

Forests and Carbon

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Authors Note: The following article is based on University of Idaho Policy Analysis Group (PAG) Issue Brief No. 11. Author Jay O'Laughlin is PAG Director and a member of the Idaho Carbon Sequestration Advisory Committee. Sources for the scientific claims and data for the figures can be found in the PAG Issue Brief document at <http://www.cnrhome.uidaho.edu/default.aspx?pid=106665>.

Introduction

Forests affect climate and climate affects forests with carbon linking the two. Forests contain three-fourths of the earth's plant biomass, about half of which is carbon. Consequently, forests play a key role in the global carbon cycle by capturing, storing, and cycling carbon.

Forests can be either a carbon "sink" or a source of atmospheric carbon. Trees absorb or "uptake" carbon dioxide (CO₂) from the atmosphere during photosynthesis, emitting oxygen while using carbon to build woody stems, branches, roots, and leaves. This carbon is stored in carbon "pools." Trees release CO₂ during respiration and after they die through decomposition or when they burn. When carbon uptake in a forest exceeds respiration and other carbon losses, forest carbon pools are increasing and carbon "sequestration" is occurring. Young forests sequester carbon faster than old forests because CO₂ uptake greatly exceeds respiration, but old forests store more total carbon than young ones. In very old forests respiration may exceed uptake, and such forests have switched from being sinks to sources of atmospheric carbon.

Carbon sequestration is the capture and storage of atmospheric carbon in other carbon pools, including forest vegetation. From 1990 through 2005, U.S. forests sequestered an annual average of 179 million tons of carbon, enough to offset about 10% of the nation's CO₂ emissions. Increased use of wood products and wood energy represent part of the solution to reducing greenhouse gases. When trees are harvested, carbon is extracted from the forest but not necessarily returned directly to the atmosphere. If trees are used to make wood products, a portion of the sequestered carbon is stored in solid form for several or more decades in the wood products carbon pool or even longer in the landfill carbon pool. If wood is used to produce energy, carbon released through combustion offsets or displaces carbon that otherwise would have been released through the burning of fossil fuels.

Positive Impacts of Forest Sector Carbon Sequestration.

- Trees remove carbon from the air and store it as wood.
- Trees and wood products have long lives.
- Wood can generate energy in biomass or co-generation facilities; indeed, most of the energy used to manufacture wood-based products is from woody biomass.
- Wood products can substitute for some concrete and steel building materials (e.g., above-grade walls in residential construction) to avoid and displace emissions associated with these energy-intensive products.

Forests can be regenerated, so while much of the carbon from a harvested forest remains sequestered in wood products, growing new trees takes more carbon out of the air.

Forest Carbon Strategies.

Forests managed for timber can help meet the world's energy needs and limit atmospheric CO₂. Strategies include: (1) increasing on-site carbon density (amount of carbon stored per acre); (2) increasing off-site use of wood to substitute for concrete or steel building materials or wood energy to displace fossil fuel energy use and emissions; and (3) increasing or maintaining the forest area by avoiding deforestation and reducing the extent of wildfires.

Storing more carbon in forests. When carbon becomes a forest management objective several factors and trade-offs need to be considered. Foremost is the trade-off between the rate of carbon uptake and the amount of carbon stored; i.e., the relative contributions of younger and older forests to carbon

sequestration. Not harvesting results in more onsite carbon storage than sequential harvest scenarios, regardless of rotation age (see **Figure 1, Page 4**). However, the fate of harvested carbon should also be accounted for.

Increasing off-site use wood as a substitute for energy-intensive building materials. Forests managed for timber production with a sequence of harvests sequester carbon on-site while trees are growing and move carbon into the off-site pool of wood products and manufacturing residues. The wood products carbon pool more than offsets harvesting and manufacturing emissions, which some groups use to challenge carbon sequestration from timber harvest. Carbon stored in wood products is gradually released as CO₂ if the wood eventually decays or burns. Wood products in landfills may store carbon for a long time, sometimes permanently. When wood substitutes for more energy-intensive products, then carbon emissions are reduced. For example, in residential construction an above-grade wall framed with concrete blocks requires 250% more energy than using kiln-dried lumber for the same purpose. Substituting lumber for cement and steel building products generates substantial benefits from energy displacement and avoided emissions. These benefits may continue almost indefinitely into the future. When wood products substitute efficiently for fossil fuel energy-intensive products, such as concrete, a sequence of sustainable harvests produces greater net carbon benefits than unused old forests (**Figure 2**).

