

Forest Landscape Sustainability in a Highly Dynamic World: Challenges for Ecosystem Management

Robert M. Scheller, Ph.D.

Conservation Biology Institute



Outline

1. Overview
2. Case studies
3. Future research directions

Landscape Sustainability

A sustainable forest landscape preserves for the **foreseeable future** desired ecosystem functioning.

Therefore, sustainability must be assessed and understood at longer time scales (decades or centuries).

Ecosystem Functioning

Ecosystem function -

The provision of a service valuable to humans.

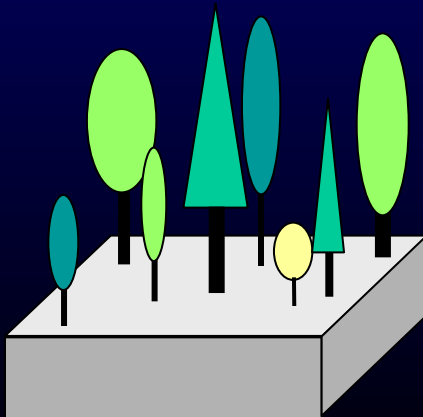
Examples of forest ecosystem functions:

- maintenance of biodiversity
- carbon sequestration
- economic returns
- recreational opportunities
- water filtration

What Is A Landscape?

Forests at Many Scales

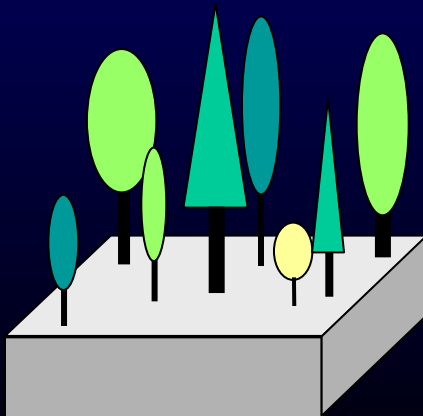
A Single
Unit



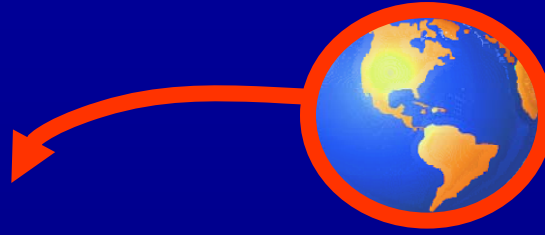
e.g., a forest stand or a
parcel or a woodlot

Forests at Many Scales

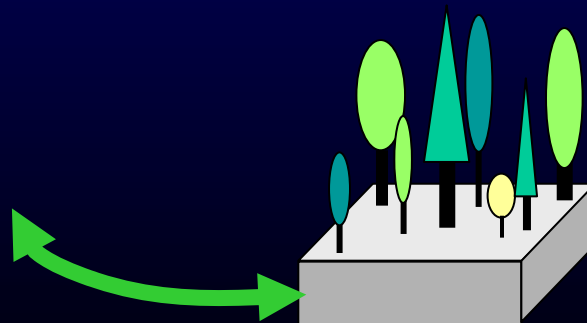
Global or
Continental



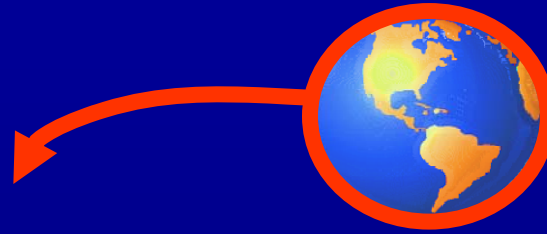
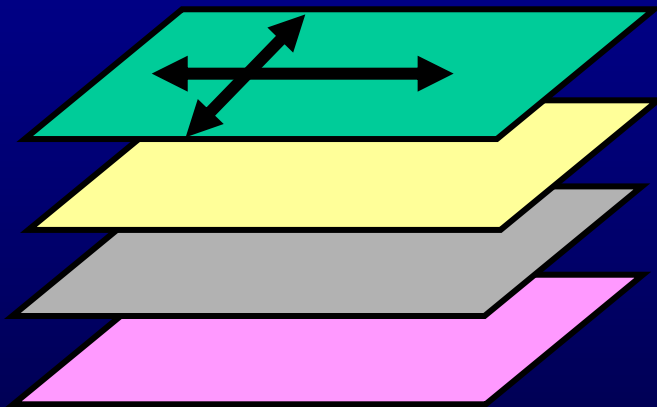
Forests at Many Scales



