NORTHEAST WILDERNESS TRUST
WILD WORKS VOLUME 1

WILD CARBON

A synthesis of recent findings

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We find ourselves not at the edge of a precipice, but beyond it. Climate change is altering the world as we know it, no matter how quickly we act to reduce our collective carbon footprint. But the worst impacts are still avoidable with natural climate solutions. Permanently protecting forests and allowing them to grow in landscapes free from direct human manipulation is proving to be one of the most effective and cost efficient methods available to address the climate crisis. While wild nature has a right to exist simply for its intrinsic value, recent science is shedding peer-reviewed light on the exceptional carbon storage capacity of unmanaged land, and its equally important benefits for safeguarding biodiversity. In this short synthesis, ecologist Mark Anderson summarizes recent studies which demonstrate that in our fragmented, fast-developing world, wilderness offers the earth and its community of life the precious gift of time.

—Jon Leibowitz, Executive Director, Northeast Wilderness Trust

A long-standing debate over the value of old forests in capturing and storing carbon has prompted a surge of synthesis studies published in top science journals during the last decade. Here are five emerging points that are supported by solid evidence.

1) Trees accumulate carbon over their entire lifespan. Plants absorb carbon dioxide from air and transform it into carbon-rich sugars. These are then converted to cellulose to create biomass (trunk, bark, leaf) or transferred below-ground to feed the root-fungal networks. Over the long lifespan of the tree, large amounts of carbon are removed from the air and stored as biomass. Growth efficiency declines as the tree grows but corresponding increases in the tree's total leaf area are enough to overcome this decline and thus the **whole-tree carbon accumulation rate increases with age and size** (Figure 1). A study of 673,046 trees across six countries and 403 species found that at the extreme, a large old tree may sequester as much carbon in one year as growing an entire medium size tree (Stephenson et al. 2014). At one site, large trees comprised 6 percent of the trees but 33 percent of the annual forest growth. Young trees grow fast, but old trees store a disproportional amount of carbon.

2) Old forests accumulate carbon and contain vast quantities of it. Old-growth forests have traditionally been considered negligible as carbon sinks. Although individual trees experience an increasing rate of carbon sequestration, forest stands experience an "S-curve" of net sequestration rates (e.g. slow, rapid, slow). The expected decline in older stands is due to tree growth being balanced by mortality and decomposition. To test the universality of carbon neutrality in old forests, an international team of scientists reviewed 519 published forest carbon-flux estimates from stands 15 to 800 years old and found that, in fact, net carbon storage was positive for 75 percent of the stands over 180 years old and the chance of finding an old-growth forest that was carbon neutral was less than one in ten (Luyssaert et al. 2014). They concluded that **old-growth forests are usually carbon sinks, steadily accumulating carbon and containing vast quantities of it**. They argued that carbon-accounting rules for forests should give credit for leaving old-growth forest intact. This is important globally, as old forests in the tropics have acted as long-term net biomass/carbon sinks but are now vulnerable to edge effects, logging and thinning, or increased mortality from disturbances (Brienen et al. 2015, Lan Qui et al. 2018).

3) Old forests accumulate carbon in soils. The soil carbon balance of old-growth forests has received little attention, although it was generally accepted that soil organic carbon levels in old forests are in a steady state. In 2017, Guoyi Zhou and colleagues measured the 24-year dynamics of the soil carbon in an old-growth forest at China's Dinghushan Biosphere Reserve. They found that **soils in the top 20-cm soil layer accumulated atmospheric carbon at an unexpectedly high rate**, with soil organic carbon concentration increasing from about 1.4 percent to 2.4 percent

