Estimating Redcedar (*Juniperus virginiana*) **Biomass in Northeastern Kansas**

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Introduction

Eastern Redcedar (*Juniperus virginiana*) has been growing rapidly across the United States; and Kansas' Tall Grass Prairie in particular (Norris, Johnson, Blair, 2001). This decreases the amount of both prairie and crop land across the state. Its presence in the prairie has lead to discussions about how the species should be maintained, put to use, or eradicated completely. More recently, the idea of utilizing Redcedar as a source of biofuel energy has become a key talking point in several arenas (McKinley, 2012). For example, since 2011, five schools in Missouri have begun using fire boilers powered by Redcedar (Biles, 2012). Before Redcedar can be used as an energy source, however there needs to be a comprehensive understanding of how much biomass a tree contains and how many trees are available.

Background

One roll that Eastern Redcedar is well suited for is its use in windbreaks. Windbreaks were widely planted in Kansas after the dust bowl in the late 1920s and early 1930s to help prevent wind erosion on crop fields (OSU Invasive Species, 2012).The Kansas Forest Service Tree Distribution Program sells tens of thousands of Eastern Redcedar seedlings at a reduced cost to people all over the state for that purpose alone (Kansas Forest Service). Both male and female species were imported into the area, not expecting that the species would prove invasive a few years down the road and threaten the way prairies have historically operated (Norris, Johnson, Blair, 2001). The Eastern Redcedar is an invasive species in that, even though the tree is native to North America, it is not indigenous to the prairies; it competes with native plants for nutrients, decreases biodiversity, and changes the landscape of the different areas it affects (Brooks *et al*. 2012) In Oklahoma alone, Redcedar invades 300,000 acres of land per year (Cameron, 2009). This has a large effect on the state's economy by reducing grazing and cropland. In Kansas, between 1965 and 2005, there was a 23,000% increase in Redcedar volume (Scientist Develop).

The best way to remove Eastern Redcedar from an ecosystem is prairie management; this includes controlled, or prescribed, burns every few years (Owensby, 2012). Once the trees reach about five years in age they have become established, and they cannot be killed by prescribed burns (Bidwell, Wier). This is why it is essential for landowners to practice proactive land management – it is much simpler to prevent Redcedar encroachment than to remove it.

The Hall property that we studied is a prime example of poor land management. While the properties around it have managed cedar trees the Hall's choose not to, leading to an infestation of Eastern Redcedar. Once these trees become settled in the land, the only way to remove them is to cut them down one by one – an expensive and time-consuming process. From this, a large amount of Redcedar products have been sold in markets, from Redcedar oil, poles and post, to mulch – even pencils (Biles, 2012).

Growing conditions have a significant influence on these trees' fair, but they are capable of growing even in formidable environments (Lawson). This explains why they have had such a large effect in the Flint Hills region. This area has remained a prairie for many reasons, such as years control burns and continual use for livestock grazing, but also the land itself is comprised of limestone, making it poor farmland, but still deep enough soil for a tree to set down roots.

Because of the obstinate nature of this species of trees, eastern Redcedar would make for an ideal energy producer; it can be grown in a variety of climate of conditions and is already in plentiful supply.

Goals and Hypotheses

In this study, we intend to gather information from existing Redcedar plots and analyze their height, age, and weight in order to determine each tree's potential biomass. Our group will achieve this goal by gathering data from three different growth sites: two from the Hall property and one from the KSU Howe property, all located in the general greater Manhattan area. The Hall property has never been burned, allowing the Redcedar to grow freely. According to our data, most of these plots were approximately in their early twenties. The KSU property has a younger population of Redcedar, and therefore will produce less biomass than the trees on the Hall property. We intend to determine each tree's potential biomass by accomplishing the following objectives:

- Determine the relationship between Eastern Redcedar height and its biomass.
- Determine the relationship between Eastern Redcedar diameter at breast height (DBH) its biomass.
- Determine the relationship between Eastern Redcedar age and its biomass.
- Determine the relationship between Eastern Redcedar crown diameter and its biomass.

Procedures/Methods for Evaluating a Study Site

The study sites used, which are depicted in Figures 1 through 4, were chosen through a set of criteria created by the group that includes species variety, canopy density, terrain, the spatial relationship of trees, and relation to other sites.

