GEORGIA ENVIROTHON FORESTRY STUDY MATERIALS

Forestry Guidelines

1. Know typical forest structure: canopy, understory, ground layers and crown classes.

2. Understand forest ecology concepts such as the relationship between soil and forest types, tree communities, and primary and secondary succession.

3. Identify the abiotic and biotic factors in a forest ecosystem, and understand how these factors affect tree growth and forest development. Consider factors such as climate, insects, microorganisms, and wildlife.

4. Understand the term silviculture, and be able to explain the uses of the following silviculture techniques: even-aged management, uneven-aged management, thinning, prescribed burning, single tree and group tree selection, shelterwood cutting, clear-cutting with and without seed trees, and coppice management.

5. Understand how the following issues are affected by forest health and management: biodiversity, forest fragmentation, forest health, air quality, aesthetics, fire, global warming and recreation.

6. Understand how economic, social and ecological factors influence forest management decisions.

7. Understand the importance and value of trees in urban and community settings, and know the factors affecting their health and survival.

8. Understand the economic value of forests and know many of the products they provide to people and society.

9. Explain the "Ecosystem Services" provided by trees, and understand why trees and forests are important to human health, recreation, wildlife, and watershed quality.

10. Understand basic tree physiology and function including photosynthesis basics, tree growth, fall leaf change, nutrient and water movement, mycorrhizal relationships, shade tolerance, and nutrient needs.

Skills to Know- Forestry

1. Be able to identify trees in the field, with preserved leaves, or with leaf images. Trees to identify will come from the specimen list. A list of scientific names will be available but will not be matched with the common name, so students should be familiar enough with scientific names to find them on a list.
2. Be able to use a dichotomous key to identify trees not included on the specimen list
3. Be able to use the following forestry tools properly: Clinometer(for height), D-tape, Measuring tape, 10 basal area prism, tree volume scale, increment borer
4. Be able to age a tree, compare dated events to rings, and differentiate basic tissues using a tree "cookie"
5. Be able to estimate timber volume for a given set of trees
6. Be able to calculate basal area.
7. Be able to recommend suitable tree species to fit urban forestry situations.

Specimen list- Forestry
All trees should be learned by leaves. If an asterisk(*) is present, learn the nut/fruit/cone. If a pound sign(#) is present know the bark.

Oaks:
White, *
Post,
Swamp Chestnut,
Sawtooth,
Live,
Laurel,
Blackjack,
N. Red,
S. Red, *
Scarlet,
Shumard,
Water*

Pines:
White, *
Shortleaf,
Virginia, *
Pitch,
Loblolly,
Longleaf, *#
Slash#

Hickories:
Pignut, *
Mockernut,*
Water,
Bitternut

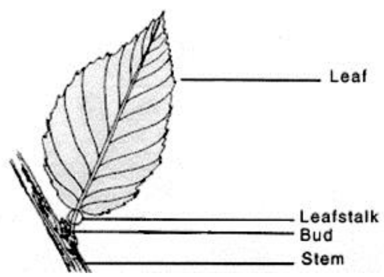
Flowering dogwood, #
Eastern Redbud,
Black Cherry, #
Tulip Poplar,
American Beech, #
White basswood,
Red Mulberry,
Sassafras,
Black Walnut,*
Pecan, *
Black Locust,
Green Ash,
Yellow Buckeye,
River Birch, #
Red Maple,
Southern Magnolia,
Sweetbay Magnolia,
Sweetgum,
Black Gum,
Bald Cypress, #
Eastern Hemlock,*
Eastern Red Cedar,
Leyland Cypress,
Bradford Pear,
American Holly,
Rhododendron,
Persimmon, *
Sourwood
American Sycamore

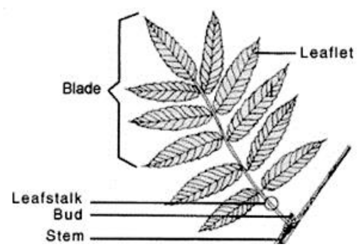
Leaves

There are three main parts to a leaf:

- The base which is the point at which the leaf is joined to the stem.
- The stalk or petiole is the thin section joining the base to the lamina - it is generally cylindrical or semicircular in form.
- The lamina or leaf blade is the wide part of the leaf

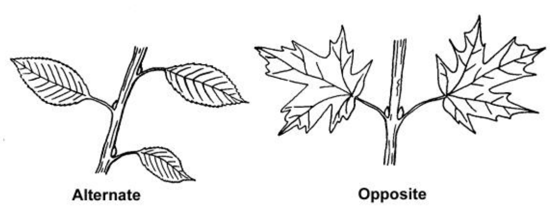
Leaves can be of many different shapes:
Primarily, leaves are divided into simple - a single leaf blade with a bud at the base of the leafstem; or compound - a leaf with more than one blade. All blades are attached to a single leafstem. Where the leafstem attaches to the twig there is a bud.



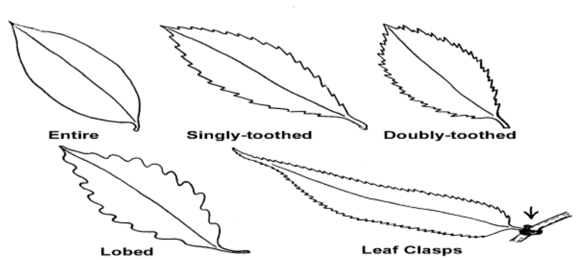


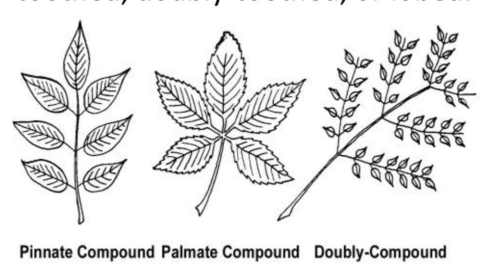
Simple Leaf Compound leaf

Leaves may be arranged on the stem either in an alternate arrangement - leaves that are staggered or not placed directly across from each other on the twig; or in an opposite arrangement - 2 or 3 leaves that are directly across from each other on the same twig.



The margin (the edge of a leaf) may be entire, singly-toothed, doubly-toothed, or lobed.



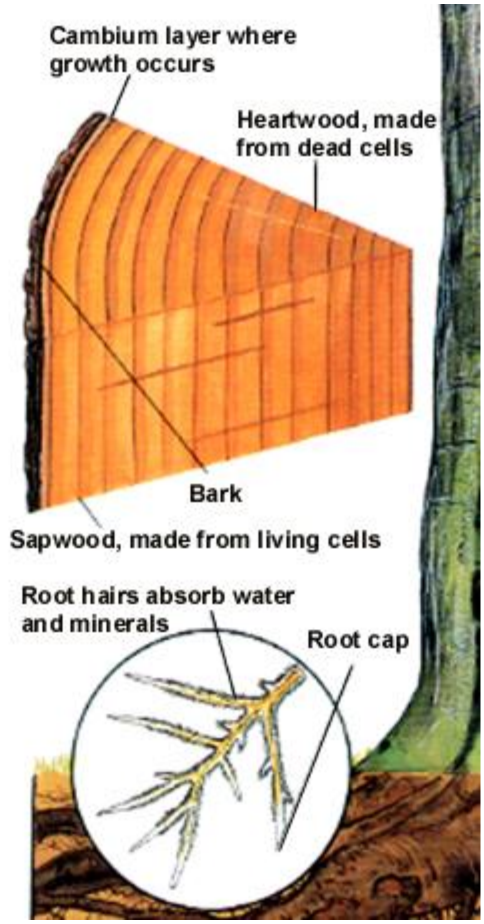


Simple Leaves - Margin Structure Compound leaf types

Compound leaves may be palmate - having the leaflets arranged round a single point like fingers on the palm of a hand; or pinnate - when the leaves are joined on the two sides of the stalk, like the vanes of a feather.
(Leaf diagrams adapted from Fifty Trees of Indiana, Purdue University, Department of Forestry and Conservation)

Tree Growth

Trees grow in two ways. In a young shoot, bundles of cells form. These are a primary kind of wood known as provascular tissue. As the shoot grows a layer of cambium forms across and between the primary bundles where cells divide and grow each year. As the cambium divides, wood and bark cells form. Cells pushed outward form the bark which eventually splits and falls off and is replaced. A tree's upward growth occurs at the tip of each twig.



The inward growth of the cambium forms the main part of the trunk and is called xylem. Tiny tubes which transport water and minerals from the roots up the trunk and branches to the leaves make up the xylem. Leaves need this water to help them make food from sunlight. The outward growth is protected by a layer of phloem. The phloem is made up of tiny tubes that transport the sugars from the leaves to the rest of the tree. If the phloem is damaged the tree will die.

Roots may not go down deep but they can spread outward as far as the tree is tall. Roots anchor trees to the soil and absorb water and soil minerals needed for growth. Some trees have deep tap roots; others have a spreading system of roots.

In some trees a difference in color exists between the outer part of the wood,(sapwood), and the inner part, the heartwood. The sapwood is the light part of the wood as seen in cross section. It is the most recently formed wood, the circle farthest from the central cylinder. Sapwood is the physiologically active part of the wood through which the sap rises and has a high level of humidity. Thus, it is susceptible to rot and vulnerable to attack by fungi and insects.

The heartwood is the part of the trunk nearest the center, the older part, which makes up the greater part of the trunk. Roots as they push through the soil are aided by a cap that forms over the tender growing point of each root. Beyond this point, myriads of root hairs extend into the soil, increasing the surface area of the root and increasing the amount of water the tree can take up.

How Plants Get Water and Nutrients (http://www.dummies.com/how-to/content/how-plants-get-water-and-nutrients.html)

Plants absorb nutrients and water through their roots, but photosynthesis — the process by which plants create their fuel — occurs in the leaves. Therefore, plants need to get fluids and nutrients from the ground up through their stems to their parts that are above ground level.

Just as animals, plants also contain vascular tissues (xylem), which transports water and minerals up from the roots to the leaves, and phloem, which transports sugar molecules, amino acids, and hormones both up and down through the plant.
The leaves of plants also contain veins, through which nutrients and hormones travel to reach the cells throughout the leaf. Veins are easy to see some leaves (a maple tree, for instance). In some plants the veins are hard to see, but they're in there.
Sap is the mix of water and minerals that move through the xylem. Carbohydrates move through the phloem. There are several different "modes of transportation" through the xylem and phloem; their main function is to keep all cells of the plant hydrated and nourished.
Inside the cells of the root, there is a higher concentration of minerals than there is in the soil surrounding the plant. This creates root pressure, which forces water up out of the root through the xylem as more water and minerals are "pulled" into the root from the soil. This force results in guttation, which is the formation of tiny droplets on the ends of leaves or grass early in the morning.
The reason the droplets are seen in the morning is because transpiration — the loss of water from leaves — doesn't occur at night, so the pressure builds until morning. Those droplets are not just water, they're sap. And, those sap droplets are proof that water and minerals get pulled up from the soil and transported through the entire plant.

Trees and mycorrhizal relationships (from http://homeguides.sfgate.com/)

Mycorrhiza means "fungus root."
The importance of fungal activity in relation to tree growth is largely overlooked. People are sometimes disturbed when they see the fruiting bodies of such fungi, because there are often negative implications to seeing mushrooms in the landscape. Mushrooms may be a sign of overly acid soils or rot in tree roots. However, the mycorrhiza fungus performs essential functions in the soils, and they form symbiotic relationships with trees through the tree's root system. Some mycorrhizae penetrate the roots and some simply surround the root tissue. It's estimated that more than 80 percent of higher plant species develop symbiotic relationships with mycorrhizal fungi.

Benefits to the Tree

Because the relationship between trees and mycorrhizae is symbiotic, both the tree and the fungi extract some benefit. Mycorrhizae are more effective than tree roots at accumulating water and nutrients, and can store excess nutrients, releasing them to the tree as needed. The fungi also inhibit invasion by damaging fungi, and extend the life to root tips. Mycorrhizae release acids that break down substances that the plant cannot use without this help, and fix nitrogen from both the soils and atmosphere so that it is more available to the tree. Mycorrhizal fungi produce hormones that encourage the production of new root tips, which aids both the tree and the fungi.

Benefits to the Mycorrhiza

The symbiotic relationship between mycorrhizae and trees benefits the fungi as well. Fungi cannot manufacture their own food due to lack of chlorophyll, a process that converts sunlight to energy used for producing sugars. Therefore, fungi must get this food from chlorophyll-producing plants. They do so by either penetrating the plant roots or forming a sheath around the root tips. This energy allows the fungi to reproduce and form large networks within the soils.

Mycorrhiza and Intertree Interaction

Because the network of mycorrhizal fungi is often vast, trees may often form a network of interlocking root/fungi pathways that connect trees to each other. Professor Suzanne Simard of the University of British Columbia identified the "mother tree" concept, which suggests that the largest trees of the forest, or the mother trees, infect the new seedlings with mycorrhizae, providing a highway by which the mother tree can provide the seedling the nutrients it needs to survive. Trees under stress may receive carbon through underground pathways from nearby trees not experiencing stress.

