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Changing stream water sources in insect-infested forests: a combined field and modeling analysis

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Climate-exacerbated mountain pine beetle infestation in the Rocky Mountains of North America has resulted in tree death over the last decade that is unprecedented in recorded history. The subsequent perturbation to tree-scale water budget processes such as interception, transpiration, and evaporation often combine non-uniformly and produce variable catchment responses across different regional analyses. Specifically, potentially offsetting perturbations such as decreased transpiration with tree death and increased exposure and evaporation with needle fall can produce changes in peak streamflow and water yield that are undetectable above typical interannual variability. These combined perturbations, however, may change streamflow generating processes and water sources that impact water quality in important mountain headwater streams.

To determine the potential impact of widespread land cover change on catchment contributions to streamflow, this study combines a chemical and isotopic separation analysis using paired watersheds and pre-infestation controls with a novel Lagrangian modeling approach that determines idealized surface and groundwater contributions to streamflow. Field observations and hydrograph separation analysis suggests that groundwater contributions to streamflow increase with recent insect infestation, as transpiration ceases to remove water from the subsurface but potentially increased ground evaporation removes water from the land and subsurface with relative uniformity. Comparing these field observations with a modeled hillslope provides additional spatial and temporal controls on inherently challenging field heterogeneities as well as a way of testing the influence of natural properties such as precipitation and topography on perturbations to streamflow partitioning from insect infestation. The modeling approach uses the physically based, integrated model PARFLOW-CLM to determine surface and subsurface fluxes representative of a range of forest cover conditions and a newly developed version of SLIM-FAST to track particles through both flow domains. By determining the flow paths of the applied particles, the sources of streamflow are identified and presented as a numerical hydrograph separation. Ultimately, identifying these changes in stream water sources provides needed insight for water resource management in MPB-infested watersheds and for changing forested landscapes throughout the region.