Tree Conservation in New Developments

A Develop Understanding Task

Purpose: Expose students to the experience of sampling as a means to estimate a population parameter. *Tree coverage* on a site is often defined as the total *basal area* of the trees on that site. This basal figure is related to the size and number of trees. Students will use gathered measurement data to classify a site as *understocked, overstocked,* or *fully stocked* with timber based on industry standards.

Career Field:
Forestry or Geomatics
WithersRavenel

WTCC Associate Program of Study and Contact Person:

NC Math 4 Standards:
Include cluster headings
NC.M4.SP.1.1 Construct statistical questions to guide explorations of data in context.

NC.M4.SP.1.2 Design sample surveys and comparative experiments using sampling methods to collect and analyze data to answer a statistical question.

NC.M4.SP.1.4 Interpret non-standard data visualizations from the media or scientific papers to make sense of real-world phenomena.

NC.M4.SP.2.1 Sampling distribution
A probability distribution of a statistic that shows how the statistic varies if all possible samples of the same size are taken from the population or if the process of sampling is repeated multiple times.

Unit Alignment:
NC Math 4 - Unit Exploratory Data Analysis
WTCC Math 110 (Statistics)

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
7. Look for and make use of structure.

Prerequisite Skills
List any prerequisite skills that may need to be addressed in a warm-up

- Know the relationship between Radius & Diameter of a Circle
- Find Circumference & Area of Circle

- Finding diameter given circumference
- Conversion between units of measure

Time Required

The time required to complete this activity is approximately 100 minutes for launch and data analysis, 200 minutes for launch, data gathering, and data analysis.

Materials Needed

- Spreadsheet file, and technology* (see extension activity after the Exit Ticket)

The Teaching Cycle:

Tree coverage on a site is important in a number of applications including urban development and timber harvesting. Many municipalities have implemented codes and statutes regulating the amount of tree coverage for a site under development or harvest. Developers want to comply with these restrictions while also considering the aesthetics of the site. Timber companies have an eye toward the amount of harvestable and renewable material on a site. This task guides students through calculations used in the forestry industry to provide the necessary information to these stakeholders.

Probing questions to be addressed in this activity:

- What does “tree coverage” mean?
- Why would we be concerned with the amount of tree coverage on a site?
- Is a 2-year old tree (18 feet tall with a 3-inch trunk) interchangeable with a 50-year old tree (35 feet tall with a 20-inch trunk)?

Launch:

Assign the Desmos Launch activity for homework the night before. In addition, possibly provide students with page 1 of the activity to make notes, highlight vocabulary terms, and/or create/identify questions. Alternatively, the lesson could be launched with the Desmos activity and launch video in class one day, and carry out the Explore and Discuss the next.

The first page of the activity was provided by our industry partner. Students may find the text dense to read and heavy with jargon. This is a valuable discussion to connect students to the use of math in industry.

This graphic has considerably more information than the activity is examining. For instance, many of the markings are topological, and the dark shaded triangle near the center is likely a dried-up pond. It can serve as an example of the complexity of making decisions about proceeding on a construction site.

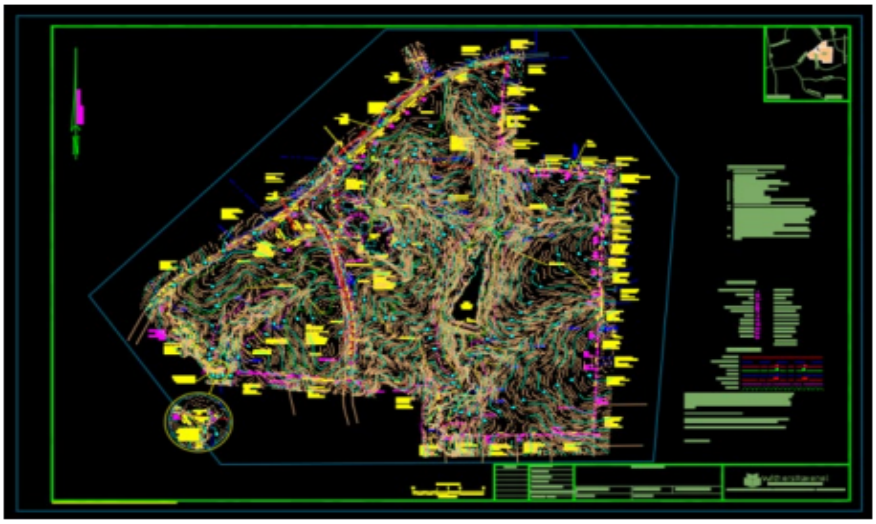


Figure 1: Digital Survey Map

🌳 Students might offer suggestions for the interpretation of the term *tree coverage*, some of which could be focused on the trees' canopy which provide an aesthetic, shade, and wildlife habitat. In forestry, tree coverage describes the density of trees on a site based on the number and size of the trees. A group of small trees might be comparable to one large tree as far as the amount of shade or habitat it provides, but could be very different in terms of potential timber harvesting.

