Emerging Regional and National Issues in Tree and Forest Health over the Next 10 Years

An Academic Perspective

Charles Canham

Senior Scientist
Cary Institute of Ecosystem Studies
Millbrook, NY 12545 USA

Ecological and Economic Impacts of Exotic Pests and Pathogens in Northeastern Forests

Cary Institute	Penn State	APHIS
Charles Canham	Mike Jacobson	Vic Mastro
Shannon LaDeau	Rich Ready	David Lance
Lora Murphy	Marc McDill	
Radka Wildova		

Synopsis

- My personal assessment of the major forces determining the current and future distribution and abundance of tree species in eastern U.S. forests
  - Introduced pests and pathogens
  - Past and future human land-use
    - Logging as the primary regional disturbance regime
  - Air pollution
  - Climate change

- Integrating these processes in a model of forest dynamics, parameterized with regional forest inventory data
  - SORTIE-ND

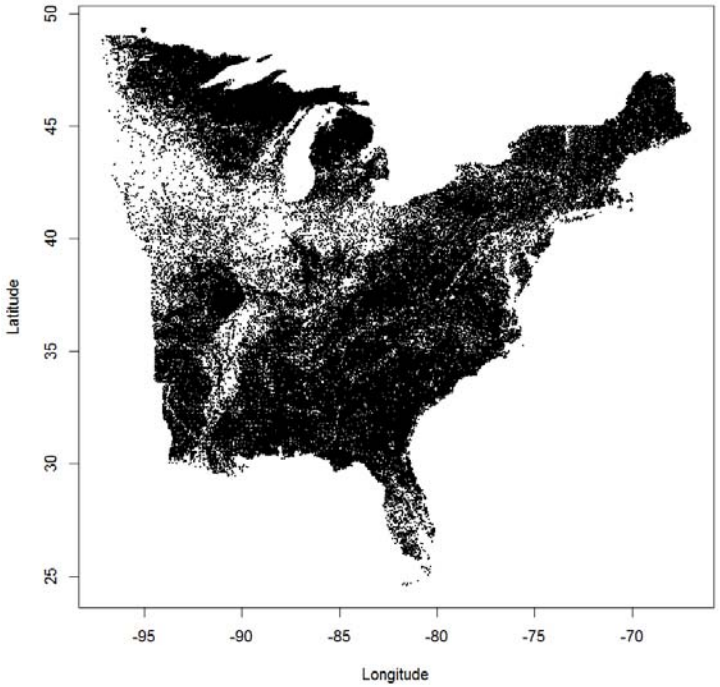
- Disclaimer: I will focus on ecological rather than economic impacts
  - And only on a very narrow range of the ecological impacts

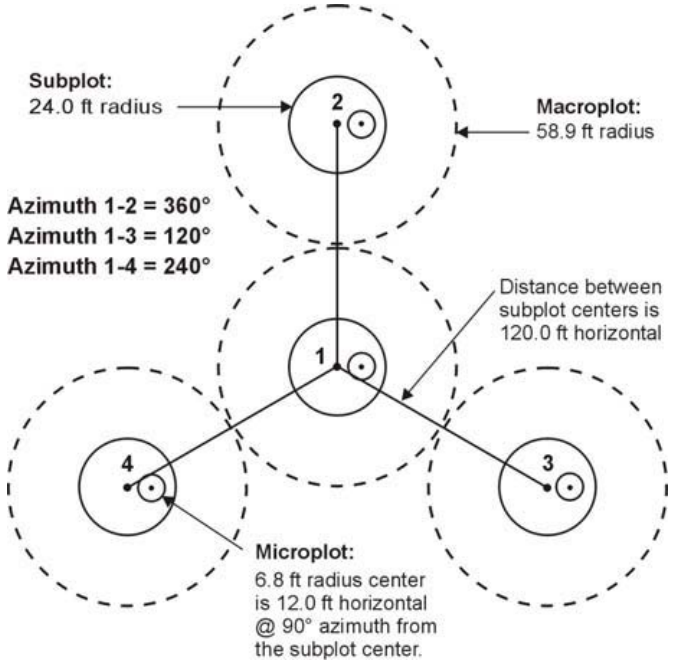
The U.S. Forest Service Forest Inventory and Analysis (FIA) Program

