Measuring forest carbon

The amount of forest carbon is estimated using easily collected tree inventory data (diameter and height) and established equations based on real samples. Scientists weighed parts of trees to derive species-specific equations that are based on a set ratio between a tree's diameter, height, and weight. Carbon content can easily be estimate from the weight of wood because a tree is about 50% carbon. For rotten trees, dead trees, or dead wood on the ground, decay is factored in the amount of decay because as a tree decomposes, it loses carbon – emitted back to the atmosphere through decomposition or added to the soil carbon pool. Soils are the hardest carbon pool to estimate because soil is highly variable even over a small area. Soils can range in depth from a few inches to many feet. Soil carbon is usually estimated from samples that are burned in a laboratory where the emitted carbon can be captured and measured.

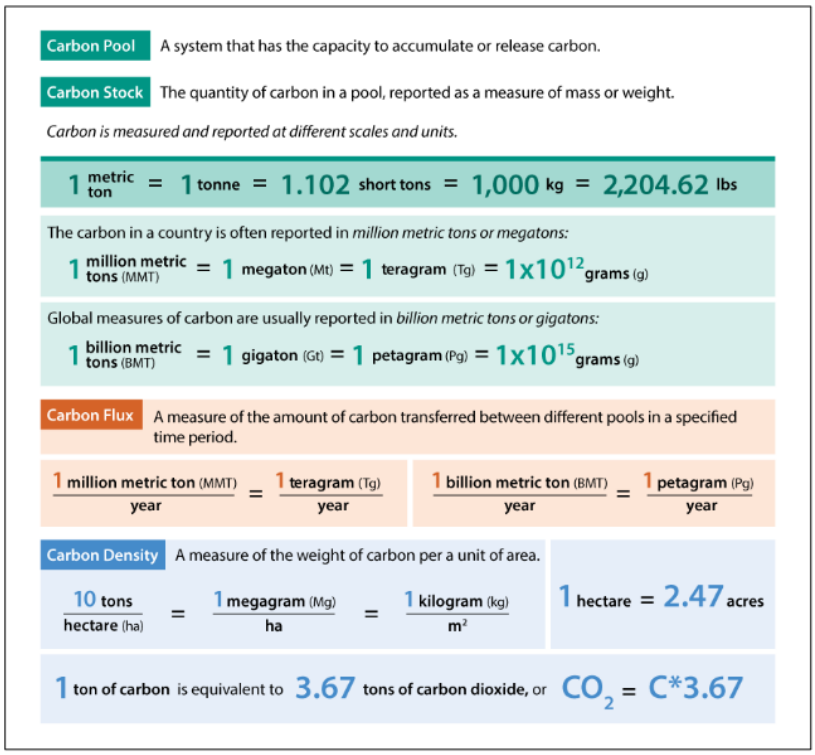


Figure 1 Source: Congress.gov

Carbon in a single tree

A single sugar maple tree with a trunk 10 inches in diameter stores about 0.75 Mt CO_2e[1] (metric tons of carbon dioxide equivalent – see Figure 8). If this tree grows a quarter of an inch in diameter (to 10¼ inches in diameter), it sequesters and stores an additional 0.04 Mt CO_2e. This is roughly equivalent to the amount of CO_2e emitted by driving a car about 100 miles.

In comparison, a 20-inch diameter sugar maple stores 4 Mt CO_2e (Figure 9), or about five times more carbon than the smaller sugar maple. As trees are three-dimensional in shape, the doubling of a tree's diameter results in a much larger increase in the tree's total size. The larger tree has more wood volume in the trunk, bark, branches, and roots. If the 20-inch tree also grows a quarter of an inch, it sequesters and stores an additional 0.1 Mt CO2e -- more than twice the increase in the tree's total size.

Note: The content of this publication draws heavily on several similar publications produced by the Vermont Department of Forests, Parks and Recreation.

The larger tree has more wood volume in the trunk, bark, branches, and roots. If the 20-inch tree also grows a quarter of an inch, it sequesters and stores an additional 0.1 Mt CO2e -- more than twice the amount of the smaller tree. Because a tree must continually add wood to an ever-increasing volume, as a tree grows larger in size it usually does not put on the same amount of diameter growth as it did when it was smaller. Usually, the amount of diameter growth decreases as the tree gets larger. If the 20-inch sugar maple only grows a tenth of an inch in diameter, it would sequester and store the same amount of CO2e as the smaller tree did by growing a quarter of an inch.

