Response of Evapotranspiration and Greenhouse Gas Emissions to the Bark Beetle and Blue Stain Fungus Epidemic in Rocky Mountain Forests

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From green trees...  

Climate, water, and nutrient impacts will be regional

Kurz et al. Nature 2008: carbon release from B.C. beetle attack greater than boreal fire

To red trees... in less than a year
Hypothesized Ecosystem Impacts of Bark Beetle outbreaks

Leaf area index (LAI), Interception, Net Ecosystem Exchange (NEE) will decline after outbreak

Litterfall, Decomposition (Rh), Dissolved Organic Matter (DOM) will increase then decrease

Soil moisture, temperature and Nitrogen availability will increase

Variability (dotted lines) will decrease as more of the trees succumb to infestation
Glacier Lakes Ecosystem Experiments Site (GLEES; Spruce/fir) & Chimney Park (lodgepole pine)

Eddy covariance towers measure ecosystem exchange
Leaf Gas Exchange

Sap Flux

Soil Respiration
GLEES: Leaf to Ecosystem Response

Photo: Josh King
Spruce needle gas exchange

Spruce needle water loss is affected by height and age. Older needles decrease more with blue stain infection. Water loss at night continues after infestation.
Blue stain fungi rapidly changes sapwood

Smaller sapwood area one month after blue stain infection due to loss of inner sapwood, supports faster decline in older needle gas exchange

Same results found in Norway spruce beetle/fungi attacks

Allometric relationship between basal and sapwood area may be predictable after attack
Blue stain fungi impact transpiration quickly

After one month, transpiration per tree is reduced to less than half.

Transpiration still responds to environmental drivers probably because younger needles are last to die.
GLEES – Ecosystem Response

H₂O - cm yr⁻¹

YEAR

CO₂ - Mg C ha⁻¹ yr⁻¹

Photo: Josh King
Chimney Park
EC tower,
July 2009
Leaf area index is lower in infested stands

- LAI is the main driver of carbon and water fluxes
- CO$_2$ uptake and water loss are expected to decrease

<table>
<thead>
<tr>
<th>LAI (uncorrected) m$^2$ m$^{-2}$</th>
<th>BB2 - 2007 Hit Stand</th>
<th>BB1 - 2008 Hit stand</th>
<th>EC - Tower Stand, Hit 2009</th>
<th>Regeneration Stand</th>
<th>Unthinned Stand</th>
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BB2 - 2007 Hit Stand
BB1 - 2008 Hit stand
EC - Tower Stand, Hit 2009
Regeneration Stand
Unthinned Stand
Soil Impacts Vary Greatly in the Short Term

In lodgepole pine stands, soil moisture is increasing in response to transpiration decline; spruce/fir is likely similar.

Soil moisture increase in attacked stands larger in late season (August).

Soil respiration impacts are not yet clear.

Finding control stands is increasingly difficult, may not be possible.
Soil moisture increases preserved even right after snow melt (June 8) and moderate precip (July 2). Only unusually high precip removes bark beetle impact (June 18).
Biogeochemistry Methods

- **Trace gases**: static open flow chambers
- **Litter fall**: 40-day intervals
- **Litter decomposition**: Infested and non-infested pairs
$N_2O$ fluxes in infested stands are more than 2x that of uninfested, unthinned stands.
Premature senescence of needles contributes to increase in $N_2O$
Soil organic matter is higher on infested stands

Beetle mortality is increasing fresh litter (Oe horizon) relative to decomposed litter (Oi horizon) biomass
CH$_4$ consumption is reduced in infested stands.
Future/Ongoing Work

• Evaluate ecosystem CO\textsubscript{2} and H\textsubscript{2}O fluxes
  – Shift in the proportion of Evaporation vs. Transpiration

• Determine successional impacts
  – Are seedlings limited by light, nutrients and/or water?

• Quantify N cycle changes

• Scale to watersheds and regional extent using other locations and FoSTER
  (Forest Steppe Transition Ecosystem Research)
Conclusions

• As hypothesized, bark beetle/blue stain impacts are rapid in high and low elevation outbreaks
  – Large reduction in transpiration, photosynthesis within a month
  – Large increase in soil moisture

• Traditional experiments using controls may not be possible due to extent of attack
  – Test mechanisms behind mass and energy dynamics with ecosystem, hydrological and regional models
Duration of shifts in water balance remain unclear

The lower forest boundary may be further compounded by drought and temperature stress (Adams et al. 2009), potentially limiting forest regeneration, leading to a shift toward shrub vegetation.