BASIC NETWORK DESIGN

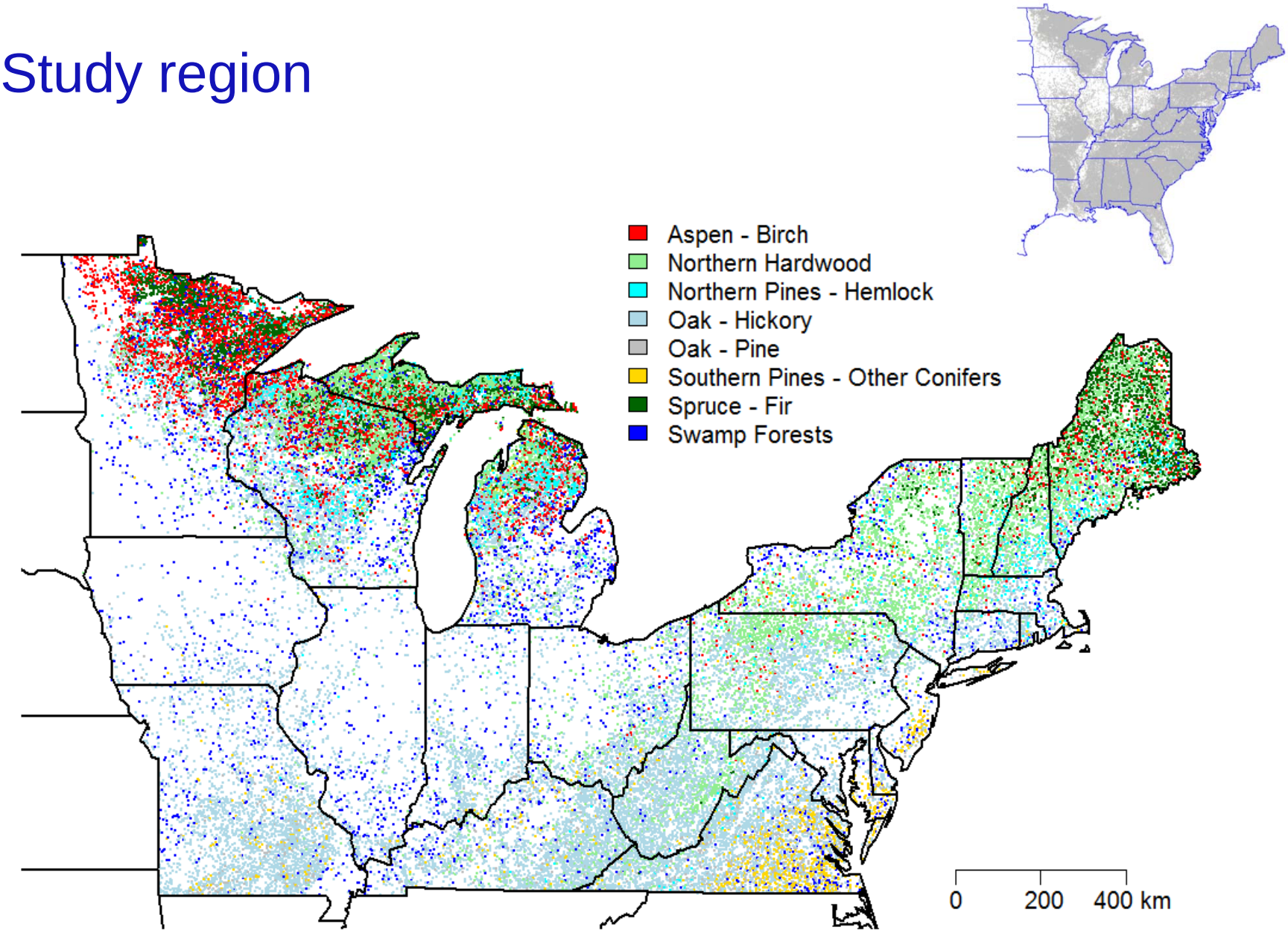
- Stratified random plot locations
- 1 plot per 6,000 acres of land
- Individual plots recensused ~ every 5-7 years (with a subset of plots sampled each year)
- Data posted and publicly available* within ~ 1 year after collection

**exact plot locations are confidential, by law…*





Study region



Individual dots are FIA plots that have been censused twice since 1999…

Pests and Pathogens

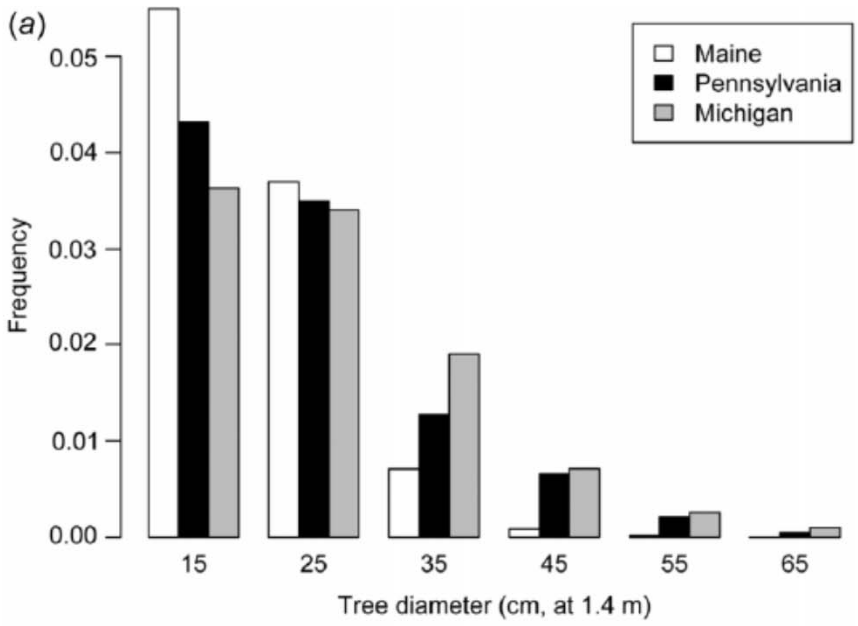
- Arguably the most pervasive human impacts* on eastern US forests over the past century have been from the introduction of new pests and pathogens…
  - Chestnut blight
  - Dutch elm disease
  - Gypsy moth
  - Beech bark disease
  - Hemlock wooly adelgid
  - Emerald ash borer
  - Asian longhorned beetle
  - …? (including changes in outbreaks of native pests and pathogens)

