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ABSTRACT

This bulletin deals with forest management and provides an overview of forestry for the non-professional. The bulletin is divided into six sections: (1) What Is Forestry Management?; (2) How Is the Forest Measured?; (3) What Is Forest Protection?; (4) How Is the Forest Harvested?; (5) What Is Forest Regeneration?; and (6) What Is Forest Improvement? Section I introduces the various practices and importance of forest management. Section II is concerned with measuring land, measuring individual trees, and measuring forest stands. Forest fires, insects, diseases, and animals are covered in Section III. Section IV deals with the harvesting process and silvicultural methods of harvesting. Natural regeneration and artificial regeneration are covered in Section V. Section VI deals with forest improvement and includes the topics of non-commercial thinnings, commercial thinnings, pruning, and control of undesirable species. All of the sections include activity-oriented activities which reinforce the topic and develop skills useful in forest management. Illustrations, maps, figures, photographs, and tables are included throughout the bulletin. Suggested readings are also included. (TK)

Agricultural Extension Service University of Minnesota 4-H Bulletin No. 87 1974

FOREST MANAGEMENT

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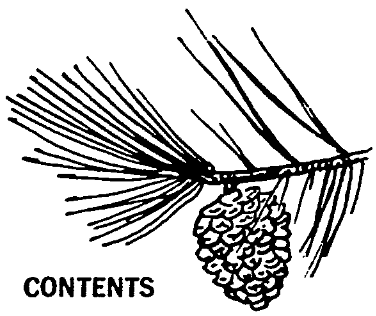
MEMBER'S MANUAL



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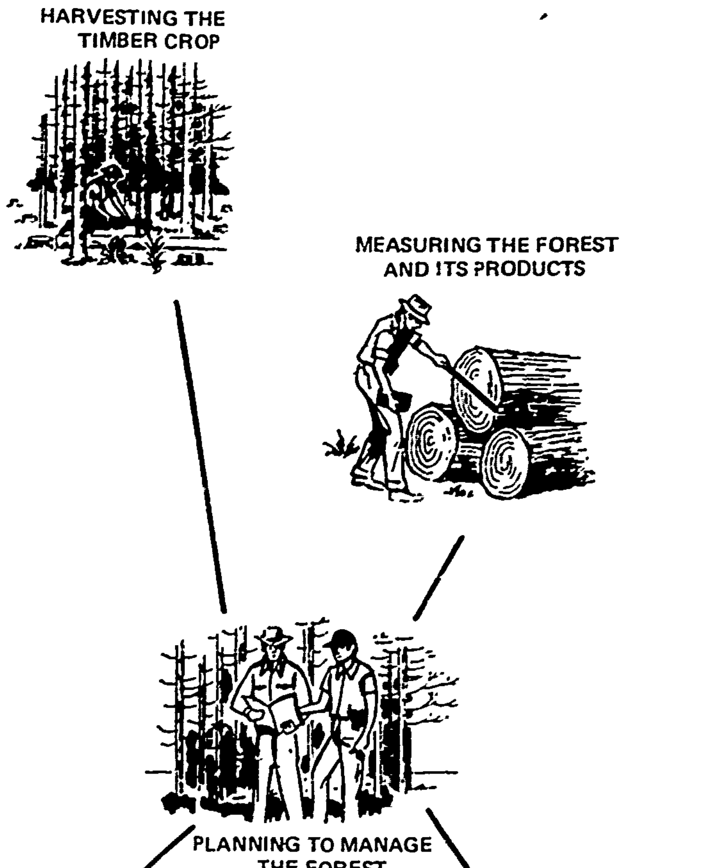
I. What is Forest Management?

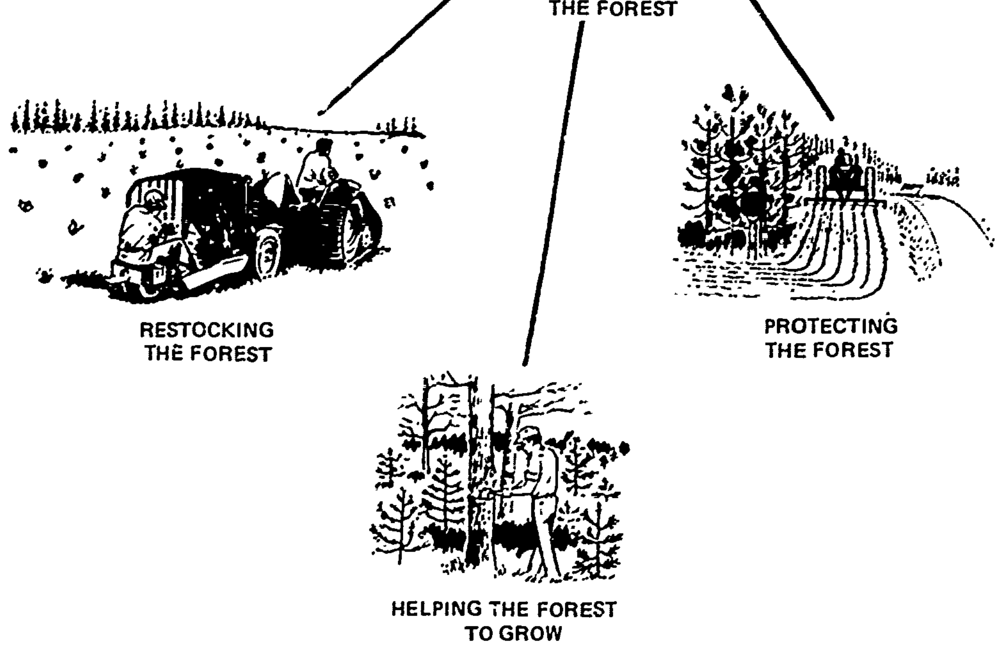
Forest management consists of people working with groups of trees or forest stands for abundant and best forest products now and for future generations. Management includes the measurement of individual trees and forest stands, protection, harvesting, regeneration, and improvement practices.

Good management considers both the economic status of the community and the social needs of the people the forest serves. These needs might include the production of timber, recreation, water, and wildlife. Sometimes these interests are in direct conflict with one another; for example, some cutting methods used to harvest timber favor the establishment of excellent wildlife habitat, yet the harvested areas might not appear pleasing to the wilderness advocate.

Each forest use can be economically beneficial to the community, but managing forest trees for timber production is traditionally considered most profitable. Timber volume can be valued in dollars and cents, but a picnic site near a forest lake has only recreational, not direct monetary value. However, managing forest trees for timber production is only one of many parts of the total forest management picture.

With these examples let's consider the various practices of managing forest trees to gain an insight into the overall practice of forest management. Remember that ideal forest management is the result of a detailed knowledge of management practices benefiting each forest use and total awareness of interactions between forest uses.





II. How is the Forest Measured?

An organized system of land measurement is a basic requirement for any phase of forest management whether it is evaluation for timber, water, recreation, wildlife, or forage. Forest management requires a system of land measurement and an organized way of measuring and comparing individual trees and forest stands. First, let us examine the way land is measured.

MEASURING LAND

The United States basic unit of land measurement is the foot (12 inches). We speak of a man being 6 feet tall; it is 340 feet from home plate to the right field fence; and a mile is 5,280 feet long. In Europe, the metric system is used with 1 meter equaling 100 centimeters or slightly longer than 3 feet. The United States may adopt the metric system soon because of its convenience and world-wide use.

In measuring the earth's surface, we use the square foot, which is 1 foot of ground, 12 inches on a side. This is a very small area to man, but a large area to an ant, earthworm, or a beetle. We might think there are not very many things in 1 square foot of earth surface, but imagine the number of blades of grass in 1 square foot of lawn.

A common unit of measurement in any management plan is the acre: 43,560 square feet. We refer to the number of bushels of corn per acre, the number of board feet per acre, or the average number of acres for each man, woman, or child living in the United States or one of its cities. One square acre of land is slightly over 208 feet on each side. A football field is 300 feet long and 150 feet wide, or 45,000 square feet, slightly over an acre in size. Not to a human being, but to smaller animals, an acre is a huge domain. It is not unusual to have a population of 400,000 to 500,000 earthworms in 1 acre.

Consider now, measuring the earth's surface, the terms used to describe where we are located, and the tools and the methods used in measuring and describing land areas.

Land is measured by surveying. Surveying means measuring and locating points, lines, angles, and elevations on and within the surface of the earth or on bodies of water.

Early in United States history, land was measured in "metes and bounds." This was convenient where boundary lines of private property consisted primarily of natural features such as tidewater shorelines, roads, fences, trees, and stones. Since these natural features could be destroyed or changed, many errors and arguments occurred in the description of boundary or property lines.

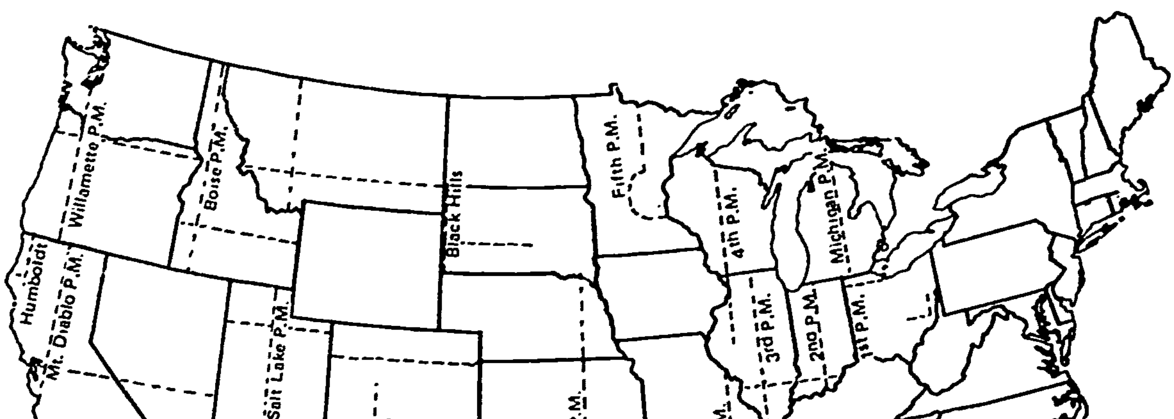


Figure 1.

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An organized system of describing the land using square-mile sections was started by the Continental Congress in 1785. This system became known as the "Cadastral Survey" and is the official system of land measurement. This rectangular land survey method is found in 31 states, primarily west of the original thirteen colonies.

West of Pennsylvania, initial surveying points were chosen at irregular locations extending from the east to the west. From these initial points a base line, running east and west, and a principal meridian, running north and south, were established (figure 1). Lines were then run at 6-mile intervals parallel to the meridian and the base line.

East-west lines were called township lines and numbered consecutively north and south of the base line; for example, Township 1 North (T.1 N.) was the first row above the base line and Township 1 South (T.1 S.) was the first row below the base line.

North-south lines were called range lines and numbered consecutively east and west of the meridian lines; for example, Range 1 East (R.1 E.) is the first row east of the meridian line and Range 1 West (R.1 W.) is the first row to the west of the meridian line (figure 2).

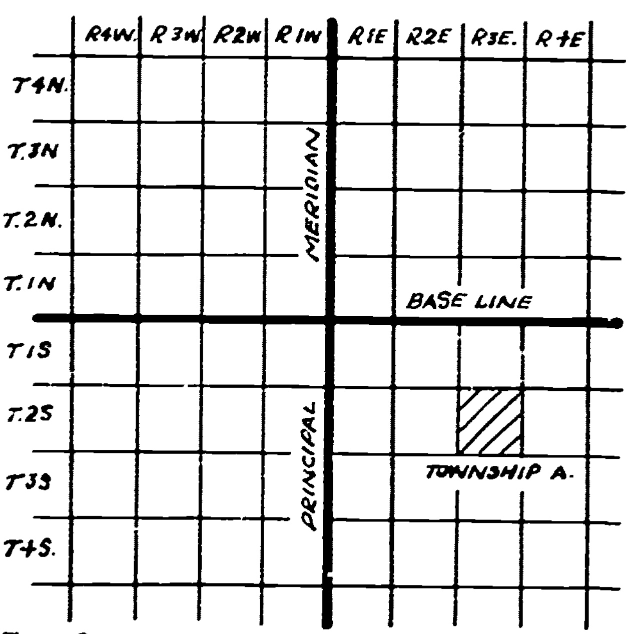


Figure 2.

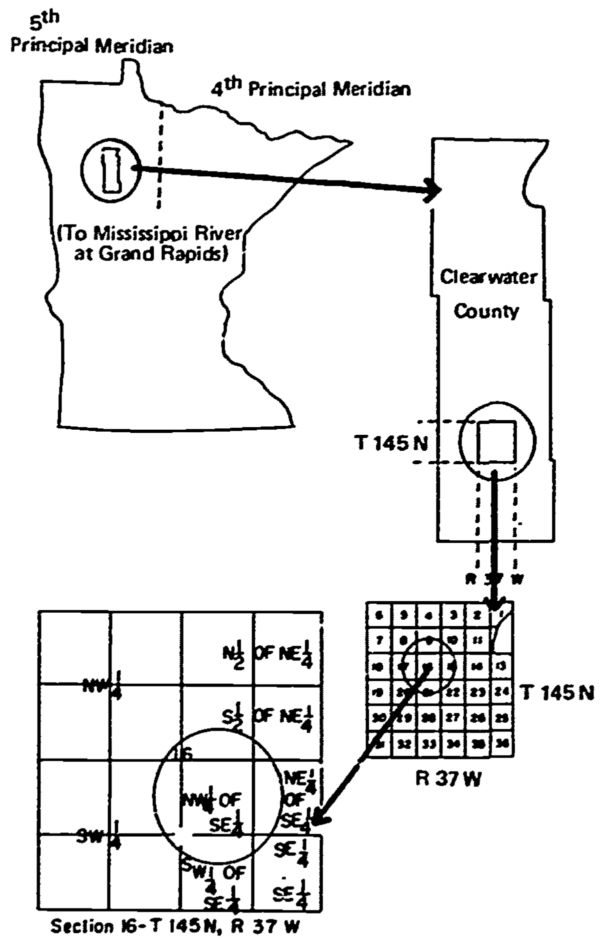


Figure 3.

In Minnesota, township and range lines are measured from the 4th or 5th Principal Meridians. In these illustrations the township and range lines are indicated as they would be numbered from the initial point with Township "A" being T.2 S., R.3 E. This land measurement system conveniently divides the land into smaller subunits or townships.

Each township (6 miles on a side) was divided into 36 sections, each 1 mile square. Each section contains 640 acres. Figure 3 illustrates the division of the township into 36 sections and shows the system of numbering these sections.

Each section was then divided into four parts of 160 acres each. These quarter-sections are further subdivided into quarter-quarter-sections, commonly referred to as "forties," each 1,320 feet on a side.

For legal purposes each tract of land must have a description so that it will not be confused with another tract of land. This legal description has been designated by the original land survey and is on record in that county's courthouse. For example, the description of the tract of land in figure 3 is legally designated as the NW¼, SE¼ of Sec. 16, T.145 N., R.37 W. of the 5th Principal Meridian, Clearwater County, Minnesota.

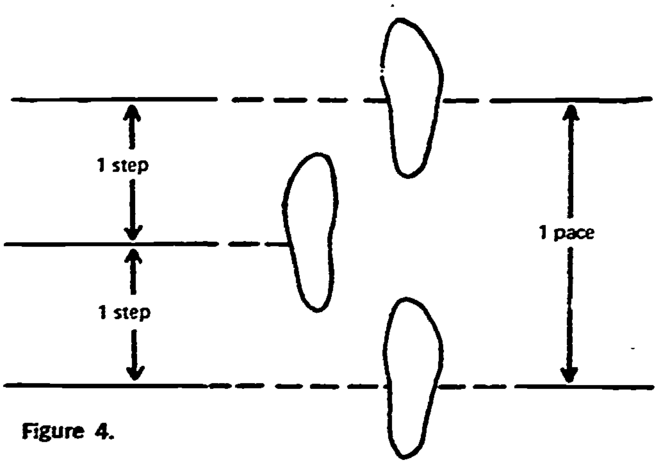


Figure 4.

There are two important and widely used measurement concepts when considering forested tracts of land: distance and direction. Forested areas are often laid out with a tape. but since a tape can be very cumbersome in a wooded area, many forest cruisers measure distance by pacing. Accurate pacing makes it easy to lay out forested areas in which you plan to apply various management practices.

A pace is two steps. Stepping off with your right foot, count a pace each time your right foot strikes the ground (figure 4).

To measure the length of your pace, a 500 foot course can be measured out along a forested road with a tape, marking the beginning and the end. Then pace the distance using your normal stride, keeping count of the number of paces, dividing this number into the length of the measured course to determine the number of feet in each pace. You can now measure distances in the field or woods. A measured course could also be laid out through the woods to get a comparison of pacing where it may be rougher going because of hills, trees, or brush. You can determine the number of acres in an area of a rectangular forest tract of land by multiplying the length of the area by its width and dividing by 43,560.

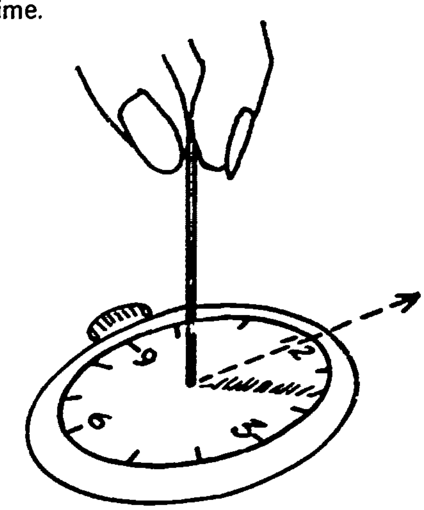
Foresters commonly use the unit of measurement called a chain, which is 66 feet long, because it is easier to simply count the number of chains than to total the paces. There are four rods (each 16½ feet long) in each chain. A mile is 80 chains long (80 x 66 = 5,280 feet). Ten square chains equal 1 acre. It does not matter whether you use chains or feet to measure your forested acreage.

Direction is the other important land measurement concept. Some people have an inherent sense of direction, but most of us must rely on other means to establish where we are going. Many objects used as references are present in nature; for example, the sun moon, and the stars.

Use Your Wristwatch

At noon the sun is always to the south in the northern hemisphere. By using a watch a person can lay out a north-south line any time during the day, providing the sun is shining. Place a small stick or pin standing upright on the center of your watch dial so that it will cast a shadow on the dial (figure 5). Rotate the watch so that the shadow will fall halfway between the hour hand and twelve. When you look from six to twelve on your watch, you will be looking north. It is important to remember that this method is more accurate in the late morning or early afternoon and that this method must always be used with standard time and not daylight saving time.

Figure 5.