Dendrochronology: Investigating the recent past

(the following text is prepared by Ms. Chris Marion. © C. Marion 2005)

Dendron (tree) + Chronos (time) = Dendrochronology: The use of tree rings as time markers
Dendrochronology can be a very powerful tool in answering ecological questions about the recent past. It also has applications in archaeology, geomorphology, forestry, climatology, and even law.

1) Introduction to wood anatomy and tree ring formation

Wood, or secondary xylem, is laid down in trees during the growing season to the inside of the cambium layer, accounting for lateral growth of trees. A tree ring is composed of two (more or less distinct) bands of cells (figure 1). The earlywood, the light-coloured band, is laid down in the spring and early summer, when water availability is highest. The xylem cells produced by the cambium are then rather large in diameter, and have thin walls. Latewood is produced later on in the summer and in the early fall. Latewood cells are somewhat smaller than the early wood cells, and have a much thicker cell wall and much smaller lumen, accounting for the darker color of the latewood. At the end of the growing season, wood production shuts down until the following spring, when large, thin-walled cells are again produced by the cambium, making a very sharp contrast with the previous year's dark, tight latewood (at least in conifers!) (Figure 2). Water availability and warmth of the growing season are the two main factors affecting tree ring width. A wet, warm season will lead to the formation of wide, light-colored bands in most boreal evergreen trees, with ring width generally increasing with the length of the favorable growing season. Dry or cold summers will result in narrower rings. Although the trees' response to growing conditions is species-specific and also depends on other factors such as nutrient and light availability, the previous generalizations usually apply to most boreal conifer species.

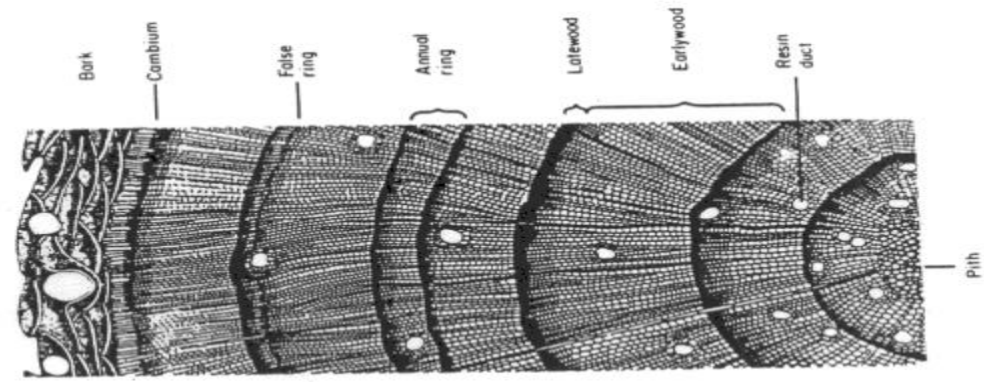


Figure 1. Cross-section of a young conifer stem showing wood structure. (From Fritts, 1979.)

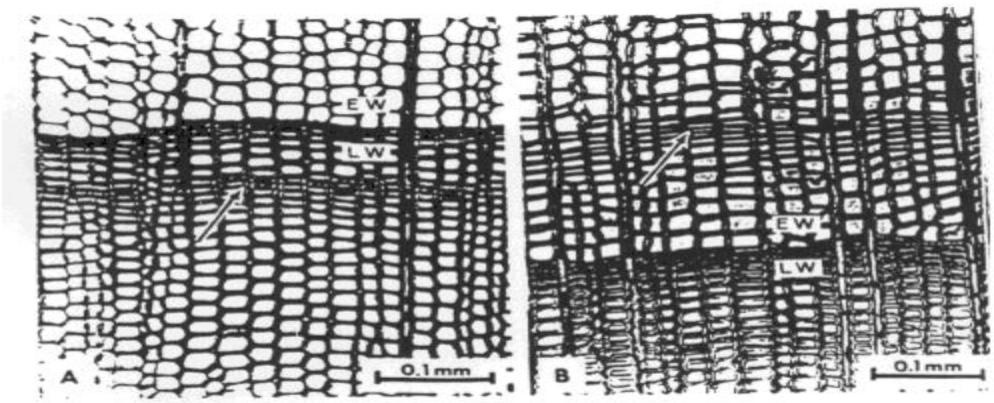


Figure 2. Annual growth rings showing earlywood (EW), latewood (LW) and false rings (arrows). (From Fritts, 1979.)

Deciduous species are more difficult to work with as the latewood is not much different form the early wood, and observation of the cells themselves is sometimes the only way to distinguish the annual rings.

Many events will happen in the life of a tree which may be recorded in its wood either at the cellular level or as more obvious scars or deformations in the tree itself. Frost, insect epidemics, and droughts are a few examples of events that will be recorded in the rings at the precise year (or series of years) at which they occurred. Fire and other cambium-destroying accidents will stop the production of wood where the cambium was damaged, leaving a scar that might eventually close with time; this scar can also be dated. Cutting down a tree will stop lateral growth altogether and tell us the year the tree was felled. Tree death by flooding, burying, or uprooting can also be dated.

2) Sampling, preparation, and dating of wood material

Sampling of the trees can be done in a few ways. It is possible to obtain cores from trees using an increment borer; this type of sampling does not kill the tree, but can be difficult if the trees are rotten. Careful crossdating of the samples collected this way is necessary, because very narrow or incomplete/missing rings may be missed since the cores represent only a small fraction of the trees' cross-section. Taking a tree disk (or 'cookie') is destructive but tree disks are the best samples as incomplete rings can be detected, narrow rings can sometimes be seen

better somewhere else around the stem, and patches of rot can be avoided when dating the disk. Scar such as fire scars are almost impossible to date without a disk.
Back in the lab, wood samples must be dried, and then sanded carefully to make dating more easily. Dating live trees is very straightforward: the last year laid down is the current year's wood production. Counting back from the outside ring towards the inside of the disk will give an approximate age for the tree. (Trees are very rarely sampled at the root collar; therefore a few too many rings may be missing from the beginning of a tree's life. Sampling as close to the ground as possible helps avoid underestimating the age of a tree.) Counting from the inside out towards a scar will then allow dating of the scar. Dead trees can be cross-dated with live trees to allow for age determination; cross-dating is discussed in section 4 (skeleton plots).
The code illustrated in figure 3 is very useful in keeping track of the number of rings counted. Pencil marks are recommended over pinprick as they can be erased should a dating mistake be detected.

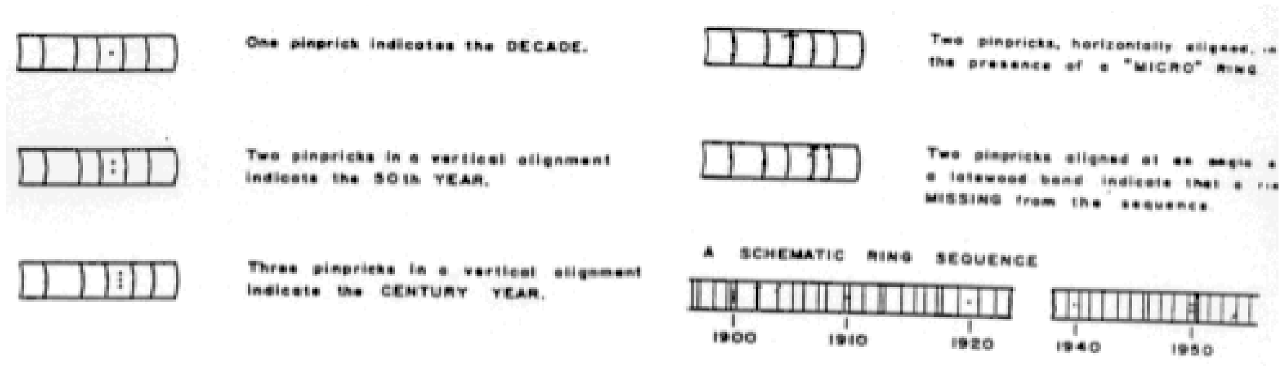


Figure 3. Keeping track of time using pencil marks on the rings. (From Stokes and Smiley 1968.)

3) Marker years

While most tree rings look more or less the same, some rings known as marker rings (or pointer years) may be conspicuously different from their neighbors. Such rings are useful for cross-dating; some of them even speak of localized or widespread disturbance events that are of interest to ecologists.

a) Frost rings- Frost rings are caused by late-spring or early-fall frost events. The cambium is affected by the cold, and a few layers of abnormal cells are produced before the cambium resumes its organized cell divisions. Frost rings appear as a band of darker, disorganized cells within a regular ring.

b) False rings and light rings - False rings happen when for a short period during the growing season, growing conditions resemble that of the end of the season, for example when drier and colder conditions prevail for several days. A few layers of thick-walled cells are formed, and they have the appearance of latewood. A close inspection of the suspicious ring will reveal that, although cell walls are thicker, cell size has not really decreased and the return to thinner-walled cells is progressive, not sharp like it would be if spring had just returned (see figure 2 for two examples of false rings).
Light rings, on the other hand, show minimal formation of latewood. A light ring may be hard to detect as the band of latewood can be very thin, very light, or even non-existent.

c) Incomplete/locally absent rings- Some tree species, for example larch, are notorious for having incomplete or even (locally) absent rings, most often due to high levels of defoliation by insects. In this case wood may be laid down only on whichever side of the tree has sustained the least defoliation, as photosynthesis might only happen there. Marker chronologies are very important in detecting absent rings; the only evidence that a ring is missing from a sample is the desynchronization of the following marker years with respect to the reference chronology.
d) Narrow rings- Narrow rings are the most useful of all marker rings. They appear faithfully in almost all of the trees of an area since they are usually caused by climate felt at a regional scale. Depending on the tree species in which they are recorded, they speak of drier/wetter or warmer/colder conditions than those preferred by the species. A series of narrow rings may indicate a few years of unfavorable growing seasons. It may also indicate an insect outbreak causing intense defoliation and therefore little growth; if that is the case, the series of narrow rings will only be present in the species that are affected by the defoliator, and other species will not show that insect signature.

4) Skeleton plots

All of the marker years described in the previous section are useful tools for building a reference chronology against which dead trees can be compared for cross-dating purposes. The most common way to build such a marker year chronology is by drawing what we call a skeleton plot. In a skeleton plot, marker years are recorded by a vertical line on a time axis (figure 4): narrower rings are represented by taller vertical lines. Narrow rings are the most reliable marker years to record in a skeleton plot, although frost rings, false rings and light rings are usually noted as well. In general, 15 to 20 samples will be enough to build a reliable skeleton plot. Marker rings are recorded on a separate time axis for each sample, then a composite skeleton plot for the site is compiled (figure 5).
Skeleton plots are very useful in identifying patterns of tree growth, and are quite often good enough to allow cross-dating of most events and even date dead trees and wood samples. Unfortunately, a wood sample that happens to fall completely in between two reliable sets of marker rings cannot be cross-dated in this manner.

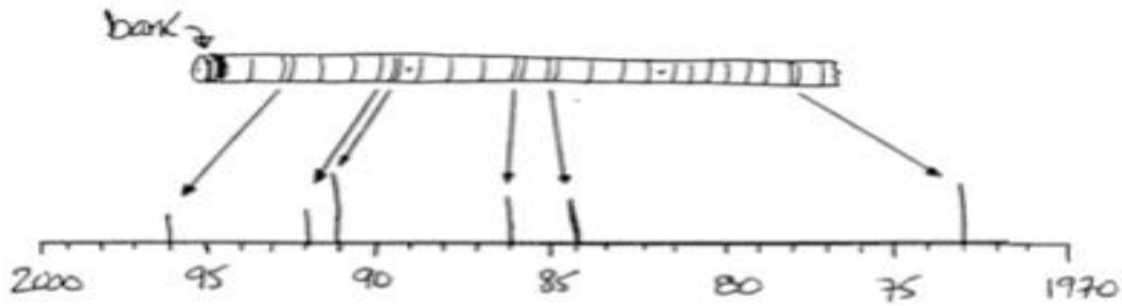


Figure 4. Narrow rings are recorded for each tree by a vertical line on a time axis; the narrower the ring, the taller the vertical line.