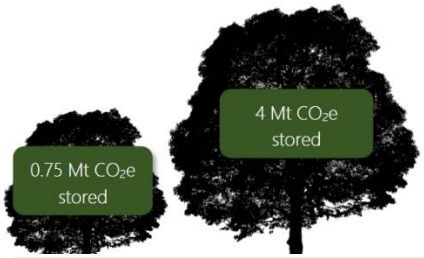
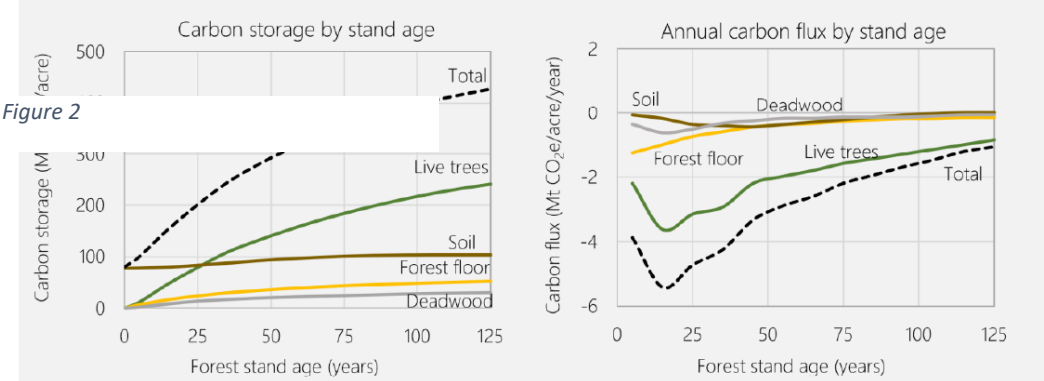


Figure 2

Carbon in a forest

In a forest, things are more complex: many small trees can occupy the same amount of space as one large tree and young trees usually have the most vigorous growth because



Carbon storage (left) increases as a forest ages and if there are no significant disturbances or stressors. Carbon flux (right, negative values indicate carbon sequestration) shows a different pattern by stand age. For this maple-beech-birch forest, carbon sequestration peaks when the stand is 15-20 years[1].

Figure 3

there is fierce competition for sunlight

and other resources. In the graphs above (Figure 10[2]), the aboveground carbon storage per acre of forest increases with age (left), but carbon sequestration peaks when forests are younger (right). When we consider the amount of carbon per acre of forest, the density, diversity, arrangement, and health of the trees are important.

Forest carbon dynamics are complex. The amount of carbon that forests store and sequester is dependent on many factors, including:

- Tree species composition
- Tree density
- Tree condition and age

[2] Carbon storage and flux data by stand age for a Maple-Beech-Birch forest from Smith et al. (2006)

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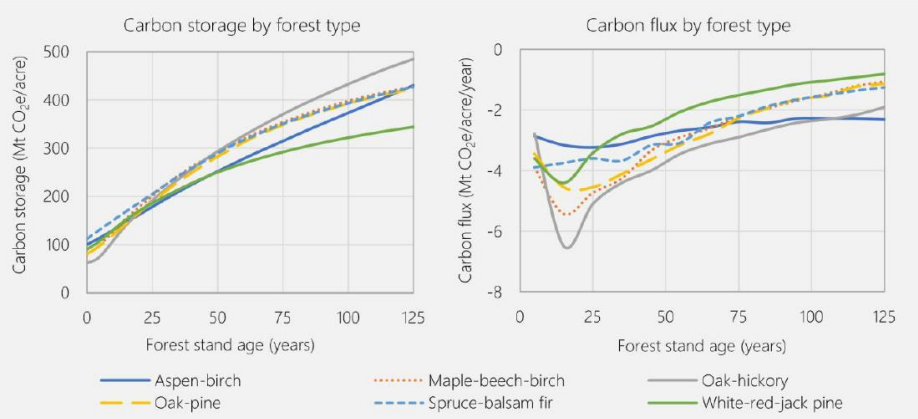
- Availability of water and nutrients
- Weather events
- Climate
- Growing season length
- Soil type and depth
- Proportion of dead standing and downed trees
- Presence of earthworms
- Animal browse pressure
- History of disturbance (wind, ice, logging, insects, and disease)

Which forest types store the most carbon?

Generally, an individual hardwood (deciduous) tree stores more carbon than a softwood (conifer) tree of the same size because hardwood trees usually have denser wood. But there can be differences among forest types. Spruce-fir forests can store high amounts of carbon in the litter and soil pools because spruce and fir needles take a long time to decompose on the forest floor, leading to a buildup of carbon in the litter and soil pools.



Forest of different types have similar patterns of carbon storage (left), although differences become more pronounced as forests age. Carbon flux (right, negative values indicate carbon sequestration) shows more pronounced differences among forest types when stands are young[10].

Figure 4

In the graphs above (Figure 11), carbon storage (left figure) increases for all forest types as the stand ages. Some forest types, like oak-hickory forests, store more carbon than other forest types, like white-red-jack pine forests. Carbon flux (right figure) shows that across all forest types, younger forests sequester carbon at a faster rate, but rates differ considerably among forest types and ages.

It is important to recognize that the amount of carbon a forest stores and the rate at which it stores carbon depends not only on the tree species and age/structure of the stand, but the weather conditions, soil, site conditions, and past disturbance regimes, and land-use history. Generally, forests that have many different species and sizes of trees, along with a deep litter layer, undisturbed soils, and lots of dead wood, store more carbon. Forests in colder climates also contain more carbon in soil and dead wood because of slower decomposition rates compared to warmer locations.

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