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

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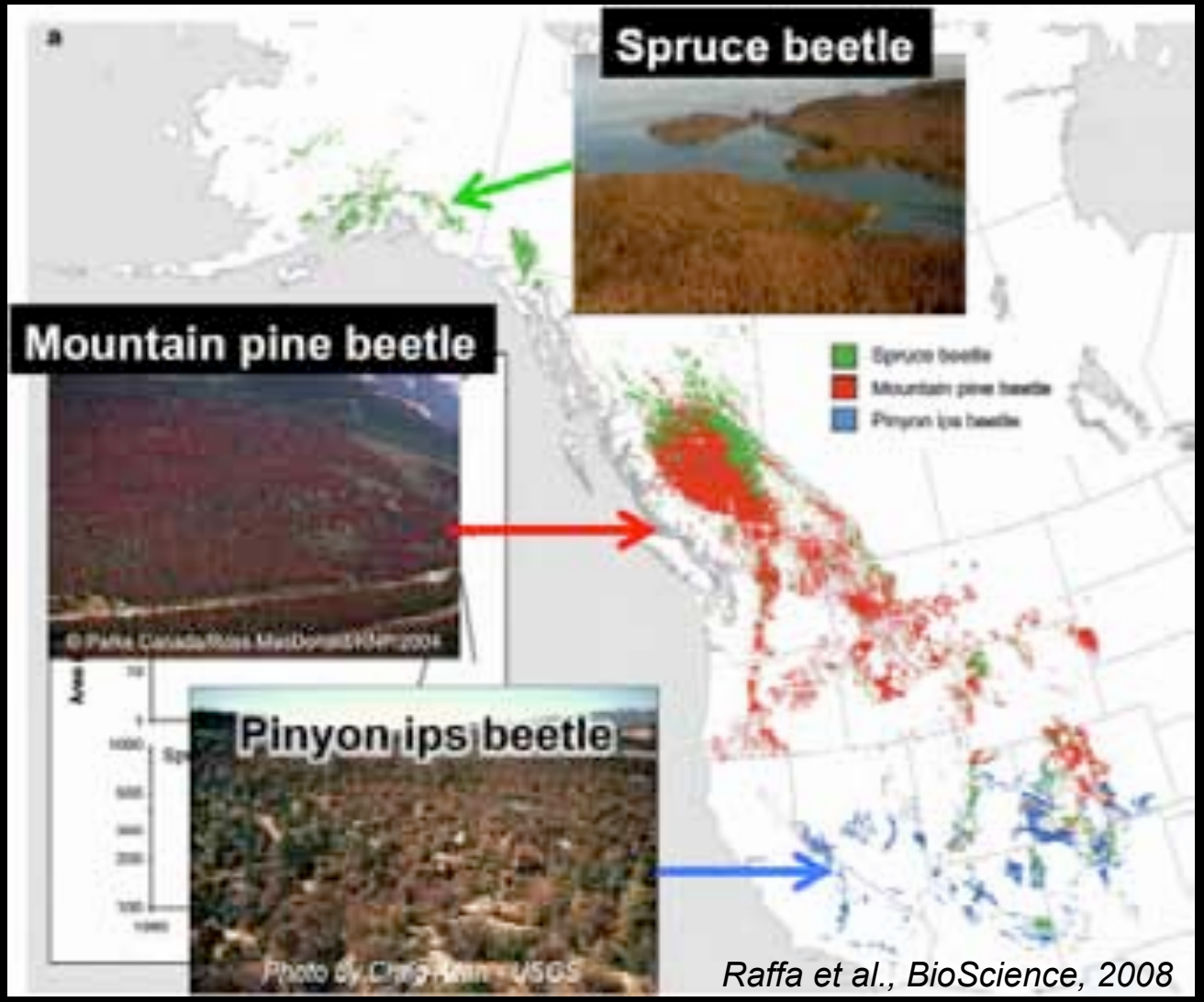
Photo by J. Hicke