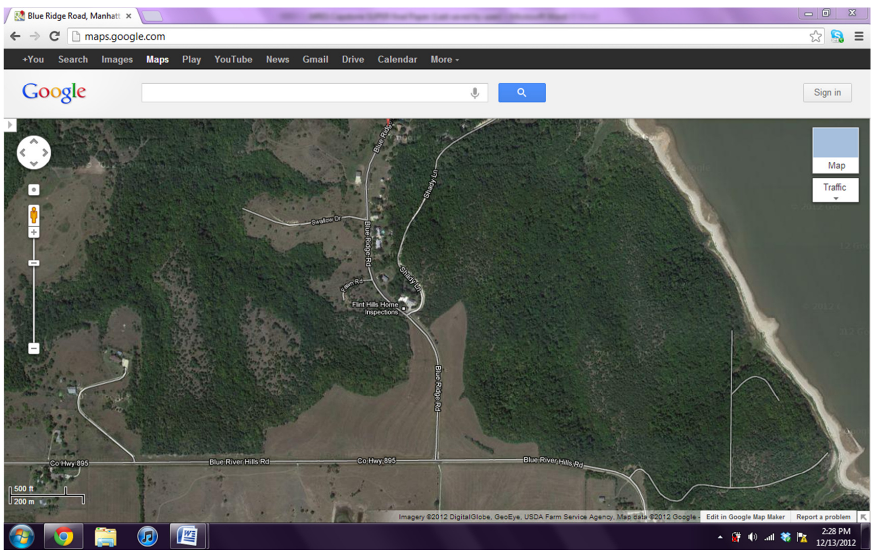

Figure 1: The KSU Howe property, off of Tuttle Creek Lake. Our site was chosen from the East side of Blue Ridge Rd, just North of the open space that comes to a point. (Google Maps)

Figure 2: Aerial imagery of the KSU Howe Property, with pushpins marking proposed site numbers. Site 20 is actual site used. (Google Earth)

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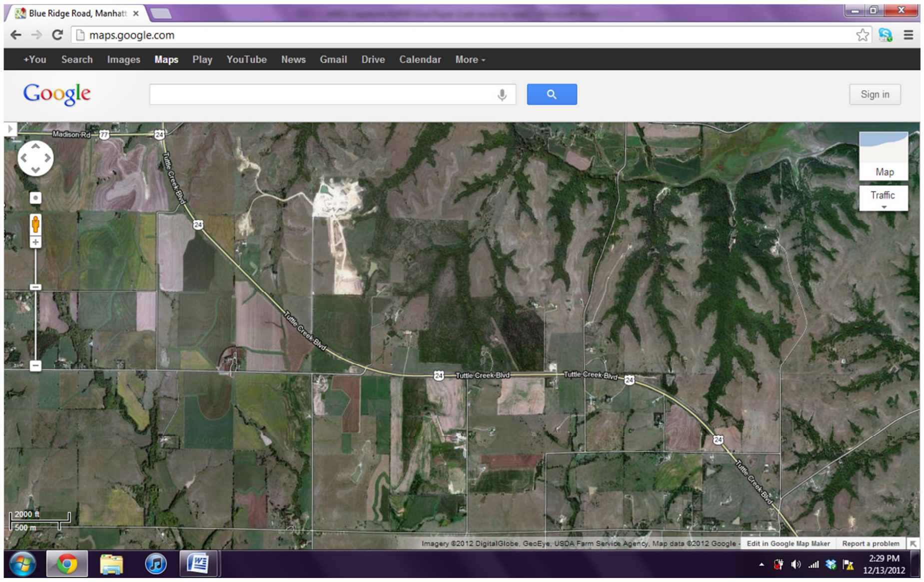

Figure 3: The Hall property, located off Highway 77 outside Manhattan, KS. The property lines are easily discernible as the block of Redcedar trees. (Google Maps)

Figure 4: Closer aerial imagery over the Hall property, with pushpins marking sites used. (Google Earth)

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The first step in field analysis was to determine the center point (CP) of the proposed site. The center point was then flagged and marked on a handheld GPS unit. From the center point 10.5 meters were measured out, using a compass, in the directions of NE, NW, SE, and SW, with midpoints marked at five meters, as in Figure 5. The four directional points were flagged and marked on GPS to create a box around the center point for use on aerial maps. The tree closest to each midpoint (CP, NW, NE, SE, SW) was used as a study tree. For each study tree four measurements were taken: age, height, diameter at breast height (DBH), and crown density.

