Wild Carbon & Wild Forests

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Recent findings on carbon storage in old-growth forests

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 seven emerging points that are supported by solid evidence.

1. Trees accumulate carbon as long as they live

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 (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 more carbon.**

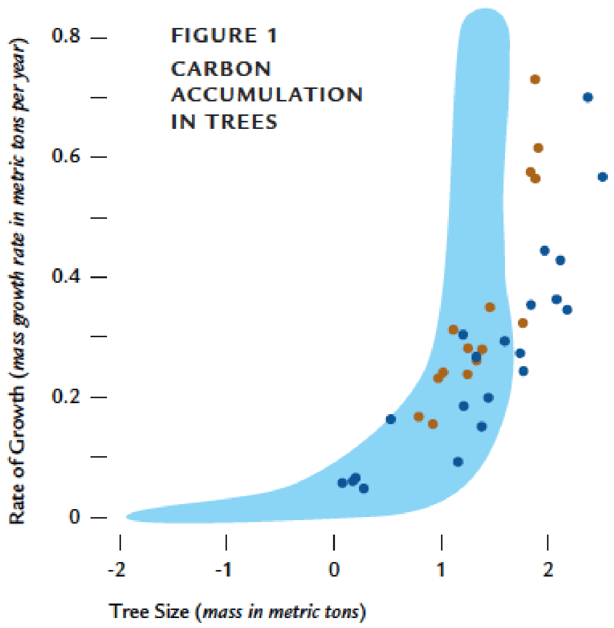


FIGURE 1
CARBON ACCUMULATION IN TREES

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.)

2. Old-growth forests accumulate and store vast quantities of carbon

Old forests accumulate carbon and contain vast quantities of it. Old-growth forests have traditionally been considered negligible as carbon sinks. However, 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. 2008). 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 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 Qie et al. 2017).

3. Old forests accumulate carbon in soils

Old forests accumulate carbon in soils. 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 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.


Photo by Robert Llewelyn

4. Carbon-sharing among and between tree species

Forests share carbon among and between tree species. Recent research made possible by stable carbon isotope labeling indicates that trees interact in 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.

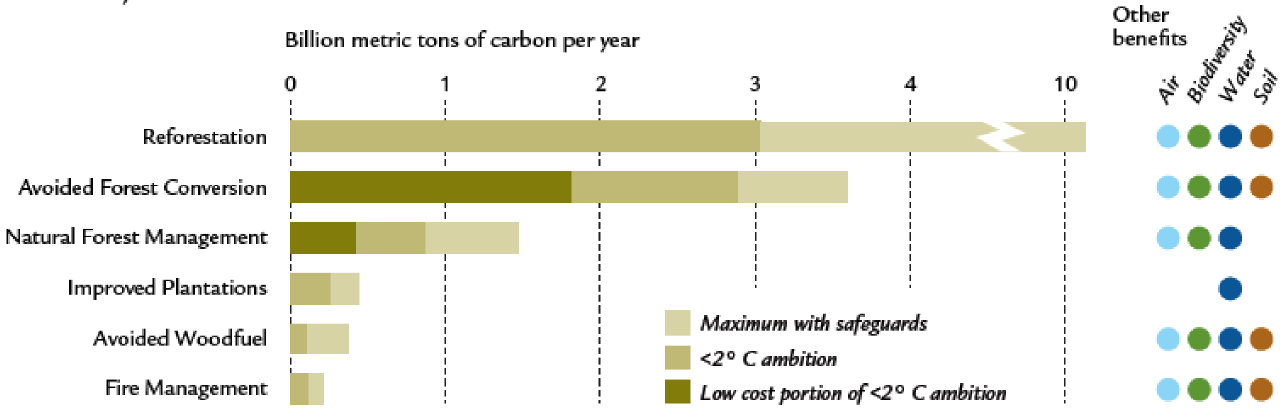
5. Forest carbon storage can help slow climate change

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 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 solutions (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.**

