

How Much Wood?

Nº. 81

SENIOR
Math



LESSON SUMMARY

Students will learn how to conduct a forest resource inventory and practice taking tree measurements in order to calculate the quantity and financial value of wood in a forested area.



Activity Information

Grade: Senior

Estimated Duration: 1 hour

Materials:

- Copies of Calculating Lumber Volume on a Fixed Area Plot and Merchantable Volume Table (one per pair of students)
- Metric measuring tape
- Metric ruler
- Ribbon
- String
- Masking tape
- Flagging tape or coloured yarn

Setting: Outdoor

Key Vocabulary: Merchantable, merchantable height, timber cruising, basal area, sustainable yield, strip cruise, diameter at breast height (DBH), point sampling

Curriculum Links

Math: Grade 12

C1.2 Estimate lengths, distances, and capacities in metric units and in imperial units by applying personal referents (e.g. the width of a finger is approximately 1 cm; the length of a piece of standard loose-leaf paper is about 1 ft; the capacity of a pop bottle is 2 L).

C1.3 Estimate quantities (e.g. bricks in a pile, time to complete a job, people in a crowd), and describe the strategies used.

C2.5 Solve problems involving the volumes and surface areas of rectangular prisms, triangular prisms, cylinders, and related composite figures in situations arising from real world applications.

Learning Goals

1. Students will learn to calculate the volume of wood in a stand and determine its fiscal value
2. Students will become familiar with common sampling methods used in forestry

Lesson Plan adapted from Morrison, G.R. A Forestry Manual. For Ontario Secondary School Teachers. Willowdale: Ontario Forestry Association, 1983.

Teacher Background

Imagine you have inherited a small piece of land that includes a wooded area. As you look over your new property, you wonder just how much wood is in your forest. How could you find the answer? You could count the trees. But how much wood is in a tree? And are all the trees the same size? If you harvested the trees to use their wood, how long would it take before you could grow the same amount of wood to replace it? These are some of the questions that foresters must answer when developing a forest management plan. It is essential to know how to measure the average height and age of a stand*, tree diameter and density in order to properly manage a forest. The answers to these questions provide a basic forest inventory and allow calculations of its economic value. This information is important in assessing how much logging can be carried out and how much timber can be produced.

The Ministry of Natural Resources and Forestry (MNRF) inventories all of the Crown land in Ontario on which forest operations take place. The inventories are reviewed every 20 years to produce an up-to-date estimate. In addition to measuring the amount of wood in a stand, foresters also determine the depth and texture of the soil, types of vegetation, moisture content, the volume of given species of trees and tree height. This ecological information is used, along with other factors such as site accessibility, to help determine the management strategy for each area.

In practice, a forest sector employee (i.e. a Forestry Technician) does not need to measure every tree. He or she may instead take a sample that represents the larger area. The standard technique for estimating the volume of wood in standing forests is called timber cruising and consists of measuring representative sample areas. Measurements collected include the diameter, height and age of sufficiently large trees (see Sample Methods section for more detail). The aim is to calculate how much can be cut to produce a sustainable yield of wood. A sustainable yield is achieved when the amount of wood harvested or lost to fire, insects, or disease is equal to the amount of wood that grows back, either naturally or through replanting, over a specified period of time.

Trees that can be sold for profit are known as merchantable timber. Measuring merchantable height can give a more accurate estimate of the volume of wood available. Merchantable height is usually determined by measuring from the stump to a specified top diameter. On conifers, the merchantable height is often hard to locate and takes much practice. In many hardwoods, the merchantable height is determined by a point of sudden branching (where the main stem begins to fork).

*A stand refers to a community of trees that possess sufficient uniformity in composition, age, arrangement or condition that are distinguishable from an adjoining area. Forests are composed of a series of stands.

Sampling Methods:

Fixed Area Plots:

There are two basic methods used for collecting data in fixed area plots*— *strip cruising* and *plot cruising*. In strip cruising, a centre line is plotted for a measured distance through a stand of trees and the diameters at breast height (DBH) of all trees within a certain distance of the centre line are tallied. Breast height is standardized at 1.3 m above the ground which makes it convenient for quick measurements, and it avoids measuring the broader base of the trunk.

In a plot cruise, the DBH of all the trees in fixed sample plots are measured. The plots may be regularly spaced along a cruise line or taken at random. The diameter measurements are converted to wood volumes using tables. The volume of wood per unit area sampled with these methods is then applied to the whole area to obtain an estimated total volume.