Stars

Another method of establishing a north-south line is by using the stars at night. The most accurate way is to use the North Star, Polaris. First, locate the Big Dipper, Ursa Major. Using the pointer star of the Dipper, the star on the top outer edge of the Dipper, the North Star will lie in a northwest direction (figure 6). Next place a long stick in the ground and with a shorter

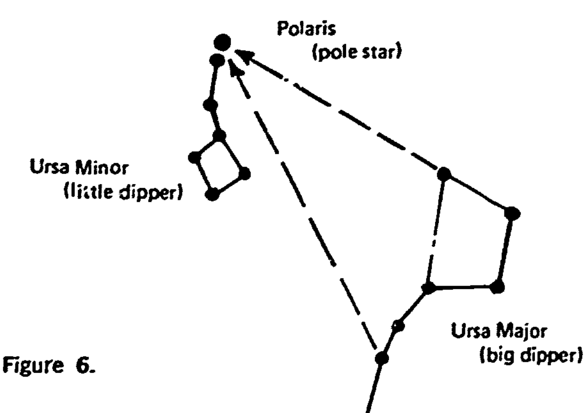


Figure 6.

stick, sight across the top of the two sticks at the North Star as if you were aiming a gun. When the two sticks and the North Star are in line, push the short stick into the ground. By connecting the short and the long stick with an imaginary line, a piece of string, or another stick, you have established a north-south line which serves as a reference point for other directions.

Compass

Clouds, tree cover, or other physical barriers often make it inconvenient or impossible to use these natural methods, so foresters use a compass.

A compass is an instrument used to determine directions on the earth's surface by means of a magnetic needle which swings on a pivot and points to the magnetic North Pole. There are many types of compasses in a varied-price range but a simple directional compass such as the Silva is adequate for most directional referencing (figure 7). Cost of the compass makes little difference. The important thing is to know how to use it.

One of the first things you should know about a compass is which end of the compass needle points north. Usually this is indicated by an arrow or by the letter "N" on the needle. The compass needle points to the magnetic north pole, but your directions are based on true north. The difference between magnetic north and true north is called magnetic declination (figure 8). The declination varies with the locality. In Minnesota

Figure 7.

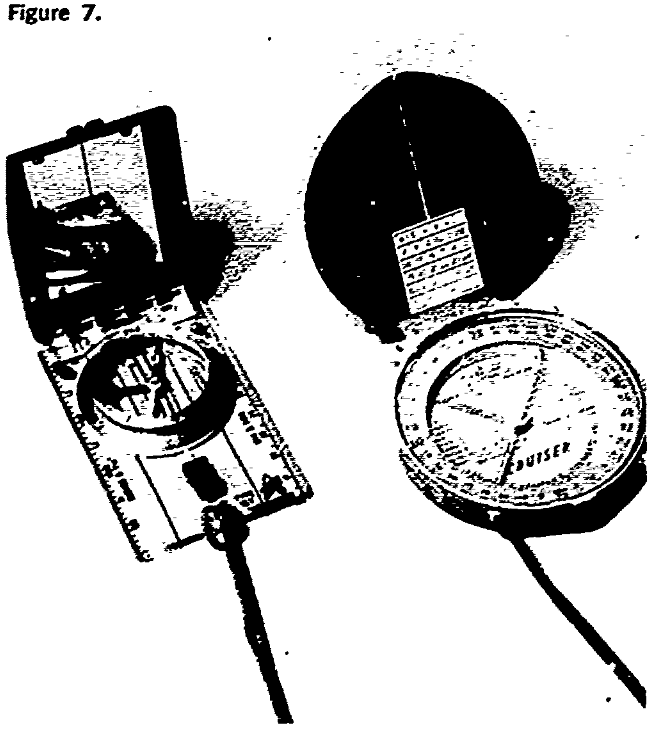


Figure 8.

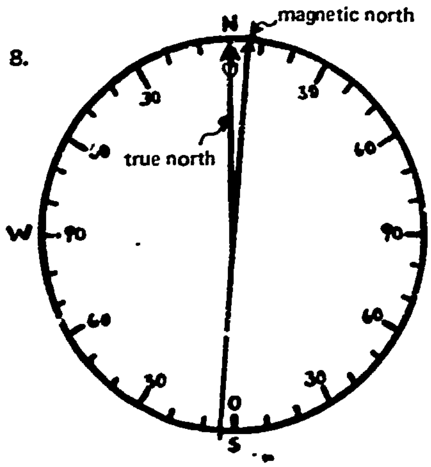
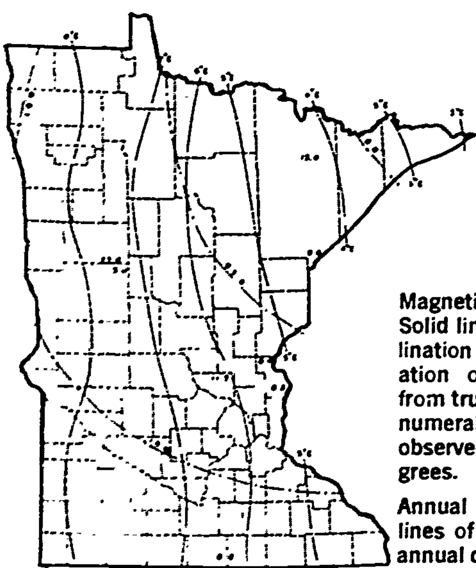


Figure 9.

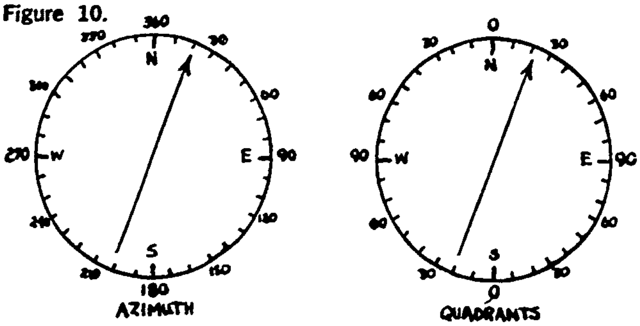


Magnetic declination—Solid lines of equal declination indicate the variation of the compass from true north. Isolated numerals are abnormal observed values in degrees.

Annual change—Broken lines of equal westward annual change are called isoporic lines and the annual rate of motion is given in minutes. (1960 data from the Isogonic Chart of the U.S. published by the U.S.C. & G.S.)

this declination varies from about 2 degrees east of true north to more than 8 degrees east of true north (figure 9). For example, the line for 4 degrees east magnetic declination is very near Duluth, Minnesota. This means that when you are in that vicinity and have a reading of 0 degrees on the compass, the true north line of sight would be 4 degrees west.

Figure 10.



Some compasses are graduated from 0° to 360° clockwise, called azimuths (figure 10) so that north is either 0° (or 360°) and south is 180°. The majority of compasses are graduated by dividing the compass into four quarters, called quadrants (figure 10) and representing northeast, southeast, southwest, and northwest. There are 90° in each quadrant or quarter. In reading a bearing (your location) start with either north or south, depending on which half of the compass you are concerned with. You will end with either east or west. For example, the direction northwest would be read on the compass as north 45° west, or the direction southeast as south 45° east.

Always stand directly behind the compass so you can sight in the direction you wish to go (figure 11). In other words, move your body, not the compass. To lay out a north-south line select a stationary object in the ground, such as a rock. Stand directly behind this object and orient the compass and yourself to face north. Sight across the compass to a distant object which lies directly north. The resulting line between the rock and the distant object is a north-south line.

Figure 11.

With a little practice, determining directions with a compass will become easy as well as accurate. Foresters depend on a pocket compass in their work. By using a compass for direction and pacing for distances, an experienced forester can travel from point to point with confidence and can make fairly accurate maps—representations on paper of an area of the earth's surface.

Maps

There are many types of maps. Perhaps you are most familiar with a highway map showing the routes between towns and cities. There are also planimetric maps which show the general features of the terrain including streams, ridges, trails, roads, etc. A topographic map shows the difference in elevation of the land by using contour lines (lines connecting points of the same elevation).

All maps have a scale that tells the distance relationship of that map to the ground. For example, 1 inch on the map might represent 1 mile on the ground. This would be noted as 1 inch = 1 mile. All maps use symbols to describe the features of the land. The symbols used on the map to represent natural or man-made features on the ground are listed in a legend on the face of the map. For example, a BM on the map indicates a benchmark monument noting the exact elevation of that point on the ground. The map may show and describe in the legend roads, fences, boundary lines, lakes, streams, and other features. With the use of the map scale and the legend symbols the map becomes a useful tool in planning a trip or locating ground position.

A good map assists in planning the management of a forested area. Areas to be planted or harvested, the location of sample plots, or the areas needing cultural treatment may be shown on such maps. The most common map used in forestry work is the cover type map This shows the location of timber types as well as lakes streams, roads, buildings, or other features. The main tree species, sizes, and density are generally written inside the type boundaries. An example of a cover type map follows (figure 12).

Most cover type maps are now made by studying aerial photograph stereoscopic pairs of the area to be mapped (figure 13). Aerial photographs are taken from an airplane flying as nearly as possible in a straight line and at a constant altitude. A camera is vertically mounted to take photos at predetermined time inter-

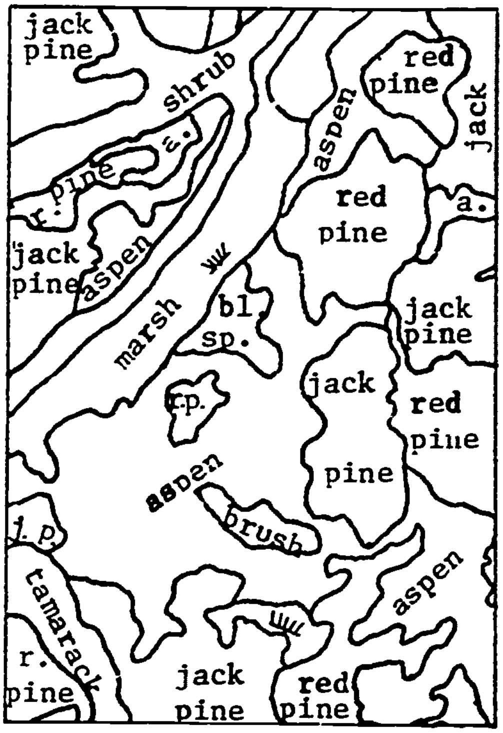


Figure 12.

vals. Use of such photographs and a stereoscope enables the mapper to get a third dimension, depth. An experienced mapper can clearly see and identify the various tree species, their height, and density (spacing).

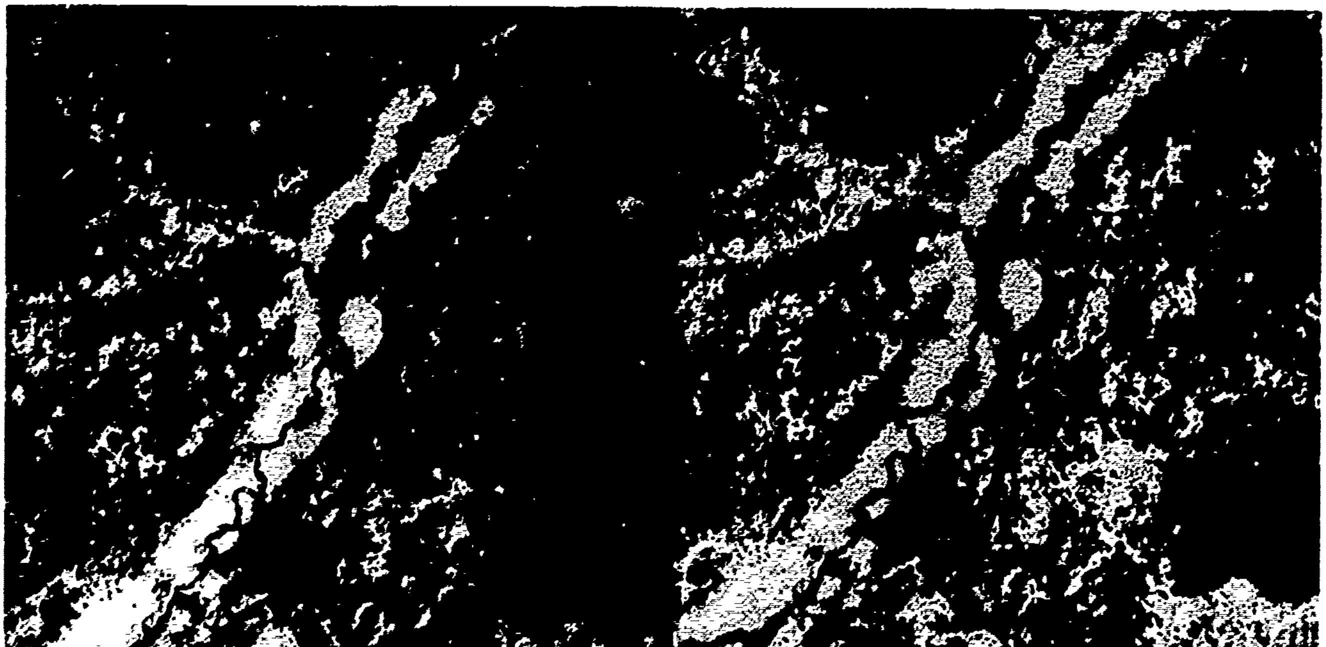
Using aerial photography to make cover type maps is the ultimate method of forest inventory. To determine the forest practices you wish to implement it is necessary to make a forest inventory.

ACTIVITIES

Pacing

Determine the length of your pace by marking off a straight line course with a 100 foot long tape measure on a forest road or in an open field. Begin at one

Figure 13.

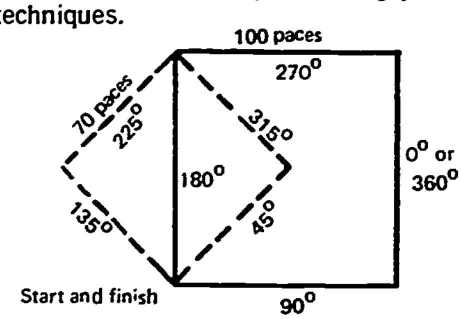


end of the line and walk to the opposite end in your normally spaced steps, counting the number of paces it takes you to cover the distance. Repeat this walk several times to arrive at the average number of paces (total number of paces divided by the number of times the course was paced). Divide the number of paces into 100 feet to get the number of feet in one of your paces. Repeat this exercise in a forest stand or on hilly terrain and compare it with the one you calculated for the level course. Are there differences? If so, why? Practice for consistency and accuracy. You could pace distances for other things such as the distance from your home to school or the distance around your land.

Direction

A traverse is an interesting exercise to practice both your pacing and direction. Design a number of separate courses which all end at the same point by varying the bearings and the distances for each bearing. The course should be simple, like the course in figure 14, so that it can be run easily in a forested area. Do this with one or more people. The object should be to see which person can come closest to the final point using pacing and compass techniques.

Figure 14.



Mapping I

Using your knowledge of pacing and direction, construct maps of familiar places. These might include your schoolyard, farmstead, community park, or others. Try to use various map symbols so that persons unfamiliar with the area may use your maps. Make sure to use a legend with an appropriate scale.

Mapping II

Choosing symbols in figure 15, construct a cover type map of any forested area. First, select an area of trees, such as a woodlot in a state forest, or in a park. By using a compass and pacing, lay out an area approximately 1 or 2 acres in size. As you walk along your boundary lines note and record the distances or points at which the natural features cross your path. Things you might look for include streams, roads or trails, telephone or power lines, buildings, and the different species of trees. By examining the general size of the trees and the distance between them you can also indicate different size and density classes (how far apart or close together trees are) within the same species. Note the direction or bearing of the natural features in reference to the path you are following. After returning from the field, draw the map to scale. Ask a state forester, SCS woodland conservationist, vo-ag teacher, or your county agent to check your map with existing aerial photographs.

Figure 15. Mapping signs should be listed on the map under the heading, Legend.

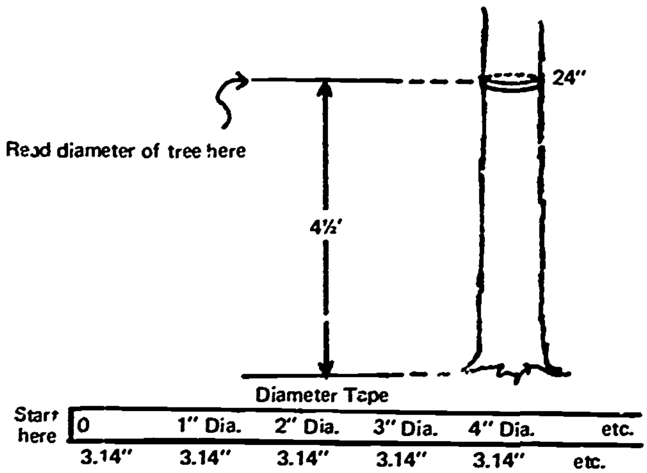
MEASURING INDIVIDUAL TREES

All foresters are concerned with forest management. Whether it be timber production, forest protection, or recreation, the forester needs information about numbers and sizes of trees and how these change with time. It is the purpose of forest mensuration (measurements) to provide this information.

Forest mensuration is concerned with diameters, heights, and volumes of standing timber or products cut from standing timber, such as sawlogs or cordwood, and prediction of growth rates of trees. Measuring individual trees is the place to begin.

Diameter and height (or length) are the principal United States units of dimension used in forest mensuration. These, in turn, are used to determine the volume of standing trees, the volume of their products, or rates of tree growth. Usually the diameter is expressed in inches and the height in feet.

Figure 16.



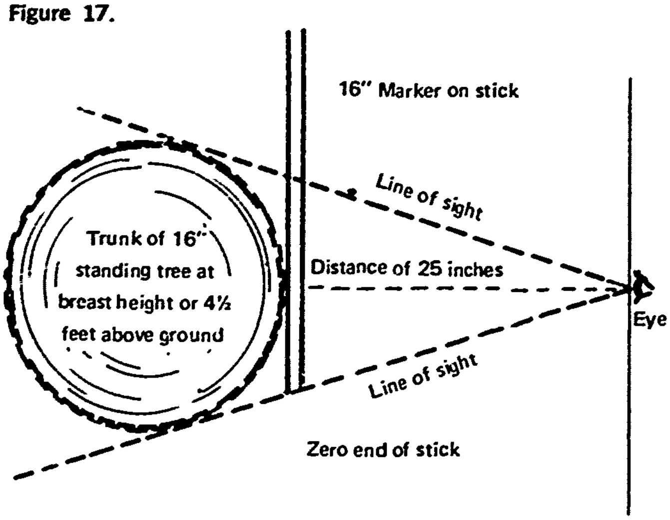
Tree Diameter

Diameter measurements of standing trees are made at breast height which is 4½ feet above the ground. This is abbreviated as d.b.h. (diameter breast height) and is a convenient measurement because it is above the swell of the base of most trees.

The two most frequently used instruments to measure the diameters of trees are the diameter tape and the Biltmore Stick. The diameter tape shows tree diameter by measuring circumference (figure 16). It is based on the fact that the circumference of a circle is equal to the circle's diameter multiplied by pi, 3.14. Consequently each division on the tape is 3.14 inches apart with each division representing 1 inch in the tree's diameter. The diameter tape is wrapped around the tree at breast height and the diameter read directly from the tape.

