Connecting Industry to Mathematics Instruction
NSF ATE Award # 1954291

Solutions: Tree Conservation in New Developments

Student Activity Sheet

Part 1

Raleigh is known as the "City of Oaks" due to the widespread tree canopy coverage throughout the city and surrounding areas. With the increase in development and mass grading, municipalities have required that various types of tree surveys be conducted prior to mass grading or site alterations that result in the changing of the natural landscape. One method to determine the average tree density throughout a tree conservation area (TCA) is the use of calculating the basal density and trees per acre (TPA). TCA's can include stream buffer areas which are a specific horizontal offset distance from a creek/stream centerline. The vegetation within it cannot be altered without specific permitting to maintain natural vegetation and canopy coverage to benefit water quality and wildlife/reptile habitat. Figure 1 (below) is an example of a topographic survey where a 60-acre parcel of land is going to be purchased by a development group to build housing. The brown lines reflect the contours of the earth and slope towards the low-lying areas such as the creeks or pond. The building contractors will grade the land with construction equipment in order to make specific areas flat for housing and roadways. Areas such as TCA's and stream buffers typically are not altered and serve as an important part of our natural ecosystem.

Figure 1: Digital Survey Map

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Another type of TCA area is that which is chosen by the client or site developer to preserve a specific amount of acreage on a site to meet requirements recommended by municipal regulations. These sporadic TCA areas ensure that trees will be part of the future layout to assist with aesthetics and environmental benefits and keep trees a part of our Raleigh skyline. These areas may not be stream buffers, but could be a buffer between the adjacent properties or undevelopable areas. Often greenways, playgrounds, or dog areas can be incorporated in additional TCA areas.

You need to know about the tree coverage in this entire 60-acre site. What do we mean by "tree coverage"? How could you measure this? Is it reasonable to survey ALL the trees? Is this a practical strategy? Why or why not?
Students may discuss coverage by the canopy, or simply the number of trees on a site. Measuring all the trees depends on the size of the site; 5 acres might be achievable, 500 acres would be very expensive and time-consuming.

Typically when a survey of this nature is carried out, a plot center is marked with a pin flag and a flexible distance tape measure is used to physically define the limits of the plot boundary. Once the horizontal plot boundary is defined, then the trees within the plot can be tallied (taking note of the tree diameter and species), and then marked with flagging or paint so they will not be recorded again. This procedure can be replicated across a site to determine a specific sample dataset that is representative of the entire site.

How many square feet are in one acre? Determine the plot radius, and square feet within a $^1/_{10}$-acre plot.
43560 square feet divided by 10 is 4356 square feet. Set this equal to pi*r^2 and solve to get 37.24 feet

Below is an overhead view of a plot of trees. Which trees would you consider to be inside the circle? What criteria did you use to determine which trees to include in your sample?

Part 2

Utilizing *basal area density* calculations, we can estimate the coverage of standing timber on a piece of land through statistical sampling. *Basal area* is used in forestry as a measure of how "occupied" with trees a forest site is. It would not be efficient to inventory every tree on a site as the time and resources to complete this would be exhausting and expensive.

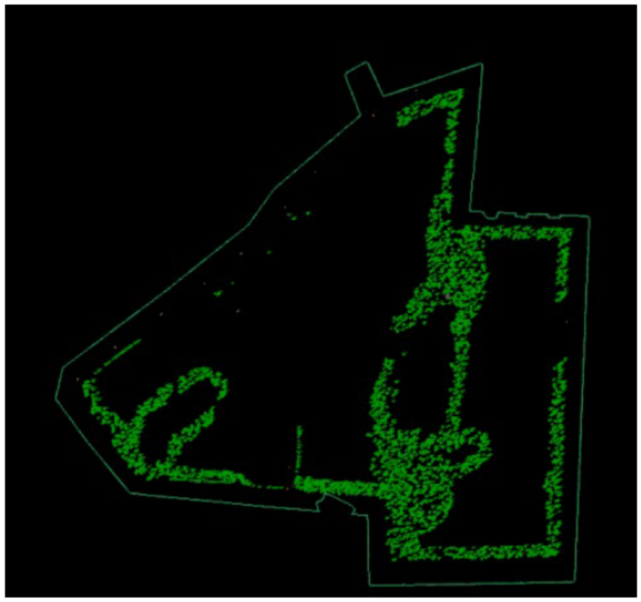


Figure 2: Tree Survey Points shown as the Green dots within the 60 acre polygon boundary
(same site as shown in Figure 1)

How would you decide how many plots to take? How would you select their locations? What should a plot look like?

Students may offer various plans. The industry standard is to survey 10-20% of the site. If the diversity of tree ages and species is low, 10% will be sufficient. Circular plots are the most manageable. Locating plots could be random or structured in some way to act as a microcosm of the site. This is a good place to touch on the discussion of sampling strategies.

What do the abbreviations "D_{BH}" and "BA" mean in the context of forestry?