Figure 5: Field group members begin to lay out the study site using a compass, flags, and a measuring tape.

The age of the study trees were determined by using an incremental borer to extract core samples, demonstrated in Figure 6.

Figure 6: A field member using an incremental borer to remove the tree core samples, used later to count tree rings and estimate tree age.

The core samples were placed in drinking straws to be transported to the lab for aging, as illustrated in Figure 7.

Figure 7: Showing the placement of the tree increment bore into a plastic straw for transportation to the lab.

The height of the study trees were determined by using a Clinometer to measure the percent of slope to the top of the tree added to the percent of slope to the base of the tree, as Grant works on in Figure 8.

The total distance of the slopes can be converted into feet or meters.

Figure 8: Shows a group member using a clinometer to measure the percent slope from the top to the bottom o the tree that was later used to estimate tree height.

The diameter at breast height (DBH) is measured with a diameter tape at the average breast height of the data collector as shown in Figure 9.

Figure 9: Demonstrating the use of a forester's measuring tape to determine the DBH of a tree.

The crown density of the four directional (NW, NE, SE, SW) sights was calculated by using a Spherical Densiometer. Each measurement was recorded in a field form so that the information could be analyzed more efficiently in the lab, as done by Laura in Figure 10.

Figure 10: A member of the field team taking notes on the customized project field form.

Biomass Field Sampling

The methods used for sampling Eastern Redcedar biomass are as follows. We were told that there were some gaps in the biomass data previously gathered my Dr. Price's graduate students, who are working on a similar project. Those gaps were between a DBH of seven and nine inches. We then went to the field and selected four trees that were inside that range and growing relatively free of other Redcedar competition. The following data from our four trees were then measured and recorded, as well as the sex of each tree.

The width of the canopy was measured in one direction, and then a second measurement was taken at a 90° angle from the first measurement. The DBH was taken using a

DBH tape measure after some of the lower limbs were trimmed off for easier access to the stem and allow for a more accurate measurement (Figure 9).

Figure 11: Field crew removing lower tree limbs of an Eastern Redcedar in preparation for feeling the tree and weighting it to get estimates of tree biomass.

Immediately after the tree was felled using a chainsaw, the height was measured using a tape measure. A four centimeter slice of the stem was removed where the DBH measurement was taken so the tree could later be aged. The rest of the limbs were then removed from the stem to allow for more efficient weighting. The limbs and stem of the tree were weighed using a steel pipe, chain, 230 lb. scale, rope, a canvas tarp and two folding chairs.

Figure 12: Field crew placing the removed limbs onto the tarp to be weighed.

The scale was attached to the pipe using the chain. The tarp was laid out flat on the ground and then loaded with cut Redcedar pieces so that it would weigh roughly 100-150 pounds. Any more than 150 pounds and the scale would be difficult to lift, any less than 100 pounds and the process would take longer than necessary. Rope was attached to the tarp at six points making a basket that it could hold the cut Redcedar pieces. The six separate ropes from the tarp were hooked onto the scale. Two people lifted by stepping onto the folding chairs which gave the lifters extra height and made lifting the pipe easier. A third person then read the scale and recorded the weight. The remains of the weighed trees were then piled to be burned at a later date.

Data Analysis

A portion of the data used for this project came from field work completed by KSU Master's students who are studying the use of remotely sensed measurements for modeling Redcedar biofuel potential in the region. Figures 13 – 17 show relationships among Redcedar biomass and other tree biophysical factors measured in the field. Compiled numerical data are available in Appendix A.

The data points displayed are from numerous research trips to various data sites. Each represents one of the principal trees measured at each site. These trees were selected at the same relative coordinates for each site. By doing this we could gather unbiased data. For each plot, a trend line was added to match the data spread. In the event of a random spread, no trend line was added. The equations for these trend lines and the R squared values are displayed, where 'y' is the biomass and 'x' is the trait being correlated. The R squared value shows the accuracy of the data in terms of how it matches the trend line. An R squared value of 1.0 would represent a perfect relationship between one factor and another. The equation and graph for biomass estimation are embedded in each graph.