The Biltmore Stick does not measure as accurately as the diameter tape but is much faster and preferred by many field foresters. It is based on a system of similar triangles (identical angles but different side lengths) to determine the distances on the stick which correspond to each inch in diameter. To use a Biltmore Stick, hold it horizontally, at arm's reach (usually 25 inches), against the tree at breast height. Line up the zero end with the outside of the tree and without moving your head, and using only one eye, look at the other side of the tree and read the figure nearest to where your line of sight crosses the stick and the edge of the tree (figure 17) for an estimate of the tree's diameter at breast height.

Figure 17.



Tree Height

Individual tree height is measured from a 6-inch stump to a certain specifiable height. Usually foresters are not concerned with the total height of a tree but rather its merchantable height; length of the tree stem or trunk from the top of the stump to a point on the stem beyond which salable sawlogs or other products cannot

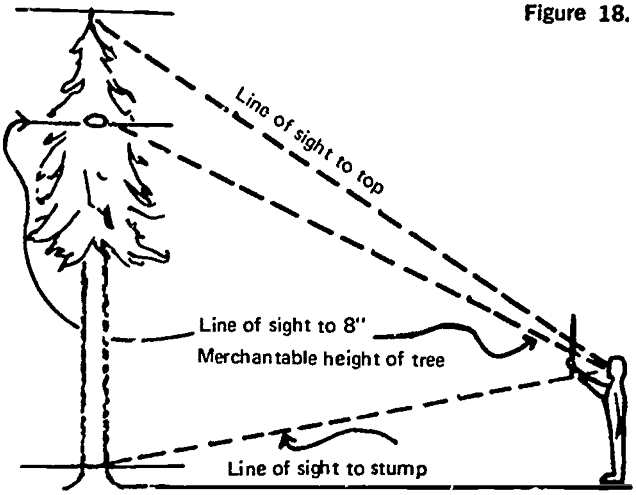


Figure 18.

be cut (figure 18). For sawlogs (a 16-foot log) the merchantable height is usually to a top diameter of not less than 8 inches, because most sawmills prefer not to buy smaller logs. Cordwood is short logs, called bolts and usually in 100-inch lengths: the merchantable top is generally not less than 4 inches in diameter. Cordwood is usually chipped to make paper pulp, fiberboard, or chipboard. Fuelwood is also measured by the cord. It is important to note that the merchantable top may occur at a point lower on the trunk than mentioned above if merchantability is limited by forking, large branches, or deformity.

Two widely used instruments measure tree heights: the clinometer and the Merritt hypsometer. The clinometer measures angles of elevation or inclination in units of percent slope, which is simply the amount of rise or fall, in feet, per 100 feet of horizontal distance (figure 19). For example: a 0 percent slope is level, while a rise or fall of 20 feet in 100 feet is a 20 percent slope. The clinometer is used by pacing out 100 feet from the tree to be measured. Then you sight along the top of the clinometer to the base of the tree and read the percent slope. The procedure is repeated for the top of the tree estimating the point at which merchantability is reached. If the readings are on the opposite sides of the zero mark, that is, one negative and one positive, add the figures for a direct estimate of the tree height in feet. If the readings are on the same side of the zero mark, subtract the readings.

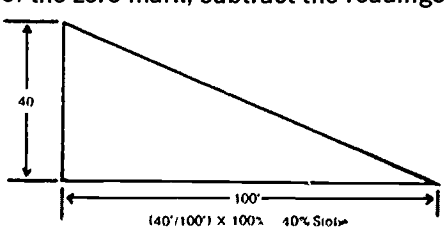


Figure 19.

The Merritt hypsometer is the other instrument used to measure tree heights. It measures tree heights in terms of the number of logs or bolts that can be obtained. It is similar to the Biltmore Stick because it uses a system of similar triangles. The distance between each mark on the hypsometer is 6.15 inches with each mark representing one 16-foot log or two bolts. To determine merchantable height of a tree, pace out 1 chain (66 feet) from the base of the tree. With your arm in a horizontal position hold the hypsometer at arm's reach in a vertical position. Move the stick, not your arm, up and down until the bottom of the stick is in line with the base of the tree. Next sight to the merchantable top without moving your head. Read the figure nearest to where your line of sight to the tree's merchantable top crosses the hypsometer (figure 20). This is an estimate of the number of 16-foot logs or one-half the number of bolts in the tree. If the tree is taller than the hypsometer is long, pace out 132 (two chains) and multiply the estimated figure by two.

Figure 20.

Tree Volume

Once the techniques of determining tree diameter and height have been mastered it becomes relatively easy to determine tree volume. For standing trees this can be accomplished by checking a volume table (figure 21) which is simply a tabulation of volumes of trees corresponding to different tree heights and diameters. It shows the average contents of different size trees of a given species in a particular area of the country. The volumes can be expressed in board feet, cords, cubic feet, or in the number of posts, poles, ties, or other specialty products.

The board foot is the most widely used unit of measure in American lumbering and forestry practices. It is represented by a board 12 inches wide, 1 inch thick,

Figure 21.

Composite Board Foot Volume Table
(Gross International)
Based on Tech. Note 203 and used height measurements on Fair Medium Timber

DBH	BD.FT.	DBH	BD.FT.	DBH	BD.FT.	DBH	BD.FT.	DBH	BD.FT.
9.0	19	15.0	117	21.0	304	27.0	551	33.0	840
9.2	21	15.2	122	21.2	311	27.2	561	33.2	851
9.4	22	15.4	127	21.4	319	27.4	570	33.4	861
9.6	24	15.6	133	21.6	326	27.6	579	33.6	871
9.8	26	15.8	138	21.8	334	27.8	588	33.8	881
10.0	29	16.0	143	22.0	341	28.0	597	34.0	891
10.2	30	16.2	149	22.2	349	28.2	607	34.2	902
10.4	32	16.4	154	22.4	357	28.4	616	34.4	912
10.6	33	16.6	160	22.6	365	28.6	625	34.6	922
10.8	35	16.8	166	22.8	373	28.8	635	34.8	932
11.0	37	17.0	171	23.0	381	29.0	644	35.0	943
11.2	40	17.2	177	23.2	389	29.2	654	35.2	953
11.4	43	17.4	183	23.4	397	29.4	663	35.4	963
11.6	46	17.6	189	23.6	405	29.6	673	35.6	974
11.8	50	17.8	196	23.8	413	29.8	682	35.8	984
12.0	53	18.0	202	24.0	421	30.0	692	36.0	994
12.2	57	18.2	208	24.2	430	30.2	702	36.2	1005
12.4	60	18.4	214	24.4	438	30.4	711	36.4	1015
12.6	64	18.6	221	24.6	446	30.6	721	36.6	1026
12.8	68	18.8	227	24.8	455	30.8	731	36.8	1036
13.0	72	19.0	234	25.0	463	31.0	741	37.0	1046
13.2	76	19.2	241	25.2	472	31.2	751	37.2	1057
13.4	80	19.4	247	25.4	480	31.4	760	37.4	1068
13.6	85	19.6	254	25.6	489	31.6	770	37.6	1078
13.8	89	19.8	261	25.8	498	31.8	780	37.8	1088
14.0	93	20.0	268	26.0	507	32.0	790	38.0	1099
14.2	98	20.2	275	26.2	516	32.2	800	38.2	1109
14.4	103	20.4	282	26.4	525	32.4	810	38.4	1120
14.6	107	20.6	289	26.6	533	32.6	820	38.6	1130
14.8	112	20.8	296	26.8	542	32.8	830	38.8	1141

Composite Pulpwood Volume Table
(Rough cords to a 3" top diameter inside bark and based on total tree height)

DBH	Cords	DBH	Cords	DBH	Cords	DBH	Cords	DBH	Cords
4.0	.013	9.0	.113	14.0	.358	19.0	.726	24.0	1.191
4.2	.014	9.2	.120	14.2	.371	19.2	.743	24.2	1.211
4.4	.015	9.4	.128	14.4	.384	19.4	.759	24.4	1.232
4.6	.016	9.6	.135	14.6	.396	19.6	.777	24.6	1.252
4.8	.018	9.8	.143	14.8	.410	19.8	.794	24.8	1.273
5.0	.020	10.0	.151	15.0	.423	20.0	.812	25.0	1.294
5.2	.022	10.2	.159	15.2	.436	20.2	.829	25.2	1.315
5.4	.025	10.4	.168	15.4	.450	20.4	.847	25.4	1.336
5.6	.028	10.6	.177	15.6	.464	20.6	.865	25.6	1.357
5.8	.031	10.8	.186	15.8	.478	20.8	.883	25.8	1.378
6.0	.034	11.0	.195	16.0	.492	21.0	.901	26.0	1.399
6.2	.038	11.2	.204	16.2	.506	21.2	.920	26.2	1.420
6.4	.042	11.4	.214	16.4	.521	21.4	.938	26.4	1.442
6.6	.046	11.6	.224	16.6	.535	21.6	.957	26.6	1.464
6.8	.050	11.8	.234	16.8	.550	21.8	.975	26.8	1.485
7.0	.054	12.0	.244	17.0	.566	22.0	.994	27.0	1.507
7.2	.059	12.2	.255	17.2	.581	22.2	1.014	27.2	1.529
7.4	.064	12.4	.265	17.4	.596	22.4	1.033	27.4	1.551
7.6	.069	12.6	.276	17.6	.612	22.6	1.052	27.6	1.573
7.8	.075	12.8	.287	17.8	.628	22.8	1.072	27.8	1.595
8.0	.081	13.0	.299	18.0	.644	23.0	1.091	28.0	1.618
8.2	.087	13.2	.310	18.2	.660	23.2	1.111		
8.4	.093	13.4	.322	18.4	.676	23.4	1.131		
8.6	.099	13.6	.334	18.6	.692	23.6	1.151		
8.8	.106	13.8	.346	18.8	.709	23.8	1.171		

and 1 foot long. For example, a board 12 inches wide, 1 inch thick, and 20 feet long would contain 20 board feet. The content of logs is usually expressed in board feet: lumber cut from these logs is also, as a rule, sold at a specified price per thousand board feet.

The second unit of measure is the cord. Fuelwood and pulpwood (wood used to make paper) is measured and sold by the cord. The standard cord or stacked cord is a pile of wood 4 feet high, 4 feet wide, and 8 feet long (figure 22). It occupies 128 cubic feet of space, but actually does not contain 128 cubic feet of wood because it includes air spaces. Under ordinary conditions a cord contains from 70 to 90 cubic feet of solid wood. Fuelwood and pulpwood are sometimes cut in 5-foot lengths. When this is done, a pile 4 feet high and 8 feet long contains 160 cubic feet. Such a pile is usually called a long cord. Firewood is often cut in 12-, 14-, or 16-inch lengths and stacked in piles 4 feet high and 8 feet long. Such a pile is called a short cord.

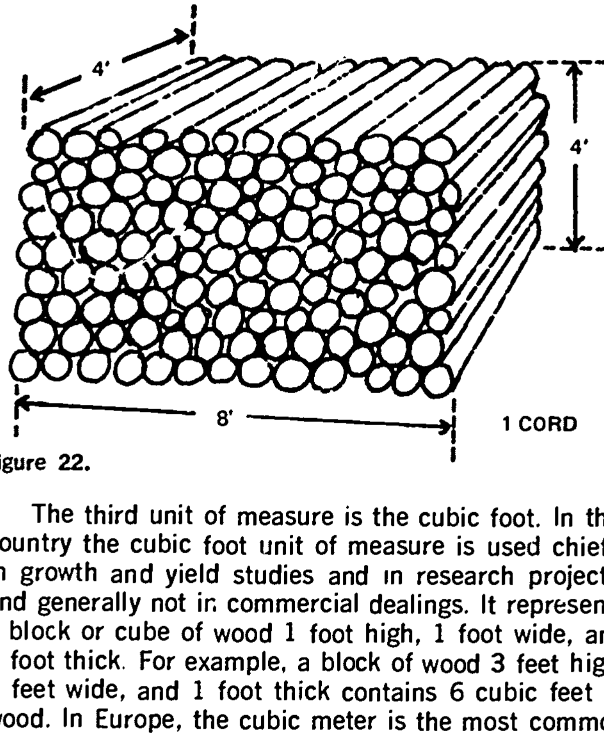


Figure 22.

The third unit of measure is the cubic foot. In this country the cubic foot unit of measure is used chiefly in growth and yield studies and in research projects, and generally not in commercial dealings. It represents a block or cube of wood 1 foot high, 1 foot wide, and 1 foot thick. For example, a block of wood 3 feet high, 2 feet wide, and 1 foot thick contains 6 cubic feet of wood. In Europe, the cubic meter is the most common forest unit of measure. The final unit of measure is the piece. Poles, posts, ties, and mine timbers are cut, measured, and marketed on a piece basis such as 5 poles, 50 posts, etc.

Log Rules and Scaling

All these units of measure can be easily applied to standing trees, but different values become apparent for trees that have been felled and bucked or sawed up.


Figure 23.

Volumes for felled trees are determined by log rules or by log scaling. A log rule is a tabulated form, designated by law, giving the volume contained in logs of specified diameters and lengths. The volume is usually expressed in board feet or can be in cubic feet and cords. A large number of log rules have been developed, each with its advantages and disadvantages. Among the log rules are the Doyle, the Scribner, the Scribner Decimal C, and the International. The Scribner Decimal C Rule has been adopted for timber sales on our national forests and it is the official log rule in Minnesota.

Log scaling is the measurement of the contents of logs to get their volume. This is usually done with a scale stick (figure 23) which is a yard-stick-like ruler from 3 to 4 feet in length. It has a log rule conveniently stamped on it. On one edge is inches in diameter and on the other, corresponding volume values according to a specific log rule. The volume of a log is read directly from the stick, making separate tables unnecessary and enabling the log scaler to work rapidly and accurately.

Growth and Yield

The final application of height and diameter measurements is in studies on the growth and yield of trees. For this reason yield tables have been developed (fig-

Figure 24. 'Normal' yield table for even-aged upland oak forests

Total age (years)	Yield per acre by site index (age 50) in cubic feet				
	40	50	60	70	80
10	0	0	0	10	20
15	0	20	40	80	190
20	20	70	170	360	620
25	100	250	510	820	1,170
30	270	540	880	1,260	1,690
35	480	820	1,240	1,690	2,160
40	680	1,090	1,580	2,090	2,610
45	870	1,350	1,910	2,470	3,040
50	1,060	1,600	2,230	2,830	3,450
55	1,240	1,840	2,520	3,180	3,820
60	1,420	2,080	2,800	3,480	4,160
65	1,590	2,290	3,050	3,770	4,480
70	1,750	2,510	3,290	4,030	4,770
75	1,900	2,710	3,510	4,280	5,060
80	2,050	2,900	3,730	4,510	5,340
85	2,200	3,070	3,920	4,740	5,600
90	2,330	3,230	4,120	4,960	5,870
95	2,460	3,380	4,300	5,180	6,130
100	2,590	3,520	4,480	5,400	6,380

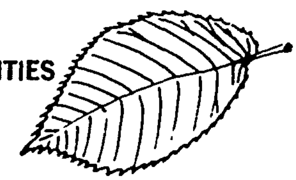
ure 24). A yield table is a tabulated statement showing the volume of wood per unit of area (usually per acre) attainable at different ages of trees (usually in 10- or 20-year periods). The ages of the trees are determined with an increment borer by taking core samples from representative trees, usually the largest or dominant trees in a forest stand (figure 25).

These values are determined and incorporated into tables, which have practical and administrative values. They show what different forest stands will yield at different ages. They are very essential in the establishment of a sustained yield plan of forest management.

When considering the various measurements applied to individual trees, the novice forester can appreciate the contribution of forest mensuration to the field of forestry. It is both an art and a science: an art, because it concerns itself with the applied aspects of forestry; a science, because it is often highly technical in nature. Realize, however, that forest management is ultimately concerned with forests, the aggregate of individual trees.

Figure 25.

ACTIVITIES

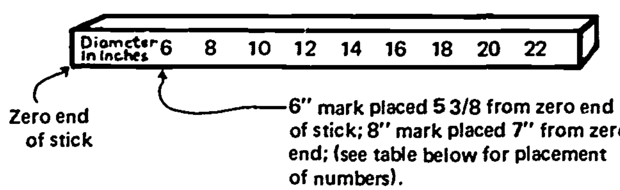


Diameter Measurements

Using an old yardstick, which has been sanded to remove the numbers, or other suitable piece of wood of similar size, construct a Biltmore Stick (figure 26) by marking off the distances listed in the following table:

Figure 26.

BILTMORE STICK



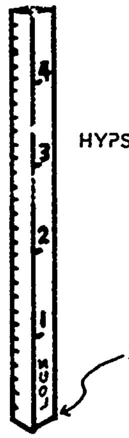
Diameter of tree—inches	Interval to be marked on stick: 23" arm reach	Interval to be marked on stick: 25" arm reach	Diameter of tree—inches	Interval to be marked on stick: 23" arm reach	Interval to be marked on stick: 25" arm reach
3	2.82	2.83	17	12.89	13.12
5	4.53	4.56	18	13.49	13.73
6	5.34	5.39	19	14.06	14.32
7	6.13	6.19	20	14.63	14.91
8	6.81	6.96	21	15.18	15.48
9	7.63	7.72	22	15.72	16.05
10	8.35	8.45	23	16.26	16.60
11	9.05	9.17	24	16.79	17.14
12	9.73	9.86	25	17.31	17.68
13	10.39	10.54	26	17.81	18.20
14	11.03	11.21	27	18.31	18.72
15	11.67	11.86	28	18.80	19.23
16	12.29	12.50	29	19.29	19.73
			30	19.76	20.22

After you have constructed your stick, practice in a forested area determining the diameters of a number of trees. After practicing you will be surprised at your accuracy in estimating a tree's diameter without using an instrument.

Height Measurements

On the other side of a Biltmore Stick construct a Merritt hypsometer by marking off divisions equaling 6.15 inches. Number each division starting with one log, two logs, three logs, etc. (figure 27). These are the numbers of 16-foot logs in the tree at one chain's distance (66 feet) from the tree. Again, measure a number of trees in a forested area and practice frequently to develop consistency.

Figure 27



HYPSOMETER – For determining number of 16 foot logs that can be cut from a tree

Zero end of stick

Volume Measurements

Obtain a volume table from your extension forester and visit a farm woodlot, school or state forest, or park. Select an area of at least ½ acre and measure all the trees over 4 inches in diameter. On a tally sheet (figure 28) record the species, diameter, and number of 16-foot logs for each tree using the following tally system. Determine the volume of each tree and keep a running tally of the tree volumes until you reach 15,000 board feet. This is the number of trees it would take to build one 4-bedroom house. Practice in other forested areas and record your observations.

Figure 28. Timber Estimating Record (cords or board feet)*

Tree No.	Kind of tree	D.B.H. (inches)	Merch. height — No. of 16-ft. logs or 8-ft. bolts	Volume — cords or board feet
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
	Total gross volume			
	Net volume			

* If this form does not provide enough space use an additional sheet of paper.

MEASURING FOREST STANDS

The exact volume of wood in a forest stand cannot be determined until all trees are felled, sawed up, and their products computed. Such a procedure is too time-consuming and undesirable. Therefore, a number of different methods of timber cruising for estimating standing timber volumes have been developed.