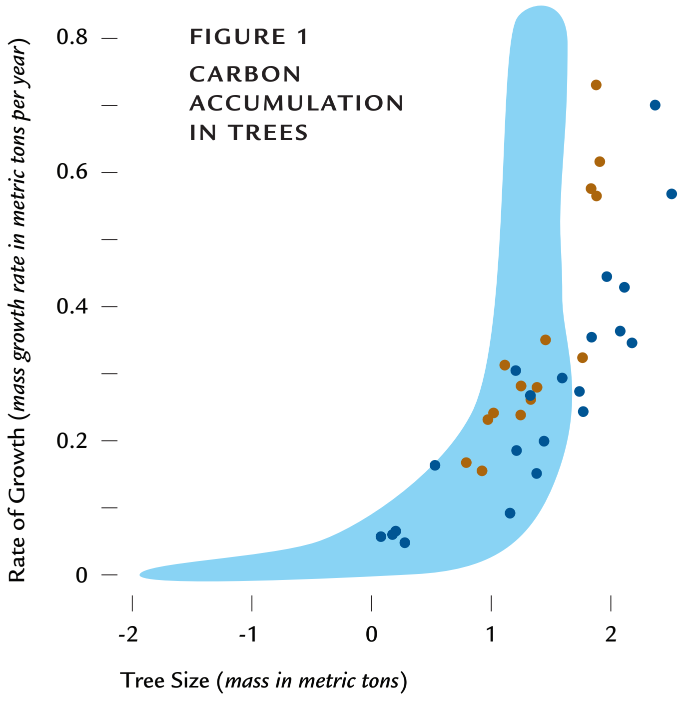


FIGURE 1
CARBON ACCUMULATION IN TREES

Aboveground mass growth rates for 58 species (shaded area) juxtaposed with two of the most massive tree species on earth: Swamp Gum (*Eucalyptus regnans*—brown dots) and Coast Redwood (*Sequoia sempervirens*—blue dots). Mass growth rate equals the total mass accumulated each year after accounting for respiration. The mass of a tree is primarily carbon, so the figure shows that annual carbon accumulation increases with the size of the tree. (Adapted from Stephenson et al. 2014.)

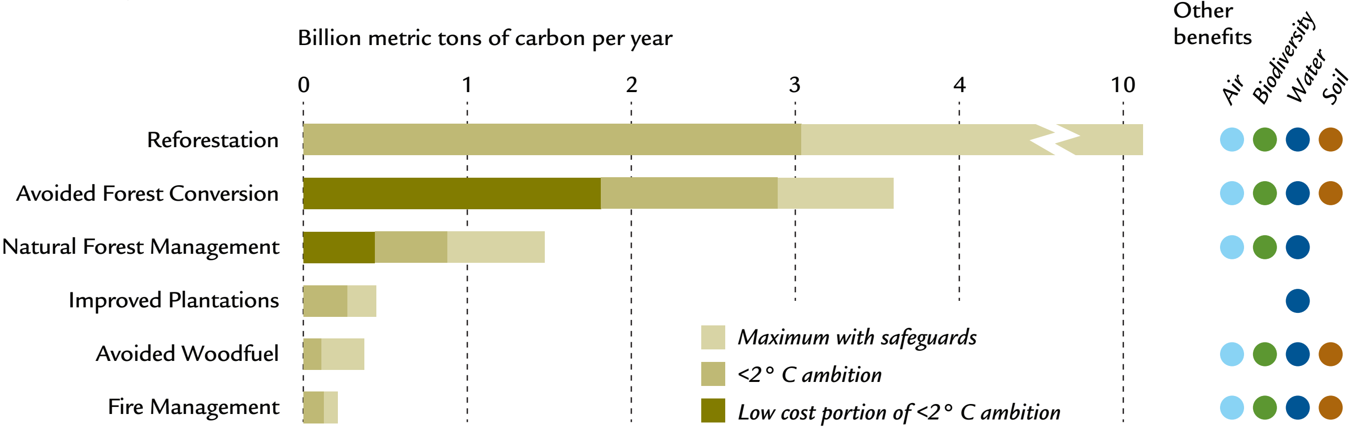
and soil carbon stock increasing significantly at an average rate of 0.61 metric tons of carbon per hectare per year (Zhou, G. et al. 2006). Their result directly challenges the prevailing belief in ecosystem ecology regarding carbon budget in old-growth forests and calls for further study.

