

WILD CARBON SUPPLEMENT

Analysis of sequestration in old forests

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In recent years, carbon has dominated many conversations among policy makers and conservationists. Questions abound on the topic such as: What is the difference between carbon storage and carbon sequestration? What role does forest carbon play as a natural climate solution? How does forest management, or lack thereof, impact forest carbon? In 2019, Northeast Wilderness Trust released *Wild Carbon: A Synthesis of Recent Findings* as part of our Wild Works series to help answer some of these questions and settle the debate on old forest carbon storage.

When it comes to avoiding the worst potential impacts of climate change, time is of the essence. Today, most forests across the

Northeast are relatively young. Thus, policy makers and conservationists are seeking clarity on what tactics to employ at this exact moment in history to maximize carbon storage *and* sequestration. This Wild Carbon Supplement aims to address ongoing confusion about carbon sequestration in young versus old forests. Once again, the science points to the power of wilderness. The studies summarized in the 2021 supplement to Wild Carbon demonstrate that allowing existing forests to grow old and wild is a critical carbon strategy and an essential natural climate solution.

—Jon Leibowitz, Executive Director

It is now well-accepted that old forests store large amounts of carbon, but there is controversy over the age at which forests sequester the most carbon annually (i.e. remove carbon from the atmosphere and fix it as biomass). The confusion arises because young trees grow in height faster than old trees and thus the rate of sequestration in a young forest can be very high. However, in the words of a carbon scientist friend, it is “not the rate we are interested in but the volume.” As with a bank account, it is not how fast deposits are made but how large those deposits are, and young forests are limited in the size of the deposits they make by their leaf area.

This was demonstrated in 2001 by a team of researchers at Oregon State University. Led by Beverly Law, they implemented a gold-standard and labor-intensive study that measured and compared all the carbon stocks and fluxes occurring in the same forest type at different stages of development. This was done in eastern Oregon, where they compared an old mixed-age stand (50–250 years) with a recently cut stand (17 years ago) within the same dry ponderosa pine forest (Figure 1).

Net sequestration is the difference between how much carbon the forest **absorbs** from photosynthesis minus how much it **emits** through respiration. The former is a function of the leaf area index (LAI), which is the total surface area of all leaves. The

latter is a function of cell respiration in soils, roots, woody debris, trunk, branches, and leaves.

The study’s results showed clearly that when all fluxes were accounted for, the old forest was **sequestering carbon** at a rate of 28 grams/meter²/year, while the young forest was **losing carbon** at a rate of -32 g/m²/year. The loss was due to the leaf area index being too small to compensate for soil respiration. The authors concluded that because the LAI is almost always small in a young forest, it takes 20–30 years for a young forest to become a carbon sink, and during that time it emits carbon every year.

Similar dynamics occur in eastern forests. A carbon study of an early successional hardwood site in Massachusetts showed that the site became a net emitter of carbon immediately after harvest and was expected to return to being a sink after 10–15 years, assuming no other disturbance (Finzi et al. 2020). Eastern forests, however, show considerably larger carbon stocks and 7–10 times higher rates of carbon sequestration than the dry forests of eastern Oregon (Table 1). This may help them recover quickly where the leaf area index is large enough that net primary productivity surpasses respiration.

The often-touted fast growth and high sequestration **rate** of young eastern forests (optimized at 30–70 years) helps the forest return to its previous state as quickly as possible, but it is helpful to remember that recovery is a two-step process. First, the forest must regrow its leaf area and return to being a carbon sink (10–30 years). Second, because the forest has been losing carbon, it must make up for those losses before it reaches neutrality. If we assume it takes an equal amount of time to replace the carbon as it did to lose it, then after 20–60 years the forest may just have compensated for the early losses from respiration and will again start to sequester “new” carbon. Comparing this cycle to that of an old forest slowly and steadily sequestering carbon every year over the same timespan, *the old forest will remove considerably more carbon from the atmosphere despite its slower growth rate* (Table 1).

The science is clear, but the full story is both messier and more hopeful. Messier, because forests are subject to natural disturbances such as fires, windstorms, and insect outbreaks that affect carbon



The carbon fluxes of Howland Research Forest in Maine, which is protected as forever-wild by Northeast Wilderness Trust, have been studied for decades. The results show a high carbon storage and sequestration potential of wild northeastern forests.

FIGURE 1) CARBON FLUXES AND STOCKS IN FORESTS

All fluxes and stocks shown here were measured in ponderosa pine forests in Oregon by Law et al. 2001. Arrows show carbon fluxes. “Carbon in” (yellow) is sequestration by photosynthesis. “Carbon out” (blue) is carbon loss from respiration. Total carbon stock is shown as a sum of the size of each pool. Carbon stock in the old forest was double the young.