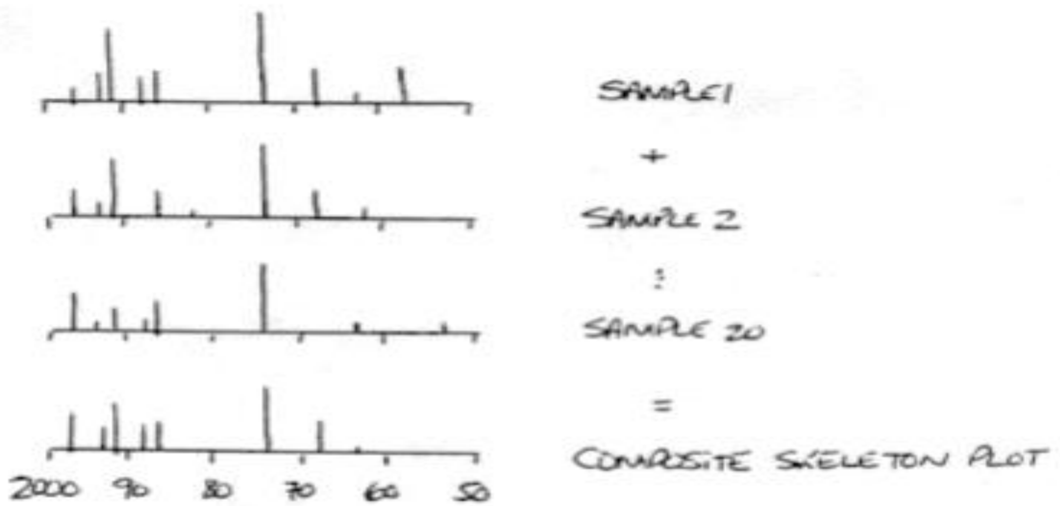


Figure 5. Compilation of the marker years from all the samples gives a reliable composite skeleton plot.

5) Master / reference chronologies

The creation of a master chronology for a specific area usually involves the sampling of many trees (>20). Ring widths have to be measured for every sample and every year, using a micrometer table or one of the software that allow on-screen measurements of digital samples. Dead trees and fossil wood that can be cross-dated to the live-tree chronology can contribute to the building of very long master chronologies (figure 6). Those can be useful in reconstructing long-term climatic trends, or to date wooden structures and objects that were built or made a long time ago, if they are reasonably well preserved.

Some master chronologies developed in Europe and in the south western United States can reach back as far as a few thousand years.

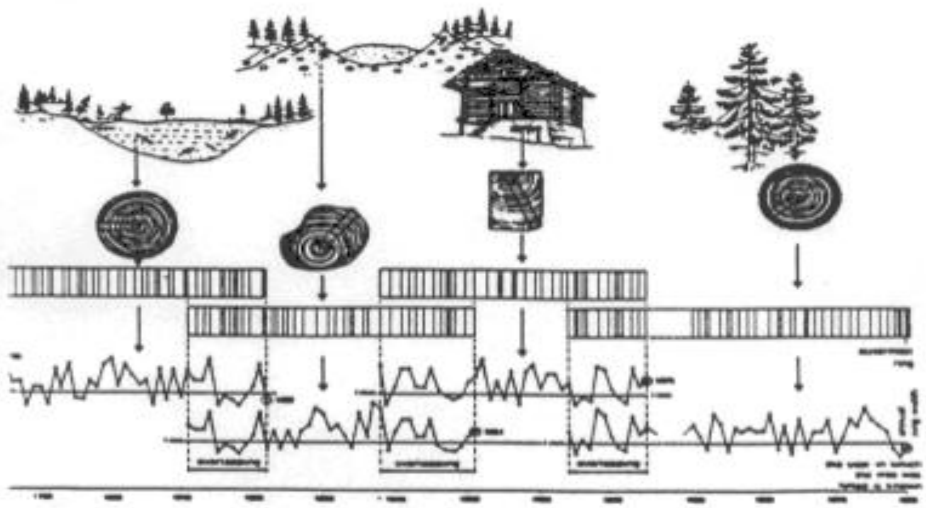


Figure 6. Cross-dating of live trees with dead or fossil trees allows the construction of long reference chronologies. (From Schweingruber 1988.)

6) Dating with wood: Some applications of dendrochronology

a) Wildfires (fire scars)

Surface fires in the boreal forest will quite often heat up some trees without killing them; the cambium will be destroyed on part of the tree's circumference, leaving a scar. Pine trees are notorious for surviving such fires, and may exhibit multiple fire scars. Trees on the edge of a burn may also be heated but not killed. In both cases the lateral cambium may be destroyed on part of the tree's circumference, leaving a wound (fire scar) that can be dated (figure 7).

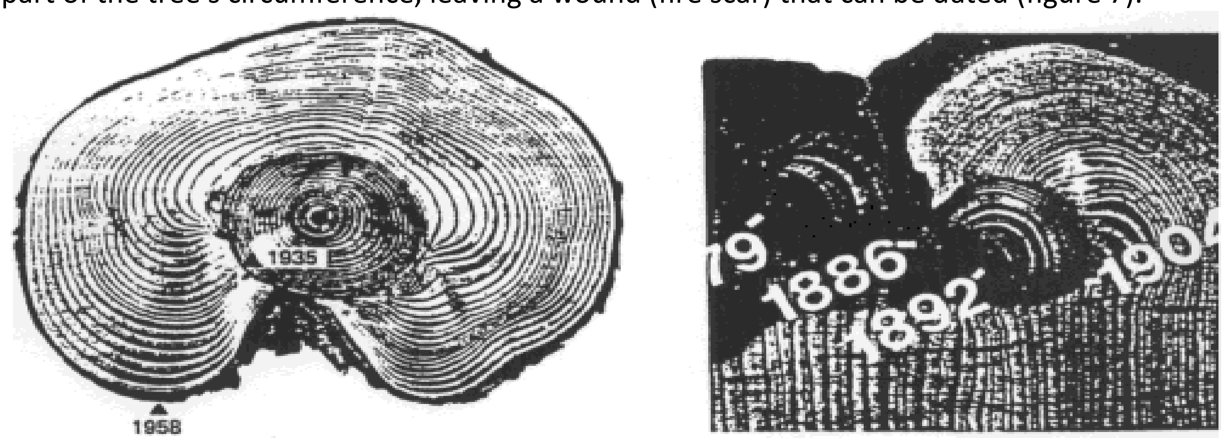


Figure 7. Fire-scarred trees can give us an accurate date of past fire events. (From Schweingruber 1988.)

b) Flood (ice scars) and avalanches (rock scars)

Ice floes carried by higher-than-usual rivers will sometimes damage the trees growing on the water's edge. Damage to the cambium will leave a datable abrasion scar. Similarly, avalanches and rock slides may leave trees scarred by rock scraping by; rocks may even become embedded in trees as the trees keep growing around them. Rock scars, like ice scars, can be rather ragged-edged and difficult to date, but they may provide a good estimate of the year of the avalanche or rock slide that caused them.

c) Sand dune migration, floods (narrow/missing rings, dead trees)

As sand dunes migrate with time, they sometimes bury or partially bury the trees that happen to be in their way. If the trees die, their death can be dated. If they survive the migration of the dune, they will show much-reduced to no growth during the period of time when they were partially buried, then better growth as they get exposed later on, and the migration rate of the sand can be calculated. Thick sediment loads deposited around trees following a flood will also reduce tree growth or cause death. Adventitious roots growing out of the trunk following partial burial can also be dated.

d) Permafrost melting, slope erosion, avalanches (reaction wood)

Reaction wood is formed when a tree is tilted at an angle from the vertical. Trees on the edge of a patch of degrading permafrost, on the edge of an eroding slope, or trees tilted by the push of snow during an avalanche, will all exhibit reaction wood starting as soon as the event happens or in the following spring, if the tilting happened in the winter. Reaction wood is usually darker than normal wood, and appears only on one side of the tree for each tilt event. Gymnosperms produce compression wood: the reaction wood is on the tilt side of the tree which tries to 'push itself back up (figure 8). Angiosperms form tension wood on the side opposite the tilt by trying to 'pull' themselves back up.

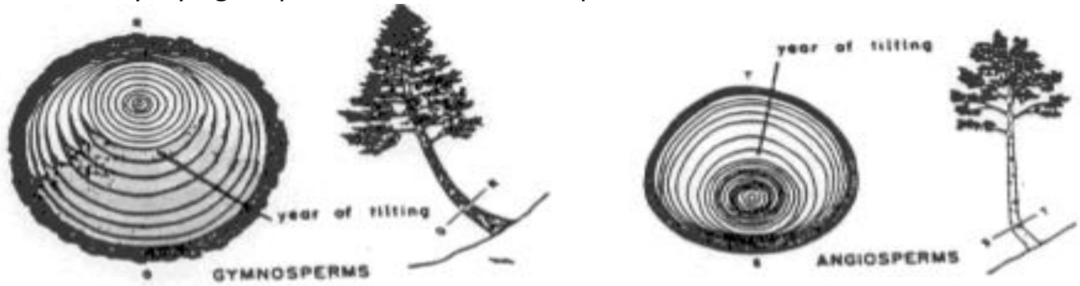


Figure 8. Tilted trees produce reaction wood in an effort to straighten up; gymnosperms produce compression wood on the tilt side of the tree, whereas angiosperms produce tension wood on the side opposite the tilt. (From Fritts 1979.)

e) Glacier advance, major ash fall, damming of lakes (dead trees, sometimes in-situ)

Dead trees that are found in-situ are most useful for dating such events, although boles that are found in moraines or at lake thrash lines can also be useful, with the caveat that they represent the latest date at which the event may have occurred (the trees may have been redeposited years after their death).

f) Opening in forest canopy, improvement in microsite conditions or climate (release rings)

Release rings may happen following a sudden improvement in climate or local growing conditions. They may also be formed following the crashing of an insect population which had been slowing down the growth of the affected trees. Any improvement in microsite conditions, such as opening of the forest canopy or major input of nutrients released by a fire, can also be reflected in the trees by the sudden production of wider rings .

g) Climate reconstruction
Climate reconstruction is better done using actual measurements of tree rings, as the use of computer software for analyses requires precisely quantified variations in ring widths. Major climatic events such as the Little Ice Age (~1570-1850) usually show up in long reference chronologies. Ash and gas clouds from volcanic eruptions may also affect climate for one to many years, as will droughts. Recorded (recent) climate data are matched to the tree-ring chronology, and temperature and precipitations can be extrapolated to pre-documented years from the relationship observed between tree growth and climate during the time data are available.
h) Archaeological use for dating of wooden objects and structures
Dendrochronology has been used extensively in Europe and the south western United States, and is being used more and more to date the many wooden objects and structures left behind by earlier inhabitants. Structures and objects need to be in a good enough state of preservation, and their ring patterns need to be matched with a reference chronology from the area where the trees were harvested. Careful interpretation of the results is necessary to avoid assigning misleadingly old dates to younger buildings, particularly when the lumber may have been recycled from previously built structures as is the case in the American Southwest.
i) Salmon streams, radioactive clouds, other elements (molecular analysis)
Since trees incorporate molecules from their surroundings (both ground and air) into their annual rings, it is possible to date the apparition of new molecules in the system (e.g. radioactive elements after a nuclear accident, or pollutants of the industrial era) or track levels of nutrients in the soils (e.g. the nutrients contributed by dead salmon after spawning). Such studies involve the molecular analysis of annual growth layers (rings), and are just beginning to be explored, although it's already been a few years since tree rings were used to calibrate the radiocarbon scale and assign calendar years to ^{14}C dates.

Wood Products

Bolts are logs less than 8' long, cut from tree trunks and are smaller than saw logs. Manufacturers cut and shape bolts to produce handles, pallets, shingles, shoe lasts, or wood squares. (Ground up bolts produce excelsior and particle board.)
Cooperage, or barrel making, industries use bolts cut into staves to manufacture barrels, buckets, cooling towers, kegs, pipes, silos, tanks, and tubs.
Saw logs are logs 8' or longer, cut from tree trunks that are big enough to make lumber. These saw logs are processed at sawmills, which may be large industrial complexes, or small one person operations set up in the forest. Processed saw logs make, but are not limited to, the following items.

Timbers are used for things like barges, bridges, building foundations, churches, columns, dams, derricks, docks and factory and warehouse buildings. Timbers are more than 5" square.

Yard or construction lumber is used for beams, boards, boat hulls and parts, dimension lumber of all kinds, factory flooring, planks, posts and rafters.

Remanufactured lumber starts as timber, yard, or finished lumber. Additional processing makes specialty items, i.e., airplane parts, agricultural tools, athletic and sporting equipment (baseball bats, skis, tennis racquets, etc, caskets, clothespins, crates, furniture, door jambs and frames, doors, gunstocks, handles, etc.

Veneer and plywood logs and bolts are chosen from the straightest and most knot free. These special saw logs and bolts are sent to plywood mills and veneer mills where they are cut or "peeled" into thin sheets. The sheets are cut into lengths and usually glued together to form plywood and veneer.

Chips, flakes, limbs, and roundwood - These four raw products are produced as primary manufacturing byproduct when other products are created or from selected trees not designated for other uses. These products may end up in hardboard and particle board plants or in pulpwood plants.