CONTINUED ON PAGE 4

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Lichens.

Yvonne C. Barkley

Lichens - anyone that has ever walked in the forest or in rocky alpine regions has seen them - multi-colored splashes clinging to rocks and trunks of trees, gray-green cascades swaying from branches, bursts of color and fantastic shapes growing high in the forest canopy.

Lichens are ancient organisms, with the oldest recorded lichen fossil dated to be around 400 million years old. This huge group of widely diverse “plants” occupies most habitats of the earth, and is the dominant vegetation in approximately eight percent of terrestrial ecosystems. Of the 14,000 species of known lichens, 3,600 of them occur in North America.

Most lichens are temperate or arctic, though there are many tropical and desert species. Lichens will colonize almost any stable and reasonable well-lit surface. Trees, as well as the surfaces of wood, rock, soil, leaves, bone, antlers, and even abandoned cars (if left undisturbed long enough) all provide places for lichens to colonize and thrive. Lichens that grow on plants are *epiphytes*. Epiphytes are organisms that grow on other plants, attaching themselves by roots, rhizomes, or fungal strands. Epiphytes are not parasitic and do not harm or feed on the plants they are perched on - instead they use these plants as platforms to grow on. Other types of epiphytes include orchids, bromeliads, and some species of ferns. Outside coastal rainforests and the tropics, lichens are the most important epiphytes of forest trees and shrubs.

Able to withstand long periods of drought, lichens are self-sufficient, taking what few minerals and little water they need for survival from dust and available moisture. They contain their own source of carbohydrates and their *propagules* (a sexual or vegetative reproductive unit) are tiny, enabling them to become established on all but the smoothest surfaces. Because of this, lichens are often referred to as “nature’s pioneers”.

Lichens are not plants and are informally grouped with mosses, liverworts, free-living fungi, and algae under the name *cryptogams*. Cryptogams are organisms reproduce by spores instead of seeds. I think it is safe to say that lichens are related to plants but are not strictly “in the family”. These perennial, symbiotic organisms arise from a union between a fungus (the *mycobiont*) and a green algae or cyanobacterium (the *phycobiont*). Within this symbiotic organism, each member plays a crucial role. The algae are photosynthetic and supply the fungus with carbohydrates and vitamins, while the fungus extracts necessary water and minerals from the air and colonized surfaces for both it and the algae. The two components of a lichen can be separated and grown apart in a lab, but when married, form a new association that is long-lived and unlike either the fungi or algal component in structure or form.

Lichens reproduce vegetatively. Pieces containing both the fungus and algae are blown in the wind or carried by water, establishing new colonies where they land. Lichens have the ability to not simply dehydrate, but completely dry up when moisture is unavailable, becoming quite brittle. Once moisture becomes available, they fully hydrate to their former state.

Filaments from the fungal component of the lichen surround and grow into the algal cells and provide the majority of the lichen’s physical bulk and shape. Lichens vary tremendously in size, shape, and color. Some lichens are familiar, such as “reindeer moss” that grows on many trees in the Northwest. Some are many meters in length while others are less than a millimeter tall. They can stand erect and look like little shrubs, drape gracefully from tree limbs, or lie flat, looking like little more than a black spot on a rock. And they transverse the color spectrum, from brilliant yellows, reds, and greens to barely noticeable grays and whites.

People have long used lichens in a number of ways. Horsehair lichens have been eaten by the native people of the Interior Northwest and are listed as a favorite food of the Interior Salish of the Okanagan-Colville language group. Fibrous lichens have been incorporated into clothing and many species of lichens are used throughout the world to make beautiful dyes. Others are used ornamentally. Over the centuries, many cultures

have used lichens as medicines and poisons. Currently the search for new pharmaceutical uses of lichens is resulting in some promising discoveries, including one that has exhibited anti-tumor activity and another that has properties that inhibits growth of the HIV-virus. Lichens have been used as ingredients in personal products such as perfumes and can be found today in many commercial products such as deodorants and toothpastes.

Contrary to what some people think, **lichens do not injure trees**. Forest habitats actually benefit greatly from lichens that inhabit trees. As rainfall

and fog passes through forest canopies, resident lichens intercept and absorb nutrients that have been shown to have an influencing effect on the composition and concentration of nutrients in forest soils below. Lichens also increase humidity by absorbing moisture during precipitation events and releasing it afterwards.

