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Pyrogenic carbon decomposition critical to resolving fire's role in the Earth system

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Recently identified post-fire carbon fluxes indicate that in order to understand if global fires represent a net carbon source or sink, one must consider both terrestrial carbon retention through pyrogenic carbon (PyC) production, and carbon losses via multiple pathways. Here, these legacy source and sink pathways are quantified using a CMIP6 land surface model to estimate Earth's fire carbon budget. Over 1901-2010, global PyC drives annual soil carbon accumulation of 337 $TgCyr^{-1}$, offset by legacy carbon losses totalling -248 $TgCyr^{-1}$. The residual of these values constrains maximum annual pyrogenic carbon mineralisation to 89 $TgCyr^{-1}$, and PyC mean residence time to 5387 years, assuming steady state. However, paucity of observational constraints for representing PyC mineralisation mean that without assuming steady state, we are unable to determine the sign of the overall fire carbon balance.

The residual is negative over forests and positive over grassland-savannahs (implying a potential sink), suggesting contrasting roles of vegetation in the fire carbon cycle. Without widespread tropical grassland-savannah coverage, the legacy effects of fires could not feasibly enhance terrestrial C storage -a result afforded by grasses' capacity for fire recovery. The dependency of the fire C residual on vegetation composition suggests that the preservation/restoration of native grasslands may be an important vector for decreasing C losses from future fire activity. We call for significant investments in understanding of PyC degradation and its drivers, in addition to improved estimates of legacy fire C fluxes. Reliable quantification of PyC mineralisation and erosion, particularly over grasslands, remains the principal missing link in a holistic understanding of fire's role in the Earth system.