Heavily diseased and resistant beech trees

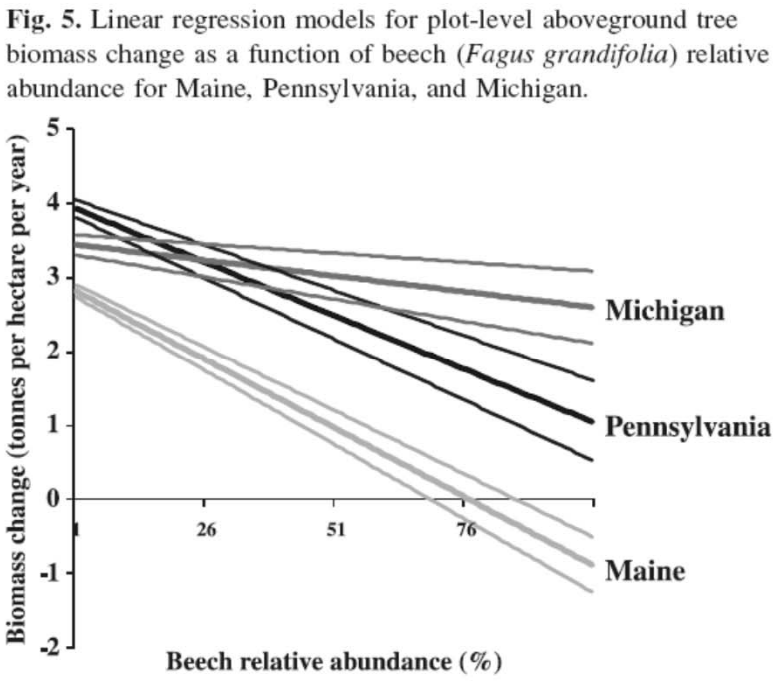
**on distribution and abundance of specific tree species*

Regional Impacts of Beech Bark Disease

Size structure of beech populations



Impact of beech abundance on stand biomass increment



Busby and Canham (2011), Canadian Journal of Forest Research 41:401-411

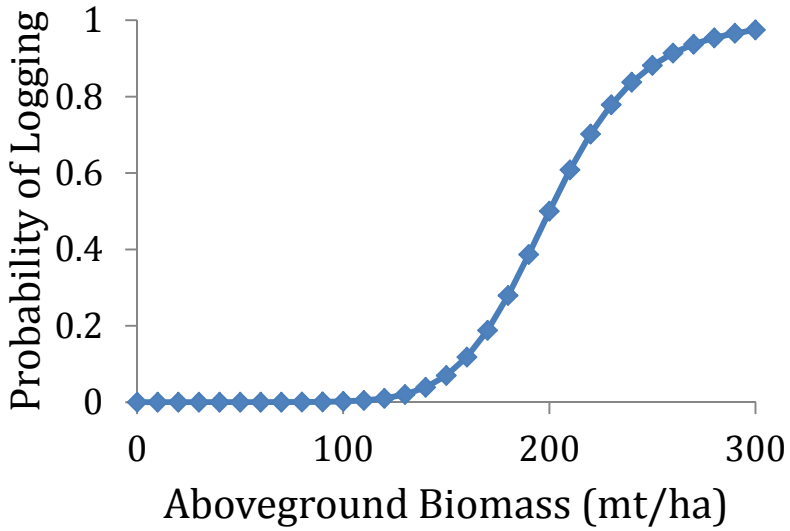
Pests and Pathogens as Biotic "Disturbances"

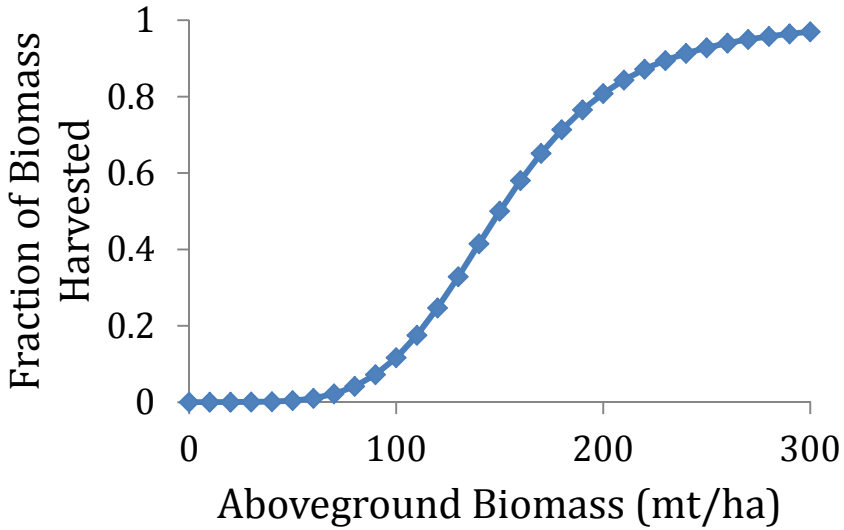
- **Windthrow** is the dominant natural disturbance in the mesic forests (hurricanes, thunderstorms, tornadoes, extra-tropical cyclones)
  - Return intervals of > 1000 years for catastrophic disturbance
  - More frequent intermediate disturbance