Sampling with Wedge Prisms (variable area plot)

This technique involves the use of a thin wedge of glass that bends light rays. When a tree is viewed both through and over the prism at the same time, a split image is obtained. The further away a tree is, the more its split image is separated. The sample is taken from a fixed point, where the prism is rotated through a 360° sweep. All trees whose prism image overlaps their real image on this sweep are counted. If there is a space between the two images, the tree is too far away for sampling and is not counted (see Figure 1). The number of trees counted from a point sample is used to calculate the total volume of wood in the area of the sweep. Point sampling is fast, simple, and relatively inexpensive.

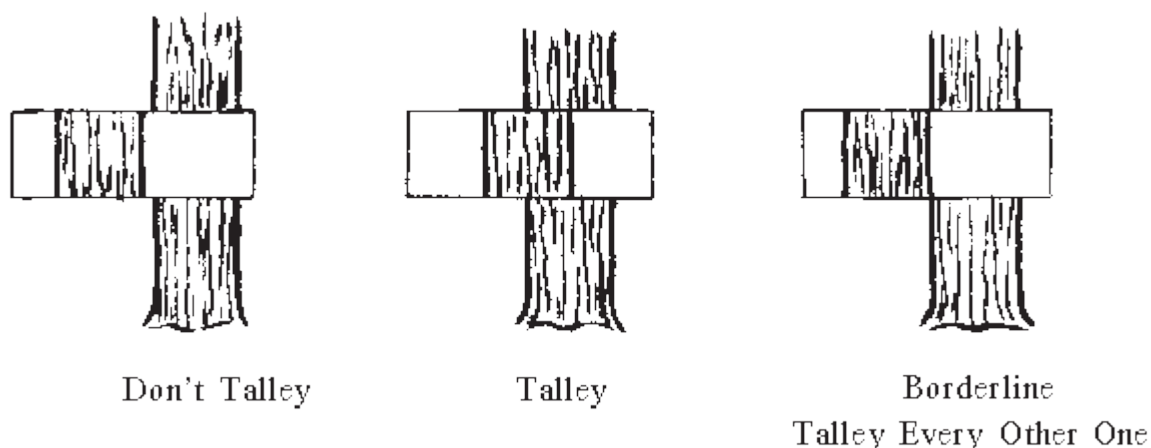


Figure 1: Determining if a tree is in or out using a prism. (Citation: University of Georgia, 1996)

*A fixed area plot is a given amount of land that is used to act as a sample for a much larger area and population of trees.

Satellite Imagery

In this technique, estimates of wood volume are calculated by computer from sample images transmitted by satellite. This technique is not as accurate as cruising and is used infrequently.

An important measure used to describe the amount of wood in a forest is basal area per hectare (m^2/ha). Basal area is the sum of the cross-sectional areas, taken at breast height, of all the trees in a hectare (the cross-sectional area of a tree is equal to) (see Figure 2).

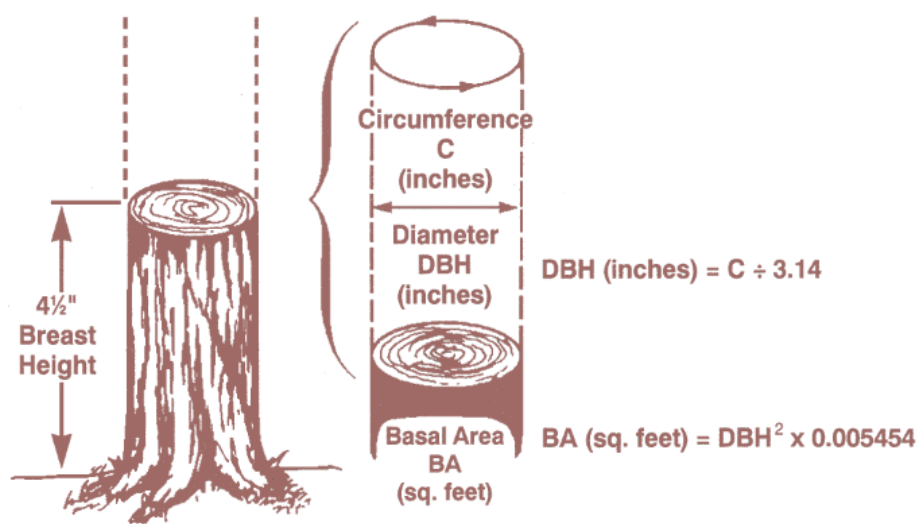


Figure 2: Determining if a tree is in or out using a prism. (Citation: University of Georgia, 1996)

A Southern Ontario tolerant hardwood forest in optimum growing condition might have a basal area of 20 m^2 per ha. At values above this, it is considered desirable to harvest some of the trees to bring the value down to 20 m^2 and stimulate new growth.

