Student Reference on FORESTRY

Department of Agricultural Education
The University of Arizona, Tucson

SPECIALIZED CURRICULUM
Student Reference Number Three
Student Reference
on
FORESTRY
for
Specialized Curriculum
in
Agricultural and Renewable Resources

Student Reference Number Three

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FOREWORD

This publication is one of a series of student references developed to complement the Specialized Curriculum in Agricultural and Renewable Resources for Arizona. The primary purpose of this publication is to serve as a reference for students studying Forestry.

The significant value of this publication is that the information on the agricultural and renewable resource subject matter in question is contained in one basic student reference. This is not to infer that additional references, such as textbooks, bulletins, etc. should not be utilized to supplement instruction. From an educational standpoint, students learn more and better when they glean information and acquire knowledge from several related sources. In addition, there is significant educational value for students by having them read and study pertinent reference material as they "dig out" answers to questions and/or solve problems identified by their teachers.

It is anticipated that teachers of agriculture will find the student reference on Forestry a valuable aid to assist them in providing meaningful instruction.

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Nathan Moore - Westwood  
Ken McPadden - Greenway

Final editing of this publication was completed by Dr. Floyd G. McCormick and Mr. Don K. Lindsey, Curriculum Specialist of the Department of Agricultural Education, University of Arizona.
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FORESTRY

INTRODUCTION

When people first invaded the North American continent, a vast forest covered much of what is now the United States of America. The original forest covered an estimated 900 million acres - more than 50 percent of the total land area. Many of these early settlers viewed the forest as a source of building materials and fuel wood. At times, however, the forest was viewed as an obstacle to progress. The land occupied by the forest had to be cleared for crop production and this required back-breaking labor. Corn and tobacco crops would not grow in the shade of the towering trees. Too frequently they harbored unfriendly Indians.

Commercial use of our forest began sometime in the seventeenth century. These commercial logging operations, while in the process to supply a growing nation with lumber, cut vast areas of timber with little thought of regrowth. Thousands of acres of land were also cleared for farming. Much of this land proved to be too poor for profitable agriculture. Many acres were too sandy or rocky and would not grow corn or tobacco.

Long before there was a serious shortage of timber, thoughtful people became concerned about how the forests were being "slaughtered". Through their efforts, laws were passed regarding the nation's forests; its conservation and wise use. Many of the present day conservation programs were brought about by the patient efforts of a few farsighted people who were often opposed by powerful individuals. Due to the efforts of these people there remains about three-fourths of the original forest area, estimated at 759 million acres, in the United States.
Besides being a large group of trees the forest has many beneficial influences. In addition to wood products, forests provide wildlife with food, water, shelter, and a breeding area. They provide nesting sites for birds, hiding places for animals, food for squirrels, and a shelter from the environment. If trees are destroyed certain animals disappear while others will use a different ecosystem.

Forests help prevent flooding and erosion. Falling raindrops are interrupted by the leaves of trees; slowing their fall. The forest floor with good plant cover, ground litter, and humus functions like a blotter. It soaks up water from rain. A non-forested area cannot absorb water as fast as a forested area. Bare soils seal over quickly and cannot absorb rain water as fast as forest soils which are high in litter. Trees send their roots deep into the soil keeping it porous and thus increasing its water holding capacity. Trees on a slope protect and hold the soil in place. These trees help to prevent the soil from washing down and polluting or filling streams and ponds. Erosion by wind is reduced by a forested area. The drawing in Figure 1 illustrates how wind speed is greatly reduced by windbreaks. Winds in treeless areas remove, dry out, and increase evaporation of soil.

Fig. 1.—Influence of a windbreak on wind speed and currents.
Forests influence the climate over the area they occupy (microclimate). The forest intercepts the sun's rays; thus, reducing the heat and light on the forest floor. The effect of the forest on temperature is most apparent during the summer months when it may be six to eight degrees cooler under the forest canopy. Loss of water by evaporation from the soil is considerably less in a forested area than in an open area. During the winter season the forest is slightly warmer than non-forested areas. This is due to an insulating effect of the forest canopy. Forest vegetation shades streams from the full heat of the sun; thus, contributing to the prevention of higher stream temperatures. Warmer temperatures are undesirable for most fish.

Besides all the other beneficial effects of the forest, it provides many Americans with recreation. Every year millions of American families escape the pressures of urban living by visiting forests. Many people visit a forest to enjoy its natural beauty, peacefulness, and wildlife. Whatever the reason for visiting the forest, each individual leaves with a better understanding of nature.

In Arizona the ponderosa pine (Pinus ponderosa) accounts for over 90% of all harvested timber. Douglas fir, white fir, Englemann spruce, blue spruce, limber pine, and aspen make up about 10% of the balance. Aspen is mostly used for special products such as evaporative cooler pads, toys, and boxes for food because it does not impart a "taste". Alligator juniper and other junipers are often used for fuel wood and fence posts. Arizona has over three million acres of commercial forest lands. Most of this land is managed by the U.S. Forest Service or the Bureau of Indian Affairs.
MULTIPLE USE CONCEPT

The term multiple use means the management of public lands so they meet the present and future needs of the American people. Management will include recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific, and historical values. Note that the greatest economic return is not the goal. Because of this concept the government agencies employ specialists in all these areas. In fact, the U.S. Forest Service is the largest single employer of professionals and non-professionals in forestry.

The Multiple Use Act of 1960 and the Federal Land Policy and Management Act of 1976 (Organic Act) broadened the authority of the National Forest Service and Bureau of Land Management to manage our public lands. These public lands must now be managed for multiple use.

CHARACTERISTICS AND GROWTH REQUIREMENTS

A knowledge of tree growth habits, tree names, and tree identification are the ABC's of beginning forestry. With this knowledge people can better apply forestry practices to their woodlands. It is just as important for foresters to know their trees as it is for a rancher to know the different breeds of livestock, their characteristics, and how to care for them.

Tree Parts

A tree is defined as a perennial woody plant with a single main stem or trunk attaining a height of at least twenty feet and a diameter of over four inches at maturity. As shown in Figure 2, a tree is composed of three main parts: (1) roots, (2) trunk or bole, and (3) crown.
Roots: Tree roots, like other rooted plants, serve a double purpose. They take up water and minerals for the tree and anchor it securely to the ground. Roots extend deep into the ground and tend to anchor it against winds and other forces of nature. Some tree roots, like the oak tree, are very extensive. An oak tree 37 feet high may have a root system which thrusts downward to a depth of 14 feet, and may extend outward in a circle around the base for 60 feet. On the other hand, some trees are shallow rooted and only extend a few feet into the ground. Tree roots absorb water, oxygen, and soil nutrients such as nitrates and phosphates. Most root systems are exposed to a large surface area of soil by many root hairs. These root hairs absorb water and dissolved nutrients and carry them upward to the rest of the tree. An additional function of some tree roots is food storage. During periods of stress, when the food-making process (photosynthesis) is reduced by drought, cold, or leaf-consuming insects, the starches held in the roots are converted into sugars and transported upward through the trunk to the food-deficient parts.

Trunk or bole: The tree trunk or bole is the most valuable part to forest industries. The trunk is the primary source of wood for construction materials, paper pulp, plywood, furniture, etc. The trunk conducts dissolved nutrients to the branches and leaves of the tree. It also acts as a storage area for certain plant foods and supports the crown. A cross section of a typical tree trunk is illustrated in Figure 2. The trunk consists of heartwood and sapwood which form a series of growth rings, one for each year of the tree's life. The darker center core is known as the heartwood, and the lighter layer encircling it is known as the sapwood. The sapwood is the light
HOW A TREE GROWS

Trees increase each year in height and spread of branches by adding on a new growth of twigs.

Light and heat are required by the leaves in the preparation of food obtained from the air and soil. The leaves give off moisture by transpiration.

CROWN

Heartwood (inactive) gives strength.
Sapwood (live) carries sap from root to leaves.

TRUNK

Cambium (layer of cells where growth in diameter occurs) builds tissues—wood inside and bark outside.
Inner bark (phloem) carries food made in the leaves down to the branches, trunk, and roots.
Outer bark protects tree from injuries.

ROOTS

Root hairs take up water-containing small quantity of minerals in solution.

The buds, root hairs, and cambium layer are the growing parts. The tree takes in oxygen over its entire surface through breathing pores on leaves, twigs, branches, trunk, and roots.

Fig. 2.—Biology of a tree.
(Courtesy: U.S. Forest Service)
colored layer nearest the bark of a tree. Sapwood is composed of xylem cells that transport water and soil nutrients. As the xylem cells get older they gradually become so clogged with sap, gum, and resins that they lose their conducting function. They then become part of the heartwood.

The heartwood (Figure 3) is made of dead sapwood cells that function to provide support. The striking color of some heartwood, such as walnut, red cedar, and redwood adds greatly to the wood's value. Heartwood of some trees often rots leaving a hollow trunk. This hollow trunk serves as a home for animals. Growth in diameter takes place in the cambium layer located between the sapwood (xylem cells) and inner bark (phloem). Growth occurs when the cambium layer gives rise to new xylem cells on the inside and new phloem cells on the outside. The inner bark conducts food made in the leaves down to the branches, trunk, and roots for tissue growth.

Food supplies of animals is often lost by covered snow. Many of these animals may girdle trees. This is done by removing a section of the inner and outer bark all the way around the tree. Because this cuts off the food supply to the roots the tree dies. The outer bark is a layer of non-living protective tissue. The bark or cortical tissue is produced by another cambium layer called the cork cambium. As the tree grows in diameter, the pressure created by interior growth causes the bark to split and form ridges, scales, or plates.

Crown: The crown is the food manufacturing part of the tree and is composed of leaves, twigs, branches, flowers, fruit, and seeds. It is in the leaves that food is manufactured by
photosynthesis. After food is manufactured by the leaves it is used for respiration, stored as starch, or moves down through the inner bark (phloem) to the growing parts of the tree.

Tree Growth

Each year new growth comes from the buds, cambium layer, and root tips. New twigs, flowers, and leaves are produced by these young tender buds. The crown increases in height and spread by adding on a new growth of twigs.

Fig. 3.--Cross section of a tree trunk.
Root tips are where growth in length, water absorption, and most root development takes place. The tip of the root is covered by a root cap made from a mass of protective cells. Just back of the cap is the growing point.

Seasonal growth in trunk diameter occurs in the cambium. Growth in diameter is due to the division and growth of cambium cells. The trunk grows in diameter when cells of the cambium layer divide to give rise, on the inner side, to new xylem cells and new phloem cells on the outside. This growth creates annual rings which are noticeable in cross sections. A close examination of a tree's cross section will reveal that each ring is made up of a darker-colored area called summerwood, and a lighter-colored area called springwood. Springwood cells are thin-walled and large; summer wood cells are thick-walled and small. Cells formed in the spring, when growth is rapid, are larger than those formed in the summer. This difference in cell size accounts for the color differences.

Variations in annual ring widths tell the story of a tree's growth. Trees growing close together, thus at a slow rate, produce narrower rings then those spaced wide apart. Thin ring widths can indicate a dry year. An over abundant rainfall will increase growth, producing wider annual rings. Factors, other than spacing and rainfall, affecting tree growth and ring widths are age, diseases, insects, tree species, soil conditions, available sunlight, temperature, and size of crown. The age of a tree can be determined by counting the annual rings from the center of the stump to the outside bark. This count must be made at the base of a tree. The number of annual rings becomes less at the top of the tree. Dating past history by using tree rings is known and dendrochronology. This was developed at the University of Arizona.
Factors affecting growth: The rate at which trees grow is directly dependent on a combination of soil, moisture and climatic factors. Unfavorable environmental conditions may hold back or suppress the growth and development of a small tree or even the germination of a seed.

Light - Light is required by all trees for photosynthesis. The quality, intensity, and duration of light affects the photosynthetic process. Trees overshadowed by taller ones are exposed to light quite different in color and intensity than the one overshadowing it. Some trees require bright open sunlight and even a little shade will prevent them from growing. If exposed to full sunlight they soon die. When deciding what species of trees to plant or harvest, shade tolerance is a prime consideration. In general, evergreens require more sunlight than broadleafs. Duration of light (day length) also influences diameter growth. Periods of long-day length is when large-celled springwood cells are produced. Growth during this period is rapid.

Air - Air is the main source of carbon dioxide used for photosynthesis. Oxygen and nitrogen required for other life processes are also obtained from the air. Air movements can also affect tree form. Timberline or border line trees can be bent and twisted by constant high winds. Trees in cities or near chemical or industrial plants can be adversely affected by waste gases and pollution in the air. If the air is highly polluted, the tree may be killed.

Temperature - Air temperature is very important for the growth and development of trees. Some species of trees can withstand cold winters; whereas, others cannot withstand prolonged cold periods and soon die. Likewise, some trees grow and develop better under warm and dry conditions. When planting trees select a species favorable to the local climate.
Moisture - Moisture is the major limiting factor affecting growth. Moisture is supplied to the forest by rainfall. The United States has a wide range of annual precipitation in its forested areas. Rainfall averages from 140 inches to a low of 15 inches per year. Very little growth occurs during dry seasons. The most important use of water is for food-making (photosynthesis).

Growing season - The growing season is when a tree does most of its growth. The longer the growing season the larger the tree will become each year.

Soil - The soil not only helps anchor the tree but acts like a sponge to soak up water from rains or melting snow. It stores some water for plant use, and allows the remainder to filter through the soil. Soil fertility, depth, texture, and structure all strongly affect forest yield and growth.

IDENTIFICATION OF TREES OF ECONOMIC IMPORTANCE

Different species of trees are found growing in different regions of the United States. Each region has varying conditions of climate, moisture, and soil. Most of the trees in one region differ from those in another; however, a few regions overlap and a tree species may be found in both. The continental United States has six major forested regions. These include the Northern, Central Hardwood, Southern, Tropical, Rocky Mountain, and Pacific Coast regions. The two in the west are the Rocky Mountain and Pacific Coast regions. Arizona is a part of the Rocky Mountain region. The various forest regions are shown in Figure 4.
Fig. 4.--Forest regions of the United States.
(Courtesy: U.S. Forest Service)
Identification of trees within these regions is based on differences in the flowers, leaves, bark, twigs, buds, fruit, or nuts. In most cases positive identification can be made from the leaves, fruit, twigs, and bark. If not, a study of the flower will give positive identification.

Tree leaves can be identified by size, shape, type, fall color, arrangement, and sometimes odor. Forest leaves are of two types; broadleaf or needle. Coniferous trees have needle-shaped leaves. These trees are usually evergreen, have cones, and produce wood known as softwood. Hardwood trees produce broad leaves and the wood is known as hardwood. Leaves are arranged opposite, alternate, or whorled as shown in Figure 5. Figure 6 shows variations in leaf type.

![Fig. 5--Arrangement of leaves.](image-url)
Coniferous Leaf Forms

Compound Leaf  Doubly Compound Leaf  Toothed Leaf

Lobed Leaf  Smooth Margined Leaf  Spined Margined Leaf

Hardwood Leaf Forms

Fig. 6.—Coniferous and hardwood leaf forms.
(Courtesy: U.S.D.A.)

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Fruits, nuts, and seeds also aid the forester in tree identification. Some common fruits, seeds, and nuts include cones, berries, acorns, pods, etc. Figure 7 illustrates various fruit, nut, and seed forms.

![Diagram of various fruit, nuts, and seeds](image)

**Fruit, Nut, and Seed Forms**
- Nut in husk (Pecan)
- Cone (Pine)
- Pod (Locust)
- Acorn (Oak)
- Multiple Fruit (Mulberry)
- Samara (Maple)
- Berry (Juniper)
- Nuts in Prickly Burr (Chinquapin)

Fig. 7.—Common fruit, seed, and nut forms.

If all the leaves are off, bark is an important means of determining tree species. As the tree grows the inner bark is pushed outward causing the dead outer layer of bark to crack into plates, scales, or ridges. These plates, scales, and ridges are unique to various tree species. Bark color can help distinguish between species.
The twigs of a tree are also helpful for tree identification during winter months. Distinctive features of the twig (bud, bark, and leaf scars) are usually different for each species.

Description and characteristics of trees of importance in Arizona are given in the appendix.

**Economic Importance of the Forest**

The forests in America have important economic values. Forests provide income from timber, grazing, recreation, fish, and wildlife. Each year billions of dollars are pumped into the economy from forest products. These products include lumber, fiber, chemical products, food, and many other products for our everyday life. Figure 8 shows products derived from a typical forest tree.

Grazing of forest ranges also adds millions of dollars to the economy through forest-grazing leases. In addition to the value for livestock, considerable forage is made available for wildlife.

Recreational value of forest land is becoming a major factor for the future use of forests. Each year millions of Americans and Arizonans use forested land for recreation, hunting, and fishing. Many forests with high social value are being set aside as public and private parks, monuments, wildlife preserves, and wilderness areas.
PLANTING TREES

Forests can grow and reproduce without interference from people. When the forest reproduces this way, it is referred to as **natural reforestation**. When we step in and plant seeds or small seedlings to reforest the land, it is called **artificial reforestation**. We use artificial reforestation when nature has failed to seed a new forest crop; where forest land is too thinly stocked; or where it is desirable to reforest open lands or fields.