- but **Logging** is by far the most common form of "disturbance" in these forests
  - Logging accounts for 57% of all adult tree mortality in northeastern U.S. forests
  - And removes 65% of net growth*

**data from 2002-2007*

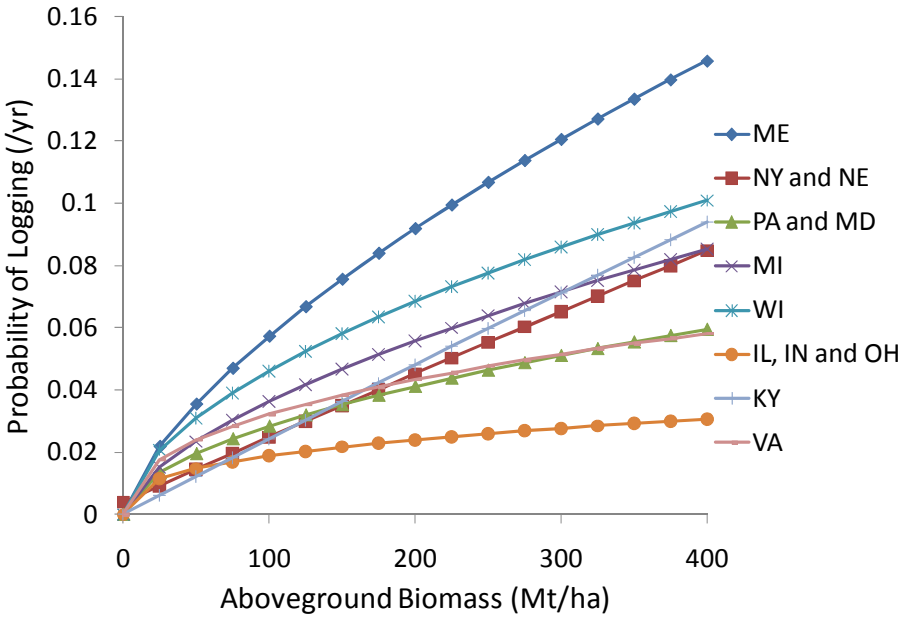
What would traditional even-aged logging look like (statistically)?

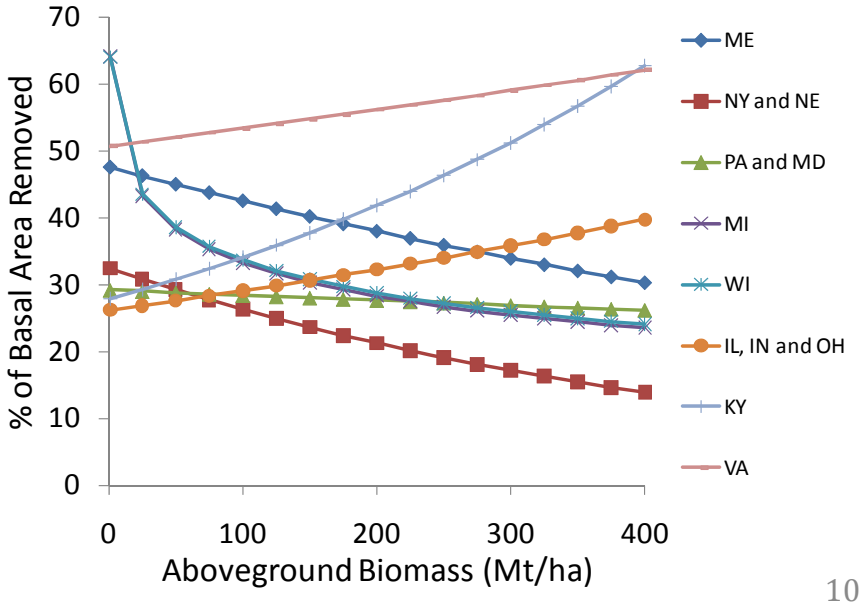




What's really going on in the woods?..