D_{BH} is "diameter at breast height", or 4.5 feet above the average ground level. BA stands for *basal area*, the cross-sectional area of a tree trunk at this height.

The units used for D_{BH} are inches but BA is in square feet. $BA = 0.005454(D_{BH})^2$ The coefficient 0.005454 is known as the *Forester's constant*. What are its units of measure? Describe where it comes from.

To convert a diameter in inches to an area in square feet, the forester's constant has *units* of $^{ft}/_{in}$.
The conversion is outlined in the spreadsheet with answers.

♁ The spreadsheet provided has data collected from 7 sample plots on the 60-acre site. Each sample plot is $^1/_{10}$ of an acre. What are your impressions of the data for each plot?

Plot 1: 8 trees with radii ranging from 2 inches to 11.5 inches. Fairly sparse with mostly medium-sized trees
Plot 2: 24 trees with radii ranging from 2 inches to 13.5 inches, but only one large tree. More densely populated with mostly small to medium-sized trees
Plot 3: 24 trees with radii ranging from 2.9 inches to 15.8 inches, with a few larger trees. Average tree size is larger than on Plot 2
Plot 4: 33 trees with radii ranging from 3 inches to 16 inches, with a few larger trees. Average tree size is larger than on Plot 2
Plot 5: 12 trees with radii ranging from 2 inches to 9.9 inches. About half small trees and half medium-sized trees
Plot 6: 13 trees with radii ranging from 2.3 inches to 9.2 inches, with only one larger tree. Mostly small to medium-sized trees
Plot 7: 13 trees with radii ranging from 1.8 inches to 8.8 inches. Mostly small to medium-sized trees

You will be calculating tree diameters, basal areas, basal area per acre, and trees per acre in the spreadsheet.
Use the formula $\boldsymbol{BA = 0.005454(D_{BH})^2}$ to calculate Basal Area. Answers in spreadsheet

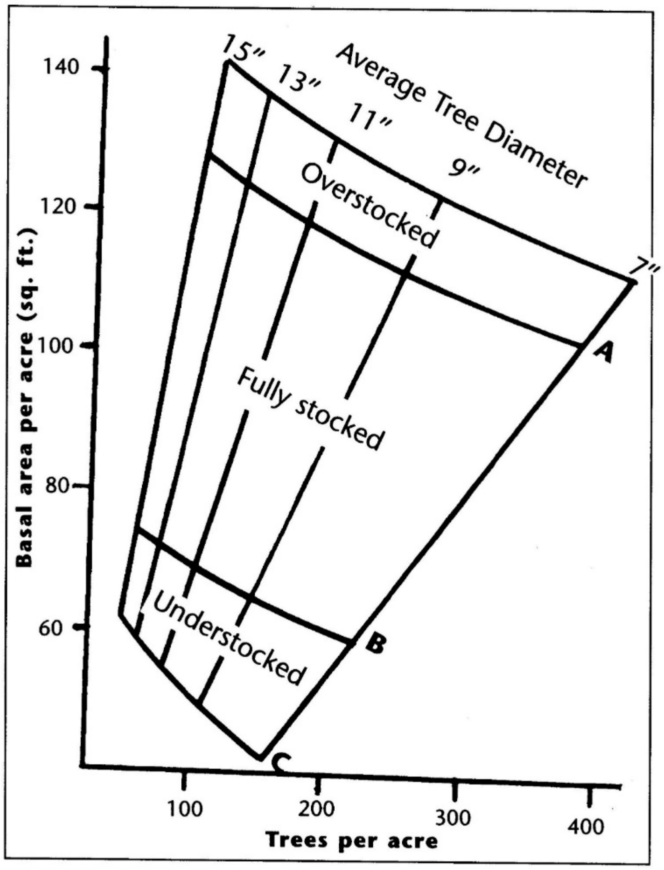
Discuss:

From your spreadsheet, find the average number of trees per acre (TPA) for all the samples AND create a data representation that shows how each plot's TPA differs from the average for the whole site. What do you notice about this information?
Answers in spreadsheet

What factors do you think could influence these differences?
Students will likely suggest that more trees on a plot would leave less space for trees to go larger. Ask if the data support that conjecture.

What relationship (if any) do you see between the basal area per acre and the number of trees? Create a representation showing the relationship in your spreadsheet.
Basal area is related to the number of trees, but not entirely. The same number of large trees will give a greater BA than a stand with the same number of small trees.

According to the chart below, would we classify this site as Understocked, Fully Stocked, or Overstocked? Explain your choice and describe how you would manage trees on this site based on this classification.



From the samples, the site is predicted to have an average *basal area* per acre of 174.6 sq.ft., and an average of 181.4 trees per acre. This point is off the top of the chart at the right, suggesting that the sampled area is overstocked, suggesting that some harvesting could be done while remaining within compliance with standards.

The Exit ticket asks students to apply the vocabulary they have learned. A plot with a high *basal area* but a low number of trees per acre should include a few large trees, while a plot with a low *basal area* and a high number of trees per acre should have several small trees.