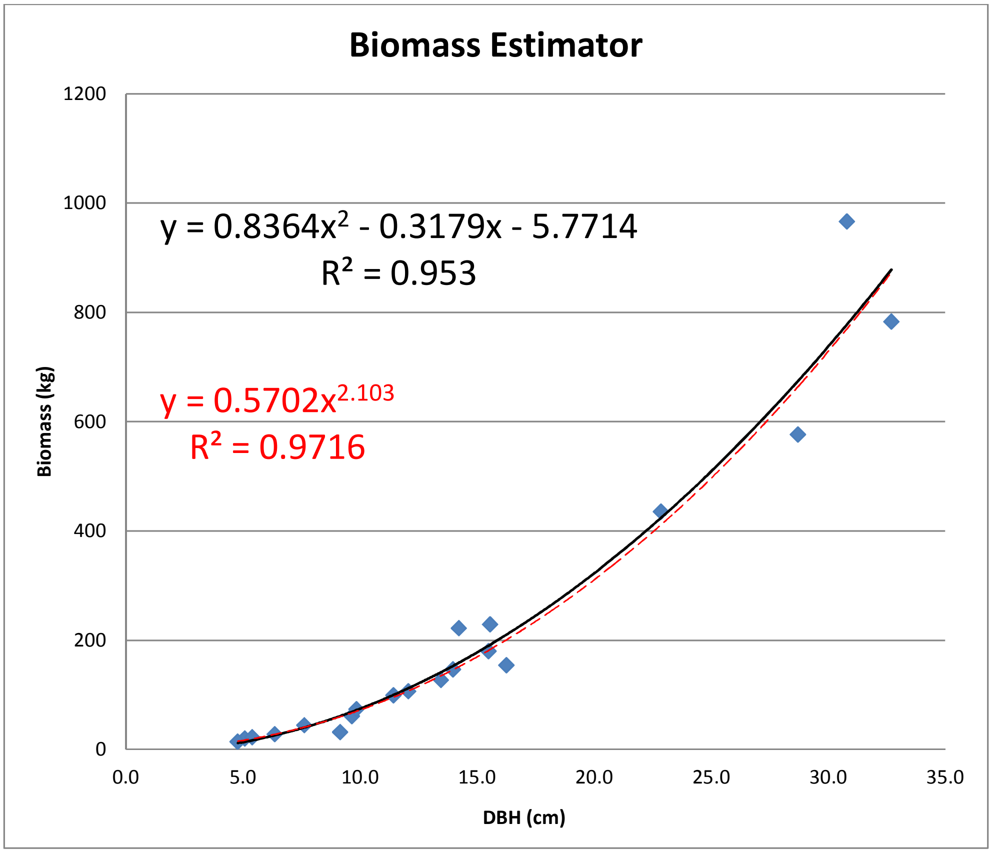

Figure 13. This figure shows a very strong relationship between Redcedar diameter at breast height (DBH) and biomass, with DBH explaining 95-97% of the variation in tree biomass.

