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Disentangling the drivers of coarse woody debris behavior and carbon gas emissions during fire

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The turnover of coarse woody debris, a key terrestrial carbon pool, plays fundamental roles in global carbon cycling. Biological decomposition and fire are two main fates for dead wood turnover. Compared to slow decomposition, fire rapidly transfers organic carbon from the earth surface to the atmosphere.

Both a-biotic environmental factors and biotic wood properties determine coarse wood combustion and thereby its carbon gas emissions during fire. Moisture is a key inhibitory environmental factor for fire. The properties of dead wood strongly affect how it burns either directly or indirectly through interacting with moisture. Coarse wood properties vary between plant species and between various decay stages. Moreover, if we put a piece of dead wood in the context of a forest fuel bed, the soil and wood contact might also greatly affect their fire behavior.

Using controlled laboratory burns, we disentangled the effects of all these driving factors: tree species (one gymnosperms needle-leaf species, three angiosperms broad-leaf species), wood decay stages (freshly dead, middle decayed, very strongly decayed), moisture content (air-dried, 30% moisture content in mass), and soil-wood contact (on versus 3cm above the ground surface) on dead wood flammability and carbon gas efflux (CO_2 and CO released in grams) during fire. Wood density was measured for all coarse wood samples used in our experiment.

We found that compared to other drivers, wood decay stages have predominant positive effects on coarse wood combustion (for wood mass burned, R^2=0.72 when air-dried and R^2=0.52 at 30% moisture content) and associated carbon gas emissions (for CO_2andCO (g) released, R^2=0.55 when air-dried and R^2=0.42 at 30% moisture content) during fire. Thus, wood decay accelerates wood combustion and its CO_2 and CO emissions during fire, which can be mainly attributed to the decreasing wood density (for wood mass burned, R^2=0.91 when air-dried and R^2=0.63 at 30% moisture content) as wood becomes more decomposed.

Our results provide quantitative experimental evidence for how several key abiotic and biotic factors, especially moisture content and the key underlying trait wood density, as well as their interactions, together drive coarse wood carbon turnover through fire. Our experimental data on coarse wood behavior and gas efflux during fire will help to improve the predictive power of global vegetation climate models on dead wood turnover and its feedback to climate.