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Forest fire effects on transpiration: process modeling of sapwood area reduction

Sean Michaletz (1,2) and Edward Johnson (1,3)

(1) Department of Biological Sciences and Biogeoscience Institute, University of Calgary, Calgary, Canada, (2) sean.michaletz@ucalgary.ca, (3) johnsone@ucalgary.ca

Transpiration is a hydrological process that is strongly affected by forest fires. In crown fires, canopy fine fuels (foliage, buds, and small branches) combust, which kills individual trees and stops transpiration of the entire stand. In surface fires (intensities $\leq$ 2500 kW m^{-1}), however, effects on transpiration are less predictable becuase heat transfer from the passing fireline can injure or kill fine roots, leaves, and sapwood; post-fire transpiration of forest stands is thus governed by fire effects on individual tree water budgets. Here, we consider fire effects on cross-sectional sapwood area. A two-dimensional model of transient bole heating is used to estimate radial isotherms for a range of fireline intensities typical of surface fires. Isotherms are then used to drive three processes by which heat may reduce sapwood area: 1) necrosis of living cells in contact with xylem conduits, which prevents repair of natural embolism; 2) relaxation of viscoelastic conduit wall polymers (cellulose, hemicelloluse, and lignin), which reduces cross-sectional conduit area; and 3) boiling of metastable water under tension, which causes conduit embolism. Results show that these processes operate on different time scales, suggesting that fire effects on transpiration vary with time since fire. The model can be linked with a three-dimensional physical fire spread model to predict size-dependent effects on individual trees, which can be used to estimate scaling of individual tree and stand-level transpiration.