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New York State College of Agriculture and Life Sciences
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Understanding Forest Ecosystems

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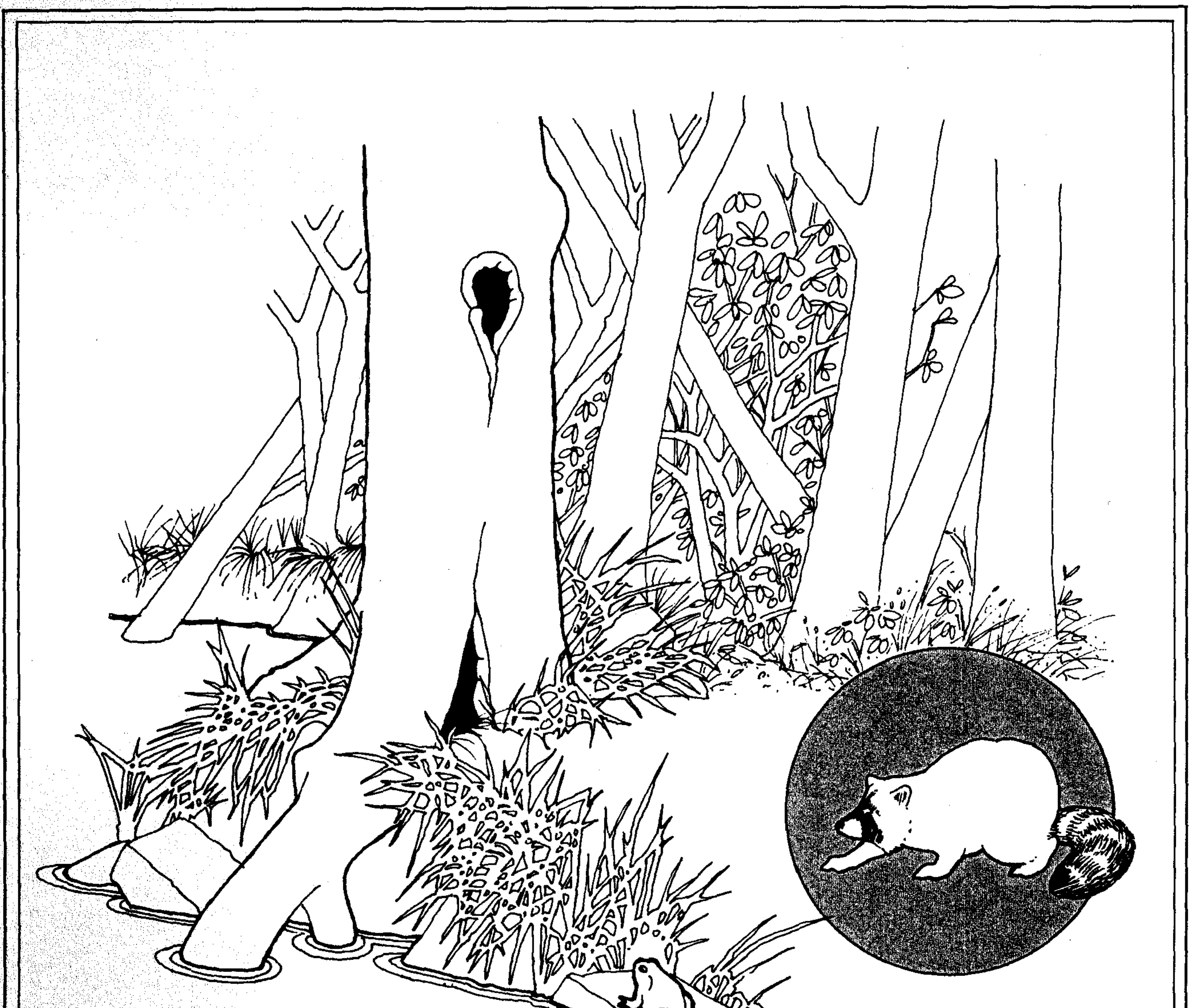

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Illustrations and cover art by Tom Parker.

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***Terms italicized in text are defined in glossary, p. 35.**

Understanding Forest Ecosystems

A forest, according to dictionaries, is an area populated by trees and underbrush. A real forest is much more than that. It is a community of many plants and animals interacting, often in complex ways. A forest exists in a physical environment that directly influences the composition and growth of the forest community.

Humans attach value to forests. This value is determined by how people use the forest and by which resources they extract from it. Traditionally, the forest's worth has been based mainly on the dollar value of the volume and species of trees present. Forest inventories have been developed to tabulate these factors for a particular wooded area. As defined by the Society of American Foresters (SAF), a *forest inventory** is "an inventory of forest land to determine area, condition, timber volume, and species for specific purposes such as timber purchase, forest management or as a basis for forest policies and programs." Taking tree measurements to estimate the volume of valuable wood is termed *timber cruising.*

People's attitudes are changing. Although wood fiber is still a major resource extracted from a forest, the importance of other forest-derived resources such as wildlife habitat, water quality, aesthetics, recreation, Christmas trees, maple sirup, and other special products is being recognized. A simple timber cruise will not give an accurate inventory of resources other than commercial trees. The method of forest evaluation presented here is designed with a broader scope than the traditional inventory. It involves a description of all major components of the forest, the physical environment of the forest, and major interactions among them. The purpose is to help youth look at the forest as an ecosystem, view the forest as the producer of many renewable resources, and recognize the intangible as well as the tangible values of the forest. It also proposes to develop a basic understanding of how forest management can be employed to maintain the renewability of the forest and to guide the forest to produce the desired resources.

The Forest Ecosystem

The key to a good forest evaluation is a background knowledge of the forest ecosystem. The *forest ecosystem* is a community in which all organisms and their environment interact. It consists of both living parts (components) and nonliving parts (the environment) that interact in an exchange of material (fig. 1).

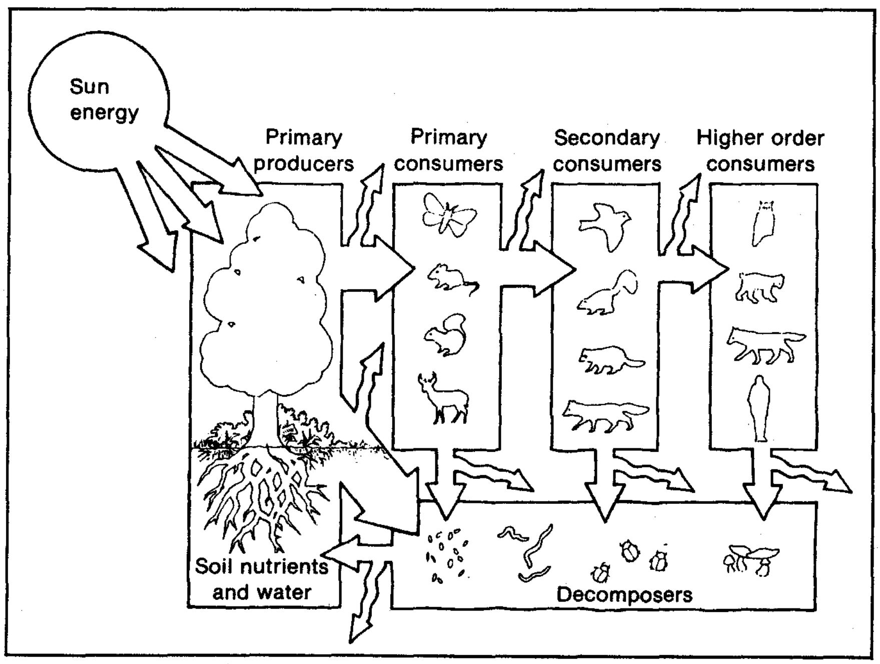


Figure 1. *A forest ecosystem consisting of living components and nonliving parts (the environment).*

Living Components

The living components of a forest ecosystem can be divided into two broad categories, flora and fauna. Flora includes all the plant life from trees to tiny mosses, lichens, and fungi.

Trees are woody perennials with an erect stem and a height of at least 7.62 meters (25 feet). Crowns of the taller trees in a stand form the main *canopy;* trees in the *understory* are those growing below the main canopy. Trees are classified as being either coniferous or broadleaf. Conifers have needlelike leaves, bear their seeds in cones, and are usually evergreen. They are also called evergreens or *softwoods.* Broadleaf trees, often called *hardwoods* (fig. 2) or deciduous trees, have seeds that develop in an enclosed ovary. Although many hardwoods are deciduous, that is, they lose all their leaves at one time, there are also many evergreen hardwoods.

Shrubs are woody perennials that have one or more spreading stems and grow not more than 7.62 meters (25 feet) in height. In addition to trees and shrubs, the forest floor includes many leafy, herbaceous plants that are non-woody and generally die back every winter. These plants, called forbs, include wildflowers and grasses. Other vegetation, such as mosses, fungi, lichens, and even bacteria, as well as roots in the soil, is also a part of the flora.

Fauna includes the animal life, which may be found in the soil, on the forest floor, in the undergrowth, or overhead in the forest canopy. It includes both vertebrates (mammals, birds, fishes, reptiles, amphibians) and invertebrates (insects, mollusks, worms, and protozoans, for example).

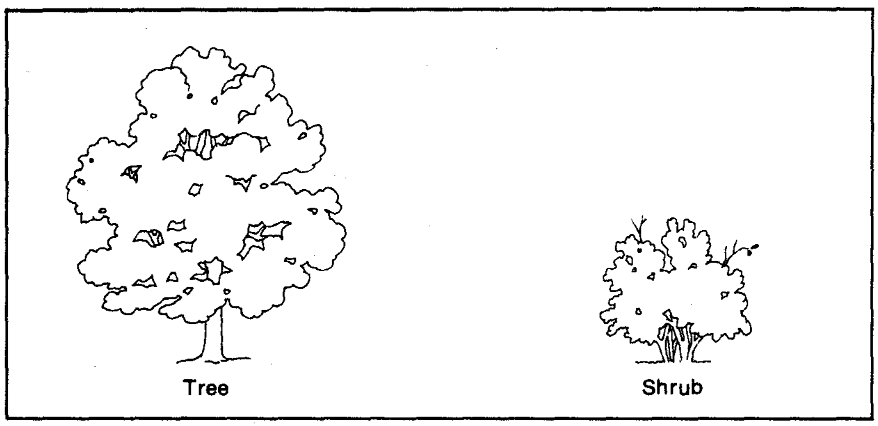
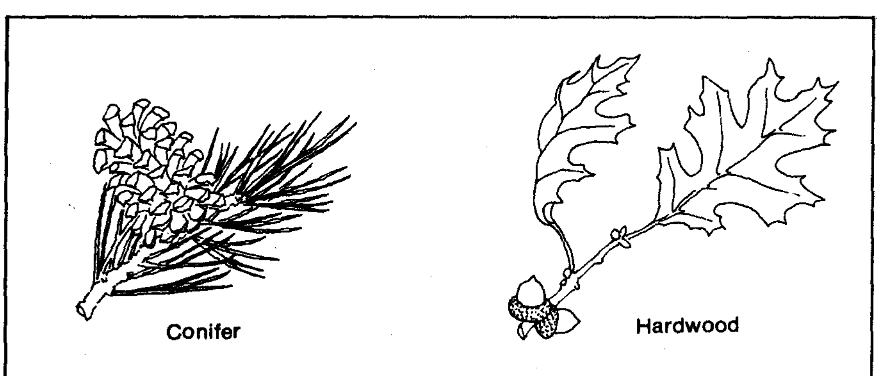


Figure 2. Above: *A tree is a woody perennial that grows at least 7.62 meters tall; a shrub is a woody perennial that spreads and grows not more than 7.62 meters tall.* Below: *Conifers, or softwoods, have needlelike leaves; hardwoods are broadleafed.*



The Environment

The environment of the forest will determine which components can exist in that particular forest community. It will also influence the growth and vigor of those organisms. Sunlight, atmospheric conditions (climate), water, and soil are all prominent environmental factors.

The sun is the primary source of energy for the forest. The amount of energy available to a forest depends on the intensity of light reaching it and the duration of exposure to this light. The quality of light is influenced by the geographic position of a forest. *Slope* and *aspect* are the terms used to describe geographic position. Slope is the steepness or flatness of the land in the forest. Aspect is the direction that the land is sloping. For example, if you were standing facing downhill on a slope with a south aspect, your face would be towards the south. The slope and aspect (fig. 3) of a piece of forested land determine at which angle the sun's rays will strike the forest. The closer this angle is to perpendicular, the more energy is available to the forest. To illustrate this principle, think of a clear winter day and a clear summer day and of the difference in the temperature: the more direct angle of the summer sun warms your skin much faster.

The atmosphere is composed of particles and gases such as oxygen, nitrogen, carbon dioxide, and various pollutants that come into contact with the forest. The air is mixed and passed through the forest by wind flows. Air temperature is not constant. It fluctuates both daily and seasonally. The geographic position of a forest influences wind strength, direction of flow, and air temperature. The top of a high ridge may be much windier than a protected valley. Rolling topography can help to break up a fierce wind

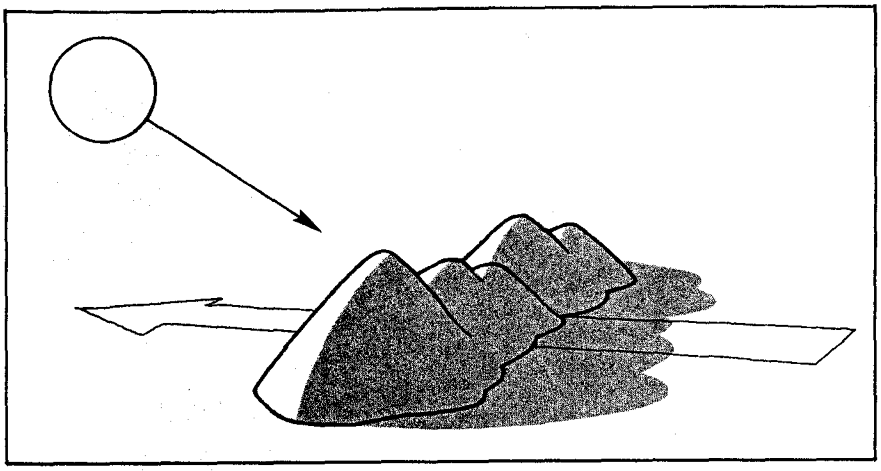
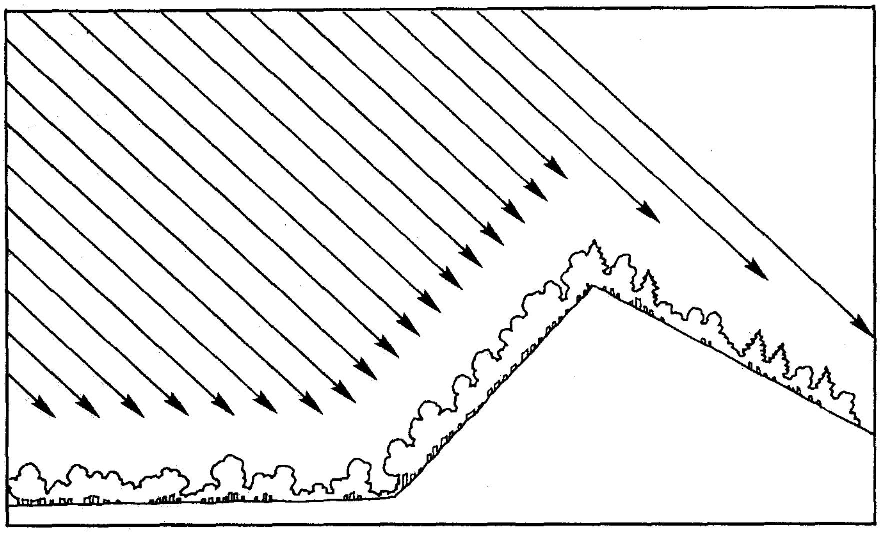


Figure 3. *The slope and aspect (*above*) of a piece of land determine the angle at which the sun's rays will strike a forest (*below*).*



driving across an open plain. Valley bottoms and depressions in the land are settling spots for cold air because it is denser (heavier) than warm air.

Water comes to the forest in the form of rain, snow, dew, overground flow (streams, rivers), or underground flows (seeps). The amount of water varies with seasons, dry spells, and wet spells. Water may come in large quantities in a short period of time, or it may come to the forest in small quantities but over a longer period of time. The temperature of water in open bodies affects how much oxygen is dissolved in it. Aquatic life, such as fish, is sensitive to water temperature and available oxygen. Depth of water and sun intensity are factors in water temperature. Deep water tends to be cooler than shallow water; water that is shaded by trees is cooler than unshaded water.

Just as the sun is the primary source of energy, soil is the primary source of nutrients for land organisms. Soil is a product of climate, the rock from which the soil has formed, and the plants and animals that live and die on it. Plants and animals contribute organic matter to the soil. Climate affects the rate at which organic matter decays and at which the rock is broken down into its mineral components. The *relief* of the land and passage of time also play a part in the formation of soil. There are two broad classifications of soil — transported soils and soils derived directly from underlying rock.

Transported soils are developed from weathered rock fragments that have been brought to their present location by water, ice, wind, or gravity. Since they are transported, the rock fragments are well mixed. A transported soil, then, contains mixed fragments of many kinds of rocks and minerals and of many sizes.

A soil that has been derived directly from underlying rock can be identified by distinct horizontal layers of different colors and textures. The layers, also called *horizons,* can be viewed in a bank cut along a road or in a pit dug into the soil (fig. 4). (An old transported soil can also be layered. The layers, however, are usually less distinct.) There are three major horizons — the *A, B,* and *C* horizons. Overlying them is usually a layer of forest debris, or *duff.* The debris consists of identifiable leaves, twigs, feathers, fur, feces, and whatever else may fall on the forest floor. As this organic matter begins to decompose, earthworms and other small animals help to mix it into the *A* horizon of the soil. In this uppermost layer, or topsoil, as it is called, partly decomposed organic matter is mixed with mineral particles. As water percolates through the *A* horizon, it carries with it organic and inorganic compounds, which mix with fine clay and silt particles in the subsoil or *B* horizon. Most of a tree's roots are found in the *A* and *B* horizons. Immediately below the *B* horizon is the *C* horizon — the parent material of the soil. It consists of slightly weathered rock and grades into unweathered bedrock at its depths.

The nutrients and water required for the life of the forest are available mainly in the *A* and *B* horizons of the soil. The parent material and organic matter found at a particular site determine the soil's mineral and nutrient con-

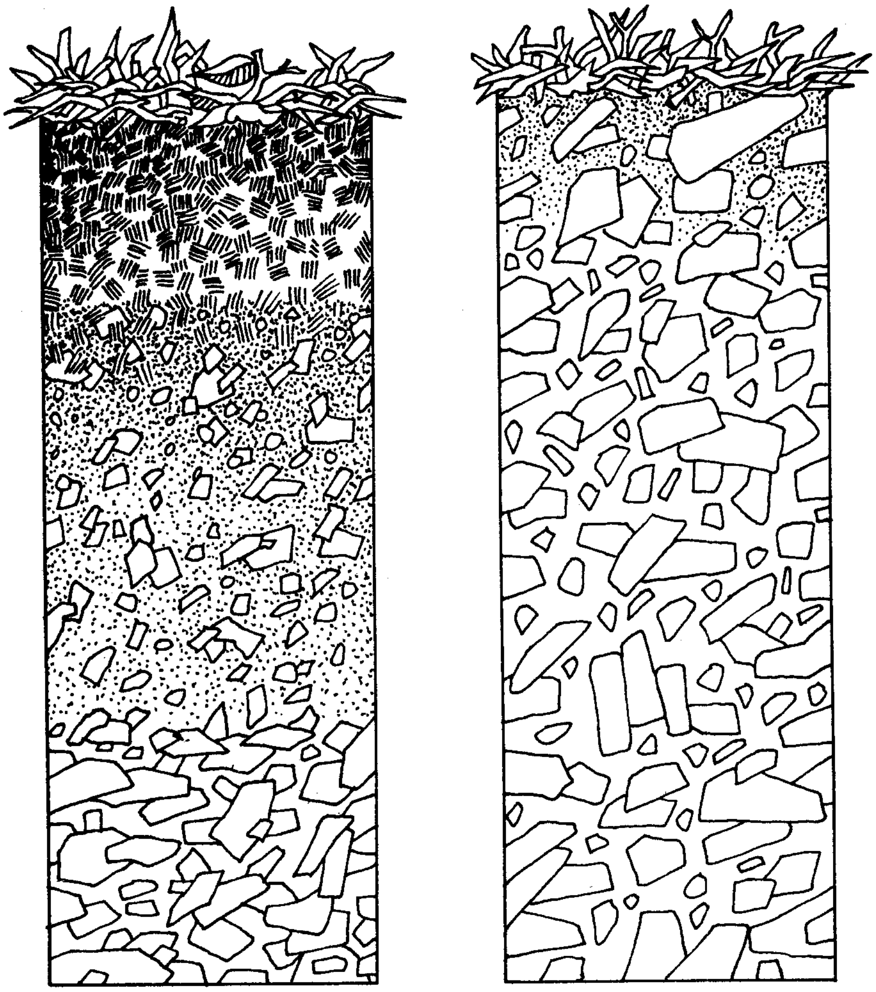


Figure 4. Left: *a soil derived directly from underlying rock, showing distinct horizons, or layers.* Right: *a transported soil, showing well-mixed rock fragments.*

tent. The amount and availability of these nutrients and of water are influenced by such characteristics of the soil as depth, texture, and pH.

A deep soil has a larger quantity of nutrients and water than a shallow soil of similar structure and content. The depth of the soil is affected by the slope of the land. On a ridge or steep slope, the soil tends to be shallower than in a valley bottom or over a flat plain.

Texture refers to the different-sized particles in a soil and is classified as ranging from sand to loam to clay. The texture affects the amount of water available, the aeration (the amount of gases in the soil — roots require oxygen to grow and absorb), and the drainage of the soil. A sandy soil holds less water than clay. Clay particles, being smaller than sand particles, have a stronger adhesion (attraction) to water and "hold" it more tightly than do sand particles. Thus a clay soil tends to hold water and be poorly drained. A clay-type soil also has fewer air spaces than a sandier soil. If such a soil is saturated with water, little oxygen will be available to roots. Without oxygen the roots are not able to absorb water or nutrients properly.