One of the most important functions of lichens in forest environments is their ability to fix nitrogen. Atmospheric nitrogen cannot be used by plants for growth nor are useable forms of nitrogen abundant in native minerals or soils. *Nitrogen fixation* is the domain of a small group of bacteria and cyanobacterium that are able to convert atmospheric nitrogen into nitrates or ammonium compounds that are available to plants for growth. Nitrogen fixed by lichens becomes available to surrounding plants when the lichens die and decay, or when nitrogen compounds leach from living lichens.

In addition, lichens growing on rocks have been found to release chemicals that speed up the process of rocks decomposing and contributing to the production of new soils. On the down side, these same lichens can cause damage to ancient, fragile rock carvings and paintings when colonizing their surfaces. This has created a tedious process of removal and maintenance for those responsible for preserving archeological and cultural treasures.

Lichens can harbor insects, though most of these are harmless. An exception to this rule is the western hemlock looper (*Lambdina fiscellaria*), which lays its eggs on mosses and lichens that are anchored on tree limbs and trunks. The last outbreak of western hemlock looper was in north-central Idaho in 2002-2003 and, though this insect does not cause widespread mortality, it does cause severe defoliation.

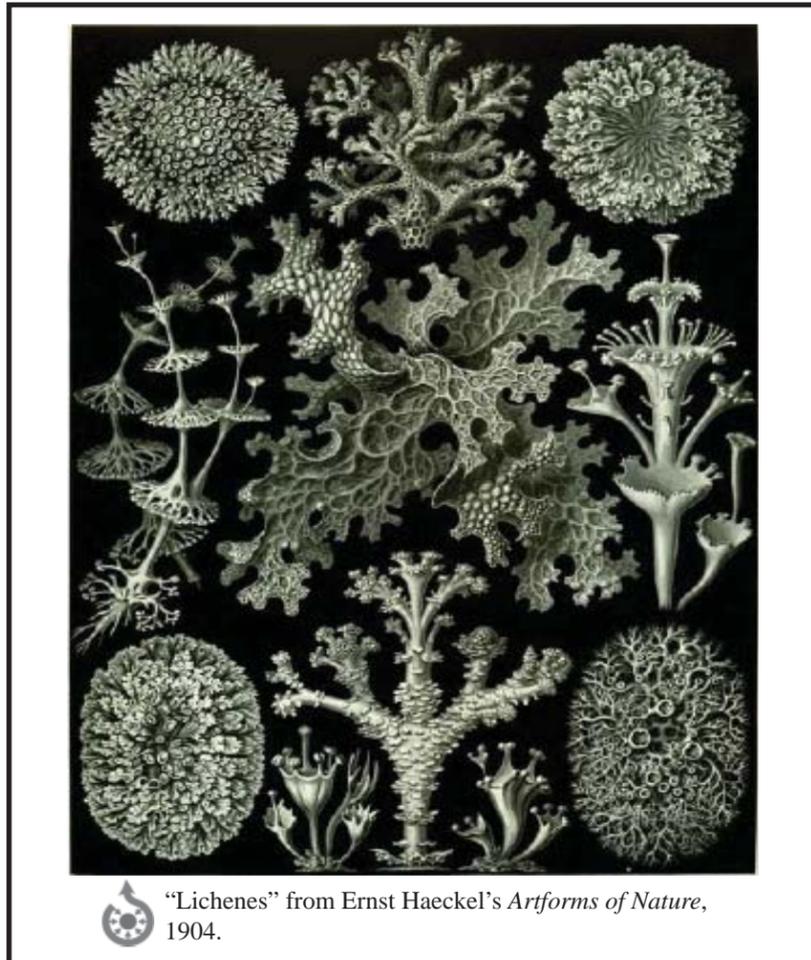
Lichens are high in carbohydrates and many animals, from mites to musk oxen, use them for food or shelter. For example, some birds and small mammals such as squirrels use lichens to build and line nests and many small mammals live in nicely camouflaged, lichen covered habitats. Lichens make up 90 percent of the winter diet of caribou and reindeer, and white-tail and mule deer, moose, elk, mountain goats, and pronghorn antelope all include lichens in their diets.

