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Climate-driven functional restructuring of wood-decay fungi dampens global deadwood carbon emissions

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Deadwood is an important component of the global forest carbon pool, with its decomposition regulated by both biotic and abiotic factors. Current Earth system models typically predict that global warming will accelerate microbial-mediated decomposition, however, these models often overlook the biogeographical constraints of wood-decay fungal communities. In this study, we integrated distribution and decomposition data of 19 representative wood-decay fungi into an interpretable machine-learning framework to simulate spatiotemporal patterns of fungal communities and quantify variations in deadwood carbon fluxes under climate change. We show that the fungal richness will increase rapidly in the future, but the global net carbon emission flux driven by fungal decomposition is projected to decline rather than rise under the high-emission scenario (SSP5-8.5). By 2100, net carbon emissions decrease by approximately 25.1% relative to the baseline (from 0.147 ± 0.052 Pg C to 0.110 ± 0.036 Pg C). This trend primarily stems from a community functional restructuring driven by temperature and moisture: the expansion of brown-rot fungi in boreal forests (+72.7%) leads to significantly enhanced carbon retention (+14.12%), whereas warming-induced moisture stress suppresses white-rot fungi decomposition rates, reducing carbon emissions in tropical and temperate forests by 37.4% and 11.7%, respectively. Our results reveal the "biological buffering" role of wood-decay fungal functional restructuring in the global carbon cycle, providing a foundation for improving future forest carbon sink simulations.