The pH, a measure of how acidic a soil is, varies between different locations in the soil and can vary seasonally. The acidity of a soil affects the availability of certain nutrients to vegetation. For example, in a strongly acidic soil, iron and manganese are more available to vegetation than in a slightly alkaline soil, and nitrogen and phosphorus are less available.

Component Requirements

All plants and animals have basic requirements that must be satisfied for them to live. These requirements vary depending upon the individual. All the organisms found in a forest exist there because their requirements for life are met in that forest environment. If you examine the forest space that an organism occupies and observe its behavior, you can learn something about the requirements of that particular organism.

To become established as part of a forest, a plant must be transported there in some form — usually as a seed, a spore, or as a vegetative segment (fig. 5). Cherry or berry-type fruits are likely to be eaten by animals and carried to a new location where the seed is deposited in the animal's scat. Sticky or burlike seeds often ride in an animal's fur or on a person's socks to a new location where they fall or are picked off. Wind transports a great many light, winged seeds and spores of mosses, fungi, and ferns. Water and gravity are other transporting agents.

A vegetative segment of a parent plant can also be responsible for more individuals of that species. For example, a cutting from a willow branch can sprout roots and develop into a tree if it is stuck into a sandy wet soil.

Plants found in a forest can also be there as a result of a "parent plant" that was already established in the forest. Roots and

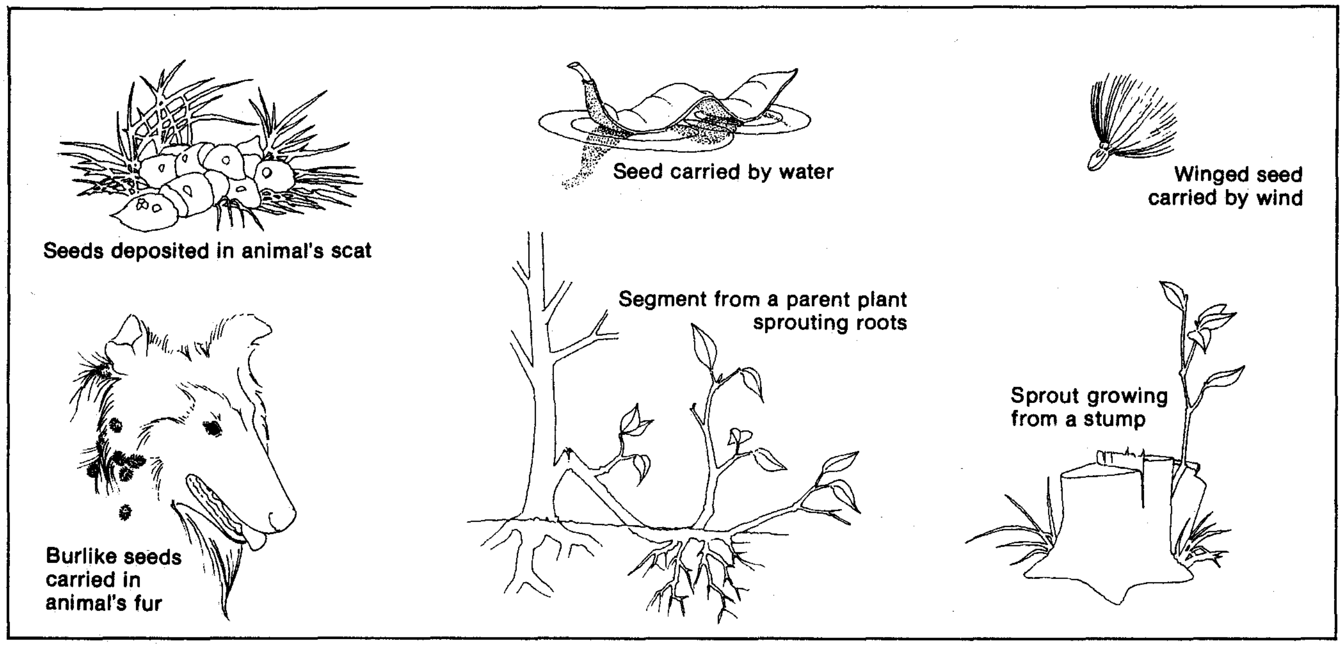


Figure 5. *Plants disperse and reproduce themselves in a variety of ways.*

stumps of many plants sprout. Because of the advantage of an established, mature root system, such sprouts have the potential to grow faster than a seed-started individual.

For a plant to get started and grow in a new environment, all of its basic life requirements must be met. These requirements include energy, nutrients, gases, and water (fig. 6).

Energy is required by all life. Green plants contain chlorophyll and are able to capture all their required energy from the sun. This light energy is converted to chemical energy through the process of *photosynthesis.* Photosynthesis, in Greek, means "put together with light." During photosynthesis, water and carbon dioxide are combined to form glucose, a simple sugar. Chemical energy is stored in the bonds that hold the molecules of glucose together. The glucose is then available to be transported to all parts of the plant (fig. 7).

Energy requirements of plants vary depending upon the needs and size of the plant. A tree, for example, requires much more total energy to build and main-

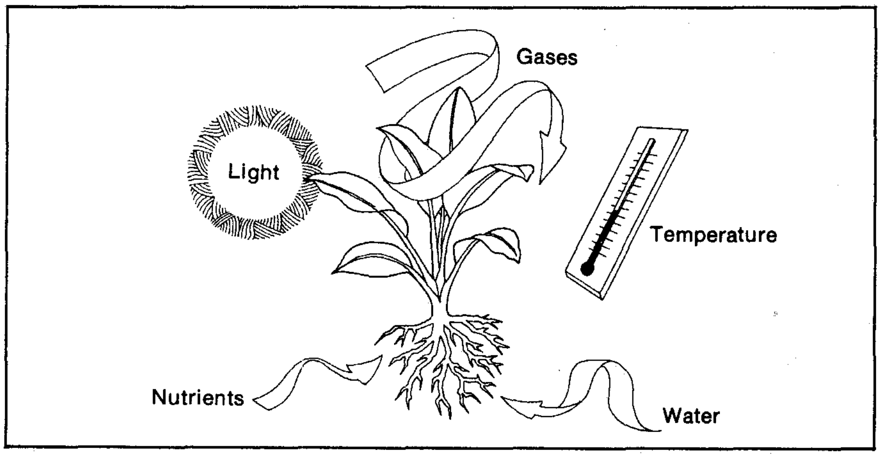


Figure 6. *A plant's requirements for growth are energy, nutrients, gases, and water.*

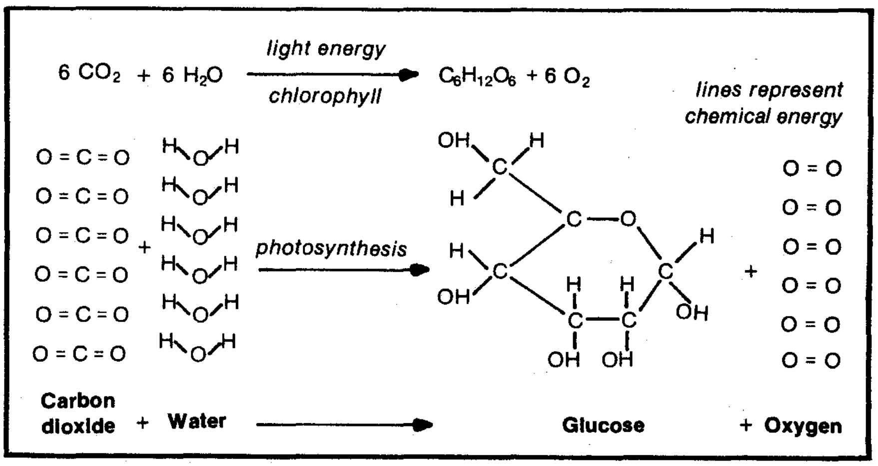


Figure 7. *In photosynthesis, water and carbon dioxide are combined to form glucose.*

tain itself than does a grass plant. Therefore, the tree has more green area than the grass.

Leaves of different plant species vary in how efficient they are at capturing the sun's energy. A term to indicate this relative efficiency is *tolerance.* Some plant species are able to use the energy found in subdued sunlight. They are able to survive in the shade and, in fact, may not grow well or at all in direct sunlight. These plants are called *tolerant,* that is, they are tolerant to shade. Tolerant trees, such as beech and basswood, are most often found growing in the forest understory. *Intolerant* plant species are not able to use indirect light and instead require full sunlight. Intolerant tree species, such as oaks and aspen, are often called pioneer species because they are the first trees to grow in abandoned fields or in areas that have been recently cleared. Why do you suppose pines, with needle leaves, are typically intolerant, whereas many tolerant trees have horizontally arranged broad leaves?

Nutrients — that is, organic compounds and minerals — are the building blocks of all living organisms. All throughout a plant's life, nutrients are required for growth and maintenance. Some of the most important elements required by plants besides oxygen, carbon, and nitrogen are potassium, phosphorus, and calcium. All plants, however, do not have the same mineral requirements. For example, beech requires more calcium, potassium, and phosphorus than most pines do.

Plants also require the proper atmospheric gases. Carbon dioxide is essential for photosynthesis, and oxygen is consumed by plants because all their live cells respire just like animal cells. Some gases, such as sulfur dioxide, may cause damage to plants.

Table 1. Relative Tolerance of Some Common Northeastern Hardwood Trees

Intolerant	Intermediate	Tolerant	Very Tolerant
Pines — *Pinus* sp.	White Spruce — *Picea glauca*	Red Spruce — *Picea rubens*	Balsum Fir — *Abies balsamea*
Red Cedar — *Juniperus virginiana*	White Oak — *Quercus alba*	Red Maple — *Acer rubrum*	Hemlock — *Tsuga canadensis*
Black Willow — *Salix nigra*	Red Oak — *Q. rubra*	Sugar Maple — *A. saccharum*	Beech — *Fagus grandifolia*
Larch — *Larix laricina*	Black Oak — *Q. velutina*	Blue Beech — *Carpinus* sp.	
Aspens — *Populus* sp.	Scarlet Oak — *Q. coccinea*	Hop Hornbeam — *Ostrya* sp.	
Cottonwood — *Populus deltoides*	Slippery Elm — *Ulmus rubra*		
Black Walnut — *Juglans nigra*	White Ash — *Fraxinus americana*		
Butternut — *Juglans cinerea*	Black Ash — *F. nigra*		
Gray Birch — *Betula populifolia*	Paper Birch — *Betula lenta*		
Black Birch — *B. lenta*	Yellow Birch — *B. alleghaniensis*		
Tulip Tree — *Liriodendron tulipifera*	Hickories — *Carya* sp.		
Cucumber Tree — *Magnolia acuminata*	Basswood — *Tilia americana*		
Sassafras — *Sassafras albidum*	Arborvitae — *Thuja occidentalis*		
Sycamore — *Platanus occidentalis*			
Thornapple — *Crataegus* sp.			
Cherries — *Prunus serotina* *P. pennsylvanica*			
Black Locust — *Robinia pseudoacacia*			
Honey Locust — *Gleditsia triacanthos*			

Water is another essential for life. Water requirements vary among plant species. Trees such as willows, alders, and cottonwoods grow mainly where much water is available. They are most typically found along seeps, creeks, or river beds. These trees usually have spreading, shallow root systems. Other trees do not require as much water and are able to survive in drier areas. They tend to have deeper root systems.

All living cells require temperatures within a certain range to survive. Extremely hot or cold temperatures can actually cause damage to cells. Temperature affects the rate of the life processes of *metabolism,* photosynthesis, *respiration,* growth, and reproduction. At colder temperatures all life processes slow down; photosynthesis and respiration occur at slower rates. The temperature of the soil is as important as is the air temperature to plants. Roots are not able to absorb water and nutrients so quickly when the soil is cold as when the soil is warmer.

Growth and reproduction are sensitive to air temperature. The sudden surge of spring greenery and flowers attests to this. If a plant were to grow during the bitter cold of winter, the succulent new growth would freeze and die and thus waste the plant's energy. Seeds are especially sensitive to temperature. The seeds of some species must be *stratified;* that is, they must be exposed to a cold temperature for a period of time and then to a warmer temperature before they will germinate. The temperatures activate sensitive growth *hormones.*

Animals also require energy, nutrients, gases, water, and a certain temperature range; but unlike plants, most animals are highly mobile. The forest in which you find them does not need to satisfy all their requirements; however, those requirements that are satisfied in the forest may be essential for the survival of that particular animal. Wildlife biologists classify the requirements of the animals they study into the categories of food, water, cover, and habitat (fig. 8).

The number and variety of animals that a forest can support are determined by the size and diversity of the forest. A diverse forest is composed of many different types of vegetation, which is usually distributed in different patterns throughout the forest. Vegetation may be spaced evenly (which usually indicates human planting), in clumps, or interspersed with openings. A forest that has different kinds of vegetation interspersed with openings represents the most diverse type of forest. The more diverse a forest is, the more different types of fauna will be found in it.

Food provides the necessary energy and nutrients for an animal to live, grow, and reproduce. The forest provides food in the form of either vegetation or other animals found in the forest. Some animals have very limited diets, like the white pine weevil, an insect that bores only into the new shoot at the tip of the main stem of a white pine. Other animals have a more varied diet, such as the sharp-shinned hawk, which eats vireos and other small birds and mammals.

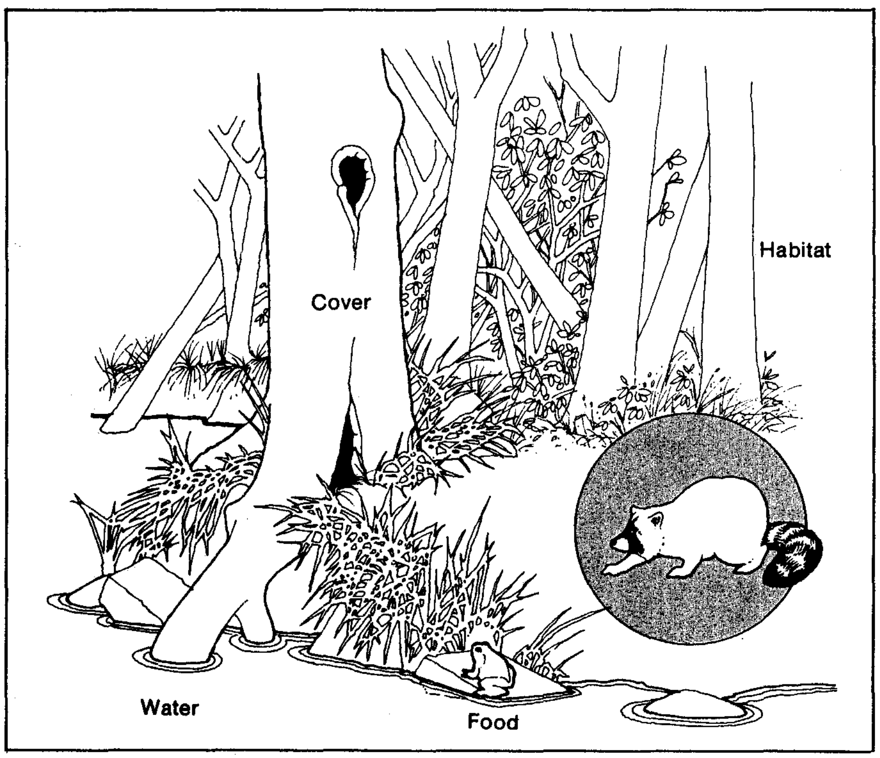


Figure 8. *Wildlife requirements for life are food, water, cover, and habitat.*

Vital water may be consumed either directly or indirectly. Direct sources of water that might be found in a forest include streams, ponds, other open bodies of water, and raindrops or dew that clings to vegetation. Succulent vegetation or the water found in bodies of prey provides all the water required by some animals.

Shrubs, a dense herbaceous layer, and tree canopies provide protective cover for animals from the weather and from predators. Small animals such as chipmunks and mice prefer to carry out their activities under the cover of shrubs. Because deer are much larger, they cannot always feed and water under cover. Therefore, they usually stick close to cover and rely on their quick legs to jump to safety. A doe with newborn fawns uses the cover of grass and ferns to hide them from danger. Just as vegetation provides protective cover from predators, it also provides a place for bobcats and foxes to hide and wait to ambush their prey. Burrows, blowdowns, and hollow trees found in the forest also become important hiding places for many animals.

The forest is a living space and breeding place for many animals. Hollowed logs provide homes for animals such as skunks and porcupines. Animals such as ground squirrels and chipmunks hibernate over winter in a nest of grass under the forest floor. Many animals reproduce in the forest. Birds nest among branches, on the forest floor, or, as in the case of woodpeckers and wood ducks, in holes in dead trees called *snags.* Weasels bear their young in burrows in the forest. Animals require a certain amount of space in which to forage for food and to carry out their other activities. Because forest resources are limited, many animals make territorial claims to a habitat, which they defend from other animals requiring the same resources as they do.

Component Interrelationships

The mere listing of the components of the forest does not suggest the essence of the forest community. It is like listing the ingredients to make a loaf of raisin bread without discussing how to put them together. Anyone can put raisins, flour, yeast, salt, oil, sugar, and spices into a bowl, but to make a loaf of delicious raisin bread is an art. Likewise, a forest is not a collection of plants and animals tossed together in a location. The components of a forest are related to each other with highly complex and often elusive links. How they are related is determined mainly by their individual requirements, but may, in turn, be modified by the environment.

The idea of interrelatedness implies an exchange of materials or energy, as seen in the food chain (fig. 9). Plants are the producers. The energy, nutrients, and organic matter of which they are made are passed on to the animals that eat them. Every part of a plant is a food source for some animal. Seeds, buds, and bark are eaten by mice, squirrels, and insects. Leaves may be eaten by caterpillars, deer, or rabbits. These animals then provide energy and nutrients for their predators, which, in turn, fall prey to other predators. Though plants are the primary link in the chain, some carnivorous plants attract and trap insects in cuplike structures containing a pool of digestive juices.

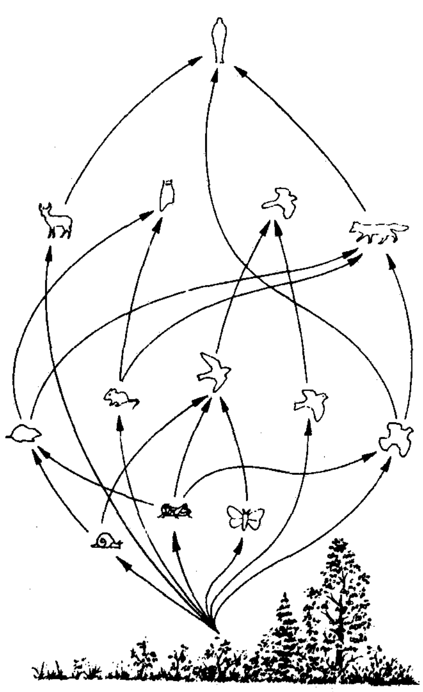


***Figure 9.** The transfer of energy through a food web.*

Even as plants and animals die, they are linked to other organisms in the forest. Scavengers obtain their energy from the wastes and remains of plants and animals. Flies and other insects lay eggs in dead animals. Opossums supplement their diets with dead animals. *Saprophytic* plants such as pine drops and invertebrates such as slugs feed on dead plants.

As these scavengers break down plant and animal remains into smaller pieces, a host of decomposers continue the chemical and mechanical breakdown. Mushrooms, other fungi, and bacteria all decompose such matter into its basic chemical elements—carbon, hydrogen, nitrogen, iron, and calcium — and other reusable forms. Worms and insects mix these minerals and nutrients into the soil and thus make them available to be absorbed by plant roots. Thus the cycle is completed.

In this whole process of exchange along the food chain, most of the organic matter, nutrients, and minerals remain in the forest ecosystem. On the other hand, most of the chemical energy and water are being used; and along each link, a portion of energy is lost as heat. Therefore, the number of animals at each successive level decreases.

In the forest, relations between plants and animals and among animals themselves are not limited solely to consumption. As mentioned before, forest vegetation provides cover and habitat for animals. Moose, deer, and elk also use the trunks of trees to scrape the velvet from their antlers. Trees are claw-sharpening posts for mountain lions, territorial markers for bears, and construction material for beavers. When a woodpecker excavates a nesting hole in a snag, it is creating a future nesting site for other birds such as nuthatches and chickadees.

Animals provide benefit for vegetation by controlling the population sizes of insects and animals that feed on the vegetation. Chickadees seen hanging upside down on branches are busy eating insects off leaves and branches of the tree. The fact that animals destroy vegetation is a benefit to the remaining plants of the forest. When a porcupine kills a whole tree by girdling it, he is making available additional sunlight, nutrients, water, and growing space, which the surviving plants can use for growth and reproduction. Animals also benefit vegetation by dispersing seeds to new locations. The red cedar berries eaten by a bird will pass through its digestive system and be deposited in a location away from the parent plant. Although squirrels dig up most of the acorns they bury, those overlooked have a fair chance of germinating.

Animal - plant relationships become harmful when population levels cause a strain on a resource or when a foreign element does not fit into the existing ecosystem. If the population of an animal species increases to the point where the animals are consuming more of a certain resource at a rate faster than it is being replaced, a negative drain on the forest results. The effects can be devastating. For example, in more than one location where predators have been reduced, deer

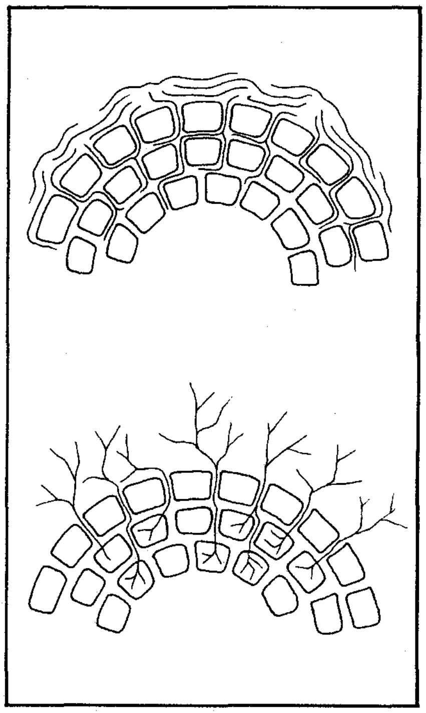


Figure 10. *Diagram of mycorrhizal fungi, which absorb sugars from the host plant but also allow the tree to absorb more minerals and water because of greater root surface area.*

herds have increased to the point where the deer have destroyed their favored foods and have been forced to eat and destroy less palatable vegetation. As a result, massive die-offs have occurred through starvation and disease. Insects normally do not kill the trees they feed on except an occasional scattered tree. Abnormally high numbers of insects, however, can kill whole stands.