**Landscape or
Regional Scales,
aka 'Meso-scale'**

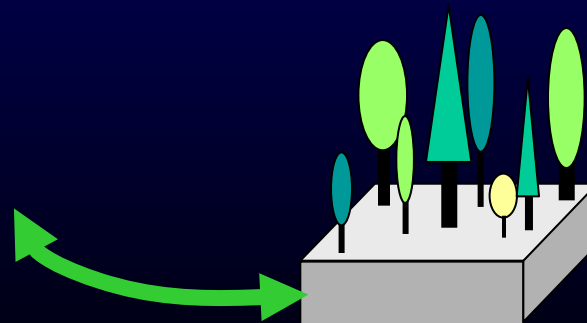


Defining Features of Forested Landscapes



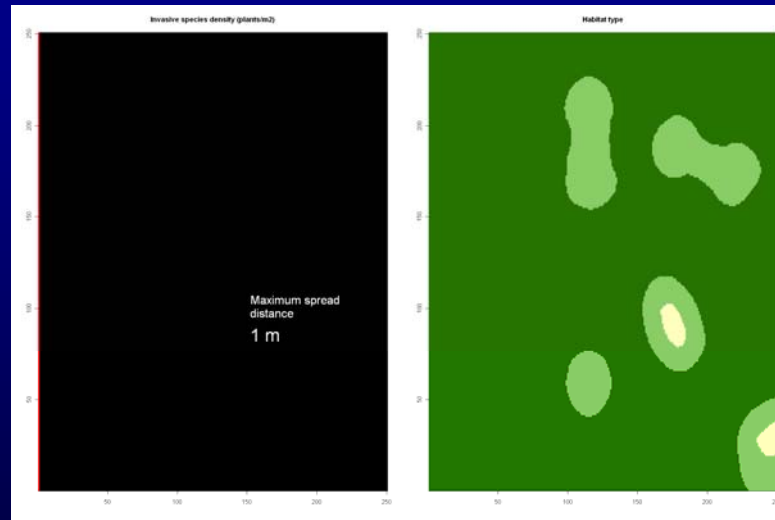
Spatial interactions:

Horizontal exchange of
information, matter, energy



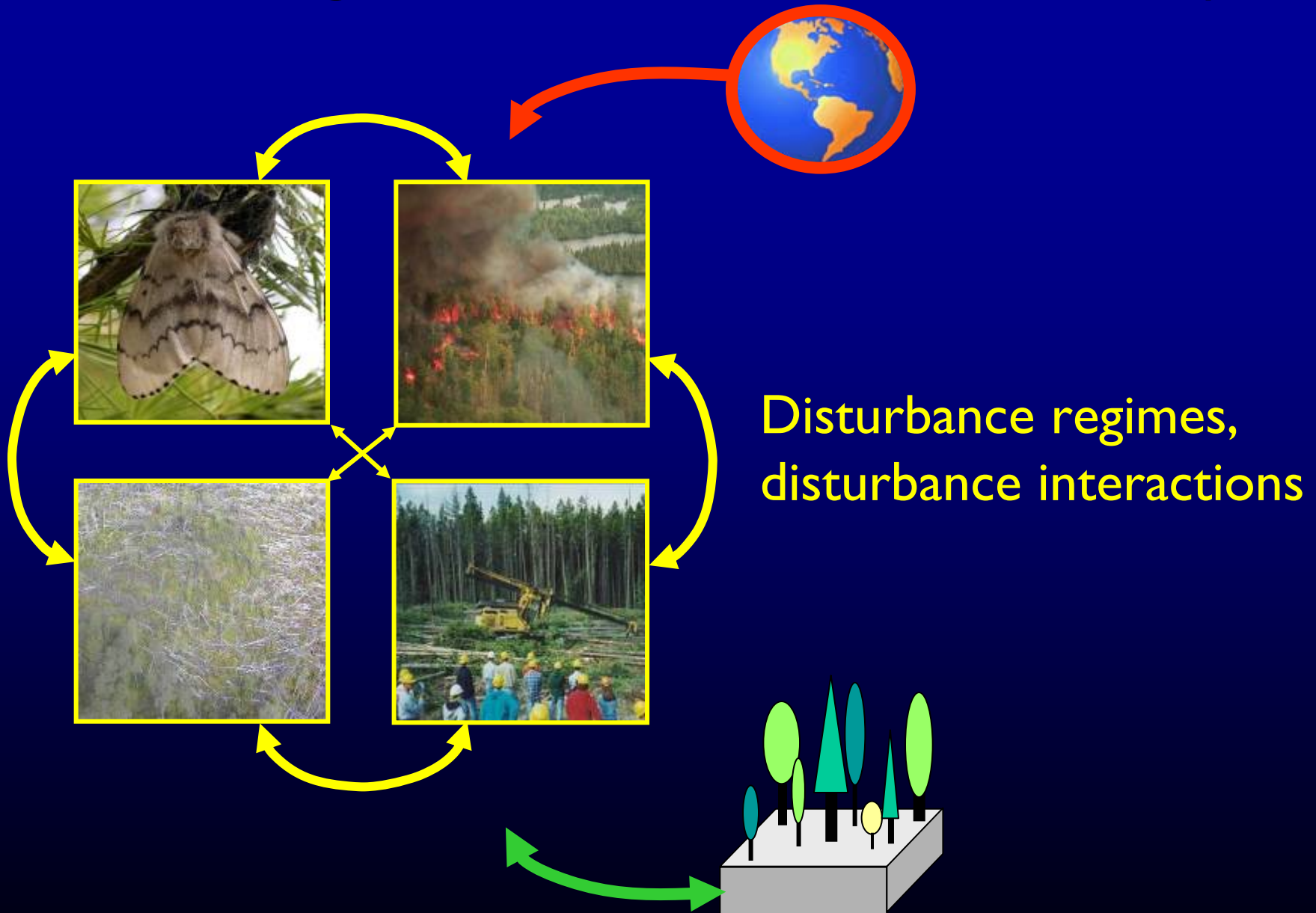
Spatial Interactions

Simulated garlic mustard invasion

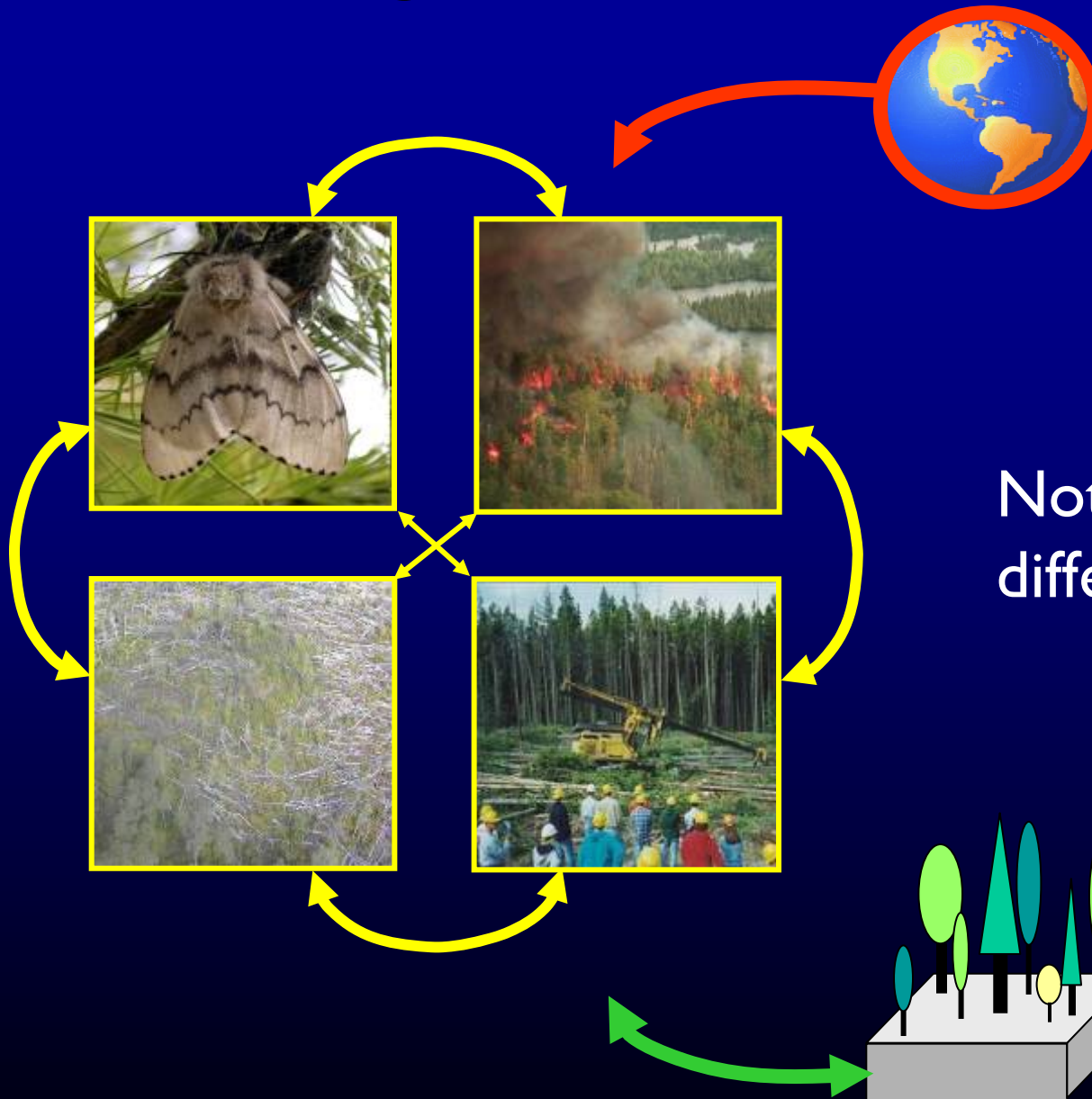


- low density garlic mustard
- high density garlic mustard
- disturbed: low light
- disturbed: high light

Defining Features of Forested Landscapes



Defining Features of Forested Landscapes



Note: Interspecific differences are critical.

Interspecific Differences and Disturbances

Genus *Pinus*

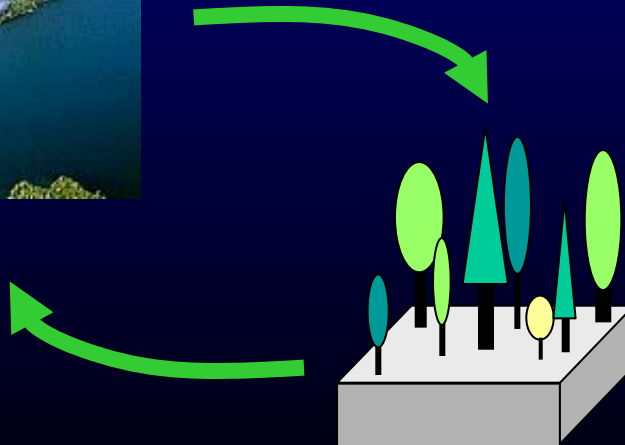


Defining Features of Forested Landscapes



Disturbance promotes biodiversity.

Biodiversity promotes resilience.