In recent years, a new use for lichens has emerged. As a group, lichens prefer unpolluted landscapes. Because they are so sensitive to pollutants, lichens are now being used as early warning systems to detect declining air quality and as indicators of ancient forests. To quote Irwin M. Brodo, one of the authors of *Lichens of North America*, “To find them in abundance is to find a corner of the universe where the environment is still pure and unspoiled.”

This fascinating group of symbiotic organisms we call lichens are not only elegant and interesting, but important and useful to humans, plants, and animals in so many ways. From food to fiber and dyes, promising medicines, nitrogen-fixers, and as early warning systems for ecosystem degradation, it is safe to say that there is much to like about lichens.

Authors note:

Portions of this article have been excerpted from *Lichens of North America* by Irwin M. Brodo, Sylvia Duran Sharnoff, and Stephen Sharnoff. 2001. Yale University Press. This is an informative and detailed book about lichens and includes over 900 fantastic colored photographs of lichens in their many and varied habitats.



“Lichenes” from Ernst Haeckel’s *Artforms of Nature*, 1904.

Mountain pine beetle

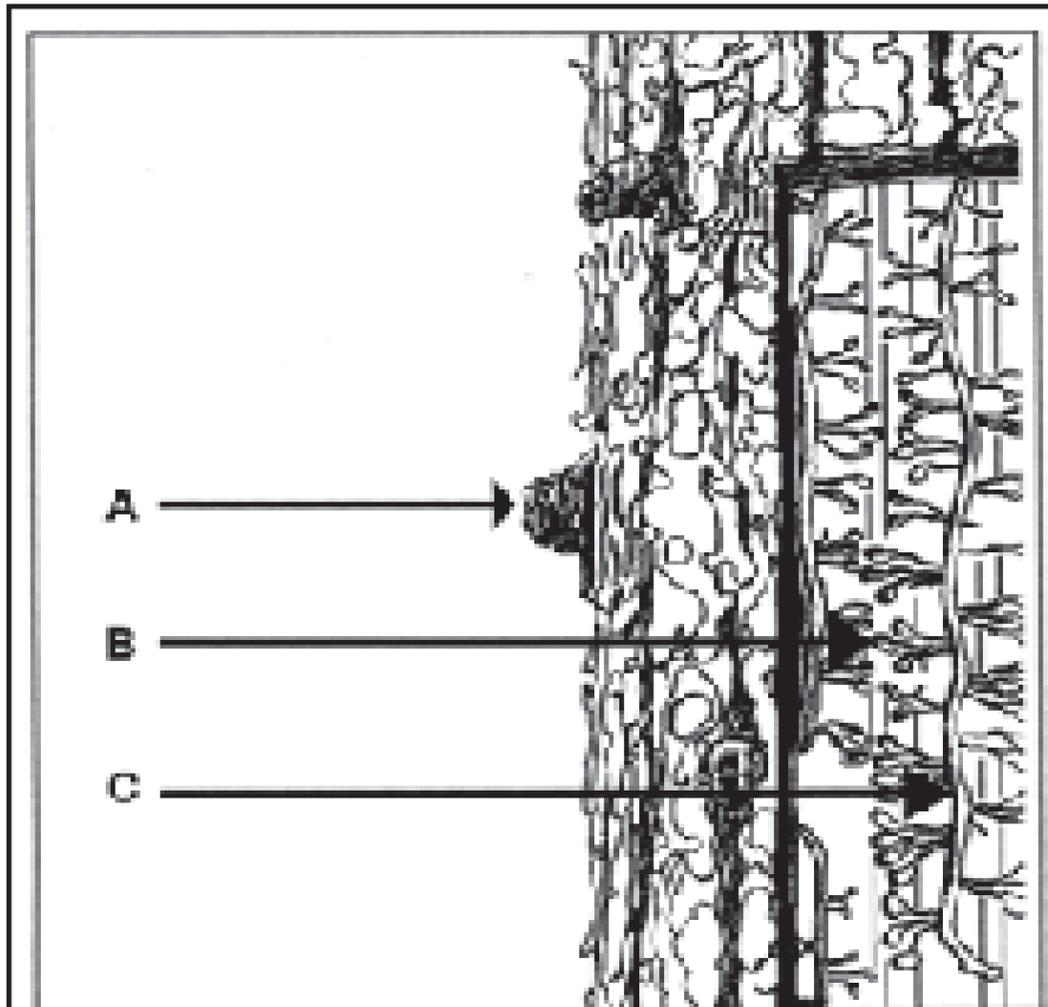
Chris Schnepf

Bark beetles are small insects about the size of a grain of rice (some are slightly larger) that feed in a tree's layer of tissue between the bark and the wood called the phloem. According to a recent booklet published by the University of Idaho on bark beetles (see references), there are 114 species of scolytids (bark beetles and similar beetle relatives) in Idaho. Most of these species do not kill trees. Of the species that do kill conifers, mountain pine beetle (*Dendroctonus ponderosae*) is currently grabbing most of the newspaper headlines.

