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Relationships Between Biophysical and Photogrammetric Measurements of Eastern Redcedar in Northeast Kansas



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Introduction:

Global climate change has become a major topic of social and political discussions and it is very likely that the release of greenhouse gases, mainly CO_2, through the burning of fossil fuels is the driving factor for many of these changes, more specifically global warming (IPCC 2007). The IPCC Report indicates that as global temperatures increase the occurrence of severe weather events such as hot extremes, heat waves, and heavy precipitation events are very likely to increase as well. The report also predicts a likely increase in the intensity of tropical storms. These problems as well as the ever dwindling supply and ever increasing price of fossil fuels leads to a search for sustainable and cost effective alternative energy sources. In the search for alternative fuel supplies, finding methods that would decrease our dependency on fossil fuels and lower the total amount of CO_2 going into the atmosphere have become a top priority.

One possible alternative energy source for many plains states could be using Eastern Red Cedar (*Juniperus virginiana*) as a biofuel for biomass heat and energy generation. The Eastern Red Cedar has started to invade grasslands and pastures over the past 50 years due to the increased wildfire suppression within these environments (Pierce and Reich 2010). A study done by Limb et al. (2010) found that species diversity and herbaceous biomass decreases with increasing canopy cover. Vegetation cover, forb cover, graminoid cover were found to be higher on the south side of the trees compared to the north side. (Linneman et al. 2006) This lack of diversity could lead to system-wide weakness against diseases and pests, which poses a potential risk to those who rely on the lands for income.

This rangeland is crucial to the cattle industry in several states including Oklahoma and Kansas where beef brings in $3.06 billion and $8.54 billion respectively (USDA 2007). In Oklahoma, studies (Zhang and Hiziroglu 2010) have shown that red cedar is invading over 750 acres of rangeland a day. That is over a square mile per day, red cedar poses a serious threat to the cattle industry in Oklahoma. While a comprehensive study on the expansion of Eastern Red Cedar in Kansas has not been done a number of localized studies have been done and they show similar rates of expansion (Briggs et al. 2002; Owensby et al. 1973). Briggs et al. (2002) also found that the conversion of "tallgrass prairie into a closed-canopy forest can happen in as little as 40 years". Which means the effects of red cedar invasion could be quite significant very soon if no mitigation techniques are enacted.

Luckily, studies have shown that these invaded rangelands are not irreversibly converted into woodlands (Pierce and Reich 2010). With the removal of the red cedar the native grasses rebound quickly. The easiest way to keep the *Juniperus virginiana* from invading is by burning the grasslands regularly (Briggs et al. 2002). This is not a popular choice with many land and home owner, however, because of liability issues and lack of proper training or knowledge on how to burn a field safely (Morton et al. 2010). Also, fire suppresses the growth of eastern red cedar but it doesn't necessarily kill the tree once it has reached a certain size. . An alternative to burning is the cutting down and removal of the trees; this method is also cheaper than the use of herbicides to remove redcedar (Ortman et.al, 1998). Cutting is also the most effective method of removal to ensure that existing redcedars do not grow back. However, this method does not remove the seed bank left behind by the redcedars. Cutting with removal is a cost prohibitive venture when there is no market for the waste.

One possible use for this woody waste is to use it as biofuel in boilers for local businesses and schools. A number of schools in Montana have already converted their old oil burning boilers into biofuel burning boilers. Eastern Redcedar stands in native tallgrass prairie could serve as an excellent renewable energy source. Norris et al. (2001) found that aboveground biomass of the trees ranges from 114,000 to 211,000 kg/ha. They also found that older trees (around 80 years old) have twice as much biomass compared to the younger trees (around 35-40 years old). There is currently a small market for Eastern redcedar, as detailed by Gold et al. (2005), that brings in about 60 million dollars nation-wide per year. It is mainly used for lumber and novelty items, and their research details that it can be used as boiler fuel.

The Eastern Redcedar may become a viable alternative energy source in the near future once the infrastructure is in place. This study aims to test the feasibility of using the invading *Juniperus virginiana* as a source of biofuel. A number of physical variables taken *in situ* as well as remotely sensed through aerial photography will be measured as a means to estimate the aboveground biomass Eastern Redcedar.