The *basal area* of a tree is the cross-sectional area of its *trunk*. Measuring the tree trunk rather than the coverage by the tree canopy (leaves and branches) is often used by timber harvesters since the trunk is the part of the tree that is useful to them.

The forestry standard for measuring the diameter of tree trunks is to measure at 4.5 feet above the ground, called Diameter at Breast Height, or DBH. We abbreviated this as D_{BH} in the activity so that students did not see "DBH" and wonder about values for D and B and H. A tool in the industry is called a *diameter tape measure*. Units on this tape give the diameter of the tree by wrapping the tape around the tree.

🌳 Students might suggest a variety of protocols for sampling, such as selecting random spots around the site; or apply a grid to the site, then choose grid sections to sample (either at random or with some system); or choose the places on the site that are easiest to access. These responses will lead well into a discussion of Sampling Methods in statistics when the time comes.

Students are invited to describe a protocol for whether to include a tree in their sample or not. They might suggest that if any part of the tree is inside the circle, it should be included; or the tree must be entirely inside; or if any part of the tree is outside the circle it should be omitted. The industry practice is that if the center of the tree trunk is inside the plot radius, then the tree should be included in the sample. *If the group collects live, "in the field" data, this discussion should occur beforehand. In this case, that section of the Student Activity Sheet can be omitted.*

Explore:

🌲Students should discuss their ideas for sampling strategies. The standard practice in forestry is to measure 10-20% of a site by randomly choosing circular sampling plots of either $^1/_{10}$ or $^1/_{20}$ of an acre. If the tree stand is consistent in age and tree species, a smaller sample of the site could be appropriate. If there is a greater diversity of ages/species, a more detailed inventory may be necessary. Hopefully, these considerations will come up in student discussion. The choice of 7 plots for this activity was for students to have a sufficient and manageable experience with the process.
D_{BH}, normally abbreviated as DBH in forestry, stands for Diameter at Breast Height, taken in inches. This is the diameter of a tree trunk 4.5 feet above the average ground level surrounding the tree. BA stands for Basal Area, the cross-sectional area of a tree trunk at that height, taken in square feet. In this exercise, all trees are single-trunk and roughly vertical. There are adjustments in practice for trees with a split trunk, or trees that deviate significantly from being perpendicular to the ground. We do not address those in this activity.

🌲Before making any calculations, encourage students to browse the data and create a "word painting" of the plots. Their impressions could include that not all plots have the same number of trees; each plot has a variety of tree sizes; for example. Following in those veins, students should understand that all the plots are the same size ($^1/_{10}$ of an acre circle), so a different number of trees suggests different densities. They might conjecture that if a plot has a lot of trees, there may not be room for any of them to grow to be very large. If you are using this activity with Math 2 or 3, students might need some prompting.

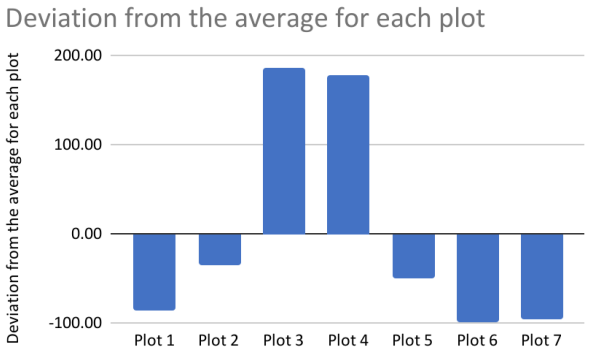
🌲The Forester's constant: to calculate an area in square feet from a given diameter in inches, first we need to convert the diameter given in inches. $\frac{\left(\frac{d\ in}{2}\right)}{\left(\frac{12\ in}{ft}\right)}$ or $\frac{d}{(2)(12)}\ ft$ gives a radius in feet.

In practice, most trees are treated as though the cross-section is a circle, giving $BA = \pi(\frac{d}{2(12)})^2 = \pi\left(\frac{1}{4(144)}\right)d^2$. The coefficient $\frac{\pi}{4(144)}$ is very close to 0.005454, the established *Forester's Constant* which is used as a standard in forestry.