Bark beetles often kill trees in patches. Typically, as they attack a tree, they release chemicals (aggregation pheromones) that signal "soup is on" to other bark beetles of their same species, which bring in many more beetles to that tree and its neighbors. Thousands of attacking beetles are necessary to overcome a tree's defenses. Tree death is hastened by blue stain, a fungus brought in by bark beetles that clogs water movement in the tree's sapwood.

Mountain pine beetle (MPB) can kill just a few isolated trees, but it is most famous for killing trees by the acre – sometimes thousands of acres at a time, particularly in forests dominated by lodgepole pine. If you have driven around in higher elevations in Idaho and western Montana in the last few years, you have probably seen many acres of lodgepole pine and some whitebark pine killed by mountain pine beetle. In the last few years, the forests of central British Columbia have seen truly epic numbers of trees killed by mountain pine beetles, numbering in the tens of millions of acres. Many believe the scale of MPB tree killing in Canada is partially related to climate change: longer warmer growing seasons and less-cold winters making survival and reproduction easier for mountain pine beetles in more northern latitudes. Longer, warmer growing seasons also put pines under more moisture stress, further enabling mountain pine beetles.

Identification.



Mountain pine beetle in lodgepole pine.

- A) Pitch tube on trunk
- B) Larval gallery
- C) Egg Gallery

Graphic source: Idaho Department of Lands.

The first symptom most people notice from any tree-killing bark beetle is individual trees or groups of trees with crowns that are fading from yellow, to red, to brown. Mountain pine beetles also commonly cause trees to produce thumbnail-sized globs of pitch and boring dust called "pitch tubes" on the trunk – the result of tree's effort to push the beetles out. Bark beetles are usually identified by studying the galleries they create between the bark and wood, which are distinctive for each species. Mountain pine beetle's

galleries are vertical (with the grain) slanting for 2-3 cm, then almost straight 30-90 cm long. Small groups of eggs are laid alternately along each side of this main gallery. Larvae mine a short distance (< 3cm) from where they hatch, at right angles to the main gallery.

Life Cycle.

Mountain pine beetles produce one generation per year. They spend most of their lives in the tree, except during the few weeks in the summer when adults emerge and fly to new trees to start new broods. Unlike some other Idaho bark beetle species (e.g., *Ips pini*) mountain pine beetles do not breed in slash. They require a living host.

Mountain pine beetles are most famous for attacking lodgepole pine, but they will attack all of our native pine species. Family forest owners most commonly find them in lodgepole and ponderosa pine. In the early 1900s, mountain pine beetles attacked many stands of older western white pine in Idaho. We have not had those kinds of white pine stands in Idaho for a long time, so many do not often associate this insect with white pines, even though mountain pine beetles can kill them. In recent years, mountain pine beetles have also been killing many high elevation white bark pine (*Pinus albicaulis*).

Managing forests against mountain pine beetle.

As with most forest insects and diseases, the best management for mountain pine beetle is preventative. The most common strategy is to thin forests to limit moisture stress so individual pines are less attractive to mountain pine beetle.

Beyond density management, there has been a lot of exciting research and development in the last 15 years on using pheromones to manage bark beetles. Chemically synthesized versions of the previously mentioned "aggregation" pheromones can be used to attract beetles to trees that can be removed once the beetles have taken home there. Bark beetles also use "anti-aggregation" pheromones to tell each other a tree already has more than enough bark beetles and that other bark beetles should fly to another tree. Synthetic versions of these pheromones can be used to get beetles to fly past trees where these pheromones are placed. Anti-aggregation pheromones have been used very effectively to manage Douglas-fir beetles. Mountain pine beetle anti-aggregation pheromones have also recently been registered and are now available for use by family forest owners. These pheromones have successfully protected 80-90% of trees on which they were placed but are less effective in areas with very high beetle populations.