Methods:

This study was designed to test a number of null hypotheses:

H_{O1}: There is no relationship between photogrammetric measurements of *Juniperus virginiana* single tree canopy and the above ground single biomass of *Juniperus virginiana.*

H_{O2}: There is no relationship between biomass of *Juniperus virginiana* productivity and DBH of *Juniperus virginiana*.

H_{O3}: There is no relationship between biomass productivity of *Juniperus virginiana* and tree height of *Juniperus virginiana*.

H_{O4}: There is no relationship between tree age of *Juniperus virginiana* and biomass productivity of *Juniperus virginiana*.

Our alternative hypotheses are:

H_{A1}: There is a relationship between photogrammetric measurements of *Juniperus virginiana* single tree canopy and the above ground single tree biomass of *Juniperus virginiana.*

H_{A2}: There is a relationship between biomass of *Juniperus virginiana* productivity and DBH of *Juniperus virginiana*.

H_{A3}: There is a relationship between biomass productivity of *Juniperus virginiana* and tree height of *Juniperus virginiana*.

H_{A4}: There is a relationship between tree age of *Juniperus virginiana* and biomass productivity of *Juniperus virginiana*.

Study Area and Methods:

Physical measurements were taken on each selected tree. The latitude and longitude for each tree was recorded. On all our sites permission was obtained to measure and cut down the trees for weighing. We selected two sites, the first site is located near Tuttle Creek Reservoir Lookout (Figure 1) and the second site is located at Baldwin Park (Figure 2). The sites were chosen for a wide range of individual tree sizes. Both sites are grasslands that are being invaded by Eastern Redcedars and have similar climates and soil types. All the trees were located near Manhattan, Kansas at approximately 39°15’02” N 96°36’35” W for the Tuttle Creek Reservoir Overlook site and at approximately 39°22’50” N 96°43’03” W.

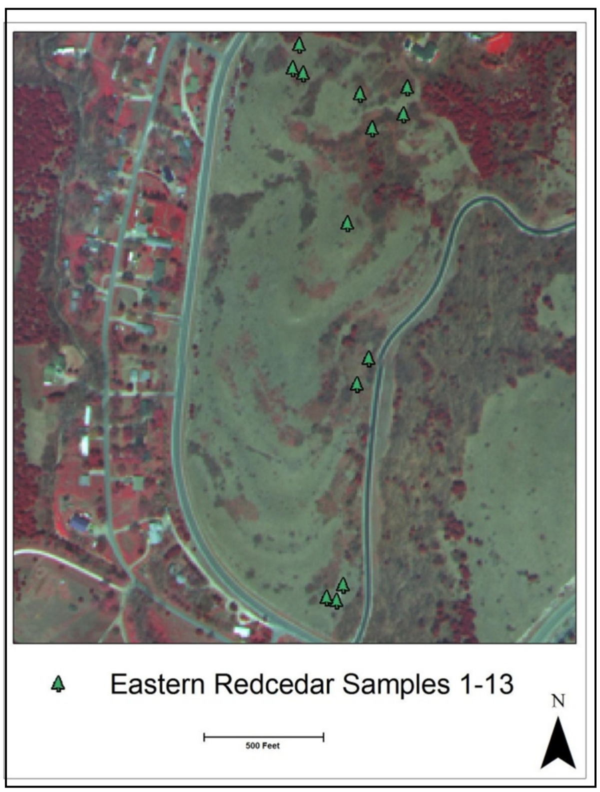


Figure 1. This figure shows the Tuttle Creek Reservoir Overlook site.