6. Forests cannot store large amounts of carbon without large trees

A global study done by 98 researchers who measured over five million trees found that **the largest 1% of trees in a forest equaled over 50% of the total carbon containing biomass**. Even large numbers of small and medium diameter trees could not equal the biomass in a few large diameter trees. Consequently, if the largest trees in a forest are removed it may take centuries for a forest to recover full carbon storage ability. Therefore, the team concluded that forests should be handled in a way that conserves large diameter trees and trees with the potential to become large. Unfortunately, a study led by Lindenmayer (2012) found that large old trees are declining worldwide. Large old trees are often intentionally removed during logging, land clearing, agricultural intensification, fire management, and for human safety.

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.)

7. Timber harvesting reduces carbon capture

When forests are harvested, more carbon remains in the atmosphere, both from the decline in carbon capture by the living trees, and from the release of carbon from the forest soil after the harvest. The replacement of older forests with younger forests results in a net release of carbon to the atmosphere. Increased carbon resulting from harvesting is five times the amount released from fire, insects, wind storms, development, and drought, combined. If current management practices continue, the world's forests will achieve only half of their biological carbon sequestration potential. The global carbon sink could be substantially increased if forests were managed with carbon sequestration as a goal (Harris et al. 2016).

Nunery and Keeton (2010) calculated that even with consideration of the carbon sequestered in harvested wood products, unmanaged northern hardwood forests would sequester 39 to 118% more carbon than any of the management options evaluated. Therefore, **growing existing trees intact, called proforestation, will sequester more carbon than newly planted and young trees**.

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 most instances, the carbon storage potential of old and wild forests far exceeds that of managed forests. We now know that the concept of "over mature" forest stands, used by the timber industry, does not apply to carbon. **Conserving unmanaged wild forests is a useful, scalable, and cost-effective complementary strategy for reducing atmospheric carbon.**


Photo by Robert Llewelyn

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References

Stephenson et al. 2014. Rate of tree carbon accumulation increases continuously with tree size. Nature 507: 90–93. doi:10.1038/nature12914

Luyssaert et al. 2008. Old-growth forests as global carbon sinks. Nature 455: 213–215. doi:10.1038/nature07276

R. J. W. Brienen, R. J. W., et. al. 2015. Long-term decline of the Amazon carbon sink. Nature 519: 346–347.

Lan Qie et al. 2017. Long-term carbon sink in Borneo's forests halted by drought and vulnerable to edge effects. Nature Communications 8: 1966.

Zhou, G. et al. 2006. Old-Growth Forests Can Accumulate Carbon in Soils. Science 314(1): 1417.

Klein et al. 2016. Belowground carbon trade among tall trees in a temperate forest. Science 352(6283): 342–344.

Morrie et al. 2017. Soil networks become more connected and take up more carbon as nature restoration progresses. Nature Communications 8: 14349.

Griscom, B.W., Adams, J., et al. 2017. Natural Climate Solutions. PNAS 114(44): 11645–11650.

Busch J, et al. 2019. Potential for low-cost carbon dioxide removal through tropical reforestation. Nature Climate Change 9: 463–466.

McKinley, D.C. et al. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. Ecological Applications 21(6): 1902–1924.

Thom et al. 2019. The climate sensitivity of carbon, timber, and species richness covaries with forest age. Global Change Biology 25: 2446–2458.

Lutz, J. A. et al. 2018. Global importance of large-diameter trees. Global Ecology and Biogeography 27(7): 849-864.

Lindenmayer, D. B. et al. 2012. Global Decline in Large Old Trees. Science 338: 1305.

Harris et al. 2016. Attribution of net carbon change by disturbance type across forest lands of the conterminous United States. Carbon Balance and Management 11: 24.

Nunery, J. S. and Keeton, W. S. 2010. Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. Forest Ecology and Management 259: 1363–1375.

Moomaw W. R., Masino S. A., and Faison E. K. 2019. Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good. Frontiers in Forests and Global Change 2: 27.