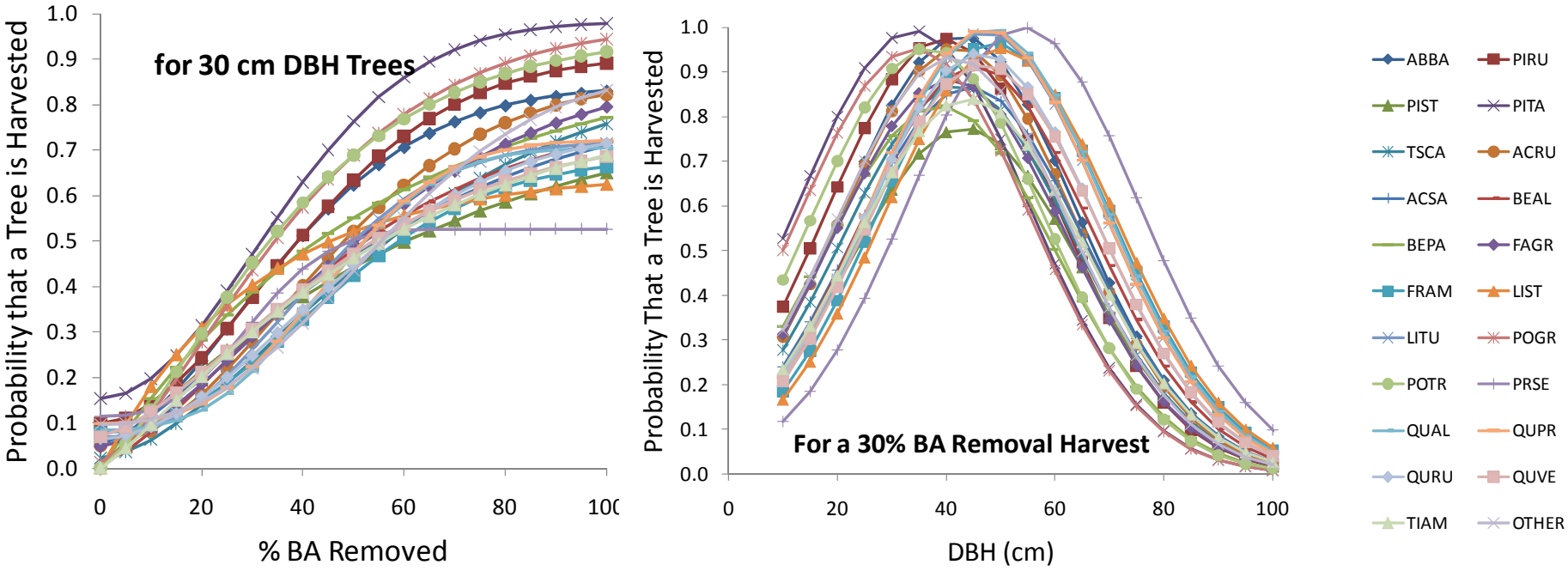
.





And logging is highly selective in terms of species and size…

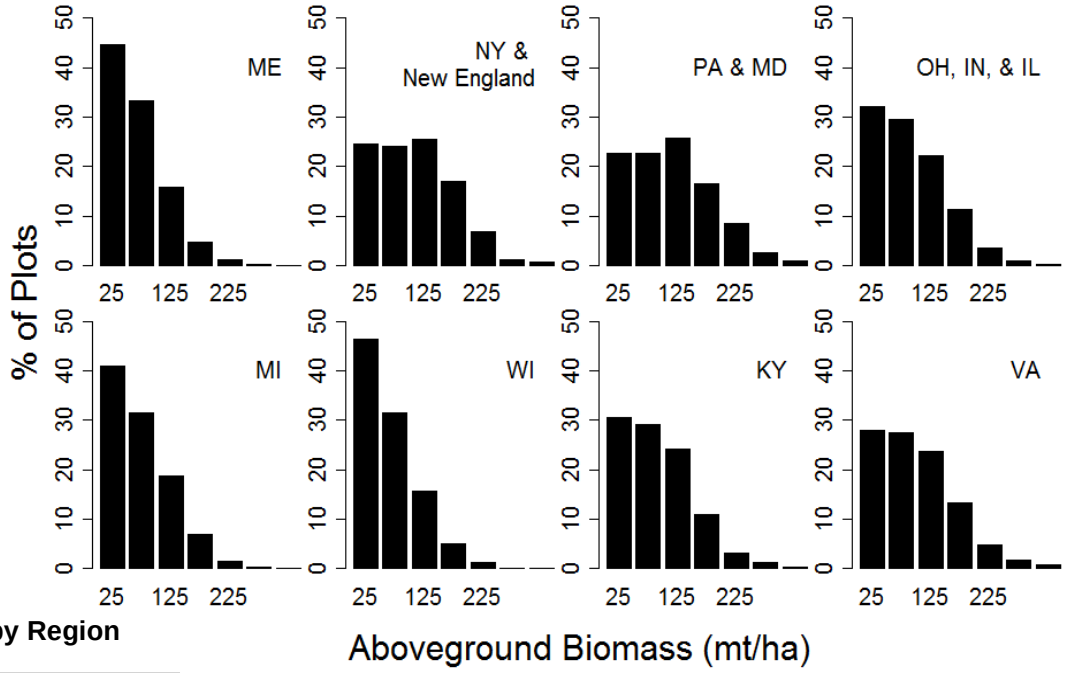
Why aren't big trees harvested?...