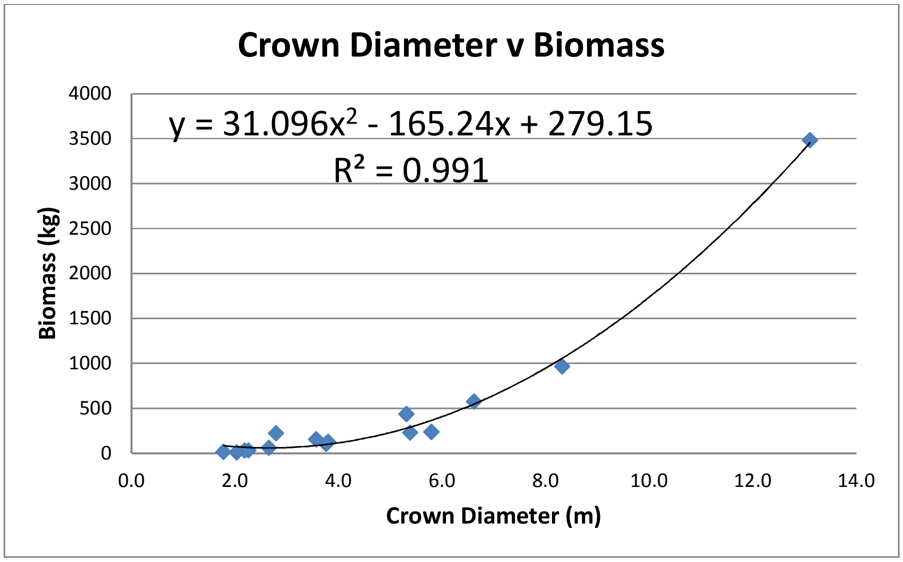

Figure 14. This figure shows a very strong relationship between crown diameter and biomass, with crown diameter explaining 99% of the variation in biomass.

Figure 14 shows a strong correlation between Crown Diameter and Biomass. This means that the diameter of the tree's canopy is an accurate estimator for the tree's overall mass and has significant implication in terms of the use of high resolution aerial photography for estimating Redcedar biomass from tree crown dimensions extracted from such photography.

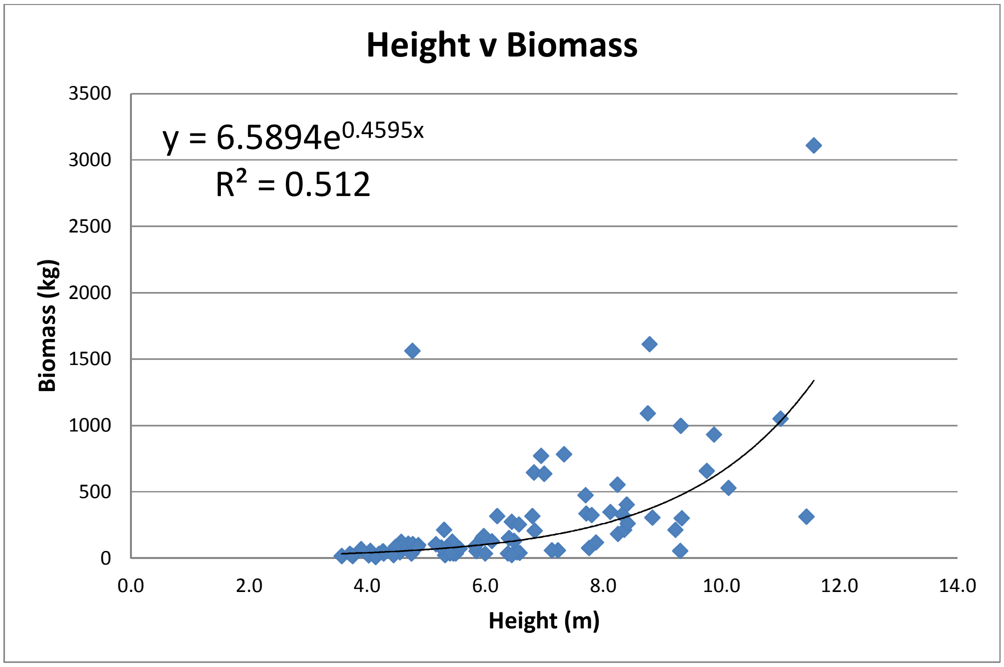

Figure 15. This figure shows a reasonably strong relationship between height and biomass, with height predicting 51% of the variation in biomass.

