Carbon Dynamics in the Temperate Forest

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Executive Summary

Twenty-five percent of the world's forests are in the temperate biome. They include a wide range of forest types, and the exact boundaries with boreal forests to the north and tropical forests to the south are not always clear. There is a great variety of species, soil types, and environmental conditions which lead to a diversity of factors affecting carbon storage and flux. Deforestation is not a major concern at the moment, and the biome is currently estimated to be a carbon sink of 0.2–0.4 Pg C/year, about 37% of the total net terrestrial carbon uptake, disproportionately higher than its representative area, with most of the sink occurring in North America and Europe.

Temperate forests have been severely impacted by human use – throughout history, all but about 1% have been logged-over, converted to agriculture, intensively managed, grazed, or fragmented by sprawling development. Nevertheless, they have proven to be resilient – mostly second growth forests now cover about 40–50% of the original extent of the biome. Although remaining intact temperate forests continue to be fragmented by development, particularly in North America, there is no large-scale deforestation at present, nor is there likely to be in the future. The status of the temperate biome as a carbon reservoir and atmospheric CO_2 sink rests mainly on strong productivity and resilience in the face of disturbance. The small "sink" status of temperate forests could change to a "source" status if the balance between photosynthesis and respiration shifts.

What We Know About Carbon Storage and Flux in Temperate Forests

- Older forests have more carbon stock than younger stands, and mixed species stands in the moist broadleaf and coniferous forest type tend to have higher carbon density than single species stands. Younger stands tend to have higher rates of carbon sequestration, as indicated by net ecosystem productivity (NEP), than mid- or older-aged stands, although the data are highly variable.
- The below ground carbon pool of living biomass (primarily roots), roughly estimated to be 5–10% of total carbon, is much smaller than the above ground pool; however, this is a tenuous conclusion because the below ground biomass carbon pool is the least studied part of the forest carbon budget.
- Soils contain at least half the carbon in temperate forests and possibly as much as two-thirds; this carbon pool appears to be stable under most disturbances, such as logging, wind storms, and invasive species, but not with land

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use change. Huge losses can occur when converting forests to agriculture or development.
- Atmospheric pollution, primarily in the form of nitrogen oxides (NOx) emitted from burning fossil fuels and ozone (O_3), is a chronic stressor in temperate forest regions. Because most temperate forests are considered nitrogen-limited, nitrogen deposition may also act as a growth stimulant (fertilizer effect). Under current ambient levels, nitrogen deposition is most likely enhancing carbon sequestration; however, the evidence regarding long-term chronic nitrogen deposition effects on carbon sequestration is mixed.

What We Do Not Know About Carbon Storage and Flux in Temperate Forests
- Data on mineral soil carbon stocks in temperate forests can only be considered approximations at this time as there is very little research on deep soil carbon (more than 100 cm).
- Global circulation models predict that higher concentrations of atmospheric CO_2 will increase the severity and frequency of drought in regions where temperate forests are found. However, there is a great deal of uncertainty about how drought will affect carbon cycles.
- Little is known about how the interactions between temperature, moisture, available nutrients, pollutants, and light influence key environmental variables, such as drought, to affect ecosystem carbon flows.

What We Think Are the Influences on Carbon Storage and Flux in Temperate Forests
- There is tremendous variability in carbon stocks between forest types and age classes; carbon stocks could easily be lost if disturbance or land use change shifts temperate forests to younger age classes or if climate change or land use change shifts the spatial extent of forest types. On the other hand, if temperate forests are managed for longer rotations, or more area in old growth reserves, then the carbon stock will increase.
- Temperate forests are strongly seasonal, with a well-defined growing season that depends primarily on light (day length) and temperature. This is probably the most important determinant, along with late-season moisture, of temperate forest productivity and hence carbon sequestration.
- On balance, the evidence regarding nitrogen deposition effects on carbon sequestration is mixed. Under current ambient levels, nitrogen deposition is most likely enhancing carbon sequestration. However, under chronic nitrogen deposition, temperate forests may no longer be nitrogen limited, thus the nitrogen "fertilization" effect will be diminished as other resources become constrained.

How We Think the Carbon Status of Temperate Forests Will Change with Changing Climate
- There is evidence of increasing productivity in temperate forests as climate has warmed in the last ~50 years: however, this is confounded by successional dynamics and environmental variables. The atmospheric system has not only experienced changes in temperature, precipitation, and radiation, but in CO_2 concentration and pollutants.
- The few studies that have modeled multi-factor influences on temperate forest net ecosystem productivity or carbon flux have found that combined effects are expected to diminish the effect of CO_2 enrichment alone.
- Natural disturbances, particularly windstorms, ice storms, floods, insect outbreaks, and fire are significant determinants of temperate forest successional patterns. The frequency and intensity of stand-leveling windstorms (hurricanes, tornadoes) is expected to increase under a warmer climate in temperate moist broadleaf and coniferous forest regions, so that fewer stands would reach old-growth stages of development.
- If changing climate alters the frequency and intensity of fires, floods and hurricanes, re-vegetation and patterns of carbon storage will likely be affected, particularly in interior coniferous forests of mountains, the woodlands and pinelands of Mediterranean climates, and coastal forests on eastern sides of continents traditionally exposed to typhoons and hurricanes and floodplains.