Salvaging beetle killed trees is also a common component of mountain pine beetle management. If you want to recover trees' economic value, beetle-killed trees should be harvested as soon as possible to avoid loss of value from blue stain and other insects and fungi. Don't just take the dead trees when salvaging. Look for evidence of attacks on green trees at the edge of a beetle pocket, as they are likely to be infested. This may also be a good time to thin the rest of the stand to enhance trees' resistance to bark beetles. For more information on sanitation and salvage of beetle killed trees, see "Salvaging Beetle-killed Trees" at <http://www.cnr.uidaho.edu/extforest/SearchTopics.htm>)

References:

Mountain pine beetles are one of the more impressive forces of nature in western forests. If you would like to learn more about these insects, a great deal has been written about them. Here are some references to get you started:

Livingston, L. 2005. Mountain Pine Beetle. State Forester Forum, Insect and Disease No. 6, Idaho Department of Lands. 5 p.

Amman G.D., M.D. McGregor, and R.E. Dolph. 1990. Mountain Pine Beetle. Forest Insect & Disease Leaflet #2 . USDA Forest Service. 7 p.

Furniss, M. and B.D. Johnson. 2002. Field Guide to the Bark Beetles of Idaho and Adjacent Regions. University of Idaho Forest, Wildlife, & Range Experiment Station Bulletin #74. 125 p.

Thanks to Sandy Kegley for review and comment.

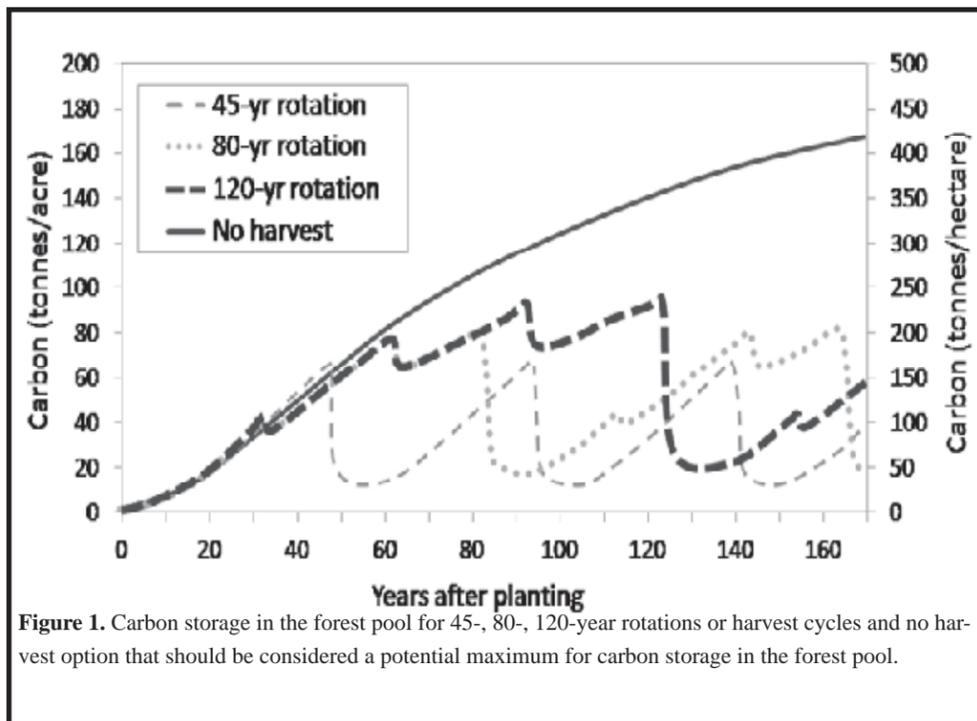


Figure 1. Carbon storage in the forest pool for 45-, 80-, 120-year rotations or harvest cycles and no harvest option that should be considered a potential maximum for carbon storage in the forest pool.