Before planting forest trees a great deal of advanced planning is essential. A forester must choose a tree species that can withstand the soil, moisture, and climatic conditions
of the planting site. Tree species which are generally adapted to Arizona are: (1) ponderosa pine, (2) Douglas fir, (3) white fir, (4) Englemann spruce, (5) alpine fir, and (6) aspen. Failure to fit species to the site may result in losses. For example, if a tree requires a moist climate and is planted in a dry climate very little growth will occur. This decreases timber production because the tree is not growing at its maximum. Likewise, if a warm season species, which cannot withstand prolonged cold periods, is planted in a cool or cold area the tree may die.

Trees, like other plants, grow and develop better when planted in the correct season. Young seedlings are usually planted in the fall or early spring after all threats of frost have ceased. Spring planting is preferred over fall. The small seedlings have more opportunity to develop a supporting root system during the growing season.

The two methods most commonly used in artificial reforestation are: (1) direct seeding, and (2) planting nursery grown seedlings. The choice of the method used depends on several factors. These include availability of seed or seedlings, cost, time required, equipment available, and chance of success.

Until recently direct seeding was considered risky with heavy losses of seedlings. Survival is now more successful with proper ground preparation and the use of chemical repellents. These chemical repellents discourage birds and rodents from eating the seed. The seedbed is prepared in advance by thoroughly disk ing the land. Seed is then distributed by hand, helicopters, airplanes, or tractors, depending on the size of the planting site.
Usually it is best to plant seedlings. By planting seedlings many problems involved in obtaining seed and growing the young seedlings are eliminated. High quality seedlings can be obtained from state, federal, or private nurseries. These seedlings are usually of good quality, free of diseases and injury, and the proper size for planting.

The two most commonly used methods of planting seedlings are (1) hand planting, and (2) machine planting. Methods of hand planting include (1) slit planting with bar, (2) hole planting with planting hoe or mattock, and (3) hole planting with mattock or shovel. Figures 9, 10, and 11 illustrate the various hand planting methods.

Planting machines are recommended for large areas with few obstacles (trees, tree stumps, rocks, gulleys, etc.) These machines are capable of planting approximately 1,000 seedlings per hour. A typical tree-planting machine is shown in Figure 12.

The initial step in any tree planting operation begins with land preparation. Ordinarily the ground of old fields, pastures, and cut-over areas need very little preparation. Since this ground was previously cultivated there is usually less competition from grasses and brush. Planting in heavy sod or dense weed or grass patches is wasted effort. Dry land areas should be summer fallowed and irrigated areas should be fall plowed previous to planting trees. The ground should be disked or harrowed early in the spring so you will have a clean, firm, and moist seedbed at the time of planting. Moderately grassy or weedy areas that cannot be plowed or where plowing is inadvisable because of soil or slope should be handled by one of the following methods:
Planting bar. Blade of ¾" armor plate, drawn and sharpened.

1. Insert bar at angle shown and push forward to upright position.

2. Remove bar and place seedling at correct depth.

3. Insert bar 2 inches towards planter from seedling.

4. Pull handle of bar towards planter firming soil at bottom of roots.

5. Push handle of bar forward from planter firming soil at top of roots.


7. Fill last hole by stamping with heel.

8. Firm soil around seedling with the feet.

Fig. 9.—Slit planting seedlings with a bar.
(Courtesy: Pacific Northwest Cooperative Extension Service)
Fig. 10.—Hole planting with a planting hoe or mattock.

(Courtesy: Pacific Northwest Cooperative Extension Service)

Fig. 11.—Hole planting with a mattock or shovel.

1. Insert mattock - lift hand and pull.
2. Place seedling along straight side at correct depth.
3. Fill in and pack soil to bottom of roots.
4. Firm around seedling with the feet.

NOTE: Use shovel to prepare hole of type shown in Step 2. Then fill in soil and pack it as shown in Steps 3 and 4.
1. Scrape or clean an area 18 to 24 inches square and plant the seedling in the center of the cleared area.

2. Plow shallow furrows to scrape off the grass if it is possible to get equipment on the planting area. Plant the seedling in the furrows. The plowed furrows should follow the contour as nearly as possible to lessen erosion damage.

3. Plant with a machine that has a scraping attachment. With such a machine, ground preparation and planting can be done in one operation.

Cut-over or burned-over forest lands that have not grown up in dense ground cover may not need site preparation before planting.
If seedlings are to be used in the reforestation program they should be ordered far enough in advance to ensure delivery. Once the seedlings have arrived they should be planted promptly to prevent drying. If planting cannot be done within one or two days the seedling should be "heeled-in". Figure 13 shows the heeling-in process. If the seedlings are to be planted shortly after arrival, the original container of seedlings should not be allowed to dry out or be exposed to warm temperatures. Exposure of root systems to drying conditions is the cause of many planting failures.

![Diagram of heeling-in process]

1. Dig V-shaped trench in a moist shady place.
2. Break bundles and spread out evenly, 3 or 4 trees thick.
3. Fill in loose soil and water well.
4. Complete filling in soil and firm with feet

Fig. 13.—Heeling-in procedure used to keep seedlings moist before planting.

(Courtesy: Pacific Northwest Cooperative Extension Service)

There are a number of methods and tools used to plant trees. How you plant is for you to decide. Whatever the method used, the following approved practices should be followed closely:

1. **Keep the roots moist.** Keep the root system covered and moist from the moment the plants are taken from
the shipping bundle or from the heel-in trench until they are planted. Any suitable container (bucket) can be used for carrying the seedlings during the planting operation. Whatever container is used there should be enough moist material (peat moss, sawdust, etc.) around the roots to prevent their damage from exposure. Never allow a handful of trees to be exposed to the sun or wind. Take one seedling at a time.

2. **Plant at the correct depth.** The seedlings should be planted at least as deep as they grew in the nursery. A color change on the stem above the root system marks the former soil line.

3. **Place the roots in a natural position.** Be sure the planting hole or slit is large enough in width and depth so the root system will not be crowded or folded up. In slit planting, push the tree down to the bottom of the slit, then with a shaking motion, raise it back to the correct level. This helps to arrange the roots in as natural position as possible.

4. **Firm the soil around each seedling.** While holding the seedling in an upright position at the correct depth, bring loose, moist soil in around the root system. Do not allow dry surface litter or soil to fall in around the roots for it may damage or kill the seedling. When the hole or slit is filled, press the soil down firmly with the heel of your shoe. To help conserve moisture, place a layer of loose material around the plant to act as a mulch.

5. **Select a natural protection on wild land plantings.** On sites that become hot and dry in the summer, try to choose a protected spot for each seedling. Shade on the north and east sides of stumps and logs is good. Next best is partial shade offered by brush. Continuous shade is unfavorable for seedling growth.
The first summer after planting is a very critical period for the young seedlings. If planting is on irrigated land, keep the weeds cut and water as you do for other row crops. Keep dryland plantings cultivated clean as long as the equipment can get through the trees.

In the spring following planting, replace all trees that have died during the year. Usually, very few trees are lost during the second year. Check the seedlings periodically for disease, insects, or rodent damage.

MANAGING THE FOREST

Foresters must analyze and apply certain practices to their woodlands to increase its productivity. These practices include tree planting, control of composition, control of stand density, thinning, etc. In the well-managed forest it is possible to plan the growth of trees so they can be harvested in a more predictable, efficient, and economical manner. It is possible to have stands located, and of such composition by species and age class, that the cost of transporting and harvesting the wood product is kept under control. The practice of controlling forest establishment, composition, and growth is referred to as silviculture. The practice of silviculture is tailored to each forest.

Tree Crown Classification

Trees can be classified based on the position of their crowns in relation to other trees. Trees can be either dominant, co-dominant, intermediate, or suppressed. A dominant tree is one in which the crowns extend above the general level of the forest canopy and receives full sunlight from above and partial light from the sides. The crowns of these trees are usually large and full. Trees with crowns which form the general level of the forest canopy and receive full sunlight
from above but very little on the sides are classified as co-
dominant. Crowns of co-dominant trees are smaller than the
dominant trees. Trees with small crowns crowded together into
the general level of the forest canopy are classified inter-
mediate. These trees receive very little sunlight from above
and none on the sides. Suppressed trees are entirely below
the forest canopy. These trees receive no direct light from
above or from the side and are over-topped by other trees in
the forest community. The drawing in Figure 14 illustrates
the four crown classifications.

Fig. 14.—Crown classification:  D = dominant,
    CD = co-dominant,  I = intermediate,
    and S = suppressed.
Composition

One of the objectives of the forest manager is to restrict the composition of a forest stand to those species that are best suited to the local climate, soil, temperature conditions, and most economical. Since inferior species grow and develop at the expense of the desirable species, every effort should be made to keep the undesirable species in check.

Size

Individual trees are classified into seven groups based on trunk diameter at breast height (dbh = 4 1/2 feet) and total tree height. Table 1 shows the seven groups beginning with the youngest and smallest size class.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Height</th>
<th>Trunk Diameter (dbh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling</td>
<td>Up to 3 feet</td>
<td></td>
</tr>
<tr>
<td>Small sapling</td>
<td>3 to 10 feet</td>
<td></td>
</tr>
<tr>
<td>Large sapling</td>
<td>10 or more feet</td>
<td>Up to 4 inches</td>
</tr>
<tr>
<td>Small poles</td>
<td></td>
<td>4 to 8 inches</td>
</tr>
<tr>
<td>Large poles</td>
<td></td>
<td>8 to 12 inches</td>
</tr>
<tr>
<td>Standards</td>
<td></td>
<td>1 to 2 feet</td>
</tr>
<tr>
<td>Veterans</td>
<td></td>
<td>Over 2 feet</td>
</tr>
</tbody>
</table>

Age

Foresters also identify forests by age. Trees in a forest that are essentially the same age, but may vary in size
because of their different rates of growth, are said to be "even-aged". A forest with trees ranging from small saplings to poles to standards to large towering veterans is said to be "all-aged". All-aged forests usually include more of the shade tolerant species than the even-aged forests. Species of trees that can grow and survive in the shade are said to be shade tolerant. Trees which cannot survive in the shade are shade intolerant. The even-aged forests are most often made up of intolerant species. From this it can be seen that a mixed forest of all ages could have intolerant trees out-topping those which are tolerant. If this situation is reversed to where tolerant overshadow intolerant trees; growth of the intolerant species will be stunted. The drawings in Figure 15 illustrate profiles of all-aged and even-aged forests.

A. All-aged forest profile.  B. Even-aged forest profile.

Fig. 15.—Forest profiles showing age differences.
Type

A group of individual trees is also classified into forest types. If a forest is composed mainly of a single tree species, it is a pure forest. One which contains several species is called a mixed forest. The Society of American Foresters recognize 156 different forest types in the United States. Most forest types are "mixed", although some are "pure" in species (redwoods of California).

Trees per Acre

Forests vary considerably in their tree density or number of trees per acre. Density refers to the relative closeness of the trees. In general, the more shade a tree tolerates, the closer it should be planted. Spacing also depends upon cost of planting and the rate of growth. Close spacing also results in an early kill of side branches. As the trees begin to grow, they begin to compete with one another causing the lower limbs to die and drop from the tree. This, in turn, reduces the number of knots. Available water, nutrients, air, and sunlight are more fully used in trees planted close together. This more efficient use of resources produces more wood in less time.

If a closely-spaced stand is kept properly thinned, it will produce more usable wood products than one that becomes overcrowded by a lack of thinning. Wide spacings allow each tree more room for growth. These trees do not lose their lower branches and thus develop large lower limbs which produce a larger quantity of wood knots. Products from these knotty trees are of low quality and value. Table 2 shows the number of seedlings for different spacing intervals per acre.
TABLE 2
Trees Per Acre for Various Spacing Intervals

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Trees Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 ft. x 4 ft.</td>
<td>2,722</td>
</tr>
<tr>
<td>5 ft. x 5 ft.</td>
<td>1,742</td>
</tr>
<tr>
<td>6 ft. x 6 ft.</td>
<td>1,210</td>
</tr>
<tr>
<td>6 ft. x 7 ft.</td>
<td>1,040</td>
</tr>
<tr>
<td>6½ ft. x 6½ ft.</td>
<td>1,030</td>
</tr>
<tr>
<td>7 ft. x 7 ft.</td>
<td>890</td>
</tr>
<tr>
<td>8 ft. x 8 ft.</td>
<td>680</td>
</tr>
<tr>
<td>10 ft. x 10 ft.</td>
<td>440</td>
</tr>
</tbody>
</table>

Quality of Site

The term site as used in forestry covers such environmental factors as climate, slope, soil, temperature, and moisture. Each of these factors has some effect on the growth and development of the forest tree. Each site or specific area of forest land has a different productive capacity for a single tree species or group of species. Many species may grow on the same site but may not grow equally well. Foresters have developed a method for determining forest "site quality" based on tree growth and age. A tree's rate of growth in height is an excellent indicator of its adaptability to the particular site. The faster the growth in height, the better the site for that species. The faster the growth, the greater the volume of wood produced. For example, a long leaf pine tree on three different sites will attain a height of 60, 70, and 80 feet in 50 years. This indicates the three sites are not equally productive for that particular species. Another species of pine may not do as well as the long leaf pine on the same three sites. In other words, sites are not
equally good for all species. The determination of site quality is very important in the study of growth as well as other forest management concerns.

Marketable Trees

Trees are usually not marketable until they reach a diameter at breast height of at least 10 inches. Other factors such as trees per acre, tree height, rate of growth, diseased trees, and use of timber also determine if a tree is to be felled or left standing.

Rate of Growth

Tree growth depends on the individual tree species and other factors such as climate, soil, temperature, age, trees per acre or density, moisture, and with the way in which the forest is managed and cutting is done. If these factors are favorable to the species then growth will be rapid; if not, growth will be slow.

Young trees are vigorous and fast growing; whereas, old trees slow down in growth, and eventually become overmature and rot or die. Older trees are less resistant to disease and insect injury and are therefore considered a poor risk by the forest manager.

Reproduction

A function of all forms of life is to reproduce its own kind. Trees can reproduce from seed or from vegetative parts; however, not all trees can be reproduced from vegetative parts. Most trees reproduce themselves by seeds. The cone-bearing pine tree is an excellent example of a tree capable of reproducing itself by seed. The seeds are produced within the pine cone until maturity. Once the cone is mature and

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dries out, the scales come apart, and the seed is dispersed by the wind. Vegetative reproduction is usually by sprouts or suckers. These are shoots from the lower portion of the stem or from the root.

**Intermediate Cuttings**

Intermediate cuttings (also known as TSI or Timber Stand Improvement cuttings) refers to cuttings made in a stand of timber from the time of its formation until it is ready for harvesting. Cuttings are made in immature stands to stimulate growth of the trees that remain and to increase their yield. Surpluses, damaged, or poorly formed trees are removed for the purpose of concentrating all available nutrients, moisture, air, and light on the remaining or favored trees. The total wood production may be increased by the fact that the favored trees grow more rapidly than they would without thinning. How much cutting should be done is determined by the density of the stand, age of the forest, and condition of the individual trees. Selection of the trees to be favored and those to be cut in thinnings is based on the relative position and condition of the crown, health of the tree, and the condition and quality of the trunk. In "mixed" stands choice between species is also a consideration. Other terms used for intermediate cuttings include thinning, salvage cuttings, release cuttings, and sanitation cuttings.

**Release cuttings:** Some large trees are so branched and have such huge crowns, that they choke off better formed seedlings or saplings which would grow into good trees if given a chance. These "wolf trees" should be cut out as soon as possible. Other poorly formed trees--bent, forked, knotty, limby--should also be removed. Useless vines of many sorts bend trees or kill them by shading. When they grow on valuable trees, such vines should be killed by cutting the main stem near the
ground. The illustrations in Figure 16 show a forest before and after release cuttings.

Fig. 16.--Forest profile before and after release cutting.
(Courtesy: U.S.D.A.)

**Salvage cuttings:** Sometimes timber stands are so severely injured by fire, windstorms, sleet, or insect attack that it is necessary to salvage the damaged trees. Salvage cuttings remove marketable dead or injured trees, leaving the uninjured trees to grow. Salvage operations also remove the weakened trees that might be an invitation to insects or disease.

**Sanitation cuttings:** Timber is sometimes attacked by insects or diseases which may kill or infect many trees within the forest. If these trees are heavily infested by insects, such
as the bark beetle, and cannot be controlled by the use of insecticides, they should be felled and removed from the forest and burned. Trees infected by a disease can also be handled in a similar manner. Sanitation cuttings remove the source of trouble from the stand and leave the healthy trees to grow.

**Thinnings:** Occasionally trees within a forest become too crowded and compete for nutrients, space, sunlight, and moisture. When crowding becomes too great, some of the trees must be cut to thin the forest. If the forest is not thinned many good trees may die. This means a reduction in total wood products produced. Most stands need thinning when the trees are between 15 and 25 years old. Thinnings are made mostly in even-aged forests. Figure 17 shows a profile of a forest before and after thinning.

![Forest profile before and after thinning](image)

**Fig. 17.**—Forest profile before and after thinning.

**Harvest Cuttings or Silvicultural Harvesting Methods**

The removal of mature trees in order to provide a more favorable condition for younger trees and to establish
reproduction is termed harvest cutting. Harvest cuttings are included in silvicultural harvesting methods to emphasize the importance placed on establishing reproduction. Harvest cuttings are the last cuttings in the timber rotation and follow intermediate cuttings. The trees cut in harvest cuttings are usually of marketable age and size. There are a variety of methods used in harvest cuttings which include: (1) selection cutting, (2) clear cutting, (3) seed tree cutting, and (4) shelterwood cutting.