Sawdust, slabs, edges, & trimmings -These items are primary manufacturing byproducts produced when a log is cut into different solid wood products. Originally this material was either burned or discarded. **Wood Hydrolysis**, in which a wood byproduct is heated in the presence of water and catalysts, transforms this solid wood into other useful products such as:

Acetic acid
Baking yeast
Carbonic acid
Ethyl alcohol
Animal food supplements
Glycerin

More products

Poles- Posts- Fuel wood- Bark- Sawdust- Christmas trees- Cellulose Acetate- Adhesives- Rosin- Vanillin- Paper products- Fruits- Nuts- Gum- Cocoa- Coffee- Cork

Managing Forests for Fish and Wildlife

December 2002 Fish and Wildlife Habitat Management Leaflet Number 18 U.S. Forest Service, Southern Research Station

Forests in North America provide a wide variety of important natural resource functions. Although commercial forests may be best known for production of pulp, lumber, and other wood products, they also supply valuable fish and wildlife habitat, recreational opportunities, water quality protection, and other natural resource benefits. In approximately two-thirds of the forest land (land that is at least 10% tree covered) in the United States, harvest of wood products plays an integral role in how these lands are managed. Sustainable forest management applies biological, economic, and social principles to forest regeneration, management, and conservation to meet the specific goals of landowners or managers. Much of the forest land in the western U.S. is managed by public agencies, whereas most eastern forests are privately owned or under a combination of private/ public ownership. National forests cover only 19% of forested land in the United States. Non-industrial private landowners own 59% of the forested land in the U.S., making private lands management critically important to the welfare of the fish and wildlife communities associated with forested landscapes.

Forest Succession

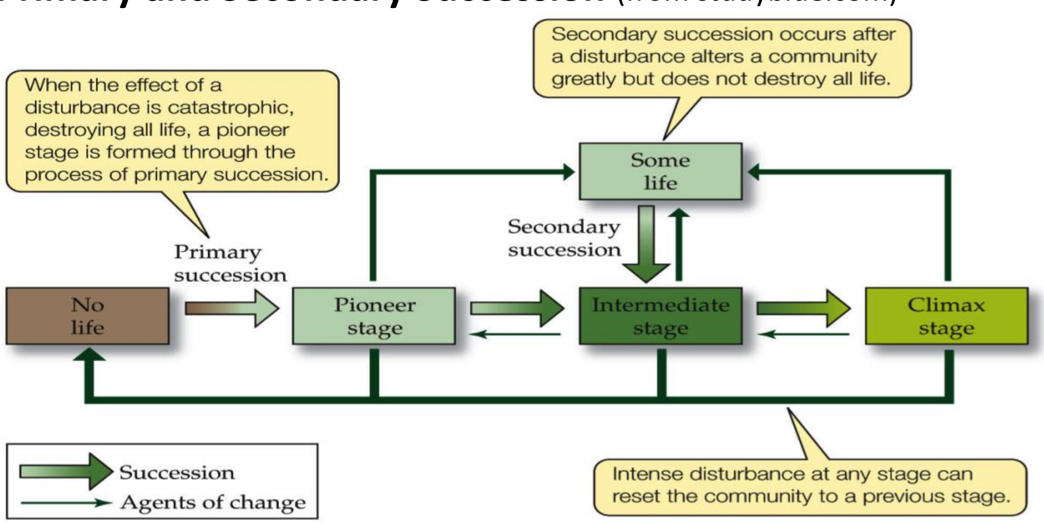
Forest vegetation typically progresses from one plant community to another over time. This forest succession can be described in four stages:

1) Stand initiation • Begins when grasses, forbs, tree seedlings, and shrubs become established in an open space created by natural (flood, tornado, fire, etc.) or artificial (timber harvest, land clearing) disturbances.
2) Stem exclusion • Sapling and pole-size trees compete for light, growing space, and nutrients. 3) Understory reinitiation
• Many trees die due to overcrowding, disease, insect blights, or other causes.
• New vacancies allow young plants to grow in understory gaps.
• Saw-timber and mature forest structure are characteristic of this stage.
4) Old-growth • Old-growth forests generally contain large and overmature trees, snags and downed logs, and a developed but patchy understory. Regeneration occurs when disturbance creates new space, and forest succession begins again. Wildlife habitat conditions shift in response to changes in stand age, structure, size, and species composition. As a result, the assemblage of wildlife species inhabiting the forest typically shifts as the stand moves through each successional stage. Forested wetlands provide food and cover for many species of wildlife. Birds and other wildlife frequently play an important role in the dispersal of heavy-seeded and fleshy-fruited tree species, contributing to the re-establishment of trees in disturbed areas.


U.S. Forest Service

Only five weeks after the Fish Day Fire in Croatan National Forest, stand initiation began with ferns and other herbaceous vegetation.

Primary and Secondary Succession (from studyblue.com)



Forest Wildlife Habitat Requirements

Forest structure affects habitat quality for many wildlife species. Tree density, canopy height, percent canopy closure, and the number of standing and fallen dead trees are some key structural features that affect habitat quality. Each wildlife species responds differently to changes in forest structure. Some wildlife species are dependent on a particular forest type or successional stage. Kirtland's warbler is an extreme example of a habitat specialist, inhabiting only extensive stands of jack pine (a fire-dependent species) six to 20 feet tall with low ground cover. These habitat conditions occur where frequent fire keeps the forest in early successional stages. The fire also releases jack pine seeds from mature cones, which allows regeneration of new trees. The warblers nest only in young trees and abandon stands that exceed a certain height.

Food -Wildlife food availability depends on the forest successional stage, season, local climate, and other factors. The stand initiation stage produces seeds and soft mast (berries and fleshy fruits) that are important wildlife foods. Tree seedlings and shrubs such as sumac, juniper, blueberry, hazelnut, elderberry and blackberry, and herbaceous forbs, legumes, and grasses provide food for songbirds and small mammals. The buds, twigs, and leaves of woody plants are browsed by deer, elk, moose, rabbits, hares and grouse, and also provide food for the insect prey of birds, bats and other wildlife. As the forest progresses through successional stages, wildlife responds to the variety of food types available. Birds and mammals associated with stem exclusion, understory reinitiation, and old-growth stages use both hard mast (nuts and seeds) and soft mast of aspen, cedar, birch, cherry, oak, hickory, maple, pine, and beech trees. Food quantity often varies seasonally, and careful forest management can help ensure its availability year-round. For example, thinning that preserves mast-producing trees and shrubs can help sustain songbirds, deer, black bear, wild turkey, and small mammals through the winter months. Landowners and managers should understand the seasonal changes in food availability for the wildlife species of concern.

Cover refers to physical features that provide animals with shelter from weather, resting places, or concealment from predators. Wildlife uses a variety of cover types depending on season and local climate. Grass-forb vegetation in the stand initiation stage provides ground cover for game birds such as ruffed grouse and woodcock, and for small mammals like voles, mice, and shrews. Many wildlife species benefit from canopy cover. In northern regions, closed, dense canopies of conifers in the understory provide thermal cover for deer ("deeryards") and other species during winter months. Snags (standing dead trees) supply foraging sites for woodpeckers and cavities for nesting and resting birds and denning mammals. Fifty-five species of cavity nesting birds in North America use snags, as do nearly half of North America's 45 bat species. Invertebrates in dead wood are a rich food source. Bats roost in cavities and under the sloughing bark. Bald eagles, goshawks, spotted owls, pine martens, flying squirrels, tree voles, red-backed voles, and some bat species prefer cover provided by old-growth woodlands. Dead trees, limbs, and litter on the forest floor provide cover and invertebrate foods for woodpeckers and other wildlife.


U.S. Forest Service

Water- water requirements vary by species. Water is obtained from plant and animal foods consumed, as well as from free water in ponds, lakes, streams, and wetlands.

Timber Harvest Management

Even-aged and uneven-aged forest management are two common silvicultural systems used to produce timber. Harvest and regeneration methods define each approach. In even-aged stands, most trees belong to one age class. Uneven-aged stands have trees of three or more age classes that are mixed, or in small groups. Combinations of even- and uneven-aged systems can be used in an area to enhance wildlife habitat and timber quality, impacting aquatic life.

Table 1. Characteristics of even-aged and uneven-aged harvest methods.

	Even-aged	Uneven-aged
Harvest method	Clearcut, shelterwood,and seed-tree.	Single-tree and group selection.
Tree type	Shade-intolerant.	Shade-tolerant.
Stand appearance	Uniform tree height within stands.	Variation in tree height. If group selection used on groups larger than 0.4 hectares, appears similar to even-aged stands.
Forest appearance	Patchwork of stands at various ages.	Uniformly mixed tree sizes.
Wildlife use	Species adapted to early and mid-successional stages and mature forest conditions, depending on stand age.	Species adapted to mature forests as well as early and mid-successional conditions.

Southern Research Station, U.S. Forest Service

The shelterwood cut in this southern mixed forest leaves mature trees on-site to produce seed and maintain some mature habitat structure for woodpeckers and other wild-life.

One potential result of timber harvest and regeneration is a high level of human activity, including sedimentation and pollution of waterways caused by construction and frequent use of logging roads and timber harvest and other land use activities.

In 1981, the Forestry Nonpoint Source Pollution Technical Task Force developed Best Management Practices, or BMPs, to minimize nonpoint source pollution Comprehensive timberland management includes measures to limit disturbance, soil erosion, nonpoint source pollution abatement in wetlands and discharge of sediments and pollutants into waterways. Forest management BMPs include:

• Permanent and temporary access roads should follow land contours and minimum grade
• Water control structures should be installed on roads with highly erosive soils.
• Landowners should limit the number, width, and length of access roads, especially at stream crossings. • Road construction should take place under dry conditions
• Dips, water bars, and water turnouts should be installed on roads to provide proper surface drainage on roadways.
• Hay bales, rocks, or silt fences should be strategically placed to help prevent sedimentation.
• Wildlife-friendly vegetation should be planted to stabilize exposed soil and supply wildlife food and cover.

Even-aged management

Under even-aged management systems, most of the trees within the stand are approximately the same age. Small stands of different age classes can form a diverse assemblage of wildlife habitats. Even-aged timber stand management often begins with the complete, or nearly complete, removal of existing timber. Clearcutting removes all marketable trees, dramatically changing the composition of wildlife in the area. Usually, mature forest flora and fauna are replaced by early successional species. Small clearcuts (1 to 15 acres) are generally more beneficial to wildlife than larger clearcuts. The flush of herbaceous growth in clearcut areas lasts for several years and provides big game animals such as white-tailed deer, elk, and moose with nutritious browse, and early successional birds and small mammals with food and cover. The shrub layer succeeds the grasses and forbs and supports “thicket” species like the yellow-breasted chat, willow flycatcher, mourning warbler, and many small mammals. The size, shape, and location of clearcuts affect the wildlife habitat quality and the species associated with clearcuts and surrounding areas. Clearcuts with irregularly shaped boundaries have more edge than clearcuts with linear boundaries. Snags, den trees, and mast-producing trees left standing can add wildlife habitat value to clearcut areas. Both shelterwood and seed-tree cuts leave some mature trees on-site as seed sources to help establish new stands. These treatments help conserve some mature forest structure required by forest birds like nuthatches and woodpeckers. Nuts and seeds produced by the mature trees also provide a source of wildlife food during the fall and winter months. Forests that contain several successional stages of even-aged stands can provide quality wildlife habitat.

Plantations are stands of trees that are established by planting or artificial seeding. Although single species plantations seem dependable timber producers, they can require intensive management at considerable expense. Insect blights, disease, high winds, and other natural disturbances can destroy susceptible trees. Conifers such as ponderosa pine, red pine, loblolly pine, slash pine, and longleaf pine often used in plantations because they are fire-resistant and produce marketable timber in short rotations. Even-aged pine monocultures typically provide limited wildlife habitat quality due to the lack of plant diversity. Tree species with serotinous cones (species like lodgepole, jack, and sand pine) usually regenerate successfully following burning of clearcut areas. Serotinous cones remain tightly closed until extremely high temperatures, or fire, causes the resin to melt and the cones to open, releasing the seeds. The open ground created in burned areas provides suitable sites for seeds to germinate.

Even-aged harvest and regeneration practices:

Clearcut.—Removal of all trees in a stand; reserve trees may be left to accomplish management objectives other than regeneration.

Shelterwood cut.—Removal of most trees in a stand, but leaving enough trees to provide shade for the regenerating age class; trees can be cut in groups, strips, or in a uniform manner to reduce competition for regeneration.

Seed-tree cut.—Removing all trees except for a small number of widely distributed trees for seed production; seed trees usually removed after regeneration is established.

In even-aged systems, the rotation is the period between regeneration establishment and final cutting.

Uneven-aged harvest and regeneration practices:

Single-tree selection cut.—Individual trees of all size classes removed more or less uniformly throughout the stand to increase growth of remaining trees and provide space for regeneration.

Group selection cut.—Small groups of trees removed for regeneration of new age classes; width of cut rarely exceeds twice the height of the mature trees.

In uneven-aged systems, the cutting cycle is the interval between partial harvests.

Uneven-aged management

Under uneven-aged systems the age of the trees within the stand varies greatly. Uneven aged forests can produce quality timber while providing largely continuous canopy cover. Single-tree and group selection cuts maintain mixed age classes within one stand. The high percentage of canopy closure (often 70% or greater) can limit herbaceous ground cover, and wildlife species associated with those vegetation types. Although mid-story levels may develop, brushy ground cover required by some wildlife species can be limited or altogether missing. Some wildlife species benefit from the continuous forest cover associated with uneven-aged systems (e.g., some forest interior birds), but others do not. The harvest of individual trees at periodic intervals creates space for adjacent tree crowns to expand. Single-tree and group selection methods create small canopy gaps, which are similar to gaps formed by natural forest disturbances. Group selection treatments remove groups of trees from one or more age classes. Moderately shade-intolerant species can benefit from this harvesting method because larger openings are created.

