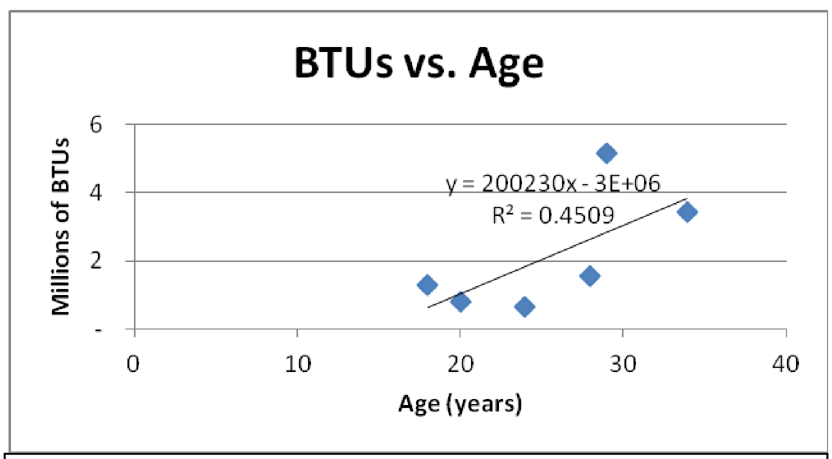

Figure 18: BTUs vs. Age

The remaining graphs show a weak relationship with BTU, Canopy Cover, Density, and Average Canopy Axis. This could be due to the problem with the aerial photography measurements. However the canopy diameter was able to be measured using Google Earth, so there is the possibility that the measurements from Google Earth were not accurate.

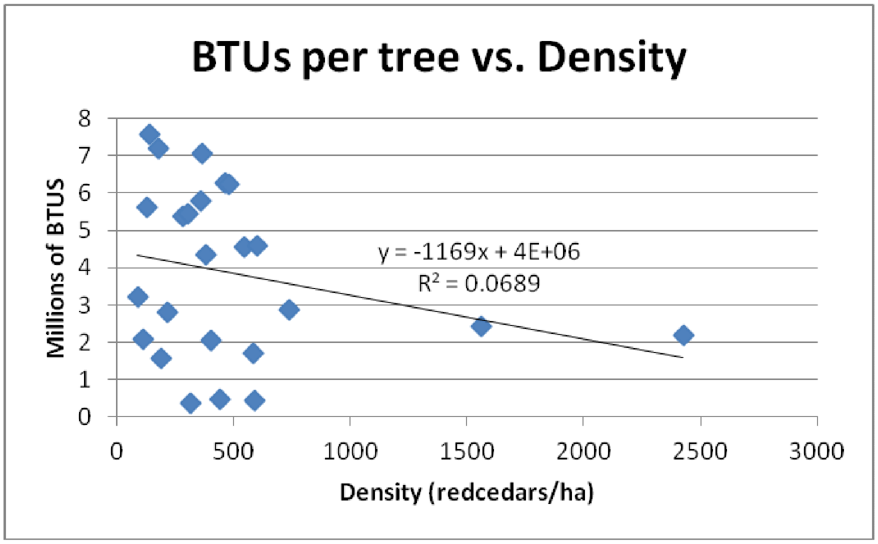

Figure 19: BTUs per tree vs. Density

It was expected for figure 19 to show a logarithmic relationship with higher densities having higher BTU's until it hits a threshold for carrying capacity and then would stabilize.