Teacher Preparation:

1. Students can practise taking measurements on trees outside the school or practise the techniques on models made from sonotubes, large appliance cardboard boxes flattened and shaped into cylinders, or garbage cans on chairs. If you are working with several classes, they can be combined for a student scavenger hunt to find materials and build a “forest” of cardboard trunks in a convenient school location.

2. Make your own diameter tapes, which do not record circumference but are marked off to record diameter. Take a plain ribbon and mark off lines every 3.14 cm. Number the lines in sequence from the end as 1 cm, 2cm, 3cm, 4 cm etc. Alternatively, you can use metric tape and put masking tape around it every 3.14 cm, labelling the tapes as 1 cm, 2 cm, 3 cm etc. Alternatively, you can also measure the circumference in centimetres and divide the circumference by 3.14 to find the diameter.
3. Make copies of Calculating Lumber Volume on a Fixed Area Plot (one per student).

Activity

Step 1: Ask the students:

- How can one measure a tree? What characteristics would you be interested in quantifying?
- Of what importance would it be to know how much wood there is in a particular woodlot or in the entire province of Ontario?
- What benefit is there in knowing how much and what kind of wood is in the stand now and potentially in the future?

Have students think of ways to measure trees, making sure their methods would allow for a statistically “fair” sample. Help them think through each step of their method and encourage them to predict its effectiveness. Assist them in using their methods to measure trees on the school grounds. Introduce ideas from the background information as required. Encourage them to draw conclusions about the value of measuring trees.

Step 2: Have students use the following methods for measuring trees:

- Take the class to a forest, a woodlot, or wooded area and pair off the students. Provide each pair with a copy of Calculating Lumber Volume on a Fixed Area Plot. Take tree identification tools with you if possible.
- Establish a plot size of 1/100th of a hectare (10 X 10 meters). Use a measuring tape and string to delineate the area.
- Have students measure the DBH of all the trees in the 10 x 10m plot and record the information on the chart provided. Students can measure DBH by using a metre stick to determine where on their body the standard diameter at breast height point is located. Then use the diameter tape to measure the DBH of several trees in the plot. Be sure the tape does not slip down. Have them record their results for each trunk.
- Have students measure the merchantable height of all the trees in the 10 x 10m plot and record the information on the chart. Students can measure merchantable height using the following method:

- **Student A** stands at the base of the tree that is to be measured. **Student B** paces off just beyond the estimated height of the tree.
- **Student B** holds his or her pencil at arm's length, lining up the tip of the pencil with Student A's head and using their thumb to mark the height of **Student A** on their pencil.
- **Student B** then uses the distance measured on the pencil to move up the tree until it reaches the point of sudden branching (for deciduous trees) or an estimated diameter of approximately 10 cm (for evergreen trees).
- **Student B** counts the number of times the pencil is moved upwards.
- To determine the height of the tree, the number of times the pencil was moved upwards should be multiplied by **Student A's** height in meters.
- Have students repeat merchantable height measurements for two or three other trees, and then compare results with others in the class.
- Discuss the following: What is the average height of the trees measured? Did your measurements equal those of others in your class? What are the possible sources of error? Why does a forester measure the merchantable height and not the total height of the tree?

Step 3: Have students use the Volume Table to calculate the volume of trees measured (e.g. a 10 m high tree with a DBH of 48 cm has a volume of 1.10 m³). Calculate the total volume of the trees in your plot.

- Take the class to a forest, a woodlot, or wooded area and pair off the students. Provide each pair with a copy of Calculating Lumber Volume on a Fixed Area Plot. Take tree identification tools with you if possible.

Step 4: Add together the volumes of all the trees measured to get the total volume of wood. Multiply by 100 to get the volume per ha.

Extension: If you do not have access to a wedge prism you can still assess basal area (BA) by using the rule of thumb. As with the wedge prism method, the sample is taken from a fixed point, from which a 360° sweep is taken. The arm is held extended with the thumb upright, and all tree trunks that are not completely "obscured" by the thumb are counted. Have each student calculate their own basal area factor based on the length of their arm and breadth of their thumb, as follows:

1. Calculate a by determining the distance from eye to thumb in cm
2. Calculate b by determining the breadth of the thumb in mm
3. Calculate k with the following formula: $k = 2a/b$
4. Now, use k to determine the Basal area factor (BAF): $BAF = 10\,000/k^2$
5. Then to get basal area per hectare (ba/ha), count number of "in" trees and multiply by your BAF.