Selection cuttings: Cuttings in which trees are removed based on their position in the stand, age, diameter, maturity, growth rate, and vigor are called selection cuttings. Selection cuts are made mostly in hardwoods with shade tolerant trees. In addition to older and larger trees being removed as they reach maturity, this system permits removal of defective and poorly formed trees. Where groups of trees are overcrowded and not growing properly, this method of selection cutting provides the stand with a more suitable spacing. The removal of certain older and dominant trees speeds up the growth rate of the younger trees and the small openings encourage new reproduction. When selecting trees to be removed by selection cutting the following points should be considered:

- Harvest all over-mature trees which are making little or no growth.

- Young, vigorous, fast-growing trees of a good species should be left standing.

- If stands of trees are overcrowded, remove undesirable species and the poorer trees. Try to maintain the proper spacing even if it means leaving a few trees that should ordinarily be cut.

- Remove forked, wolf, bent, knotty, and limby trees to allow vigorous young saplings and poles growing space.
- Make light cuts at periodic intervals (usually every five or ten years).

It is advisable to mark the trees to be cut in some manner before the cutting operation is undertaken. Paint is used by many foresters. When more than one product is to be cut or there is more than one buyer, various colors of paint are used.

Clearcutting in strips or blocks: In this method of harvest cutting, virtually all trees in a stand, either large or small, are cut. Clearcutting is applicable on even-aged forests where trees are no longer worthy of being kept for growth, value, reproduction, or protection. Clearcutting is used for shade-intolerant species which need open sunlight for growth. After cutting, reproduction may occur by direct seeding, planting seedlings, or from seeds from adjacent trees. To obtain reproduction from adjacent trees clearcutting is performed in blocks, circles, or strips. The wind carries seed from the forested area into the clearcut area. Block clearcutting is shown in Figure 18.

Some advantages of clearcutting are (1) new seedlings do not have to compete with older trees for moisture, light, air, and nutrients, (2) new species can be introduced on the cleared area, (3) harvesting and transportation costs are reduced, and (4) wildlife will increase in numbers as more food plants appear in the cleared area.

This system also has some limitations. For example, (1) water and wind erosion may be increased, (2) fire danger may increase due to the large amount of slash, and (3) the sudden exposure of the forest cover to the sun may cause severe and undesirable changes in the cover.
Seed tree cuttings: This is a form of clearcutting in which seed-bearing trees are left suitably dispersed throughout the harvest area for reproduction purposes. These trees can be left scattered singly or in groups over the area cut. The hope is that the trees left will disperse enough seed over the logged area to reproduce the forest. The trees to remain on the site should be selected on their seed-bearing structure. These trees are no longer protected by other trees, therefore are subject to blow-down.

Shelterwood cuttings: Some species of trees need partial shade and shelter during the first few years of growth, but are delayed in growth and development if this shade persists. A series of cuttings, which gradually allow increasing amounts of light to stimulate seedling growth are called shelterwood cuttings. Shelterwood cuttings are taken in three phases: preparatory cutting, seed tree cutting, and removal cutting.
Preparatory cuttings remove mature and defective trees and create openings in the forest canopy. These openings allow enough light to stimulate seedling growth.

Phase two is termed seed-tree cutting. This is the heaviest cutting made in this method. A few scattered trees are left to produce seeds. New seedlings are produced from these seeds.

The final or removal cutting occurs after new seedlings are well established. All timber of marketable size is removed from the area.

Reproducing the Forest

There is more to reforestation than scattering seed or placing a seedling in the ground. The success or failure of a reforestation program hinges greatly upon site preparation.

Preparing the site: Whenever grass, weeds, or brush occurs, diskimg prior to planting must be done. If seeds or seedlings are planted with this vegetation many trees will fail to establish themselves. This is due to competition for moisture, light, space, and nutrients. On fairly level ground the site can be prepared by fall plowing, followed by diskimg just prior to planting. Disking prior to planting destroys newly germinated grasses and weeds which may compete with the young seedlings. On sites covered by dense shrubs or brush, spraying with chemical herbicides is the cheapest and most effective means of preparing the site. Once the vegetation has died, bulldozers can be used to clear the site.
Girdling may be used to remove inferior trees from stands. This is used when cutting them would cause damage to standing trees. Inferior trees may overshadow the site and should therefore be killed. When trees are girdled they usually do not die for 2 to 3 years. The benefit from their removal is postponed, but the cost is often cheaper than cutting. They gradually decline and fall to the ground.

Parts of trees that are too small to be used is known as slash. Removal of slash is important for the reproduction of the forest. During the logging operation slash, resulting from cutting, remains on the forest floor. The amount of slash varies with the volume of timber cut, species, and age. Cuttings in older stands create more slash than in younger stands. Slash has several advantages and disadvantages. Slash enriches the soil upon decomposition, aids in the prevention of soil erosion, and provides habitat for wildlife. On the other hand, it may represent a fire hazard and obstruct seed germination and growth. Sometimes slash is allowed to pile up in spots and is so dense it prevents tree seed from reaching the soil.

Selecting a source of seed: When selecting seed species, variety and genetic characteristics should be considered. Some species grow well in Vermont but not in Arizona. A species must be selected that is suited to the local soil, climate, growing season, and moisture conditions. A few species have been genetically improved to produce trees with good form, rapid growth, straighter limbs, and good seed-germinating ability. A few are resistant to certain diseases. It is best to obtain seed from locally grown planting stock.
Although some seeds are produced each year, trees normally do not produce seeds in large quantity every year. Seeds in quantity are produced at intervals. This interval varies from 2 to 10 or more years. These are termed seed years and result when the tree has a large reserve of stored food.

Methods of reproduction: The act of replacing trees, either naturally or artificially, is called reproduction or regeneration.

Natural reproduction - Natural reproduction can be accomplished in the forest without help from people. Natural regeneration depends on such factors as temperature, moisture, climate, light, and the amount of growing space. Other factors are the amount of slash, insects, rodents, and wildlife. There is no known way a forester can predict the success or failure of natural reproduction. A seed may fall to the ground but there is no assurance it will germinate and grow. Much time is involved in natural reproduction. Nature reproduces forests slowly and gradually over a period of years.

Natural reproduction can only reproduce the kind of trees found on the site. People have found methods of aiding natural reproduction. These methods usually involve cutting competing trees or brush.

Artificial reproduction - When people reproduce the forest it is termed artificial reproduction. Two commonly used methods of artificial reproduction are planting nursery-grown seedlings and direct seeding. The sowing of seed on
an area where trees are desired is known as direct seeding. Large areas can be seeded by broadcasting seed by hand, airplane, seeder, or grain drill. The cost of direct seeding is usually less than planting tree seedlings. The success or failure of direct seeding depends greatly upon site preparation.

The most effective means to be assured of a good stand is to plant nursery grown seedlings. When seedlings are planted the forester is not concerned with germination or seed damage caused by birds, rodents, or wildlife. The seedlings are already established and growing.

In artificial reproduction we eliminate the slower time factor of natural reproduction. We can plant seeds or seedlings each year and not have to wait on nature. Desirable species can be planted with artificial reproduction.

PROTECTING THE FOREST

Since we first set foot on the North American continent millions of forested acres have been destroyed by fire, disease, insects, or storm damage. Severe losses are caused by these enemies yearly. People throughout history have been able to conquer their enemies by knowing their behavior. A knowledge of the behavior of forest enemies and the steps taken to combat them is called forest protection.
Protecting Against Fire

Uncontrolled fire is the number one enemy of forests. Yearly fires destroy thousands of acres of forests. This causes a loss of valuable natural resources. The cash value of the wood destroyed is only a part of the damage. Burning kills some of the larger trees and weakens and slows down the growth of others. Insects and diseases enter easily through the burned places. Fire may destroy the fertile, moisture-holding litter on the forest floor, robbing trees of nourishment and perhaps starting erosion. Fire injuries often lower the sale value of timber products by half to two-thirds. Sometimes forest fires may take the life of humans or wildlife.

Parts of a fire: The diagram in Figure 19 shows the various parts of a fire. Knowing these parts will assist the forester in understanding fire control.

![Diagram of fire parts](image)

Fig. 19.--Parts of a fire.

The basic parts of a fire are the head, rear, and flank. The head is the portion of the fire toward which the wind is moving. This portion is moving the fastest. Fingers are small leads from the head. Spots are starts of new
fires set by sparks blown ahead by the wind. The rear of the fire is the portion from which the wind is moving. This portion is moving the slowest. A side of the fire parallel to the direction of movement is referred to as a flank.

Fire classes: Forest fires can be classified as (1) surface fires, (2) ground fires, and (3) crown fires.

A surface fire is the most common of all forest fires. It moves along the forest floor burning litter, leaves, slash, vines, shrubs, etc. It is driven by the wind and burns intensely for a short period of time. The most destructive aspect of a surface fire is that it destroys millions of young germinating seeds and seedlings.

Surface fires may develop into ground fires. This type of fire consumes the humus and peat content of the forest floor. Some may penetrate to a depth of 6 feet. Ground fires are uncommon because the humus and peat are rarely dry enough to burn. Ground fires burn slowly and continuously, sometimes for months. Ground fires destroy the productive soil making it incapable of supporting life.

The crown fire may also originate from a surface fire. This type of fire is very spectacular and destructive. Sparks, flames, or heat from a surface fire may ignite dry crown needles and start a crown fire. In a strong wind a crown fire pushed by wind is known as a running crown fire. A crown fire causes the greatest timber and property damage of all fires.

Fire causes: Most forest fires are caused by human carelessness or negligence. Some of the common causes of forest fires include:
(1) incendiarism, (2) lightning, (3) railroads and logging
operations, (4) careless smokers, (5) campers and picnickers, (6) debris burning, and (7) miscellaneous or unknown causes.

Incendiaryism - Approximately one-fourth of the forest fires are caused by incendiaryism. Incendiary fires are deliberate fires usually set on someone else's property and without the owner's permission. Reasons for setting incendiary fires are numerous. Some of the more common being to drive out snakes and pests, obtaining employment in fighting the fire, to "get even", destroying evidence of a crime, and mischief. Law enforcement and education can reduce the number of incendiary fires.

Lightning - Forest fires caused by lightning cannot be prevented. Each year lightning accounts for approximately ten percent of reportable fires. In the Rocky Mountain Region, however, two-thirds of the fires are lightning caused.

Railroads and logging operations - Any fire associated with a railroad right-of-way, equipment, employees, or passengers is considered a railroad caused fire. Railroad caused fires have been reduced in recent years. Improved spark arresters and conversion to electric or diesel locomotives has contributed to this reduction.

Fires caused by harvesting, hauling, or saw-milling are classified as lumbering fires. Logging companies today are well aware that fire risks are high in their business. They demand safety precautions from their employees and the companies voluntarily submit to fire regulations.

Careless smokers - Careless smokers are responsible for 20 percent of all forest fires each year. Many smokers develop the habit of carelessly tossing aside lighted
cigarettes. This careless disposal of burning material does little, if any, harm on the paved streets of a city, but can destroy a forest. Preventive materials (signs and posters) or slogans such as "Don't Be a Flipper", "Break Your Match", and "Only You Can Prevent Forest Fires" have been used along forest trails and highways. This reminds careless smokers to be careful about their disposal of burning material.

Campers and picnickers – Approximately 6 percent of all forest fires are caused by careless campers and picnickers. Forest fires are caused by campers who build campfires in unsafe places or who abandon their still burning campfires. Educational efforts to induce campers to douse their campfires with water before leaving are reducing the number of fires from this cause.

Debris burning – Too frequently, fires are started by people burning trash or brush to clear land. These fires sometime get out of hand and spread to adjacent woodlands. Most states require burning permits which can be obtained from forest officers or other forest officials. When applying for the permit the applicants are told how to burn safely and what precautionary measures to take. They are required to sign an agreement indicating they will take the necessary precautions.

Miscellaneous or unknown causes – Fires of unknown causes which do not fit in any of the above categories are termed miscellaneous or unknown. A car may leave the highway and burst into flames; a spark from a chimney may be carried into dry needles and catch fire; an electrical wire may fall onto a flammable object; from these incidents fire may spread to the forest.
Fire prevention: Fire prevention is a vital part of every foresters job. The most effective and least expensive way of protecting a forest from fire is to keep the fire from starting. A fire prevented is no fire at all. People must be made aware of potential fire danger. There are two methods of fire prevention; namely, reduction of risks and hazards.

Reduction of risk is keeping an ignition source from coming in contact with forest fuel (wood, litter, grass, etc.). Campfires, chainsaws, and careless burning are examples of risks. Reduction is accomplished by education, posters, closures, etc.

Hazards refer to fuels. If fuels are reduced there is less material to burn if a fire does start. Prescribed burning, chipping, and clearing will reduce hazards.

The National Forest Fire-Danger Rating System: Foresters have long felt the need for a uniform fire-danger rating system. It was common for experienced fire control officers to differ greatly about the fire potential for a specific area at a specific time. The purpose of the National Forest Fire-Danger Rating System is to provide uniform guidelines for evaluating forest fire potential. These guidelines are based upon environmental conditions (temperature, amount of clouds, humidity, precipitation, windspeed, and wood moisture), subjective estimates (lightning and man-caused risks, slope, live fuel moisture, and fuel model), and fire behavior components (ignition, spread, and energy release). All these factors give the forester a fire danger index of a specific area at a specific time. Figure 20 shows the structure of the National Forest Fire-Danger Rating System.
Fig. 20.--National Forest Fire-Danger Rating System.

Organizing a fire crew: Even with the best prevention, forest fires are bound to occur. It is, therefore, the forester's responsibility to maintain fire fighting equipment and personnel in a readiness condition. A fire-control plan is made with instructions for the fire fighting organization in the event of fire.

Most public and national forests maintain recruiting and fire fighting training programs. These training programs instruct those employed how to use various hand tools and new equipment in fighting forest fires. Highly organized schools for Smoke jumpers, where people are trained to parachute near isolated fires, are maintained and operated by the Forest Service.

Methods of fire protection: Foresters have several methods which they can utilize to protect the forest from fire. These
include (1) fire lookouts, detection methods and equipment, (2) fire lanes, (3) slashing, (4) communications, and (5) roads and access routes.

**Detection** - To attack a fire properly, it must be discovered promptly in its early stages. The most effective detection system today is combined aerial patrols and lookout towers, although lookout towers are gradually being phased out. Most lookout towers are equipped with communication equipment (telephone, shortwave radio, etc.) and a fire finder. The fire finder is a piece of equipment used to locate the position or location of a forest fire when smoke is visible. It has a front sighting arm containing a set of cross hairs for accuracy in sighting the smoke column. It is mounted on a map table oriented so that the map directions agree with the compass direction on the ground. The rim of the table is graduated in degrees starting with 0 degrees at the North and returning there at 360 degrees.

When the lookouts discover smoke, they take a sighting and immediately report it to ranger headquarters. The dispatcher will probably receive several smoke sighting reports and will plot them on a map. The intersection of the plotted lines of sight gives the exact location of the fire. The dispatcher then dispatches an initial fire fighting crew.

Fire detection by regularly scheduled "air patrols" has proven feasible in many roadless or remote forest areas. When the danger of fire is high these patrols are usually increased. Air patrols are also used to detect fires in "blind spots" not visible to lookout towers.

Ground detection is another means of fire detection. In areas not visible from fixed lookout points, patrols in cars, trucks, or on foot will be sent into the area. Such
patrols take place mostly when the danger of fire is high. Foot patrols are equipped with two way radios.

A highly developed and effective method of detecting fire is with an infrared sensing system. This system has sensitive receptors which are able to detect the energy released by a forest fire. It can be used to detect fires at night and can also measure the fire size and location. This system is very expensive. It must have an unobstructed view of the fire source and it cannot be used in cloudy weather. However, it can penetrate smoke.

Fire lanes - A fire lane is an area cleared of inflammable material a considerable distance in advance of the fire. This provides the fire fighters a vantage point from which a fire may be fought. Figure 21 is a drawing of a fire lane.

Fig. 21.--Plowing a fire lane.
Backfiring is started from the fire lane. Backfiring consists of starting a fire ahead of the forest fire. These two fires are then allowed to meet. "Backfiring" can be dangerous and should be used with extreme caution.

Slashing - Slashing is the disposal of debris from the forest floor. Slashing is primarily used to reduce the potential fuel for forest fires. The greatest fire hazard existing from slash is the dry foliage and small branchlets that burn readily and give off large quantities of heat. The following methods are used to aid in the disposal of slash: (1) broadcast burning, (2) spot burning, (3) burning of piled slash, (4) scattering of slash, and (5) chipping of slash.

In broadcast burning, slash on clearcut areas is burned as it lies within prepared fire lanes. Practically all vegetation on the clearcut area is burned without damaging the physical properties of the soil.

Spot burning is a modification of broadcast burning. It is the burning of dangerous concentrations of slash patches on spots. It should be only employed where there is little risk that the fire will spread.