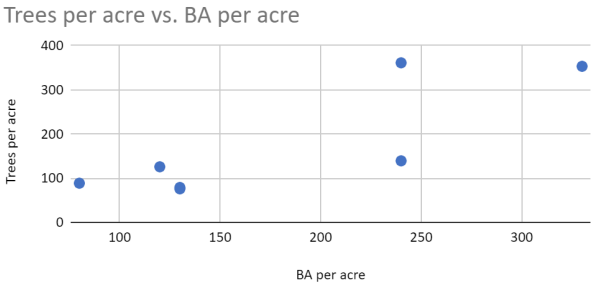
🌲Students are given a spreadsheet of sample data from 7 plots on our 60-acre site consisting of the radii of trees found in each plot. Students should use spreadsheet formulas to convert radius to diameter, then use the Foresters' Constant (0.005454) to calculate the basal area for each tree in each sample to fill in only the cells shaded in yellow. Completed Spreadsheet (Note: If downloading and opening from Word, the link must be copied and pasted into the browser.)

Discuss:

The graph shown here is one possible representation of the differences of each plot average and the whole-site average. Students might try to see a pattern in the differences, but keep in mind that the Plot numbers are arbitrarily chosen. The data seem to show that there is significant variability among the Plots.



There is a moderate positive relationship between the BA per acre and Trees per acre. This makes sense considering more trees per acre means that there are more basal areas on that acre to be summed. The strength of the correlation makes sense in that the basal area incorporates both the number of trees and the diameter of each tree.



Discussion Items following the Exploration

Municipal Ordinances are in place to regulate the preservation and harvesting of trees. For example, find attached a copy of an ordinance from the Town of Cary, NC regarding a *Champion Tree*.

Technological Developments

Advancements in new handheld LiDAR (Light Detection and Ranging) is leading industry down a path where a forester can hold a coffee mug size device that is collecting thousands of colorized 3D points per second in order to virtually replicate everything around it. This type of data collection would allow for us to walk around a timbered site with this tool, for computer algorithms to then define the tree sizes, types (a tree with a split trunk, or one that leans significantly from vertical), and the systematic statistical sampling that would generate the basal density and trees per acre. A visual of how this technology works is shown for Plot 1 in the image below.

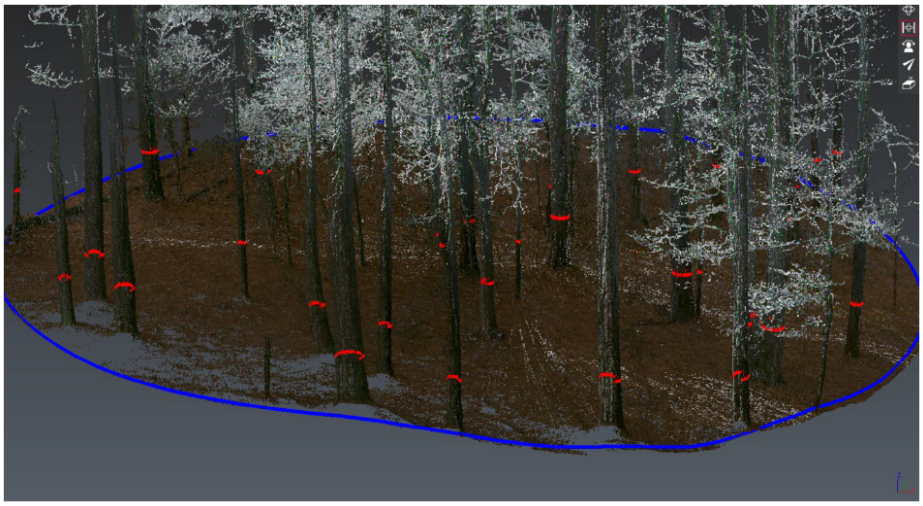


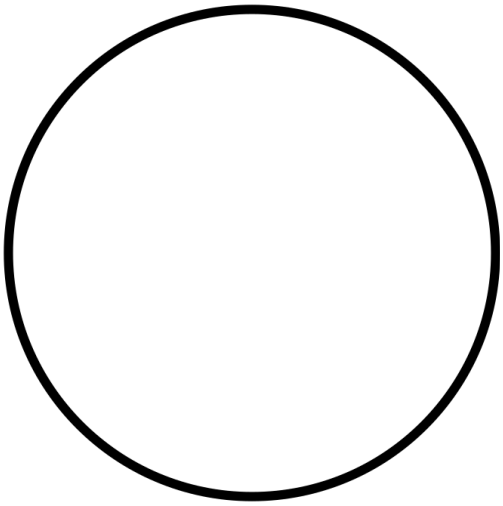
Figure 4: Plot 1 visualized in 3D from a LiDAR point cloud. Red Circles are the Diameters at 4.5ft (DBH)

This image could be projected for students to see how a measured plot can be recorded from a 3D Point Cloud