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

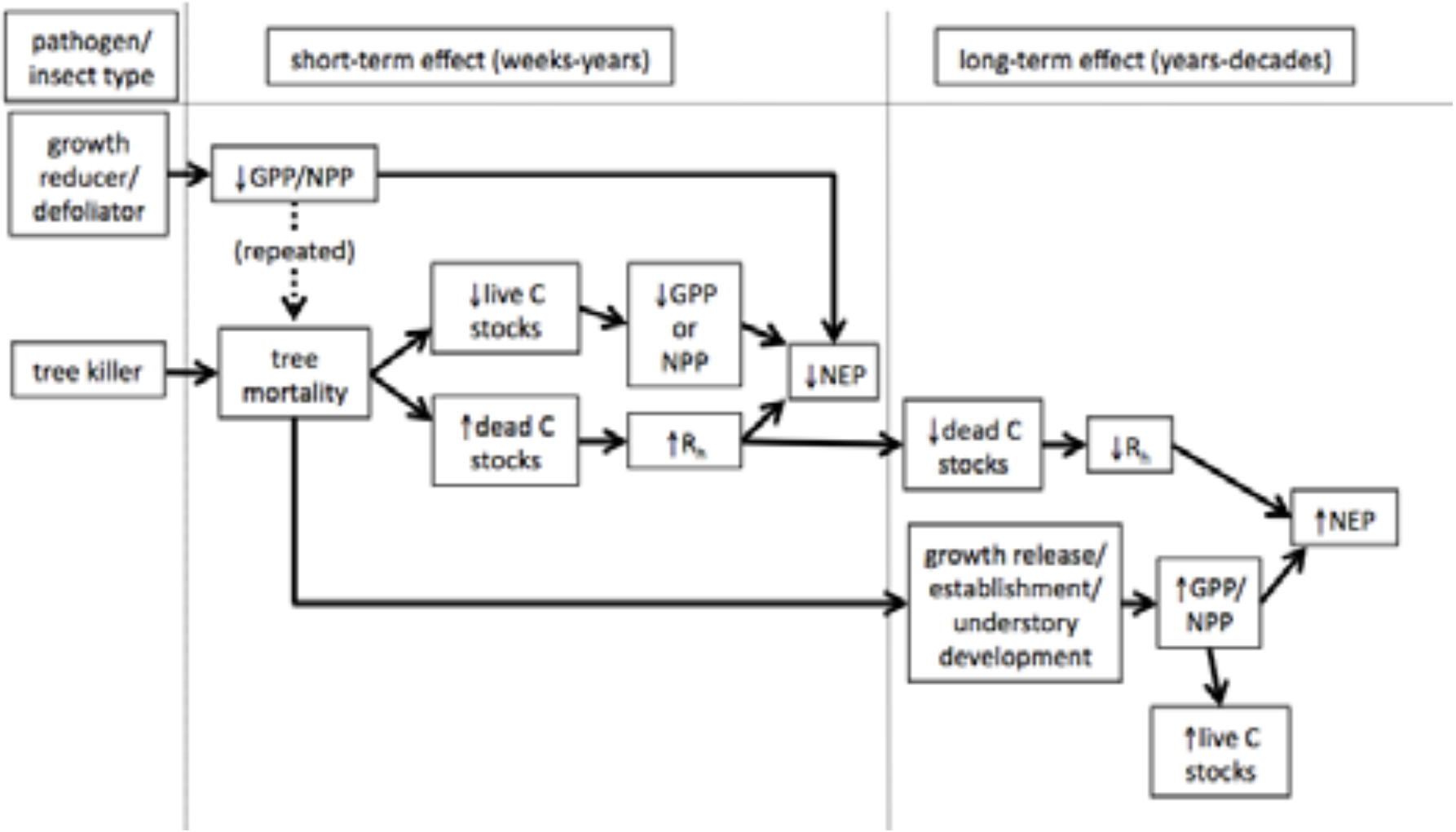
Biotic disturbance agent	Number of studies
Insects	17
bark beetles	5
mountain pine beetle	4
defoliators	6
gypsy moth	2
forest tent caterpillar	2
eastern spruce budworm	2
hemlock woolly adelgid	5
Pathogens	4
beech bark disease	2
Swiss needle cast	1
dwarf mistletoe	1
Multiple species (insects)	1
Total	21