Relations among plants in the forest can be either harmful or beneficial to one or more of the individuals involved. A mutually beneficial relationship exists between *mycorrhizal fungi* and root systems. Roots inoculated (fig. 10) with mycorrhizae are able to absorb more minerals and water because of increased root surface area and actions of the fungus itself. The mycorrhizae benefit by absorbing sugars that the tree makes. Other types of fungi may be harmful to live trees by causing heartrot and other rots. These rotted, hollow trees are then susceptible to wind breakage.

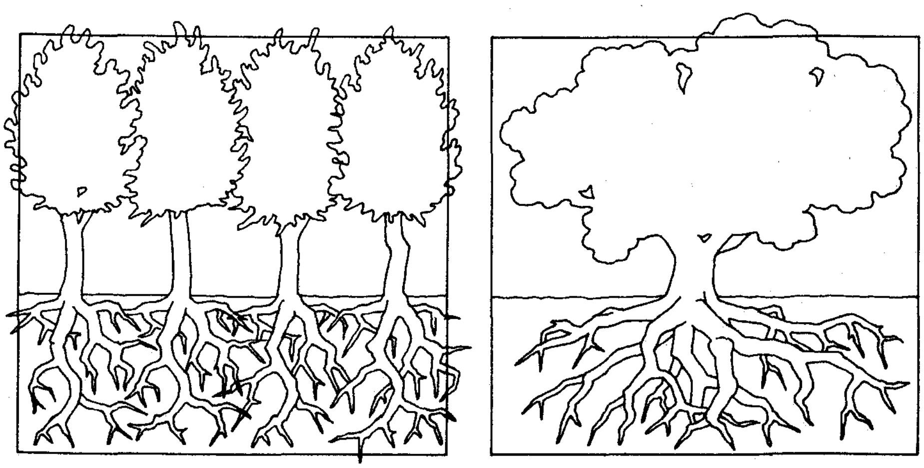
Some tree species form root grafts among different individuals. Though such grafts may aid in absorption of water and nutrients and allow the exchange of genetic material, they may also be pathways for fungal infections. Grapes and other vine plants seeking sunlight grow into the crowns of taller trees. The vines may become heavy enough to kill the supporting tree.

Plants indirectly influence the growth and survival of their neighbors by modifying the immediate environment. As trees grow taller, they create a shelter from temperature extremes, wind, heavy rain, and direct sunlight for the plants growing under them. Their leaf litter may provide nutrients not available in the soil but required by other species. Some trees such as alder even have bacterial nodules on their roots that add usable nitrogen to the soil. As a result, plants that otherwise could not grow in the understory can grow there. This relationship is not always beneficial, however. Roots of certain plants secrete chemical substances called *allelopaths* into the soil; these are toxic to other plants trying to become established nearby. The establishment of seedlings is affected in another manner. *Damping-off fungi,* which exist under certain conditions in leaf litter, attack and kill the newly germinated seedlings of some species.

Within a certain area, only a fixed amount of water, light, and nutrients is available for a plant to draw upon to satisfy its requirements. As plants grow closer together, a *competition* arises in which two or more plants must draw on the same supply. One organism is detrimental to its competitor by making similar demands on the same environmental resources (fig. 11). The larger and rapidly growing plants are often better able to satisfy their demands and thus cause slower growth and even death to their neighbors. Growing space becomes limited. As trees begin to crowd their neighbors, the growth rate of all trees drops dramatically and dense "dog-hair" thickets of thin, closely spaced trees develop. Trees in such thickets may appear to be young because of their small size, but actually they may be quite old.

Plants modify the environment in other ways. Trees along streams and rivers shade the water. When trees are removed, the water may become warmer, and fish species

Figure 11. Left: *competition arises when two or more plants must draw on the same supply of water, light, and nutrients.* Right: *plants that do not have to compete grow taller and larger than those that must compete.*



may change from cold-water species to those more tolerant of of warm water. Trees are also important in helping to control soil erosion. A vegetative cover reduces the impact of rain drops, which actually displace soil where they hit bare ground. Vegetation also prevents the wind from blowing away dry top soil. The roots of plants help hold the soil in place and prevent erosion.

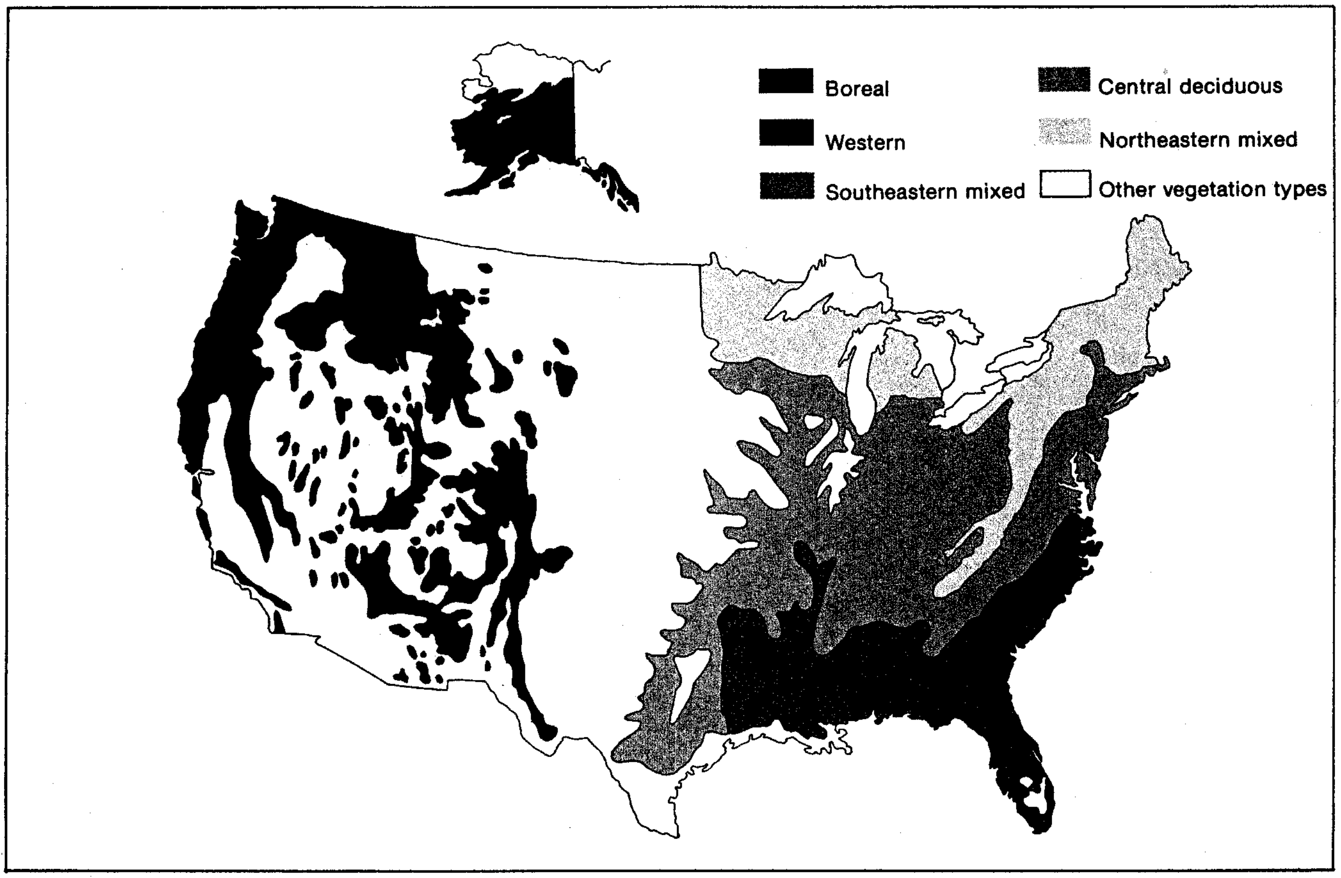
Plants affect the formation of soil. Leaf litter and plant wastes add organic matter and return minerals to the soil. Roots add minerals to the developing soil by chemically and mechanically breaking down rocks. Roots also extract nutrients from the soil and thus change the soil fertility. In fact, most of the nutrients in jungle forests are thought to be tied up in the lush vegetation. Jungle soils are actually low in those minerals required by plants.

Environmental Relationships with Plants and Animals

The environment has a direct relationship with the forest community. It controls the establishment, growth, and survival of plants and animals in the forest by satisfying the requirements of some organisms and not of others. Because of the varied environments across the continent, there are different types of regional forests — boreal, western, northeastern mixed, central deciduous, and southeastern mixed forests (see map). On a smaller scale, the light, temperature, water, soil type, and depth of soil vary from ridge top to slope to valley bottom to slope to the next ridge top. Ridges tend to be drier and the soil tends to be shallower than in the valley bottom, where water often flows and soil is deposited. Slopes range somewhere in between, but south-facing slopes tend to be drier and hotter than north-facing slopes because of the direct angle of the sun. As a result, different types of trees are likely to be found on each of these locations. For example, in a northeastern mixed forest, oaks and hickories are likely to be found on dry, warm ridges and slopes; hemlocks and birches will grow in the colder, moister valley bottoms (fig. 12).

Differences are present on an even smaller scale. The environment within a stand of trees is, in a sense, a microenvironment. Trees in the upper canopy influence how much water and light fall on the vegetation below them. The climate within the stand is different from that outside it. The forest floor is not uniform. It may have a pit-mound relief created

Map 1. *Types of forests growing in different regions.*



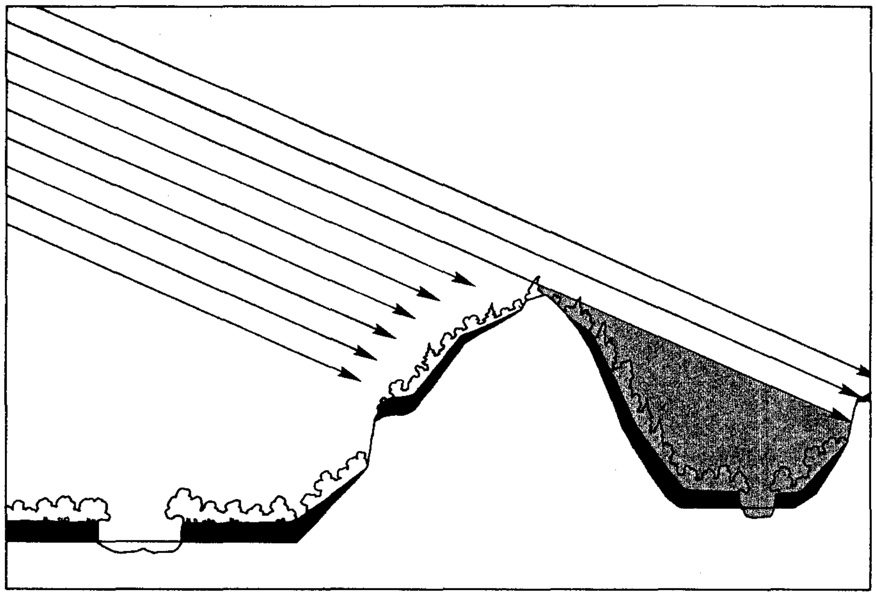


Figure 12. Schematic of local factors that influence soil depth and sunlight available to plants.

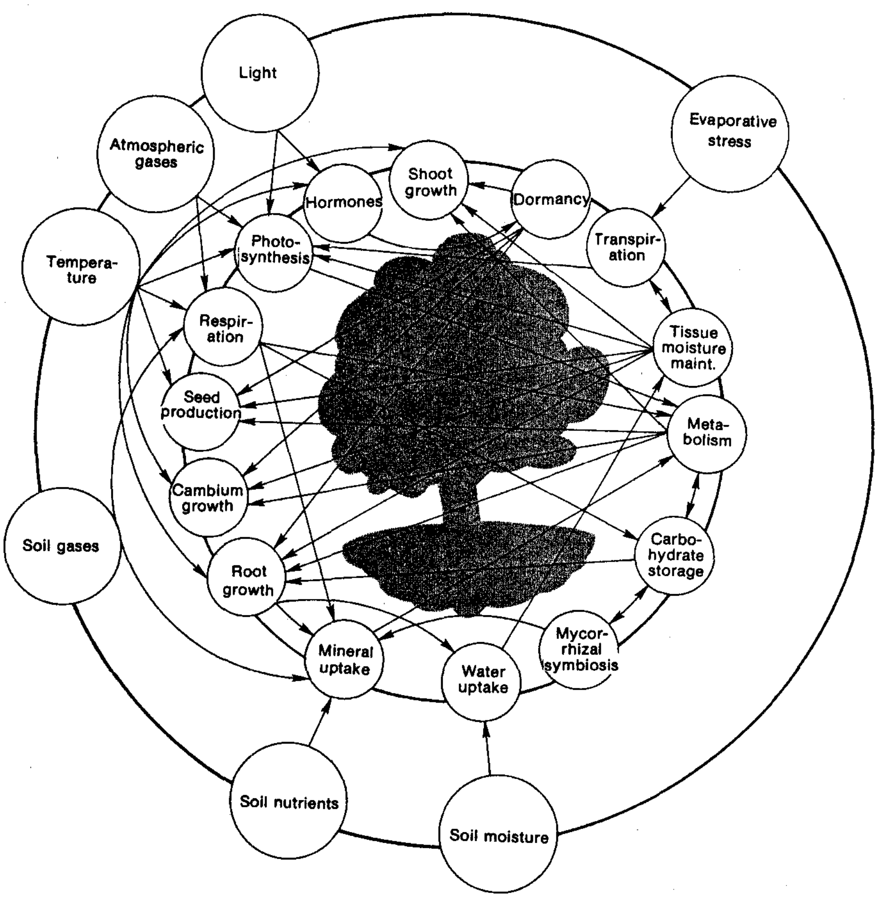


Figure 13. Interacting environmental factors that influence the life processes of forest plants.

by fallen trees. When a tree falls, the roots pull up the soil surrounding them; a mound of soil is made with a pit behind. A 3-meter transect of the soil will most likely show differences in structure, texture, acidity, and water and mineral content. Thus each individual potential growing space is unique and not suitable for every type of plant.

All life processes of forest plants are regulated to some extent by the environment. The uptake of water, minerals, and nutrients; metabolism; photosynthesis; respiration; growth; and reproductive systems are all affected by atmospheric gases, light, air temperature, humidity, and by nutrients, gases, and moisture in the soil (fig. 13). The ranges or amounts of those essentials and their combination in the environment affect the rate at which the above systems proceed. For example, growth and photosynthesis slow down when the temperature gets cold. On the other hand, certain life processes are triggered by temperature extremes. The sap that makes delicious maple sirup requires subfreezing temperatures at night and above 4.4°C (40°F) temperatures during the day to flow.

Photoperiod, the length of exposure to light per day, plays an important role in the growth, dormancy, and reproduction of a plant. As the days get shorter, hormones in plants respond to the briefer exposure to light and cause the plant to cease growing and become dormant. During this time, deciduous trees lose all their leaves, and the sap flows to the roots for overwinter storage. As longer days signal the beginning of spring, buds swell and open to flowers and leaves.

It is important for their survival that plants do respond to the environment. As each new season approaches, a plant must be prepared to adjust to changes. It must become dormant to survive the winter, and it must take advantage of the favorable spring and summer climates to reproduce and grow as it competes with its neighbors for survival.

Questions for thought:

How are animals attuned to the environment? Do you think that their relationship with the environment is as direct as the relationship between plants and the environment?

Forest Dynamics

A forest is dynamic, constantly changing. What you see when you walk into a forest is a balance of the components and their requirements, the environment, and interrelations. It exists only at that instant of time. The changes may not be noticeable. The process of decay and growth proceeds so slowly that you usually cannot tell the differences from day to day. New leaves are growing as others fall or are eaten. Minerals and water are continually recycling through the forest. New seedlings are sprouting; old veterans are dying.

Some changes can be quite noticeable and even catastrophic. An ice storm might hit and cause many broken branches or topped trees. A landslide, a fire, or logging can change a lush forest into a cleared open area overnight. When such an opening occurs, a process called succession begins its cycle. Many resources are available in a clearing: sunlight, air, water, and soil nutrients — if the soil was not eroded badly — are not being used. The seeds of many plants fall into the area. If bare mineral soil is exposed, those seedlings susceptible to damping-off fungi can survive. Tree, shrub, and herbaceous seedlings that start growing must be able to grow in intense sunlight; otherwise, they will die. These plants, known as pioneers, include such species as goldenrod, viburnums, aspen, oaks, cherries, and certain pines. As the trees grow taller, they begin to change the environment below them. The shrubs and herbaceous plants begin to die from lack of sun, water, and nutrients. "Open spots" appear. Many different seeds continue falling into the area. A layer of organic matter accumulates on the forest floor and damping-off fungi are present. In the Northeast, only certain species such as maple, birches, and spruces are able to thrive in less-intense light and moister conditions. The forest continues growing. Less sunlight reaches the forest floor and only the seeds of tolerant trees are able to survive. An understory forms, made up of hemlock, basswood, and sugar maple. The older, taller trees begin to die off. Trees in the understory whose small size might be masking their true age are able to take advantage of the newly released space, nutrients, and increased sunlight. These spruces, beeches, and maples now become the dominant trees of the stand. If the area is again disturbed — if a fire burns through, a windstorm blows down a stand of tall, shallow-rooted trees, or the weather changes — the succession cycle will occur again. If, however, the final vegetation is able to replace itself and the forest composition stays relatively constant, a *climax forest* is said to have been achieved (fig. 14).

Stage 1. *Pioneer grasses, forbs, and shrubs.*

Stage 2. *Shrub stage with invasion of intolerant seedlings.*

Things to do:

1. Take a trip into a forested area. Observe the forest environment. Sit in one place for awhile and observe closely around you. Walk around the area and list components of the forest. Try to observe the things that you have read about. After at least ½–1 hour, discuss with your group what you have found.
2. Go to an open field. Observe it closely as you walk around and then sit down for awhile. How is the open area different from the forest observed in #1?
3. Pick a tree species and read about it. Jot down its requirements for life. Go to a forested area with your group and look at the forest. If you were that tree, would you be able to survive in this forest? Explain why or why not. Select a forest animal and do the same thing.
4. With your group, have each member choose a living component or environmental factor of the forest. Allow each person to take a turn to explain how his or her component or factor is related to all the others represented by club members.
5. Look at the forest environment section of *Environmental Awareness*. Do any of the activities that interest you and your group.
6. Go to an open or abandoned field that is not being plowed, mowed, or grazed. Do you see signs of succession taking place? What are they? If succession is not taking place, why?

Stage 3. *Mixed species stand of young intolerant trees.*

Stage 4. *Mature stand of intolerant trees with understory of tolerant seedlings.*

Stage 5. *Mature stand of tolerant species with understory of their own seedlings.*

Figure 14. *Typical succession in a northeastern forest.*

The Forest as a Renewable Resource

The forest ecosystem satisfies the requirements of many animals. It also provides many useful materials for the human animal. We call these materials *forest resources.*

Since the beginning of human history, forest-dwelling people have found a rich source of food, clothing, tools, shelter, and fuel in the forest. In North America, native Americans and pioneers depended upon the wild animals and the nuts, berries, fruits, buds, and roots from the forest to supplement their food supply. Maple sirup, which the pioneers learned to make from the Indians, provided a valuable sugar source. Roots, bark, and herbs were also important for their medicinal properties. Today many people still gather berries, mushrooms, and other special products from the forests. The wildlife and fish populations of forested lands are now managed by our government to assure sport and meat from fishing and hunting.

Fur and hides from forest animals in the past were an important source of clothing for Indians and settlers alike. Today trappers supply the fur industry with the hides of forest animals. Also, rayon, a product of wood pulp, is used to make fabrics for the clothing industry.

Tools of the past were made mainly from wood. Pails, baskets, handles, and brooms were all shaped from wood. Although metals have replaced some of the uses of wood, many tools today have wooden handles or are made of wood-derived synthetics.

The need for shelter has been served for centuries by wood. Pole frames thatched with bark, branches, grass, or hides were the homes of primitive people. The settlers built log cabins furnished with wooden furniture. Even today, many houses are made of wood, or they at least contain some wood or wood product. Insulation, wood finishes, stains, and other building accessories are made from wood products.

Fire used for heating and cooking has greatly expanded the adaptability of humans by allowing them to live in many climates and to eat various foods. Wood was the main source of fuel for fire until the 1900s when other sources of heat and power were developed. Because of increasing costs of coal, gas, heating oil, and electricity, some people in the U.S. are beginning to convert their homes to wood heat. Wood fuel is again renewing its importance among the many uses of wood.

Today, forest resources provide direct income for many people. The growing, cutting, preparing, transporting, and selling of such wood products as timber, pulpwood, firewood, charcoal, and Christmas trees employs a large number of people. Many individuals supplement their income with the sale of special products including floral greenery, maple sirup, seed cones, and tree burls. The money derived from forest resources can in fact indirectly support an entire community. For example, a local sawmill may provide employment for members of most families in a small town. Because these families need services such as stores, hospitals, and gas stations, their money earned from timber goes towards supporting the commercial establishments in town. This is known as the multiplier effect of money. Recreation is another important forest use. A growing number of people enjoy hiking, skiing, camping, hunting, and fishing in our forests. Recreation also provides income for those who operate private campsites and recreation facilities.

Forests supply a clean source of water for many communities. A forest cover absorbs and slowly releases water from rain and snow. The forest floor helps to filter the water. Forests also prevent erosion and the resultant sedimentation of streams, rivers, and lakes.

Many people value the *aesthetics* or beauty of the forest. An intangible forest resource, aesthetics is a combination of visual quality and the emotional feelings one has about a place. Its worth truly is in the eye of the beholder. Some people prefer forest vistas, others prefer an old growth forest of a single or mixed species. The solitude, the filtered sunlight, the wildness, and spiritual feelings are all reasons why people enjoy being in a forest.