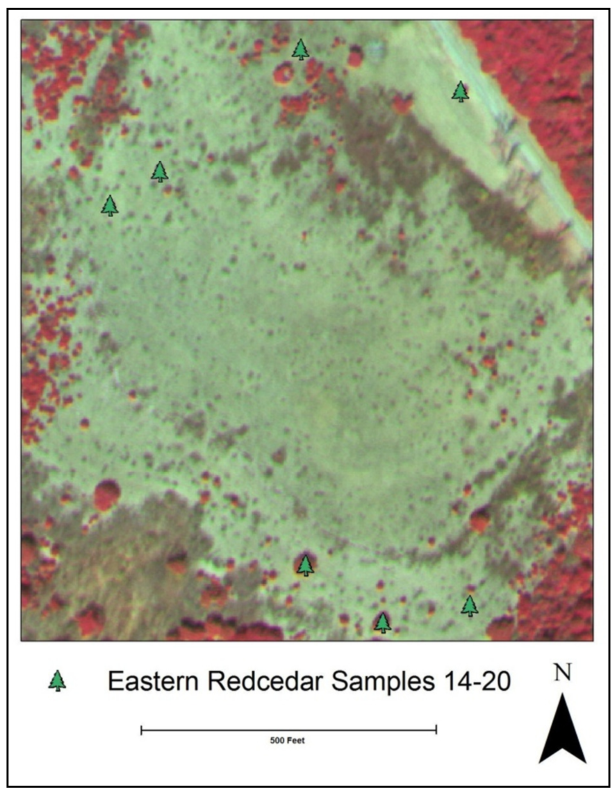


Figure 2. This figure shows the Baldwin Park site.

Tree diameter measurements:

For each tree, the tree's Diameter at Breast Height, or DBH (roughly 4.5 feet), was measured using a diameter tape.

Tree Height Measurements:

Using a clinometer (Figure 3) and simple Euclidean Geometry the height of each tree was determined. The following equation was used to determine height:

$$\boldsymbol{Height = (Tan(angle) \times Distance\ from\ tree\ trunk) + Eye\ Level\ Height}$$

Figure 3. The clinometer measures the angle between the object being viewed and level.

Crown Size:

The crown size was measured by running a distance tape from the estimated end of the crown to the other end and then done again on and axis perpendicular to the first one (Figure 4). The two measurements were then averaged.

Tree Age:

A core sample was taken from each tree at breast height through the center of the trunk (Figure 5). These cores were then stored and later analyzed to determine tree age (Figure 6). Tree age was determined by starting at the center of each core and counting the rings outward to the end. The cores were counted three to four times and the results were averaged.

Figure 4. This figure shows how the canopy axis was measured.

Figure 5. This figure shows how the core samples were taken.

Figure 6. This figure shows how a core sample and how a core sample was stored.

Aerial Photography Single Tree Canopy Area Estimation Methodology:

Multispectral aerial photography, with a spatial resolution of 0.6 m, was taken on 4/12/2011 over the sample sites. A Cessna 172 (Figure 7 A) equipt with Terrahawk Aerial Imaging System (Figure 7 B) was flown over the two sites and used to capture multispectral images in the green, red and near infrared wavelengths. Smokey conditions slightly distorted the spectral information recorded, however the spatial information required for this study remained intact. Using ERDAS Imagine 2011 the sample trees were identified and then each tree's areal canopy extent was visually estimated and then measured using the simple measure area tool provided by the software package.

Figure 7. A) The KSU-Salina Cessna 172 plane used to capture the aerial photographs. **B)** The TerraHawk imaging system with the DuncanTech MS4100 multispectral imaging camera mounted in the plane.

Results and Discussion:

The data that we collected is found in Appendix A. We recorded the latitude, longitude, height, age, DBH, and average canopy axis *in situ*. We estimated the aerial canopy area by using ERDAS Imagine 2011. Due to time constraints the weights were determined for only 12 trees of the 20 trees sampled in the field. These trees ranged evenly in size from small to large.

The relationships between each variable were then graphed. Figure 9 shows the relationships between four biophysical properties of eastern redcedars and the estimated aerial canopy area. All of the relationships have a positive linear relationship meaning as one variable increases, so does the other. The coefficients of determination (R^2) for these graphs were all above 0.5, meaning that they are statistically significant models and can be used for future biophysical property determination. Figure 9 (A, C and D) have a coefficient of determination greater than 0.8. This means that the data collected is strongly correlated. The three figures that are strongly correlated show the relationship between juniper tree canopy aerial extent and the biophysical properties of canopy axis, age, and DBH. Figure 9 (B) shows the relationship between height and aerial area. This graph had a coefficient of determination of 0.65. weaker relationship might be due to the irregular shape of the tree canopies making it more difficult to get a completely accurate areal measurement. So, determining an area of a tree may be difficult based on only its height.

Table 1. This table shows the multicollinearity of each variable in r values. Since each variable is highly correlated between every other variable, we can use a single variable regression model and produce respectable results.