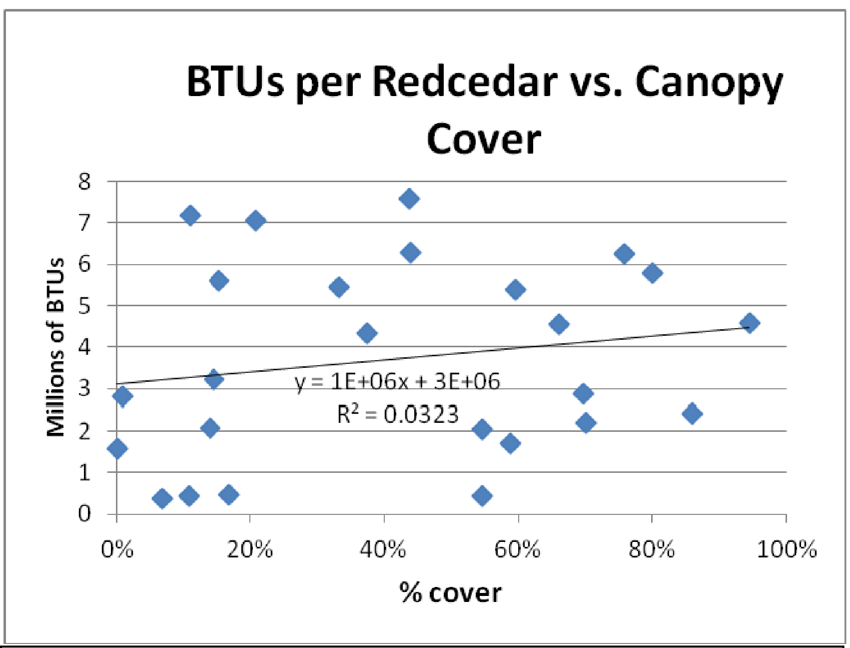

Figure 20: BTUs per Redcedar vs. Canopy Cover

It was expected that there would be a relationship signifying that the lower percentages of canopy cover are directly related to increased average BTUs.

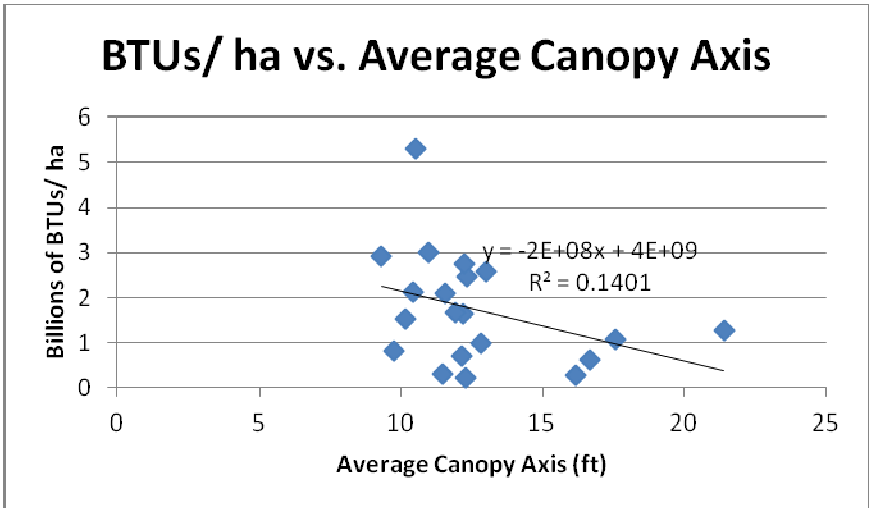

Figure 21: BTUs per ha vs. Average Canopy Axis

For figure 21, the group expected a relationship that as average canopy axis sizes increased, the BTUs/ha would decrease. This comes from the idea that larger canopies signify larger trees, and in turn (to a threshold), less dense areas of forest, giving less BTUs per hectare.

6.0 - Conclusion

Overall, the observed results do not correspond to the groups' expected results. The majority of this is due to insufficient amounts of data and complications obtaining accurate measurements from aerial imagery. Thus the hypotheses **H_1** and **SH_2** of this particular study were incorrect. **Hypothesis_1** - There is a relationship between BTU output and eastern redcedar tree stand density. This group did not find a relationship between BTU output and tree stand density. **Sub-Hypothesis_2** - aerial photography can be used to relate tree stand density to BTU output. In this particular study, using aerial photography the group was not able to relate tree stand density to BTU output.

However, the group has found positive correlations between biophysical characteristics and BTU output. Thus, sub-hypothesis **SH_1** proved to be correct. **Sub-Hypothesis_1** - Biophysical characteristics such as biomass and basal area of the trees can be use to relate to BTU.

