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The impact of extreme wind events on natural forest ecosystem dynamics

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In high latitude coastal regions, such as portions of Europe and the west coast of North America, extreme maritime windstorms cause widespread disturbance to forested ecosystems by snapping trees and turning up tree roots, which in turn can initiate landslides in steep mountainous areas. In forests topographically exposed to windstorm activity, these effects may be repeated, possibly altering the dynamics of the ecosystem over the long-term. To better understand how these disturbances impact forest ecosystem dynamics, the movement, storage, and quality of soil carbon, forest hydrology and streamwater chemistry along a windthrow disturbance sequence was studied in the natural forests of southeast Alaska. Soils were described, and the thickness of the major organic and mineral horizons was measured, every 5 meters along transects in three catchments with contrasting windthrow histories. A subset of the soil description sites was randomly selected, then sampled to determine the quantity and quality of soil C. Mineral soil samples were physically fractionated based on particle density. Total C and N, natural 15N and 13C abundance, micromorphologic analysis (using scanning electron microscopy), and solid state 13C-NMR were used to compare C pools in the three catchments. An event based sampling scheme was then used to compare hydrochemical properties of each catchment. Nine storms were sampled over a 14 month period, representing a range of antecedant and intensity conditions. Streamflow was measured, and solution samples were collected every 4 hours during each storm from each catchment. Evidence for two distinct pathways for soil carbon accumulation was found; 1) mineral and organic particle mixing from windthrow, 2) soil water transport of mobile organic carbon (MOC) to mineral soil horizons. Forested catchments that experienced more intense soil mixing from windthrow had lower levels of strongly humified carbon, and more in a partially decomposed particulate form. Streamflow on more-disturbed catchments peaked 4 to 12 hours later than in less-disturbed catchments. During storm events, streamwater temperatures were more equilibrated to ambient air temperatures in more-disturbed catchments than in less-disturbed catchments. Streams in more-disturbed catchments had higher pH, bicarbonate and base cation concentrations than streams in less-disturbed catchments. These results suggest that catastrophic windthrow disturbance smoothes hydrograph response to rainstorm events and increases the chemical interaction of rainwater with mineral soil horizons by increasing rainwater infiltration and storage in deeper soil profiles. Changes in the concentration and characteristics of organic carbon in mineral soil which result from soil mixing disturbances (windthrow, landslides) can strongly influence the hydrology, chemical properties of catchments, and the rate of nutrient cycling. The implications of this research are that strong biogeochemical shifts in forested ecosystems can result from extreme wind events. Such changes may be most pronounced and persistent in forests prone to recurrent extreme wind disturbance events.