The forest provides something that is often taken for granted — environmental improvement. Trees serve as windbreaks and noise and vision buffers. Besides providing us with oxygen, they act as air filters. Branches and leaves collect particles from the air, and leaves actually absorb some pollutants. Homesites benefit from the shade and beauty provided by trees.

Forest resources are special (fig. 15). Most are *renewable,* that is, resources that are properly removed can be naturally replaced. The appropriate environment and appropriate seed (plant) or population (animal) sources assure the regeneration of that which was removed. We need only wait for time to pass as the forest grows and renews itself. The forest environment, however, can be altered significantly by a sloppy job of resource removal or by overuse. It may take several human generations to replace itself. In such cases, the forest can be considered to be nonrenewable. Abuse and overuse, the story of our past, should be avoided. If unwise practices do cause a forest resource to become nonrenewable, the decision of use then becomes ethical.

Questions to consider:

1. How do you feel about using a nonrenewable resource?
2. What do you think about conserving resource supplies for future generations?
3. What nonrenewable resources do you currently use? How do you feel about it? Is there anything you can do to avoid using them? What if it means an inconvenience to you?
4. What renewable resources do you use? How do you feel about it? Because they are renewable, does that mean you can use them frivolously?

Things to do:

1. Tour a wood-using mill or factory. Find out what kinds of trees they use as raw materials.
2. Have a forester take you out in the woods to show you what types of trees are appropriate for sawlogs, pulpwood, firewood, and other wood products.
3. Have a hunter, trapper, or naturalist take you through the woods to show you how to look for animal signs.

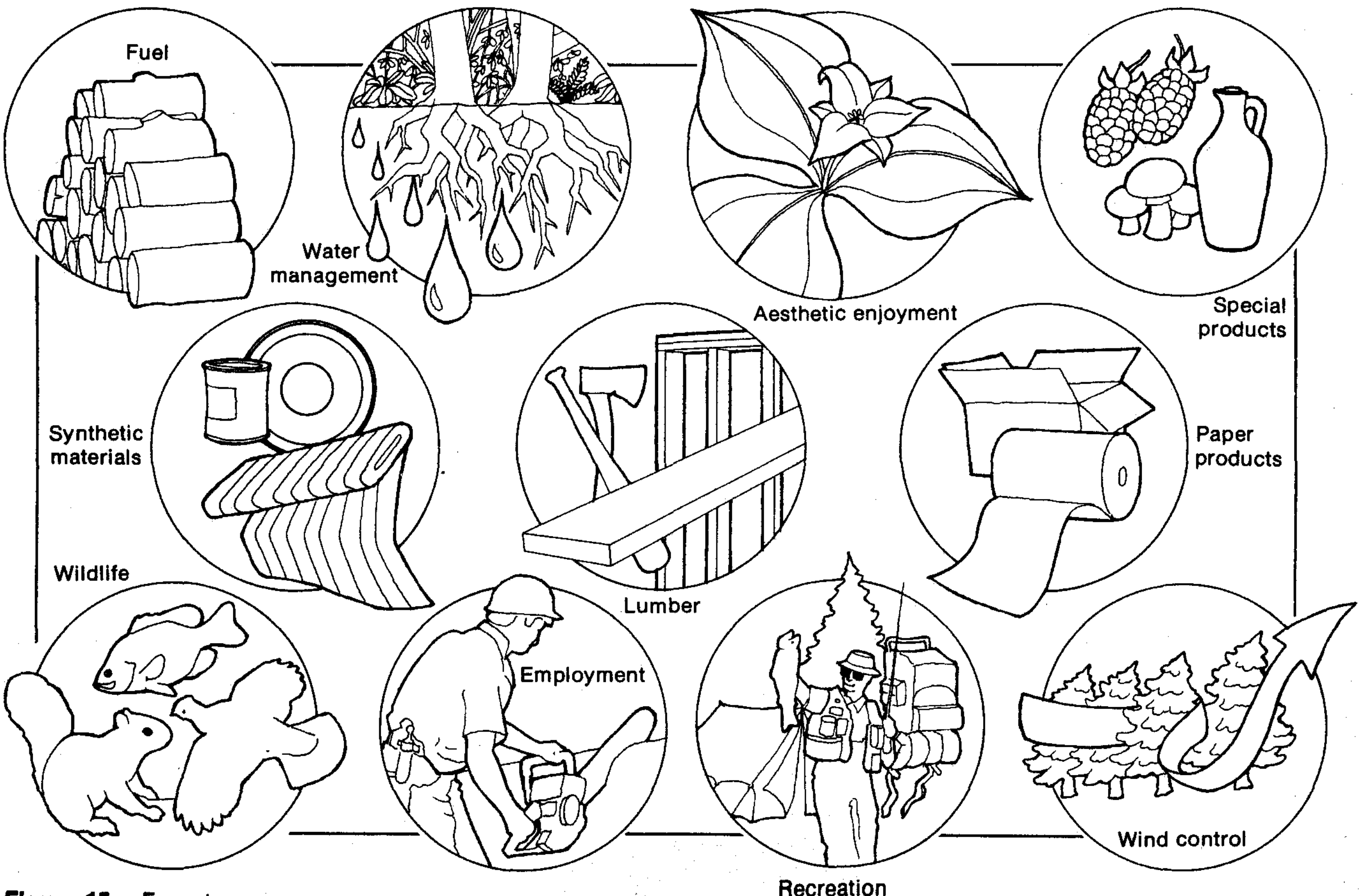


Figure 15. *Forest resources.*

Forest Description and Inventory

With the understanding of forest ecosystems and forest resources you have developed, you now have the background to proceed with the forest inventory. For the inventory you will be sampling a piece of a forest ecosystem.

Objectives of the inventory are as follows:

1. To see what exists in the forest — to examine the components and environment of the ecosystem, and to study the possible forest resources in your forest;
2. To measure the timber resources;
3. To look at the dynamics of the forest ecosystem;
4. To see how forest dynamics affect the growth, quality, and renewability of forest resources.

Equipment you need to conduct the inventory:

- pencils
- hammer
- wooden or pipe stake
- Bright flagging — plastic, cloth, toilet paper (be sure to remove flagging when finished)
- a 22.86-m (75-ft) tape measure or a rope knotted 16.06 m (52.7 ft) from the end
- compass (optional but handy)
- slope-measuring device (see Appendix 2 for construction details)
- *Biltmore* stick for measuring tree diameter and height (see Appendix 1 for construction details)
- chalk or a sock filled with powdered chalk to mark trees that have been measured
- shovel
- ruler
- clipboard to write on

Be sure to keep track of all equipment out in the field. It is hard to see them lying on the forest floor. If they are flagged with a bright color, they are much easier to find.

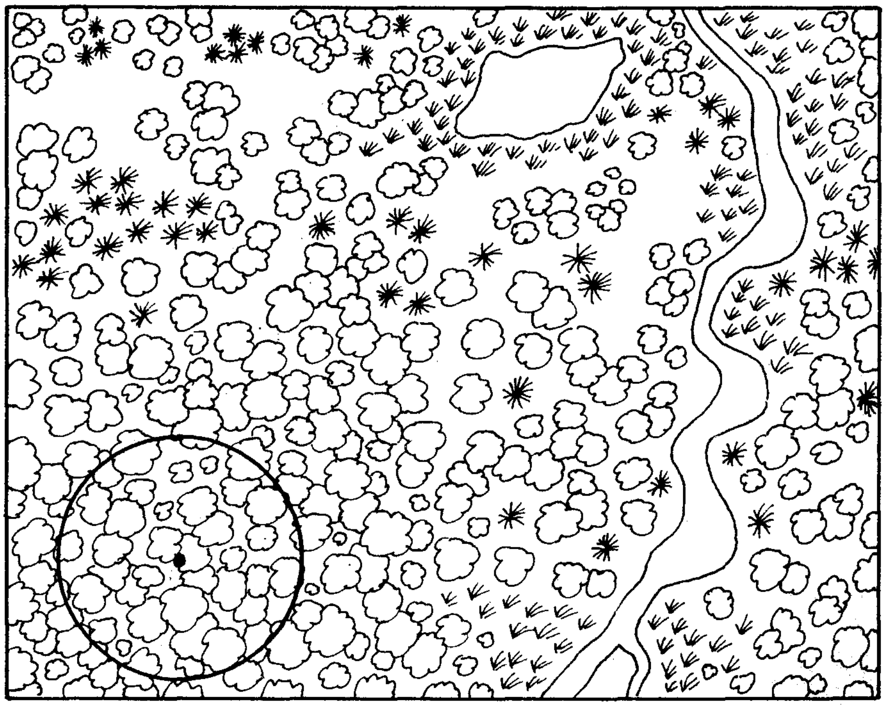


Figure 16. *Sample plots should be typical of the area being studied.*

Plot Location

Locate a wooded area in your own or a neighbor's backyard or on state land; or ask a private woodlot owner for permission to carry out this exercise on his or her land. Walk through the area to get an idea of what the forest looks like. To choose the location for your plot, try to find an area that represents the rest of the forest. (Do not pick the only hemlock stand in the middle of a hardwood-cover type unless you are measuring other "typical" hardwood plots.) Do not locate the plot on the edge of a stream unless that is typical of the forest you are sampling (fig. 16).

For a more accurate sample of your woods, it is best to measure more than one plot. Measure as many plots as you wish or have the time for; the more plots, the more complete your information will be. These plots should all be located to represent typical stands of your woods.

You may wish to sample a variety of different forest types. To do this, locate one plot in a hardwood stand, one in a conifer stand, and one in a mixed hardwood - conifer stand. Compare the differences among these plots. If you are interested in the effect of environment on the forest, locate one plot on a ridge top, one in a valley bottom, and one on each a north- and south-facing slope. Compare any differences. *Hypothesize* why they might occur.

History

To help give you some possible insights about the forest you are sampling, learn something about the land-use history of the area. Libraries or land ownership records will provide you with some information. You may have to deduce past land-use practices by using clues and evidence you actually find in the woods.

Questions to consider:

1. Was the land originally forested? If so, what was the forest type? (What species of trees most likely occurred in the original forest?)
2. Did any Indians live in your woods? What type of activities did they carry out in the woods? Did they burn the area to provide habitat for the wildlife they hunted? Did they plant crops?
3. Was the area cleared for fields or cut for timber? If the forest floor is relatively smooth, chances are that the area was cleared for fields or pasture. If there is a distinct pit-mound relief, it was never plowed and was most likely cut over or burned at one time. Are there any cut stumps? Are there any signs of fire? Any charred stumps?
4. What resources did this forest supply in the past to white people?
5. When was the forest last cut, or when was it abandoned if it was cleared? Ages of trees will give a good approximation of this. Ages can be estimated by counting the growth rings on recently cut stumps or by counting the whorls of branches on conifers. The whorl is the level at which several branches are attached around the trunk of the tree. Each whorl represents 1 year.
6. Is there evidence of soil erosion? Gullies or streams running down old roads indicate erosion.
7. Was the area planted or did it naturally seed in with trees? Rows of trees indicate planting.
8. What does the history indicate about the renewability of the forest?

Conducting the Inventory

The inventory can be done by one person, although it is much easier and less frustrating to do with two people.

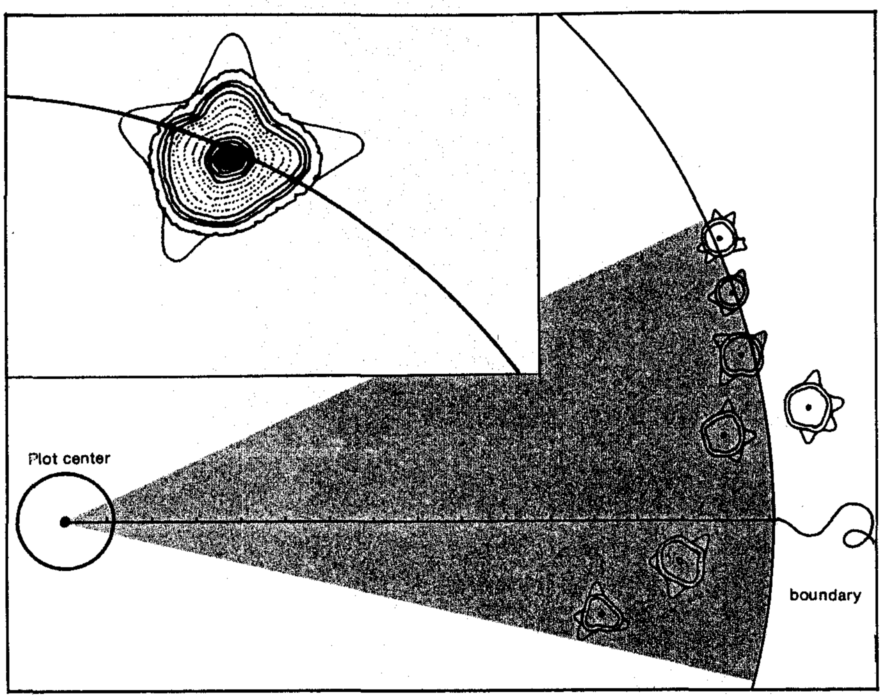


Figure 17. *Plot boundaries should be marked carefully.*

Set up the plot.

After you have found an appropriate location, drive a stake into the ground to mark the center of a 2/25-hectare (1/5-acre) circular plot. A flagged tree can also serve as a plot center. To establish the plot boundary, use a tape measure or a knotted rope to measure out from the plot center 16.06 m (52.7 ft). Flag all trees close to the boundary that are in the plot. Carefully measure borderline trees. Should the distance from the stake to the center of the tree be greater than 16.06 m (52.7 ft), the tree is outside the plot (fig. 17).

Inventory form.

Once the plot has been established, fill in the inventory (see p. 20), using the following guidelines:

A. Technical data.
Record the plot number, the date, and the field crew. If you are working with more than one person, only one form should be filled out for each plot measured. Property owner and town and county should be recorded.

B. Environmental factors.

- Indicate if the general *topography* (the configuration of the land's surface) of the area is flat or hilly. If it is hilly, is it steep are the hills rolling hills or is it a gradually rising slope?
- Topographic site refers to the specific site of the plot. Indicate where the plot is located.
- Slope indicates how steeply the land rises. Slope, measured here in percentage, is the number of meters rise (upward) for each 100 meters level distance. A 45° angle is a 100% slope. Take a measure of the average slope of the plot using the clinometer you made.
- Record the aspect of the slope that the plot is on. Face downhill as you stand at the plot center. Use a compass or the position of the sun to determine which direction you are facing, and record this direction.

C. Vegetation.

- Record the general forest type of your plot: hardwood, conifer, or mixed hardwood-conifer.
- Origin of stand — Look first at the overstory to determine how most of these trees became estab-

lished. Indicate if they originated from seeds or root sprouts (these will look like individual, independent trees), from stump sprouts (stump sprouts are all of the same species and will share either a common base or will be closely clustered together at their bases), or if they were planted (planted trees are usually arranged in rows).

Indicate which category most of the overstory trees fall into and mark it with an *O*. Determine the origin of the understory trees, if any exist, and mark the appropriate category with a *U*.

• Vegetation other than trees — Give a brief description of the shrub layer and the ground cover of forbs, grasses, mosses, mushrooms, lichens, and so forth. Give an idea of species present and of how dense the shrub layer and ground cover are.

D. Forest floor and soil.

• Indicate the absence or presence of organic litter (leaves, branches, humus, etc.). Measure its depth in centimeters from top to mineral soil, and describe its composition. Identify the leaves if you can.

• Dig a deep pit into the ground. Ideally, the soil pit should be dug to the bedrock to expose all soil layers. In some cases, only a backhoe would work; give it a good effort by hand, but you don't need to break your back or the shovel. Bury the pit when you are done; otherwise, it could become a trap for small animals. Determine if the soil has been developed from the underlying rock (indicated by distinct layers) or if it was transported to the site (no distinct layers, mixed rock fragments).

• For the first instance, measure in centimeters the depth of each layer and describe its color (fig. 18).

• Test the texture of the soil at each layer (see table 2). Squeeze a bit of moistened soil in your hand. Which category does it fit into?

• For transported soil, give a description of rock color, type, and sizes. Are they all the same size or does the size vary greatly? If you have any idea of how the soil was transported, write it down.

• Note where you find most of the roots. How well drained is the soil? Is it mucky, does the pit fill in with water, or is it fairly well drained?

• Is there a distinct pit-mound topography (fig. 19)? When a tree falls over, it creates a hole or pit where the roots were and a mound from the soil that is wrenched out of the ground by the roots. In most cases, the tree will have decomposed and no longer be evident. This pit-mound topography is very common in northeastern forests. (Make sure that you have not dug your soil pit in a pit or mound.)

• Water — Indicate the presence of open bodies of water nearby or on the plot. Describe the color, depth, and width of the water. Note any fish or other aquatic animal life dependent on this water.

E. Note signs of wildlife and signs of human activity.

F. Damage.

Look around at the vegetation. Pay particular attention to the trees. Look up into the tops, at the base ends, and along the trunks of trees. Describe the presence of damage, its cause, its extent, and relative abun-

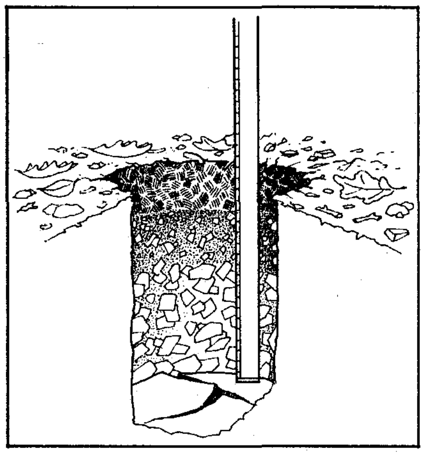


Figure 18. *Soil pit showing soil horizons.*

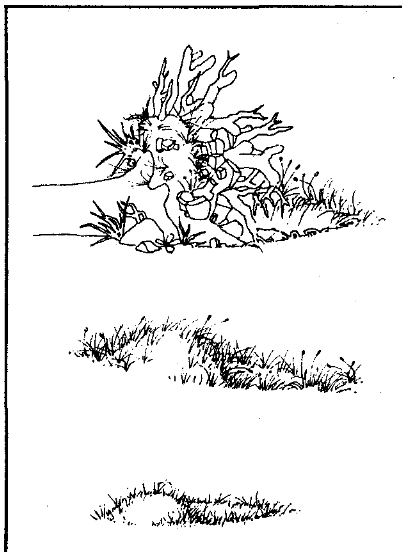


Figure 19. ***Pit and mound topography resulting from decay of windthrown trees.***

Table 2. Soil textures

Texture	Characteristics
Sand	Loose; squeezed in the hand when dry, it will fall apart when pressure is released; squeezed when moist, it will form a cast* which will crumble when touched.
Loam	Somewhat gritty, yet fairly smooth and able to hold a form when moist; squeezed when dry, the cast will not break if handled carefully; when moist, a cast can be handled freely without breaking.
Clay	Forms hard lumps when dry; when wet, is sticky and able to hold a form; moist clay can be pinched out between thumb and finger to form a long, flexible ribbon.

Source: K. A. Armson. 1977. *Forest Soils: Properties and Processes*. University of Toronto Press.
*Cast: a form, a mold

dance in the stand. Keep an eye out for cankers, rot, wounds, insects, animal damage, storm damage, and so forth. Mushrooms and other growths on living trees indicate fungal diseases. An abundance of broken tree tops may be the result of ice storm damage. The presence of many uprooted trees indicate wind storm damage.

Tree Measurements

Two types of tree surveys are conducted for this inventory. First, a survey of small trees is taken to give an idea of regeneration. Second, all trees of commercial value are measured to determine the volume of valuable wood in the forest.

Regeneration Survey.
The purpose of this survey (p. 21) is to focus on the abundance and species of trees regenerating in the forest. This information is important because it helps to determine when to cut and which harvest and regeneration systems to use. A simple tally is taken of the regeneration on a 1/2500-hectare (1/1000-acre) plot.

Procedure: The regeneration plot is a subplot of the main 2/25-hectare (1/5-acre) plot. Using the same plot center, set up a circular plot with a 1.13-m (3.71-ft) radius. Within this plot, tally all seedlings and trees according to their species and size class. All seedlings less than 1 m (3 ft) tall are categorized by their height. Taller trees are categorized by diameter class. Be sure to measure diameter at 1.37 m (4.5 ft) from the ground whenever possible (this is the *DBH* — Diameter Breast Height). (See instructions for making and using a Biltmore stick in Appendix 1.)

Merchantable Tree Inventory.
The purpose of this inventory (p. 21) is to assess the quality and wood volume of trees of commercial value. Diameter and height measurements are taken, and a qualitative description of each tree is made. With this information, the forest manager can assess the quality and amount of wood products the forest is producing. This helps him/her to decide when to harvest trees and which harvest system to use.

For this inventory, all trees of merchantable size — that is, large enough to be sold as a specific wood product — in the 1/25-hectare (1/5-acre) plot boundary are measured with a Biltmore stick. The merchantable size limit varies depending upon the wood product. Therefore, before measuring any trees, you must decide which wood product(s) you prefer from the forest.