Broadcast and spot burning, better known as prescribed burning, is only undertaken when weather, fuel, and topographic conditions are carefully evaluated and a "prescription" for the burn has been met. Prescribed burns usually take place in the Southwest in late fall before winter snows.

disposing of slash after partial cutting usually involves the burning of piled slash. Bulldozers can be used to push the slash into piles for burning.

Slash disposal can sometimes be accomplished without burning. Slash can be redistributed or scattered to prevent
excessive amounts from piling up in one area. This technique does not reduce the total amount of fuel but redistributes it for easier decay.

Portable chipping machines are sometimes employed in slash disposal. These machines chop or cut up slash and spread the chipped debris over the forest floor. Chipping in many respects is the ideal solution because no burning is necessary and the debris decomposes faster.

Communications - Fast and reliable communications are a must if the forest is to be protected. It does little good for observers to spot a fire if they cannot report it to those concerned with suppression. Commercial telephones and radios are the two most commonly used means of forest communication.

Roads and access routes - It is essential that a systematic trail and road system be provided throughout the forest. Good roads will help avoid any unnecessary delays enroute to a fire. In areas inaccessible to vehicles, the initial attack comes from aerial tankers dropping slurry or helitack crews transported near the fire. Where no helitack crews are available, Smoke jumpers may be used if stationed close by.

Fighting the fire: There are three basic methods of fire fighting -- the direct attack, the indirect attack, and flanking.

The direct attack at a fire's head is made only on the smallest of fires. The head of a fire is no place to be if the fire is moving uphill or pushed by wind. Figure 22 shows a minimum crew fighting a fire by direct attack. Fighting very small fires may be done with a three-person crew: (1) a swatter to smother part of the burning material, (swatters used for grass fires only) (2) another swatter following
and working as a teammate to catch the remaining burning material and (3) a mop-up, with a rake to catch any material that flames up after the swatters pass, also to rake and throw burning wood or trash into the area already burned over. Fires, other than grass fires, use the Pulaski digging tool, council rakes, etc. More people and equipment may be required for larger and more difficult fires. As the head of the fire is brought under control, the flanks and rear are extinguished. The direct attack may be used only where the heat and rate of spread will permit successful control.

The indirect attack is used where heat and rate of spread will not safely permit a direct attack. On the indirect attack, the attack is made with a fire lane and a backburn to remove fuel ahead of the oncoming flames of the main fire. The fire lane is made a sufficient distance ahead of the oncoming flames. This assures ample time to make the line, set a backburn, and burn out the fuel over a wide area. The fire
boss must place the fire lane as close as possible. This will save unnecessary sacrifice of woodlands. A road or stream can also serve as a fire lane.

A fire lane can be made by two or more people with rakes or shovels. They rake the grass, leaves, and other fuel away from the oncoming fire. The area is cleared until soil is exposed. A tractor with a plow can be used to make the fire lane. Making a fire lane with a tractor is faster and better than by hand. The lane ranges in width from 12 to 18 inches if by hand, and 3 to 4 feet if by tractor and plow. Handmade lanes should be no wider than necessary to hold the backburn.

As the fire lane progresses in length, a third person sets a backburn on the side of the lane toward the fire. A fourth person serves as a mop-up behind the backburn. Rakers prevent break-overs to the side away from the oncoming main fire. The backburn may be started by two people at the center, ahead of the oncoming fire, working outward. As with direct attack, when the head of the fire is controlled, the flanks and rear are brought under control. Figure 23 illustrates the indirect method of fire fighting.

When building a backburn the following points should be kept in mind:

1. Locate the fire lane in advance of the fire. Allow enough time to build the lane through or across danger points. Get the intervening areas burned out toward the main fire.

2. Make use of barriers such as roads, streams, and bare soil.
3. Avoid running the fire lane through patches of dense undergrowth.

4. Make no sharp angles in the line.

5. Avoid running fire lanes straight up or down hills.

6. Pass the fire lane around stumps, logs, brush, snags, etc.

Probably the most common method of controlling a fire is by flanking. Here crews on each flank "pinch" the head of the fire. Figure 24 illustrates the flanking method. Flanking is a safe way of fire fighting because people are not at the head of the fire and usually the smoke and heat are being drawn from the flank to the fire center.

Fig. 23.—Minimum crew in action on indirect attack.
Fig. 24.—Flanking method of fire fighting.

The final step in fire fighting is to mop up the fire completely. Every bit of fire that may possibly break out must be made "dead out".

**Cooperating agencies:** Small forest owners have several cooperating agencies which will assist them in fire control. These agencies include the forest service, soil conservation service, local fire departments, and private companies.

**Protecting Against Insects and Diseases**

Fire is not the only enemy of the forest. Disease and insects may destroy more timber yearly than fire. Both reduce the growth rate and vigor of many more trees than they kill outright. Insects cause the most tree mortality. Diseases slow the growth rate and make trees more susceptible to insect attack.
Some loss from the attacks of forest pests is unavoidable, but much can be prevented by careful management. The presence of either disease or insects in the forest is of major importance. Forest managers must be able to identify the more important insects and diseases. They also must be able to recommend methods of control.

Insects: Trees weakened by diseases, fire, grazing animals, logging operations, or storms offer good homes for thousands of kinds of insects, some of which do great damage. Insects can also damage trees that seem to be perfectly healthy, with no weakness noticeable.

Forest insects can be grouped into eight classes based on the way they attack trees. These classes are as follows:

1. Bark Beetles - These insects do their work under the bark and cause damage to the cambium layer. They can cause death by girdling or through the introduction of a disease organism.

2. Wood Borers - These insects bore into the sapwood and heartwood making it useless for commercial use (termites, beetles).

3. Leaf Eaters - These insects either eat (defoliate) or suck juices from the foliage. The insect larvae usually cause the damage. The foliage is usually destroyed (larvae of moths, butterflies, and sawflies).

4. Terminal Eaters - These insects eat the terminal buds or leaf buds (larvae of moths and beetles).

5. Sucking Insects - These insects cause damage by sucking sap and juices from the trees (aphids, mites, scales).
6. **Gall Makers** - These insects cause abnormal growths on limbs, trunks, twigs and leaves (wasps, mites, gnats, midges).

7. **Seed Feeders** - Some insects destroy fruits, nuts, or seeds (chalcids).

8. **Root Feeders** - These insects are most serious to young seedlings. They attack roots of small trees (weevils, white grubs, wireworms).

**Control of insects:** There are several methods of reducing the damage caused by injurious insects. These methods include natural control, silvicultural control, and chemical control.

**Natural control** - Nature has its own way of controlling life. Insect activity is controlled to some extent by temperature. Few insects can survive temperature above 120° F. or extremely cold weather. Insects, such as the bark and wood borers, can be controlled by exposing the infested log to direct sunlight.

Insects are also controlled by natural predators or enemies. Birds, mice, chipmunks, and squirrels all help keep the insect population under control.

Many species of insects are beneficial and feed on harmful insects. Most of these insects feed on the immature stages (eggs, larvae, nymph).

**Silvicultural control** - In a well-managed forest, certain preventive measures are taken to control insect infestations. These measures involve the removal of susceptible trees, sanitation, and salvage cuttings, the selection of insect resistant varieties, careful site selection, and cutting cycles and methods.
Chemical control - The use of toxic chemicals (insecticides) to control insects is called chemical control. Insecticides used on forest insects are of three types; contact, stomach, and systemic poisons. Contact poisons kill insects upon contact. This type of poison is absorbed into the insect's body. Stomach poisons are swallowed by insects as they feed on plant material. Systemics are taken up by the plant internally. Systemics are mostly for the sucking insects.

Insecticides can be applied by a hand sprayer or by aerial spraying (airplanes) for large areas.

Diseases: Tree diseases, like insects, are always present in a forest stand. They are present when a tree emerges as a seedling to the end of its life.

Tree diseases are of two main types; parasitic and non-parasitic. The parasitic diseases are often highly contagious. They are caused mainly by bacteria, fungi, viruses, nematodes, and mistletoe. Among the nonparasitic diseases are such things as winter injury, drought injury, nutritional disorders, injury from fire, etc.

Control of disease: Effective control of forest diseases must be based on a sound knowledge of the diseases and of the environments under which they occur. Both direct and indirect methods are used. Direct methods include the use of fungicide sprays, dust, and soil treatments; the removal and destruction of affected trees or parts; the prescribed use of fire; and the removal of alternate hosts. Indirect methods involve the proper timing of cutting; the control of stand composition to give mixtures of tree species instead of pure stands; fire prevention; and the use of disease resistant varieties.
READING AND INTERPRETING MAPS AND LAND DESCRIPTIONS

Reading and interpreting maps and land descriptions are basic to forest management. These maps show many things about the forest. With a reliable and accurate map, present and future forest operations can be planned. Land descriptions assist the forester in identifying parcels and subdivisions of land.

Equipment and Instruments

Instruments used for surveying and mapping woodlands include (1) the steel tape, (2) the compass, and (3) the surveying instrument.

For measuring the length of lines or horizontal distances, the 100 foot or 2-chain steel tape is most accurate. Measuring with a steel tape is called chaining. The two people required to measure with a steel tape are referred to as rear and head "chainmen". Accuracy is determined by the knowledge of the equipment and the skill of properly using, reading, and recording measurements. Figure 25 shows a reel-type steel tape used in measuring horizontal distances.

The compass is used for determining direction. Compasses used in forestry are of two types -- the hand held compass and the staff compass. The major differences between the two are that the staff compass is mounted on a rod, is steadier, and is more accurate. A common compass is shown in Figure 26. The direction is always expressed as a bearing or as an azimuth. The azimuth may be read from the outer circle of numbers on the compass face.
Fig. 25.—Reel type steel tape.

Fig. 26.—Standard hand compass.
Fig. 27.—Bearings and corresponding azimuths.

For example, North is 0 degrees, East is 90 degrees, South is 180 degrees and West is 270 degrees. Bearings, on the other hand, are read from the inner circle of numbers and never exceeds 90 degrees; is measured from North or South, and divides the circle into four parts (See Figure 27 above).

There are many types of surveying instruments used by foresters. One of the most commonly used is the dumpy level similar to the one shown in Figure 28. The dumpy level can be used to determine differences in elevation for topographic mapping.

Land Description

The method used by foresters in the western states to describe sections or tracts of forested land is called the rectangular survey system. The basic system is laid out in reference to a true North-South line called a principle meridian and an East-West line of latitude called the base line. Where the principle meridian crosses the base line is known as the initial point. The initial point serves as the origin for public land surveys. Guide meridians are laid out running parallel to the principle meridian and standard parallels run parallel to the base line at 24 mile intervals.
These lines divide the land up into 24 mile square grids. Each 24 mile square tract is then divided into 16 townships by locating range lines parallel to the principle meridian and tier or township lines parallel to the base line.

A series of adjacent townships running east and west is known as a tier. An adjacent series of townships running north and south is known as a range. The tiers of townships are numbered consecutively, both to the north and south of the base line. The ranges of townships are likewise numbered, both to the east and west of the principal meridian. A township is designated by the serial number of its tier and the letter N or S to indicate the position of the tier north or south of the base line; the serial number of its range and the letter E or W to indicate the position of the range east or west of the principal meridian.

Each township is further divided into 36 sections of one square mile each (640 acres). The sections are numbered by starting at the northeast corner and continuing west and east
across the township until the number 36 section is found in
the southeast corner of the township.

Sections are then divided into quarter sections and then
into 40 acre tracts \( \frac{1}{4} \) of a mile square (See Figure 29).

Fig. 29.—Subdivision of the rectangular survey system.

Aerial Photographs

Aerial photographs are invaluable in forest management.
A good photograph shows roads, valleys, ridges, streams, lakes,
rivers, railroads, buildings, forest types, insect infestations, etc. Foresters using aerial photographs can estimate
timber volumes. Forest types can be determined by the use of
a stereoscope similar to the one shown in Figure 30. Aerial
photos are usually read by the use of the stereoscope. The
stereoscope shows detail through magnification; including hills, valleys, and even tree height. In reading aerial photos, they should be placed so that the shadows of objects fall toward the reader. Acreage and distances can also be determined by the use of a planimeter. This precision instrument is used for measuring areas of any shape and contour.

Fig. 30.—Stereoscope.

**Topographic Maps**

Topographic maps are maps which show contour lines of known elevation. Topographic mapping is a complex operation requiring the use of leveling instruments. The level is used to determine differences in ground elevation. Foresters use topographic maps for laying out roads, building bridges, and many other forest improvements. Topographic maps can also be used when planning lookout tower locations and other forest fire detection devices. The drawings in Figure 31 shows two topographic maps.

**Deeds and Searchers**

A deed describing the legal boundaries of the forest should be kept in a safe place. Any disputes with adjacent
landowners over property boundaries should be settled in writing and placed with the deed. If boundary lines are legally described by a licensed surveyor and marked, the risk of timber trespass is minimized.

Occasionally when forest land is sold a searcher is initiated. A searcher is an organization hired to check to see if any liens are held against the forest property. The land cannot be sold until the lien has been cleared.

Right-of-Way

When the forest manager is planning the harvesting operation, it may be necessary to cross the lands of others with roads, railroads, etc. The forest manager must acquire a right-of-way before proceeding with the logging plan. This right-of-way may be purchased, leased, or an easement (privilege to use land) may be obtained from the landowner or landowners concerned.

ESTIMATING THE STAND

Forest products should be measured before they are sold. It is unheard of to sell cattle without weighing them or at
least counting them; however, some small forest owners do just that when they sell their forest products. If foresters do not know the amount of timber they have to sell, they have little chance of obtaining full value for it. Trees or logs can be measured easily and accurately.

Calculating Yields

To determine the yield or volume of a standing tree, you must find out the diameter and useable height of the tree. The diameter is always measured in inches at breast high (dbh), 4½ feet above the ground. The cut-off point for useable height is usually at the point where the diameter becomes 4 to 6 inches.

One instrument used to obtain diameter at breast height is the tree caliper. The tree caliper, usually constructed of wood or metal, is a simple device consisting of an arm and two prongs, one of which is free to slide along a graduated scale on the arm. The prongs are placed against opposite sides of the tree and the diameter is read on the graduated arm. Figure 32 shows a tree caliper in use.

The diameter tape (D-tape) is most frequently used in determining tree diameter. It is a steel tape of pocket size with a bark hook at the zero end (See Figure 33). Each surface of the tape is marked in tenths and inches. Although the tape is placed around the tree, the scale is calibrated to give the tree's diameter. If a diameter tape is not available, a common

Fig. 32.—Tree calipers.
measuring tape can be used. Stretch the tape around the tree to determine its circumference in inches. Divide the reading by 3. To be strictly accurate, the reading should be divided by 3.1416. The approximate diameter obtained by dividing by 3 is within the standards of accuracy usually required. The diameter measurements are taken at breast height (4 1/2 feet).

The Biltmore scale is also used to determine tree diameter. To measure the diameter, hold it horizontally against the tree trunk, 25 inches from the eye, and at breast high. Move the stick until the left end (zero end) is in line with your eye and the left side of the tree. Then without moving the stick or turning your head, note where the line from the same eye to the right side of the tree crosses the stick. The reading at this point gives the diameter in inches. The drawing in Figure 34 illustrates this use.

To determine the useable height using the Biltmore stick you must stand 66 feet from the tree. Hold the stick vertically about 25 inches from your eye. Be sure the side of the stick with the number of 16-foot logs is facing you. Move the stick up or down so that the line of sight from the eye to the stump height of the tree touches the bottom of the stick. Then, without moving your head, note where the line from the eye to the "cut-off point" (useable height) crosses the stick. Estimate to the nearest half-log. This will give the number of 16 foot logs and half logs in the tree (See Figure 35).
Fig. 34.—Using the Biltmore stick to determine trunk diameter.

After the diameter and height of the tree is determined, the board foot volume of the tree can be found by using Table 3. A board foot is a piece of wood 12 inches wide, 12 inches long, and 1 inch thick.

To measure the board feet in a tree that has been felled, a common yardstick or ruler can be used. The contents of the logs can be determined by using Table 4. To measure a felled log follow the following steps:

Fig. 35.—Height measurement with a Biltmore stick.
1. Measure the average diameter of the log in inches inside the bark at the small end. If the log is fairly uniform in diameter only one measurement is needed. If it is uneven take the average of the short and long diameters.

2. Measure the length of the log to the nearest foot, allowing about 4 inches for trim.

3. Find its contents by using Table 4. Suppose the felled log is 13 inches in diameter at the small end and 16 feet long. Run down the left-hand column to the number 13. Move across to the 16-foot column. The figure there is the estimated number of board feet that can be sawed from the log, in this case 115.

So each log will not be measured twice, it should be marked with chalk after being measured.
## TABLE 3
Amount of Timber in Trees, by Diameter and Useable Height (U.S.D.A.)

<table>
<thead>
<tr>
<th>Diameter of tree, breast-high (inches)</th>
<th>Volume (board feet) according to number of usable 16-foot logs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
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### Cruising

A timber cruise is an estimate to determine what kind of trees are growing, how many are marketable, the volume of standing timber, etc. It may be done at a 100 percent cruise or a partial cruise depending on the size of the stand and timber value. The 100 percent cruise is seldom used.

**100 percent cruise:** This method of cruising involves measuring all trees within a stand. It is the most accurate method of cruising and the most time consuming. The entire forest volume is determined by summing individual tree volumes.
## TABLE 4
Contents of Logs in Board Feet (U.S.D.A.)