Two principal types of volume estimates are now used for cruising timber: total estimates and partial estimates. Total estimates require the measurement of every tree on the area. This is the most exact method of estimating, but the time required, the expense involved, and other limiting factors generally discourage its use, except in special research studies. Experience has shown that the partial estimate is usually satisfactory for general forestry purposes.

Timber cruising, using partial estimates, is the process of sampling various timber types and estimating volume per acre for each timber species. The samples are usually measured and tallied or recorded on plot sheets. If in a 20-acre stand of red pine two sample plots are measured which have per acre volumes of 20 cords and 14 cords, respectively, the stand average would be $20 + 14 \div 2 = 17$ cords per acre. On the entire 20 acres you would have an estimate of 20 times 17 or 340 cords of red pine. The accuracy of this estimate depends on the skill and experience of the cruiser and the number of plots or the percentage of the area sampled.

The most commonly used sample plots are the circular one-fifth acre (radius 52.7 feet), the circular one-tenth acre (radius 37.2 feet), and the one-fourth acre strip (2 rods wide and 5 chains long). Generally, one-fifth acre circular plots or one-fourth acre strip plots are used in forest stands having large, scattered trees, while the one-tenth acre circular plots are often used in dense, uniform-sized timber.

The sample plot locations should be determined in advance to avoid bias. This is done by locating plots at regular intervals on lines run at definite distances apart and on a predetermined bearing. Laying out the plots on a cover type map is an excellent procedure for a forested forty (figure 29).

Care should be taken to cover each type as uniformly as possible so that the sample plots will average out the areas of greater or lesser volumes. Course lines should be run at right angles to ridges and drainage courses so that all conditions are covered sufficiently. Sufficient plots should be taken to get the desired percentage of sample. For high value, large volume trees you might want a 10 percent sample, but usually a 5 to 8 percent sample suffices and in large areas a 1 to 3 percent sample. For example, a 10 percent cruise would be obtained in a jack pine forest type if three plots, each one-tenth acre in size, were measured on 3 acres:

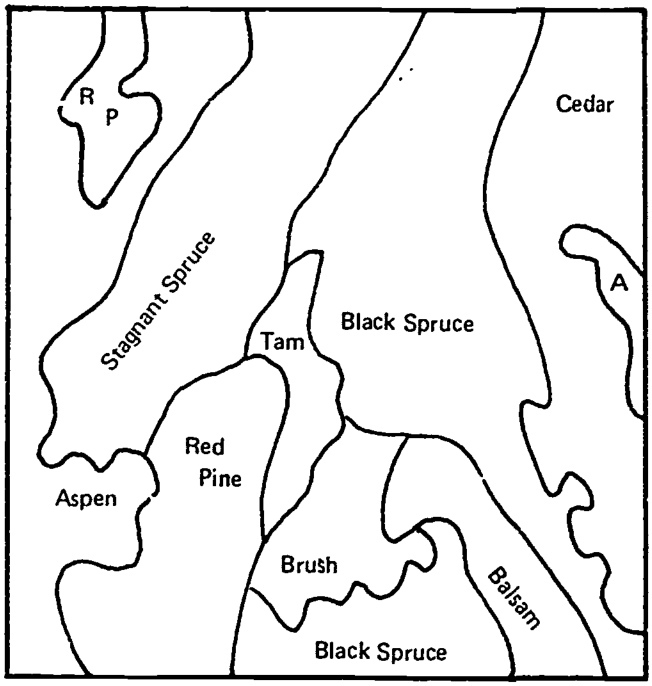


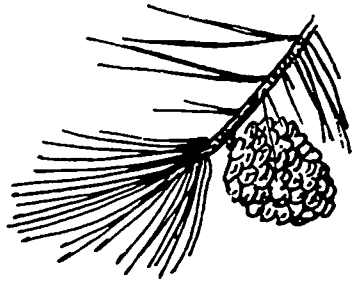
Figure 29.

$$\frac{0.3 \text{ acre (sample)}}{3.0 \text{ acres (total area)}} = \text{one-tenth or 10 percent}$$

Besides measuring the heights and diameters of the trees and tallying this information on plot sheets, other information is also noted in each timber type. Usually one tree is chosen as a representative average of the forest type and a boring made with an increment borer. As noted before, when measuring individual trees this instrument allows a core of wood to be taken out for observation as to the age of the tree (number of annual rings), the soundness of the tree (absence of decay), and the diameter growth of the tree (closeness of the annual rings). Information is given on the general condition of the trees, presence of insects and disease, losses due to wind or fire, general slope or topography, soil, and possible harvest.

A thorough understanding of the techniques of timber cruising is essential to all foresters because an accurate measuring job precedes a good timber sale. Before the forester can make an equitable bargain, he must know through timber cruising how much he has to sell.

ACTIVITIES



Timber Cruising

Using your knowledge of distance, direction, and mapping, lay out a study area of at least 1 acre. Construct a cover type map of the forested area noting the major timber types. After returning from the field and drawing your cover type map, lay out the plan for your sample plots using a 10 percent sample in each of two major timber types. Locate the necessary number of one-tenth acre circular plots in each type on predetermined compass lines. Now return to the field to make height, diameter, and age measurements, tallying this information separately for each plot on tally sheets. A rope or piece of string 37.2 feet long will aid you in determining the boundary line for your plots. Make sure to record the tree species, height, and diameter for each tree over 4 inches in diameter on each plot. Finally, using a standard volume table calculate the volume in board feet per acre for each major timber type. Make other observations about the forest stand. Think what you would do with the area if it were your job to develop a management plan.

Establishing a Permanent Growth Plot

To study forest growth, it is advisable to establish permanent plots on which the individual trees may be observed and measured at periodic intervals. From these observations and measurements precise data on tree growth and losses through mortality or cutting may be obtained.

Using a one-fifth acre circular plot establish a permanent growth plot in a forested area by marking the plot center with a brightly painted stake (preferably preservative-treated wood or iron pipe). Make a record and a map of the area describing exactly how to locate the plot. Measure each tree for diameter and height as well as tree class by starting from a true north line and measuring clockwise. Number the trees with small metal tags. Your tree classes can be based on crown classes or diameter classes. Measure the trees each year and keep accurate records. Note the plot changes.

III. What is Forest Protection?

Minnesotans depend on 17 million acres of commercial forest land for much of their livelihood and well-being. Fire, insects, disease, and animals are the forests' greatest enemies. Since some of these destructive agents are beyond our control, complete protection is not possible. However, we can minimize the loss of growing trees and merchantable timber by applying certain control measures known as forest protection. First, examine how we protect the forest from the most dramatic influence, forest fires.

FOREST FIRES

Fire is the most spectacular and can be the most damaging enemy of the forest. Anyone who has witnessed a forest fire spreading with explosive violence, roaring through the trees like a thousand locomotives, generating waves of heat and gas that fan the flames to even greater fury, knows that it can be terrifying. It destroys nearly everything in its path.(figure 30).

That was what happened when the Peshtigo Fire in Wisconsin in 1871 wiped out whole settlements, burning 1,280,000 acres of pine, and killing 1,500 people; and when the Hinckley Fire in Minnesota in 1894 burned 160,000 acres killing 418 people. It happened again in 1918 when the Cloquet-Moose Lake Fire burned more than 250,000 acres of timber worth more than $30 million, killed 538 people, and wiped out the town of Cloquet, most of Moose Lake, and more than a dozen smaller villages. In mid-May 1971 in northern Minnesota the Little Sioux Fire burned almost 15,000 acres of forest land in 3 days.

Figure 30.

Surface Fires

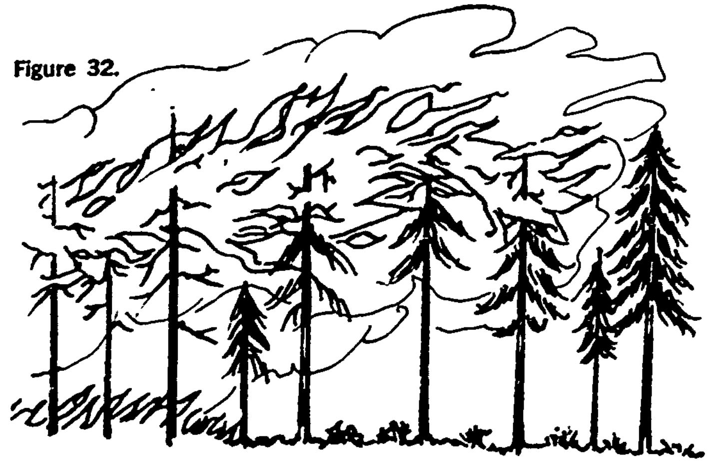
Most of the forest fires, especially in the East and South are "surface fires," burning mostly in the duff or leaf litter on the forest floor (figure 31). These fires, consuming the dry leaves, grass, twigs, and underbrush on the forest floor, may permanently injure, but not kill, many of the larger trees, but they will kill seedlings and small trees. Fought promptly with adequate manpower and equipment, such fires are fairly easy to control. But nearly every small forest fire has the potential of a big one. Surface fires, with the right combination of dry weather and high winds, may develop into crown fires.

Figure 31.

Crown Fires

It is usually the "crown fire" or combined surface and crown fires that cause the greatest timber and property damage and loss of human life. Such a fire is usually the result of a surface fire which, driven by a strong wind, leaps into the tree tops and rushes through the timber, often jumping barriers such as open fields or large rivers (figure 32). Crown fires occur mostly in coniferous forests because the green leaves of hardwoods are not easily ignited. These fires may, however, travel through forests of mixed hardwoods and conifers. Usually they create showers of flying embers or brands which set fires far in advance. Crown fires may kill all the trees over wide areas; they may destroy homes, personal property, and even entire villages and towns.

Figure 32.



Ground Fires

Sometimes fires burn below the surface in the thick duff of decayed leaves or needles, or in peat soils that have become dry (figure 33). Giving off very little smoke between surface outbreaks, such ground fires may smolder for days or weeks before being discovered. and it is difficult to know when they may safely be declared out. Ground fires are common in our northern forest region. These fires usually kill most of the trees in their path, for although they burn slowly, they generate intense heat beneath the surface.

Losses of merchantable timber and personal property are direct or tangible losses because the loss can be determined in dollars. During the past 25 years the average fire loss in Minnesota was about $150,000 annually. The highest loss, about $1,000,000 occurred in 1949; while the lowest, $27,000, occurred in 1966.

Forest fires also cause damage not easily measured. These indirect losses are usually greater than the direct ones. Burning results in future tree mortality because the trees have been weakened, making them more susceptible to insect and disease damage. Losses also occur through the reduction of soil fertility and increased water runoff and soil erosion caused by the destruction of plants, leaf litter, and organic matter on the forest floor. This means that timber growth will be

Figure 33.

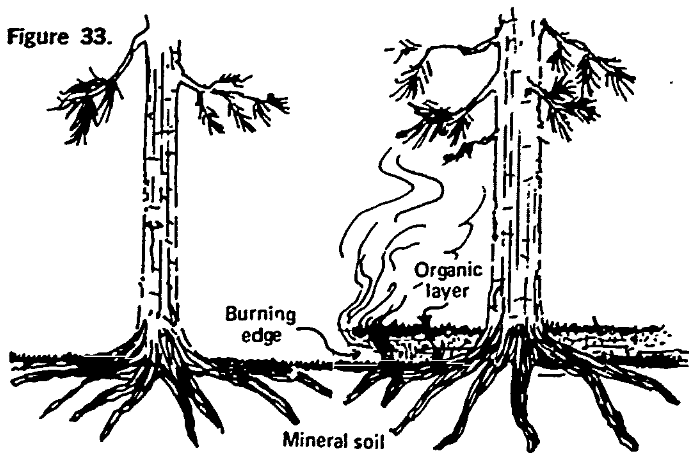
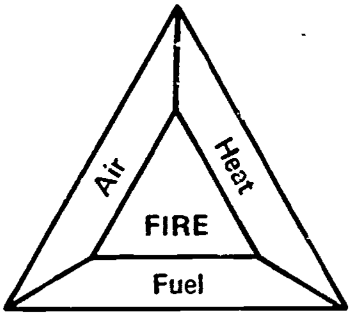


Figure 34.



reduced due to the loss of soil fertility and moisture. Finally, losses include the destruction of wildlife (including fish) and their natural habitat.

Fires represent a drain on the state's resources and manpower and added to the cost of controlling fires to keep the damages from mounting to an even greater total may be a severe strain to state economy. If we are to effectively minimize losses due to forest fires we must first know something about this destructive force we are dealing with, how we can prevent it from occurring, and how we can control it when it does happen.

Fire is created by bringing fuel, oxygen, and heat together under the right conditions. This is called the fire triangle (figure 34). In any forest there is always an abundance of oxygen and fuel present. Needed to complete the triangle or start a fire is sufficient heat or ignition caused by such things as lightning, burning cigarette butts, unattended campfires, or runaway rubbish fires. The following list shows the percentage of fires which are started by each of the causes reported on protected forest and watershed lands in the United States:

Cause	Percent
debris burning	25
incendiary	23
smokers	18
lightning	12
campers	4
railroads	4
lumbering	2
miscellaneous	12

Human carelessness, negligence, or ignorance is responsible for more than 99 percent of the fires in Minnesota.

Since man is the principal cause of forest fires, fire prevention depends on a better understanding of the importance of forests, an awareness of the danger of fire in the woods, and a sense of personal responsibility to safeguard the forests from damage.

Prevention of human-caused fires ultimately depends on cooperation. Every person should realize the values of forests, recognize the forest's great susceptibility to fire damage, and be aware of personal responsibility in preventing fires.

Forest fires are still started by acts of God such as lightning, or by accident such as sparks from logging equipment. For this reason we must always be prepared by building up and training an effective fire control organization.

Except for the federal forests, the Minnesota Division of Lands and Forestry is responsible for the fire protection of all Minnesota's forest lands. The U.S. Forest Service protects the Chippewa and Superior National Forests.

The goal of fire fighting is to extinguish a fire while it is still small. Actual fire fighting plans depend on the type of forest, severity of the burning conditions, topography, weather, and many other factors (figure 35).

Wherever systematic, organized fire control has been undertaken, a pronounced decrease in forest fire losses has resulted. Fire protection must be backed by continued and intensified research and development work, aimed at making it more effective.

Research has shown that under certain circumstances and if carefully applied and controlled, fire can be a useful tool in the forests. Prescribed burning can sometimes be used to get rid of undesirable plants and trees, or to remove heavy accumulations of inflammable ground cover and thus reduce the hazard of destructive wildfire. Such uses of fire, however, should never be attempted except under expert direction.

More research in this field is needed, but the fact that fire can be beneficial must never be used to condone uncontrolled wildfire in the forest. Because of fire's great potential destructiveness, constant prevention and control efforts are a must.

Figure 35. Treeless area at center of photo is a fire lane.

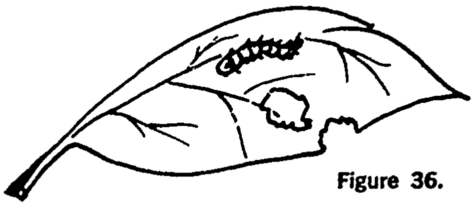


Figure 36.

FOREST INSECTS

Insects are the greatest single cause of damage to living trees. Each year they kill more than 5 billion board feet of sawtimber (large enough to be sawn into lumber). They are also responsible for an estimated growth loss of 3.6 billion board feet of sawtimber per year. Given favorable conditions, the insect population present in most forests nearly all the time, suddenly builds up and spawns epidemics. No tree is immune to insect attack, and no part of the tree is spared from this devastation. Insects damage trees by defoliation; by girdling the stems, twigs, and roots; by sucking the sap; and by boring into the wood, cones, and fruit (figure 36).

Caterpillars, measuring worms, and other similar kinds of insect larvae that feed on leaves and needles of trees are probably most familiar to you. In some years, they occur in great numbers over large areas and strip the trees of all their leaves or needles. When this happens, thousands of trees may be killed and large volumes of valuable timber lost. The forest tent caterpillar, spruce budworm, larch sawfly, and pine tussock moth are examples of insects that feed on leaves and needles.

The forest tent caterpillar periodically spreads throughout northern aspen forests damaging and sometimes killing trees by devouring leaves.

The spruce budworm is another example of a defoliator that has caused widespread damage in Minnesota. It has destroyed millions of cords of balsam fir and white spruce by removing the needles.

Another important forest pest is the larch sawfly which attacks tamarack trees. This insect virtually eliminated the tamarack in the early 1900's. During the past 15 years about 500,000 acres of tamarack in Minnesota have been damaged or destroyed.

In 1961 a spectacular pine tussock moth epidemic destroyed about 1,000 acres of jack pine near the General Andrews Tree Nursery near Willow River. This was an unprecedented outbreak, for in the past this forest defoliator was held in check by its natural wasp parasites. In 1962 and 1963 it was necessary to control this insect with pesticides.

Other destructive defoliators in Minnesota are the jack pine budworm, various sawflies (figure 37), and the cankerworm.

Several kinds of weevils attack trees of sapling size. Weevils are snout-nosed beetles. A sapling is a young tree grown to a trunk diameter of from 2 to 4 inches. The weevils like to chew the leaders (tops) and twigs of these small trees. This prevents the young tree from growing normally and often kills the top. The tree then becomes crooked as the undamaged parts continue to grow. When the tree is cut, its lumber is not very valuable because straight trees command the best prices for lumber.

Seedlings growing in a nursery or young trees growing in the forest are often killed by white grubs that feed on the roots. White grubs are the larval stage of the June beetle. These grubs increase the cost of growing trees in the nursery and reduce the number of new trees growing in the forest.

Borers that attack trees are the larvae of beetles or moths. Normally, weakened trees suffering from shock or unfavorable environmental conditions are their victims. An example of a borer is the bronze birch borer. This serious pest attacks birch trees growing in the open.

Bark beetles are the most destructive insects in pine, fir, and spruce forests. They usually attack and kill mature and over-mature trees. "Over-mature" trees are those which are old and have stopped growing. As they become older, they become weaker and more susceptible to attack. The larvae or worm-like forms of these beetles feed under the tree bark next to the wood. They usually kill a tree in a single season by girdling the main trunk and cutting off the flow of sap from the roots to the needles. Severe outbreaks of bark beetles may annihilate a forest in 3 or 4 years.

These are just a few of the many insects which cause damage to our forests. It is predicted that insect outbreaks will increase as plantations of trees grow old. Therefore, some form of control is necessary.

Insects that damage or kill forest trees may be controlled in several ways. Birds, insects, or parasites that prey on the insect pest may be introduced into an infested area. Fast-growing forests are less likely to be attacked by insects, consequently by harvesting the old, weak, and diseased trees before they become worthless, damage can be prevented. After careful planning to make sure wildlife will not be harmed, leaf-feeding infestations over large areas are sprayed with insecticides which break down rapidly in the environment. This is usually done by controlled hand spraying or by spraying from the air with helicopters or airplanes. Bark beetles, difficult to attack because they are hidden beneath the bark, can be controlled by cutting the tree down and burning the bark or by spraying the bark with a chemical that soaks in to kill the larvae.