	DBH 1 (Inches)	*Axis Avg. (inches)*	*Height (inches)*	*Age (Years)*	*Area Estimated by Aerial Photography (sq ft)*	*Wet Weight (lbs)*
DBH 1 (Inches)	1					
Axis Avg. (inches)	0.95	1				
Height (inches)	0.87	0.90	1			
Age (Years)	0.90	0.89	0.80	1		
Area Estimated by Aerial Photography (sq. ft.)	0.89	0.94	0.96	0.78	1	
Wet Weight (lbs)	0.92	0.86	0.94	0.81	0.87	1

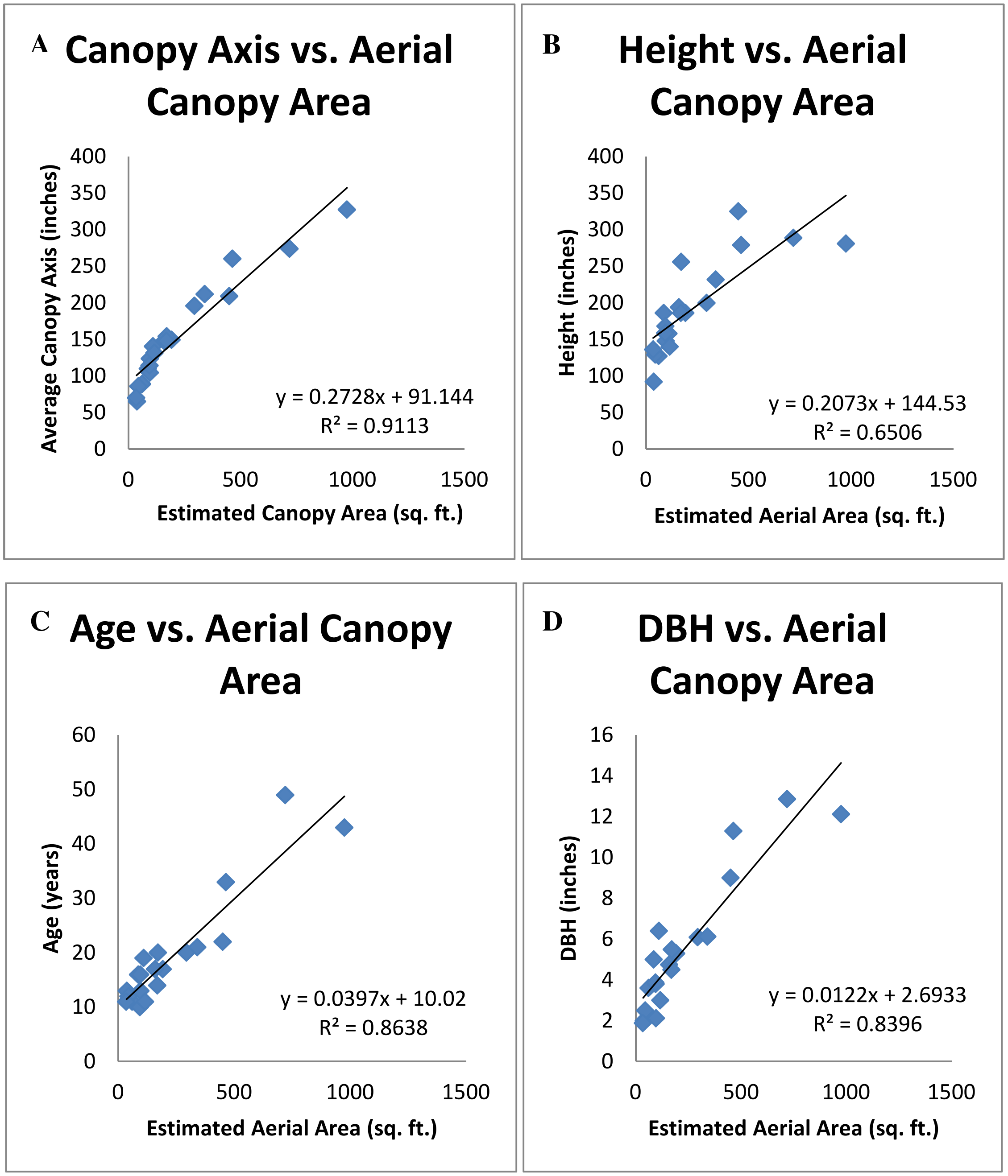
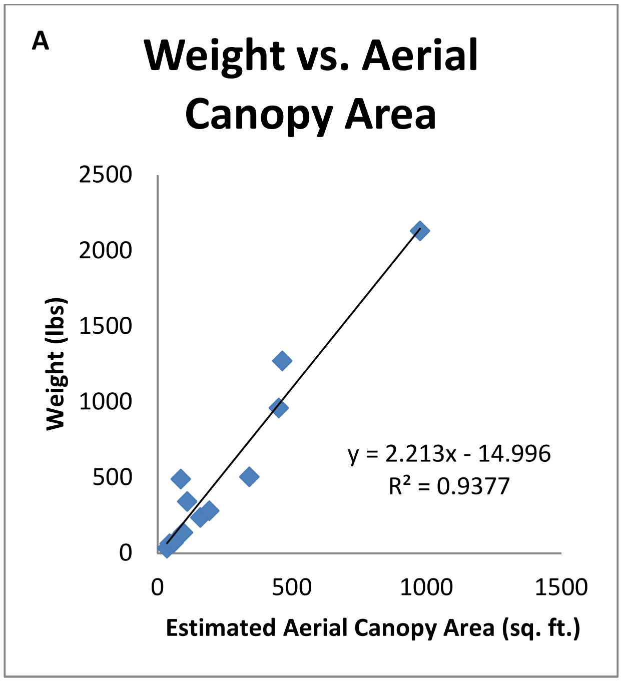