Sawlogs: trees that are to be sold for lumber. Sawlogs should have fair to good form — that is, long, straight trunks that are mostly free of branches. Measure only

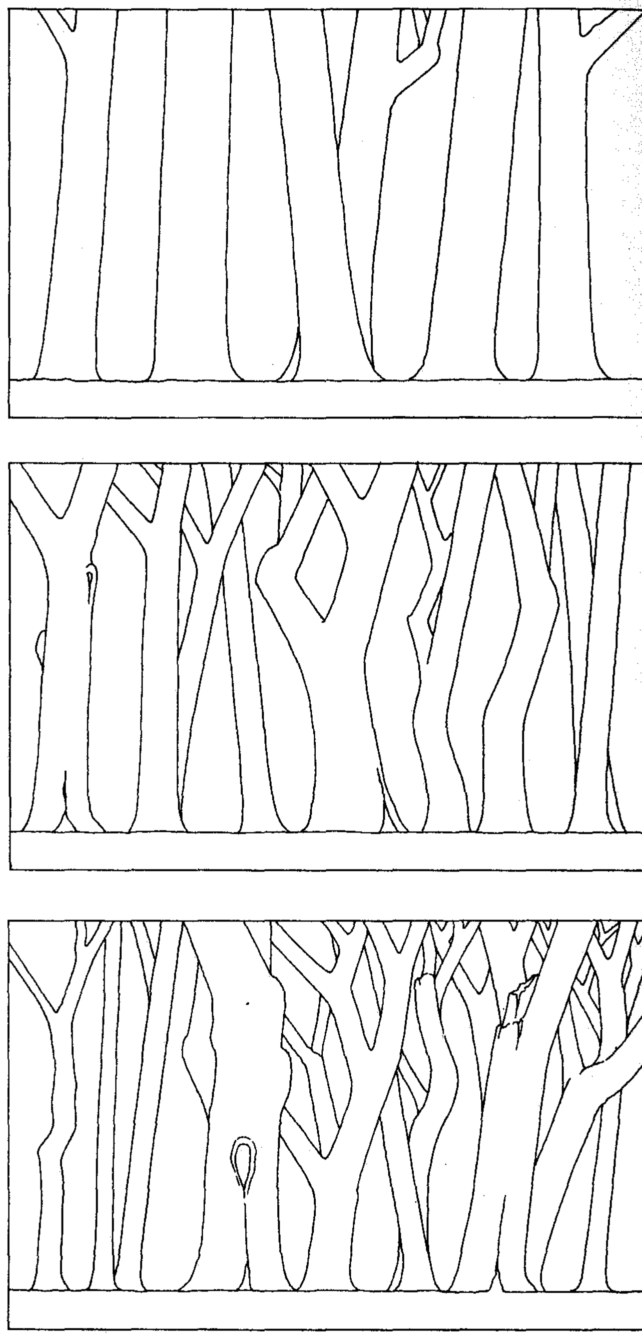


Figure 20. *The size and shape of trees determine what wood products can be obtained from them.*

Sawlogs *are taken from large, clean-boled trees.*

Pulpwood *makes use of trees that are crooked, forked, or otherwise defective for sawlogs.*

Fuelwood *can come from small trees taken in thinning operations or from trees too poor in form for sawlogs or pulpwood.*

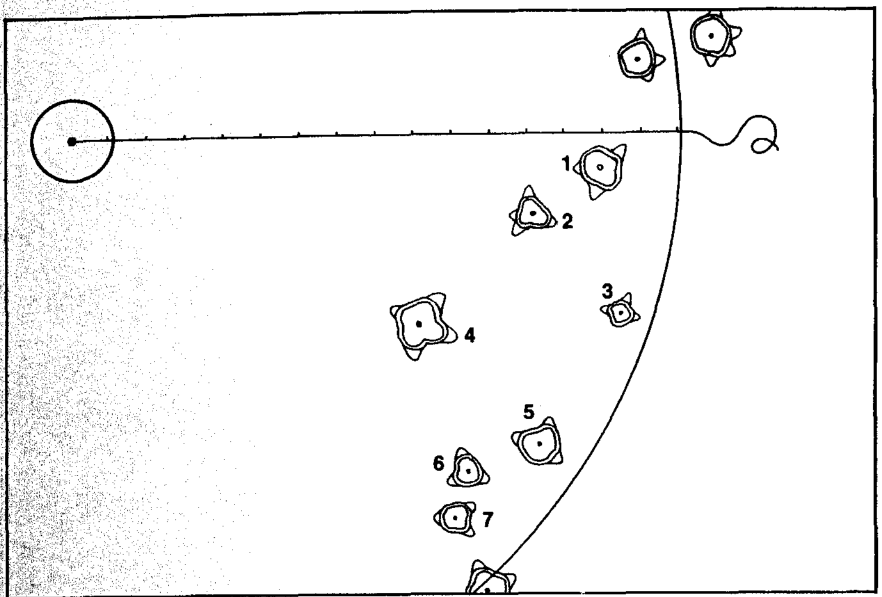


Figure 21. Measure trees in sequence, starting along a radius and measuring all merchantable trees in a clockwise progression. Only trees with their center inside the plot should be measured.

those trees that are 30 cm (11.8 in) DBH or greater. Record the diameter and the height. The recorded height is equal to the number of logs (5-m or 16.3-ft segments) in the tree up to a 15-cm (6-in) top. Trees with excessively poor form are best measured as pulpwood.

Pulpwood: trees that are to be sold as pulp for paper and fiber products. Form is not as important for pulpwood as for sawlogs. Trees that are 15 cm (5.91 in) DBH or greater qualify for pulpwood. Height is measured to the closest meter up to a 9-cm (3.54-in) top.

Firewood: form is not important here. Any size tree will qualify for firewood, but for your purposes, measure only those trees that are 10 cm (3.94 in) at DBH or greater. Measure height to the nearest meter up to an 8-cm (3.14-in) top.

When deciding which wood products to measure, consider the relative value of the products (fig. 20). Large trees of good form and valuable species bring in more money if sold as sawlogs than as pulpwood or firewood. You may wish to combine all three products. In such a case, measure all trees on the plot that are 10 cm or greater. Trees that are at least 10 cm and less than 15 cm should be measured as firewood. Those that are from 15 cm to 29 cm should be measured as pulpwood. Any larger trees should be considered as sawlogs. You may also decide to measure your trees solely for pulpwood or firewood. Whichever product or combination of products you wish to measure is perfectly valid.

Procedure: Stand at the plot center and face in one direction (such as north). Measure all trees of merchantable size, proceeding in a clockwise direction from the plot center. Ignore trees that are less than merchantable size. Mark each measured tree with chalk to avoid remeasurement (fig. 21). For each tree, record the following information on the Merchantable Tree Inventory (p. 21):

- Species — record species. Use *Know Your Trees* if you have difficulties.
- Diameter — be sure to measure at DBH — 1.37 m (4.5 ft) from the ground.
- Height — record height up to a merchantable height in logs or meters, as specified previously. Be sure to include the units.
- Form — Record the form as good, fair, or poor (fig. 22).

Good — a hardwood that is branched only at the top and has a straight trunk; a conifer that is not excessively branched with a straight trunk.

Fair — a tree that has minor defects of form. Note defects.

Poor — a tree that is excessively forked, twisted, branchy. State why.

- Damage — record any rot, wounds, or damage to the tree. Note cause (if detectable) and extent of damage.
- Animal signs — Note any signs of animal use of the tree, such as nests, claw marks, actual sightings.
- Miscellaneous — Record anything unusual about the tree that has not been covered by the previous categories.

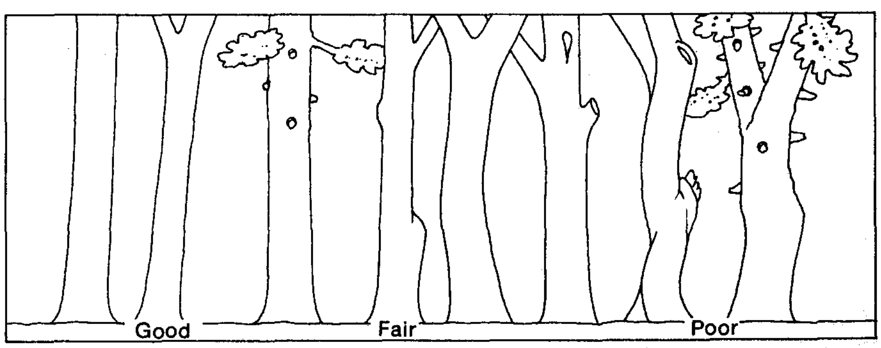


Figure 22. Tree form depends upon size, straightness, length of clean bole, and freedom from disease, damage, or holes.

Forest Evaluation Inventory Sheet

A. Technical Data

Plot #________ Date measured____________________ Field crew ________________________
Property owner______________________________ Location ______________________________

B. Environmental Factors

General topography: Flat_______ Hilly_______ (Steep_______ Rolling_______ Gradual_______)
Topographic site: Ridge top_______ Mid-slope_______ Valley bottom_______ Riverbank_______
Other____
Slope____________________ Aspect ____

C. Vegetation

Forest Type: Hardwood_______ Origin of Stand: Seeds or root sprouts_______
Conifer _______ Planted_______
Mixed _______ Stump sprouts_______

Vegetation other than trees: Brief description of shrubs, forbs, leafy, and other vegetation present. Give some idea of abundance. ____

D. Forest Floor and Soil

Litter: Absent (mineral soil)__________
If present, Depth__________ Composition ____

Soil: Developed from underlying rock_______ Transported _______
Description: ____

	Depth	*Color*	*Texture*
A Horizon	________	________	________
B Horizon	________	________	________
C Horizon	________	________	________

Description of soil drainage and where most of the roots are located.

Evidence of pit-mound topography:__________

Water: Description of open bodies of water — color, depth, width. Note animal life associated with it.

E. Animal Activity

Wildlife: Note scats, evidence of feeding (browsing of limbs, pile of seed shells, etc.), actual sightings, nests, songs, snags with woodpecker holes, bones, etc.______________________________

Human: Note trails, stone walls, fences, buildings, stumps, trees painted or flagged. ____________________

F. Damage

Description of damage due to fire, weather, insects, fungi (rots), animals, humans. Include the extent and relative abundance in the stand.______________________________

Regeneration Survey

1/2500-hectare (1/1000-acre) plot. Tally all trees including sprouts by species and size class within this plot.

Species ***Size Class***

	Less than .3 tall	*.3 - 1 m tall*	*>1 m and≤2.5 cm in diameter*	*2.5 - 8.0 cm in diameter*	*9 - 15 cm DBH*

		16 - 30 cm DBH	*31 - 45 cm DBH*	*46 - 60 cm DBH*	*61 + cm DBH*

Merchantable Tree Inventory

2/25-hectare (1/5-acre) plot. Measure all trees 15 cm (5.9 in) or greater in DBH.

Species	*Diameter*	*Height*	*Form*	*Damage*	*Animal Signs*	*Miscellaneous*

Review of Forest Inventory

1. **Forest Summary.** Using points *A-D* as a guide, summarize the information you have gathered.

A. Summarize the forest stand that you inventoried. Give a brief description of its composition of plants and animals and its environment. Briefly describe the condition of the forest.

B. Regeneration Survey. Using the data you obtained, calculate the number of trees per hectare for each species and age class.

Multiply the total number of trees for each category by 2,500. For example:

Species	*Less than .3 m tall*
Sugar maple	
Beech	

Sugar maple 9 × 2,500 = 22,000 TPH (trees per hectare).

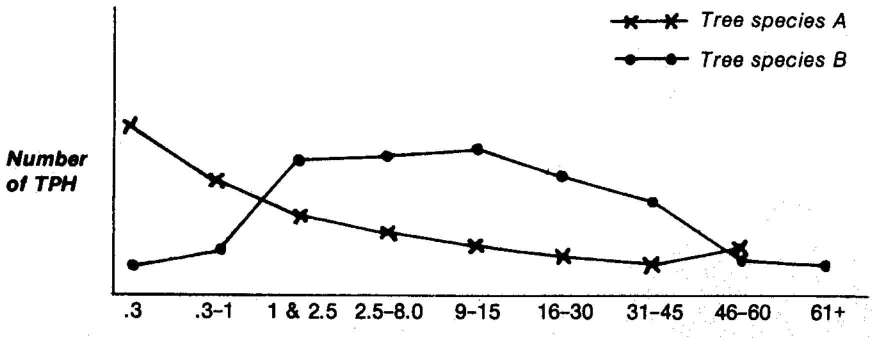
Fill in the following table:

Trees per hectare

Species	*Less than .3 m tall*	*.3 - 1 m tall*	*>1 m & ≤2.5 cm DBH*	*2.5 - 8.0 cm in diameter*	*9 - 15 cm DBH*

Species	*16 - 30 cm DBH*	*31 - 45 cm DBH*	*46 - 60 cm DBH*	*61+ cm DBH*

From the table, make a graph like this one:



Answer the following questions:

- Is there any pattern in size distribution of specific tree species?
- Which tree species are regenerating?
- Which species of trees are of merchantable size?

C. Volume of Merchantable Trees. To determine the volume of wood on the plot, first organize your data according to wood products. Using the Volumes of Wood Products form (p. 23), make a list of the diameter and height dimensions of each tree under each category. Using these dimensions, look up the volume for each tree on the appropriate volume tables in Appendix 3. Add these figures to calculate the total volume of wood for each wood product. Multiply this number by 2.0235 to get the volume of wood per hectare. Use the form to show your volume calculations, and record the total volume of each wood product per hectare.

Firewood volume is measured in cords. A cord is a stack of wood 4 ft (1.46 m) by 4 ft by 8 ft (2.92 m). Traditionally, pulpwood volume has been measured in either cords or cubic feet and the volume of sawlogs measured in board feet. The board foot is equivalent to a plane 1 inch thick and 1 foot square. In the metric system, both of these volumes are measured in cubic meters. Be sure to use the correct metric units of measure in determining volume.

Remember that the final volumes you come up with are estimates. They would be correct only if the whole forest was exactly like the plot you measured. Each tree would also have to be measured with complete accuracy.

Questions to consider:

- Why are volume estimates important?
- Is it important to be accurate with volume estimates? When? Why?
- What causes volume estimates to be inaccurate?

D. Basal Area. *Basal area,* like volume estimates, is a numerical way of describing what the forest is like. Basal area is the total cross-sectional area of trees in the stand (fig. 23). In other words, if every tree on 1 hectare of land was cut off at DBH and you were to look down on it from the sky and measure the area of the hectare occupied by the flat tops of the stumps, you would get the basal area of trees per hectare. Basal area is therefore a general measure of stocking or density. The portion of basal area occupied by each species is a measure of relative dominance for each species.

Volumes of Wood Products

Wood product ____			Wood product ____			Wood product ____		
DBH cm	Height ____	Volume ____	DBH cm	Height ____	Volume ____	DBH cm	Height ____	Volume ____
	Total			Total			Total	
		× 2.0235			× 2.0235			× 2.0235
	Total vol./hectare			**Total vol./hectare**			**Total vol./hectare**	

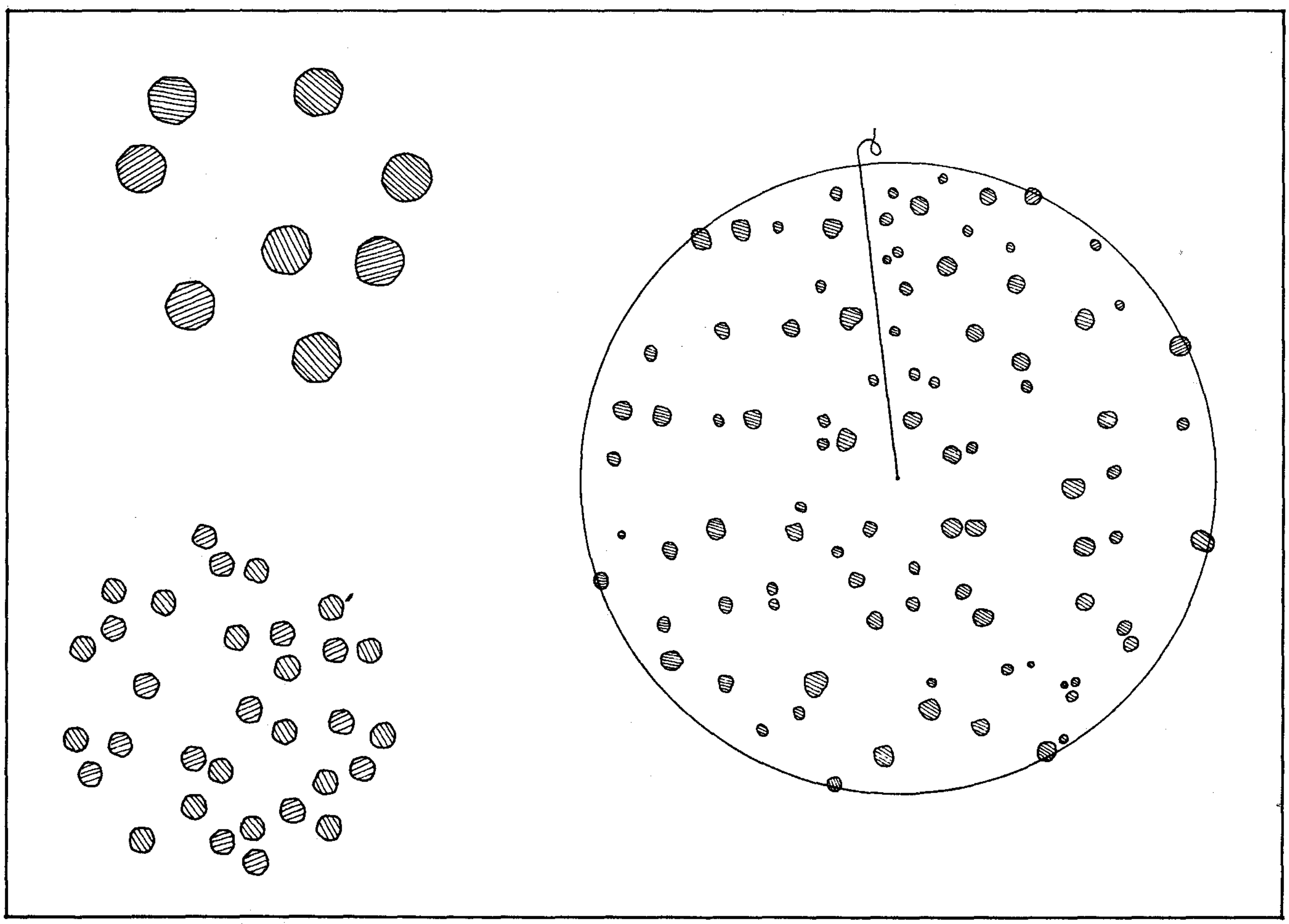


Figure 23. *Basal area includes the total area of the plot covered by trees if they were measured as stumps. As seen on the left, where shaded areas are equal, basal area measures can be misleading.*

Using the Basal Area Calculation form below, calculate the basal area of each species and the total basal area of your forest per hectare as follows:

- First organize a list of the trees you measured on the large plot by species. Record the diameters for each tree. Then use the Basal Area Table in Appendix 3 to calculate the basal area for each tree. Record.
- Add to find the total BA/species. Multiply each of these numbers by 2.0235 to obtain BA/species/hectare. Record these and sum them to find the BA of all trees/hectare.

Basal area calculations are important when planning forest management. It gives the forester an idea of how densely the trees are arranged in the forest. From this information, she or he can determine how much basal area to harvest from a stand to create a favorable environment for desired tree species.

But basal area can be confusing. If the basal area is the only information provided, it does not say anything about the size of trees in the stand. For example, a forest with a basal area of 3.76 m^2/hectare (100 ft^2/acre) may be composed of 62 trees/hectare (152 trees/acre) that are 27.9 cm (11 in) in diameter, or of 116 trees/hectare (287 trees/acre) that are 20.3 cm (8 in) in diameter. More information is provided, therefore, if basal area is accompanied by the average diameter of trees in the stand, called average stand diameter (ASD).

To calculate the ASD for your forest, sum all the diameters of trees measured in the large plot and divide by the total number of trees. Compare this with the basal area of all trees/hectare.

Questions to consider:

- Think back to your stand. Does the ASD really represent your forest? What other information might be useful to include to more accurately describe your forest?
- Explain the value of using an estimate for basal area. Explain some pitfalls of the use of such an estimate.

2. If you measured more than one plot, complete the analysis for each and compare the plots as follows.

Basal Area Calculations

	Species ______		*Species* ______		*Species* ______	
	Diameter (cm)	*BA (m^2)*	*Diameter (cm)*	*BA (m^2)*	*Diameter (cm)*	*BA (cm^2)*
Total	cm	m^2 × 2.0235	cm	m^2 × 2.0235	cm	m^2 × 2.0235
BA/hectare		m^2/ha		m^2/ha		m^2/ha

Total BA of all trees/hectare ______________

Total diameters (cm) ______________

Total number of trees ÷ ______________

Average stand diameter ______________

A. For plots that represent different forest types, such as conifer and hardwood, or that represent different environments, such as ridge, hillside, and valley bottom, compare the estimates of regeneration, volume, and basal area.

- Is there more regeneration in a certain forest type or environment?
- How do volumes differ between plots?
- Do different plots offer different resources? If so, what are they? Why?
- Summarize any other differences or similarities among plots.

B. For plots that represent the same type of forest, calculate average estimates as shown below.

Regeneration Survey: Set up a table showing average trees per hectare, and fill in the average number of trees for each species in each size class. For example:

Plot 1

	Trees per hectare
Size class	*Less than .3 m tall*
Species	
Maple	22,000

Plot 2

	Trees per hectare
Size class	*Less than .3 m tall*
Species	
Maple	25,000

$$\text{Average} = \frac{a + b + c \ldots}{\text{number of plots}}$$

$$= \frac{22{,}000 + 25{,}000}{2}$$

$= 23{,}500$ trees per hectare

Average number of trees per hectare

Size class	*Less than .3 m tall*
Species	
Maple	23,500

Make a graph of regeneration by species as you did before, but use the data from the table showing average trees per hectare.

Volume Estimates: Take the final estimates of total volume per hectare calculated for each wood product and average them. For example:

Plot 1

Sawlogs
0

Pulpwood
108.5 m^3/hectare

Firewood
8.4 cords/hectare

Plot 2

Sawlogs
20.3 m^3/hectare

Pulpwood
79.6 m^3/hectare

Firewood
17.2 cords/hectare

Average

Sawlogs

$$\frac{20.3 + 0}{2} = 10.2 \text{ m}^3\text{/hectare}$$

Pulpwood

$$\frac{108.5 + 79.6}{2} = 94.2 \text{ m}^3\text{/hectare}$$

Firewood

$$\frac{8.4 + 17.2}{2} = 12.8 \text{ cords/hectare}$$

Basal Area: Determine the average basal area per hectare from all plots by adding up BA estimates and dividing by the number of plots. Total the average stand diameter from all plots, and divide by the number of plots. This will give you an estimate of the average diameter of trees in the forest where your plots are located.

By sampling more than one plot and calculating average estimates as above, your final estimate is more representative of the whole forest. Sampling just one plot can give you an inaccurate picture of the total forest because the plot you measure may have certain peculiarities that are not common throughout the forest, or it may be lacking a character that is present in the rest of the forest. By calculating an average estimate from several similar plots, these peculiarities will have less influence on the final estimate, and any character that one plot is lacking most likely will show up on another plot.

