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The role of forest disturbance in global forest mortality and terrestrial carbon fluxes

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Large-scale forest disturbance dynamics such as insect outbreaks, wind-throw and fires, along with anthropogenic disturbances such as logging, have been shown to turn forests from carbon sinks into intermittent sources, often quite dramatically so. There is also increasing evidence that disturbance regimes in many regions are changing as a result of climatic change and human land-management practices. But how these landscape-scale events fit into the wider picture of global tree mortality is not well understood. Do such events dominate global carbon turnover, or are their effects highly regional? How sensitive is global terrestrial carbon exchange to realistic changes in the occurrence rate of such disturbances? Here, we combine recent advances in global satellite observations of stand-replacing forest disturbances and in compilations of forest inventory data, with a global terrestrial ecosystem model which incorporates an explicit representation of the role of disturbance in forest dynamics. We find that stand-replacing disturbances account for a fraction of wood carbon turnover that varies spatially from less than 5% in the tropical rainforest to ca. 50% in the mid latitudes, and as much as 90% in some heavily-managed regions. We contrast the size of the land-atmosphere carbon flux due to this disturbance with other components of the terrestrial carbon budget. In terms of sensitivity, we find a quasi log-linear relationship of disturbance rate to total carbon storage. Relatively small changes in disturbance rates at all latitudes have marked effects on vegetation carbon storage, with potentially very substantial implications for the global terrestrial carbon sink. Our results suggest a surprisingly small effect of disturbance type on large-scale forest vegetation dynamics and carbon storage, with limited evidence of widespread increases in nitrogen limitation as a result of increasing future disturbance. However, the influence of disturbance type on soil carbon stocks is very large, illustrating the importance of further efforts to distinguish disturbance drivers at the global scale. Setting our knowledge of forest disturbance into the wider uncertainty in forest mortality processes generally, we offer a perspective for improving understanding of the role of disturbance in global forest carbon cycling.