Improving Fish and Wildlife Habitat with Forest Management Practices

Successful forest management for wildlife requires an understanding of how specific timber management treatments affect the targeted fish and wildlife species. Characteristics of effective management strategies include:

- A thorough inventory and description of forest management areas, including vegetation species composition and age structure.
- An understanding of how the managed area fits into the surrounding landscape.
- Clearly defined timber management objectives for the management area.
- Clearly defined fish and wildlife management objectives for the management area, such as managing target species or increasing biodiversity.

- ❖ A thorough evaluation of the quality and quantity of habitat available for the targeted species.
- ❖ Continuous evaluation and modification of timber stand treatments and other management practices.

Regeneration establishes new growth in an open space created by natural or artificial disturbance. Stands can be regenerated artificially using mechanical treatments, prescribed burning, herbicide applications and planting tree seeds, seedlings or cuttings. Stands can also be regenerated by relying on germination of existing seeds and sprouting of stumps. Regeneration of native trees and shrubs provide food and cover for many wildlife species.
Thinning removes weak or suppressed trees and opens growing space for the remaining healthy trees. Periodic thinning treatments help reduce the risk of insect infestations, disease, and catastrophic fires. There are four common methods used to select individual trees for thinning:

¤ Low thinning removes trees from lower crown levels to enhance upper crown level growth; soft mast, seeds, and grasses typically increase after low thinning.

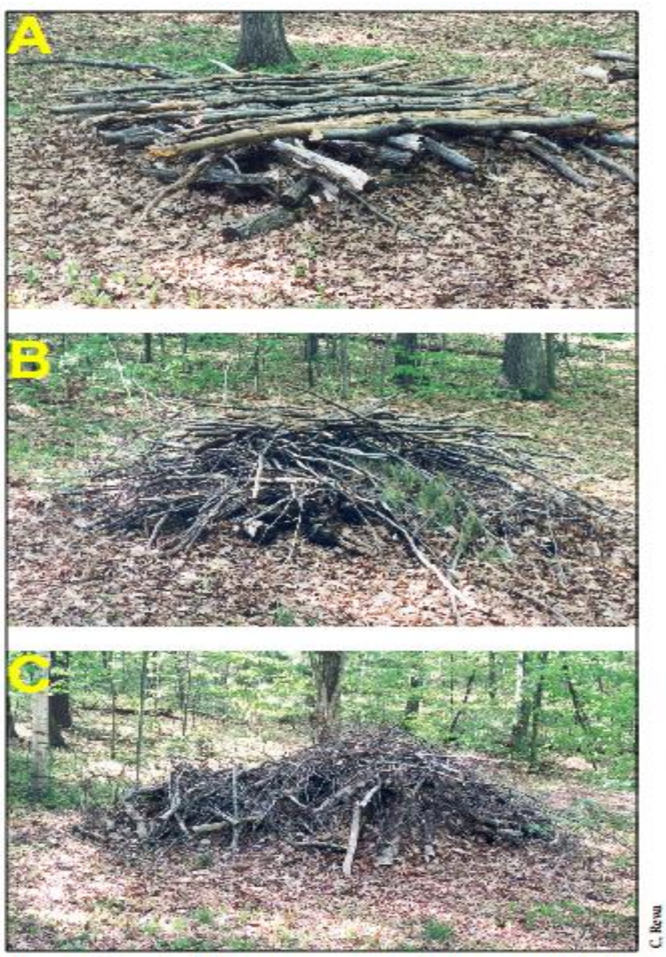
¤ Crown thinning removes trees from the mid- to upper crown classes to favor growth of larger trees.

¤ Selection thinning harvests trees from upper crown levels and promotes growth in lower canopies of uneven-aged stands.

¤ Free thinning removes trees with no preference to crown level, but cutting patterns are used to improve growth.

Thinning can improve wildlife habitat by stimulating new growth in the understory and improving mast production by overstory trees, and by increasing flight space under the canopy for foraging bats and forest raptors.

Brush piles Small mammals, amphibians, reptiles and other wildlife of the forest floor use brush piles for escape, resting and nesting cover. Effective brush piles are built on a base of coarse materials so openings are available at ground level for wildlife movement. A few piles of large rocks at least 12 inches wide and 2 feet tall, and several crisscrossed logs at least 6 feet long and 6 inches in diameter make good brush pile bases. Stumps can also make good bases. Progressively smaller limbs and brush are piled onto the base until the brush pile is about 6 feet tall.

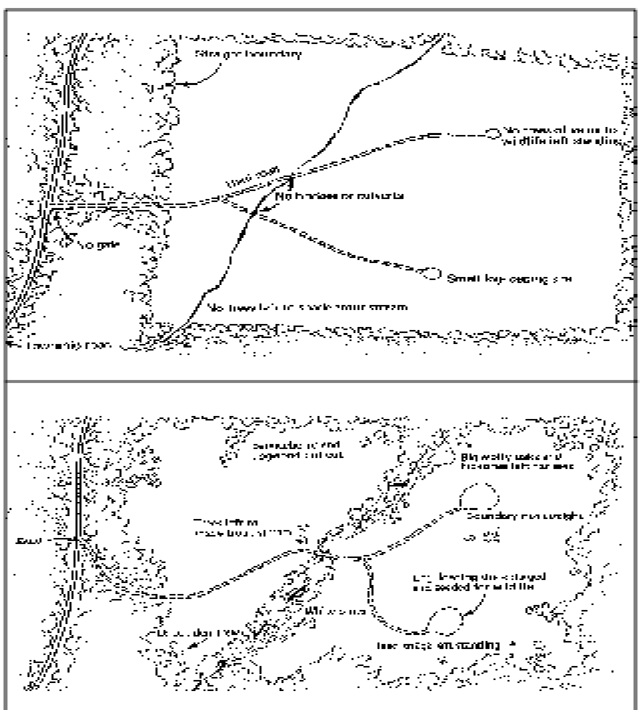


Brush piles should be constructed with heavy material at the base (A) with increasingly finer material on top (B and C) to provide cover for small mammals, reptiles and other wildlife.

Living brush piles can be made by partially cutting small trees near the base and pushing them to the ground using the bark left intact at the base as a hinge. The partial severing of the tree allows it to remain alive, providing dense live foliage near the ground.

Prescribed fire Fire is a natural disturbance element of many native ecosystems. Prescribed fire can be an economically and ecologically beneficial forest management tool when applied properly. Prescribed burning is conducted to achieve specific management goals such as increasing timber production, eliminating undesirable vegetation, improving wildlife habitat, or reducing fire hazards. Fire type, frequency, and intensity are three important factors to consider when planning a prescribed burn. Most prescribed fires are carried out under cool, moist conditions to reduce the chance of wildfire. Prescribed burns that simulate natural fire regimes can stimulate new herbaceous growth that benefits deer, turkeys, and other wildlife. Studies show that most wildlife escapes direct mortality from fire. For many wildlife species, habitat quality is improved by fire, especially for species adapted to early successional vegetation. Surface fires stimulate new herbaceous growth used by deer, elk, moose and other herbivores, and enhance production of berries used by black bears, songbirds and other wildlife. Small mammal populations generally increase in response to new vegetation growth, providing a food source for carnivores.

Edge habitat Edge is the boundary where two different plant communities meet. There is generally vegetation associated with edge habitats, where some animals take advantage of the close proximity of different forest successional stages for food and cover. In the past, forest wildlife managers have tried to produce the maximum amount of edge to increase habitat for game species. However, edge does not benefit all wildlife. Many populations of forest interior birds are declining due to fragmentation of forested habitats into smaller patches and the increasing amount of edge and the associated effects of predation and nest parasitism. Forest interior species typically avoid edge habitats and require large tracts of contiguous forest. Wildlife species adapted to edge conditions readily outcompete forest interior species for resources along forest margins. Creation of edges has the following general effects on forest wildlife:



Top: Clearcut timber harvest without considerations for wildlife. Bottom: Clearcut timber harvest that takes into account the needs of wildlife associated with edge habitats. From Hassinger et al. (1981).

- Habitat quality for edge-generalist species (those species whose fitness is enhanced near edge habitats) is improved.
- Habitat quality for area-sensitive species (those species requiring large blocks of contiguous forest) is reduced.
- Habitat quality for edge-sensitive species (those forest species whose survival and reproductive capacity is reduced near edges) is reduced.

Clearcuts often create abrupt edges, and cutting patterns determine the amount of edge habitat created. Circular cuts produce the least amount of edge. Landowners and managers can increase edge by elongating circles or creating several smaller circles. Irregularly shaped cuts containing islands of residual trees significantly increase edge, whereas straight linear cuts minimize edge.

Forest fragmentation is a process in which contiguous forested landscapes are broken up into smaller islands of forest. Forest fragmentation is a major concern because noncontiguous forest cover can negatively impact some wildlife populations. Besides forest interior birds, many wide-ranging carnivores (e.g., bobcat, lynx, black bear, fisher, wolverine) need large blocks of contiguous forest habitat. Adverse effects of forest fragmentation include:

- Increased predation and nest parasitism on forest interior birds.
- Abandonment of otherwise suitable habitat by area-sensitive species due to close proximity of forest edges.
- Increased interspecific competition.
- Overall habitat loss.

Single-tree and small group selection cuts help preserve areas of contiguous forest by imitating natural forest disturbance processes. Clearcuts and large group selection cuts should be avoided in areas managed for area-sensitive species. Maintenance or establishment of forested corridors linking forest habitat patches can mitigate the effects of fragmentation to some extent. As forest fragmentation and urban sprawl increase, corridors become increasingly important habitat elements for many species of forest wildlife. Natural corridors include strips of woody riparian vegetation along waterways, and artificial corridors include windbreaks, shelterbelts, and other plantings.

Corridor Functions and Benefits:

Wildlife habitat

- connect habitat remnants to increase habitat area for plants and animals
- increase opportunities for emigrating and immigrating wildlife, such as increasing travel lanes for migrating or juvenile animals
- may serve as home range for corridor "dwellers" such as insects, amphibians, reptiles, small mammals, and birds
- increase foraging opportunities and cover for some wildlife species

Other environmental functions

- reduce flooding
- reduce soil erosion and stabilize stream banks
- improve water quality and quantity
- help improve air quality

Social and economic functions

- recreational and educational opportunities
- aesthetics
- introduced corridors can help increase crop yields and quality, decrease energy consumption, and increase property values

Vernal pools, also called ephemeral or snowmelt pools, in forest lands of the eastern U.S. are shallow depressions on the forest floor that fill with water when groundwater levels are high, particularly in the spring. Woodland vernal pools provide important spring breeding habitat for wood frogs, salamanders and other amphibians. Conserving vernal pools includes managing adjacent upland habitat. In forested areas, the loss of surrounding trees and vegetation around vernal pools reduces shade, increases water temperatures, and increases evaporation causing the pools to dry up more quickly. Natural, undisturbed buffers approximately 300 yards wide around pools should help protect animal movements to and from the pools. Forested corridors connecting pools should be preserved, and debris or fill should not be dumped into vernal pools. Roads can be lethal barriers for animals trying to reach vernal pools. Drainage containing road salt, roadside pesticides and other chemicals can have negative effects on vernal pool habitats. Habitat alterations that must take place should be carried out from November through March to minimize disturbance to breeding and resident animals. These unique habitats provide a safe haven for some specialized breeding populations of amphibians and invertebrates and food and cover for migrating birds and other wildlife. Many species that inhabit vernal pools are adapted to harsh conditions. High nutrient levels produced by decaying organic material support rapid development of amphibian larvae and other organisms before pools dry up. Animals that breed exclusively in vernal pools and require those habitats for survival are called vernal pool obligate species. The wood frog, a terrestrial amphibian, breeds only in vernal pools as do several species of mole salamanders (including the marbled salamander, and others).

Riparian zones are terrestrial areas adjacent to and influenced by perennial or intermittent bodies of water. Riparian zones provide transition areas between terrestrial and aquatic ecosystems, which create unique and highly valuable fish and wildlife habitats. Riparian vegetation provides essential nesting habitat for songbirds, and foraging habitat for songbirds and bats, especially in arid western environments. Forested riparian zones adjacent to streams and rivers provide a variety of important ecological functions, including the following:


C. Rewa

Riparian vegetation provides shade and a source of organic matter and large wood to stream ecosystems.

• Stream shading: Riparian areas that are heavily vegetated can moderate stream temperatures by shading the stream in summer and providing a buffer from extreme cold in winter.

• Large wood: Riparian forests are a source of large wood, which when it falls into the stream, provides structural complexity to stream channels. Instream wood often results in the development of pools which can slow down stream flow and provide fish refuge from high velocity water, hiding cover and over-wintering habitat. Also, in-stream wood increases the retention time of smaller organic detritus by capturing leaves and twigs in branches and roots. This allows more time for aquatic invertebrates to break down the detritus, supporting the food chain that sustains fish and other vertebrate species. In-stream wood is also habitat to aquatic insects.