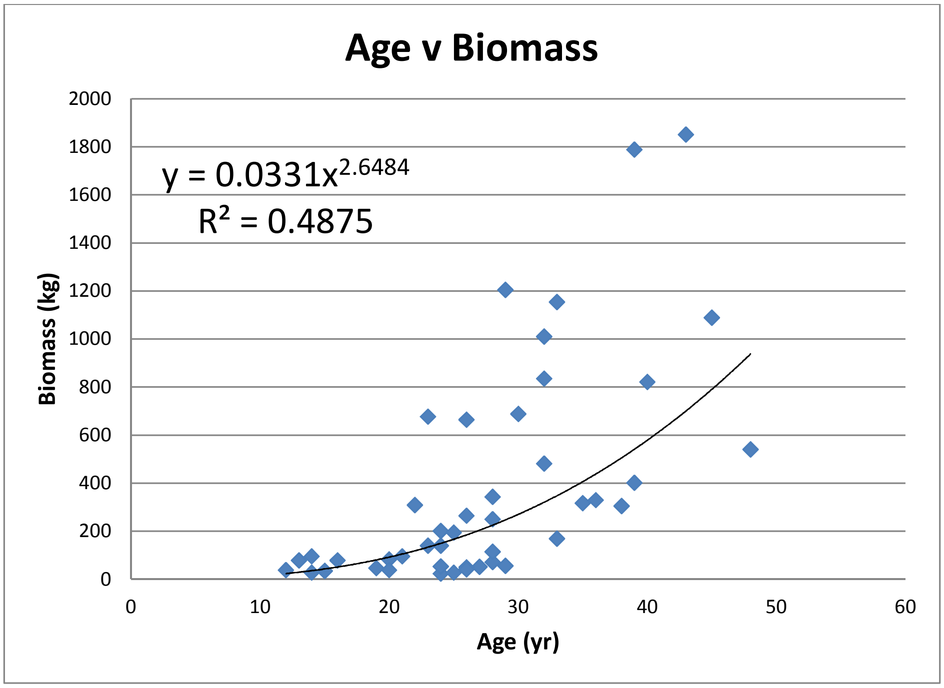

Figure 16. This figure shows a reasonably strong relationship between tree age and biomass, with age explaining 48% of the variation in biomass.

The results of our team's research have developed previously established equations further. The accuracy of the Biomass Estimation equation has improved significantly. This data only prompts minor changes to previous solutions and further proves the relationships already established.

Conclusion

Harvesting Redcedar trees can have a positive impact on the environment. Some have proposed using Redcedar as a biofuel; by using our data one would be able to see what the best way to predict biomass is. This would come in handy when mass harvesting begins. Companies will have to find areas that contain the greatest amount of biomass in order to increase their productivity and decrease their cost. By doing this they will be able to get the greatest "bang for their buck". Throughout all of our fieldwork and research, our group's goals were to evaluate the relationship between Redcedar biophysical factors including: height, age, crown diameter and diameter at breast height (DBH) as predictors of biomass. Our first null hypothesis was that there is no positive relationship between Eastern Redcedar (*Juniperus virginiana*) height and Eastern Redcedar biomass. There was a statistically significant correlation between tree height and biomass, and the model explained over 50% of the variation in biomass. While the strength of this model was not as strong as other relationships we tested, the relationship is clearly not random. The areas we studied could explain this weaker correlation. Some areas were more densely populated so trees had to compete with each other for growth, while other areas the trees were able to grow without much competition. So we can reject our null hypothesis and accept our alternative hypothesis that there is a positive relationship between Eastern Redcedar height and Eastern Redcedar biomass.

Our second null hypothesis is that there is no positive relationship between Eastern Redcedar diameter at breast height compared to Eastern Redcedar biomass. We can also reject this null hypothesis and accept our alternative hypothesis that there is a positive relationship between Eastern Redcedar diameter at breast height compared to Eastern Redcedar biomass. The model again explained over 50% of the variation in biomass. Our third null hypothesis is that there is no positive relationship between Eastern Redcedar age and Eastern Redcedar biomass. After our research, we found that we there was a correlation between these and therefore we can reject our null hypothesis and accept our alternative hypothesis. Again this relationship between age and biomass was not as strong as DBH and crown diameter compared to biomass but the relationship was still significant and not random. Our fourth and final null hypothesis is that there is no positive relationship between Eastern Redcedar crown diameter and Eastern Redcedar biomass. We can reject this null hypothesis and accept our alternative hypothesis that there is a positive relationship between Eastern Redcedar crown diameter compared to Eastern Redcedar biomass.

Overall, Eastern Redcedar is an important invasive species that must be controlled and monitored. We found that there is a strong correlation between aspects of the trees and biomass. The use of Eastern Redcedar as a biofuel as suggested by some seems like it could be a valuable idea and estimating biomass will be a large factor in deciding which trees to use as fuels. We hope that our research helps show that biomass can be estimated fairly easily based on crown diameter, diameter at breast height, age and height. We believe that using aerial photography and flyovers to find the crown diameter of trees to estimate their biomass would be the most cost effective way to estimate biomass.

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