However, prevention is the best method of controlling an insect problem. Prompt action in reporting infestations to local public officials may prevent widespread damage.

Figure 38. Fruiting body of a fungus on a tree.

FOREST DISEASES

Trees, like humans, are subject to many diseases in a lifetime. Some diseases affect leaves, others the main woody parts (trunks, branches, and twigs), and still others the roots. They cause losses by killing or deforming trees, by lessening their rate of growth, and by destroying the wood already produced. Each year they kill 2.3 billion board feet of sawtimber and are responsible for 17.6 billion board feet of growth loss per year, more than any other single forest enemy.

There are two types of disease: (1) infectious and (2) noninfectious. Noninfectious diseases are caused by unfavorable environmental conditions, chemical, and mechanical injuries. Moisture extremes and temperature extremes are the most common unfavorable environmental conditions. Nutrient deficiencies, herbicide damage, salt toxicity, and air pollution are examples of chemical injury. Mechanical injuries are usually the result of poor transplanting practices or damage from ice, snow, hail, lightning, wind, and machinery. Most noninfectious diseases do cause mortality or serve as entrance points for disease.

Infectious diseases include fungi which are the primary cause of most tree diseases. Fungi are small plants which reproduce by means of spores. Often microscopic in size, they lack chlorophyll. Without chlorophyll they must rely on the plants they infect for their food. We call organisms living on live plants, parasites, and those living on dead organic material, saprophytes. Some fungi are capable of living in both ways, but usually they restrict themselves to one or the other (figure 38).

There are more than 100,000 different fungi in the world—all capable of causing plant diseases. This does not mean that they are all detrimental; in fact, many of them perform the essential function of converting plant and animal remains into a form which can be used by plants. Some plants could not live without the fungi invading their roots. Mychorrizae (fungus root) are an example of a fungus-plant association. The plant supplies the fungus with food and the fungus provides the plant with substances necessary for plant growth. We are all familiar with the wonder drug. penicillin. A species of fungi known as Penicillium is used industrially to produce this antibiotic. Other fungi are also important in the production of antibiotics and certain kinds of cheeses.

Tree diseases are usually classified into groups based on their habits or how they affect trees. Such a classification might include wood decay, canker diseases, rusts, root rots, or vascular wilts.

Heart rots are an example of wood decay. They are the greatest single cause of disease losses in forest

Figure 39.

stands because they change the sound wood of the trunks into useless, rotten masses. Many form conks or fruiting bodies on infected trees but only after they have been living in the tree for many years.

The growth of heart rot cannot be stopped once it has infected a tree. The only control is prevention. The fungus enters at a wound or gets to the heartwood through a top broken off by wind or ice, large limbs broken off, fire scars, logging damage, or lightning wounds.

Heart rot is found in all kinds of trees, but it spreads faster, and is therefore more destructive in some species than in others.

Canker or visible dead areas in the bark of a tree are common on both hardwoods and conifers. They may resemble mechanical injuries at first, but they remain open and may grow larger while ordinary wounds heal. Hardwood cankers seldom kill the trees. They do deform trees, however, and the rot that sets in behind them often causes the tree to break off at the damaged spot. Severely cankered trees should be removed.

Most of the important pine cankers are caused by fungi called rusts. They usually produce blisters beneath the bark on infected trees during the spring (figure 39). Most rust diseases spend part of their lives on one kind of plant and part on another: a fact that helps to control some of them.

One of the most destructive rust diseases of forest trees in Minnesota is white pine blister rust. It causes widespread damage to native white pine by girdling them. This disease was accidentally introduced to the United States on nursery stock shipped from Europe in the 1900's before there were quarantine laws. The fungus causing this disease alternates between two hosts, the white pine and certain species of gooseberry or currants.

Major efforts used to be aimed at destroying the alternate host, but today this is only done in or near high-value recreation or scenic areas.

Root rots cause loss of timber growth, result in windthrow (blown down by wind) of some trees, and kill others outright. Particularly serious is the *Fomes* root rot of coniferous forest plantations. Since the infected part of the tree is not exposed, the disease is usually not discovered until it has been well established and the tree is seriously damaged, dying, or blown over.

A serious disease of great concern to Minnesotans because of the large numbers of elms in our cities is Dutch elm disease. It is transmitted from diseased to healthy elm trees by bark beetles which breed underneath the bark of dead elm branches, trunks, and stumps. The symptoms are rapid wilting and yellowing of the foliage early in summer. Dutch elm disease can be positively identified only in the laboratory where the fungus is cultured. There is no cure once the tree has become infected (figure 40).

Breeding for resistant trees, using systemic fungicides, and working with sex attractants are some of the present research projects being conducted to control Dutch elm disease.

Oak wilt, another serious wilt disease in Minnesota is endangering oaks in forest stands and prized shade trees in cities. It usually spreads through root grafts (roots from a diseased tree growing together with roots from healthy trees).

All species of oak are susceptible to oak wilt, but the red oaks are more easily infected than bur or white oaks. First the leaves in the top of the tree turn brown around the leaf margins. The tree dies in a few weeks after the symptoms appear. On less suspectible species, the diseased trees may live for more than a year.

Viruses usually stunt the growth of plants and reduce their yields, but some, such as elm phloem necro-

Figure 40. Dutch elm disease killed these trees.

sis, also cause mortality. Only a few pathogenic bacteria attack trees and none is classified among major causes of loss in forest trees.

There are many other diseases that are serious enemies of the forest. Trees weakened by insect attack or by fire, wind, and animal damage are prime targets for all fungi, bacteria, and viral infections. Control efforts should be aimed at the limitation of disease losses.

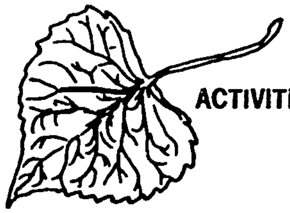
ANIMALS

Animals, both wild and domestic, seriously damage trees. Bears rip wide strips of bark to get the sap they relish. Deer overrun some forests so that it is almost impossible to get young forests started. They eat seedlings and also browse the leaves and twigs of older trees as high as they can reach. Porcupines feed on the inner bark of both conifers and hardwoods, often girdling them. Beaver not only cut trees down (figure 41) but flood large areas of standing timber by constructing their dams. Rabbits, mice, rats, chipmunks, shrews, gophers, and other rodents eat seeds and young trees that should be growing into the next timber crop. Domestic cattle and sheep can cause heavy damage to farm woodlots in hardwood forest areas (figure 42). Their trampling hooves make the soil of the forest floor so hard that rain and melting snow cannot penetrate. In one summer they may eliminate the low vegetation so that it takes years to revegetate.

In controlling the depredations of wild animals, wildlife experts and foresters do not want to eliminate the damaging creatures just to keep animal populations and their food supplies in balance. When animal damage is at a low level trees and animals can live in harmony for the benefit of both humans and animals. Where necessary, wildlife experts may recommend a larger harvest by hunters or trappers, or they may introduce other animals which prey on those destroying the forest. Fencing is usually a satisfactory solution to destruction caused by grazing animals.

Figure 41.

Figure 42.



ACTIVITIES

Fire

Develop the fire history of your county as a demonstration. Use county road maps to outline the boundaries of important past fires. Read old newspapers, talk to long-time county residents, and consult the extension agent to try to get as much information as possible about each fire. Such information might include: where and what burned, loss of human life, and damage to dwellings. You might include the forest changes that occurred. Visit old fire sites. Look for old charred stumps and logs, charcoal in the forest litter, or fire scars on living trees. Do not cut down a tree, but determine the year of the fire with an increment borer, counting the rings past where the fire scar occurs on a living tree.

Place all of your information (including maps) in chronological order in a folder. You may also take pictures of some of the fire evidence from different burns, but be sure to label it right away so you do not forget where it came from.

Fire Break

With the assistance of your local forester or county agent, plan firebreaks and access roads in a forested area or on your land, taking advantage of natural barriers (lakes and streams) and existing roads. Construct a model to show how you would incorporate your ideas.

Effects of Fires

Visit a recently burned area with a forester and study the effects of fire. Take pictures of the area, and using any available references, write your observations. Observe changes over a number of years.

Insects and Diseases I

Select a problem insect or disease in your area. Study its life history, make a display that shows its life cycle, and add collected specimens or pictures to it to show what you have learned. Your display could include examples of damage caused and possible control methods.

Insects and Diseases II

Collect leaves, twigs, branches, stems or roots damaged by insects, diseases, animals, fire or weather to mount and label on a board. Identify the forest enemy and suggest methods of control. Illustrate the display with pictures of the damaging agent. Example: picture of a caterpillar under a partially eaten leaf, or picture of a fire under charred wood. Look for animal damage from mice, rabbits, pocket gophers, porcupine, deer, cattle, etc. Use photographs to show damage which is too large to display, such as a pocket gopher-killed pine tree, or woodlot grazing.

Sediment From Land Areas

Collect water from streams located in different land use areas, such as woodland (grazed and ungrazed), pastureland, cropland, and construction areas. Pour the water into glass containers of equal volume (pint jars work well). Stir or shake the water and note differences in color and density. Do this immediately after a rainfall and during a dry period. Allow the matter to settle to the bottom noting the time it takes to settle and the amount of sedimentation. What conclusions can be drawn? Use this as a demonstration or labeled exhibit.

IV. How is the Forest Harvested?

Harvesting means removing trees from a forest and using those trees to benefit mankind. The harvesting process is called logging and the people who harvest the trees, loggers.

Logging is one of man's oldest professions. We have used trees for shelter, fuel, and food since earliest recorded history. You may wish to study early accounts of tree harvesting which are included in references in the back of this publication.

In the United States, our American Indian predecessors were using trees for shelter and food when the pilgrims landed at Plymouth Rock. Consider the birchbark canoe, bows and arrows, maple sugar, and the history of the Indians' use of fire to furnish fuel and to improve wildlife habitat.

Those pilgrims, landing in a boat constructed of wood, constructed shelters of wood as one of their first jobs. Throughout early United States history, trees were an item of demand and controversy. The reservation of white pine trees by the King of England for use as spars in ships of the British Navy was one of the issues which led to the Revolutionary War.

As America gained her independence and settlers moved westward, the forest hampered agricultural development. Wood was needed to build homes, factories, railroads, bridges, and to furnish fuel for U.S. citizens and industries. This led to the exploitation of forests and the unfortunate idea that "timber was a one-time crop." Now we recognize that wood is a renewable resource and plan for the future growth and harvest of many crops of forest products from the same land area.

Logging in Minnesota's forests started in the early 1800's and continues today. Perhaps the heyday of the logging industry occurred during the 1880-1920 period when white pine abounded and large sawmills were cutting logs from the St. Croix and Mississippi watersheds to International Falls and Duluth.

Today, harvesting forest crops is still a vital component of our economy and forestry ranks as Minnesota's third largest industry, employing more than 40,000 people in forest products and allied manufacturing units. Over $500 million is generated each year in Minnesota from manufacturing of wood and fiber products. All of this depends on the harvesting of trees from our forest lands. Consider the job of logging: the harvesting of trees (figure 43).

THE HARVESTING PROCESS

The harvesting process consists of the following steps:

(1) Selection of area and trees to be logged;
(2) Felling, limbing, and bucking the trees;
(3) Skidding the trees or logs;
(4) Loading and unloading the trees or logs;
(5) Hauling the trees or logs to the mill;
(6) Preparing the land for a new crop of trees.

Figure 43.

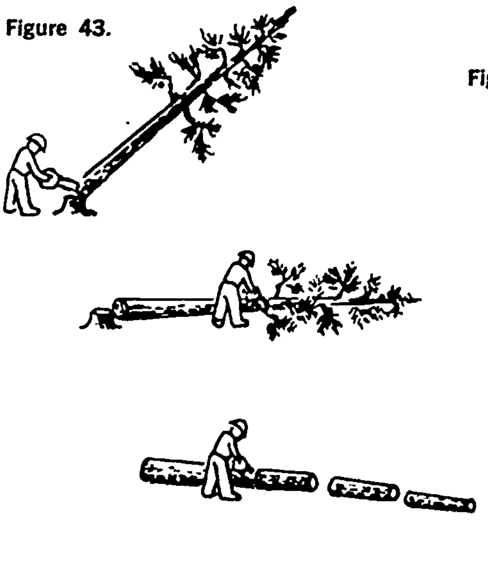
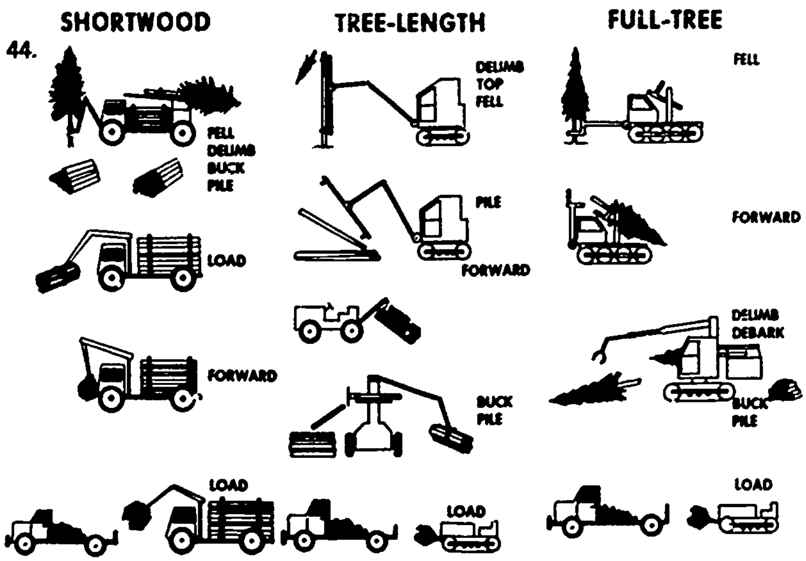


Figure 44.



Selection of Area and Trees to be Harvested

The selection of the area and trees to be harvested is part of the management plan which has been developed by the forest landowner. The age of the mature forest stand which is ready for harvesting, called the rotation age, is determined years beforehand. For example, in Minnesota, aspen may be logged at 60 years, red and white pine at 120 years. It is also important to consider what products are desired from the forest in determining cutting. Once these decisions are made, certain areas will be selected for harvest. These areas are then marked on the ground (commonly by spraying the boundary trees with paint), the volume of trees to be cut determined, and a timber sale made.

Felling, Limbing, and Bucking

The logger purchases the right to harvest trees, then cuts them down: this is called felling. Years ago this was done with an ax and crosscut saw; now it is done with power saws. A new technique involves the use of hydraulically operated shears mounted on the front of a crawler tractor. The shears clip off trees 20 inches in diameter or smaller at the stump. However, the power saw is the most used tool in felling trees. Limbing means removing limbs from the bole (trunk) of the tree. Topping means cutting the top from the bole. Bucking means cutting the tree into certain lengths. For cordwood bolts in Minnesota, lengths are 100 inches. This is known as a shortwood system in pulpwood harvesting. Logs to be cut into lumber are generally longer, up to 40 feet in the Pacific Northwest.

In Minnesota pulpwood operations, logging the entire tree is becoming more common. In the "tree-length" method, the tree is felled and the top and limbs removed before dragging it to the landing. In the "full-tree" method, the entire tree including top and limbs are dragged to the landing where the top and limbs are removed. There are three distinct systems in Minnesota pulpwood harvesting: shortwood (100-inch bolts), tree-length, and full-tree (figure 44).

Skidding or Yarding

The process of dragging the felled tree or logs to a central point (landing) for loading onto a truck is called skidding or yarding. Formerly, oxen or horses did this, now tractors or skidders are used (figure 45). The rubber-tired skidder with chokers (cables attached to the logs) is commonly used in this operation. In the West, cable systems skid logs to the landing. Also, helicopter systems are used to reach more inaccessible forest stands, and balloon logging is experimental in Oregon.

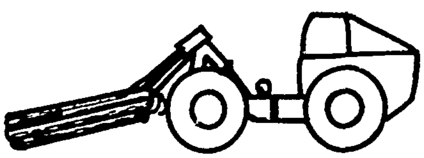
Loading and Unloading

At the landing the logs or tree-length boles are loaded onto trucks (figure 46). In the "glory days of logging," this was accomplished using crosshauls powered by horses or oxen. Now a front-end loader or a loading machine mounted on a truck does this. Unloading takes place at the mill or railroad yard. This, too, is accomplished with the same loading machinery.

Transportation

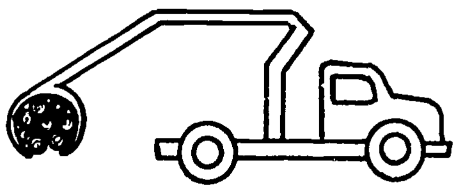
Trucks are the standard method of transporting the logs to the mill or railroad shipping point (figure 47). The log truck, which may be carrying cordwood in 100-inch sticks or bolts or sawlogs to the mill, has replaced horses and oxen which once pulled sleighs to the railroad or to lakes or rivers where the logs were moved by water during the spring breakup to the mills.

Figure 45.



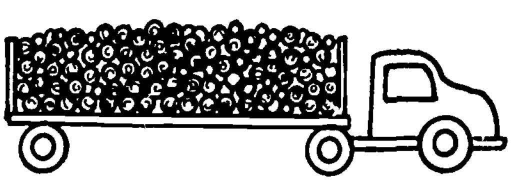
Skidding

Figure 46.



Loading

Figure 47.



Hauling

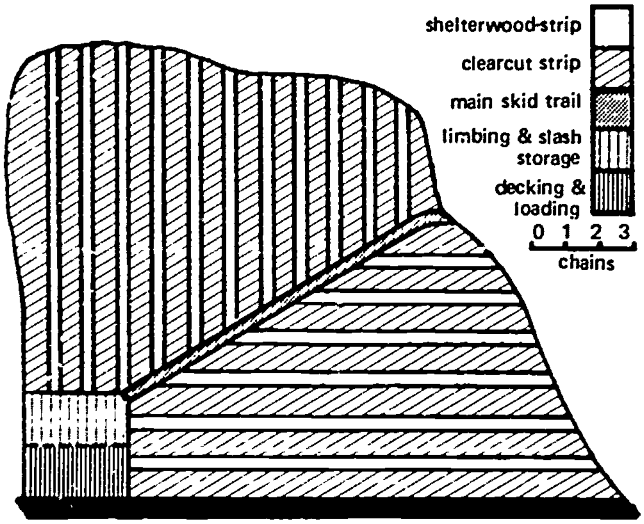


Figure 48.

Preparation for a New Crop of Trees

In any forest management plan, the preparation of the land for regeneration of a new stand of trees will be considered in the method of harvesting. For trees which cannot tolerate shade, such as the pines and aspen, the slash must be removed either by piling it or by burning. Controlled burning is preferable since it converts the tops, limbs, and smaller vegetation to ashes, which provide a fine seed bed with nutrients immediately available to the seedlings. Piling and/or burning also clears the area for future planting.

Harvesting patterns are also important in determining future roads and landings for machine movement in the new forest. Consider where lanes should be created for firebreaks to allow thinning, pruning, and finally harvesting the present crop of mature trees (figure 48).