Although **H_1** and **SH_2** were proved incorrect for this study, the group does feel that the expected observations would hold true on a statistically significant level if there was more time and area given to the study. Further data collection and more critical statistical analyses would be warranted to verify the groups' hypotheses, as parts of the data shows promise.

Overall, eastern redcedar is an important invasive species that must be controlled to ensure native grassland biodiversity. The use of eastern redcedar as biofuel is a viable source of energy and there is promise for future prosperity in this field. Further research must continue to adequately predict areas of maximum energy potential in order to efficiently map out probable sites for harvesting. All in all, the use of eastern redcedar as an energy source is in fact feasible and should optimistically become a significant energy choice in the near future.

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Appendix A

Site	Ave. DBH (in)	Mean BA (cm^2)	BA (sq ft/acre)	Redcedar cover (m^2/ha)	Weight (lb)	BTUs	% cover	Ave. dist. from center (ft)	Density (redcedars /ha)	BTUs/ha	Average Canopy Axis (ft)
High #0											
Plot 1	8.175	390.4	40	21.2	857.26	4,546,066	66.15%	14.05	543	2.47E+09	12.31
Plot 2	8.75	432.4	60	12.3	1013.46	5,374,430	59.64%	19.42	284	1.53E+09	10.14
Plot 3	9.325	470.8	40	21.8	1185.43	6,286,379	44.01%	15.23	464	2.92E+09	9.30
Plot 4	9.025	429.8	35	15.5	1093.71	5,799,995	79.95%	17.29	360	2.09E+09	11.58
Plot 5	9.3	461.5	45	22.2	1177.62	6,244,957	75.78%	14.96	481	3.00E+09	10.97
High # 2											
Plot 1	5.925	196.5	125	7.9	388.01	2,057,622	54.69%	16.33	403	8.29E+08	9.75
Plot 2	8.2	378	100	22.7	863.73	4,580,378	94.53%	13.37	601	2.75E+09	12.22
Plot 3	6.8	268.9	130	19.8	544.70	2,888,549	69.79%	12.06	738	2.13E+09	10.43
Plot 4	6.075	215.7	95	52.4	412.65	2,188,288	70.05%	6.66	2427	5.31E+09	10.51
Plot 5	8.025	362.9	95	13.8	819.04	4,343,399	37.50%	16.87	379	1.65E+09	12.21
Med # 1											
Plot 1	6.725	243.5	40	5.3	530.02	2,810,725	0.78%	22.27	217	6.10E+08	16.66
Plot 2	9.775	515.7	40	18.8	1331.31	7,060,003	20.83%	17.19	364	2.57E+09	12.99
Plot 3	9.85	503.8	25	8.9	1356.61	7,194,149	10.94%	24.71	176	1.27E+09	21.41
Plot 4	5.95	185.9	40	2.1	392.05	2,079,069	14.06%	30.92	112	2.33E+08	12.29
Plot 5	5.325	146.7	45	2.8	298.30	1,581,896	0.00%	23.81	190	3.01E+08	11.46
Med # 6											
Plot 1	10.07	525.9	55	7.5	1431.28	7,590,138	43.75%	20.33	142	1.08E+09	17.59
Plot 2	7.10	278.2	80	2.5	605.80	3,212,567	14.58%	29.89	89	2.86E+08	16.17
Plot 3	5.48	157.5	25	9.2	319.42	1,693,901	58.85%	13.56	586	9.93E+08	12.81
Plot 4	8.80	461.9	30	14.1	1027.78	5,450,375	33.33%	18.77	306	1.67E+09	11.90
Plot 5	8.90	420	60	5.4	1056.79	5,604,168	15.36%	29.04	128	7.17E+08	12.17
Form 1											
Plot 1	3.2				85.11	451,363	54.69%	15.91			
Plot 2	3.275	65	30	2.9	90.11	477,862	16.93%	15.66	440	2.10E+08	
Plot 3	6.325	206.5	35	32.3	455.73	2,416,768	85.94%	8.31	1562	3.77E+09	
Plot 4	3.175	64.3	35	3.8	83.49	442,728	10.68%	13.00	589	2.61E+08	
Plot 5	3	50.4	20	1.6	72.61	385,037	6.77%	18.50	314	1.21E+08	