Findings: Characteristics of studies

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

Findings: Types of impacts to C cycling

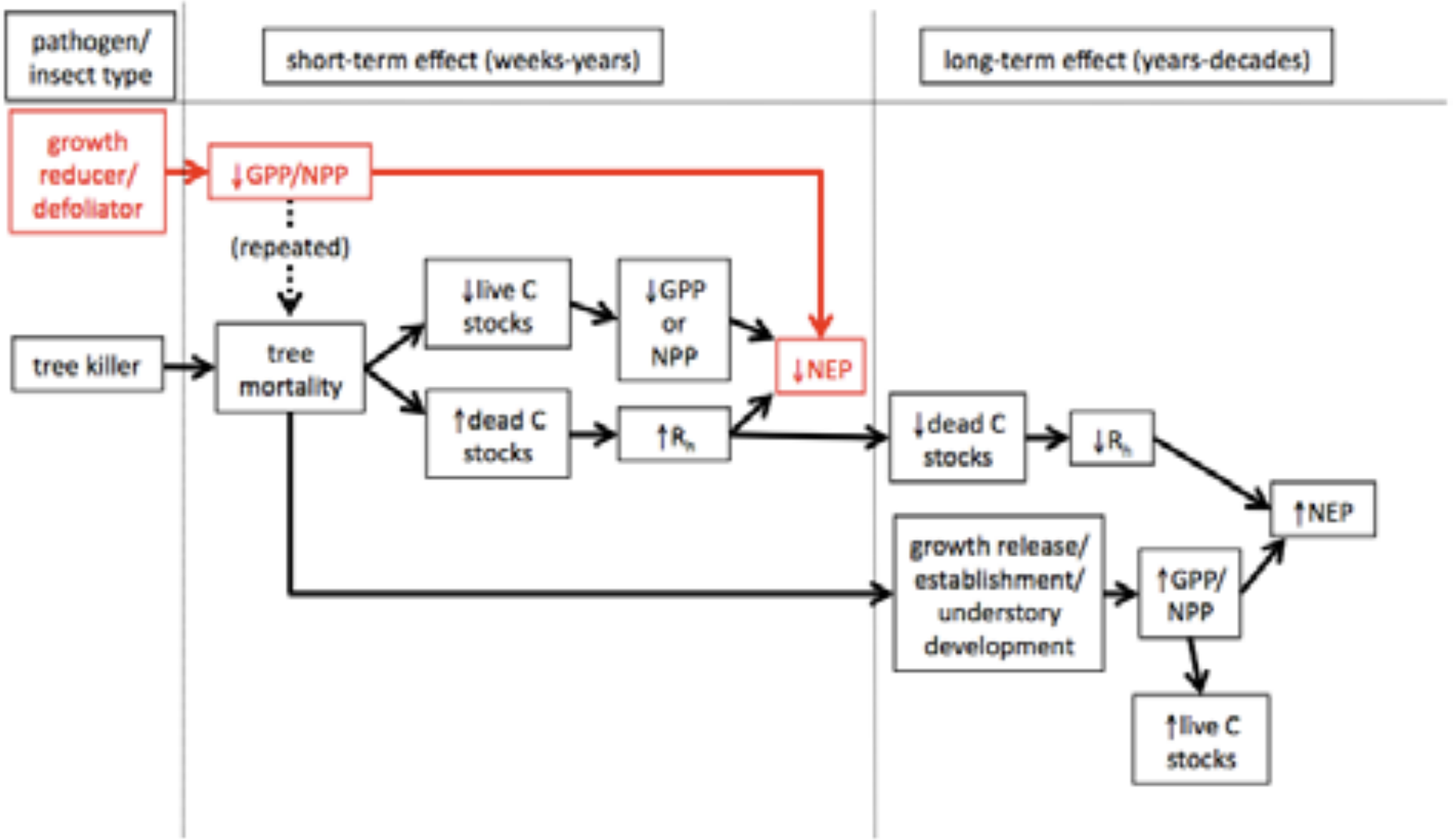
Conceptual diagram



Hicke et al. in revision

Findings: Types of impacts to C cycling

1. Growth reduction leading to decreased NEP (temporary)



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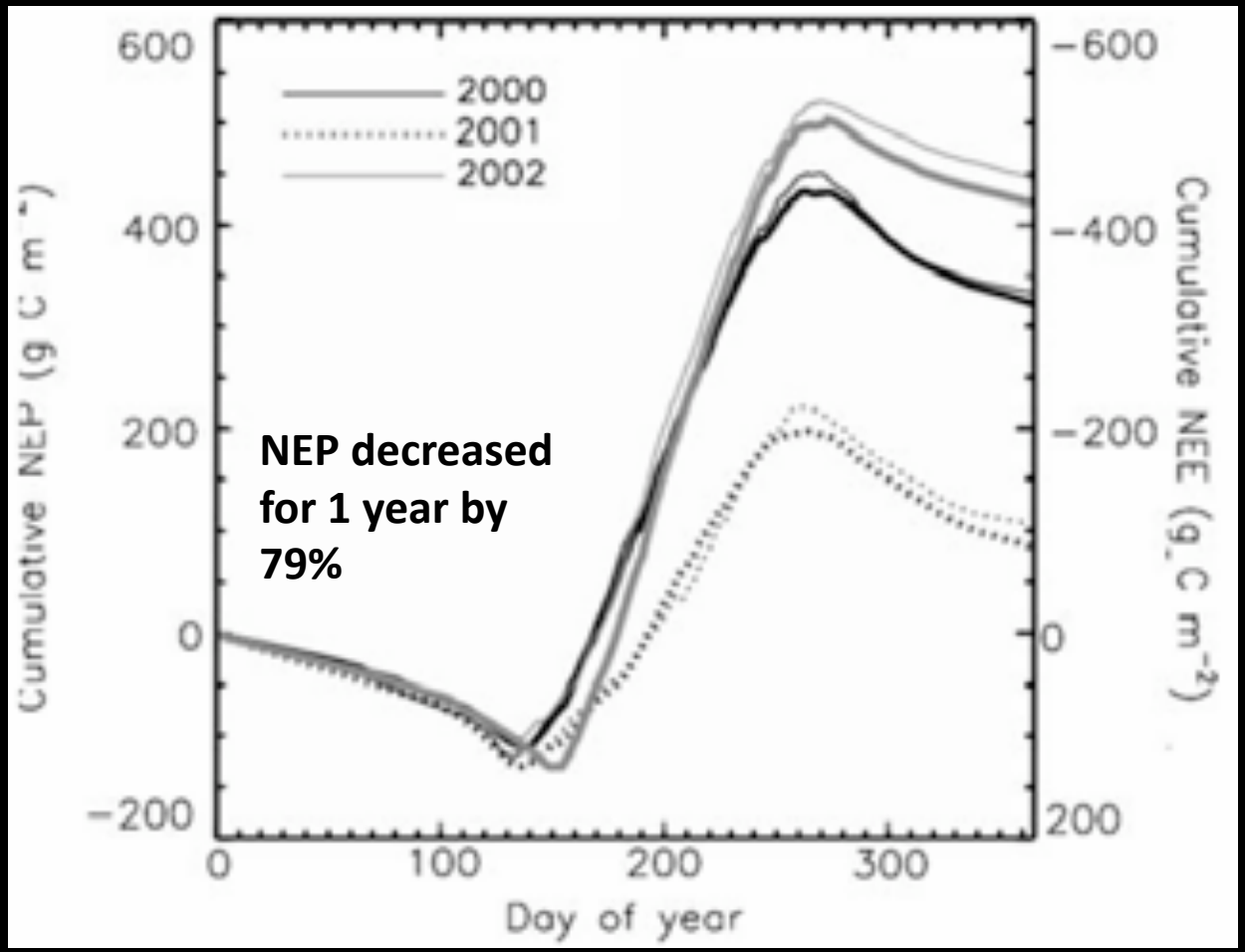
Findings: Types of impacts to C cycling