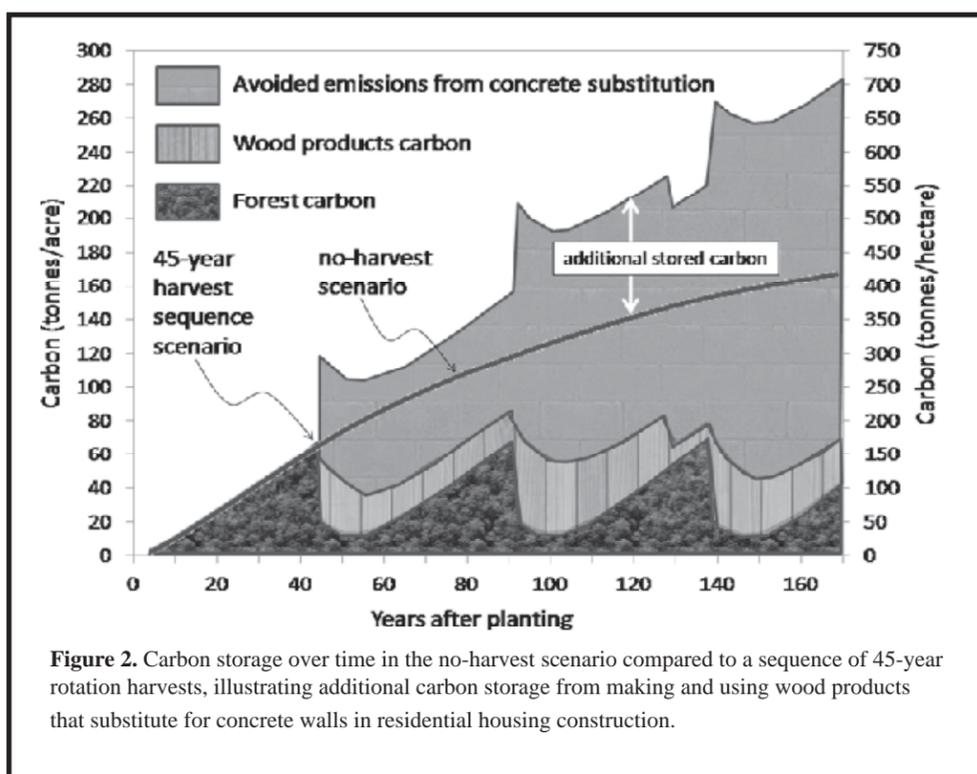


Figure 2. Carbon storage over time in the no-harvest scenario compared to a sequence of 45-year rotation harvests, illustrating additional carbon storage from making and using wood products that substitute for concrete walls in residential housing construction.

Increasing or maintaining forest area by avoiding deforestation and reducing wildfires. Much of the international focus on forest carbon stocks has been on preventing deforestation. Although some forest land is lost to urban development in the U.S., deforestation is low compared to many other countries, so other concerns may be more important. Disturbances such as fire, wind, insects, or timber harvest remove large quantities of carbon from forests. Wildfires emitted an annual average of 65 million tons of carbon in 2002-2006 as CO₂, and another 2 million tons per year as particulates. Fine particulate matter is the major pollutant in smoke, and is linked to many adverse human health effects, including premature death for people with respiratory problems.

Wildfire releases carbon into the atmosphere, whereas timber harvest can transfer a substantial amount of this carbon into the wood products pool. The releases of carbon by historic wild fires were largely offset by re-growth over longer time scales. However, the recent trend is a dramatic increase in wildfire extent and intensity (Figure 3). In the U.S. from 1970 to 1999, an annual average of 3 million acres per year burned. In 2000-2004, the annual average doubled to 6 million, and in 2005-2007, increased to 9 million acres per year; meanwhile the number of fires has stayed approximately the same since the mid 1980s. The smoke and carbon emission implications of this trend make wildland fire management urgent.

What to do?

Concerns about carbon management have created a new vector of interest directed at forest management. Issues about the potential contribution of forests to carbon sequestration discussed below include when to cut trees and wildland fire management.

Harvest or preservation? Does a forest harvested periodically for wood products sequester more carbon than an old-growth forest? Yes and no. The answer depends on three factors: (1) considering only the growth of trees, not harvesting will always sequester more carbon, regardless of the harvesting rotation age; (2) not harvesting remains the better choice even after adding off-site conversion of harvested timber into long-lived wood products; but (3) harvesting is the better choice if wood products substitute

for concrete or steel building materials to avoid emissions by displacing fossil fuel use (Figure 2), but only in forests with above-average productivity and only if the product substitution is efficient.

Research also shows that when wood products and fossil fuel-intensive product substitution are considered, the shorter the forest rotation age, the more favorable the carbon balance becomes over time. To sum up, for productive forests the reply is yes, harvested forests do sequester more carbon than preserved old forests, but only with efficient use of wood products that substitute for fossil fuel-intensive products such as concrete or steel, and/or using wood products manufacturing residues to displace fossil fuel energy use. For forests with below-average productivity and/or inefficient use of wood products to displace fossil fuels, the reply is no.

