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Science for Environment Policy

Increased fire frequency may cause long-term changes to soil carbon and nitrogen

Fire frequency is changing globally, yet it is unclear how such changes affect soil carbon and nitrogen storage, and, in turn, impact on ecosystem productivity. A study was conducted to evaluate how increased fire frequency drives changes in soil carbon and nitrogen over multiple decades. Data from 48 sites that have experienced altered fire frequency were analysed, spanning up to 65 years. The meta-analysis found that frequently burned sites experienced a significant decline in surface soil carbon and nitrogen over time — on average having 36% less carbon and 38% less nitrogen, after 64 years, than sites that were protected from fire. The researchers also observed comparable changes in an independent field dataset and in dynamic model simulations of global vegetation. The results indicate that future changes in fire frequency may lead to long-term changes in the amount of carbon and nitrogen stored in soils, especially in savanna grasslands and broadleaf forests. This has implications for the global carbon cycle and for ecosystem productivity and should, therefore, be considered in the design and implementation of relevant policy instruments.

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Source: Pellegrini, A. F. A., Ahlström, A., Hobbie, S. E., *et al.* (2018). Fire frequency drives decadal changes in soil carbon and nitrogen and ecosystem productivity. *Nature*, 553: 194-198. DOI: 10.1038/nature24668

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Fire frequency is changing globally due to alterations in climate and land use, and is predicted to continue to change as temperatures rise and populations grow. In some sites, burning is becoming more frequent, while in others fire suppression has risen. It remains uncertain what impact such alterations have on soil carbon and nutrient storage and subsequently on plant and ecosystem productivity. Studies looking at such responses over long periods of time (i.e. decades) have been limited, meaning that the generalised long-term effects remain unclear. This limits our ability to model carbon storage in the ecosystem and predict how plant productivity may alter in response to changing fire frequencies.

To fill this knowledge gap, researchers set out to evaluate how long-term differences in fire frequency alter soil carbon and nutrients and to look at the accompanying shifts in plant productivity. A meta-analysis was conducted using data from 48 sites worldwide (including savanna grasslands, broadleaf forests and needleleaf forests) to test how frequent burning changes soil carbon and nutrients over time spans as long as 65 years. It was found that frequently burned sites experienced a long-term decline in surface soil carbon and nitrogen, having 36% (±13%) less carbon and 38% (±16%) less nitrogen after 64 years than plots that were protected from fire. Notably, fire-driven carbon and nitrogen losses were substantial in savanna grasslands and broadleaf forests, but not in temperate and boreal needleleaf forests.

The researchers observed comparable soil carbon and nitrogen losses in an independent field dataset and in dynamic model simulations of global vegetation. Importantly, the model study predicts that long-term losses of soil nitrogen caused by more frequent burning may in turn decrease the carbon that is sequestered by net primary productivity (NPP — the rate at which an ecosystem accumulates energy or biomass, excluding the energy used for respiration). Consequently, omitting the multi-decadal changes in soil pools that result from shifting fire frequencies may lead to an underestimation of ecosystem carbon losses. Indeed, the model estimates that, by failing to account for multi-decadal changes in soil carbon, the effects of differing fire frequency on ecosystem carbon storage may be underestimated by as much as 30%, especially in drier savanna grasslands.

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Increased fire frequency may cause long-term changes to soil carbon and nitrogen *(continued)*

Overall, these findings suggest that future variations in fire frequency may shift ecosystem carbon storage by changing soil carbon levels and the nitrogen limitation on plant growth, altering carbon-sink capacity. Frequently burning savanna grasslands and broadleaf forests were found to be particularly vulnerable. Since this fire-driven effect appears to strengthen over time and emerge over multiple decades, it is important that it is accounted for when considering the long-term stability of carbon in soils. The results indicate that present estimates of fire-driven carbon losses (which fail to account for these multi-decadal effects) may significantly underestimate the effects of long-term fire frequency trends.

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