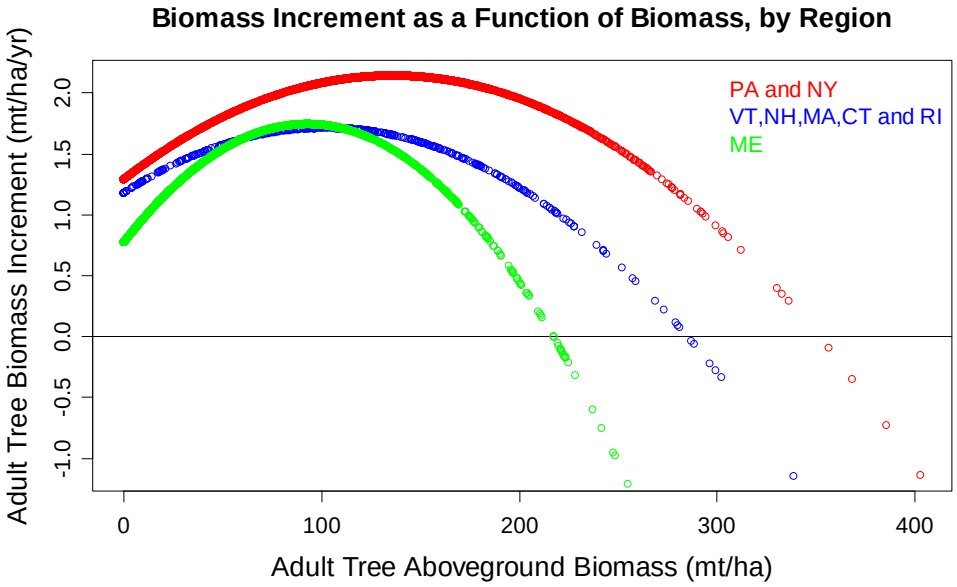


Canham et al. 2013. Ecol. Appl. 23:515–522

Why is it important to know this?

- Misunderstanding of potential future rates of carbon sequestration and sustainable yield in forests…





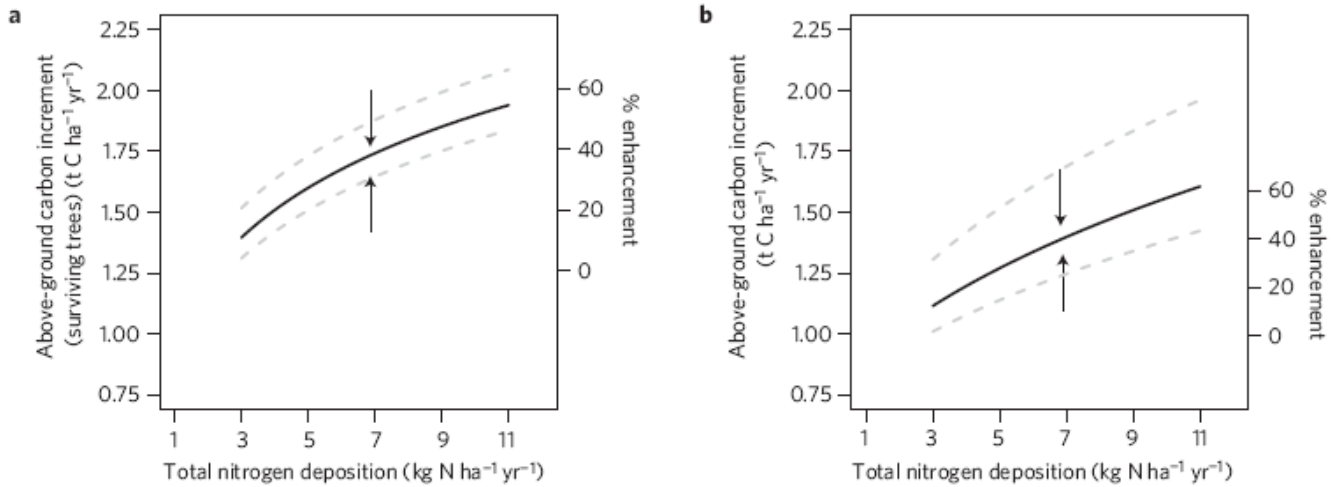
Canham et al. (2013)
Ecol. Appl. 23:515–522

Other issues to consider…

- Will logging be used to pre-empt mortality from pests or pathogens?
- Will harvests be increased substantially for biomass energy?
- Will landowners change their management in anticipation of climate change?
- What fraction of the forest land base is effectively "reserved" from logging

Air Pollution...

- Acid deposition and soil calcium depletion
- Ozone exposure
- CO_2 fertilization
- Nitrogen deposition



Thomas, R. Q., C. D. Canham, K. C. Weathers, and C. L. Goodale. 2010. Increased tree carbon storage in response to nitrogen deposition in the US. Nature Geoscience 3:13-17.