1. Growth reduction leading to decreased NEP (temporary)

Cook et al., *Ecosystems*, 2008



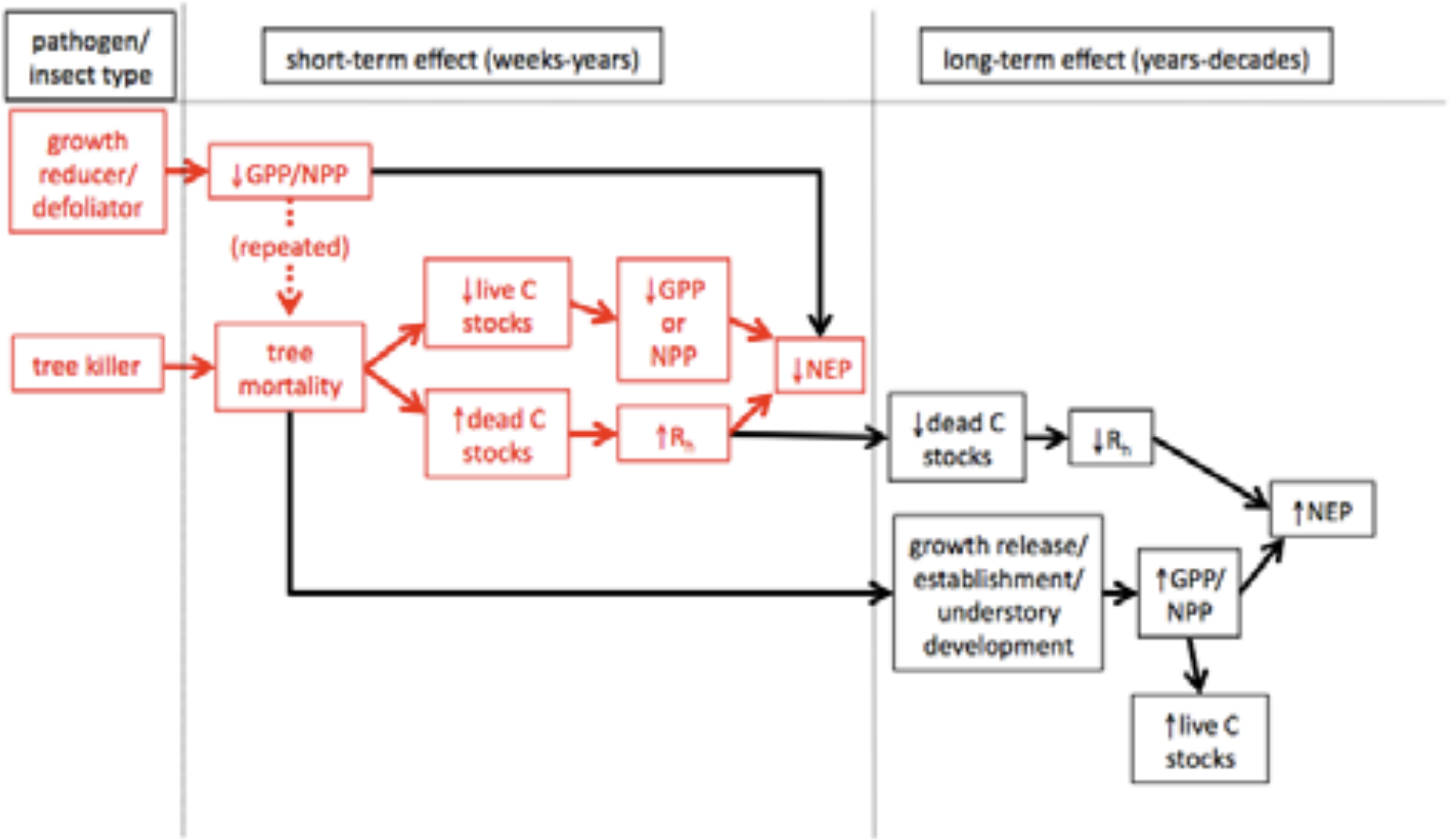
Year after

Year before

Year of attack

Findings: Types of impacts to C cycling

