Effects of forest disturbance on water yield and peak flow in low-relief glaciated catchments assessed with remotely sensed drivers and Bayesian parameter estimation

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Abstract

The catchment approach has been traditionally limited to small, experimental catchments where water fluxes can be determined with high accuracy. However, larger catchments where landscape management occurs have emergent drivers of streamflow at scale, and thus may exhibit novel responses to land cover disturbance. We used statistical models of water yield and annual maximum peak streamflow for multiple forested catchments in the low-relief glaciated region of central North America to investigate how forest disturbance may affect water yield and peak flows in similar landscapes. We utilized linear models, linear mixed effects models, and probabilistic flood-frequency analysis, with Bayesian parameter estimation in two case studies in Minnesota, USA: 1) a wildfire comprising ~30% of a 650km ^{2} wilderness Upper Kawishiwi catchment, and 2) 11 catchments within the St. Louis River Basin ranging from 56 to 8,880 km ^{2} with a patchwork disturbance regime wherein ~0.25% to 1% of the catchment is harvested or converted to non-forest land use each year. We also assessed for the most likely hydrological recovery year after forest disturbance, and the relative importance of stationary and nonstationary drivers of streamflow. We found forest disturbance correlated with declines in water yield for low-level disturbance regimes, but that water yield increased in response to the large-scale wildfire. Positive and negative associations of forest disturbance with peak flows were observed, generally with low confidence. Hydrologic recovery time ranged from 5 to 12 years for water yield and peak flows following disturbance. Despite these effects of forest disturbance on streamflow, effects of climate variability and stationary catchment size factors were more prominent drivers of streamflow. Basins larger than ~50 km ^{2} in low-relief glaciated regions were resilient to forest cover change when it comprised <30% of basin area, but climate change may have a larger effect than could be mitigated by land management.

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