3. Consider the dynamics of the forest ecosystem you have just evaluated.

A. How do you think past human history has influenced the forest as it exists now?

B. If you measured a mixed stand of trees, what can be said about each group of species? How are the species mixed? Do they occur in clumps together? Where do different species occur — on ridgetops, valley bottoms, slopes, wet spots, dry spots, other? Which species are intolerants, intermediate tolerants, and tolerants? Where do they occur? In which layer of the forest — understory, upper canopy?

C. Choose the three major species of your forest. Describe how each of these species reproduces, by seeds or by sprouts. How are the seeds dispersed? What are the requirements of each of these species to become established and grow?

D. How have plants, animals, and environmental factors influenced the development of your forest into what it is now?

E. What evidence is there that the forest is not static? How is it changing? Why do certain species and individual trees survive while others die off throughout the growth of the forest?

F. What will the forest be like in the future if allowed to grow without any modifications such as harvesting or fire?

G. What unusual or unexpected things did you see in your forest?

4. What renewable resources exist in this forest?

A. Wildlife resources:
What animals live in the forest now?
What are their requirements for life?
Which requirements are satisfied by this particular forest?

B. Recreation:
What types of recreation exist now in the forest?
Does there exist potential for other recreational activities?
What requirements must be met for these kinds of activities?

C. Water:
How does this forest affect the water cycle?
Does it supply water for direct usage?
How does the forest affect nearby open bodies of water?
Does it affect water temperature and aquatic life?

D. Aesthetics:
Is this forest unique?
Does it offer a view?
Does it have potential for a nature trail?
Should the forest be thinned and/or cleaned to make it more pleasing to the eye?

E. Special Products:
What special products does this forest provide?
Is there any potential to supply other special products?
Could this forest provide Christmas trees?

F. Environmental Improvement:
Is this forest located close to cities, towns, villages?
How does it directly or indirectly affect environmental quality?

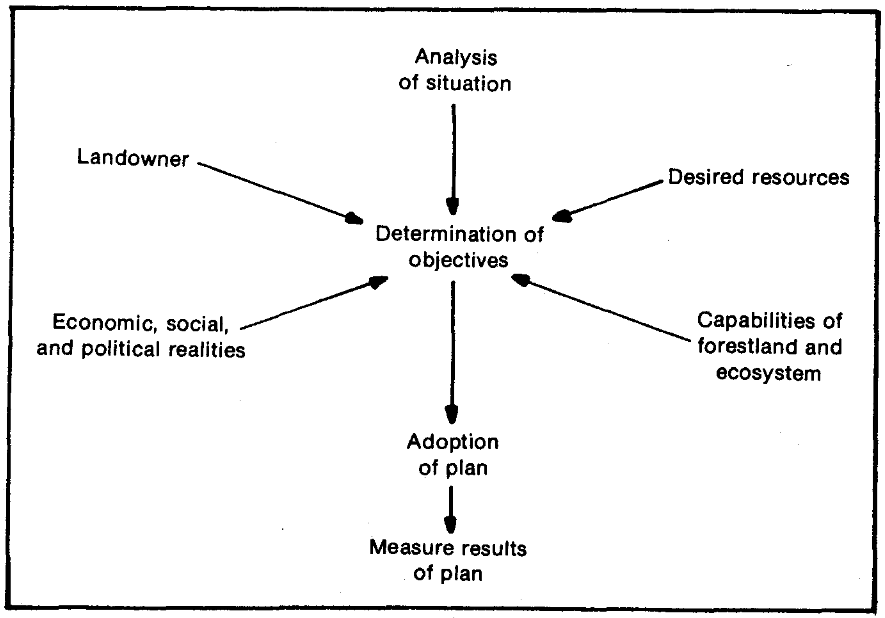
G. Wood Products
Timber —
What valuable timber species exist in this forest for sawlogs and for pulpwood?
Are they of good form?
What is the volume of sawlogs? of pulpwood?
What is the basal area of sawlogs? of pulpwood?
Firewood —
Which species in this forest will make the best firewood?
In which size class are they?
How much basal area do they represent?
Would they be more valuable as sawlogs or pulpwood?
How much volume of firewood exists per hectare on your forest?
Do you wish to produce firewood for sale or just for your own needs?

Forest Management

To survive, humans have always modified their environment in some way to produce what they need. Unfortunately, too many times these changes have been unorganized and have led to deterioration of the world around us. Land management is a more organized way of modifying the environment. Land management is based on a plan that uses scientific knowledge about the ecosystem. It analyzes a situation, agrees on objectives, adopts a plan, and measures the results of the plan (fig. 24).

Forest management is defined by the Society of American Foresters (SAF) as "the application of business methods and technical forestry principles to the operation of a forest property." Forest management works to keep forest land productive and to maintain the *renewability* of the forest resources. Since forest lands can produce a variety of resources, they are usually managed to provide us with more than just one resource. *Multiple use* conflicts arise, however, when certain forest resources are *mutually exclusive* — that is, they cannot be produced at the same time on the same piece of land. The forest manager must weigh the conflicts to determine the best use of the land. This decision demands skill, technical knowledge, responsibility, and open-mindedness. It's not easy, especially when we realize that managers do not know all the answers. The amount of information is vast,

Figure 24. *Flow chart of forest management process.*



and we still have much to learn about ecosystems. The forest ecosystem is much more complex than we realize; we can only know the tip of the vast iceburg of knowledge to be had.

Forest management includes everything from intense management to neglect. If a forest stand is unmanaged or neglected, chance occurrences in nature will shape it. Such a stand might be presumed to be "natural". However, it is probably being influenced indirectly by the actions of people. If it is not a virgin forest, past uses of the land have shaped what the forest is today. Previous harvest or land clearing could affect forest composition and the fertility of the land. Our policy of stopping all fires and controlling flooding also indirectly affects forests today. Fires, floods, and other natural "disasters" have always played a part in the cycles of ecosystems. Also, heavily polluted air from our cities drifts to outlying areas and enters forest ecosystems. The effects may not be noticeable, but in many cases, damage has been documented. For example, some trees in the San Bernadino Mountains close to the Los Angeles basin are unhealthy and are dying because of air pollution. The acid precipitation in the Northeast is affecting forests and even the acidity of lakes in the Adirondack Mountains. This effect, in turn, is causing fish in these lakes to die off. Neglect is sometimes the worst form of management because in doing so we are not aware of how we are indirectly changing the system. Irreversible damages can result if we are not aware of the effects of our actions.

After nonmanagement comes every type of management from low level (such as the removal of diseased trees) to intensive management (as displayed in tree plantations). The intensity of management depends on the management objectives and, in most cases, on how much money is available for management.

Questions to consider:

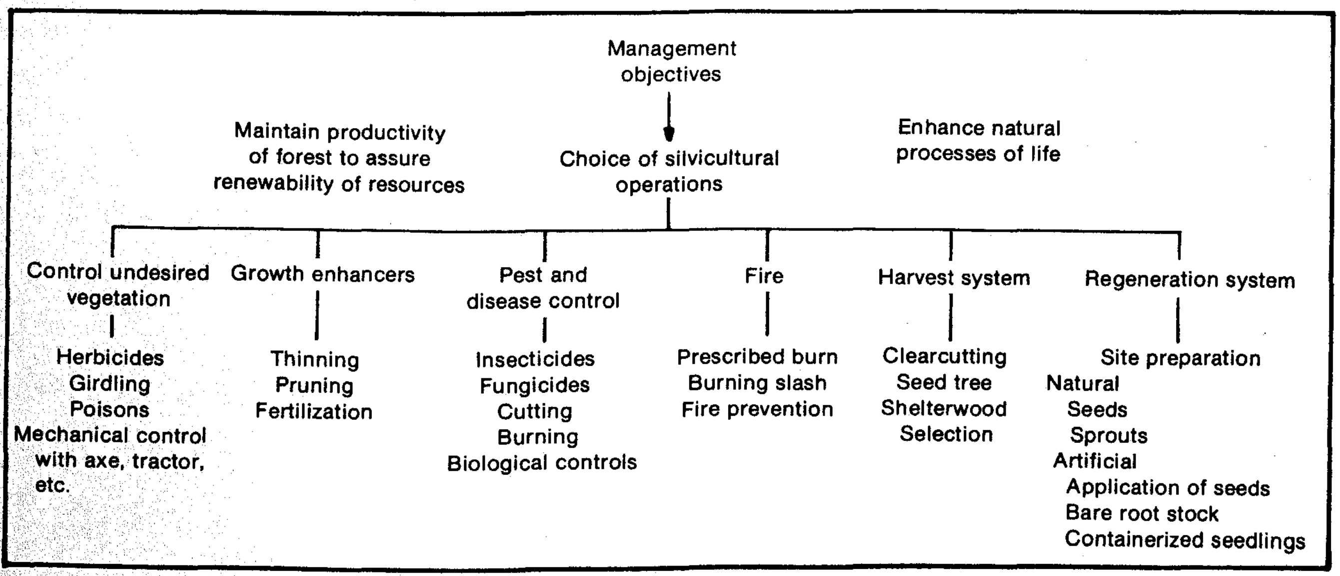
1. Is the forest you inventoried managed? If so, how is it managed? Ask the landowner.
2. If the forest is unmanaged, are there any indirect forces influencing its development? What are they? How are they affecting the forest?

The key to good forest management is to start with a clear idea of the reason for management. Objectives must be set. The objectives vary depending upon (1) what resources are desired from the forest, (2) what the forest land and ecosystem are capable of producing, (3) who owns the land, and (4) what is realistic economically, socially, and politically.

Take, for example, the owner of a woodlot who wishes to establish a red pine plantation for future sawlog production. A study of the plantation site shows that the soil is shallow, poorly drained, and of low fertility. A dense cover of shrubs and alders already is growing on the site. Before even planting the trees, the owner must spend a considerable amount of money to put in drainage ditches, to clear the brush, and to add fertilizer. After all that, pines will probably not grow well in the shallow soil. It would be best for the owner to choose objectives that are more suited to the capabilities of the land and that are affordable. Perhaps the area would be better managed to encourage wildlife. Hunting rights could then be leased for a small fee.

Having set the objectives, the forest manager than chooses the *silvicultural operations* (fig. 25)

Figure 25. *Choice of silvicultural operations.*



that will best meet the objectives but will not destroy the forest's productivity. Silvicultural operations include all the operations that go into developing and managing a forest stand. Questions a forest manager might ask in deciding which operations to use are: How can I manipulate the environment to favor the growth of the desired resources? What are the drawbacks of using these operations? What side effects will they have on the forest ecosystem? Are these methods socially, environmentally, and economically realistic?

Whole textbooks have been devoted to the topic of silviculture. A brief description of only the major silvicultural operations is provided below.

Control of Undesirable Vegetation

Shrubs, trees, and forbs competing with the desired vegetation for sun, nutrients, space, and other requirements should be controlled. Herbicides may be applied to kill or stunt the competing plants. Weed trees often are girdled, that is, a ring of bark is removed completely from the trunk. This cuts off the phloem and does not allow sugars to reach the roots. The tree in most cases dies. Poison can be injected to kill trees or sprouts and is sometimes combined with girdling. Bulldozers equipped with cutters or rakes are often used to destroy competing brush. An axe is a simple but effective tool for controlling undesirable vegetation.

Growth Enhancers

Growth of desired vegetation can be enhanced by thinning, pruning, and fertilizing. These silvicultural techniques are mainly applied to timber stands, although they can aid the production of other forest resources.

The most valuable sawlogs are made from trees that have a straight, branchless trunk and are fairly large in diameter. This good quality tree form can be obtained by thinning to control the spacing between trees. Trees that are closely spaced must put energy into height growth to compete for light. Tall, straight, thin, and small-crowned trees result. Widely spaced trees tend to be shorter, larger in diameter, and have more branches. To encourage diameter growth but still maintain the branchless, straight trunk, these stands should be *thinned* to an ideal spacing (fig. 26). This spacing varies depending upon the species and the age of the trees. After thinning, the trees will grow quickly, but growth slows down as the trees begin to crowd again. The stand is therefore thinned periodically. Poorly formed trees and undesirable species are removed. The remaining well-formed "crop" trees grow faster. Thus, it takes less time to produce wood products, and, in the long run, more usable wood is produced.

The purpose of *pruning* is to produce quality sawlogs free of knots formed by branches. The lower branches of individual trees are periodically removed with a pruning saw. Care must be taken to leave no branch stubs and to avoid injury to the trunk. Otherwise the tree may not heal correctly and rot can occur. No more than one-third of the height of the tree should be pruned at any time. Because pruning costs time and money, usually only the best, high-value trees are pruned. Often the trees in a Christmas tree plantation are pruned, but in a slightly different manner. Here the crown is pruned to give it a full, nicely shaped Christmas tree form.

Fertilizing a forest that is lacking in nutrients will increase tree growth. Although seedlings are sometimes fertilized when first planted, the majority of timberlands in the United States are not fertilized. Fertilization is rather expensive, and it is not clear whether the cost is equal to or exceeds the value of the increased

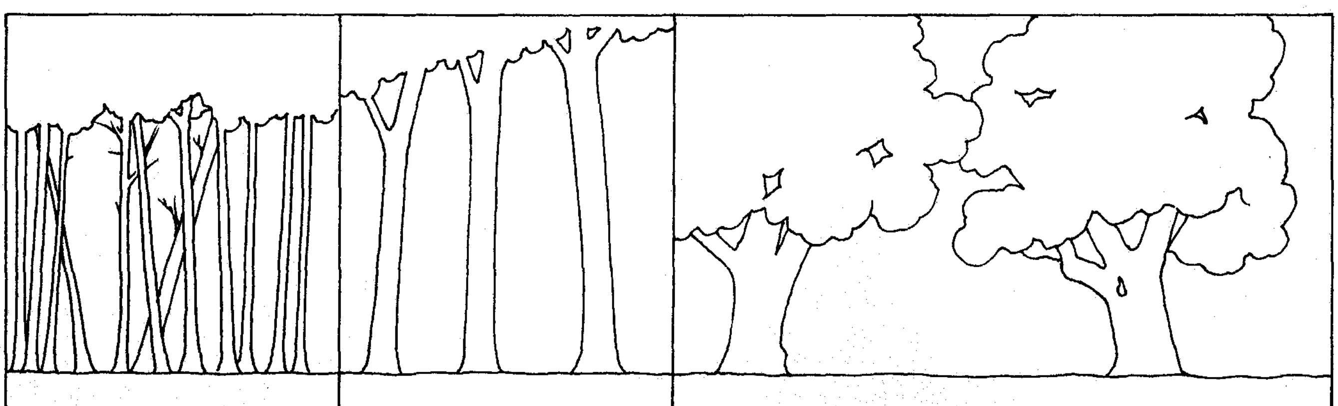


Figure 26. *Thinning can produce an optimum density of trees for good growth and form:* left — *too thick;* middle — *optimum density;* right — *too thin.*

growth. Perhaps an area that requires fertilization to produce timber would be better managed for a different forest resource.

Pest and Disease Control

Fungal diseases and damage by insects or other animals affect trees of all ages from seedling to mature tree. Diseases and pests become a problem that needs control when they cause wide-scale damage to forests or when they prevent the planned establishment of seedlings. Insecticide and fungicide sprays are commonly used for insect and fungal attacks. Epidemics can sometimes be controlled by cutting diseased trees and burning branches and logging residue that may harbor insects or diseases. Animal pests are usually controlled by extermination, by habitat destruction, or by methods to deter them. For example, in areas where regeneration is a problem, seedlings are often scented with unpleasing odors to discourage deer from eating them.

Fungicides and insecticides can create some problems while solving others. Organisms that are beneficial or neutral may be exterminated along with the target pest. The control is sometimes applied after the damage has already been done; it is therefore important to apply the control at the proper time.

Fire

Fire can play either a beneficial or an extremely destructive role in a forest. It has always been a part of the natural ecosystem. Certain organisms even depend on fire to survive. In the past, burns were sometimes frequent enough that the fuel load did not build up. "Cool" fires resulted, which could not burn through the thick bark of older trees. Many of the pine and redwood forests we have today are the result of periodic burns that killed the repeating crops of hardwood understory. Fires are destructive when they burn hot and completely destroy the forest. Repeated hot fires can "bake" the soil and turn a once forested land into a wasteland.

Every year, millions of acres of forested land are destroyed by "hot" wildfires. Forest managers work to prevent and suppress these burns. Because people cause 89 percent of wildfires, public education such as Smokey Bear campaigns are an important part of fire prevention. During periods of high fire danger, forested areas may be closed to public access. Other prevention techniques include building fire breaks and removing fuels in areas of high fire risk. The wildfires that do occur must be suppressed if they threaten to cause heavy damage to forest resources. Large crews of fire fighters are required to control the fire front and to mop up any hot spots after the fire has been contained. Often, air tankers and helicopters carrying flame retardants are used along with the fire crews. Federal, state, and local governments pool money to fight these costly battles. The complex science of firefighting must predict the fire's path and intensity, organize firefighters and equipment, and develop new tools and techniques to fight the fire.

Forest managers have recently been taking more advantage of the beneficial side of fire. In fact, the control or *prescribed burn* is often the easiest, most efficient management tool. Such fires are set in the proper place, under the right weather conditions, and under strict surveillance. Slash and other debris left over from logging can be burned to reduce the amount of fuel available to a wildfire. Seedbed preparation often includes a prescribed burn. Along with reducing weed competition to future seedlings and improving access for planting crews, a burn exposes bare mineral soil which enhances seed germination of certain important tree species. A prescribed burn can help to control undesirable vegetation, perhaps a hardwood understory in a pine forest. Despite their usefulness, prescribed burns can easily get out of control and should be attempted only by persons experienced in control burns.

Harvest Systems

Some forest resources, such as timber and firewood, must be removed or harvested from the forest to be used. Other resources, such as wildlife and recreation, can be maintained in the forest by periodic removal of trees. The method of tree removal is called the harvest system.

Harvest systems can be viewed as imitations of the continual harvest of trees in nature. In nature, insects, fungi, and old age sometimes cause the gradual death of trees scattered throughout the stand. This harvest is balanced by new growth. Natural harvest may also claim large tracts of forested land by windstorm, high intensity fire, or insect infestation. Unless excessive erosion, poor environmental conditions, or other factors interfere, a succession of plants and animals will invade the area and will gradually rebuild the forest. Periodic natural harvest helps maintain diversity and renews the vigor of the forest.

There are four main harvest systems used by people today: *clearcutting, seedtree, shelter-*

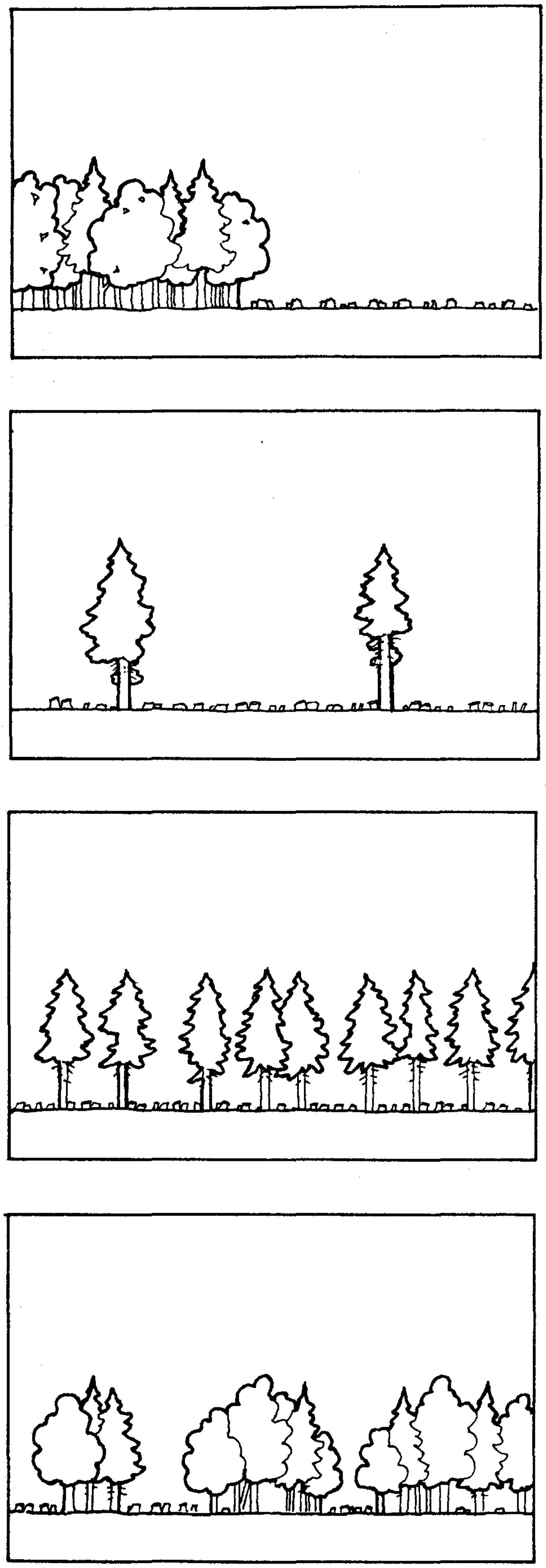


Figure 27. *Schematic diagram of harvest systems.*

Clearcut

Seed tree

Shelterwood

Selection

wood, and *selection* (fig. 27). The system to be used is determined by the desired resource and its requirements for life. To assure the renewability of the resource, a regeneration method is combined with the harvest system. Regeneration is either artificial or natural. *Artificial regeneration* involves planting live seedlings or applying seeds. *Natural regeneration* relies on seeds from the surrounding forest or on sprouts for reproduction of the forest.

Clearcutting System

Clearcutting is best suited for intolerant trees, which require full sunlight for proper growth, or for shallowly rooted trees, which are subject to windfall if scattered individuals are left uncut. In this system, all trees in a block ranging from 4 to 40 hectares (10 - 100 acres) in size are cut. This cutting creates a large opening that many desirable and undesirable plants will invade. Sometimes the clearcut site must be prepared (burned, brush control) or even planted to favor the regeneration of the desired tree species. In responsible forest management, the cut must be followed with planned regeneration.