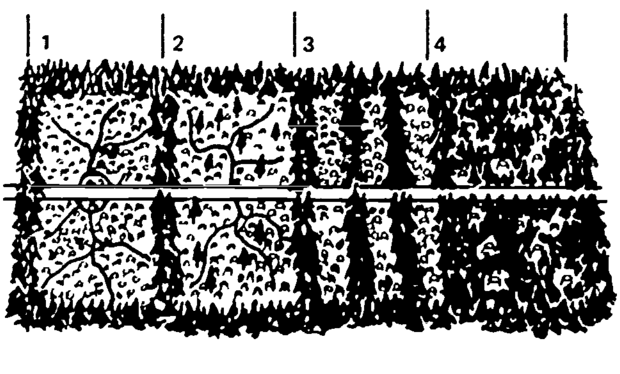
SILVICULTURAL METHODS OF HARVESTING

Silviculture is the art of producing and tending a forest. One of the ingredients in tending the forest includes the harvesting of trees. There are four main methods of harvesting: (figure 49)

(1) Clearcutting (figure 50)
(2) Seed-tree (figure 51)
(3) Shelterwood (figure 52)
(4) Selection (figure 53)

Clearcutting and selection represent the two extremes.

Figure 49.



Clearcutting Method

An area of the forest is marked for harvesting and every tree, regardless of size and species, is removed. Clearcutting is used when the forest to be established consists of species which will not live under shade. It is also used where the present forest consists totally of trees which are mature or overmature. It may also be applied where the expense of other methods of cutting would prevent their use.

Clearcutting in Minnesota is used with stands of jack, Norway (red), and white pine; white and black spruce; and aspen. These are all trees which cannot reproduce or grow well under shade. They also are species which do well as even-aged stands (all about the same age or age class).

Clearcutting is also used with those species which can reproduce in nature after fire or some other disturbance. In Minnesota, these are the pines, spruces, and aspen-birch and in the West, Douglas-fir, the pines, spruces, and redwood.

In the new forest, we may expect the clearcut area to be naturally reseeded from standing trees in the surrounding forest. We may artificially spread seed on the harvested area, or we may plant the area with trees of desired species which were produced in a nursery. This latter method is becoming more popular as it insures the type and spacing of ees and to some degree eliminates the problems of early survival of the seedling, brush competition, and too much competition between trees of the same species. With aspen, we expect the suckering from stumps and roots of the cut trees to provide the future forest.

Clearcutting with proper regeneration is a necessary method of harvesting the forest. Again with aspen, it provides excellent habitat for wildlife such as deer, moose, and ruffed grouse.

There are some drawbacks to clearcutting. For several years the area may be unsightly. However, those forested areas of northern Minnesota which are traditionally pictured as representing the primeval forest were created by nature's methods of clearcutting: the wildfire or windstorm. Also, if the cutting area is on a steep hillside and improper techniques are used in the harvesting job, excessive soil erosion may occur. This is

Figure 50. Clearcutting method.

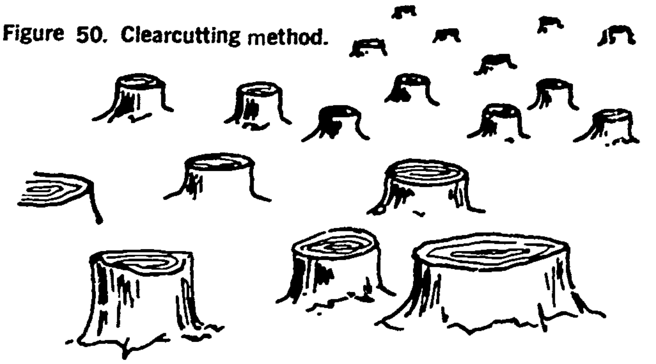


Figure 51. Seed-tree method.

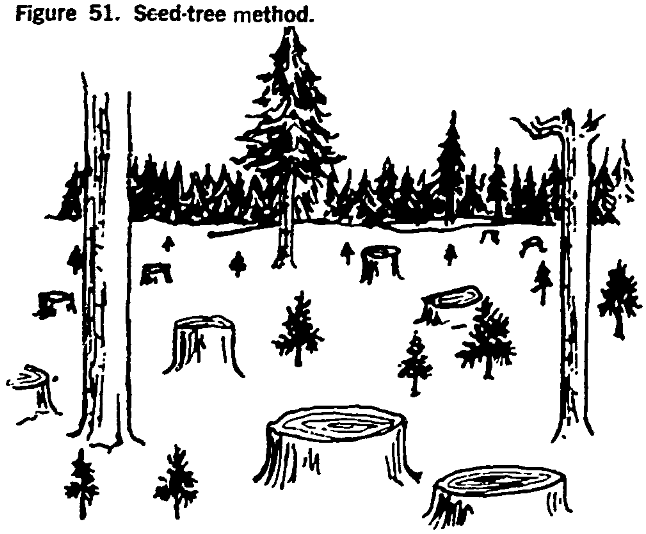
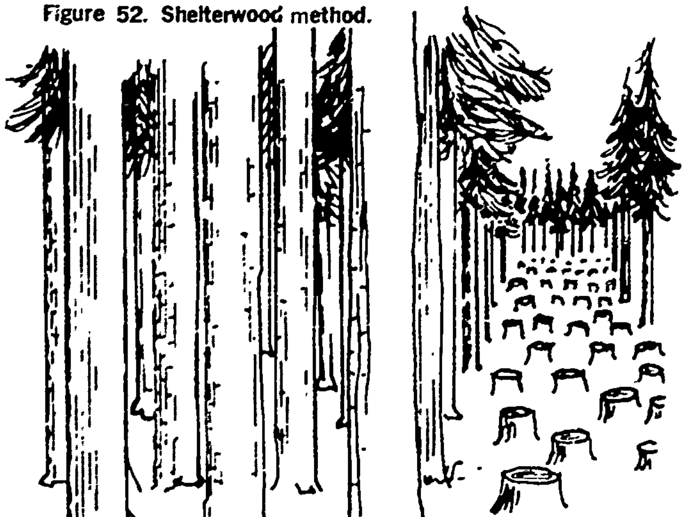


Figure 52. Shelterwood method.



more a problem in mountainous country with the main erosion problems found in conjunction with road building.

Clearcutting is a very proper method of harvesting. It has occurred in nature over millions of years since trees first grew on the land. It has been used by man in Europe for centuries without loss of soil nutrients or degradation of the land. It was used by the Indians in this country, through the setting of wildfires, for thousands of years before the white man, farmer-logger, came to this continent. It will be used in the future if we are to provide those essentials of timber and fiber for human welfare.

Seed-Tree Method

In this method, certain trees are left in the harvested area, either singly or in groups, to furnish seed which will fall on the cut area, germinate, and grow to become a future forest. Once the new forest is established the seed trees may be harvested. This system is rarely used in Minnesota, but is more common in the southern and western forests of the United States.

The seed-tree method is generally applied with species which do not tolerate much shade. Since natural seed source is from the standing trees in the cut-area, it is not necessary to depend on adjacent trees to the cutover area for natural seeding, thus the area cut may be larger than in the clearcutting method.

One of the main disadvantages in this system is the possibility of loss of the seed trees by wind, fire, or insect attack before they produce seed. Because of the increasing dependence on tree planting, the seed-tree method has not been used as extensively in recent years. Aesthetically, there is little difference between the clearcutting and seed-tree methods.

Shelterwood Method

In this method, portions of the forest stand are removed gradually over the latter part of the rotation period. As the name of the method implies, the trees not cut serve to shelter the new crop of trees which starts to grow in the areas where trees were removed. So a new crop of trees is started before the mature trees have all been removed.

Obviously, the intensity of shelter or protection of the new trees can be varied by cutting many or few of the mature trees. Thus, the system provides for a considerable range of tree removal, similar to a heavy thinning: the best trees are left standing as a shelter while the poorest trees are removed.

This method can be used with even- or uneven-aged stands. It is generally done over the last one-fifth of the rotation age. For example, when growing white pine on a 100-year rotation age (that length of time from the germination of the seedlings to the final harvest), shelterwood cutting might begin at age 80 and the final cut would be at age 100.

Several factors must be considered in this method. First, the new crop must be shade tolerant enough to survive and grow normally. Second, the trees which are left should not be subject to windthrow.

Third, the standing trees must not be susceptible to damage in the removal of the partial cuttings; and fourth, the cost of logging may be more expensive than in the clearcutting or seed-tree methods.

There are many variations of the shelterwood system, generally classified under:

(1) Uniform method—harvesting throughout the entire stand,

(2) Group method—groups of trees are cut and removed, or

(3) Strip method—strips of trees are removed.

The latter method is sometimes used in cutting spruce-fir in northern Minnesota. Because of the economics of harvesting, the shelterwood method has not been utilized as much as may be desirable. This method is preferred from an aesthetic standpoint to the clearcut or seed-tree method. It is especially adaptable to white pine and northern hardwoods; it cannot be used with jack pine or aspen; and it may have some potential with Norway (red) pine.

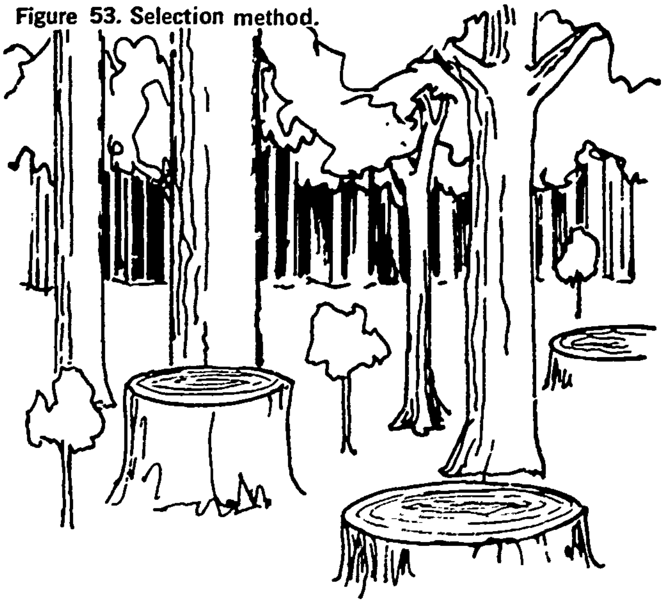
Selection Method

As the name implies, the individual tree is considered and selected or left in this method. It is primarily employed with northern hardwoods and in stands where single or groups of conifers, such as white pine, are found. The selection method is aimed at retaining an uneven-aged composition within the forest. Only mature trees or species which are highly desirable are removed. For example, in Minnesota, black walnut is a highly sought-after tree and loggers may enter a stand to remove only this species. Another example might be the removal of mature trees, with crowns occupying too much space.

Selection cutting can proceed throughout the life of the stand since there are older, middle-aged, and very young trees in the uneven-aged stand. This method depends on the ability of new trees to reproduce and grow without hindrance from shading. Generally, natural reproduction is expected but planting is possible, in fact desirable, when growing certain species such as black walnut.

There are a number of factors to consider in using the selection method, several of which were discussed

Figure 53. Selection method.



with the shelterwood method. Tolerance of shade, ability to reproduce, wind-firmness, damage from logging, and economics are the most important. Also, the selection method affords the least impairment of stand beauty if the slash is removed or cut and scattered throughout the stand. This system is most widely used in Minnesota in the northern hardwood types found in central and southeastern Minnesota.

ACTIVITIES

Model of a Logging Operation

Using plywood for a base, construct with plastic, styrofoam, or other materials an area being logged. You may wish to show the four silvicultural systems of logging: clearcutting, seed-tree, shelterwood, and selection. Purchase or construct models of tractors, trucks, and loading machines. Show a landing with piled logs waiting for loading on the truck. In another model you could show the three methods of pulpwood harvesting: shortwood, tree-length, and full-tree.

Print small, neat labels indicating the various parts of your model, such as an area of felled trees, piles of cordwood, the landing, methods of harvesting, etc.

Photo Exhibit or Scrapbook of Harvesting Operations

Visit an area being harvested or where trees are being felled. *BE SURE TO GET PERMISSION AND LET THE FALLERS OR WOODSWORKERS KNOW YOU'RE THERE—FOR SAFETY'S SAKE!!* Photograph the various harvesting operations and develop a sequence of pictures showing the process from stump to mill. Label the steps appropriately. Mount this on display board or in a photo album. If your camera takes slides, develop a slide set and prepare a script showing one or more harvesting operations.

Collect pictures from magazines, newspapers, and old catalogs of logging operations and/or the equipment used in harvesting trees. Arrange these according to steps in the logging process. For example: the first picture(s) might be of an area of mature standing trees; then a picture of a power saw; a man felling a tree; the limbing or bucking; a tractor; skidding the tree to the landing; a loading machine; a truck; etc.

Label each step of the pictured operation and describe the activity shown. Your sequence need not be of just one operation or limited to one part of the country, Good sources are farm magazines, Sunday newspaper supplements, power saw company sales literature, and some of the references listed on pages 45-46.

These can be entered in a scrapbook or mounted attractively on a display board. To complete a club or fair exhibit, you might purchase small toy tractors and trucks, or construct your own, which might be used in the logging operation. Arrange these as part of your display. Visit your County Historical Museum, or the State Historical Society Building, or the College of Forestry Exhibit Room (the latter two in St. Paul), or some other place where old logging equipment is preserved.

Take pictures or make drawings of this equipment. Also visit your library and read the history of logging and forestry in Minnesota, the Lake States, and the United States.

With these pictures, drawings, and from your reading, write a story of the logging industry. You might wish to dramatize your story. You can add local color by reading stories about Paul Bunyan and Babe the Blue Ox, or books by such authors as Stewart Holbrook, James Stevens, Jack London, and Vardis Fisher.

V. What is Forest Regeneration?

Forests are a renewable resource capable of perpetuating and extending themselves even though trees, like all other living organisms, grow, mature, and die. The forest, a community of trees, reproduces new trees to replace trees which have died.

Forests can also change from one type to another, due to changes in light, wind velocity, and temperature, as well as in the structure, depth, moisture, and fertility of the soil. This is the concept of plant succession. Succession is the replacement of the original vegetation by another type of vegetation which is better adapted to the modified environment. These changes continue to take place until the climax or final stage, which is in equilibrium with the environment, is reached.

In this sense forests are climax formations owing their origin to natural regeneration. Where natural regeneration is unsatisfactory, foresters may use artificial regeneration to increase stocking or to improve tree species. Natural and artificial regeneration in terms of plant succession play an important role in forest growth and development.

Figure 54.

NATURAL REGENERATION

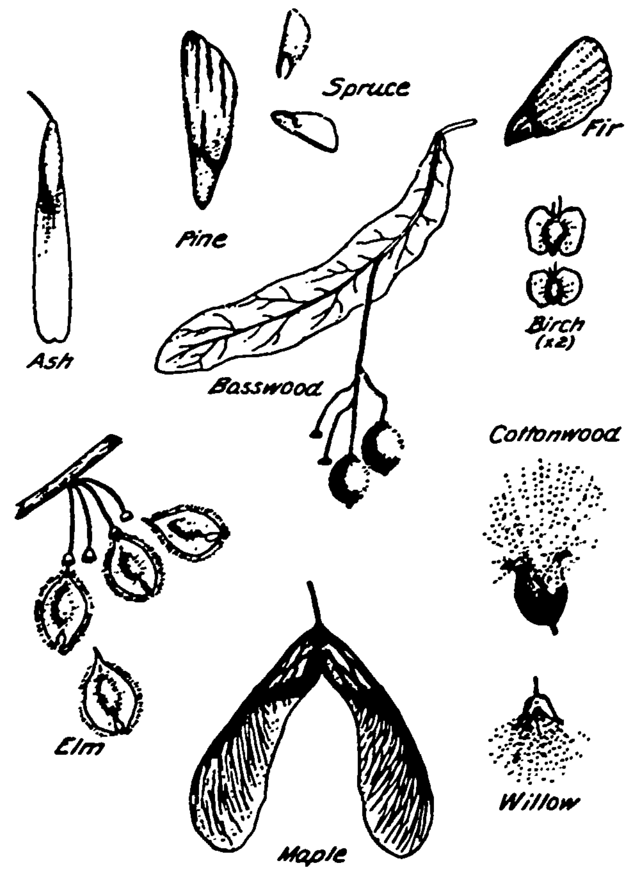
In nature, trees reproduce themselves in a variety of ways. These are: (1) vegetative reproduction which includes layering, sprouting, and suckering; and (2) sexual reproduction by seeding. The success of each of these reproduction methods depends on the tree species and the various environmental factors which determine succession. Most of the broadleaf (hardwood) trees will sprout (a shoot or tree originating from a dormant bud at the base of a tree or from a root) if cut when small; some like birch, oak, maple, and basswood will sprout regardless of age. If you see trees growing in a clump in the forest you might guess that they are from stump sprouting and if you look closely you might even find the original stump (figure 54). Other trees like black locust, lombardy poplar, and aspen will send up shoots from the roots at a considerable distance from the parent tree. This is known as suckering and the group of trees is called a clone. It is a result of surface roots in the soil being warmed either by fire or by sunlight entering the stand when logging removes trees.

The only American conifer (evergreen) which sprouts is the redwood, not native to Minnesota. Some Minnesota conifers may reproduce vegetatively, but by another method called layering. The lower limbs of black spruce, balsam fir, and white cedar sometimes touch the ground and where they come in contact with mineral soil or where moss grows over the limb in back of the branch tips, roots develop and finally the tip of the branch becomes a new tree. While layering occurs naturally, it is not an important reproduction method in terms of reproducing entire forests.

In some modern-day forestry practices we use the ability of trees to reproduce vegetatively. Entire forest stands, such as aspen, are allowed to reproduce by sprouting or suckering after logging and they are encouraged by applying prescribed burning methods. Cuttings from small branches of willow, poplar, and walnut bearing several new buds can be set in the ground to grow because they will develop roots. Other methods like budding or grafting are also used, but only to propagate horticultural varieties which are used in ornamental plantings.

Most forest trees grow from seed produced by sexual reproduction of the trees. If forests are to be successfully reproduced this way a number of favorable factors must be present in nature or created. First, there must be a seed source or trees that provide quality seed. By leaving individual trees or scattered blocks of trees during a logging operation or by cutting narrow strips of trees from the downwind side of the forest stand, a natural source of seed is provided for future reproduction. Once the seed is released it must be carried to a favorable site for germination. Site requirements vary with each species of tree; some requiring mineral soil, others growing only where there is a deep litter layer. Disturbing an area with logging equipment exposes mineral soil so some species of trees may grow if other environmental conditions are right.

Figure 55.



Since some trees mature their seed in the spring and others in the fall, and since seeds vary greatly in size and weight (figure 55), nature has developed several methods of scattering or planting the seeds. Among these are wind, water, gravity, or animals. Seeds from aspen and cottonwood are very light (3,600,000 per pound) and so perishable that they must come in contact with moist mineral soil within a few hours after their release. Since they are covered with a cottony down and are very light, they are carried by the wind. These two characteristics have enabled aspen to reforest many of the burned over areas after forest fires.