And on and on…

Fire suppression in oak forests

Over-abundant herbivores
White-tailed deer
(*Odocoileus virginanus*)

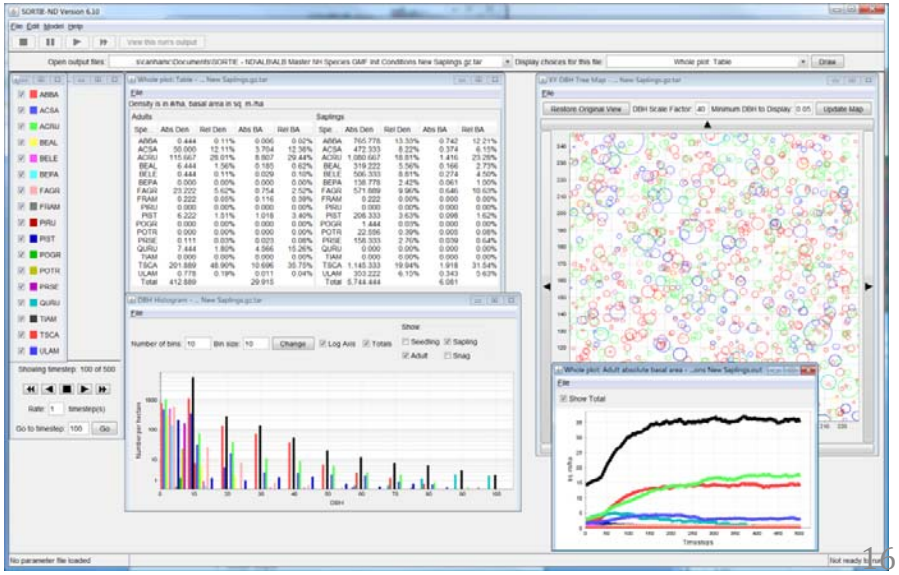
Invasive plant species
Garlic mustard
(*Alliaria petiolata*)

How do you tie this all together?

SORTIE-ND

A spatially-explicit model of neighborhood dynamics

- Individual-based
  - Simulates the birth, growth, and death of all seedlings, saplings and adult trees
- Spatially-explicit
  - The spatial locations of all individuals are tracked, and can be used in processes ranging from seed dispersal to resource competition
- Adaptable
  - Users create and assemble "behaviors" based on available field data
- Open-source
  - The source code and programming guides are available to all users (www.sortie-nd.org)
  - changes made by any user are incorporated in the base model available to all



Parameterizing SORTIE-ND from FIA data

- Basic strategy:
  - Use FIA data to develop statistical models of all of the functions needed to characterize birth, growth, and death of each of the tree species in the region (e.g. Canham et al. 2006, *Ecological Applications*).
  - Incorporate climate data (temperature and precipitation) in the functions so that the model can be regionalized, and run under climate-change scenarios (e.g. Thomas et al. 2012, *Nature Geosciences*, Canham and Thomas 2012, *Ecology*)
  - Use FIA data and expert knowledge to design subroutines to simulate impacts of exotic pests and pathogens (i.e. Busby and Canham 2012, *CJFR*)
  - Use FIA removal data to characterize regional harvest regimes (i.e. Canham et al., *Ecological Applications 2013)*
  - Run simulations initialized with current FIA plot data to capture effects of land-use history, and to allow regionalization of output

Incorporating Climate…

How do specific demographic rates respond to variation in climate?

- Data:
  - Used the most recent, recensused FIA plot data for upland forests from all eastern US states
  - Bilinear interpolation of 800 m resolution PRISM climate data for the time period between censuses for each plot location

- Analyses
  - Fit statistical models for the 50 most common tree species in eastern NA for
    - Seedling recruitment and survival
    - Growth and survival of juveniles and adults

Initial Model Results

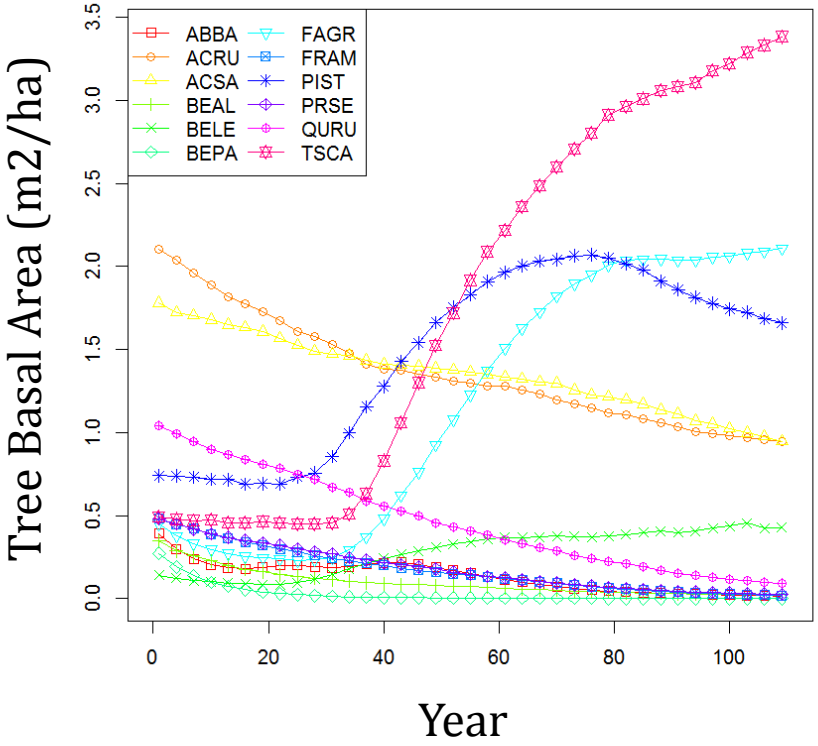
- Initialized 1000 runs of the model with 1000 randomly selected FIA plots from the study region
- Scenarios
  - No climate change, but with current harvest regime
  - Current harvest regime + climate change
    - 3º C or 6º C temperature rise over 100 years
    - 10% increase in precipitation
  - Harvest + Climate change + Asian Longhorned Beetle