Other problems are also associated with clearcutting. Cutting large blocks of land on unstable soil can cause serious erosion, as can the presence of the skid trails and improperly constructed roads of any logging operation on such soil. Another problem is that at first clearcut is unsightly, and this causes a negative social reaction. Clearcuts, however, can be shaped with irregular borders and in other than square patterns to blend in with the natural landscape and reduce visual trauma. The site must be tailored correctly to meet the regeneration requirements of the desired tree species. If trees of intermediate tolerance are to be regenerated, the cut must not be too large. Clearcutting definitely is not satisfactory for tolerant trees. Methods of regeneration must also be considered. Planting, of course, poses no problem. However, to take best advantage of natural regeneration, the cut should be planned to coincide with a good seed fall. It should be also located in a good area and be of the right size to allow for seed fall over the whole site.

Although it is a very controversial harvest system, a well-planned clearcut is the most appropriate method of harvest and regeneration of some intolerant species.

Seed Tree System

In this sytem, the area is cut clear except for certain selected trees left standing singly or in groups. Trees of good form are carefully chosen as seed trees to furnish seed to restock the cut. After seedlings have become established, the seed trees may be removed in a second cutting or left indefinitely. The seed tree method of harvest is best suited for trees that develop strong root systems and need abundant sunlight to grow properly.

This system has many of the same disadvantages as clearcutting, to which it is quite similar. The seed trees relieve some of the problems of natural regeneration that occur with clearcutting; however, there is nothing to guarantee that the seed trees will have a good seed crop when desired. Sometimes seed trees are injured in the initial logging, and the removal of the seed trees themselves incurs additional expense and can cause harm to the newly established seedlings.

Of the methods of natural regeneration, however, the seed tree system allows the most control over species and quality of seed source.

Shelterwood System

In this system, a greater number of mature trees are left standing than in the seed tree system. These mature trees provide a seed source and protection for the next regeneration. After seedlings have become established and are well on their way, the mature sheltering trees are harvested. The new seedlings can then make full use of the growing space. The degree of shelter and exposure provided by the shelterwood can be adjusted to meet the environmental requirements of almost all species. Only intolerant species cannot be managed by this system.

The greatest disadvantage of this system is that the new generation of trees is susceptible to injury during the harvest of the shelterwood. Also, they can be in the way during harvest. However, regeneration is more certain and complete than with the previous two systems. There is also more protection of the site and of aesthetics. By creating openings rotated throughout the forest, the shelterwood system provides diversity, which is important for many of the nontimber resources.

Selection System

The selection system is designed to perpetuate a stand of trees varying greatly in age and size from seedling to mature trees. Under this system, individual, scattered mature trees or groups of them are harvested periodically. At the same time, undesirable trees are removed. The small openings created by harvest improve the growing conditions for the remaining trees. Within a few years, new trees are established on the soil disturbed by the logging operation, and other trees are mature and ready for harvest. This system favors trees that grow well in partial shade and is suited for trees with shallow root systems. Mutual protection prevents wind throw and exposure to the elements.

Logging under the selection system is both difficult and expensive. It requires frequent trips to the forest with heavy machinery, which can harm the remaining trees. It is unsuitable for intolerant species.

Of all the harvest systems, the selection system disrupts the forest and the aesthetics the least. It can provide a continuous supply of mature timber from a small tract of land.

Regeneration Methods

Regenerating a forest after harvest is the key to renewability. Removing trees makes extra space, nutrients, water, gases, and energy available to any organism. If left to nature, a succession of organisms will occupy the space. Trees will probably eventually become reestablished there as long as the site suffered no serious degradation. This natural succession may take too long for a forest managed to produce timber, and there is no guarantee that the desired trees will be among those ending up on the site. The forest manager may decide to speed up the establishment of desired species by using an appropriate method of regeneration.

Site preparation is often the first step to regeneration of a harvested area. Vegetation such as brush and grass occupying the site may prohibit or delay the prompt regeneration of trees. Logging debris and slash may physically inhibit the reproduction as well as be a fire hazard. Some forest soils are covered with a thick layer of duff, which prevents many seeds and seedlings from developing because of lack of water or presence of damping-off fungi. Site preparation methods such as prescribed burns and the use of herbicides and heavy machinery can modify these situations appropriately. The exact method used depends on the given ecological situation.

A forest can be regenerated in several ways. Natural methods of reproduction may be relied upon, or artificial measures may be used.

Natural Regeneration

Trees reproduce themselves naturally by seeds. Seed production, however, can be erratic, and not all crops are fertile. The forester cannot always depend on a good seed year to follow a harvest. This form of reproduction does not give complete control over which species will regenerate, over the desired mix and number of species, or over the location of seed fall. It is usually not suitable for intensive timber management.

Many hardwoods and a few conifers form root or stump sprouts that can become mature trees. In some cases, this type of vegetative reproduction, called the coppice system, creates the next forest. Because many sprouts tend to develop, one good sprout per stump is selected after a few years and all others are cut.

Sprouts have the advantage of a developed root system enabling them to grow faster than seedlings. As a result, the coppice system can produce more wood over a given time period than any other system. With age, however, the vitality of the root system decreases, and eventually a completely new forest must be established (fig. 28).

Artificial Regeneration

When natural methods of regeneration are not suitable, artificial means are used. Artificial measures cost more, but in the long run allow the forester more control over forest composition and tree quality. Applying seeds directly and planting tree seedlings are the methods used to artificially regenerate a forest.

The seed, which is usually spread by plane, is collected during years of abundant seed crop from high quality trees. When properly stored, the seed can remain viable for a number of years. Direct seeding, however, is not as common as it used to be. Because of high losses from predation, infection, poor environments, and other factors, large amounts of seeds are required to produce relatively few trees.

The seeds are better used if they are sown in a nursery to produce seedlings. The seedlings are grown in the nursery for a year or two and are then lifted and planted out in the field. Some seedlings are grown in individual tubes and are known as *containerized stock.* Although more expensive to produce than *bare root stock,* the containerized seedlings usually have a better field survival rate (fig. 29). Bare root stock must be planted with great care to prevent the roots from drying out or being damaged. Root damage is avoided with containerized seedlings because the soil around the roots remains intact during planting.

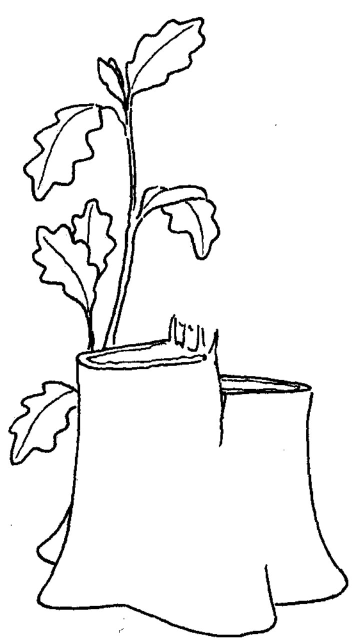


Figure 28. *Regeneration by the coppice system permits development of one robust sprout per stump.*

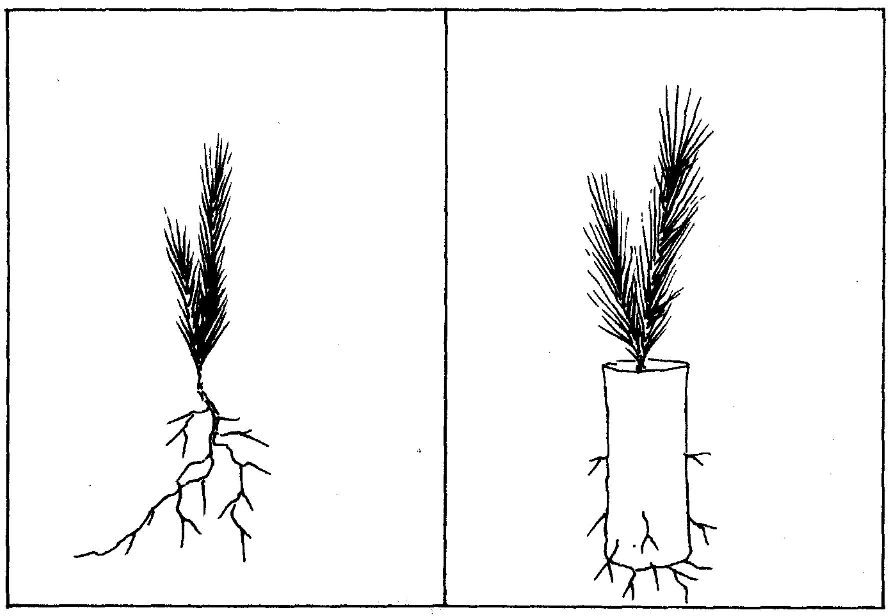


Figure 29. *Bare root and containerized transplanting stock.*

Exercise in Forest Management

This exercise is a followup to the forest inventory. It is designed as a discussion that, ideally, is conducted at the forest site you evaluated. Write up a summary of the main ideas you discuss.

Imagine that you own the land you inventoried. If necessary, imagine that the forest is large enough to be worth managing, and assume that the plots you measured are typical of this expanded forest. As the owner, you have decided to manage your forest. You are wealthy enough to carry out any practices that you desire. Where should you start?

1. Management Philosophy

Develop a management philosophy and a set of management objectives from the following questions.

A. Why do you want to manage your forest?

B. What resources do you desire from your forest? Look at the forest inventory to help you decide.

- What resources already exist in your forest?
- Are there any forest resources you would like that are not currently produced by your forest?
- Is it possible to produce them? (Can their requirements for production be met in your forest?)

For example, you may like to hunt grouse, but grouse are currently not found in the forest. If you were to create openings where aspen and shrubs can become established (to provide food and cover), you could be successful in attracting grouse to your land.

C. If you desire more than one resource from the forest, is their production compatible or mutually exclusive?

D. Do you wish to produce resources to sell? If so, is there a local market for these resources?

E. Are the resources you desire renewable? As a responsible forest owner, how will you assure the renewability of your forest?

F. Forests take a long time to grow, and it may take many years to reap the benefits of management. Do you wish to manage the forest just for yourself? Will you consider future generations?

G. How will your neighbors react to your plans for management? Your community?

2. Forest Management Recommendations

Obviously, you do not have the proper background to come up with a complex management plan. You will instead develop a set of management recommendations. Use your common sense, the knowledge you have gained, and your deductive ability.

Ask yourself:

- What are the requirements of the resources I desire?
- What can I do to enhance the production of the resources I desire?
- How can I provide the necessary requirements?
- What management tools can I use to create an environment that will enhance the desired resource(s)?
- What problems might I encounter, especially if I desire more than one resource?

In planning your recommendations, consider the following information about specific resources.

A. Water

Quality

Water is collected on the land and either runs over or seeps through the soil until it reaches an open body of water. As it passes through the soil, large particles, sediment, and impurities are filtered out of the water. Water that runs over the land may carry rocks, sediment, and debris if it is moving fast enough.

The forest cover and litter layer break the impact of water falling on the land and cause more of it to be filtered through the soil rather than run over the land. Roots also hold the soil in place and help prevent landslides and erosion that often occur on unforested slopes.

Special consideration should be given to how logging operations in the woods will affect water quality. Roads can be a major source of erosion and sedimentation if poorly built and improperly maintained. Doing sloppy logging jobs and skidding logs up streams can also cause erosion. Avoid logging close to open bodies of water, and provide proper bridge crossings for streams. Roads should be properly drained and maintained.

Quantity

Trees and vegetation remove water from the ground through their roots and transpire water through their leaves into the atmosphere. Thus, trees growing along a stream can influence the amount of water in the ground that will seep into streams and springs. Removal of trees can increase the water flow, and the establishment of trees can help to dry out a wet spot.

B. Recreation

Access to the location is important for recreation. If required, roads and parking layouts must be planned to enhance the recreational values. Their construction should cause the least environmental disruption possible (see water quality, above). Trails need to be carefully planned and clearly marked. They must be built properly to handle traffic without causing deterioration of the environment. Steepness and switchbacks should also be considered.

Location of any campsites should be planned to provide a balance of sun and shade, and a nearby water source is needed. Avoid swampy, insect-inhabited areas, and keep heavy camping at least 30 m (100 ft) from the water's edge.

C. Aesthetics
Areas may be cut to provide views. Trails may be built. Decide upon the aesthetic values you desire, and determine how to enhance them.

D. Wildlife
Requirements for cover, food, and habitat vary with different animals. The requirements of larger animals are more difficult to fulfill than those of smaller animals. For example, deer need a larger area and consume more food than birds.

An area of given size can only support a limited number of animals. This limit is called the carrying capacity of the area. If the population of animals goes beyond the carrying capacity, the animals will begin to destroy the area. They can no longer remain healthy, and many die through starvation or disease.

Wildlife can be pests, too, if they occur in large numbers and destroy things of value to people. Management practices such as trapping, hunting, or habitat destruction may be required to alleviate the problem.

E. Wood Products
The many wood products that can be obtained from our forest include sawlogs or timber for construction materials, pulpwood for paper products, firewood, cooperage stock, railroad ties, handle bolts, utility poles, and more. Several tree species may be suitable for producing a specific product, but those species with superior properties are more highly valued. They can be classified accordingly. On page 65 of *Know Your Trees,* species are listed by worth for timber, and *Conservation Circular* 6(1), "Wood for Fuel," compares the fuel values of various species. In managing for a specific wood product, the superior species are favored over the inferior.

The quality of an individual tree affects its value for certain wood products. A tall, straight tree with a clear trunk that branches only at the very top is worth more for sawtimber than a crooked, low-branched, and forked "wolf" tree of the same species. Trees free of rot bring a higher price, as do trees of larger diameter.

The key to successful management for wood products is to create the right growing environment for producing quality trees and to provide for regeneration of desired species. To reproduce quality trees, the life requirements of the desired species should be studied. The forest is then manipulated to produce a favorable environment for best growth of the desired species. Trees that are restricting the growth of good quality trees should be removed. As the crop trees are harvested, the valuable species must be regenerated immediately so as not to lose time between crops. Information on regeneration and life requirements of individual species may be obtained from *Silvics of Forest Trees of the United States,* USDA Forest Service, Agriculture Handbook 271.

Multiple Use

Forests can be managed to produce more than one resource at the same time. The combinations are numerous and depend on the individual situation. Low intensity timber management, for example, can be compatible with management for wildlife, recreation, aesthetics, and water. Brush and other wildlife encouragers can grow in openings created by harvests. These openings can also become camping spots. The thinning of a stand can be combined with clearing a trail for hiking, skiing, and snowshoeing. The views opened up by harvested areas and the openness created by thinning can add to the aesthetic appeal of an area that previously was a "dog's hair" thicket of trees. A forest cover helps maintain water quality. An area that is harvested does not necessarily decrease water quality if the roads and harvest are done with care and if the area is quickly regenerated with trees.

In some areas, certain uses are incompatible. Maple sirup production and timber production are examples of incompatible uses. The best trees for sap production are fully crowned, large trees. Tapping the tree causes the wood to stain. Such trees do not make good sawlogs because they will have too many knots and stained wood. The determined forester can get around the problem of mutually exclusive resources. The forest, if large enough, can be divided into compartments. Each compartment can then be managed intensely to produce one or more compatible resource.

Conclusion

You have gone through the steps of evaluating a forest. A forest should seem different to you now. It is alive, changing, and renewing itself. The many organisms living there depend on each other and the total forest environment to exist. Because it is dynamic, a forest can produce many renewable resources that people depend upon. Through careful planning and management, we can guide it to produce more of those resources we need without destroying its vitality. However, no matter how much forests are studied and used, there will always be a certain quality that cannot be described or measured. It is the magic possessed by a forest that has in the past and will continue in the future to enchant and enrich the lives of us all.

Glossary

aesthetics — visual beauty
allelopaths — chemical substances secreted by roots and toxic to plant species
artificial regeneration — the reestablishment of a forest by planting seedlings or applying seeds
aspect — the direction a particular location is facing; exposure
bare-root stock — seedlings grown in nursery beds and packaged without soil around the roots for planting
basal area — the amount of area occupied by the cross-sectional base of a tree
Biltmore stick — a device used to measure the heights and diameters of trees
blowdown — an uprooted tree that has been blown over by wind
browse — small bushes, sprouts, herbaceous plants, small trees, and other vegetation fed upon by wildlife
canopy — a collective term for the crowns of all the tallest trees in a forest
catface — partly healed fire scar or wound on a tree, usually at the base
clearcutting — the harvesting method in which all the trees in a particular area are cut; usually followed by some form of regeneration
climax forest — a forest maintained over a long period of time by natural forces that does not change in species composition
competition — struggle for survival that occurs between organisms making similar demands on the same environmental resources
containerized stock — seedlings grown in individual containers in nurseries to be planted in the field later
damping-off fungi — fungi that kill germinating seedlings; these fungi often grow in duff on the forest floor
DBH — the diameter of a tree at roughly breast height (4½ feet off the ground). This is a convenient height at which to measure a tree; moreover, many trees have large swells in the stem below this point which would add errors in computing tree volumes
duff — litter, humus, and decaying organic matter that makes up the top layer of the forest floor
edge — a wildlife management term referring to the division between forest cover and open clearings
forest ecosystem — a forest community in which all organisms interact with each other and their environment
forest inventory — a survey of forest land to determine area, condition, timber volume, and species for specific purposes such as timber purchase or forest management or as a basis for forest policies and programs
hardwood — flowering, dicotyledonous trees, usually broadleaved; many are deciduous
horizons — distinct layers of soil as exposed in a pit; they differ in texture, color, composition, and other characteristics
hormone — a substance produced by the organism and transported by blood or fluids to produce a specific effect on the activity of cells remote from its source; plant growth hormones are called auxins
hypothesize — to make an educated guess based on scientific evidence
intolerant — term for a plant that does not grow well in the shade of other plants or trees and requires full sunlight to grow well
metabolism — all the chemical changes that occur in living matter
multiple use — the use of land for more than one product or benefit
mutually exclusive — two or more products or benefits that cannot be produced at the same time or in the same area
mycorrhizal fungi — fungi associated with roots that can benefit roots by increasing the absorption of essential minerals. They in turn absorb food from the roots
natural regeneration — reestablishment of a forest by seeds from neighboring trees transported without human help or by sprouts
overstory — the canopy formed by the tallest trees of a forest
photoperiod — the relative lengths of alternating periods of light and darkness
photosynthesis — the process by which green plants combine water and carbon dioxide to form glucose; oxygen is produced as a by-product
pruning — the cutting off of lower branches of trees to eliminate knots in the new growth or the shearing of a tree to produce a better shaped crown
relief — the elevations or inequalities of land's surface
renewable — able to be produced again
resource — tangible or intangible items of value and use to humans
respiration — the process by which cells consume oxygen and break down glucose to produce energy; carbon dioxide and water are the by-products
saprophytic — living on dead or decaying matter
sawlog — a log of suitable size for sawing into lumber
silvicultural operation — specific manipulations of forests, such as thinning and cuttings, with the purpose of improving growth and maintaining the forest's renewability
silviculture — the culture or tending of trees
site — specific location
slash — tops, branches, defective logs, and other wood debris left over from a logging operation
slope — the slant of land measured as the number of units of

rise or fall over a certain distance
snag — a standing dead tree
softwood — tree that usually bears its seeds in cones, has needlelike leaves that are usually evergreen.
static — showing little change
stratify — to store seeds in a cold, moist environment for a specific period of time
thinning — removal of selected trees in a grove to allow more space for the remaining trees
timber cruising — measuring trees to estimate the volume of valuable wood in a forest
tolerance — the relative capability of a plant to grow in varying amounts of light
tolerant — term for a plant that grows well in the shade of other vegetation
topography — configuration of the land's surface
tree crown — a collective term for the limbs, branches, and leaves of a tree
understory — all those trees in a forest that grow below the canopy
wolf tree — limby, gnarly, broad-trunked tree

Appendix 1. How to Construct and Use a Biltmore Stick

On a stick about the size of a yardstick (at least 82 cm [32.3 in] long), mark with a sharp knife and waterproof ink as shown in figure 30. Follow chart 1 in determining where to make the markings.

On the opposite side of the stick, mark as shown in figure 30. Follow chart 2 in making the marks.

Mark logs with Roman numerals every 5 meters as illustrated.

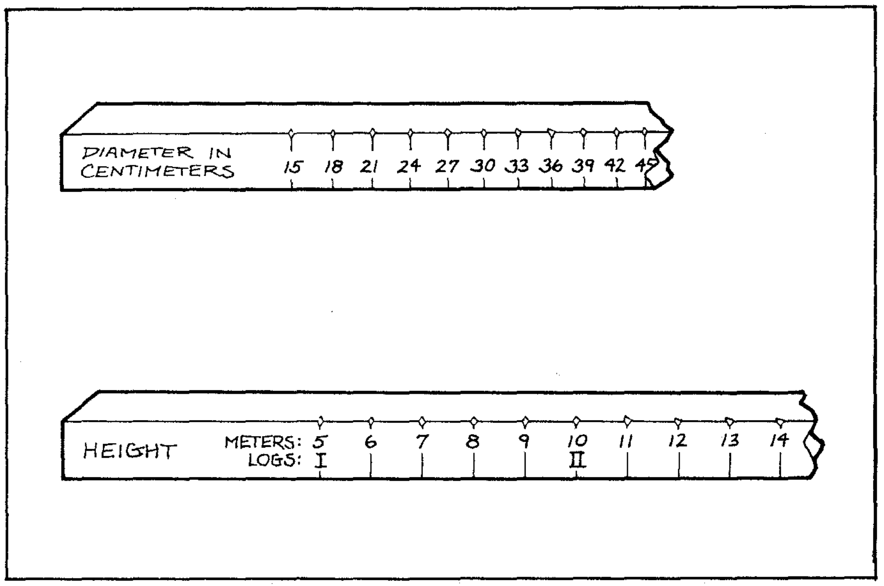


Figure 30. *Biltmore stick design.*

Chart 1.

Diameter of tree in cm	*Distance to mark in cm from zero end of stick*
15	13.46
18	15.85
21	18.15
24	20.38
27	22.54
30	24.63
33	26.66
36	28.63
39	30.56
42	32.43
45	34.25
48	36.04
51	37.78
54	39.48
57	41.14
60	42.77
63	44.37

Chart 2.

Height of tree in meters	*Distance to mark in cm from zero end of stick*
5	15
6	18
7	22
8	25
9	28
10	31
11	34
12	37
13	40
14	43
15	46
16	49
17	52
18	55
19	59
20	62
25	77

Using your Biltmore Stick.