Evaluation

Present your students with the following scenario:

A lumber company has offered to pay the class \$20/m³ for all the wood on the school grounds (or nearby park or woodlot). What would they need to know to estimate how much money the wood is worth in total? How could they calculate the volume of wood on the school grounds? What measurements would they need to take (e.g. the area of the school grounds, the height and DBH of all trees)? Have students devise ways to obtain a rough estimate of the volume of wood and then multiply the volume by \$20 to determine how much money they would make.

Calculating Lumber Volume on a Fixed Area Plot

Crew Names: _____ Date of Cruise: _____

1. Record the name of all tree species and the number of trees in a 10 X 10m area (1/100th ha).
2. Measure the DBH and merchantable height of each of the trees. Then, use the volume conversion table and record the volume of trees measured (e.g. a 10m tree with a DBH of 48cm has a volume of 1.10m³).
3. Add together the volumes of all the trees measured to calculate the total volume of wood in the plot. Multiply by 100 to get the volume/ha.

Timber Tally

Tree Number	Tree Species	Tree Diameter in cm (dbh)	Merchantable height in meters	Volume in cubic meters
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
Total Lumber Volume in plot:				

Volume Table (m³)

Merchantable Height in Meters

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Diameter in Centimeter	24	0.03	0.06	0.10	0.13	0.17	0.19	0.22	0.24	0.26	0.28	0.30	0.31	0.32	0.33	0.33	0.34	0.34	0.34
	26	0.04	0.08	0.12	0.16	0.20	0.23	0.26	0.29	0.31	0.34	0.36	0.37	0.39	0.40	0.40	0.41	0.41	0.41
	28	0.05	0.10	0.15	0.19	0.23	0.27	0.31	0.34	0.37	0.39	0.42	0.44	0.45	0.47	0.48	0.49	0.49	0.50
	30	0.06	0.12	0.17	0.22	0.27	0.31	0.35	0.39	0.42	0.46	0.48	0.51	0.53	0.55	0.56	0.57	0.58	0.59
	32	0.08	0.14	0.20	0.26	0.31	0.36	0.40	0.45	0.48	0.52	0.55	0.58	0.61	0.63	0.65	0.66	0.67	0.68
	34	0.09	0.16	0.23	0.29	0.35	0.40	0.46	0.50	0.55	0.59	0.63	0.66	0.69	0.72	0.74	0.76	0.77	0.79
	36	0.11	0.18	0.26	0.33	0.39	0.45	0.51	0.57	0.62	0.66	0.71	0.74	0.78	0.81	0.84	0.86	0.88	0.90
	38	0.12	0.21	0.29	0.36	0.44	0.51	0.57	0.63	0.69	0.74	0.79	0.83	0.87	0.91	0.94	0.97	0.99	1.01
	40	0.14	0.23	0.32	0.40	0.48	0.56	0.63	0.70	0.76	0.82	0.88	0.93	0.97	1.01	1.05	1.08	1.11	1.14
	42	0.16	0.26	0.35	0.45	0.53	0.62	0.70	0.77	0.84	0.91	0.97	1.02	1.08	1.12	1.17	1.20	1.24	1.27
	44	0.17	0.28	0.39	0.49	0.59	0.68	0.76	0.85	0.92	1.00	1.06	1.13	1.18	1.24	1.29	1.33	1.37	1.40
	46	0.19	0.31	0.43	0.54	0.64	0.74	0.83	0.92	1.01	1.09	1.16	1.23	1.30	1.36	1.41	1.46	1.51	1.55
	48	0.21	0.34	0.46	0.58	0.70	0.80	0.91	1.00	1.10	1.18	1.27	1.34	1.42	1.48	1.54	1.60	1.65	1.70
	50	0.23	0.37	0.50	0.63	0.75	0.87	0.98	1.09	1.19	1.28	1.38	1.46	1.54	1.61	1.68	1.75	1.80	1.86
52	0.25	0.40	0.54	0.68	0.81	0.94	1.06	1.18	1.29	1.39	1.49	1.58	1.67	1.75	1.83	1.90	1.96	2.02	
54	0.28	0.43	0.59	0.73	0.88	1.01	1.14	1.27	1.38	1.50	1.60	1.71	1.80	1.89	1.97	2.05	2.12	2.19	
56	0.30	0.47	0.63	0.79	0.94	1.09	1.23	1.36	1.49	1.61	1.73	1.84	1.94	2.04	2.13	2.21	2.29	2.37	
58	0.32	0.50	0.68	0.84	1.01	1.16	1.31	1.46	1.59	1.73	1.85	1.97	2.08	2.19	2.29	2.38	2.47	2.55	