2. Tree mortality leading to decrease in NEP

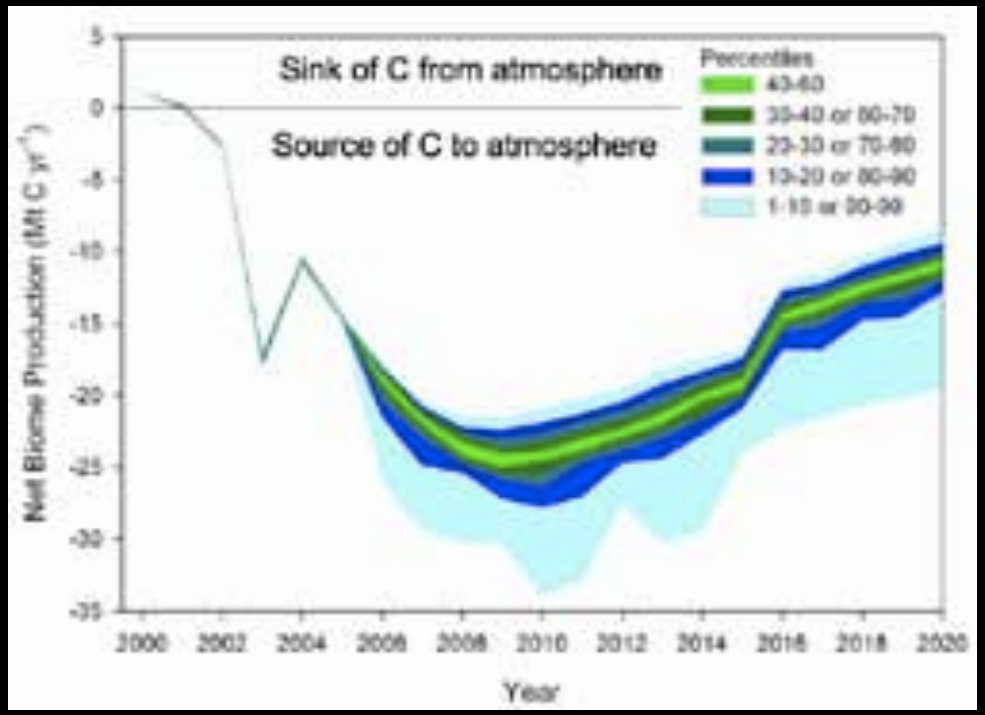


Hicke et al. in revision

Findings: Types of impacts to C cycling

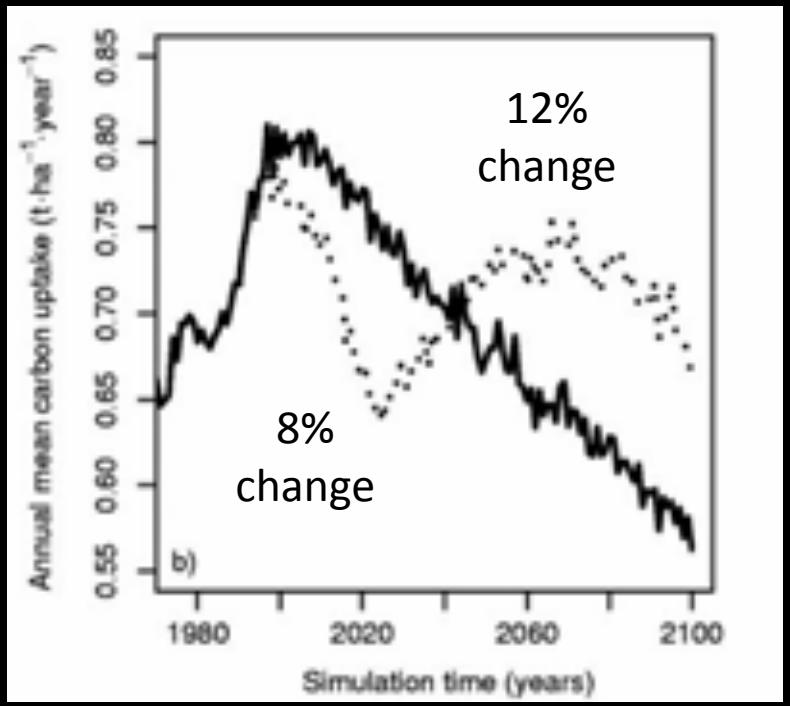
2. Tree mortality leading to decrease in NEP