4) Forests share carbon among and between tree species. Forest trees compete for light and soil resources, and competition for resources is commonly considered the dominant tree-to-tree interaction in forests. However, recent research made possible by stable carbon isotope labeling indicates that trees interact in more complex ways, including substantial exchange and sharing of carbon. In 2016, Tamir Klein and colleagues applied carbon isotope labeling at the canopy scale, and found that carbon assimilated by a tall spruce was traded with neighboring beech, larch, and pine trees via overlapping root spheres. Aided by mycorrhiza networks, **interspecific transfer accounted for 40 percent of the fine root carbon** totaling roughly 280 kilograms per hectare per year tree-to-tree transfer (Klein et al. 2016). In a subsequent study, Morrie et al. (2017), found that mycorrhiza soil networks become more connected and take up more carbon as forest succession progresses even without major changes in dominant species composition.

A large old tree accumulates impressive amounts of carbon every year while also releasing oxygen, filtering pollution, and creating food and habitat for wildlife.

5) Forest carbon can help slow climate change. There has been debate about the role of forests in sequestering carbon and the role of land stewardship in achieving the Paris Climate Agreement goal. In 2017, Bronson Griscom and colleagues systematically evaluated twenty conservation, restoration, and improved land management actions that increase carbon storage and/or avoid greenhouse gas emissions. They found the maximum potential of these natural climate solutions was almost 24 billion metric tons of carbon equivalent per-year while safeguarding

FIGURE 2) CLIMATE MITIGATION POTENTIAL



Climate mitigation potential of six forest pathways estimated for reference year 2030. Bars represent maximum possible with safeguards (i.e. constraints applied to safeguard the production of food and fiber and habitat for biological diversity). Darker portions represent cost-effective mitigation levels assuming a global ambition to hold warming to <2° C. Darkest portions indicate low cost portions. Ecosystem service benefits linked with each pathway are indicated by colored dots for biodiversity, water (filtration and flood control), soil (enrichment), and air (filtration). (Adapted from Griscom et al. 2017.)

food security and biodiversity. About half of this could be delivered as cost-effective contributions to the Paris Agreement, equivalent to about **30 percent of needed mitigation as of 2030**, with 63 percent coming from forest-related actions (Figure 2). **Avoided forest conversion** had the highest carbon potential among the low-cost solution (Griscom et al. 2017). New research suggests this strategy is the most cost-feasible option by a large margin (Busch et al. 2019) and it should receive high priority as a policy consideration in the U.S. (McKinley et al. 2011). An analysis of 18,507 forest plots in the Northeast found that old forests (greater than 170 years) supported the largest carbon pools and the highest simultaneous levels of carbon storage, timber growth, and species richness (Thom et al. 2019). In addition to carbon, old forests also build soil, cycle nutrients, mitigate pollution, purify water, release oxygen, and provide habitat for wildlife.

CONCLUSION

Recently published, peer-reviewed science has established that unmanaged forests can be highly effective at capturing and storing carbon. It is now clear that trees accumulate carbon over their entire lifespan and that old, wild forests accumulate far more carbon than they lose through decomposition and respiration, thus acting as carbon sinks. This is especially true when taking into account the role of undisturbed soils only found in unmanaged forests. In many instances, the carbon storage potential of old and wild forests far exceeds that of managed forests. We now know that the concept of overmature forest stands, used by the timber industry in reference to forest products, does not apply to carbon.

In the Northeast, a vigorous embrace of natural climate solutions to mitigate global overheating does not require an either/or choice between managed and unmanaged forests. **Conserving unmanaged wild forests is a useful, scalable, and cost-effective complementary strategy to the continued conservation of well-managed woodlands.**

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