Figure 9. These graphs show the relationships between various biophysical attributes and estimated aerial canopy area.

Table 2. Shows the wet weight of the twelve selected trees. We converted the wet weight to Btu's using Slusher's (1995) approximate weight per standard cord for redcedars and its available Btu per cord.

Energy Produced by Eastern Redcedar				**Required amount needed of other fuel sources to produce the same amount energy**				
Sample #	Wet Weight (lbs)	BTUs per Redcedar	Cord per Redcedar	Fuel Oil (gallons)	Anthracite Coal (tons)	Natural gas (Cubic Feet)	LP gas (gallons)	Electric heat (kilowatt)
1	490	2,840,798	0.18	24.5	0.143	3430	37.69	1008.86
2	70	405,828	0.03	3.5	0.020	490	5.38	144.12
3	340	1,971,166	0.13	17	0.099	2380	26.15	700.02
4	280	1,623,313	0.10	14	0.082	1960	21.54	576.49
5	960	5,565,644	0.36	48	0.281	6720	73.85	1976.53
6	135	782,669	0.05	6.75	0.040	945	10.39	277.95
9	1271	7,368,681	0.47	63.55	0.372	8897	97.77	2616.85
10	62	359,448	0.02	3.1	0.018	434	4.77	127.65
11	505	2,927,761	0.19	25.25	0.148	3535	38.85	1039.74
12	32	185,521	0.01	1.6	0.009	224	2.46	65.88
13	235	1,362,423	0.09	11.75	0.069	1645	18.08	483.84
18	2130	12,348,773	0.79	106.5	0.623	14910	163.85	4385.43

The approximate wet weight is 3,260 pounds per cord and the potential available heat from a standard cord with 100% efficiency is 18.9 million BTU (Table 2). With these numbers, we were able to convert to cords and then BTU's. Table 2 also shows the how much fuel oil, anthracite coal, natural gas, LP gas, and electric heat you will need to produce the same amount of BTU's that a specific tree can produce. This table shows that as the weight increases, so does the amount of BTU's produced.