• Organic matter input: In upland streams that are shaded by streamside forests, as much as 75 percent of the organic food base is supplied by dissolved organic compounds or detritus such as fruit, limbs, leaves and insects that fall from the riparian canopy. This is known as *allochthanous* input. Benthic detritivores, the stream bottom bacteria, fungi and invertebrates that feed on the detritus, form the basis of the aquatic food chain.

• Minimize sediment input: Riparian ground vegetation acts as a very efficient filtration system by removing sediment and other suspended solids, as well as sediment bound nutrients and pesticides from surface runoff. This function is critical for maintaining good water quality.

• Nutrient assimilation: Riparian areas function as a sink when nutrients are taken up by plants and stored in plant tissues. In wetter areas, nutrients in leaf litter may be stored for long periods as peat. Also, sediments filtered out by vegetation remain in the riparian sink to become incorporated into the riparian soils.

Forest Health (from Eco Link Vol 11 Number 1)

An ecosystem is a natural system, which functions as a unit. It is an assemblage of living organisms reacting with each other and their non-living environment in a particular area. It can be anything from a rotten log to the entire planet. A forest is simply an ecosystem dominated by trees, with a unique combination of plants, animals, microbes, soil, and climate. Forests thrive on the natural chaos or disturbance in the ecosystem. Disturbance is common and important in all ecosystems. Forests have evolved in response to disturbance-response regimes that have recurred over millions of years. Disturbance caused by drought, disease, fi re, insects, and wind is very common in forests. Recurrence of these disturbances and recovery within forest ecosystems is an important mechanism for: energy flow; nutrient cycling; and for maintaining age, species, genetic, and structural diversity. The results of disturbance are both short and long-term. In the short-term, social and economic impacts may dominate and then decrease as other goods, services and amenities replace ones that were lost. In the long-term, biological impacts may dominate (e.g. one species replaces another that was lost or diminished due to disturbance). Although disturbances have social and economic impacts, they can release: nutrients, light, water, and space, and make those available to remaining or new species. Many plants become marginal producers as they experience competition and stress, yet they continue to consume resources. Disease, insects and fi re eventually kill weakened plants, creating the conditions for colonization by other vegetation. The "ancient forests" which the Europeans found were forests that had been shaped by natural disturbances including the aggressive use of fi re by the Native American peoples. The ancient forest landscapes were diverse mosaics caused by disturbances, the harvesting of timber, and the conversion of forestlands for agriculture. Certainly, "old growth" forest stands were a component of those landscapes. People have a misperception of ancient forests being all "old growth," teeming with wildlife and without human inhabitants. The forests are imagined as a landscape painting. However, there was never a time when forests could be preserved in a steady-state. Forests were always dynamic and disturbance-response regimes reshaped the landscapes.

There is no way to overstate the importance of Native Americans in shaping our native forest landscapes. The historical record indicates that Native Americans were responsible for up to 50% of the fi res that burned in our native forests. Native American burning and subsistence practices are even more important in the Southeast, where Native Americans helped to make longleaf pine forests the most diverse native forests in North America. Unfortunately, many of our forests are now unhealthy because they have had fire excluded for so many years. Many stands are overstocked and there is an excessive buildup of dead trees, woody debris on the forest floor, flammable brush and dense understories which can carry fire into the crowns of larger trees. It has become increasingly difficult to salvage dead and dying trees; setting up conditions for disease, insects and wildfire.

In its 1999 Health Update the US Forest Service lists seven key issues.

1. **Wildfires** - Fire is a major disturbance factor in the majority of forest ecosystems. Forest fire is part of natural ecological processes in which the forests have functioned for thousands of years. Almost a century of fire control has led to a forest that is, in many places, substantially overstocked with old, dead, and dying trees. Small natural fires have not been allowed to fulfill their function of removing ground litter and fuel buildup, and helping to thin overly dense stands. Prescribed burns, designed to mimic the impact of small natural fires, are often applied on forests that have excessive buildup of flammable materials. Prescribed burns are useful, cost effective, and environmentally safe in areas with less fuel buildup. Areas with excessive fuel buildup should be treated to reduce the density of forest stands and to provide fuel breaks in critical areas, such as near human populations. Due to the value of harvested materials, such projects can easily cover some, if not all, of the management cost.
2. Exotics (non-native & invasive) - Exotics refer to species primarily of European or Asian origin that have been accidentally or intentionally introduced to North America. Some of these species are invasive meaning they have the ability to spread, dominate, and out-compete native communities. Therefore, these species thrive since they were introduced without the insects' diseases and organisms that kept them in check in their homelands. When brought into new ecosystems, exotic species often have no natural enemies and can therefore cause extensive damage.
3. Urban-Wildland Interface - Urban areas are pressing-up against "wildlands" and managed forests. This creates some unique challenges in monitoring and managing forest health while protecting human health, safety, and property. One of the most serious issues is fire. Many homes are built in, or adjacent to, fire dependent ecosystems, which need to be burned using prescribed fire. Urban dwellers don't like to breathe in the smoke and consider smoke a hazard on the highway. Yet trees like the longleaf pines in southern coastal plains need fire and so do the red-cockaded woodpeckers that live in these trees. The ponderosa pines of the west are also fire dependent.

   With the increase in population, the demand for forest products is also increasing. Today the average person uses 80 cubic feet of wood and 750 lbs of paper, an equivalent of a 100' tree with an 18" trunk, per year. With so much public forest land set aside from commercial harvesting, we will need to get more and more of our wood fiber from private lands and intensively managed plantations.

   The National Forests offer a great outdoor recreation opportunity. These forests contain 380,000 miles of roads that carry over 20 million vehicles per day. It is a tremendous challenge to meet the growing need for recreation while protecting the health, diversity, and productivity of the land. Sixty percent of National Forest roads are not maintained to the public safety and environmental standards for which they were built. A $10 billion reconstruction backlog exists for highly traveled roads.
4. Degraded Watersheds and Riparian Zones Healthy watersheds are vital to ecosystem health. Watersheds absorb rain and recharge underground aquifers. They serve as habitat for thousands of species of fish, wildlife, and rare plants. They dissipate floods across floodplains, increasing soil fertility and minimizing damage to lives, property, and

streams. Over 80 percent of the freshwater sources originate on forestland. Downstream communities depend on the clean water that flows from watersheds for consumption, food production, agricultural development, employment, power generation, and recreation. Poorly maintained roads can promote erosion and landslides, degrading riparian and wetland habitat. Sedimentation causes changes in stream flow, water temperature and water quality. High quality riparian (streamside) areas trap sediments; slow runoff; and provide cooling shade and excellent habitat for wildlife, fish and plants. Degraded riparian areas lose many of these functions. The US Forest Service estimates that 50 percent of the riparian areas in National Forests and National Grasslands need aggressive management.

5. Biodiversity Loss - Biodiversity means a variety of life forms. It can be considered at three levels: ecosystem, community, and individual species. All three levels are interconnected and hierarchical; species are dependent on communities, which are dependent on the larger ecosystems in which they reside. Biologically diverse ecosystems tend to be more productive and resilient than those with less diversity. Ecosystems can be lost or impoverished in basically two ways. The most obvious kind of loss is quantitative, the conversion of a native prairie to a corn field or to a parking lot. The second kind of loss is qualitative and involves a change or degradation in the structure, function, or composition of an ecosystem. Across a forest landscape, structural diversity is the key to all the other kinds of diversity. Biodiversity declines, as stands become dense, instead of having the openings and grassy areas of pre-settlement forests. Loss of species can affect higher levels of organization.

6. Air Pollution - Air pollution, particularly acid rain and ground-level ozone, impacts forest ecosystems. Pollutant emissions associated with increased industrialization, resource consumption, and other human activities are expected to continue to increase nationally and globally. This change in atmosphere affects the function, productivity and health of forest ecosystems. The capability to understand and to predict the consequences of the long-range transport of air pollutants on forests, and to pinpoint the sources of air pollutants, is essential for achieving the sustainable-management of forests. Today, there are two major pollutant types threatening forest ecosystems: photochemical oxidants, of which ozone is the primary compound, and nitrogen pollutants. Ozone is toxic (plant-killing) to sensitive plant species. It has been shown to alter forest ecosystems in areas of high deposition. Nitrogen is the primary growth-limiting nutrient, yet it is also a pollutant when in excess. As nitrate levels increase, tree growth rates decrease because nutrients are lost.

7. Changed Ecological Conditions - Each agent in an ecosystem acts in an environment produced by its interactions with other agents in the system. Therefore, every agent is constantly acting and reacting to what the other agents are doing. For example: “Insect outbreaks frequently are associated with drought, which, in turn, can exacerbate the adverse effects of insect activity. Drought also can enhance the ignitability of fuel and create a greater potential for fire, especially in ecosystems rarely affected by fire. Root diseases can predispose some trees to attack by insects such as bark beetles, which can subsequently be triggered to outbreak levels by other disturbance agents. Trees affected by root disease also are more prone to wind-throw. Loss of root-diseased trees by wind-throw increases the risk of adjacent trees to wind-throw during the same or future wind events. Increased tree mortality can enhance the amount of ignitable fuel and increases the chances of fire and its intensity when it occurs." Therefore, change is constant and the process, which regulates forests, is continually changing.

Due to the cumulative-effect of the concerns discussed, North America's forests contain many examples of habitat change. Past management practices such as fi re suppression, combined with native and non-native invasive species, have created landscapes that experience more frequent or intense disturbances. These landscapes are more costly to manage, less able to provide the values humans desire and are less ecologically sustainable. There is an estimated backlog of $40 billion in forest health work to be done on the US National Forests alone. Forests need active management. In order to have diverse, productive and resilient forests, we need to learn how to mimic some of yesterday's disturbances, and utilize the safest and most effective tools available. We must learn to restore the real ancient forest, but on smaller landscapes. This means that the uncontrolled disturbances of the past are unacceptable and nature cannot just take its course. These forests must have mechanical thinning and harvesting as well as prescribed fire. They can contain some old growth mixed with stands in all stages of ecological succession. We must also have intensively managed plantations to meet our need for wood.

Key Forest Management BMPs *(Best Management Practices)*

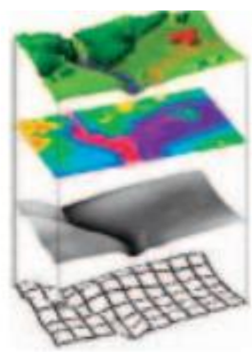
The following is a representation of some important BMPs for good forest management

- Inventory all resources on the property
- Work with a resource professional to plan and set goals
- Mark and maintain property lines. Consider management effects on adjoining properties
- Assess best options for regeneration
- Control regeneration problems such as competing vegetation, browsers, and pests
- Protect the residual stand with less intermediate cutting, proper timing, and a well-laid-out plan for equipment movement
- Monitor for and take appropriate control measures for insects and diseases
- Use soil surveys, topographic maps and on-site surveys to determine sites for landings, skid roads and haul roads
- Design roads to shed or divert water quickly, to avoid wetland soils and to minimize contact with riparian areas
- Consider the viewscape both during and after operations. Clean up human debris daily, minimize activity when possible near areas with greater public access, leave visual buffers, re-vegetate roadways, minimize straight lines (follow contours), and keep mud off public roads
- Consider wildlife. Plan for species' needs, protect sensitive areas, snags and cavity trees, and provide appropriate riparian buffers
- Look for threatened or endangered species but target invasive species for removal

Forest Technology Primer (From Eco-Link Vol 12 No 2)

Technology is helping the forest products industry produce more with less: less waste, less pollution, less impact on the environment and less raw material input. Foresters are under increasing pressure to meet the public's growing needs for wood and paper as well as amenities from the forest. However, they often have to work under the yoke of negative public perceptions, which were created by images of our pioneering past, when the forests were seen as endless, and something to be conquered rather than sustained. Yet the reality of the modern forest products industry is sustainable forestry, to benefit current and future generations.

GIS (Geographic Information Systems) Information is the key for modern-day forest managers. For planning, writing management prescriptions, and forecasting effects of prescriptions, managers need immediate access to data and information that is accurate and meaningful. Information like stand size and geography, stand density and species composition, timber size and value; as well as spatial data such as vegetation and wildlife distribution and the locations of rivers and roads. A geographic information system is a computer-based tool for mapping and analyzing geographic phenomenon that exist, and events that occur on Earth. Data is collected on the ground or through remote sensing and is added to a database. This data can be processed by computer for visualization applications (map layers) such as; forest cover type and habitat classification; location of ecologically sensitive lands and endangered species; identification of land ownership boundaries; ground cover mapping and characterization (forest, wetlands, etc.); facility siting; and efficient transportation routing.



Foresters can use GIS data to help in forest management. For example, users can see on one layer how much of a particular stand is forested, the size of the trees on another layer, and the species variety on another. The selected layers can be superimposed into a graphic image for a picture of what exists at that time. *Image from GeoLas Consulting.*

Global Positioning System (GPS)

A primary tool in GIS is Global Positioning System (GPS). Using technology developed by the U.S. Department of Defense, operated by the military, and adapted for general use, foresters are able to more accurately plot location data (latitude, longitude, and altitude) for use in calculating timber volume, surveying timber plots and mapping roads and features in the forest. This data, combined with photogrammes and other geographic data help foresters to accurately manage modern forests.