Some tree seeds such as cherries are dispersed by birds which eat the cherries and drop the seeds far from the parent tree. Other seeds have hooks or barbs that adhere to an animal to later drop off and regenerate at a distant spot.

Seeds of pine, maple, and basswood have wings and are carried by the wind, while the heavy nuts and acorns are often buried by squirrels and forgotten. Other seeds of trees such as the willows which grow along rivers and streams are carried by the water and deposited in the rich silt along the banks.

One species of tree, the jack pine, has cones which protect the seeds from fire. Most of the cones open the first autumn, but a few remain closed, sometimes for many years. Following a fire these closed cones will open from the heat (140° F.) and drop the seeds on the charred land, which is an excellent seedbed. In this way jack pine predominates on lands which originally carried red or white pine. This is simply one of nature's mysterious ways of ensuring ecological success.

We can use the information regarding natural reproduction of trees to reforest certain areas. In Minnesota we rely on natural seeding for reproduction of jack pine, white pine, Norway pine, black spruce, tamarack, and most hardwoods even though the conditions for good seeding are not always present in nature.

ACTIVITIES

Vegetative Reproduction I

List species of trees which reproduce by stump sprouting and those which reproduce by suckering. Try to find an example of each in a hardwood forest stand, recording the location. Follow this by taking black and white pictures of your examples and making an appropriate, well-labeled display, including some possible reasons why each clone developed or why each tree produced suckers.

Vegetative Reproduction II

Write a short essay examining the influence of the season of the year when cutting is done on the vigor and the growth of sprouts or the influence of age of the parent tree on the success of sprouting. Cut select species in an available forest stand to try to reproduce the species vegetatively at various times of the year.

Cuttings

Grow some cuttings from black walnut, cottonwood, willow, and others. In the spring of the year immediately after the frost has left the ground select your cuttings. Make sure they have new buds on the branches and that they are about 18 inches long. Place the cuttings in the soil where they can get moisture and observe how quickly they take root. This can also be done in damp sand flats in the classroom.

Seed Dispersal

Make a collection of seeds to learn the various methods of seed dispersal. Your classification can be based on the type of seed produced, such as those with cottony down or wings or by the manner in which the seed is dispersed: by wind, gravity, water, or animals. Mount the seeds on an appropriate display either by gluing them directly to the board or by putting them in display bottles. Identify each species by its common name.

Make a list of tree species in your area showing how often they produce good seed crops. Observe and make a record of this information for selected trees in your area over a period of years.

Natural Reproduction

Lay out an area approximately 6 feet wide by 18 feet long near a seed source such as a pine, elm, maple, or spruce tree or groups of trees. Divide the area into 3 plots of equal size. On 2 plots remove all the vegetation and cultivate the soil to a depth of 6 inches; leave the other plot alone (called a "control" plot). Keep one plot free of vegetation from spring until fall (one year). Then allow it to vegetate naturally starting the spring of the second year. Note any tree seedlings which germinate. Leave the plot unattended until the third year. Note any new tree seedlings and the growth of seedlings noted in the second year.

On the second plot, immediately after clearing and cultivating, plant 25 seedlings, or 25 seeds, approximately one foot apart. Note their survival over the second and third year. Note also any trees which have seeded naturally. How do these plots compare? Which is the best and quickest way to assure tree reproduction? What observations can you make about animals found in or near the plots (this includes earthworms, spiders, insects, and larger species such as moles, mice, rabbits, etc.).

ARTIFICIAL REGENERATION

Modern forest management carefully considers the role of ecological succession in the reproduction of forests by providing for natural regeneration. In most of Minnesota's forests, natural regeneration proceeds slowly so planting is necessary to remove the forest cover or to provide more desirable tree species. For this foresters use methods of artificial regeneration to insure forests' future growth.

The methods of artificial regeneration are commonly referred to as reforestation. With today's emphasis on the multiple use concept of forest management, reforestation has been broadened to include any artificial tree planting for the purpose of increasing the value of the land, to protect the watershed, to establish wildlife habitat, to protect the land from erosion, or to create beauty. It is in this light that the two principal methods of artificial regeneration, direct seeding and planting, are considered.

Direct Seeding

Direct seeding is the process of sowing or planting seeds of a certain species of tree to be established on an area. The several methods of direct seeding include hand sowing seed (or using a cyclone seeder or on the back of a motorized vehicle), or by air with an airplane or helicopter (figure 56). These methods are commonly used for seeds that are dispersed by wind. Larger seeds such as walnuts or hickories are planted by hand.

The seeds of most tree species must fall on exposed mineral soil, consequently, foresters treat the soil before such methods are applied. Some of these methods include discing or controlled burning of the forest litter.

In Minnesota, direct seeding is used to establish such species as jack pine, Norway pine, and black spruce, because seeding has the advantage of being faster and lower in cost. This is true in areas with dense underbrush, burned areas with logging debris, or open areas where proper seedbed preparation has been done before planting begins. Unfortunately, the results of direct seeding have varied and sometimes completely failed.

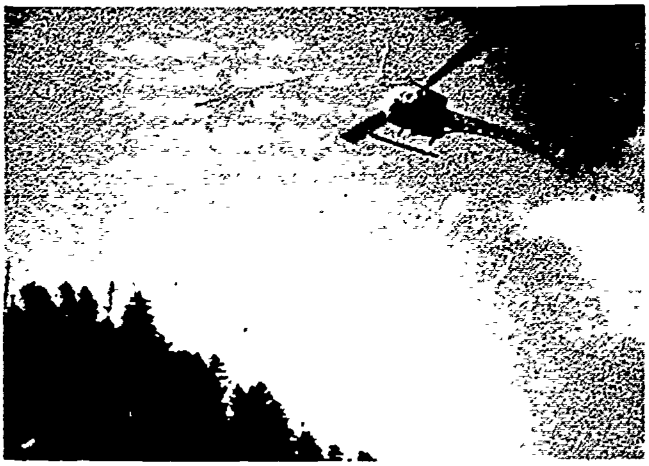


Figure 56.

Planting

Trees are planted for a number of reasons in Minnesota. Trees increase land values whether planted to restore idle acres to useful purposes, to establish wildlife habitat, to protect against wind and erosion, to produce forest products, or simply to create beauty. To-date over 880,000 acres of trees, consisting mostly of coniferous species, have been planted in Minnesota on publicly owned lands. Over 30,000 acres of land are planted each year on state, county, federal, industrial, and small private ownerships.

Choosing the species of tree to meet the purpose of the planting is but one of the factors to consider. The general site, soil, and moisture requirements of each

Figure 57. Soil texture table.

Moisture condition	Soil texture: Sandy‡‡ (coarse)	Loamy (medium)	Clayey** (fine)
Wet*	Willows Cottonwood	Willows Cottonwood	Willows Cottonwood
Moist†	Red pine White pine Black spruce White spruce	Black walnut Cottonwood Silver maple Colorado spruce White spruce White pine	Cottonwood American elm Green ash Silver maple Colorado spruce White spruce
Moderately dry‡	Ponderosa pine Jack pine Scotch pine Red pine	Green ash American elm White spruce Ponderosa pine	Green ash American elm Silver maple Cottonwood Eastern redcedar
Dry§	Jack pine Scotch pine Ponderosa pine	Green ash American elm Eastern redcedar	Green ash American elm Eastern redcedar

* Subject to standing water from a few hours to a few weeks.
** At least one-third clay.
† The most moist sites in the forested part of the state exclusive of bogs and other sites classified as wet. This would include north-facing slopes having deep soils in southeastern Minnesota, areas where water tables are between 3 and 8 feet below the surface, etc.
‡ The nonforested part of the state in general, exclusive of river bottoms. Also level areas where water tables are beyond 8 feet in the drier forested parts of the state. Other similar sites.
§ Water tables below 12 feet in the nonforested parts of the state. Driest sites in the forested parts of the state such as southwestern facing slopes in southeastern Minnesota. Shallow soils less than 3 feet in depth.
‡‡ At least two-thirds sand.

Figure 58.

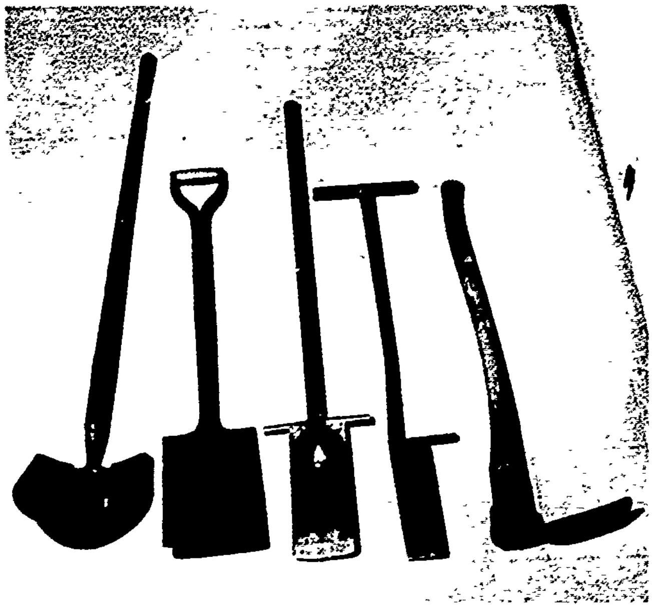


Figure 59.

species should also be carefully considered. For example, pines grow better in sandy soils than in fine-textured soils: the opposite is true of hardwoods. On fine-textured soils with poor drainage, spruce, balsam fir, and cedar are recommended (figure 57). Besides the factors of moisture, soil characterictics, and competition with other vegetation, consider the amount of exposure to wind and sun, the possibility of animal, insect, or disease damage, and the species' ability to endure Minnesota's severe winter climate. These factors are particularly important when the trees planted are not native to this climate. Observe tree species that are growing near you to determine how they will do if you plant them. For further information, see "Planting Trees in Minnesota," Agricultural Extension Bulletin No. 350, University of Minnesota.

Field planting of trees is done by hand or by machine (figure 58), with the method of planting dependent on such things as the availability of labor, the steepness of the terrain, the type of soil, and the length of the planting season.

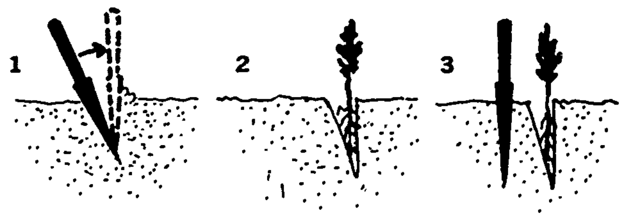
Hand planting allows for greater care and generally better survival of the trees. The commonly used tools include the round-pointed shovel, the mattock, the grub hoe, and the planting bar or dibble (figure 59).

The following diagram illustrates the proper way to plant a tree seedling with the planting bar (figure 60).

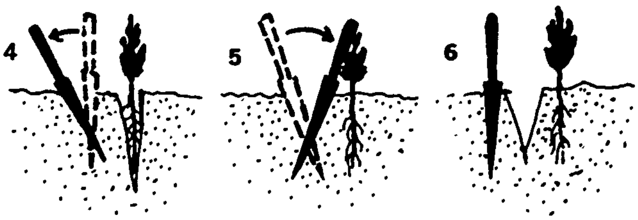
Mechanical tree planters were developed shortly after World War II to supplement hand planting, which is much slower. In an 8-hour day, the average man can plant about 400 trees in rough, rocky land, or 800 in smooth, sandy land. With the planting machine, it is possible to plant up to 1,000 trees per hour. Its major disadvantage is that it cannot operate on rough topography or in wet soil. It is not economical to operate on any area less than 5 acres large. Since most tree planters are expensive and only used occasionally, they are loaned to private landowners in nearly every county in Minnesota by the district forester, county agent, or district soil conservationist. A nominal fee is usually charged for maintenance and repair.

There are two major types of mechanical tree planters in use today: one is attached to an ordinary farm tractor, using that tractor's hydraulic system; the other

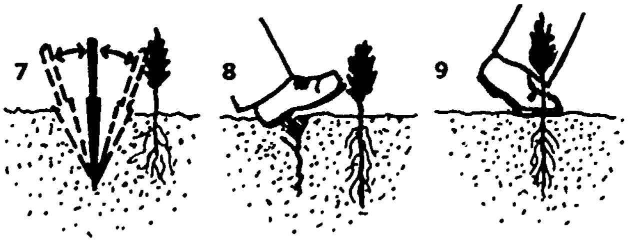
Figure 60. Using the planting bar following furrowing.



1. Plunge bar at above angle, then push forward to upright position. 2. Place seedling against flat side of planting hole. 3. Plunge bar into ground 3 inches from seedling.



4. Pull handle of bar toward planter, firming soil at bottom of roots. 5. Next push handle of bar forward to pack soil at top of roots. 6. To close hole, plunge bar into ground 3 inches from last hole.



7. Work it forward, then pull backward filling hole. 8. Last hole can be filled by tramping in loose soil with heel. 9. Stamp loose earth around seedling with feet to prevent air pockets.

Figure 61.

is pulled by a tractor, but operates independently. These are the essential features of a mechanical tree planter (figure 61).

The need for planting trees is obvious, faced with an increasing population demanding more forest products. With the land area for growing trees decreasing because of the construction of new power lines, home and industrial sites, and recreation areas being established, trees will have to be grown more efficiently on the existing land. Natural regeneration cannot meet this objective alone. Artificial regeneration is a necessary supplement.

ACTIVITIES

Seed Germination

Many projects relate to seed germination. Think of an experiment showing one or more of the following:

- The effect of cold on germination.
- The effect of light on germination.
- What is inside a seed?
- What happens when seeds are planted upside down? Sideways?

Use bean seeds or seeds easy to germinate. Place some of these against the glass in a jar so you can observe the underground actions.

After plants have germinated there are other projects you might consider such as:

- How do plants respond to light?
- How do nutrients get from the soil to the leaves?
- The process of photosynthesis—light and chlorophyll relationship.
- The transpiration process.
- Plant genetics.

Tree Seed Germination

Environmental factors such as water, temperature, and light affect the germination of seeds in different ways. Conduct a seed germination test using the following procedure to determine how each environmental factor influences germination. Collect or obtain some seed from different tree species native to Minnesota, such as oak, red pine, or jack pine. Using three circular pie plates or other suitable pans, line the bottom of each with three or four layers of paper toweling. Place 20 seeds from one tree species in three separate pans and cover with one or two layers of paper toweling. To the first add enough water to submerge the seeds; to the second only enough to moisten the toweling; and to the third no water at all. Store at room temperature and check daily, maintaining the water levels as described above. Determine which moisture conditions give the best results (that is, number of seeds germinating). Repeat using other seeds from different species. Also try varying the temperature or light for one or more different species. After you have determined the best moisture, temperature, and light conditions for one individual species, conduct a test to determine the germination percentage; for example, if you use 100 red pine seeds and 72 germinate, your germination percentage is 72 percent. You will be surprised how germination percentage varies with individual tree species.

Growing Pine Seedlings

Most Minnesota timber species are conifers. The seeds are found in cones on the tree. When the cones ripen in the fall they are gathered; the seeds are removed from the cones, cleaned, and planted in a seedbed. In late fall the seedlings are dug and lifted for planting. They can also be left until the following spring when they can be lifted for planting.

Collect cones from healthy, straight trees as soon as the cones change color from green to brown or on the collection date recommended for that particular tree species. Gather enough cones so you will have seed for at least 200 seedlings. Then follow the procedure outlined in *Growing Trees From Seed,* Agricultural Extension Service Folder No. 249, University of Minnesota.

After the seedlings are 2 years old, transplant to your forested area, windbreak, or recreational area. Take pictures during your project and keep a diary of your activities.

Planting a Windbreak or Shelterbelt

Plant or assist in planting a farm windbreak or shelterbelt. Develop a plan on paper and a model before you actually plant. Contact your county agent or extension forester for information on how and what to plant in your area. See *Planting Trees for Farmstead Shelter,* Agricultural Extension Service Bulletin No. 196, University of Minnesota.

Forest Planting

Make a planting of at least 500 trees on your land or a rural area near your community. Select an appropriate area of about ½ acre and examine the site to determine what species will do best. Select at least four different species of trees that would be best suited to the land and that would best suit the purpose of the planting (wildlife habitat for example). Determine the number of trees of each species you will need for the area by considering the desirable spacing for that particular species. Make a cover type map of the area and construct a model using suitable materials. You might want to take pictures of your planting to keep with your planting record (figure 62).

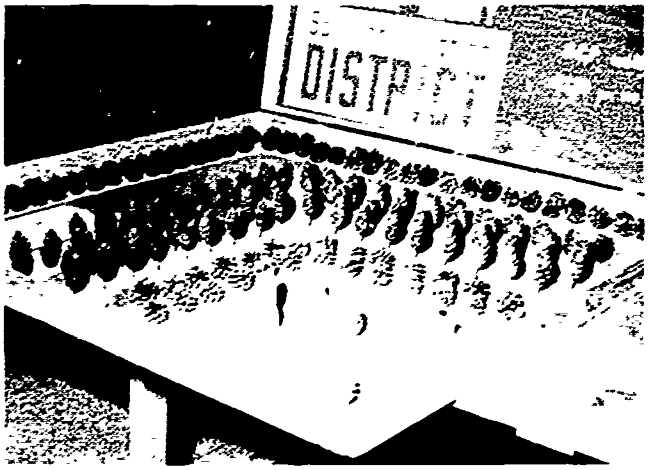
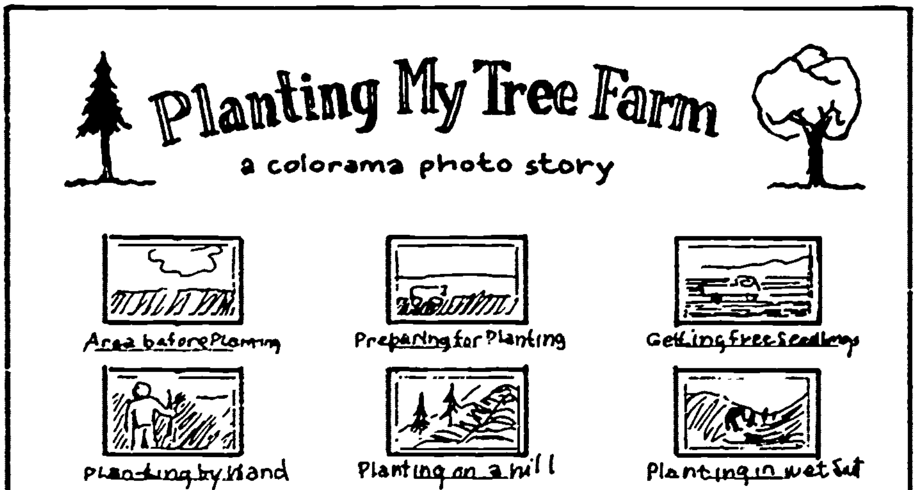


Figure 63.

Construct a Model of a Farmstead Shelterbelt

Use different types of cones to represent different species of trees. Label the different species. Indicate the dimension of the shelterbelt and distances to buildings, roads, etc. (figure 63).

Figure 62.