<table>
<thead>
<tr>
<th>Diameter of log, small end, inside bark (inches)</th>
<th>Contents, according to length of log in feet</th>
<th>BOARD FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>9</td>
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<tr>
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<td>26</td>
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<td>27</td>
<td>280</td>
<td>320</td>
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<td>345</td>
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<tr>
<td>29</td>
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<td>370</td>
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<tr>
<td>30</td>
<td>350</td>
<td>395</td>
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<td>31</td>
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<td>420</td>
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<tr>
<td>32</td>
<td>400</td>
<td>450</td>
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<td>33</td>
<td>425</td>
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<td>34</td>
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<td>35</td>
<td>475</td>
<td>540</td>
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<td>36</td>
<td>505</td>
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</tr>
<tr>
<td>37</td>
<td>535</td>
<td>605</td>
</tr>
<tr>
<td>38</td>
<td>565</td>
<td>635</td>
</tr>
<tr>
<td>39</td>
<td>595</td>
<td>670</td>
</tr>
</tbody>
</table>

Partial cruise: If the forest is too large or the available time is short a partial cruise may be taken. A partial cruise measures only a fraction of the trees in a stand; (usually 5-25 percent); therefore, the forester must assume the remaining trees are similar to those measured. For example, 20 acres of a 100-acre forest is cruised and is considered as representing a fair sample of the whole forest. The trees within the 20-acre tract are measured and their individual volumes are determined. Then the volume for all measured trees is multiplied by five to get an estimate of the total timber volume of the entire 100 acres.

-71-
There are several methods used in partial cruising - (1) strip, (2) line plot, and (3) point sampling.

In the strip method of cruising, a strip 66 feet wide is run across the forest, and the volume of every marketable tree in the strip is estimated. A strip 66 feet wide and 660 feet long equals one acre. At the end of each 660 foot stretch, a new tally sheet is begun. Tally sheets will be discussed later. Spacing the center line of the 66-foot strips 264 feet apart will measure a quarter of the forest; 132-foot spacing half of it. To determine the percent cruise and its relationship to the strip width and distance between centers the following equation is used:

\[
\text{% cruise} = \frac{\text{Width of strip}}{\text{Distance between centers}} \times 100
\]

**NOTE:** Width of strip and distance between centers must be in the same units (feet, yards, inches, etc.)

The percent cruise of the strip cruise illustrated in Figure 36 is calculated as shown below:

\[
\text{% cruise} = \frac{66 \text{ ft.}}{264 \text{ ft.}} \times 100
\]

\[
= ¼ \times 100
\]

\[
= 25\% \text{ cruise}
\]

Two people are needed for strip cruising. The chainman walks along the centerline of the strip and the tallyman calls out the tree species, diameter at breast height (4½ feet), and height of each marketable tree. When they reach the edge of the forest they move over 264 feet (if they are measuring a quarter of the forest) and run another 66 foot strip back. Figure 36 illustrates the strip method of cruising. To obtain an estimate of the total stand, the volume of timber determined in these strips would be multiplied by four.
Timber stands can also be estimated by the line plot method. Circular plots are located in checkerboard fashion at specific intervals throughout the forest. These plots are spaced at set distances from each other along parallel compass lines which are regularly spaced over the timber stand. The forest manager of the tract shown in Figure 37 made 10 strips across the forest, each strip and each sample on each strip being 208 feet apart. Each circular plot contains a quarter-acre. Merchantable trees within each quarter-acre plot are measured for volume. At the end of the cruise the forest manager's tally sheets showed 12,000 board feet of timber on 52 quarter-acre samples. This is the same as 12,000 board feet on 13 acres, or about 920 board feet per acre. If the forest contained 55 acres, then an estimated 50,600 board feet of merchantable timber exist in the entire 55 acres of forest.

To determine the percent cruise for the line-plot cruise the following formula is used:
\[ I = \frac{a}{(0.1)(L)(B)} \]

where:  
- \( I \) = cruise intensity as a decimal  
- \( a \) = area per plot (acres)  
- \( L \) = spacing between cruise lines (in chains)  
- \( B \) = spacing between plots on cruise lines (in chains)

The percent cruise for the line-plot cruise shown in Figure 37 is determined as illustrated below:

\[ 208' = 3.15 \text{ chains} \]
\[ 104' = 1.575 \text{ chains} \]
\[ 66' = 1 \text{ chain} \]

\[ I = \frac{.25}{(0.1)(3.15)(3.15)} = \frac{.25}{.99} = 25\% \text{ cruise} \]

Fig. 37.--Line Plot method of estimating timber.  
(Courtesy: U.S.D.A.)

While foresters are measuring the trees on a forest cruise they tally merchantable trees by diameter at breast height (4½ feet), merchantable height, and species. Figure 38 shows a standard tally sheet used to record trees on a
sample plot. A dot is made for each tree in a box of four. The four dots are connected with straight lines to make eight trees; and finally, crossed lines are put diagonally across the box giving a total of ten trees. The number and symbol for each number are shown below.

<table>
<thead>
<tr>
<th>Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
</tbody>
</table>

**TALLY SHEET**

Estimator: ___________________________ Plot No: ___________________________
Date: ___________________________ Size of Plot: ___________________________
Owner: ___________________________

<table>
<thead>
<tr>
<th>Diameter Breast Height (inches)</th>
<th>Number of 16-ft. logs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spruce</td>
</tr>
<tr>
<td>10</td>
<td>. .</td>
</tr>
<tr>
<td>12</td>
<td>.</td>
</tr>
<tr>
<td>14</td>
<td>.</td>
</tr>
<tr>
<td>16</td>
<td>.</td>
</tr>
</tbody>
</table>

**Fig. 38.--Standard tally sheet.**

A new system which can speed up the cruising procedure considerably is called **point sampling**. In this method a glass wedge prism is held by the cruiser a convenient distance from his/her eye. The prism is held over a fixed point while the cruiser rotates to check all trees. Point sampling does not
require that plot diameters or tree diameters be measured as in the other methods. The cruiser only counts the number of trees and their height in logs whose diameter at breast height does not appear to be detached from the stem when viewed through the glass prism (See Figure 39). When using the glass wedge prism the section of the tree covered by the prism appears to be displaced. If the section of the tree covered by the prism appears to be completely displaced from the main stem the tree is not counted. Those in which opposite edges line up are considered to be borderline trees and every other tree is counted. Those sections that do not appear to be completely displaced from the main stem are counted (See Figure 39).

![Diagram of the Wedge Prism]

Fig. 39.—Point sampling. The wedge prism and how it tells which trees to count.

Calculating Growth Rates

Calculating growth rates provide the forester an estimate of the periodic volume (board feet) increase in a forest.
stand. This information provides a means of determining if the timber is growing at the rate it is capable of. It also provides him/her with a means of estimating the amount of timber that may be harvested.

The periodic rate of volume increase may be determined by measuring the number of annual rings in the last inch of tree growth. This can be accomplished by using an increment borer. This instrument is a hollow-tubed drill which cuts out a round core sample of wood. The sample is taken at breast height.

Keeping Records on Forest Lands

One of the major responsibilities of the forester is keeping accurate and complete records on forest land. A description of legal boundaries of the forest land must be kept so that corners and property lines can be legally established. Any disputes with adjoining land owners about property boundaries should be settled in writing. It is the landowners' responsibility to establish and mark their property lines. Establishing and marking boundary lines minimizes trespassing and the accidental harvesting of other landowners' trees.

Accurate records and reports must be maintained on various developments and work accomplished in the forest. These records include logging information, timber volumes standing and cut, trees planted, work days expended on each kind of job, estimates of annual growth, and other forest operations.

The forester must keep a financial ledger of all receipts and expenses incurred on a daily, monthly, and yearly basis. Each day's receipts are listed showing date, from whom received, the total received, and finally the nature of the receipt (sale of logs, pulpwood, or other forest products).
The cash disbursements are likewise recorded. At the end of each month and year the total receipts and disbursements are totalled and posted in the ledger. Forest tax laws are very complex; therefore, forest owners who keep accurate records and accounts are in a better position to deal with their income tax filing.

**NATURAL DEFECTS IN WOOD**

Perfect trees are never found in nature. Most trees in a forest have some type of defect which reduces the quality and value. These defects include cross grains, knots, reaction wood, growth stresses, brashness, frost injuries, pitch defects, and bark pockets.

**Cross Grains in Woods**

Whenever the wood fiber runs at an angle to the long axis of a piece of wood, the piece is said to be cross grained. There are two types of cross grained defects, namely, (1) spiral grain and (2) diagonal grain.

**Spiral grain:** The spiraling of wood fiber in a tree trunk that gives it a twisted appearance is referred to as spiral grain. This spiraling effect can be noticed only when the bark has been removed (See Figure 40).

**Diagonal grain:** Diagonal grain is a milling or sawing defect. It results from timber being cut so that the wood fibers (grain) do not run parallel with the long axis of the board. This improper sawing weakens lumber.

**Knot**

A knot is a branch or limb base that is embedded in the wood of a tree trunk. Knots are caused by limbs which have
been cut or broken off from the tree trunk. They can protrude, be flush, or be depressed into the log. A knot on the log surface represents a knot in the underlying wood. This knot, no matter how small, degrades the log's quality and value. There are two types of knots -- black knot and red knots. A black knot is formed by a dead branch, whereas a red knot is formed by a live branch. The picture in Figure 41 shows two red knots.

Fig. 41.--Knot. (Courtesy: U.S.D.A.)

Split

A longitudinal crack or fissure in a log is called a split (See Figure 42). A split is generally caused by operational accidents or carelessness, but sometimes it results from the release of internal stress or pressure when the tree is felled.

Brashness

This is an abnormal condition in wood that permits it to break suddenly and completely across the grain. The break is usually at a stress point; which a normal piece of wood would
fail to break. Brashness is a very objectionable natural defect in wood, because it gives no warning of breaking in advance. The surfaces exposed by a brashness break are relatively smooth when compared to the jagged surfaces of a break in normal wood.

![Image](image-url)

**Fig. 42.--Split.**  
(Courtesy: U.S.D.A.)

**Reaction Wood**

Not all trees grow erect and straight. A few trees in the forest lean and are responsible for the formation of wood distinctly abnormal in structure. The woody tissues developed in leaning tree trunks as they straighten have been designated as reaction wood. There are two types of reaction wood -- compressed and tension.

**Compressed wood:** The abnormal wood developed in this tree forms on the underside of leaning trunks. Compressed wood usually occurs in conifers. Figure 43 shows a cross section of a log with compressed wood.

**Tension wood:** In comparison to compressed wood, tension wood develops on the upper side of the leaning trunk. Hardwoods are noted for tension wood.
Ring Shake

A ring shake is a separation of the wood fibers along parts of the annual rings (See Figure 44). Sometimes it is confined to definite sections along the outer rim of wood, sometimes it is confined to the center, and sometimes it is found throughout the log. Shakes are difficult to see in green wood, but show up readily when the wood is dry.

Fig. 43.--Compressed wood.

Fig. 44.--Ring shake.
(Courtesy: U.S.D.A.)
Wind Shake

A wind shake is a single radial split extending to both sides of the pith (See Figure 45). Wind shakes are caused by severe winds and become serious near the middle of slopes. The damage is greatest on ridgetops.

Fig. 45.—Wind shake.
(Courtesy: U.S.D.A.)

Compression Failures

Compression failures refer to the buckling of wood fibers. This buckling causes ridges on the wood surface that may be visible with the naked eye or so slight that a microscope must be used. Compression failures may be caused by felling trees on uneven ground or when they strike other trees or rocks, from rough handling, or they may develop in standing trees when they are bent by severe winds. Compression failures considerably reduce the wood's strength and shock resistance.

Frost Injuries

Freezing temperatures can also cause wood defects in living trees. Two types of frost injury result from freezing temperatures. These are known as frost cracks and frost rings.

Frost cracks are radial splits in the wood and bark near the base of the tree.
Frost rings are brownish lines within the boundaries of the growth rings. These lines extend in the same direction as the growth rings. Frost rings result from frost injury to the cambium layer.

Bark Pockets

Bark pockets are small patches of bark embedded in the wood of a tree. These are usually caused from some type of injury. A small area of the cambium layer dies while the surrounding tissue continues to grow. A new cambium develops and forms over the gap in the inner bark, thus embedding a portion of the bark in the wood (See Figure 46).

Pitch Defects

Pitch streaks are defects developed through the accumulation of resins in the wood. The wood cells become resin-soaked and cause discolored streaks or patches in the wood.

Pitch pockets form in an opening in the wood grain where two growth increments meet. This pocket between the two growing tissues fills with resin.

Pith Defects

When a tree trunk forks and a log is cut just at the base of the fork, the end of the log will seem swollen. This swollen part of the log will have two pith centers separated by a bark pocket similar to the one pictured in Figure 46. A double pith leads to cross grained logs and a split or potential split from the bark pocket.
Fig. 46.--Double pith with a bark pocket.
(Courtesy: U.S.D.A.)

**Spider Heart**

A spider heart is a radial separation of wood fibers starting at the pith center and running out in at least three directions. Spider heart occurs most in large, fully mature, or overmature trees. Figure 47 shows a cross section of a log with spider heart.

Fig. 47.--Spider heart.
(Courtesy: U.S.D.A.)
Loose Heart

Loose heart is the separation of wood fibers completely around a growth ring within the heart or core of a log. The area is generally not over 6 to 12 inches in diameter. Figure 48 shows a log with a loose heart.

Fig. 48.—Loose heart.
(Courtesy: U.S.D.A.)

DEFECTS DUE TO SEASONING AND MACHINING

Freshly cut or "green" lumber contains a large amount of moisture. In this condition the lumber is heavy and unfit for many uses. It must be seasoned to remove the moisture. As the lumber is seasoned some defects may occur, because when moisture in green lumber is reduced, the lumber shrinks in width, thickness, and length. Careless or improper seasoning methods may cause loss in quality of lumber through checking, splitting, honeycombing, hardening, and various forms of warping.

Defects can also be caused by improper machining. These defects include raised, chipped, or torn grain.

Seasoning Defects

Properly seasoned lumber should be straight and flat. It will stay in place when nailed and will retain paint better than poorly seasoned or unseasoned lumber.
Checks: Checks are ruptures or splits in wood along the grain which occur during seasoning. As shown in Figure 49 there are two types of seasoning checks - end checks and surface checks. As the name implies, end checks develop on the end of a piece of lumber and surface checks develop on the surface. Checks are usually caused by rapid and irregular seasoning of lumber.

![End and Surface Checking](image)

**Fig. 49.**--Lumber showing end and surface checks.

Warping: The term "warping" is used to describe any distortion in a piece of wood from the true plane or flat surface. The principal types of warping include cupping, bowing, twisting, and crooking. Figure 50 shows the various types of warping which are caused by uneven drying.

![Types of Warping](image)

**Fig. 50.**--Types of warping.

Case hardening: Case hardening develops when lumber is dried too rapidly. Case hardening occurs when timber is dried so rapidly that the outer layers (shell) want to shrink while the interior (core) is still saturated with moisture. If drying continues at this rapid rate, the shell may dry to a "permanent set" without attaining full shrinkage. As the drying of
the lumber continues more moisture is lost from the core causing it to shrink further. However, the shell has "set" and now prevents the normal shrinkage of the core. This produces stresses which may cause checks and honeycombing.

Reverse case hardening: This is a condition that develops in lumber as a result of oversteaming, usually in an attempt to relieve case hardening. During conditioning at high humidity, the shell is permitted to soak up moisture in excess to that of the core. The shell begins to swell; however, this tendency is resisted by the drier core. This causes cupping and in some cases honeycombing.

Honeycombing: Internal checks that develop in drying is referred to as honeycombing. These checks are caused by internal stresses or by the closing of surface checks.

Collapse: This defect occurs when very wet heartwood of certain species is dried. It generally occurs as a result of abnormal or irregular shrinkage. Collapsed lumber has irregular depressions and elevations on the surfaces of a board.

Machining Defects

A few defects are a direct result of improper or careless machining.

Raised grain: Raised grain is a roughened condition of the surface of dressed lumber. The raised grain has a corrugated appearance and is due largely to the crushing of the hard summerwood into the softer springwood. This is generally caused by planer knives. The corrugated effect is increased by dull planer knives. Raised grain is also affected by moisture content changes after the lumber is planed.
Chipped or torn grain: Chipped or torn grain is grain that has been torn entirely free between growth increments. These strips of torn grain resemble loosened splinters. Torn grain is caused from pressure exerted in planing and sanding.

LOGGING

There is more to logging than meets the eye of the layman. Much planning must go into the logging operation. This operation includes cutting down the trees (felling), removing the limbs (limbing), sawing the logs into proper lengths (bucking), and dragging (skidding) to a place where they can be piled (decked) for loading. Each step must be carefully planned to insure the safest and most economical use of labor, equipment, and resources. The forester must consider topography; size, distribution, location, and volume of timber; equipment availability; and the demand for the products to be produced. In most areas cutting permits must be obtained from State and Federal agencies before the logging operation begins.