Major impacts to regional NEP
by mountain pine beetle



Kurz et al. 2008

Minor impacts to regional NEP
by hemlock woolly adelgid

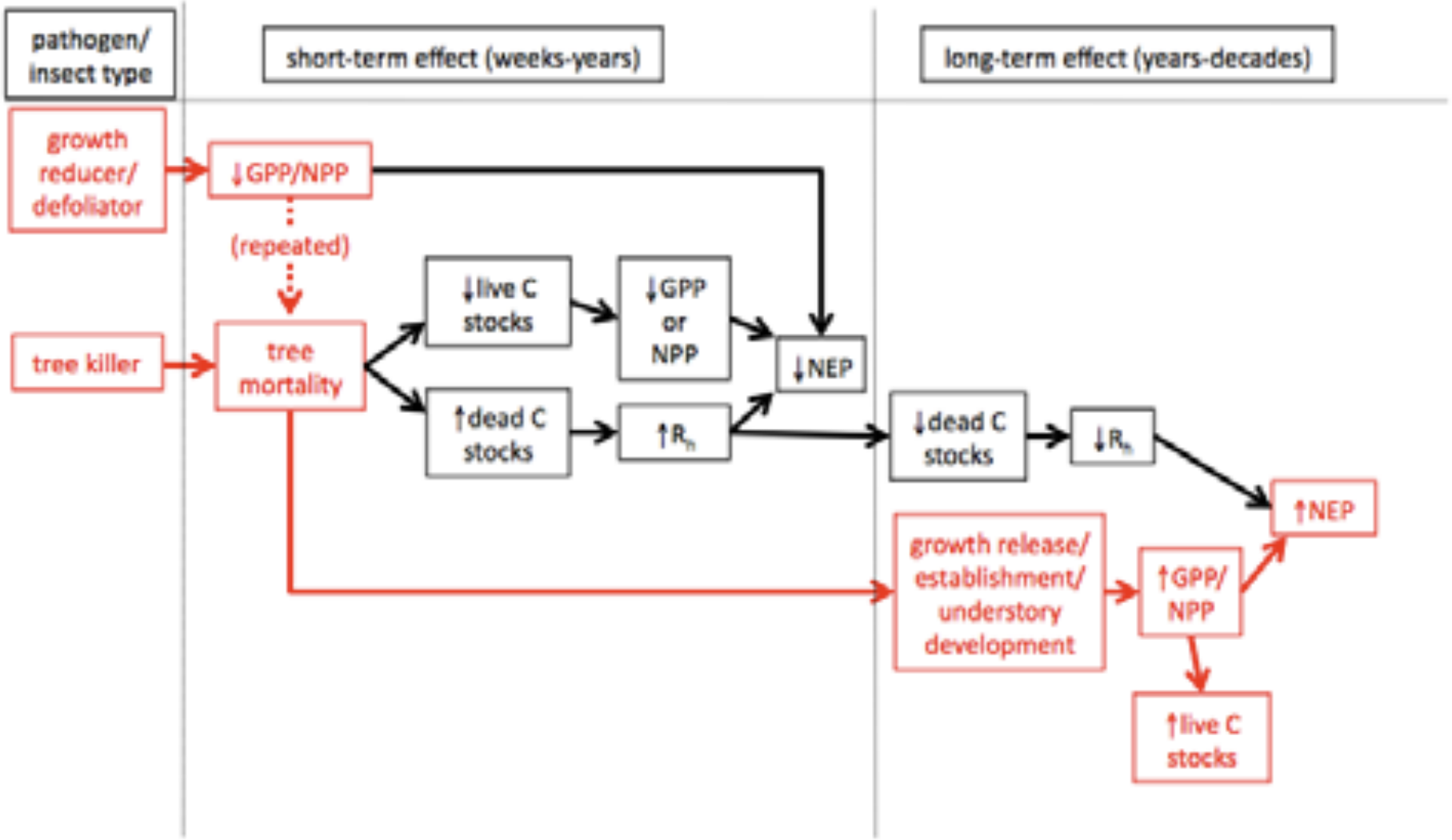


Albani et al. 2010

Impacts depend on #trees affected within study region

Findings: Types of impacts to C cycling