STUDY REGION

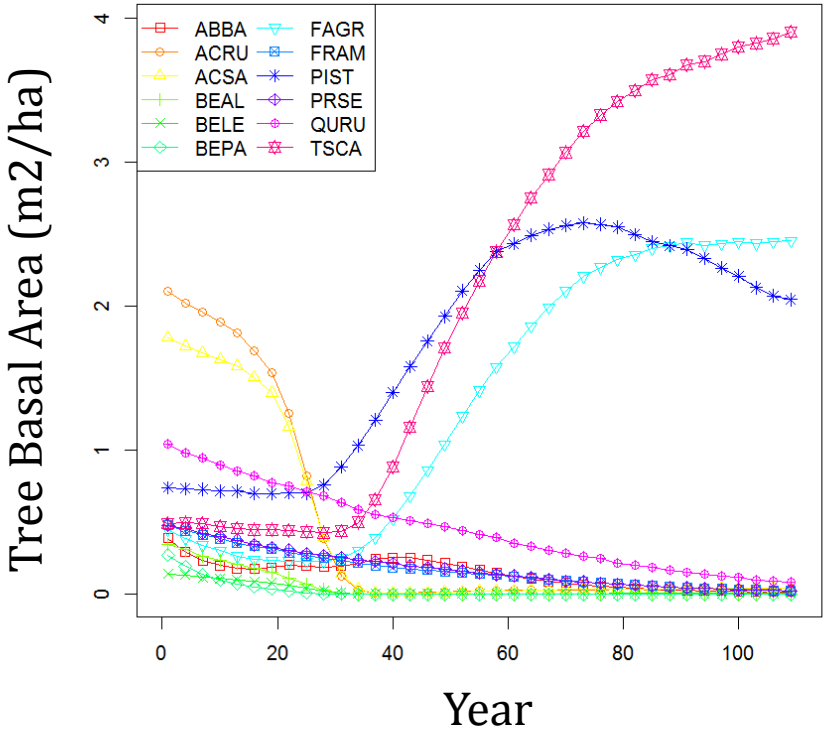
Initial model results …

- Unchecked spread of ALB causes dramatic decline in forest biomass, and loss of *Acer, Betula,* and *Populus* species
- Decline in biomass takes 60-80 years to recover to pre-ALB levels
- Overall timber value loss of ~ $18 billion over the 19-state study region

Without ALB



ALB arrives in year 10



Some initial conclusions

- Current forest management strongly favors succession to shade tolerant tree species
  - And the three most common shade tolerant species in the region (beech, hemlock, sugar maple) are all threatened with an exotic pest or pathogen
- It's not possible to predict the ecological or economic impact of any one of these pests or pathogens in isolation from the others, or in isolation from the other major forces shaping forests
  - Climate change impacts on tree health and distribution and abundance of pests and pathogens
  - Effects of air pollution on tree health and susceptibility to pests and pathogens
  - Effects of deer and understory invasive species on tree regeneration following overstory mortality due to pests and pathogens

But the direct effects of climate change, *per se*, are very small

- Temperate tree species have extremely broad climate tolerance!
  - Particularly for both mean and extreme temperatures
- They are rooted in place!
  - Potential for migration is limited
- And possession is 9/10's of the law!
  - Current occupants have a strong competitive and demographic advantage over new colonists…

Bottom line: eastern forests may be among the most resistant to climate change of any ecosystems on the planet…

Current work

- Use FIA data through 2012 and west to include 32 eastern states to roughly double the amount of data available for parameterization
- Include topographic and soils data to capture variation in effective soil moisture within a given climate
- Incorporate the 4 major current pests and pathogens threatening eastern forests
  - Beech bark disease, hemlock wooly adelgid, emerald ash borer, Asian longhorned beetle
- Increase computing capacity to allow simulation of 10-50K "stands" per scenario, initialized with composition and structure from randomly selected FIA plots

Cary Institute of Ecosystem Studies

PENNSTATE 1855

APHIS ANIMAL and PLANT HEALTH INSPECTION SERVICE

NSF