Wildland Fire Management. A century of fire suppression in the interior northwest has created fuel conditions that lead to very large, intense, and destructive wildfires. **In Idaho, emissions of CO₂ from wildfires during 2006 were 1.6 times greater than annual fossil fuel-burning emissions from vehicles, industry and other sources in the state.** Reducing fuels can reduce wildfire emissions. As a first step in increasing carbon sequestration in the forest sector, the federal government should examine how it can modify management practices on its extensive lands to emphasize carbon sequestration consistent with other management objectives such as habitat protection, erosion control, and timber production. The most promising action is to reduce the risk of stand-replacing wildfires. Others include use of wood products in “green” building certification programs, and in carbon credit offset programs designed to reduce CO₂ emissions.

Conclusion.

Although increasing the growth rates or carbon storage of existing forests, the use of wood products, and tree planting provide carbon benefits, larger benefits may come from avoiding deforestation and reducing wildfires. Forest management cannot fully solve the problem of carbon accumulation in the atmosphere, but it can contribute significantly to the solution. Over the course of the next 50 years, reforestation, afforestation (planting previously unforested areas), and reduced deforestation globally could provide a cumulative additional sequestration of 28 billion tons of carbon. This is similar to the effect of doubling the fuel economy of cars. Increased carbon storage, in combination with a host of emission reduction measures, can help reduce, and even end, the ongoing rise of carbon concentration in the atmosphere. Consider, however, that although existing forests annually sequester enough carbon to offset 10% of the nation’s annual CO₂ emissions, attempting to attain a similar amount of offset by afforestation would require new forest plantations covering an area the size of the state of Texas. Although there are many ways to improve our planet’s carbon balance, some strategies such as wildfire reduction are more effective than others, and most have additional benefits such as reducing demand for oil or improving air quality.

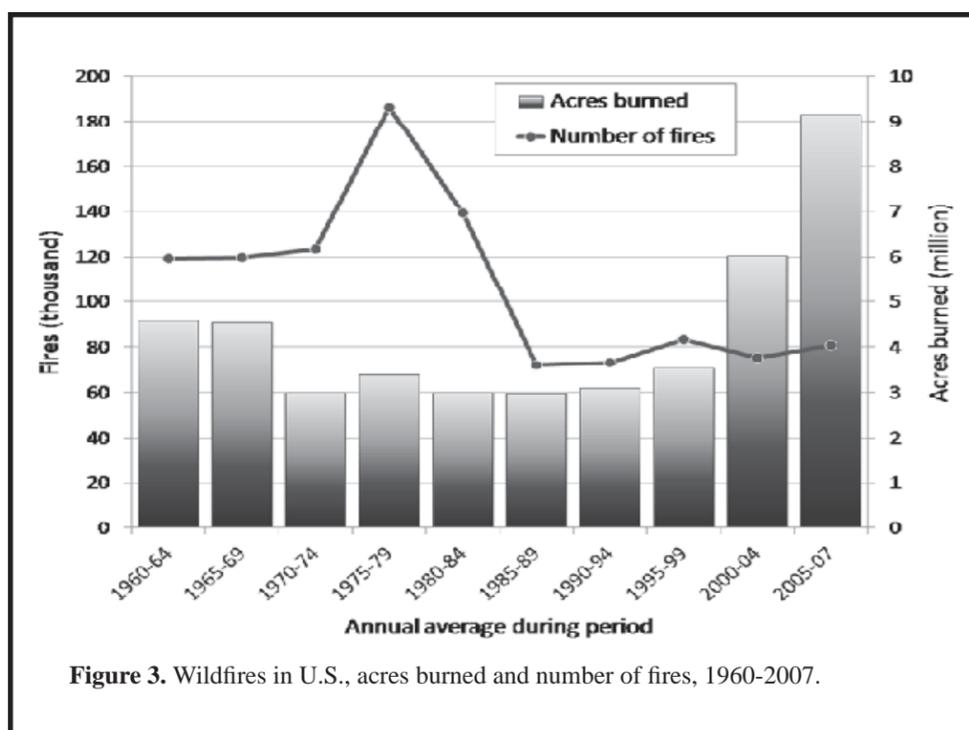


Figure 3. Wildfires in U.S., acres burned and number of fires, 1960-2007.