3. Tree mortality affecting recovery of C stocks, fluxes

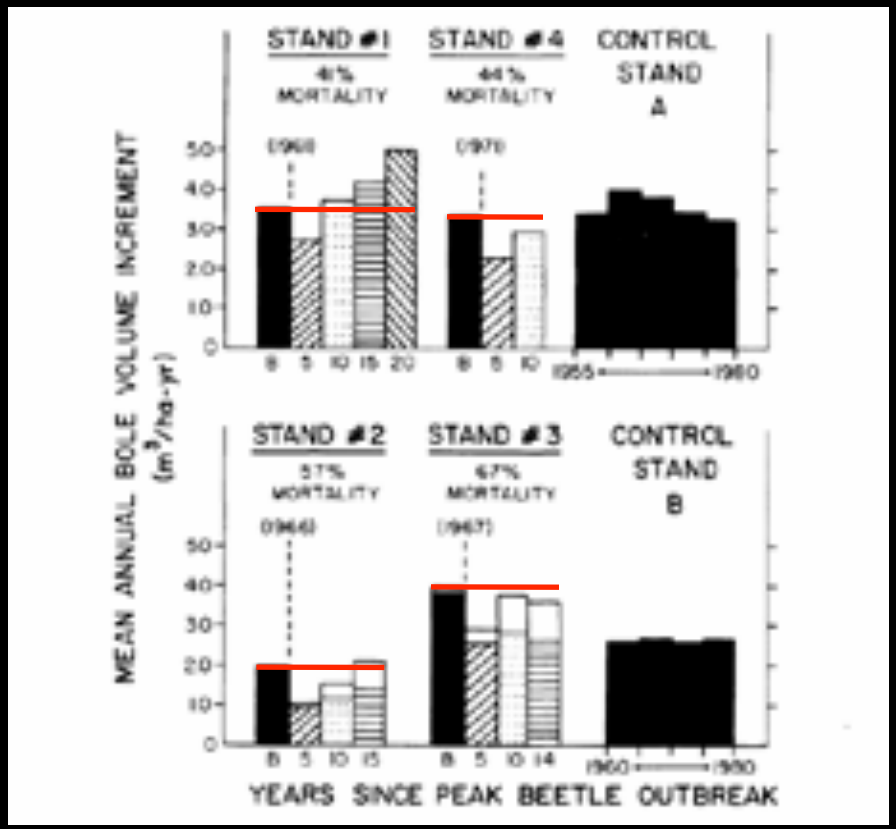


Hicke et al. in revision

Findings: Impacts to C cycle

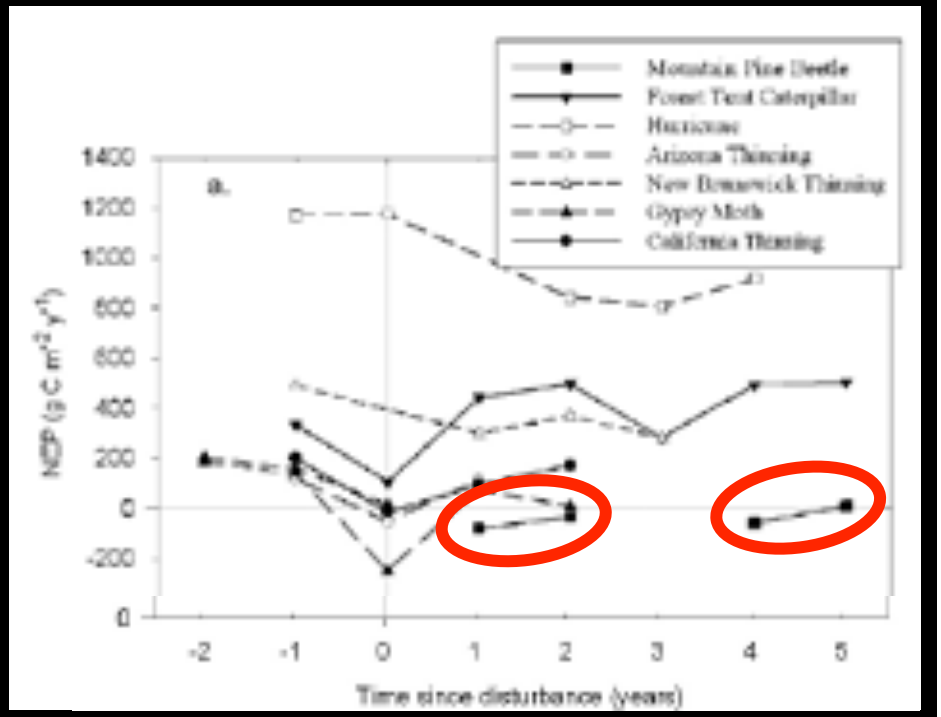
3. Tree mortality affecting recovery of C stocks, fluxes