To measure diameter (fig. 31):

1. Diameter is measured at what is called Diameter Breast Height (DBH). This is 1.37 m (4.5 ft) up the trunk from the ground. If the tree you are measuring is on a slope, diameter should be taken at 1.37 m on the uphill side of the tree.
2. Hold the Biltmore stick against the tree, 62 cm (24.4 in) from your eye. (If you make a mark 62 cm from the end on one side of your stick, you can check exactly where to hold the stick.) Make sure the edge of the stick that reads diameter is facing you.
3. Sight past the zero end of the stick and the edge of the tree.
4. Without moving your head, sight to other side of the tree and read the black diameter centimeter nearest to your line of sight.
5. Tree trunks usually are not round. If a trunk is very much out of round, you should measure wide and narrow diameters and take the average.

To measure height (fig. 32):

1. Stand 20.12 m (66 ft) from the tree so that —
   - you are about on a level with the base of the tree. Walk out across slope instead of up or down slope from the tree.
   - the tree is not leaning away from you.
   - you can see the top up to its merchantable height. If you are measuring for sawlogs, the merchantable height is the point where the top is 15 cm in diameter. For pulpwood, merchantable height is to a top 9 cm in diameter; and for firewood, it is an 8-cm top. Practice estimating these top diameters by standing back from a tree with a known diameter of 15, 9, or 8 cm and comparing this to the tops of other trees.
2. Hold the stick vertically 62 cm from your eye.
3. Line up the zero end of the stick with the stump height — the height of the stump if the tree were cut. This is usually not more than .3 m (1 ft) from the ground.
4. Without moving your head or the stick, sight to the merchantable top.
5. The nearest meter or log mark is the merchantable height of the tree.

Practice measuring heights and diameters to develop your skill before recording actual measurements from your plot.

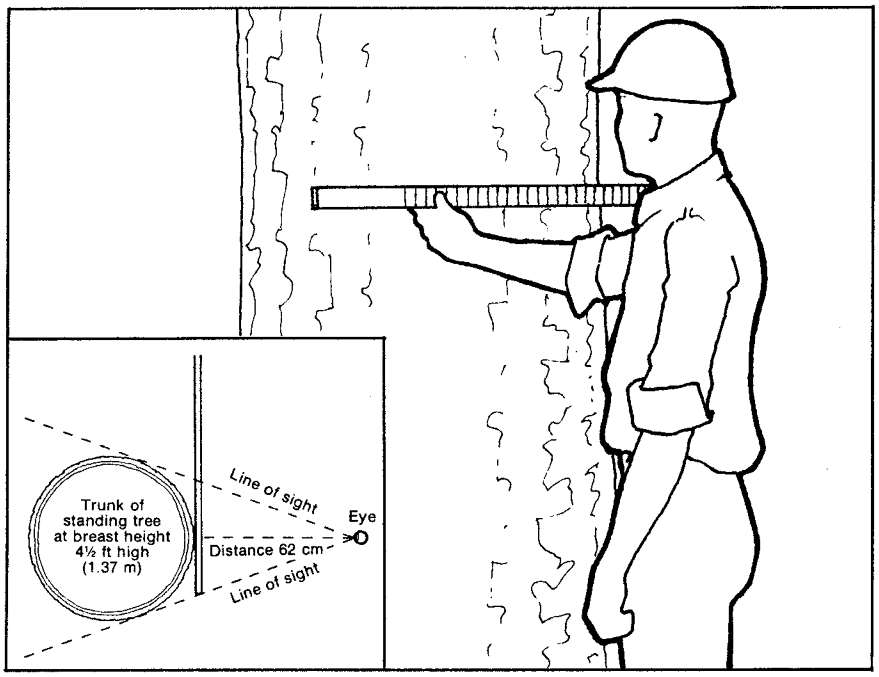


Figure 31. *Using a Biltmore stick to find tree diameter.*

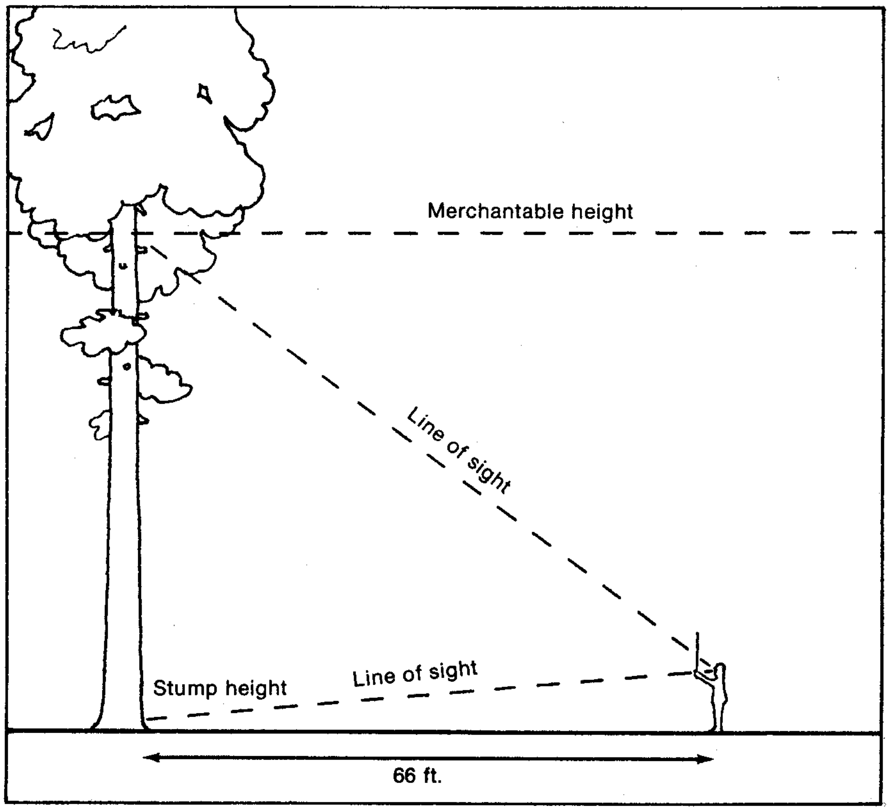


Figure 32. *Measuring tree height with a Biltmore stick.*

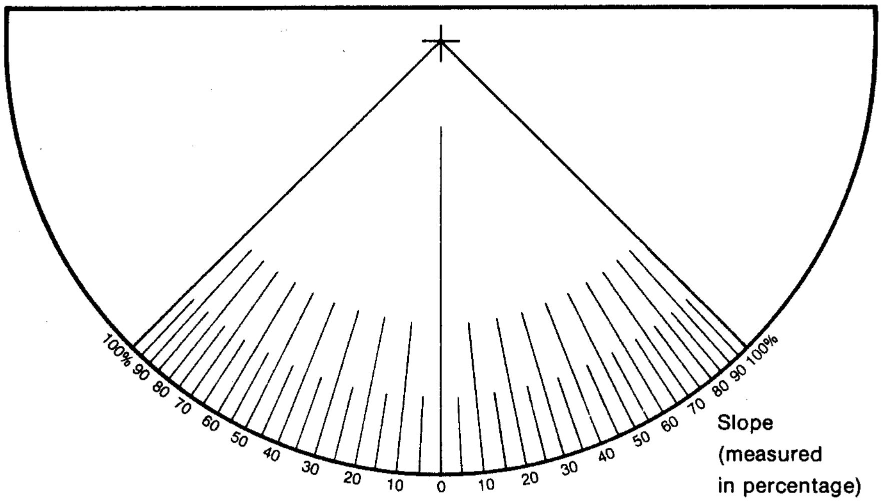


Figure 33. *Clinometer scale for building your clinometer.*

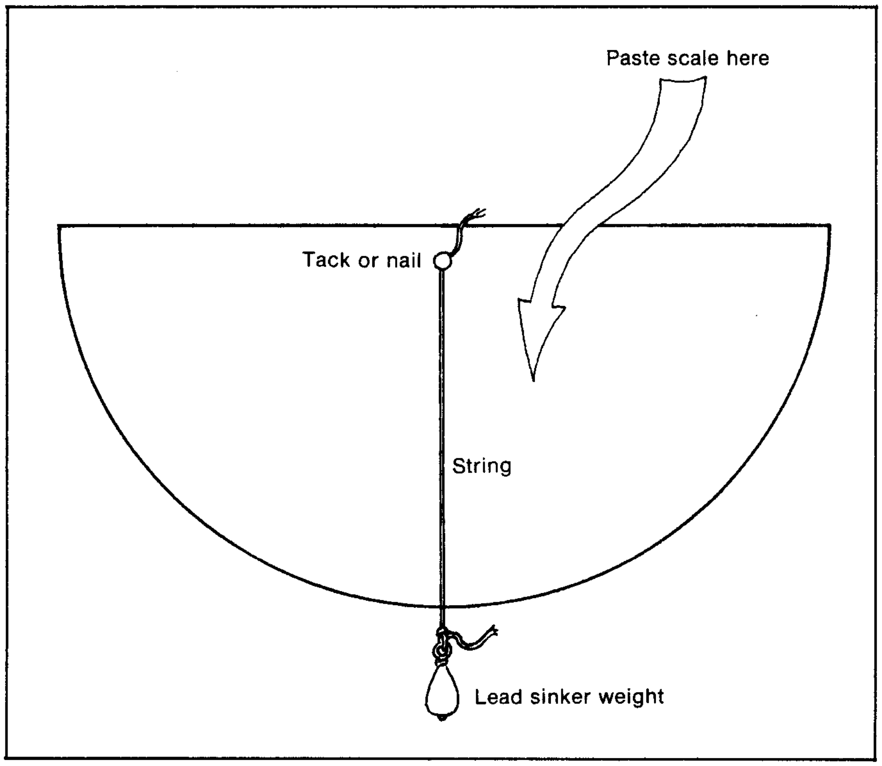


Figure 34. *Diagram of clinometer construction.*

Appendix 2. How to Construct and Use a Clinometer

Glue a traced copy of the scale (fig. 33) on a piece of cardboard or thin wood cut to the same size and shape. Clear varnish or shellac may be applied for protection. Drive a thumb tack or small nail into the center, and to this attach a piece of string with a lead sinker weight on the end (fig. 34).

To measure slope with the clinometer (fig. 35):

1. Face across the slope. Line up the straight edge of the clinometer with the line of the slope of the hillside. Let the string hang freely.
2. Read the mark the string hangs closest to. This reading is the slope measured in percentage. It indicates how many meters the land rises for each hundred meters level.

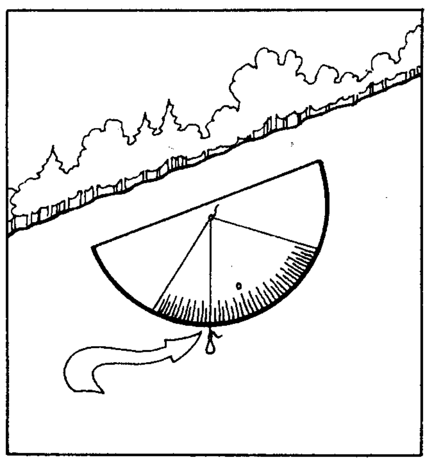


Figure 35. *Using the clinometer to determine slope.*

Appendix 3. Volume Tables

Appendix Table 1. Sawlog volumes in cubic meters

DBH	*Volumes by 5-meter log intervals to a 15-cm top*				
	1 log	*2 logs*	*3 logs*	*4 logs*	*5 logs*
cm					
30	0.26	0.44	0.62	0.79	0.97
33	0.30	0.51	0.73	0.94	1.16
36	0.34	0.60	0.85	1.11	1.37
39	0.38	0.69	0.99	1.29	1.59
42	0.43	0.78	1.14	1.48	1.84
45	0.48	0.88	1.29	1.69	2.10
48	0.54	0.99	1.45	1.92	2.38
51	0.59	1.11	1.63	2.15	2.67
54	0.66	1.24	1.82	2.41	2.99
57	0.72	1.37	2.02	2.67	3.32
60	0.79	1.51	2.23	2.95	3.67
63	0.87	1.66	2.45	3.25	4.04

Adapted from R. D. Hyland. 1977. *Cubic Volume Tables for Second-Growth Northern Hardwoods in New York Including English and Metric Units.* AFRI Research Report 35.

Appendix Table 2. Basal Areas

DBH cm	*BA m^2*	*DBH cm*	*BA m^2*
15	0.02	45	0.16
18	0.03	48	0.18
21	0.03	51	0.20
24	0.05	54	0.23
27	0.06	57	0.26
30	0.07	60	0.28
33	0.09	63	0.31
36	0.10	66	0.34
39	0.12	69	0.37
42	0.14	72	0.41

$BA = 0.00007854\ d^2$

Appendix Table 3. Gross cubic meter volumes for pulpwood

DBH	*Height in meters to a 9-centimeter top*															
	5	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
cm																
15	0.06	0.07	0.08													
18	0.08	0.10	0.11	0.12	0.14	0.15										
21	0.11	0.13	0.14	0.16	0.18	0.20	0.21	0.23	0.25	0.27	0.28					
24	0.13	0.16	0.18	0.20	0.23	0.25	0.27	0.30	0.32	0.34	0.37	0.39	0.41	0.43	0.46	0.48
27	0.17	0.19	0.22	0.25	0.28	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.52	0.54	0.57	0.60
30	0.20	0.24	0.27	0.31	0.34	0.38	0.42	0.45	0.49	0.52	0.56	0.60	0.63	0.67	0.70	0.73
33	0.24	0.28	0.32	0.37	0.41	0.46	0.50	0.54	0.59	0.63	0.67	0.72	0.76	0.80	0.85	0.89
36	0.28	0.33	0.38	0.43	0.49	0.54	0.59	0.64	0.69	0.75	0.80	0.85	0.90	0.95	1.00	1.05
39	0.32	0.38	0.45	0.51	0.57	0.63	0.69	0.75	0.81	0.87	0.93	0.99	1.05	1.11	1.18	1.24
42	0.37	0.44	0.51	0.58	0.65	0.73	0.80	0.87	0.94	1.01	1.08	1.15	1.22	1.29	1.36	1.43
45	0.42	0.51	0.59	0.66	0.75	0.83	0.91	0.99	1.07	1.15	1.23	1.32	1.40	1.48	1.56	2.04
48	0.48	0.57	0.66	0.76	0.85	0.94	1.03	1.13	1.22	1.31	1.40	1.49	1.59	1.68	1.77	1.84
51	0.54	0.64	0.75	0.85	0.96	1.06	1.16	1.28	1.37	1.48	1.58	1.68	1.79	1.89	2.00	2.10

Adapted from R. D. Nyland. 1977. *Cubic Volume Tables for Second-Growth Northern Hardwoods in New York Including English and Metric Units.* AFRI Research Report 35.

Appendix Table 4. Gross volume in rough cords for firewood

	Height in meters to an 8-cm top															
DBH	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
10	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		
13	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03		
15	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05
18	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07
21			0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.11
24					0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.16
27								0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
30								0.14	0.15	0.16	0.18	0.19	0.20	0.21	0.23	0.24
33								0.17	0.18	0.20	0.21	0.22	0.24	0.25	0.27	0.30

Adapted from S. R. Gevorkiantz and L. P. Olsen. 1955. *Composite Volume Tables for Timber and Their Application in the Lake States. U.S.D.A. Tech. Bul. 1104.*

References

Annotated Resource Guide for Forestry Leaders. W. Richberger and R. Howard, Jr. 4-H Leaders' Guide L-5-14. N.Y.S. College of Agriculture and Life Sciences. Distribution Center, 7 Research Park, Cornell University, Ithaca, NY 14850. In press.

Decay Losses in Woodlots. T. C. Weidensaul, C. Leben, and C. W. Ellett. Bulletin 629. Cooperative Extension Service, Ohio State Univ., Extension Office Information, 2120 Fyffe Rd., Columbus, OH 43210. (75¢/copy). 1977. 14 pp.
Provides information for the layperson about the ways disease organisms damage trees and how losses can be minimized. Has many informative photos of disease wounds and general information on tree growth.

Introduction to Forestry. 4th edition. G. W. Sharpe, C. W. Hendee, and S. W. Allen. McGraw-Hill Book Co., New York. 1976. 544 pp.
Easy reading. Gives general overview of forestry in the U.S. Covers history; forests; environments; forest products; forestry practices such as reproduction methods, intermediate operations, and harvest; forest protection; forestry planning and policy; and forestry careers.

Judging Land for Forest Plantations in New York. E. L. Stone, R. Feuer, and H. M. Wilson. Extension Bulletin 1075. Dept. of Natural Resources, N.Y.S. College of Agriculture and Life Sciences, Cornell Univ., Ithaca, NY 14853. 1970. 16 pp.
Describes a method of judging land to determine if it is suitable for plantations of conifers and hardwoods. Outlines how to describe the soil, how to judge the site conditions, and how to improve the land. Includes a checklist for organizing and conducting a land-judging school for 4-H clubs and adult groups.

Know Your Trees. J. A. Cope and F. E. Winch, Jr. Bulletin J85. N.Y.S. College of Agriculture and Life Sciences, Distribution Center, 7 Research Park, Cornell University, Ithaca, NY 14850. 1974. 72 pp.
This Cornell 4-H bulletin is an identification guide to the common native trees of New York. Has winter and summer identification keys and information about each species.

The Life of the Forest. J. McCormick. Published in cooperation with World Book Encyclopedia, McGraw-Hill, New York. 1966. 232 pp.
Well written; easy to read and understand by all audiences. Gives a good background on forest ecology with an excellent section on seasonal changes. Includes a discussion of national parks and forests.

The Living Forest. J. McCormick. American Museum of Natural History. Harper and Brothers, New York. 1959. 127 pp.
Easy-to-read, well-written book for general audiences. Discusses forest insects and diseases, weather, forest types of North America, and human use of the forest. Does not cover forest ecology completely, but does give a good background on those topics mentioned.

Managing Small Woodlands for Wildlife. Information Bulletin 157. N.Y.S. College of Agriculture and Life Sciences, Distribution Center, 7 Research Park, Cornell University, Ithaca, NY 14850.
Focuses on how to combine a wildlife management strategy with other woodland uses, such as recreation and production of timber, sirup, and Christmas trees.

Woodland Ecology. L. S. Minckler. Syracuse Univ. Press, Syracuse, NY. 1975. 229 pp.
Discusses woodlot ownership in relation to forest ecology, management, and multiple use. Stresses environmental forestry for the owners of small woodlots. Enjoyable, easy reading.

Forestry Organizations and Information Groups

American Forestry Association
1319 18th St., N.W.
Washington, D.C. 20036

American Forest Institute
1619 Massachusetts Ave., N.W.
Washington, D.C. 20036

Extension Forester
Extension Service — USDA
Washington, D.C. 20250

National Forest Products Association
1619 Massachusetts Ave., N.W.
Washington, D.C. 20036

New York Forest Information Group
P.O. Box 69
Old Forge, NY 13420

New York State Department of Environmental Conservation
50 Wolf Rd.
Albany, NY 12233

Office of Information
Forest Service — USDA
Washington, D.C. 20250

Society of American Foresters
Wild Acres
5400 Grosvenor Lane
Bethesda, MD 20014

Southern Forest Institute
3395 Northeast Expressway
Atlanta, GA 30341

Headquarters Addresses for Ten Major Forest Products Companies in the U.S.

Boise Cascade
1 Jefferson Square
Boise, ID 83728

Champion International
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Stamford, CT 06921

Crown Zellerbach
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San Francisco, CA 94119

Georgia-Pacific
900 S. W. Fifth Ave.
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Weyerhaeuser Co.
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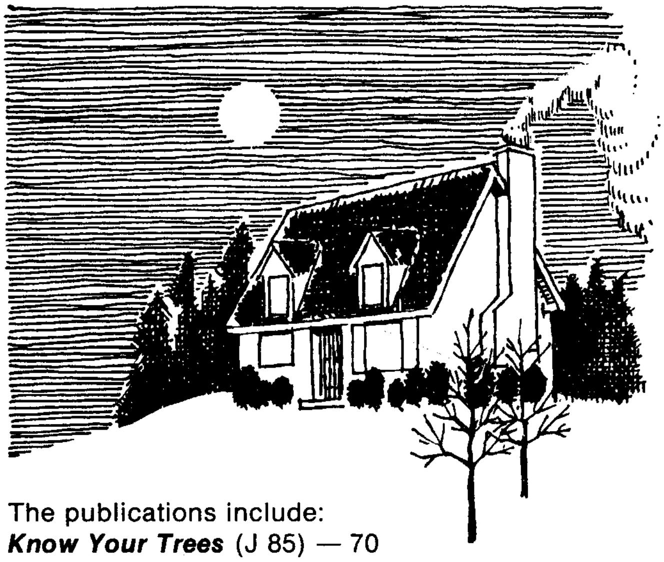
Tacoma, WA 98401



Several other publications and audiovisuals on forestry and forest management are available to you. They have been prepared by resource people in Cooperative Extension and the Colleges of Agriculture and Life Sciences and Human Ecology at Cornell University.

The publications include:
Know Your Trees (J 85) — 70 pages of drawings and descriptions to help you identify tree species.
Managing Small Woodlands for Wildlife (IB 157) — focuses on how to combine a wildlife management strategy with other woodland uses, such as recreation and production of timber, sirup, and Christmas trees.
Sugar Bush Management (IB 110) — how to plan, establish, and manage a stand of sugar maples for sirup production.
Production of Maple Sirup and Other Maple Products (IB 95) — how to manage the sugar bush, tap for sap, and make sirup and other maple products. Includes checklist for commercial maple operation.
Firewood: From Woodlot to **Woodpile** (L-5-12) — discusses tools and skills needed to cut, haul, and store your own firewood safely and efficiently.
Burning Wood (NE 191) — gives information on wood supply and storage; compares types of fireplaces, heating units, wood burning stoves, pipes, and chimneys.
The Warmth of Woodfires (IB 150) — tips on selecting and storing wood, and on care and use of wood stoves; advice and recipes for cooking on wood stoves.
Christmas Tree Production and Marketing (IB 103) — outlines the total business, including planting, fertilizing, pruning and shaping, and harvesting Christmas trees.
Shaping Christmas Trees for Quality (IB 81) — answers all your questions on shaping spruces, firs, pines, and Scotch pines for quality and beauty.

These publications and others on forestry, conservation, and other topics may be obtained for a nominal charge. Ask for a free copy of the KNOW HOW catalog, showing prices and availability, from:

Distribution Center
7 Research Park
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Ithaca, New York 14850

Films about the forest and land are also available. Titles include
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