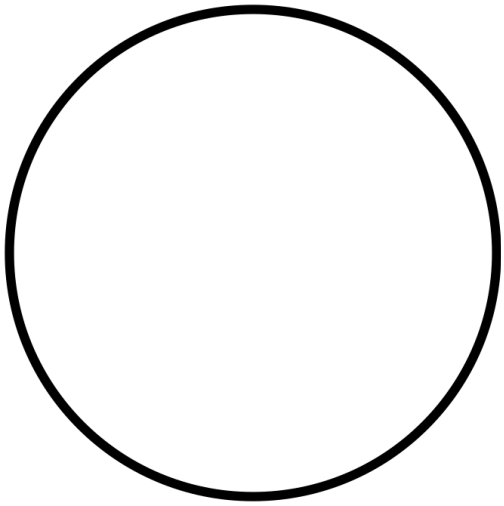
Exit Ticket:

Name _____

For the sample plot below, draw a sample with a high basal area but a low tree-per-acre.



For the sample plot below, draw a sample with a **low** basal area, but a high tree-per-acre.



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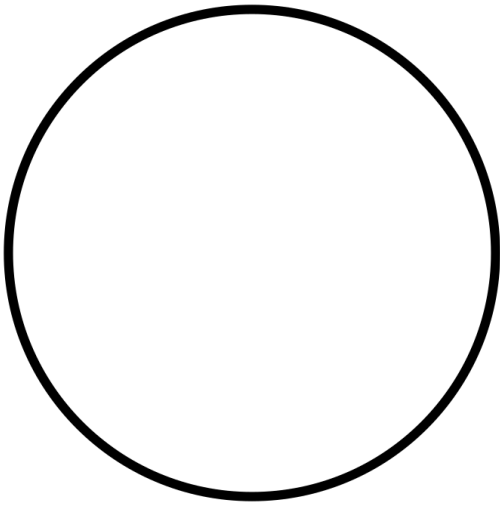

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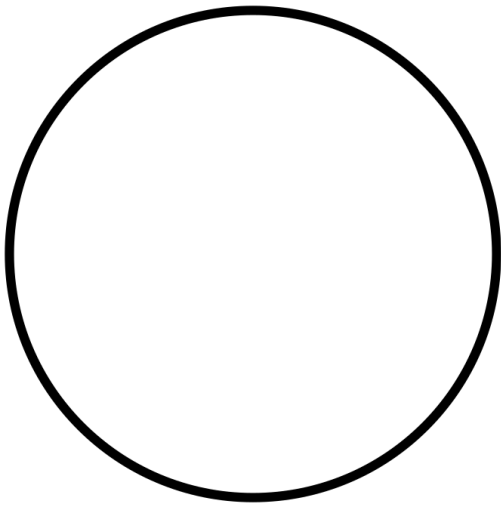

Data-Gathering Activity

Students can gain additional insight by collecting data.
After students have completed the Desmos and Part 1 of the activity (but before part 2), there is an opportunity to take the students “into the field” (outside) for a data-gathering experience.

Materials:

- Diameter tape measure (1 per student group) These can be purchased or made, or students can measure the circumference of the trees in inches and find the diameter for each tree.
- Wooden stakes (1 per plot to be measured)
- Inflexible string (for marking plot radius and for finding the measurement height of 4.5ft)
- Ribbon/sidewalk chalk for marking trees that have been measured

Scout an area near your school where you have a stand of trees in at least a ~37 foot radius. If there is limited space available, industry also uses $^{1}/_{20}$-acre plots for sampling (18.62-foot radius). Mark the center of each plot with a wooden stake. Having cords for the plot radius already on the data-gathering site can save some time. This can be done ahead of time.

Students, in their groups, will measure trees in their plot with the diameter tape and record the diameter at breast height (DBH) of each tree in the circle. Students will count a tree as ‘in the circle’ by attaching their radius string to the stake and determining if the center of the tree is closer to the stake than the end of the string.

Suggest that students work in wedges, clearly marking each tree with chalk or ribbon as they record the DBH of each tree. Once data is collected, it can be added to the student spreadsheet as “Plot 8” on a separate sheet.

The next page is a data sheet for the exercise. Print a copy for each group.

Tree Sampling Data Sheet

Which site are you measuring? A B C D E F G H

Names of team members _____

Directions: Using the cord from the site center, identify the trees that should be included in your sample. Use the diameter tape to measure each tree in your sample. The correct side of the tape has the word DIAMETER.
When a tree has been measured, mark it with chalk so that it is not duplicated in the sample data.
Record the diameter of each tree in the table below.

Tree	Diameter (inches)	Tree	Diameter (inches)
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

NOTE: If you have more than 20 trees in your sample, keep going on the back of the page.

Describe your sample. For example, " only a few trees, but they were large"; "a lot of trees but most were small. One was large.", etc.