The forest manager must first determine the timber available for harvesting and its location, volume, size, and species with respect to known points such as rivers, towns, railroads, and other features. Surveys must be taken to locate property lines to minimize trespassing. Except where logs are taken out by water, roads must be made available for removing the harvested logs. Machinery must be selected depending on the size of the logs to be removed. Large timber require heavier and more powerful equipment than smaller timber. The forester must also consider the market demand for the type of product to be harvested. If there is no demand for poles or pilings then possibly the wood could be used for paper or plywood. This must be considered and contracts completed before the logging begins.
Topography of the forested land has several effects on the logging operation. Some equipment cannot be used on steep slopes or along hillsides. When trees are removed from a hillside it exposes the site to water runoff and gully and sheet erosion. Not only is there a loss of site quality, but siltation of streams will impair fish life. It is the forest managers responsibility to minimize the damage to the forest and its environment when logging operations are undertaken.

Preharvest Timber Estimating

A preharvest timber estimate of timber to be cut should be made before the logging operation begins. This will aid foresters in determining the quantity and types of equipment necessary for the harvesting operation. It will also give them an estimate of harvestable timber in the forest. Several systems are used to estimate standing timber. These include the strip cruise, plot cruise, and point sampling. These methods of estimating timber volume are discussed in detail on pages 70-76.

Mapping the forest area is usually done at the same time as estimating the volume of standing timber. When mapping, one must locate the boundary of the forest starting at a known section corner. With the use of a leveling instrument and compass, the section is broken into sixteen 40-acre parcels of land. Each 40-acre parcel is then drawn to scale and the forest types, stand density, and range in tree size noted. Land features such as roads, railroads, swamps, lakes, streams, etc. are also shown. Forest type maps aid the forest manager in planning an economical and efficient logging operation.

Forest products should be measured and yields estimated before they are sold. This estimation of yield should be
accomplished before the logging operation is undertaken. If forest managers do not know the amount of timber they have to sell, they have little chance of obtaining full value for it. Several methods of estimating yields are available to the forester. These include tree calipers, diameter tape, and the Biltmore stick. These methods are discussed on pages 66 to 70.

**Periodic Annual Increment**

Frequently the forest manager needs to know how fast the trees are growing in the forest over a specific period of time. Growth determinations provide an estimate of the periodic volume increase in a forest stand. This information can be used to determine if timber is growing at the rate it is capable of producing and to determine the amount of timber which may be harvested from it.

Trees grow both in diameter and height. Repeated measurement at periodic intervals can provide an accurate estimate of growth during the period between the measurements. The difference in volume of the two measurements can be expressed as either annual or periodic growth.

Growth of a stand of trees is usually predicted on the basis of sample tree measurements. Usually one or two sample trees are taken in each sample plot.

The growth rate of an individual tree is evaluated on the basis of the width of the annual rings and changes in merchantable height. Tree ring diameter measurements are made with the use of an increment borer. The auger-like hollow borer removes a core sample when twisted into the tree trunk. This core sample shows the annual rings of the tree. The core sample is taken at breast height.
Yield tables give a measure of yield at different ages (usually 10 year periods) per acre of forested land. Yield tables are made to give the yields of a single tree species. They are prepared for fully stocked even-aged stands. Separate tables are given for each of the qualities of site; in terms of height of the average dominant and co-dominant trees at a given age. Table 5 shows an example of a normal yield table for red spruce.

### TABLE 5
Normal Yield Table for Red Spruce

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>264</td>
<td>26</td>
<td>4.3</td>
<td>17</td>
<td>210</td>
<td>--</td>
</tr>
<tr>
<td>40</td>
<td>703</td>
<td>88</td>
<td>4.8</td>
<td>28</td>
<td>1,110</td>
<td>90</td>
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<tr>
<td>50</td>
<td>1,007</td>
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<td>39</td>
<td>2,760</td>
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<td>990</td>
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<td>6.3</td>
<td>47</td>
<td>4,200</td>
<td>144</td>
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<tr>
<td>70</td>
<td>811</td>
<td>228</td>
<td>7.2</td>
<td>52</td>
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<td>95</td>
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<td>80</td>
<td>715</td>
<td>237</td>
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<td>55</td>
<td>5,700</td>
<td>55</td>
</tr>
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<td>90</td>
<td>665</td>
<td>242</td>
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<td>56</td>
<td>6,000</td>
<td>30</td>
</tr>
<tr>
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<td>640</td>
<td>246</td>
<td>8.4</td>
<td>58</td>
<td>6,190</td>
<td>19</td>
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<tr>
<td>110</td>
<td>623</td>
<td>250</td>
<td>8.6</td>
<td>59</td>
<td>6,350</td>
<td>16</td>
</tr>
</tbody>
</table>

(Site index 50 ft. at 65 years. Includes trees 4 in. and over d.b.h.)

Another term commonly heard when determining periodic annual increment is site quality and index. **Site quality** indicates the productive capacity of a specific area of forest land. Although many species may grow on the same site, they may not grow equally well. A method of determining site quality is on the basis of average total height attained by dominant trees at certain index ages (usually 50 or 100 years). This relationship between tree height and age is called **site index**. Site indices are mostly used on pure stands of even-aged tree species. Site index tables and growth curves have been developed for each tree species. Table 6 is a site index table for white pine. If the average height of the dominant trees is 80 feet and the stand age is 34 then the site index is 100.
TABLE 6  
Site Index Table

<table>
<thead>
<tr>
<th>Site Index (height at 50 years of age)</th>
<th>Total Age, Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>20 30 40 50 60 70 80 90 100</td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Forest Mensuration; Husch, Miller, Beers. Ronald. 1972.)

Stand density can affect site index. Density refers to the relative closeness of the trees, closeness of the crowns, or number of trees per acre. A good forest density means the forest area is producing all of the timber it is capable of growing. A forest with a good crown canopy brings about early pruning of the lower limbs and provides adequate competition to force maximum height growth.

Timber Sales

Selling timber for the highest returns involves following certain timber-marketing practices. These practices include marking and estimating timber products to be sold, selling the timber for the highest-value products first, offering the timber to several buyers on a bid basis, and selling the timber by the use of written contracts. These contracts are written by a lawyer competent in timber harvesting practices.
There are two major sources of timber sales in the United States; namely, federal and private. Federal timber sales originate from cuttings taken in National Forests. The profits made from federal timber sales is put back into the National Forest System. Private timber sales are made by individuals, private companies, and corporations.

Safety

Logging is a hazardous occupation. Most logging accidents are caused by cutting tools, such as saws and axes, by falling or swinging objects, or by human falls. There are very effective protective devices available. These include aluminum leg guards, steel-toed shoes, hard hats, and front padded pant legs that protect against chain saw blades. Some chain saws are equipped with a top blade shield. The tractor drivers are protected by steel cages over the driver's seat. Goggles and gloves should be worn at all times to protect hands from cuts and eyes from flying wood and metal splinters. First-aid kits and fire extinguishers should be ready at all logging areas.

Safety in the logging or harvesting operation is important. Injured workers lose working time and employers lose job efficiency. Most accidents are caused by inexperienced or careless workers. Generally an experienced worker is a careful one; the careless ones are eliminated by accidents. A logging safety program should be initiated to educate all workers in the practice of safe working habits. This program could be through group training, placing posters at strategic places throughout the working area, and distributing individualized education material.
Logging Tools and Equipment

The tools used for felling, bucking, skidding, and processing trees are numerous. Only the more common ones will be discussed.

Axe: The axe has been in existence since the "stone age". Those used today are characterized by having steel heads and wooden handles. Many shapes and sizes of axes are available. The heads range in shape and weight from 1 3/4 to 5 pounds. The choice of the head weight depends on the strength of people using them. Most axes used in logging work weigh at least 3 1/2 or 4 pounds.

Saw: Many trees are felled by use of the power crosscut saw. These saws are powered by a one or two cylinder gasoline engine developing 3 to 8 horsepower. The blade or cutter bar length ranges from 12 to 48 inches.

Handsaws are also used in the logging process. Handsaws are made in a variety of lengths, widths, and types. Most hand crosscut saws are equipped with one or two handles, depending on whether one or two people are to use them.

Mechanized equipment: Most harvesting systems in the United States are moving toward the fully mechanized operation. These include rubber tired equipment, crawler tractors, self-loading equipment processors, combines or harvesters, cable systems, boom powered loaders, and others. This equipment is designed to make the logging operation safer and more efficient.

Timber Marking

Marking timber to be cut by some visible means is known as timber marking. The most desirable method of marking
timber is with paint. Paint is used because various colors can be used, ease of application, and trees can be marked without damaging them in any way.

With paint marking, a color must be used that can be seen and that is durable enough to last several months. Yellow, blue, and white paints are most commonly used.

Paint can be applied by two methods: (1) brush or (2) hand-type pressure gun. The paint gun is most desirable because paint is sprayed into crevices of rough bark and does not flake off. It is also faster and more convenient.

Paint marks are made on the downhill side of the tree at dbh level and ground level. (See Figure 51). Marks at dbh can be seen for some distance and the ground or base mark is used to check the stump after logging to see if the tree was marked for cutting. There are many variations and combinations of methods of marking trees for cutting. They are all adapted to the individual needs of the owner. Fig. 51.--Marking trees.

Marking trees with an axe cut is another method of marking timber. This form of timber marking has two major disadvantages: (1) once the marks are made it is difficult for the markers to change their mind. The cut (blaze) cannot be removed from a tree except by making a bigger one or obscuring it in some way; and (2) the wound or cut provides an excellent entry for insects and diseases.
The Felling Operation

The felling operation must be carefully planned. There is more to felling a tree than cutting it and letting it fall. How a tree is felled affects the value of the tree, the efficiency of the operation, and the future condition of the forest.

Avoid felling trees on fences, fire lanes, telephone and power lines, public roads, and other areas. Felling trees on these not only damages property but damages the tree.

Before a tree is felled the fallers must choose the direction of fall. They must consider breakage, slope, wind, damage to other trees, and direction of skidding. Much time is lost when a felled tree lodges or "hangs up" in another tree. This unnecessary complication can be avoided by accurate felling. Falling trees that strike irregular surfaces such as rocks, stumps, mounds, etc. often break. Any breakage causes serious losses in both merchantable volume and value. It is particularly important to fell trees being harvested so that they will not needlessly destroy or damage standing trees. Trees felled in the direction of skidding make it easier to get the logs out. Trees with rot or mechanical damage weakens the wood fibers and influences the direction of fall.

When felling trees the faller must make sure that all people, animals, and equipment are safe.

Undercut: After the direction of fall has been determined, the undercut is made in the direction of fall. An undercut is a notch cut into the tree at the base of the stump (See Figure 52). This notch removes support and thereby increases the tendency of the tree to fall in that direction. The depth of the undercut varies with tree size. To make an undercut, make the first cut with the saw horizontal and at
a right angle to the trunk. Cut about one-fourth the distance through the trunk. The cut should be made as close to the ground as possible, generally under twelve inches. Make a second cut about 5 inches above the first. It is made slanting at a 45 degree angle to the trunk and down to the back edge of the first cut.

**Backcut:** When the tree has been undercut, the tree is felled by backcutting on the opposite side. The backcut on a straight tree is made at the middle of the side opposite the undercut. In leaning trees, the backcut is made 1 to 8 inches above the bottom of the undercut. A wedge is driven into the backcut to prevent binding and to aid the tree in tipping in the desired direction.

**Leaning and lodged trees:** A tree that has lodged in another while falling, can be brought down by the use of a chain and tractor. The ground end of the hung tree can be pulled clear with a tractor on a long chain.

Leaning trees should be chopped down, not sawed, in the direction in which they lean.

**Safety on felling operations:** In felling trees there is danger on all sides for the careless observer or worker. The swinging axe or the power saw is a potentially dangerous tool that can cause serious injury. When trees are being felled there is always the danger of being struck. A careful worker always insures that people, animals, and equipment are out
of the felling area. Careful loggers yell T-I-M-B-E-R to warn others out of the way. When a tree begins to fall, the worker should move a safe distance away from the tree to avoid both falling debris and "kickback". Kickback occurs when an improper undercut is made. The butt of the falling tree can strike the worker and cause serious injury (See Figure 53).

Fig. 53.—Kickback.

**Log Bucking, Scaling, and Grading**

The merchantable portions of felled trees require some preparation or processing before they are removed from the forest. This usually involves trimming and cutting the trees into proper lengths. Sawing the felled tree into proper lengths is called bucking. The objective of bucking is to separate the high value sections from the poorer, lower grade parts. Often high grade logs can be cut between major defects like knots and crooks, but cutting many short logs should be avoided. A general rule for sawlogs is to cut as many 16-foot
lengths as possible. Bucking is a step in the harvesting operation that is usually done at the stump site.

**Trim allowance:** It is impossible to buck logs exactly at right angles to the trunk, therefore, a trim allowance must be made. If a 16-foot log is cut and no allowance is made for trim or if the allowance is insufficient, the lumber will be cut off to a 14-foot length at the trimmer in the sawmill. This results in a 2 foot loss of merchantable lumber entirely due to insufficient trim allowance. Usually a trim allowance of 4 inches is sufficient for logs up to 16-feet if the saw crew is skilled and can make a straight cut. Logs of greater length may require an allowance from 6 to 12 inches.

**Scaling:** Scaling or measuring bucked logs is done to keep an accurate record of daily or weekly production. A scale stick is used to measure the sawlogs. The scale is placed over the small end of the log. After determining the length of the log the yard worker can determine the number of board feet in the log. This is the volume of lumber the sawmill will pay.

**Grading:** Logs are purchased on the basis of grade. Log grades usually refer to log dimensions, quality of grain, and freedom from defects. Larger logs are generally more valuable than smaller ones of the same grade. Log grades vary from region to region by species. Specific grades for hardwood and softwood lumber have been developed in each region. Hardwood and softwood grades used in Arizona are shown below.

<table>
<thead>
<tr>
<th>Hardwood Log Grades</th>
<th>Softwood Log Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade No. 2 or Veneer Grade</td>
<td>Veneer Grade</td>
</tr>
<tr>
<td>Select Veneer Grade</td>
<td>Grade No. 1</td>
</tr>
<tr>
<td>Grade No. 2</td>
<td>Grade No. 2</td>
</tr>
<tr>
<td>Grade No. 3</td>
<td></td>
</tr>
</tbody>
</table>
Skidding

The steps in the harvesting operation which involves the greatest cost, time, and effort are those that entail the movement of logs. This operation involves the bunching, skidding, decking, and loading of timber. Skidding is that portion of the logging operation in which the logs are dragged or moved from the point of bucking to a central location for loading and transportation to the mill. Because felled timber is generally 12 to 40 feet long and may weigh up to 10 tons, powerful equipment is needed to move them (See Figure 54).

Fig. 54.—Skidding logs to the log deck for loading onto trucks.

Cable skidding: Where terrain is rough or where road construction is expensive cable skidding can be used. Cable skidding is frequently called yarding. This is a form of skidding logs by means of stationary power units some distance away from the felling area. This method of skidding is not economical unless harvesting is heavy, because of the heavy investment in equipment and the high cost of rigging. It is especially adapted to the clearcutting system.
There are three methods of cable skidding: namely (1) ground lead, (2) high lead, and (3) skyline or overhead. In the ground lead method, the logs are dragged on the ground by spooling in the line on the main drum of the logging engine. In high leading, the mainline is elevated at the pulling end so that logs being skidded are partially elevated in front. This elevation helps eliminate "hang-ups" against stumps or other obstructions. In skylining, the yarding line is attached to the rigging by running through a carriage running on the skyline which is steel cable, extending between two trees or spaces so that logs are lifted entirely off the ground. The drawing in Figure 55 illustrates a simple cable system.

![Diagram of ground lead cable system](image)

**Fig. 55.**--Ground lead cable system.

**Crawler tractors:** Ground skidding with the use of crawler tractors is preferable on soft ground and slopes too steep for effective use of light rubber-tired tractors. Crawler type tractor tracks provide more ground contact over soft or irregular terrain than rubber-tired tractors. These tractors are also equipped with a rear winch. Logging arches can also be towed behind crawler tractors to elevate the front ends of logs.

**Rubber-tired and rubber-tracked vehicles:** A wide variety of rubber-tired and tracked vehicles are available for skidding.
The rubber-tired vehicle shown in Figure 56 has a self-loading clam hoist and can be maneuvered into nearly every kind of terrain. Many of these tractors have four-wheel drive and a no-spin differential in the rear axle, which eliminates spinning due to loss of traction.

Fig. 56.--Mechanized, rubber-tired skidder with a self-loading clam hoist.

(Courtesy: Pettibone Corporation)

Helicopters and balloons: New logging systems receiving more interest and attention among loggers is harvesting timber with the use of balloons and helicopters. Through the use of balloons and helicopters, logs can be lifted and flown out of the forest. This permits the harvest of forests inaccessible to rubber-tired tractors and other logging equipment. Balloons can be used in areas with unstable soil, where timber grows on benches interspersed with cliffs, or where steep, rocky terrain and relatively low volumes per acre make logging with conventional systems uneconomical because of high road costs.
Skid trails and landings: Skid trails should be located throughout the forest. These trails are cleared of brush and obstructions and provide definite channels for moving logs. If a skidding trail is laid out and used, the damage to young growth is confined to the paths.

Skidding distances for tractors seldom exceed 600 to 800 feet, however, the distances are frequently shorter.

