The Impacts of Biotic Disturbances on Carbon Budgets of North American Forests


Thanks to Eric Kasischke for organizing the NACP Disturbance Synthesis

Funding from USGS,
USDA Forest Service Western Wildland Environmental Threat Assessment Center

Photo by J. Hicke
Extensive bark beetle-caused tree mortality suggests large impacts to C cycle…

…so what is known?
Methods

1. Team of forest ecologists, biogeoscientists, entomologist, pathologist

2. Identified publications using standard search methods

3. Characterized studies by a few key factors
   - insect/pathogen species
   - severity of disturbance
   - time since disturbance
   - study methods
     - observation vs. modeling
   - carbon variable(s) studied

Photo by J. Hicke
## Findings: Characteristics of studies

<table>
<thead>
<tr>
<th>Biotic disturbance agent</th>
<th>Number of studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insects</strong></td>
<td></td>
</tr>
<tr>
<td>Insects</td>
<td>17</td>
</tr>
<tr>
<td>bark beetles</td>
<td>5</td>
</tr>
<tr>
<td>mountain pine beetle</td>
<td>4</td>
</tr>
<tr>
<td>defoliators</td>
<td>6</td>
</tr>
<tr>
<td>gypsy moth</td>
<td>2</td>
</tr>
<tr>
<td>forest tent caterpillar</td>
<td>2</td>
</tr>
<tr>
<td>eastern spruce budworm</td>
<td>2</td>
</tr>
<tr>
<td>hemlock woolly adelgid</td>
<td>5</td>
</tr>
<tr>
<td><strong>Pathogens</strong></td>
<td></td>
</tr>
<tr>
<td>Pathogens</td>
<td>4</td>
</tr>
<tr>
<td>beech bark disease</td>
<td>2</td>
</tr>
<tr>
<td>Swiss needle cast</td>
<td>1</td>
</tr>
<tr>
<td>dwarf mistletoe</td>
<td>1</td>
</tr>
<tr>
<td><strong>Multiple species (insects)</strong></td>
<td></td>
</tr>
<tr>
<td>Multiple species (insects)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>21</td>
</tr>
</tbody>
</table>
Findings: Characteristics of studies

<table>
<thead>
<tr>
<th>Characteristic</th>
<th># studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>study type</td>
<td></td>
</tr>
<tr>
<td>field measurements</td>
<td>15</td>
</tr>
<tr>
<td>(eddy flux tower)</td>
<td>(4)</td>
</tr>
<tr>
<td>simulations</td>
<td>10</td>
</tr>
<tr>
<td>spatial scale</td>
<td></td>
</tr>
<tr>
<td>needle or tree</td>
<td>2</td>
</tr>
<tr>
<td>plot</td>
<td>14</td>
</tr>
<tr>
<td>regional</td>
<td>5</td>
</tr>
<tr>
<td>C cycle variables</td>
<td></td>
</tr>
<tr>
<td>growth/photosynthesis/GPP/NPP</td>
<td>14</td>
</tr>
<tr>
<td>net C flux/NEP/NBP/NEE</td>
<td>8</td>
</tr>
<tr>
<td>other (C stocks, soil respiration, etc.)</td>
<td>several</td>
</tr>
</tbody>
</table>

Photo by J. Hicke
Findings: Types of impacts to C cycling

Conceptual diagram

Hicke et al. in revision
Findings: Types of impacts to C cycling

1. Growth reduction leading to decreased NEP (temporary)

Hicke et al. in revision
Findings: Types of impacts to C cycling

1. Growth reduction leading to decreased NEP (temporary)

Cook et al., *Ecosystems*, 2008

- NEP decreased for 1 year by 79%

![Graph showing NEP changes over the years.](image-url)
Findings: Types of impacts to C cycling

2. Tree mortality leading to decrease in NEP

Hicke et al. in revision
Findings: Types of impacts to C cycling

2. Tree mortality leading to decrease in NEP

Major impacts to regional NEP by mountain pine beetle

Minor impacts to regional NEP by hemlock woolly adelgid

Kurz et al. 2008

Albani et al. 2010

Impacts depend on #trees affected within study region
Findings: Types of impacts to C cycling

3. Tree mortality affecting recovery of C stocks, fluxes

*Hicke et al. in revision*
Findings: Impacts to C cycle

3. Tree mortality affecting recovery of C stocks, fluxes

- mountain pine beetle killed 41-67% of trees
- NPP = preoutbreak values in 5-15 years for two plots

- mountain pine beetle killed >95% of trees
- NEP ~ 0 within 5 years of attack

Romme et al. 1986

Brown et al. 2010, Amiro et al. 2010
Findings: Impacts to C cycle

3. Tree mortality affecting recovery of C stocks, fluxes

- two plots attacked by mountain pine beetle
  - similar aboveground C (30-40 Mg C/ha) and mortality (~60%)
  - very different postdisturbance trajectory of modeled C flux

Size, number of surviving trees is key
Findings: Key knowledge gaps

- few studies = large uncertainty
  - pathogen impacts
  - regional-continental scales

- spatial and temporal characteristics of outbreaks
  - amount of growth reduction and/or mortality
  - Mexico

- lack of predictive models
  - insect/pathogen
  - integration into C cycle modeling

- interactions with other disturbances
Summary and conclusions

- impacts of insects, pathogens on C cycling can be substantial
  - large reductions in growth
  - net C release to atmosphere

- variation in C responses
  - different insect/pathogen types
  - different amounts of trees affected
  - different residual/surviving stand structure

- additional research needed to reduce major uncertainties in North American C cycle