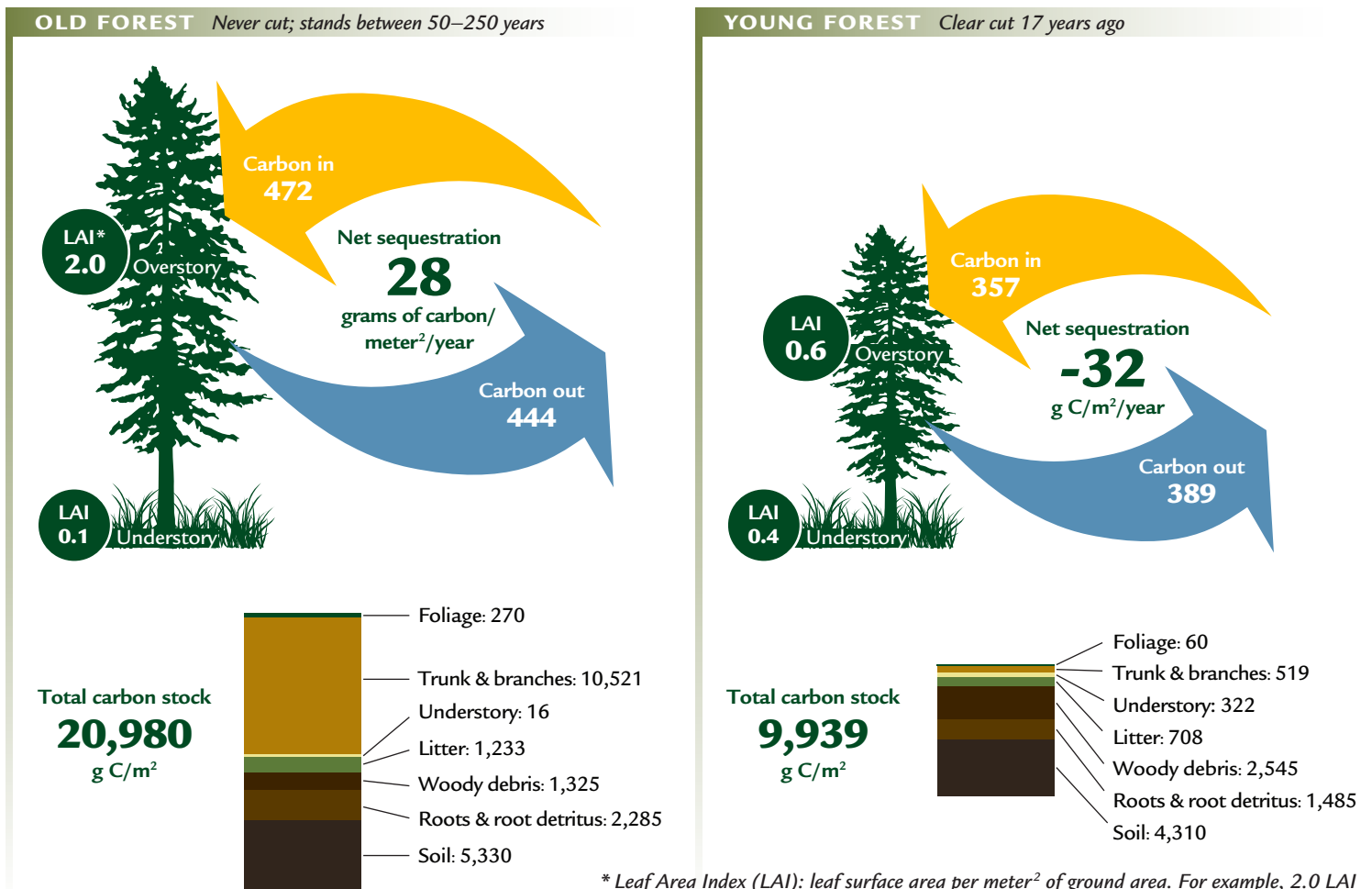


TABLE 1) COMPARISON OF CARBON STOCKS AND ANNUAL SEQUESTRATION (g/m²/year)

State	OR	OR	ME	MA	MA
Forest Type	Ponderosa Pine	Ponderosa Pine	Red Spruce- Eastern Hemlock	Red Oak- Red Maple	Eastern Hemlock- White Pine
Stand Age (years)	17	50–250	100–200	80–120	100–230
Total Carbon Stock	9,939	20,980	23,300	29,580	34,573
% above ground	9	52	45	40	40
% below ground	49	35	48	53	54
% debris	42	13	7	7	6
In: Net Primary Productivity	357	472	629	733	746
Out: Respiration	389	444	418	435	281
Carbon Flux (In – Out = Sequestration)	-32	28	211	298	465

Data sources: Law et al. 2001 (Oregon), Finzi et al. 2020 (Massachusetts), Hollinger et al 2021 (Maine)

storage in ways similar to timber harvest. The Massachusetts hemlock forest data in Table 1 were collected just before an outbreak of the insect pest hemlock wooly adelgid (*Adelges tsugae*). This resulted in a steep decline in ecosystem productivity and reset the forest from a carbon sink to a temporary source, until the leaf area grows back (Finzi et al. 2020). Still, natural disturbances such as this also offer hope as they rejuvenate wild forests with an influx of abundant coarse woody debris, an important feature largely missing from northeastern forests. These downed logs and branches help mediate carbon loss, maintain root-mycorrhizal relationships, and increase biodiversity and wildlife abundance.

In addition to the benefits of wild forests, hope can also be found in the way that foresters are improving management practices. Retention forestry, longer rotations, and attention to soil carbon pools can promote both carbon and diversity in managed forests. Post-harvest practices that reduce carbon waste during the processing, transportation, and use of wood products is an active area of research with much promise. A better understanding of the dynamics of sequestration and storage again demonstrates that allowing existing forests to grow old and wild is necessary, and complementary to exemplary forestry.

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The amount of space that the leaves in a forest canopy take up determine how much carbon can be taken out of the atmosphere by that forest. Older forest stands have more leaf area, resulting in larger "deposits" of carbon.

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