Logging Roads

Careful planning is required to obtain the most efficient and economical pattern of logging roads. A good road system to make the forest accessible is extremely important to the harvesting operation. The logging road system is laid out so that it passes near the heavily timbered areas. This helps hold skidding distances to a minimum. Roads do not need to be built to a high standard. Road building and maintenance can become expensive. Most trucks used to haul timber are capable of traveling over a fairly rough road.

The cost of constructing logging roads vary with topography and soil conditions; whether rocky, firm, or soft. The more rugged the terrain, the higher the cost of road construction. Whenever possible, stream or river crossings should be avoided because of the high cost of installing bridges and fills. Whenever a road must cross another land owner's property, the forest manager must acquire a right-of-way.

Topographical and aerial maps are extremely useful in planning a logging road system. Such maps show in accurate detail many features of both stand density and topography.
Logging roads should be maintained and kept in good condition. Frequent grading will keep most logging roads in satisfactory condition.

**Trucking**

Trucks are the most common means of hauling logs from the landing in the forest to the sawmill. Logs are loaded at the yard with "jammers" or "heel booms". Figure 57 shows a log fork used to load logs onto trucks or move logs in the yard. The size of the truck to be used in the logging operation depends on the products to be hauled, the types of roads and bridges, and the distance hauled. In some harvesting operations a combination truck-trailer is essential for hauling. Most trucks used in logging are of the diesel type and are capable of hauling as much as 100 tons in a single load.

![Log fork used to load or stack logs.](image)

*Fig. 57. --Log fork is used to load or stack logs.*

*(Courtesy: Marathon Le tourneau Company)*
Hauling logs by trucks can be dangerous. It is, therefore, the forester's responsibility to ensure that only safe and experienced personnel are allowed to operate these vehicles. Drivers should be observed periodically to ensure that they are using safe practices.

SAWMILLS

Logs are raw material not yet processed for human use. The mill or sawmill is the firm which treats or handles this raw material. Once the logs reach the mill they may be handled in a variety of ways to manufacture one of many wood products. These products include lumber, paper, veneer, plywood, poles, piling, railroad crossties, furniture, charcoal; to name only a few. Figure 8, page 17, illustrates some of the important products derived from a typical forest tree.

There are approximately 40,000 sawmills, pulp mills, and other wood processing plants in the United States. These mills, both large and small, produce a wide variety of paper and wood products, and provide employment for many Americans.

Sawmill Operations

When logs arrive at the sawmill they must be unloaded, sorted, graded, and measured by skilled and experienced wood yardmen. The log is measured lengthwise and by width at its small end. After scaling (see page 99) the first step in processing lumber is barking (removing the bark) from the log. Logs are sometimes stripped of their bark in the forest; however, most logs arrive at the sawmill retaining their bark. Barking at most mills is accomplished by special mechanical equipment. At others, the logs are raised by special machinery into a building called the barking shed. Here giant cog-wheels turn the logs slowly as huge knife-like jets of water force the bark from the log, literally peeling it (See
Figure 58). In a large mill using a hydraulic barker, 300 logs can be barked during an eight-hour period. After barking, the logs are moved into the sawmill by a "jack ladder" (endless chain conveyor) or some other means where they are placed onto a moving carriage for sawing. Figure 59 shows a log being

Fig. 58.—Debarking a log by blasting it with a jet of water under high pressure.
(Courtesy: California Redwood Association)

Fig. 59.—A log moves up the chain belt into the sawmill for sawing.
(Courtesy: California Redwood Association)
moved into a sawmill by an endless chain belt. The carriage advances the log against the saw and holds it in place while it is being cut. Several types of saws are used to cut the logs into boards. The circular saw is a circular plate having cutting teeth on the circumference. A band saw is an endless belt-like blade of steel, toothed on one or both edges. These saws are used to saw the log into numerous sizes. The sawyer, who is the person who controls the sawing operation, is the key person in the operation because it is his/her judgement that determines how a log is to be cut up. He/she must cut up the log so that the most and best lumber is obtained from each log. Figure 60 shows a log and the number of ways it may be cut.

Fig. 60.--The lumber contents of a douglas fir log. The log might be cut in a number of ways. The purpose of the illustration is to show the portion of a log from which various items are cut.

(Courtesy: Weyerhaeuser Company)
Once the log enters the sawmill it goes to the bandsaw. This whirling band of toothed steel, operated by a sawyer, quickly cuts the log into large sections called cants (See Figure 61).

Fig. 61.--When the bandsaw has cut the log into cants, a mill hand guides them onto a conveyor belt leading to the trimmer.

(Courtesy: California Redwood Association)

These cants are either resawn or go to circular saws where they are edged and trimmed into boards of various lengths and widths. Figure 62 shows a gang of circular saws cutting boards crosswise into the best lengths. The boards have already been cut lengthwise into various widths with a circular saw. From the trimmer the lumber is carried by a "green chain" into a large sorting shed. Here the lumber is graded according to specifications for quality. The lumber is then stacked for air drying or kiln drying. Following drying the lumber is put through a planing mill to surface it before shipment. The waste (sawdust, shavings, chippings, etc.) is conveyed to a storage bin. It is then sold to pulp or paper mills.
Fig. 62.—The trimmer cuts boards into the best lengths. A row of circular saws is controlled by an operator in a suspended booth.

(Courtesy: California Redwood Association)

The power requirements of sawmills differ. The power requirements depend on (1) width of saw kerf, (2) width of cutting face or width of board being sawed, (3) feed rate, and (4) type or species of wood being cut; each of these change the power requirements.

**Hardwood Lumber Grades**

Hardwood lumber is graded on the amount of clear useable material that can be cut out of the piece. Grades are established by the National Hardwood Lumber Association. Hardwood lumber grades include firsts and seconds, selects, Nos. 1 and 2 common, sound wormy, and Nos. 3A and 3B common.

**Softwood Lumber Grades**

Softwood lumber is classified into yard, structural, and factory or shop lumber. Yard and structural are graded by the quality of the piece as a whole. Factory, or shop is graded on the percent of area that will produce cuttings of specific size and quality. Yard lumber grades, as established
in the American Lumber Standards, include four grades of Select (A, B, C, D,) suitable for natural or paint finishes, and five grades of Common (1, 2, 3, 4, 5), not of finishing quality but useable, and allowing for waste in the three lowest grades. Structural and factory and shop lumber are graded variously according to intended use. Table 7 illustrates the general classification of softwood lumber.

**TABLE 7**

General Classification of Softwood Lumber (U.S.D.A.)

<table>
<thead>
<tr>
<th>Softwood lumber (this classification applies to rough or dressed lumber; sizes given are nominal)</th>
<th>Finish (less than 3 in. thick and 12 in. and under in width)</th>
<th>Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yard lumber (lumber less than 5 in. thick intended for general building purposes; grading based on use of the entire piece)</td>
<td>Boards (less than 2 in. thick and 8 in. or over in width). Strips (under 8 in. in width)</td>
<td>A select</td>
</tr>
<tr>
<td>Structural material (lumber 5 in. or over in thickness and width, except joist and plank; grading based on strength and on use of entire piece)</td>
<td>Planks (2 in. and under 4 in. thick and 8 in. and over wide)</td>
<td>B select</td>
</tr>
<tr>
<td></td>
<td>Dimension (2 in. and under 5 in. thick and of any width)</td>
<td>C select</td>
</tr>
<tr>
<td></td>
<td>Scantling (2 in. and under 5 in. thick and under 8 in. wide)</td>
<td>D select</td>
</tr>
<tr>
<td></td>
<td>Heavy joists (4 in. thick and 8 in. or over wide)</td>
<td>No. 1 boards</td>
</tr>
<tr>
<td></td>
<td>Joist and plank (2 in. to 4 in. thick and 4 in. and over wide)</td>
<td>No. 2 boards</td>
</tr>
<tr>
<td></td>
<td>Beams and stringers (5 in. and over thick and 8 in. and over wide)</td>
<td>No. 3 boards</td>
</tr>
<tr>
<td></td>
<td>Posts and timbers (6 by 6 in. and larger)</td>
<td>No. 4 boards</td>
</tr>
<tr>
<td></td>
<td>Factory plank graded for door, sash, and other cuttings 1 in. to 4 in. thick and 5 in. and over wide</td>
<td>No. 5 boards</td>
</tr>
<tr>
<td></td>
<td>Factory clear upper grades</td>
<td>Nos. 1 and 2 clear factory</td>
</tr>
<tr>
<td></td>
<td>Shop lower grades</td>
<td>No. 3 clear factory</td>
</tr>
<tr>
<td></td>
<td>In thick (northern and western pine, and Pacific coast woods)</td>
<td>No. 1 shop</td>
</tr>
<tr>
<td></td>
<td>All thicknesses (cypress, redwood, and North Carolina pine)</td>
<td>No. 2 shop</td>
</tr>
<tr>
<td></td>
<td>Select shop</td>
<td>No. 3 shop</td>
</tr>
<tr>
<td></td>
<td>Tank and boat stock firsts and seconds, selects, No. 1 shop</td>
<td>Select shop</td>
</tr>
<tr>
<td></td>
<td>No. 2 shop, box</td>
<td>No. 3 shop</td>
</tr>
</tbody>
</table>
DRYING LUMBER

As soon as a tree is cut down, it begins to lose its moisture. This lumber is "green" and contains a large quantity of moisture. In this condition the lumber is heavy and unfit for many uses, therefore, it must be dried to reduce its moisture content. This drying process is called seasoning. Two types of seasoning processes are used - air drying and kiln drying.

Air Drying

Air drying is the drying of lumber by the natural circulation of air through piled lumber. This method of drying takes a long time, usually from 2 to 9 months, depending on species, thickness of lumber, weather, time of year, method of stacking, location, and protection. When lumber is being prepared for air drying several considerations must be made in advance. These considerations include: (1) site selection, (2) yard layout, (3) pile foundations, and (4) methods of piling.

Site selection and yard layout: Choose a site with both good soil and air drainage. Air drying requires air movement; therefore, the piles of lumber should not be located in building corners or on wet, low spots. They should be located in the open and preferably on a gentle slope. The piles should be laid out at least four to six feet apart to facilitate air movement. The yard or site where the lumber is to be dried should be free of brush and weeds.

Pile foundation: A good pile foundation helps keep the lumber properly aligned and allows air drainage and movement under the pile. The best pile foundation is constructed of concrete, because it will not hold moisture and can be kept clean. The floor of the foundation must be kept free of
rubbish, plants, and wood waste. This material provides the opportunity for wood-rotting fungi and insects to breed and spread to the sound timber. The height of the foundation is governed by the floor type. A height of 8 to 12 inches is sufficient with concrete floors, but less than 18 inches is undesirable with earth floors. Slope the foundation from front to back at the rate of not less than eight inches in sixteen feet. This slope permits rain to run off the top boards instead of soaking into the timber below. Figure 63 illustrates a pile foundation.

![Diagram of Pile Foundation]

Fig. 63.—Pile foundation.  
(Courtesy: U.S.D.A.)

Method of piling: The width of the pile is governed by the desired drying rate. Wide piles cause the lumber to dry slowly, with danger of strain, whereas narrow piles six to eight feet wide are satisfactory. The height to build the pile depends on ease of handling lumber and the stability of the pile.

Air must circulate through the stack of lumber. The layers are separated by wood stickers (Figure 64). The thickness of the stickers regulates the rate of air flow. The stickers should be of sound and seasoned lumber
and placed 2 to 4 feet apart. Sticker alignment is important. Proper alignment will keep the lumber straight and flat. Figure 65 shows distortion caused by improper sticker alignment.
Whenever possible, choose lengths of lumber within one foot of the designed pile length. Long boards in a short-length pile warp and check. This can make the exposed portion worthless.

When there is not enough lumber for more than one pile, use the box-piling method (See Figure 64). Construct the pile foundations for the longest boards. Place these boards on the outer sides of the pile. The short boards should be placed alternately so their ends are flush with the front and rear of the pile.

End coating: In spite of correct piling procedure, wide, high grade boards will sometimes end-check severely. Shading the end may reduce the drying rate and cut down on end-checks. For valuable lumber, the ends of the boards can be painted with an aluminum paint, or a thick paint of white lead and linseed oil. Painting is effective if applied shortly after the green lumber has been stacked.

Seasoning defects: Seasoning defects include end and surface checking, cupping, bowing, twisting, and crooking. These defects are usually caused by fast drying and improper pile formation. These types of seasoning defects are illustrated in Figure 66.

Kiln Drying

Kiln drying is usually considered the most satisfactory method for removal of moisture. Below are several advantages over air drying:

1. faster
2. more precise than air drying
3. used yearlong
4. uniform moisture content
5. timber is sterilized
6. "bleeding" reduced
Fig. 66.--Seasoning defects.

The kiln is constructed like an air-tight shed. This allows control of the temperature, humidity, and air circulation. With the proper atmosphere, rapid and proper drying takes place.

There are two main types of timber drying kilns - (1) progressive and (2) compartment kilns.

In the progressive kiln, green lumber is placed into the kiln chamber at one end and emerges at the other end dry. The air becomes drier as the lumber progresses through the chamber's length. The success of this kiln depends upon a steady supply of timber of the same species and size.

In the compartment kiln, the green lumber is placed in the kiln chamber and it remains in the same position in the kiln throughout the drying period. The temperature and humidity of the circulating air is constantly changed. This type of kiln is desirable because the environment can be changed to season different species and sizes.
During the seasoning process, air temperature and humidity are constantly changed. The temperature is gradually increased. The humidity is decreased until a state of equilibrium is attained in the lumber. The amount of time it takes lumber to reach the equilibrium stage is dependent upon initial moisture content, size, and species. Two to six weeks is common. When this stage is reached, there is no further interchange of moisture between the wood and the atmosphere. Wood samples are taken from the kiln at periodic intervals to determine if their moisture content is at equilibrium. If so, the lumber is removed from the kiln. If not, the lumber continues the seasoning process.

The process of drying lumber must follow a drying schedule with sample boards taken frequently. Board samples are taken frequently to determine their moisture content. The temperature and humidity may be changed depending upon the board sample results (See Table 8).

Wood Preservation

After lumber has dried it can be treated. This prevents decay, insect attack, and shipworm damage. Most wood has some natural strength to resist attacks, but none is completely immune. The number of trees per acre (density), rate of growth, climate, season of cutting, and type of wood all affect the woods ability to resist.

The problem of decay and insect attack is greatly reduced by treating timber with wood preservatives. Three classes of
TABLE 8
Sample of a Kiln Drying Schedule

<table>
<thead>
<tr>
<th>Moisture Content (%) of the Lumber</th>
<th>Dry Bulb</th>
<th>Wet Bulb</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>105</td>
<td>40</td>
<td>99</td>
</tr>
<tr>
<td>60</td>
<td>105</td>
<td>40</td>
<td>97</td>
</tr>
<tr>
<td>35</td>
<td>110</td>
<td>43.5</td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td>110</td>
<td>43.5</td>
<td>98</td>
</tr>
<tr>
<td>30</td>
<td>110</td>
<td>43.5</td>
<td>96</td>
</tr>
<tr>
<td>25</td>
<td>115</td>
<td>46</td>
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<td>20</td>
<td>115</td>
<td>46</td>
<td>96</td>
</tr>
<tr>
<td>16</td>
<td>120</td>
<td>49</td>
<td>98</td>
</tr>
<tr>
<td>14</td>
<td>120</td>
<td>49</td>
<td>96</td>
</tr>
</tbody>
</table>

Wood preservatives are used to treat lumber; namely (1) oils and oil-borne preservatives, (2) water-borne preservatives, and (3) patented preservatives.

Oil and oil-borne preservatives are derived from fuel oils. Coal-tar creosote used to treat railroad ties and telephone poles is a widely used example. Water-borne and patented preservatives include zinc chloride, sodium fluoride, and salts of copper, potassium, arsenic, and borax. A few chemical solutions are sold under registered and patented brand names. Some of these patented water-soluble solutions employ two water-soluble salts and an oxidizing agent. The object is to deposit insoluble forms of these salts in the wood.

All timber should be seasoned before treatment with a preservative. Seasoned lumber absorbs preservatives better than green timber. All trimming and boring must be performed before treatment. This ensures all surfaces are treated.
The processes used to treat timber are the non-pressure and the pressure methods. **Non-pressured** methods are spraying or brushing the preservative on. **Pressure treatment** involves expensive equipment consisting of metal cylinders and cars, tanks, pumps, transportation, and hoisting devices. Lumber to be treated is loaded on cradle-like cars and run into a long cylinder which is then sealed at both ends. A vacuum is created and the preservative is applied under pressure.

**GROWING CHRISTMAS TREES**

The Christmas tree is an established custom in many countries. Christmas trees are not always chance by-products of forest lands. They can be a managed crop. In many parts of the United States they are big business.

Christmas tree varieties adaptable to Arizona soils and climate include the Balsam fir, red and white spruce, Scotch and red pine, Eastern red cedar, and Douglas fir. Size, shape, density, needle characteristics, freshness, color, and market preference should all be considered when choosing a variety to plant. Most people will select their tree on the basis of these characteristics. Price seems to be a secondary consideration if a certain tree meets all other requirements.