VI. What is Forest Improvement?

Many unmanaged forests could be improved if certain treatments known as forest improvement were applied to the forest during development. This involves the application of treating individual trees through cultural practices. These practices are intended to make the forest better by increasing the quality of trees and at the same time speeding up the growth rate. These cultural practices are: (1) noncommercial thinnings; (2) commercial thinnings; (3) prunings; and (4) control of undesirable species.

NONCOMMERCIAL THINNINGS

Thinning means cutting some of the trees in the forest stand. Noncommercial thinnings are those which improve the quality of the forest stand but are not intended to return an immediate profit. None of the trees felled is removed and used. Noncommercial thinnings include weeding, cleaning, liberation, and improvement cuttings (figure 64).

Weeding is the removal of all plants competing with the timber species. Rarely is there a market for any of the weed species of trees removed for they are too small. Usually they are cut and left where they fall. This very intensive practice is hardly ever used in forests, but is frequently practiced in forest nurseries where both woody and herbaceous weeds are removed.

A similar method, cleaning, is a treatment applied in stands of trees up to the sapling size (less than 4 inches in diameter). It is intended to release desirable trees from the competition of undesirable trees of about the same age. These trees overtop the desirable species or they are likely to. None of the undesirable species removed is used. This practice and liberation cutting are referred to as timber stand improvement (T.S.I.).

The removal of trees which overtop seedlings or saplings is often referred to as a liberation or release cutting. This treatment is made to release young stands, not past the sapling stage and usually between 1 and 20 years old. The older and overtopping trees may be a desirable species but poor form (called wolf trees), or species less desirable than the young stand. If the older or overtopped trees are marketable, they can be removed by a commercial sale. But often there is no market for such trees so they are killed or disposed of cheaply without endangering the stand's desirable trees. Methods of killing or disposing of the trees include girdling, felling, and poisoning.

The final noncommercial thinning operation, an improvement cutting, is a thinning made in a stand past the sapling stage (more than 4 inches in diameter at

Figure 64. Killing the tree by girdling.

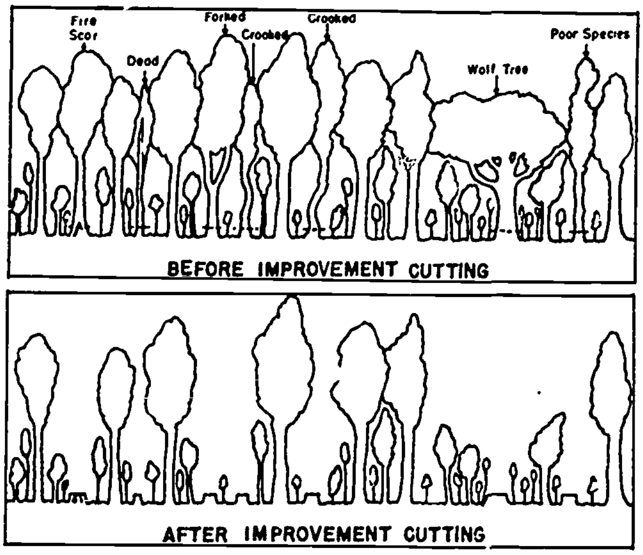
breast height) to improve composition and character by removing trees of less desirable species, form, and condition (figure 65).

The undesirable trees may be removed by making a commercial timber sale if it is marketable size. However, if the trees are culls and cannot be sold, it is necessary to kill them and leave them in place.

COMMERCIAL THINNINGS

The primary purpose of commercial thinning is to improve the quality of the trees left standing. Secondarily, it is to return a profit from the removal of trees which are interfering with the quality of growth of the

Figure 65.



remaining trees and removal of trees which would not live until the next thinning or final harvest.

Commercial thinnings are most often applied to even-aged stands (all the trees are nearly the same age) such as plantations (figure 66). These stands may contain more trees than the land is capable of sustaining. When the trees become so crowded that the tops are competing for available sunlight, enough trees should be removed periodically to maintain normal growth of trees to be kept through to the final harvest. Crowding is evident when the live crown of the average tree in the stand becomes one-third or of the total height of the tree. Another indication of crowding is when the smaller, individual trees begin to die.

The result of overcrowding in any forest stand is a keen competition for the available water, light, and the soil nutrients. This competition results in a forest stand in which there are suppressed or deformed trees; low value species crowding out valuable species; and slow growing trees. Figure 67 shows the effect of thinning on tree growth.

Some crowding is desirable in young stands so that the lower branches will be shaded out causing them to die. This develops long, clear stems that will later yield knot-free lumber. The thinning operation should be conducted when the trees to be removed have a marketable value for such products as fuelwood, fence posts, or pulpwood.

A simple rule-of-thumb that most foresters follow in spacing the thinned trees for maximum timber production is to add 6 to the d.b.h. in inches. The resulting figure in feet is a good spacing for trees of that diameter. For example, the recommended spacing for trees averaging 6 inches in diameter at breast height would be 6 plus 6, or 12. This means an average spacing of 12 feet between trees so that a well-stocked stand of 6-inch d.b.h. trees should have about 300 trees per acre.

Thinnings are usually conducted every 5 to 10 years or until the crowns of the trees come together again. If the stand has been properly thinned, there should be 150 to 200 trees per acre at the time of the final harvest (approximately 120 years for Norway pine).

These simple rules are not a substitute for common sense in the field. A clump of eight or ten good trees, such as a basswood clump, with sufficient room on the outside but crowded on the inside, might be thinned to two or three of the best trees; or cutting of perhaps only three trees might give the rest enough room to grow. Each tree should be assessed for its chances of growing into profitable timber.

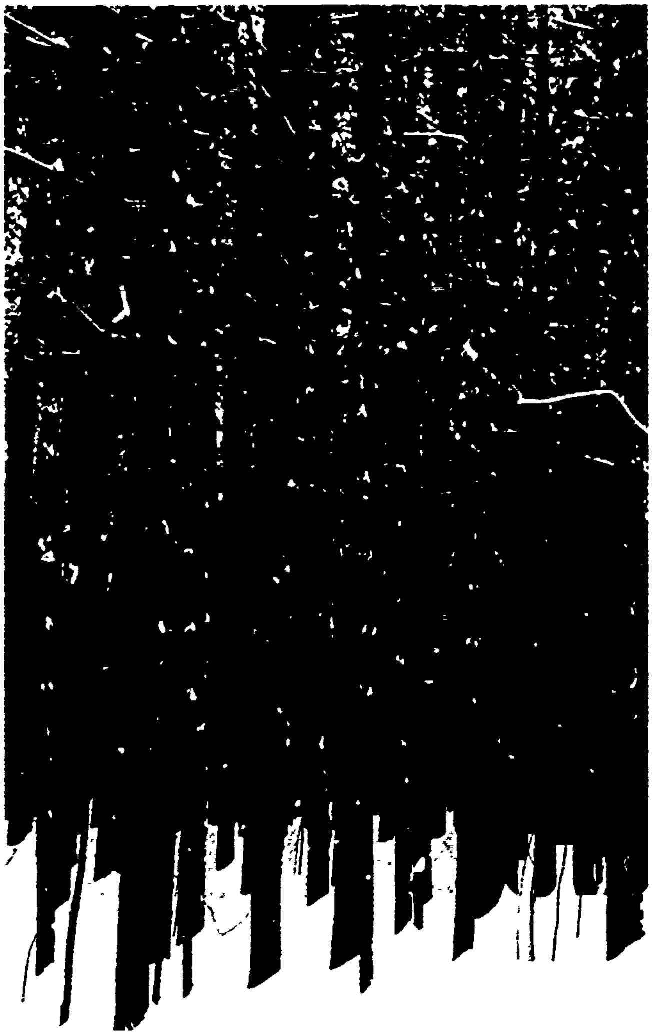


Figure 66.

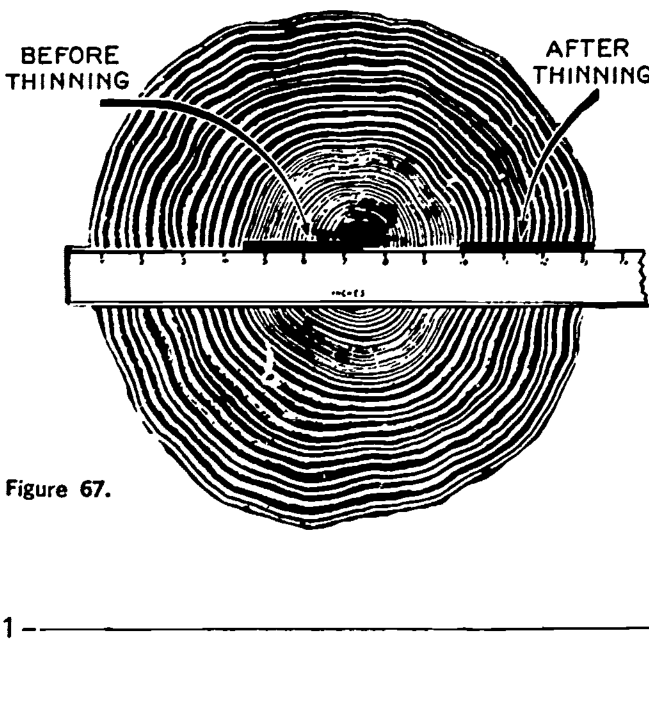


Figure 67.

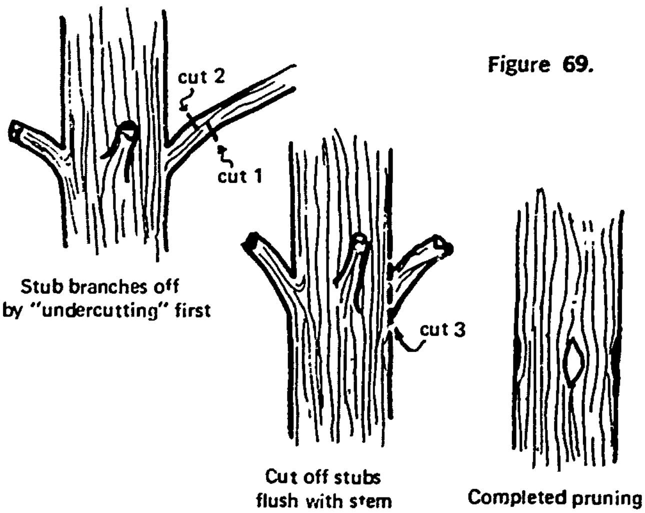
If some of the trees to be removed in a commercial thinning have no marketable value the forester may recommend that they be killed and left. Three common methods are used to kill trees for this purpose. The first is to simply kill the trees by cutting with a power saw or other cutting tool. The second is to girdle the trees which will be removed at a later date. This involves cutting completely through the sapwood around the trunk of the tree with a hatchet or an ax. Once the cambium is severed, the tree will die. The third method is to poison the trees. Poisons are either injected with a special tool or they are applied in frills (cuts made through the bark and cambium) using a hatchet at intervals every 6 inches around the trunk. Lethal dosages of herbicides such as Ammate or 2,4-D are used to kill undesirable trees.

PRUNING

The removal of live or dead branches from the main stem of a standing tree is known as pruning (figure 68). Forest owners can afford to prune the most promising trees in some open-grown young stands. Pruning increases the yield of knot-free, high-grade lumber that can be obtained from any one tree, particularly in the butt log (first 16 foot log) of selected crop trees.

Figure 68.

Figure 69.



If you look closely at a forest stand you will notice that trees around the perimeter of the forest have branches almost all the way to the ground. When you enter the interior of the stand you notice less branching on the lower portions of the trees. This is nature's way of pruning trees. The lower branches die because they are shaded out by the upper branches. However, if there is no natural pruning taking place in a forested stand, foresters will sometimes use a pruning saw.

Only about 200 to 300 trees per acre should be pruned. These should be trees that are sound and well-shaped and can be left for crop trees at the final harvest. The first pruning in any stand should be done when the trees are young and 3 or 4 inches in diameter. At this age the wounds heal rapidly leaving only small knots. The best time to prune is just before the growing season begins and before the buds begin to swell. All pruning cuts should be as close to the main stem as possible without injuring the bark (figure 69).

Individual trees should be pruned to leave the upper 30 to 40 percent of the tree in the live crown. Second prunings are usually needed in later years to get a knot-free, 16-foot bole or butt log. This operation should be conducted after the trees reach 8 inches in diameter or when the limbs to be removed exceed $1\frac{1}{2}$ inches in diameter. The trees in the forest stand should remain growing for at least 25-50 years to obtain a profitable return from pruning.

CONTROL OF UNDESIRABLE SPECIES

In young forest stands, less valuable trees, known as weed trees, may crowd the better trees from which more desirable forest products may be obtained. These weed species should be removed or killed. Realize that some of these undesirable species, such as aspen or willow, are preferred by wildlife, consequently some trees may be left for wildlife food and cover.

Wolf trees, described on page 40 should be cut for sale or home use or killed. In addition, all diseased and insect-infested trees should be removed as they are sources for infestations in healthy trees. Severely damaged trees due to wind or ice storms should also be removed.

Undesirable trees can be controlled by tree injection, frilling, girdling, stump treatment, basal spray, and foliage applications of various chemicals. They can also be controlled mechanically with brush cutters, tractors equipped with cutting and shearing blades, and sometimes prescribed burning. Each of these methods is suited to different conditions and species and sometimes a combination of methods is the best approach.

The forest will probably grow by itself, but it will grow faster and more profitably when tended. The forest landowner's goal should be to have as many trees as possible of the best species and quality while still maintaining a good rate of growth. The stand must be neither too thin nor too overstocked and undesirable species eliminated. To meet this objective, the forest landowner must apply certain methods of timber stand improvement or cultural practices. It is not an easy job. It may take years to realize progress toward the development of sustained yield management.

ACTIVITIES

Thinning

Visit a tree plantation. This can be a Christmas tree plantation, a newly planted shelterbelt or windbreak, or a forest plantation. Record the condition of the plantation. What kind of trees are in the plantation? How old are they? Are they all the same height? If not, why? Is there any evidence of damage to individual trees? What caused the damage? What would you do to protect the plantation? What products might be harvested from it? Does it need thinning? How many trees per acre? Consider writing a plan for thinning, pruning, protecting, and harvesting the plantation. Use your camera to add to your record and plan.

Timber Stand Improvement

Mark a mixed hardwood stand of varying ages, such as the following (figure 70), for an improvement cutting.

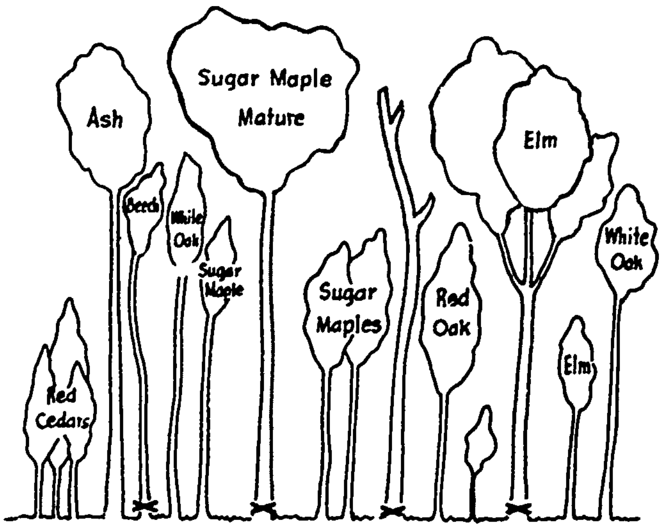


Figure 70.

Lay out one or more areas to be improved by marking the corners of the plot. Stakes can be placed in the ground to mark the corners or trees located on the corners can be marked by painting a 2-inch band around the tree at breast height. Include at least two line stakes or marked trees also on the sides of the plot between each corner.

Select and mark each tree to be removed using the following guidelines:

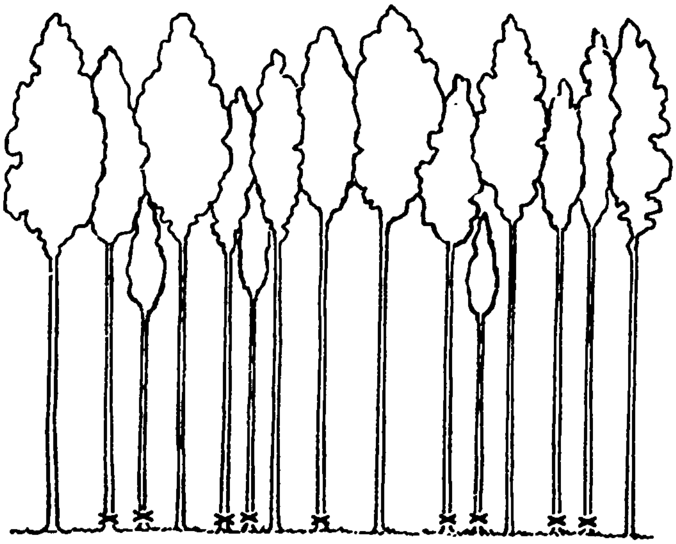
(1) diseased and insect-infested trees
(2) trees with fork, crook, or other poor form
(3) trees much larger than the rest of the trees (wolf trees)
(4) overtopped and suppressed trees of poor vigor
(5) undesirable species of trees

A circular mark about 4 inches in diameter made with bright colored paint at breast height can designate trees to be removed. Mark only the trees to be removed. If you are in doubt whether a tree should be removed, let it stand, since it can always be cut later during a thinning.

Make a record, by number and species, of all trees on the plot 4 inches or more in diameter at breast height. These should be separated into two groups: those to be taken and those to be left. When all of the trees are marked, ask your county agent or local forester to check your plot.

If possible, conduct the actual removal of the trees by cutting, girdling, or poisoning them. Ask an adult to supervise these activities.

Figure 71.



Establishing a Thinning Plot

Mark a typical even-aged pine stand such as the following (figure 71) for a commercial thinning. Use the procedure outlined in the forest improvement activity to lay out your study area.

Select and mark the trees to be removed on the basis of the final desired spacing. First establish a 1/100-acre circular plot in the study area to determine the number of trees per acre. A rope 11.8 feet long tied to a tree in the center of the plot will be sufficient. Count the number of trees that lie within this circle. This number, multiplied by 100, will give you an estimate of the number of trees per acre.

"Thin" the area to about 300 trees per acre (about 4 to 6 feet of free space in the crown for best growth) by marking the trees to be removed. These should be crooked, forked, and defective trees that would never make good sawlogs, poles, or piling.

Again ask your county agent or local forester to check your marking job. Trim, stack, and measure the felled material. Keep a careful record of the work, showing the time and cost of laying out the plot, marking, felling, and working up the material, and the ultimate sale value of the products.

Pruning

Develop and give a demonstration using various charts and drawings showing the number of trees to prune, correct ways to prune, and type of trees to prune. If possible assist in an actual pruning operation in a forest stand.

Effects of Forest Improvement

Make a drawing of a cross section of a tree (or obtain an actual cross section) to show the effect of thinning on tree growth. Your cross section should include the pith, heartwood, sapwood, cambium layer, inner bark, and the outer bark as well as the annual growth rings. Do a similar project to show how a tree grows over a pruned branch stud.

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