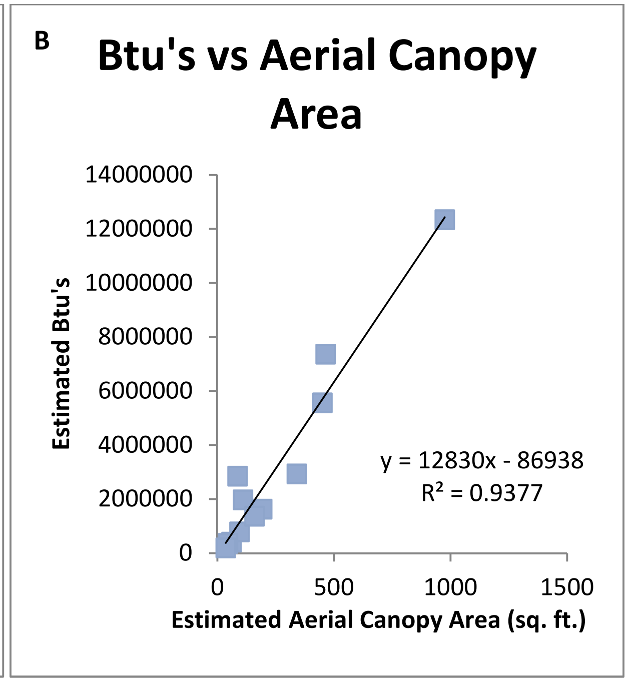


Figure 10. These graphs show the same relationship, graph A shows Estimated Aerial Canopy Area versus Tree Weight in pounds and graph B shows Estimated Aerial Canopy Area versus Tree Weight converted into BTU's

Conclusion

The many researchers over the years have shown that the Eastern Redcedar is an ever increasing ecological and economic problem for Kansas. The species' invasive tendencies and rapid growth from seedling to closed canopy only exacerbate the devastating impacts on local ecosystems. This study set out to find if a correlation existed between canopy area measured from aerial imagery and single biomass of Eastern Redcedar. The present research shows that there is a very strong correlation between photogrammetric area measurements and single tree biomass. Therefore, the null hypothesis **H_{O1}:** There is no relationship between photogrammetric measurements of *Juniperus virginiana* single tree canopy and the above ground single tree biomass of *Juniperus virginiana*; must be rejected and the alternative hypothesis: There is a relationship between photogrammetric measurements of *Juniperus virginiana* single tree canopy and the above ground single tree biomass of *Juniperus virginiana*; can be accepted. This is also the case for the other three hypotheses as well, reject the null and accept the alternative hypotheses.. It should be noted that this research focuses on individual trees and the vast majority of Eastern Redcedar exists in closed canopy stands. The estimation of biomass for closed canopy stands will likely prove to be more difficult but must be done to produce an accurate assessment of redcedar biomass available for consumption. Further research in this area is necessary to better inform policy makers and administrators looking for a local alternative energy source. The research here finds excellent correlations between ground data and aerial imagery data, laying the groundwork for future studies regarding viability of utilizing of the Eastern Redcedar as an alternative energy fuel source. Whether or not the redcedar can be utilized as an alternative energy fuel source remains to be seen, what is known however is that if the redcedar is left unmanaged the prairies, grasslands and rangelands of Kansas will continue to be an ever dwindling resource.

Appendix A.

Sample #	Latitude	Longitude	Height (Inches)	Age (Years)	Diameter at Breast Height (Inches)	Average Canopy Axis (Inches)	Wet Weight (lbs)	Area Estimated by Aerial Photography (sq ft)
1	39.25416	-96.61253	186	16	5	110	490	86.9273
2	39.25392	-96.61238	127	11	3.6	89	70	61.5824
3	39.25393	-96.61221	158	19	6.4	140.5	340	110.568
4	39.25415	-96.61158	186	17	5.3	149.5	280	193.1776
5	39.25434	-96.61111	325	22	9	209	960	451.145
6	39.25416	-96.61097	168	16	3.8	104.5	135	95.8661
7	39.25375	-96.61127	200	20	6.1	196	-	295.7659
8	39.25151	-96.61018	92	13	2	65	-	38.4726
9	39.25192	-96.60944	279	33	11.3	260.5	1271	464.9559
10	39.25168	-96.60939	129	12	2.5	86	62	45.6205
11	39.24995	-96.60803	232	21	6.125	212	505	341.502
12	39.24979	-96.60822	136	11	1.88	70	32	35.5293
13	39.24991	-96.60806	194	17	4.75	148	235	160.3865
14	39.38184	-96.71716	256	20	5.5	154	-	171.881
15	39.38142	-96.71798	148	13	2.125	123.5	-	96.8831
16	39.38083	-96.71803	186	14	4.5	148	-	170.1624
17	39.38077	-96.71801	159	10	3.875	114.5	-	94.857
18	39.38027	-96.71623	281	43	12.125	327.5	2130	975.8109
19	39.38035	-96.7159	289	49	12.875	274	-	720.4885
20	39.38068	-96.71571	140	11	3	131.5	-	117.0931

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