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



Romme et al. 1986

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

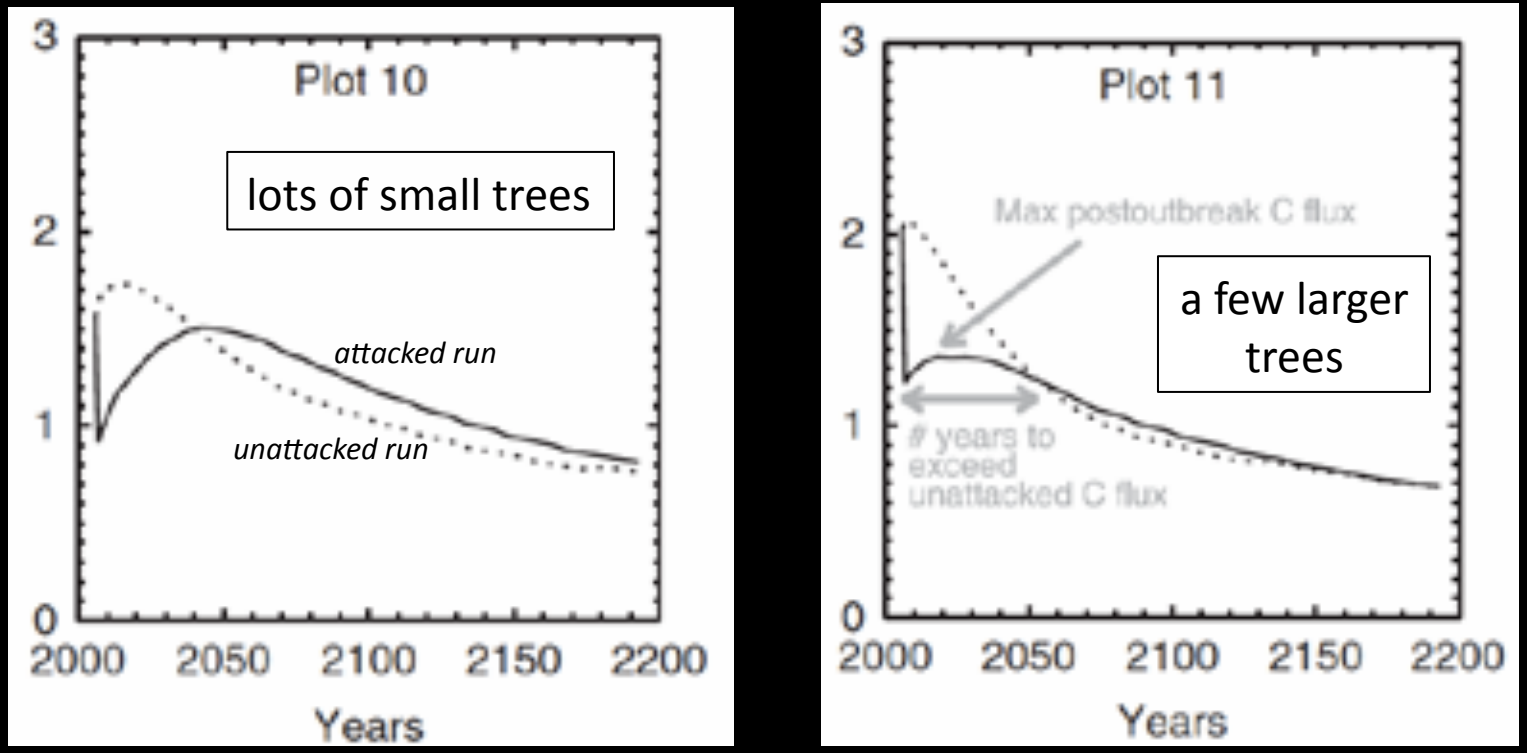


Brown et al. 2010, Amiro et al. 2010

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



Pfeifer et al. 2011

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