Using a handheld receiver, GPS takes advantage of a constellation of 24 satellites that orbit the earth as reference points to calculate position in three dimensions as well as in time. At any time, this constellation provides the user with between five and eight satellites visible from any point on the earth. GPS technology could accurately plot your position within a centimeter.

One example of a GPS receiver used by foresters to collect data

Foresters can download data gathered from handheld GPS receivers into databases and modeling programs that marry it to other GIS information that can help in planning. As the technology gets smaller, foresters will have access to portable GIS tools that help them make on-the-job decisions.

Lasers and LIDAR (Light Detection and Ranging)

Laser technology provides a very accurate way of measuring distance and dimensions and is finding many applications in surveying and mapping applications. Laser ranging works by emitting laser pulses towards the object to be measured. These pulses are reflected by the ground and/or objects upon it such as trees and buildings. For each pulse the elapsed time between the emitted and returning signals is measured, which enables a slant distance to be computed. This technology is useful on the ground by foresters as well as for remote sensing data collection through laser altimetry.

Laser Rangefinders

Handheld lasers have simple applications for foresters, collecting measurement data within and among tree stands. Foresters can use laser rangefinders in combination with GPS technology in timber cruising, GPS offset mapping and data collection, etc. When used correctly, lasers are much more accurate than traditional methods.

Remote sensing is a way to obtain information on forest biomass and stand conditions over large areas in a timely and cost-effective manner. The term remote sensing, sometimes known as photogrammetry, refers to measuring objects on earth without actually touching them, usually by means of some sort of photogramme. Photogramme commonly refers to photographs, but more generally means any sort of imagery. Remote sensing utilizes aerial photographs, satellite images, laser altimetry, and radar

Advances in technology over the last century have allowed **harvesting and processing techniques** to evolve at a lightning fast pace to help keep up with demand for forest products while complying with economic and ecological demands. In the U.S., national timber harvest is approximately 16 billion cubic feet which goes to provide the public with lumber, wood products, paper and pulp products, and wood by-products. In 2000, for example, over 90 percent of single-family homes built in this country (approximately 1.6 million—each using 13,127 board-feet of framing lumber) were constructed with wood framing. In addition, Americans also used an average of 718 pounds of paper per person. The business of harvesting and processing trees was traditionally very labor intensive, dangerous, and often destructive to the sites. Processing logs required much manual labor which resulted in many injuries and very high workers compensation insurance costs. Road building and some harvesting techniques degraded the environment and caused damage to residual trees. Numerous roads were built to access harvesting sites which contributed to erosion and watershed and habitat degradation. Forestry today looks nothing like that of a century ago. Modern equipment is now able to harvest and process trees to log lengths in one motion, saving processing time in the mills and helping keep organic matter on-site. Computer systems are integrated into harvesting systems, allowing optimization of the harvest. The machines themselves are purpose-built and designed to be more versatile and to have lower impact on the site.

Tree Length Systems Modern harvesting systems completely mechanize the felling operation getting the labor off the ground and minimizing impact to the site. Machines like feller-bunchers fell and bunch trees mechanically using a boom-mounted head equipped with high speed or high-torque saws combined with accumulator arms. The feller-bunchers are able to saw the tree as the accumulator arms clasp the tree in its head, holding it while other trees are gathered until they can be piled. Once piled, a grapple skidder equipped with a loading arm can collect the piles and take them to the landing to be delimbed, topped, and bucked into log lengths by a stroke delimber. Finally a hydraulic log loader sorts and loads the logs onto a truck. Harvesting systems offer many advantages; speed, better wood utilization due to low stumps, lower production costs, and dramatic safety increases for workers who work off the ground in the safety of a cab. The tree-length method is most applicable to clear cutting, but can be used in row thinning and partial cutting.

Cut to Length Systems (CTL) -have proven ecological and economic advantages in small timber tracts and in stands where uneven aged harvesting methods are used. CTL mainly consists of a harvester and forwarder. A harvester is a machine that can process trees in one motion with a sophisticated processor head. The harvester’s head can grasp a tree near the base and cuts it off near the ground. While the tree is still in the grip of the processor, it is delimbed, topped, and bucked into log lengths using an on-board computer that measures the tree and computes optimized cut lengths. From here the other part of the CTL system, a grapple-equipped forwarder, can pick up the cut logs, load them into its payload cradle, and carry them out off the ground instead of dragging them from the site. Cut-to-length systems have several advantages. Harvesters process the trees in the woods, leaving the tops and limbs on the forest floor where the nutrients can return to the soil. This organic material also protects the soil from compaction and rutting as the machines drive over it. Instead of skidding or dragging “turns” of logs, the self-loading forwarders carry the logs piggy-back style to the road where they load them onto trucks. This helps alleviate erosion and soil loss to the site. The need for large landings is eliminated, along with the problem of what to do with the debris (slash) which was the result of processing at the landing.

Feller-buncher

Grapple-Skidder

Harvester

Forwarder

Urban Forestry

Benefits of Urban trees

- ✓ Trees combat the climate change- Trees absorb CO_2, removing and storing the carbon while releasing the oxygen back into the air. In one year, an acre of mature trees absorbs the amount of CO_2 produced when you drive your car 26,000 miles.
- ✓ Trees clean the air
- ✓ Trees absorb odors and pollutant gases- (nitrogen oxides, ammonia, sulfur dioxide and ozone) and filter particulates out of the air
- ✓ Trees provide oxygen- In one year an acre of mature trees can provide enough oxygen for 18 people.
- ✓ Trees cool the streets and the city- Trees cool by shading homes and streets, breaking up urban “heat islands” and releasing water vapor into the air.
- ✓ Trees conserve energy-Three trees placed strategically around a single-family home can cut summer air conditioning needs by up to 50 percent.
- ✓ Trees save water- Shade from trees slows water evaporation
- ✓ Trees help prevent water pollution

- ✓ Trees reduce runoff by breaking rainfall thus allowing the water to flow down the trunk and into the earth below the tree. This prevents stormwater from carrying pollutants to the ocean.
- ✓ Trees help prevent soil erosion
- ✓ Trees shield children from ultra-violet rays
- ✓ Trees provide food
- ✓ Trees heal-Studies have shown that patients with views of trees out their windows heal faster and with fewer complications. Children with ADHD show fewer symptoms when they have access to nature.
- ✓ Trees reduce violence
- ✓ Trees create economic opportunities- Fruit harvested from community orchards can be sold, thus providing income..
- ✓ Tree plantings provide an opportunity for community involvement and empowerment
- ✓ Trees provide a canopy and habitat for wildlife
- ✓ Trees block things from view
- ✓ Trees provide wood
- ✓ Trees increase property values
- ✓ Trees increase business traffic- A tree-lined street will slow traffic – enough to allow the drivers to look at the store fronts instead of whizzing by.

These **ecosystem services** provided by trees are valuable enough wherever the tree is located, but are especially important in the urban environment,

Street tree master plans

Many urban forest management plans call for the development of a street tree master planting plan. Street tree master plans take streetscape design and species selection in to consideration. The goals of a street tree master plan commonly include:

- Choosing trees that are suited to the local environment,
- Ensuring a good match between the limitations of the planting site and the characteristics of the tree to minimize tree-hardscape conflicts,
- Diversifying tree selection within and between neighborhoods,
- Harmonizing tree selections within blocks and neighborhoods,
- Producing an aesthetically pleasant effect and sense of place that will enhance property values.

Factors to consider when evaluating a site for trees

Hardiness zone	Overhead obstructions	Compacted soil
Light exposure	Buildings	Drainage
Slope exposure	Signs	Soil depth
Wind	Vandalism potential	Water table depth
Salt	Rooting space	Underground utilities
Other trees	Soil pH	

Right tree-Right Place (From the Urban Forest Ecosystems Institute)

Utility Precautions

Planting or pruning trees near utility lines requires careful consideration.

Fire Safety

Tree species and location can influence the fire safety of your home. Although all vegetation can burn, research has shown that some resist fire better than others.

for each associated listing*:

Favorable fire performance rating is based on the following characteristics:

- a low surface area to volume ratio, such as plants with thick, broad leaves
- high moisture content,
- low % of dead matter or debris

Root Damage

Root damage is usually caused when tree roots remain close to the surface of the soil. Tree roots can cause costly damage to paving, structures or even water and sewer lines. Because roots nearer the tree trunk will enlarge earlier and grow more rapidly, care should be taken to space trees appropriately from structures. Local environmental and tree care conditions, such as soil type or watering habits, can affect a tree's root development. Long, deep waterings can encourage downward root growth. Shallow soils will force roots to grow horizontally rather than vertically.

Invasive Plants

Some plants are vigorous and aggressive plants which can be invasive in the right environment. Invasive plants harm the environment by displacing native plants and wildlife, may increase fire danger, consume water, reduce recreational opportunities, reduce or destroy production from ranch and forest lands, and take funding from other programs to fight their establishment and spread.

Hazardous Trees

Hazard tree information is an important component of the information required for successful tree ownership and care.

Correct tree selection can help avoid future hazards and conflicts as the tree matures.
Trees with defects in trunks, roots or branches can **fail.**

Tree Maintenance

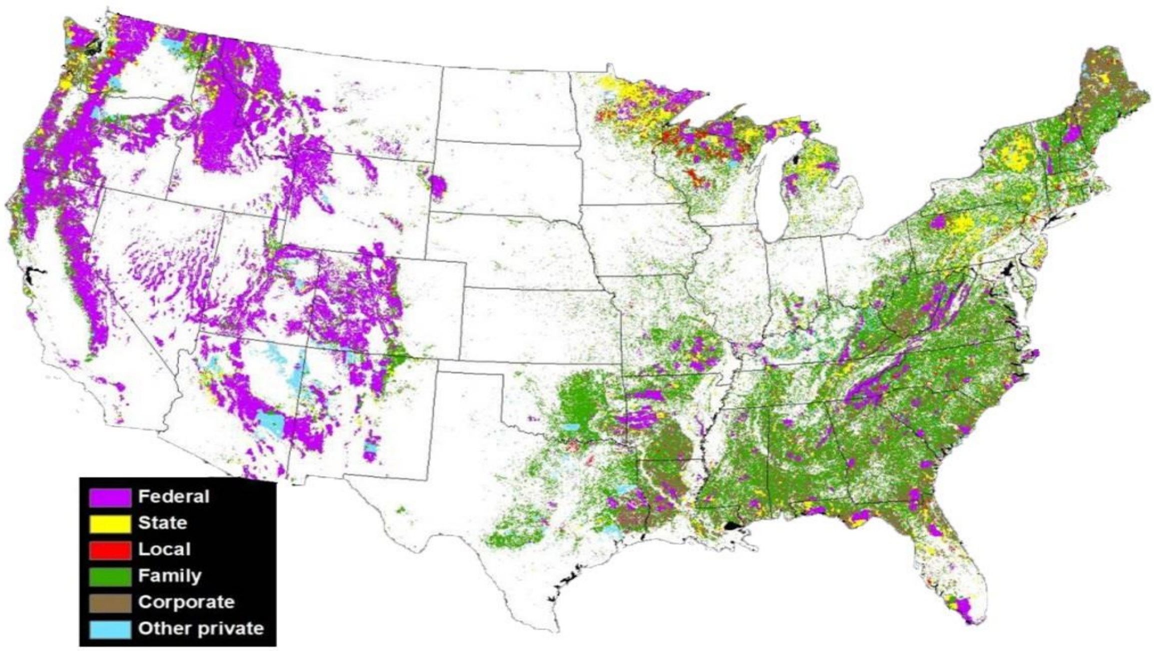
Appropriate tree selection for your planting location will lessen maintenance pruning and excessive green waste. Tree maintenance and green waste reduction begins with proper species selection and good landscape design. After selecting the right tree and the right location, proper planting, watering, feeding and pruning will lengthen a tree's life, maintain its safety and improve its aesthetics. Proper planting involves establishing the appropriate depth, providing proper growing medium, and establishing a support system for the tree.
Follow up care should include watering, mulching and minor pruning as needed.
Pruning is a key component to successful plantings. Reasons for pruning include safety, health, and aesthetics. Poor or improper pruning can lead to weak, diseased and unsightly trees. Each cut should be carefully considered and appropriately made. Proper pruning techniques are described in the following online resources.

Allergy & Toxicity

Some plants produce substances or allergenic materials which can harm humans or animals who come in contact with them.

- Allergy = the tree may cause an allergic reaction due to its airborne pollen or a chemical it extrudes onto its bark or leaves.
- Irritant = some aspects of the tree such as plant hairs, oils or odor may cause irritation to the skin, eyes, nose or throat.
- Poisonous = a substance produced by the tree can cause injury, illness or death.

