



## **Fire and the carbon balance of terrestrial ecosystems**

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### **Abstract**

Fire can have a major impact on terrestrial carbon(C) stocks in biomass, dead organic matter (DOM) and soils at site, landscape, and regional scales. Site-level changes can be very marked and dynamic over time, whilst landscape and regional changes are more damped, even when there are extensive wildfires in particular years. These effects occur because:

- Fire can change the average (across the landscape) C stocks in biomass. Live biomass at a particular site can range from zero after a severe wildfire to a maximum in mature vegetation communities. In fire disturbed landscapes, the average C stocks will always be less than the maximum, and can have significant temporal variance in response to the extent and nature of fire in particular years.
- Intense fire can kill trees in many forests and creates a significant pool of C in standing dead wood that can persist for many decades.
- Fire usually reduces the average stock of C contained in DOM (litter) on the soil surface.
- Fire can affect soil C stocks, either by direct combustion loss, loss via fire-induced erosion, or by changes caused by differences between C inputs in litter and C outputs from respiration.

Fire (and fire regimes) affect C stocks via the following mechanisms:

- Combustion of C in fuels (biomass or DOM), and during intense fires of organic matter in surface soils. Loss of C during combustion of fuels can range from up to 95% of available fuel in intense fires in shrubland or grassland, to <10% in low-intensity forest fires. Wildfires in standing forests rarely combust more than 40% of the C contained in biomass and DOM. Combustion of C in organic matter in the surface few centimetres of dry soils can be significant during wildfires.
- The formation of small amounts (up to 7%, but typically <3 % of the C consumed in fire) of black carbon (char) that is very resistant to decay in the environment. However, there is still only very limited specific knowledge of the rates of formation and chemical nature of char produced under a range of burning conditions, of the rates of transport of char, or of decomposition rates of char in soils and sediments.
- Fire-induced change in vegetation dynamics, resulting either from successional processes, or the recovery of fire-damaged communities. This can result in significant change in rates of C storage in biomass during the post-fire recovery phase.
- Loss of nutrients and changes to nutrient cycles that affect vegetation growth after fire. In particular, nitrogen and phosphorus budgets and cycles are markedly affected by combustion processes, and sometimes by erosion or leaching during the years following fire. It there are consequent changes in plant growth, this directly affects the pattern of C stock recovery in biomass and litter. If fire alters litter inputs to the soil, there are direct consequences for maintenance or rebuilding of soil organic C stocks.

A process-based model (CenW) was used to explore the interactions between the frequency of low-intensity fire, rates of char formation, and changes to nutrient cycles and consequent effects on forest growth and biomass and soil C stocks in an Australian sub-alpine *Eucalyptus delegatensis* forest. The model was parameterised and tested using extensive field data, and shown to accurately simulate the forest C cycle. The insights from this analysis for our understanding of the effects of fire on ecosystem C storage will be discussed.