**Managing and Improving Natural Stands**

In managing natural Christmas tree stands, foresters must start with the area as they find it. Brush and other
competing vegetation must be cut to allow the Christmas trees to grow without competition. Now, they can develop into bushy, well-formed, and well-colored trees. They need enough room to grow in all directions. All undesirable trees should be cut down. These undesirable trees should be limbed so that they lie close to the ground and rot fast. Dead trees with limbs make it difficult to get around the area and also deform small trees that may grow through or near them.

Another consideration is thinning. Christmas trees spaced too close together interfere with each other's growth. In a densely stocked stand, harvest as many marketable trees as possible. Cuttings should be taken at intervals to ensure proper spacing.

**Clipping** is a practice that upgrades the quality and value of a Christmas tree. It is also called pruning, shaping, shearing, trimming, or forming. They all seek to grow a fuller bodied, uniform, good quality tree that will compete well on the market. Clipping involves the practice of trimming the branch ends to even them up. Also, cutting back the terminal leader to keep the branch whorls spaced uniformly or to keep the height in check. By careful clipping it is possible to get a tree ready in less time. By clipping, long branches can be evened up and openings in the crown can be made to fill in. Clipping the branch ends stimulates the formation of additional buds back along the branch and greatly increases the leaf surface area of the tree. This makes the Christmas tree more desirable to the buyer.
Figure 67 shows the suggested branch whorl spacing and taper for a 6½ foot height Scotch pine.

After harvesting merchantable trees, spot planting may be necessary to replenish trees within the stand. This is usually done either in the spring or fall, but most important, it is done during the dormant season. Plant vigorous young seedlings using the planting procedure as described on pages 17 through 25.

![Fig. 67.—Suggested branch whorl spacing and taper for a 6½ foot height Scotch Pine.](image)

(Courtesy: Pacific Northwest Cooperative Extension Service)

Establishing a Christmas Tree Stand

Establishing a Christmas tree stand has several advantages over the natural stand. The forester can prepare the site before planting, choose a tree species in demand, select a site with suitable soil, and develop a uniform tree spacing.

There are some disadvantages in establishing a Christmas tree stand. The forest manager must select and obtain planting stock, plant the seedlings, and see that they become established. The production costs are higher than those on natural Christmas tree stands.

In planning the Christmas tree operation, the manager must plant a species that is in demand. It will do little good to plant a species unwanted or undesirable to the consumer. The
species selected must be suitable to the soil type, site, and climate conditions. Poorly drained soils should be avoided. Most agricultural soils are suited for Christmas tree growth and development. Weed and grass competition is less on agricultural soils. In general, sites too steep or broken for use of rubber tired tractors are not suitable for Christmas tree production; therefore, excessive slopes should be avoided. The forest manager must also consider the time and money available to finance the Christmas tree operation. It takes considerable time and effort to prepare the site, plant, clip, and care for the Christmas tree plantation. A return on the initial investment will not be realized for six to ten years. Enough funds must be available to offset expenses during this period.

Source of seedlings: Quality planting stock can be purchased from either public or commercial nurseries. Public nurseries produce seedlings primarily for reforestation purposes and do not necessarily have the species and quality of trees that are best for Christmas trees. Commercial nurseries are probably the best source of planting stock. They use seed from the best varieties of Christmas trees, and they produce seedlings especially for this purpose. It may be necessary to order Christmas tree stock in advance, because many nurseries do not have a large supply on hand.

Site preparation: The site on which the Christmas trees are to be planted must be cleared of undesirable vegetation. This vegetation may compete with the young seedlings for moisture, light, and nutrients. Old agricultural fields are excellent for growing Christmas trees because there is less competition with weeds, grasses, and brush. Old fields should be plowed, disked, and harrowed before planting.

Where any appreciable grass competition exists, mowing will be required. Where only a small area is involved,
hand-guided mowers are satisfactory. On larger areas, the labor of operating hand-guided walking mowers, becomes uneconomic. If the row spacing will permit, the use of a farm tractor with a rotary mower attachment is best.

In some areas where plowing cannot be done, or plowing is inadvisable because of soil or slope, sod scalping may be required to prepare the site. Scrape or clean an area 18 to 24 inches square and plant the young seedling in the center or plow shallow furrows to scrape off grass and plant the seedlings in the furrows. The furrows should follow the contour of the land to lessen erosion.

**Planting:** All planning, regardless of how thorough, will mean little if the tree planting is done incorrectly. Improper planting will result in fewer living trees and may adversely affect the growth of those surviving. Careful consideration should be given this phase of the Christmas tree venture.

Planting stock may become damaged very easily through careless or improper handling after it is received and before it is planted. As soon as the seedlings are received, they should be watered and kept in a cool and shaded place. Most seedlings arrive in bales or crates. Cool water should be added to moisten the inside of the bales, but do not soak them.

It is best to plant young seedlings as soon as they are received; however, this is not always possible. Then it is necessary to store them properly so the trees will remain fresh and moist until they can be planted. If the seedlings must be held for a long period of time before planting, they must be "heeled-in". Heeling-in is an effective way to hold seedlings for many days. To heel-in trees, dig a V-shaped trench deep enough to accommodate the roots in a well-drained shady location near the planting site. Untie the bundles and
spread the seedlings along the sloping side of the trench in layers three or four deep, then pack soil around the roots and moisten. It is important to keep the seedlings moist but not soaked. Stock may be removed as needed for planting. Figure 13, page 23, illustrates the heeling-in procedure.

Two methods are used to plant young seedlings, namely machine planting and hand planting. Hand planting is well suited for areas that are small, stony, or too rough for machine use. Even after machine planting operations, hand planting is used to spot plant where the machine skipped or a seedling failed to establish itself. Hand methods of planting are illustrated in Figures 9, 10, and 11, pages 20 and 21.

Planting machines are advisable for large areas with few obstacles. These machines are capable of planting approximately 1,000 seedlings per hour. A tree planting machine is shown in Figure 12, page 22.

Row spacing and tree spacing within the rows governs the number of trees per acre. It may be desirable to use a 5 x 5 foot spacing (1,742 trees per acre), a 6 x 5 foot spacing (1,410 trees per acre), or a 6 x 6 foot spacing (1,210 trees per acre), to utilize the land more fully. A space of 4 x 4 feet (2,722 trees per acre) or less is used only when small trees are grown for the market. If large trees (6-footers) are the desired end product, then a 5 x 5 foot spacing will be the minimum.

A good road network is needed throughout the Christmas tree area. These roads should make all parts of the tree area accessible so that harvesting operations will be efficient and economical. Often roads can be planned so they will serve as fire breaks. Other fire breaks should be planned throughout the Christmas tree area. A well-laid road will pay for
itself in reduced road upkeep costs, harvesting efficiency, and savings on equipment repair.

Cultivation: Cultivation is used to control competing vegetation. This vegetation often hurts the survival or development of well-formed trees. The competition may be controlled by mowing or by a combination of mowing and chemical control. When mowing, care must be taken to avoid cutting small trees hidden by grass. Chemical control alone often results in a trash build-up. This interferes with personnel movement along the rows. It becomes difficult to apply future applications. The build-up of litter can become a fire hazard. Do not spray chemicals on the young trees. Band spraying (12 to 15 inch strips) on each side of the tree is satisfactory if you mow the row centers.

Shaping techniques: Shearing, pruning, and clipping are used to form desirable tree shape and density. These techniques include lateral clipping, shearing, basal pruning, bark scarring, and tip pruning.

Lateral clipping or shearing: Clipping of lateral branches forms the desired taper and increases foliage density. A taper of between 65 to 75 percent produces an attractive tree shape. Tree taper is found by dividing tree width (at the base of the tree) by tree height. All lateral branches which extend beyond the limits of the taper are cut. This normally involves only cutting the current year's growth. The practice of cutting lateral branches to establish tree taper is called side shearing.
**Tip pruning** - Tip pruning is performed to obtain a desirable terminal whorl (See Figure 68). A desirable whorl consists of one well-developed terminal shoot and 6 to 10 lateral branches.

![Figure 68](image-url)  
*Fig. 68.*--The desirable terminal whorl.
*(Courtesy: Pacific Northwest Cooperative Extension Service)*

**Basal pruning** - The removal of lower branches slows growth and causes the tree to become dense and bushy. Figure 69 shows a tree with the lower branches removed. Note where the tree will be cut for harvesting.

**Bark scarring** - When trees grow too fast to become well-formed, scarring slows their growth. In scarring, a strip of bark is removed from one or two sides of the lower trunk (See Figure 69).

**Growth period:** It takes 6 to 10 years for a tree to reach marketable size. Popular Christmas tree sizes range 5 to 8 feet. In determining which trees are ready for market, each tree must be judged on its own merits. You must consider its present value in relation to its value a year or two later. Individual trees in an area will vary in size, color, and shape.
Fig. 69.—Parts of a Christmas tree.

(Courtesy: Pacific Northwest Cooperative Extension Service)

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Insects and diseases: Insect damage may be minor and scattered, or it may reach epidemic proportions. Precautionary measures to prevent infestations, coupled with constant observation for insect activity, should be standard operating procedures. Foresters should make it their business to learn to recognize the more common insects, their habits, signs of their activity, and controls.

Disease, like insects, are many and varied. As with insect problems, growers should familiarize themselves with the plant diseases in their area.
APPENDIX

Native Trees of Importance in Arizona
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Tree Size</th>
<th>Uses</th>
<th>Identifying Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limber Pine</td>
<td>Medium</td>
<td>Lumber for rough construction, mine timbers, railroad ties, and fuel.</td>
<td>Bark dark brown, broken into rectangular scaly plates. Needles 5 in cluster, slender, 2 to 6 inches long, dark green. Cones short-stalked, 3 to 6 inches long, yellow brown, with thick, rounded scales and large seed 3/8 to 1/2 inch long. Found between 6,000 to 10,000 feet elevation.</td>
</tr>
<tr>
<td>Blue Spruce</td>
<td>Large</td>
<td>Lumber for building construction and boxes. Also mine timbers, railroad ties, and poles. Ornamental.</td>
<td>Bark gray or brown with scaly ridges. Needles 4-sided, 3/4 to 1 1/8 inch long, dull blue green. Cones 2 1/2 to 4 inches long, light brown, with long, thin flexible scales irregularly toothed and more or less pointed. Found at higher elevations.</td>
</tr>
</tbody>
</table>
Common Name | Tree Size | Uses | Identifying Characteristics
---|---|---|---
Engelmann Spruce | Large | Lumber for building construction, boxes, mine timbers, railroad ties, and poles. Ornamental. | Bark grayish or purplish brown, with loosely attached scales. Needles 4-angled, 5/8 to 1 1/8 inches long, dark or pale blue green, of disagreeable odor when crushed. Needles not in groups. Cones 1 1/2 to 2 1/2 inches long, light brown, with long, thin, flexible scales irregularly toothed and more or less pointed. Found 8,500 ft. to timberline.

Ponderosa Pine | Large | Important timber tree; the most important western pine. Lumber for many uses, such as building construction, boxes, crates, and mill-work; also caskets, furniture, toys, etc. Piling, poles, posts, mine timbers, veneer, railroad ties, and fuel. Ornamental. | Bark brown or blackish with reddish tint. On older trees bark becomes yellow brown with large, flat, scaly plates. Needles 3 or 5 in cluster, stout, 4 to 7 inches long, dark green. Cones short stalked, 3 to 6 inches long, light reddish brown; the scales with prickles. Found 5,000-7,000 ft. elevation.
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Pinyon Pine</td>
<td>Small</td>
<td>Mine timbers, fuel and ornamental.</td>
<td>Bark reddish brown with scaly ridges. Needles 2 in cluster, stout, 3/4 to 1 1/2 inches long, dark green. Cones egg-shaped, 1 1/2 to 2 inches long, light brown, with stout, blunt scales, and large, edible seeds 1/2 inch long, known as pinyon nuts. Found 5,000 to 7,000 ft. elevation.</td>
</tr>
<tr>
<td>Singleleaf Pinyon Pine</td>
<td>Small</td>
<td>Edible seeds are sold as Pinyon nuts and pine nuts.</td>
<td>Bark dark brown with scaly ridges. Needle in a sheath, stout, 1 to 2 inches long, gray green. Cones egg-shaped, 2 to 2 1/2 inches long, light brown, with stout, blunt scales, and large edible seeds 3/4 inch long, known as pinyon nuts. Found 4,000 to 6,000 ft. elevation.</td>
</tr>
</tbody>
</table>
Alpine fir

Large

Lumber for building construction, chiefly in houses, boxes, crates, and general millwork.

Bark gray and smooth. Needles flat, 1 to 1 3/4 inches long; blue green and not in groups. Cones upright, 2 1/2 to 4 inches long, and purplish. Found 8,000 ft. to timberline.

Emory Oak

Medium

Ornamental. Fuelwood. Feed for wildlife.

Bark blackish, divided into thin plates. Leaves evergreen, broadly lance-shaped, 1 to 2 1/2 inches long, with a few short teeth, thick, stiff, leathery, flat, shiny dark green on both sides, and nearly smooth. Acorns 1/2 to 3/4 inch long, rounded, and edible. Common in southern Arizona mountains; 4,000 to 6,500 feet.
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<tbody>
<tr>
<td>Canyon Live Oak</td>
<td>Medium</td>
<td>Ornamental and Fuel</td>
<td>Bark gray brown, scaly and flaky. Leaves evergreen, oval or elliptical, 1 to 3 inches long, with edges spring-toothed or smooth, thick and leathery, bright green and smooth above, yellow-hairy or whitish beneath. Acorns 1 to 2 inches long, broad, with thick yellowish cup.</td>
</tr>
<tr>
<td>Gambel Oak</td>
<td>Small tree or shrub</td>
<td>Fence posts, fuel, and wildlife food.</td>
<td>Bark gray, brown, and scaly. Leaves shedding in fall, oblong, 4 to 8 inches long, 7 to 11 deep lobes, halfway or more to middle, dark green and soft-hairy beneath. Acorns 5/8 to 3/4 inch long, broad and rounded with deep cup. Found 5,000-7,500 ft. elevation.</td>
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<tr>
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<td>Uses</td>
<td>Identifying Characteristics</td>
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<tr>
<td>White fir</td>
<td>Large</td>
<td>Lumber for building construction chiefly in houses, boxes, crates and millwork. Pulpwood. Ornamental and shade tree.</td>
<td>Bark gray, scaly ridges. Needles flat, 1 1/2 to 2 1/2 inches long, pale blue green. Cones upright, 3 to 5 inches long, greenish, purple, or yellow. Found 6,000 to 9,000 ft. elevation.</td>
</tr>
<tr>
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<td>Tree Size</td>
<td>Uses</td>
<td>Identifying Characteristics</td>
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<tr>
<td>Quaking Aspen</td>
<td>Small to Medium</td>
<td>Pulpwood, food boxes, crates, evaporative cooler pads, and matches.</td>
<td>Bark yellowish green or whitish, smooth, thin; on large trunks becoming black, thick, with black ridges. Leaves nearly round, 1 1/2 to 3 inches long, short-pointed, finely toothed, smooth, shiny green above, dull green beneath. Leafstalk flat. Found 7,000 to 9,500 ft. elevation.</td>
</tr>
<tr>
<td>Arizona Cypress</td>
<td>Medium</td>
<td>Fence post, ornamental and shelterbelt.</td>
<td>Bark gray, rough, fibrous, with thin scales. Leaves scale like, 1/16 inch long, pale blue green. Cones 3/4 to 1 1/4 inches in diameter, on stout stalks 1/4 to 1/2 inch long and remaining attached several years. Found in mountain canyons along creeks 4,000 to 7,000 ft. elevation.</td>
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<tr>
<td>Rocky Mountain Juniper</td>
<td>Small to Medium</td>
<td>Fence posts, fuel, and lumber. Ornamental and shelterbelt.</td>
<td>Bark reddish brown, thin, fibrous and shreedy. Leafy twigs slender, about 1/32 inch in diameter. Leaves scalelike, 1/16 inch long, usually gray green, or on leading shoots, needlelike, up to 1/4 inch long. &quot;Berry&quot; 1/4 inch in diameter, bright blue, usually 2-seeded maturing the second year. Found 5,500 to 8,500 ft. elevation.</td>
</tr>
<tr>
<td>Utah Juniper</td>
<td>Small</td>
<td>Fence posts, fuel, and interior finish.</td>
<td>Bark gray, fibrous and shreedy. Leafy twigs stout, about 1/16 inch or less in diameter. Leaves 1/16 inch or more in length, yellow green. &quot;Berry&quot; 1/4 to 1/2 inch in diameter, brownish, with 1 or 2 seeds. Found 3,500 to 7,000 ft. elevation.</td>
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<tr>
<td>Common Name</td>
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<tr>
<td>Alligator Juniper</td>
<td>Medium</td>
<td>Fuel and fence posts.</td>
<td>Bark gray, thick, with checkered or square plates. Leaf twigs 1/32 to 1/16 inch in diameter. Leaves scalelike, 1/16 inch long, blue green, glandular, often with whitish drops of resin, or on leading shoots, needlelike, up to 1/4 inch long, pale or whitish. &quot;Berry&quot; 1/2 inch in diameter, bluish or brownish, 4-seeded, maturing the second year. Found 4,000 to 7,000 ft. elevation.</td>
</tr>
</tbody>
</table>
List of References


University of Georgia Department of Agricultural Education. *Forestry Practices*. Athens, Georgia: July 1955.