Forests Reduce Climate Change(from the American Forest Foundation webpage)



The United States has more than 1.5 times as much forestland as cropland, and U.S. forests contain the majority of our carbon stocks (59%).[2] Forests and forest products currently offset nearly 13% of U.S. annual greenhouse gas emissions, which are the driving force behind climate change.[3]

FORESTS CAN DO MORE

Nationally, forest carbon sequestration has grown by 14% since 1990,[4] due in large part to reforestation of agricultural land, and forest management practices that increase growth and support forest health. Healthy forests that are actively cared for are able to store carbon through vigorous growth, and are better able to resist pathogens and insect outbreaks, as well as recover from events such as wildfires.

Our forests store 192 million metric tons of carbon per year – the equivalent of taking 135 million cars off the road. Numbers such as these provide hope that U.S. forests can continue to have a significant impact on CO_2 emissions.

FORESTS IMPACT CO_2 EMISSIONS IN MANY WAYS

1. Forests store carbon in biomass – that is, in trunks, branches, leaves, and roots, as well as in dead wood, leaf litter, and soil. This carbon storage is called sequestration. Increased forest cover means increased carbon sequestration.
2. Sequestration continues when forest products such as lumber are removed and used in construction – homes, buildings, furniture and flooring made with wood continue to store carbon. The benefits are even greater when forest products are used to replace more fossil-fuel intensive products, such as steel, concrete, or brick.[5] One of the

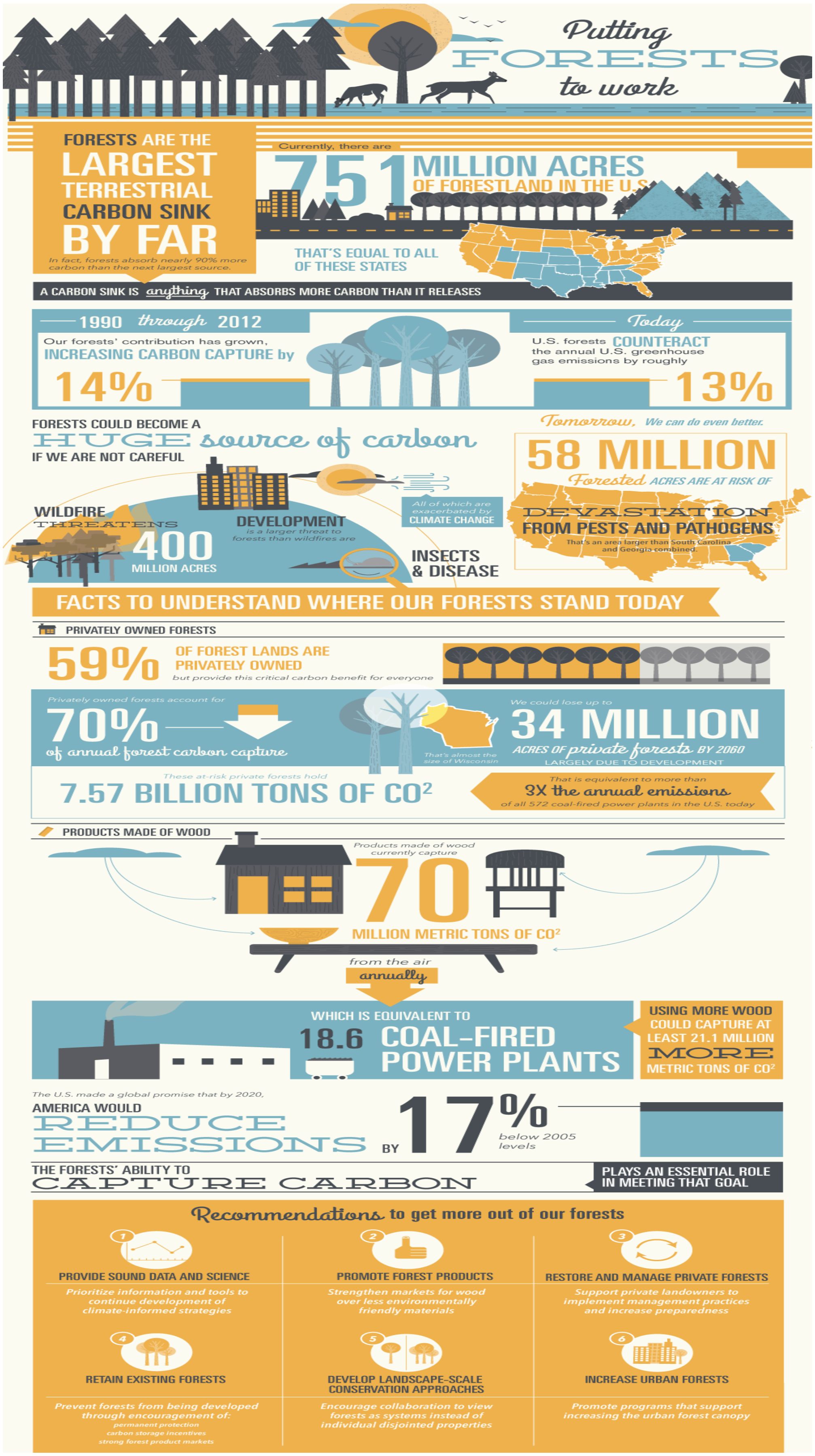
greatest benefits of using wood is that it creates a strong market for forest products, and thus a reason to prevent forests from being converted to other uses, like agriculture or development.

3. Managing forests can also reduce wildfires because potential fuel is removed. Wildfires are responsible for over 3% of annual greenhouse gas emissions in the U.S.[6] , so reducing this threat creates an additional reduction in carbon emissions.

MAXIMIZING CARBON SEQUESTRATION

Managing forests can result in more climate benefits than just leaving forests alone because management can increase forest growth and health and decrease the risk of wildfire. Forest management activities that maximize biomass production and forest health, and minimize soil disturbance are most effective at increasing forest carbon storage.

1. Image: U.S. Woody Biomass 1999-2002. Retrieved April 23, 2014 from: http://earthobservatory.nasa.gov/IOTD/view.php?id=76697
2. Nickerson, C., Ebel, R., Borchers, A., & Carriazo, F. (2011). Major Uses of Land in the United States, 2007. Economic Information Bulletin No. (EIB-89) 67 pp.
3. EPA. (2013). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012.
4. EPA. (2013). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012
5. Malmsheimer, R. W. et al. 2008. Forest Management Solutions for Mitigating Climate Change in the United States. Journal of Forestry:115–173.
6. EPA. (2013). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012


Putting FORESTS to work
FORESTS ARE THE LARGEST TERRESTRIAL CARBON SINK BY FAR
In fact, forests absorb nearly 90% more carbon than the next largest source.
Currently, there are
751 MILLION ACRES OF FORESTLAND IN THE U.S.
THAT'S EQUAL TO ALL OF THESE STATES
A CARBON SINK IS anything THAT ABSORBS MORE CARBON THAN IT RELEASES
1990 through 2012
Our forests' contribution has grown, INCREASING CARBON CAPTURE by
14%
Today
U.S. forests COUNTERACT the annual U.S. greenhouse gas emissions by roughly
13%
FORESTS COULD BECOME A HUGE source of carbon IF WE ARE NOT CAREFUL
Tomorrow, We can do even better.
58 MILLION
Forested ACRES ARE AT RISK OF DEVASTATION FROM PESTS AND PATHOGENS
That's an area larger than South Carolina and Georgia combined.
WILDFIRE THREATENS 400 MILLION ACRES
DEVELOPMENT is a larger threat to forests than wildfires are
All of which are exacerbated by CLIMATE CHANGE
INSECTS & DISEASE
FACTS TO UNDERSTAND WHERE OUR FORESTS STAND TODAY
PRIVATELY OWNED FORESTS
59% OF FOREST LANDS ARE PRIVATELY OWNED
but provide this critical carbon benefit for everyone
Privately owned forests account for
70% of annual forest carbon capture
That's almost the size of Wisconsin
We could lose up to
34 MILLION ACRES OF private forests BY 2060
LARGELY DUE TO DEVELOPMENT
These at-risk private forests hold
7.57 BILLION TONS OF CO²
That is equivalent to more than
3X the annual emissions
of all 572 coal-fired power plants in the U.S. today
PRODUCTS MADE OF WOOD
Products made of wood currently capture
70 MILLION METRIC TONS OF CO²
from the air annually
WHICH IS EQUIVALENT TO
18.6 COAL-FIRED POWER PLANTS
USING MORE WOOD COULD CAPTURE AT LEAST 21.1 MILLION MORE METRIC TONS OF CO²
The U.S. made a global promise that by 2020,
AMERICA WOULD REDUCE EMISSIONS BY 17% below 2005 levels
THE FORESTS' ABILITY TO CAPTURE CARBON
PLAYS AN ESSENTIAL ROLE IN MEETING THAT GOAL
Recommendations to get more out of our forests
1 PROVIDE SOUND DATA AND SCIENCE
Prioritize information and tools to continue development of climate-informed strategies
2 PROMOTE FOREST PRODUCTS
Strengthen markets for wood over less environmentally friendly materials
3 RESTORE AND MANAGE PRIVATE FORESTS
Support private landowners to implement management practices and increase preparedness
4 RETAIN EXISTING FORESTS
Prevent forests from being developed through encouragement of:
permanent protection
carbon storage incentives
strong forest product markets
5 DEVELOP LANDSCAPE-SCALE CONSERVATION APPROACHES
Encourage collaboration to view forests as systems instead of individual disjointed properties
6 INCREASE URBAN FORESTS
Promote programs that support increasing the urban forest canopy

Glossary

Abscission layer - layer of cells that forms at the base of each leaf petiole where it is attached to the twig when the veins that carry fluids into and out of the leaf gradually close off.
Alternate - leaves that are staggered or not placed directly across from each other on the twig.
Anthers - sac-like component of a flower where pollen grains are produced. The anthers open to release pollen.
Anthocyanins - pigments in plants responsible for pink and purple colors.
Bark - outward covering of the tree.
Base - where the point at which the leaf is joined to the stem.
Broadleaf - A tree with leaves that are flat and thin and generally shed annually.
Calyx - the outermost whorl of sepals whose job is to protect a developing flower. It is usually green and is what we would recognize as the outside covering of a bud.
Cambium - layer which forms across and between primary bundles where each year cells in this layer divide and grow. As the cambium divides, wood and bark cells form.
Carotenoids - pigments in plants responsible for yellow and orange colors.
Carpel - the female part of the center whorl of a flower. Also known as the pistil.
Chlorophyll - the green pigment in plants that absorbs energy from sunlight necessary for photosynthesis.
Chloroplast - the organelle in the cytoplasm of plant cells where chlorophyll is stored.
Compound - a leaf whose blade is divided into distinct leaflets.
Conifers - cone-bearing trees where the seeds are present in cones or catkins.
Corolla - the whorl of petals of a flower.
Deciduous - shedding all leaves annually.
Evergreen - trees with needles or leaves that remain alive and on the tree through the winter and into the next growing season.
Fertilization - joining of a sperm to an egg cell. Results in an embryo which triggers development of a seed.
Filaments - thread-like structures that support the anthers out from the flower base.
Heartwood - the inner part of the wood; also called duramen.
Lamina - the wide part of the leaf; also called the leaf blade.
Leaflet - one of the subdivisions of a compound leaf.
Opposite - 2 or 3 leaves that are directly across from each other on the same twig.
Ovary - The inner part of carpel or pistil where eggs are borne.
Palmate - having leaflets radiating out from a central point.
Pedicel (Pedicuncle) - the flower stem.
Petals - outer part of a flower; protects the inside parts of a flower.
Petiole - thin section of leafstalk joining the base of the leaf to the lamina; generally is cylindrical or semicircular in form. Also called the stalk.
Phloem - a protective layer made up of tiny tubes that transport the sugars from the leaves to the rest of the tree.
Photosynthesis - the process by which plants make sugar from sunlight, water, and carbon dioxide.
Pinnate - having leaflets on both sides of a common axis.

Pistil - Female part of a flower; also known as the carpel.
Pollination - the movement of pollen from a stamen to a pistil by **pollinators** (birds or insects).
Provascular tissue - bundles of cells in young tree shoots.
Root hairs - threadlike extensions that grow from a plant root and takes in water and minerals from the soil.
Roots - anchors the tree to the soil and absorbs water and soil minerals.
Sapwood - the outer part of the wood; also called alburnum.
Senescence - death of a leaf triggered by an increase in the enzymes that promote the breakdown of plant cells. Begins when shorter days and cooler temperatures occur.
Sepals - the separate parts of the flower calyx that is the outside covering of a bud.
Simple - a single leaf blade with a bud at the base of the leafstem.
Stamen - the male part of a flower that makes pollen.
Stigma - The sticky surface of a flower pistil on which pollen adheres during pollination.
Stomata - openings in a leaf through which gases and water enter or leave.
Style - extending from the center of a flower, it supports the stigma where pollen adheres during pollination.
Tannins - pigments in plants responsible for brown colors.
Xylem - the main part of the tree trunk made up of tiny tubes which transport water and minerals from the roots up the trunk and branches to the leaves.