Evapotranspiration response of a high elevation Rocky Mountain (Wyoming, USA) forest to a bark beetle epidemic

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Overview

I. The impact of the spruce beetle epidemic at the Glacier Lakes Ecosystem Experiments Site (GLEES) on ...

II. Photosynthesis and the net ecosystem exchange of CO$_2$, ...

III. Evapotranspiration and the annual flux of water vapor, and ...

IV. The annual water cycle
I. The status of the bark beetle epidemic at GLEES

• An spruce beetle (*Dendroctonus rufipennis*) outbreak has been occurring over the last decade.

• The peak of the epidemic was 2008.

• ~30% of the trees (~50% of the spruce) accounting for ~70% of the basal area (90% for spruce) have been impacted.

• Beetle-attacked trees were larger (27 cm dbh) than those that were not attacked (8 cm dbh).
II. The impact of the spruce beetle epidemic on photosynthesis and the net ecosystem exchange (NEE) of CO$_2$
Eddy-covariance CO$_2$ Flux

Respiration to the atmosphere

CO$_2$ uptake by the ecosystem
Ecosystem NEE Light Response Curve

- **2005**: $R^2 = 0.770$
- **2006**: $R^2 = 0.755$
- **2007**: $R^2 = 0.804$
- **2008**: $R^2 = 0.777$
- **2009**: $R^2 = 0.749$
- **2010**: $R^2 = 0.670$
Quantum Yield: The efficiency that light is used by the ecosystem to assimilate carbon.

**Diagram:**
- **2005:** $\Phi_a = 0.0251 \text{ mol mol}^{-1}$
- **2006:** $\Phi_a = 0.0195 \text{ mol mol}^{-1}$
- **2007:** $\Phi_a = 0.0207 \text{ mol mol}^{-1}$
- **2008:** $\Phi_a = 0.0157 \text{ mol mol}^{-1}$
- **2009:** $\Phi_a = 0.0135 \text{ mol mol}^{-1}$
- **2010:** $\Phi_a = 0.0106 \text{ mol mol}^{-1}$
Maximum ability of the ecosystem to assimilate carbon
II. The impact of the spruce beetle epidemic on photosynthesis

• \(~30-50\%\) reduction in the light efficiency of assimilating CO\(_2\) (quantum yield).

• \(~20\%\) reduction in the maximum CO\(_2\) assimilation rate in 2008-09.

• \(~50\%\) reduction in the maximum CO\(_2\) assimilation rate in 2010.
III. The impact of the spruce beetle epidemic on evapotranspiration (ET) and the annual flux of water vapor
Eddy-covariance Water Vapor Flux
ET Light Response Curve
III. The impact of the spruce beetle epidemic on ET

- ≈25% reduction in the evapotranspiration response to sunlight in 2008-10.
III. The impact of the spruce beetle epidemic on the flux of water vapor

- Summer ET was reduced from $\geq 25 \text{ cm}$ in 2005-07 to $\leq 22 \text{ cm}$ in 2008-10.
III. The impact of the spruce beetle epidemic on the flux of water vapor

- Annual ET was reduced from \( \geq 67 \text{ cm} \) in 2005-08 to \( \leq 62 \text{ cm} \) in 2009-10.
IV. Implications of the spruce beetle epidemic for the annual water cycle
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- The 2008-10 annual snowpacks were the deepest and latest melting.
IV. Implications of the spruce beetle epidemic for the annual water cycle

- Annual precipitation was highest in 2009 and 2010.
- By contrast, these years had the lowest annual ET.
IV. Implications of the spruce beetle epidemic for the annual water cycle

- In summer, deep soil moisture was highest in 2008-10.
Conclusions

The spruce beetle epidemic at GLEES caused ...

- A $\sim 50\%$ reduction in the ecosystem’s maximum $\text{CO}_2$ assimilation rate ...

- Which was linked to a $\sim 25\%$ reduction in summer evapotranspiration response ...

- And led to a 5-10 cm reduction in annual ET, despite higher than average precipitation.

- Some of the excess water was detected in deep soil moisture.
Acknowledgements

Paula Fornwalt
Laurie Huckaby
Mage Skordahl
Heather Scott
Jose Negron
Josh King

Questions?