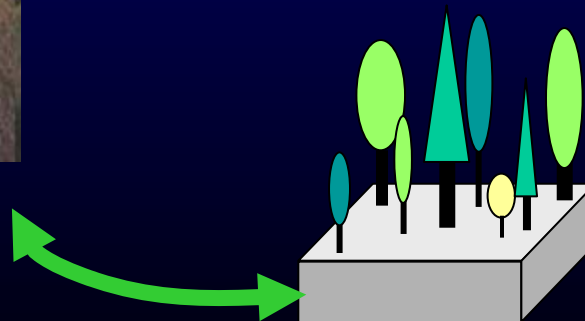


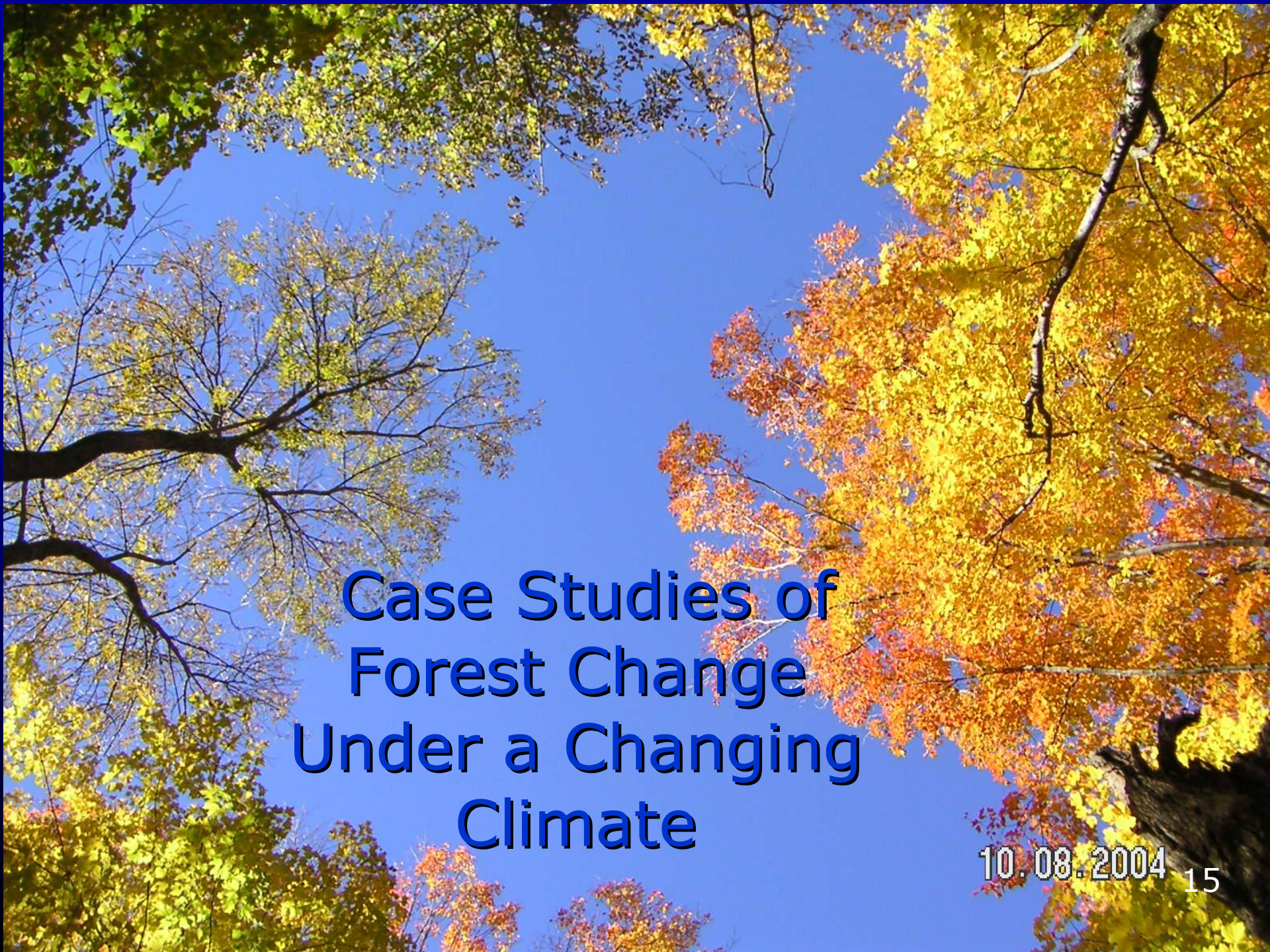
Defining Features of Forested Landscapes



Management

Considering only individual parcels will not achieve ecosystem sustainability objectives.





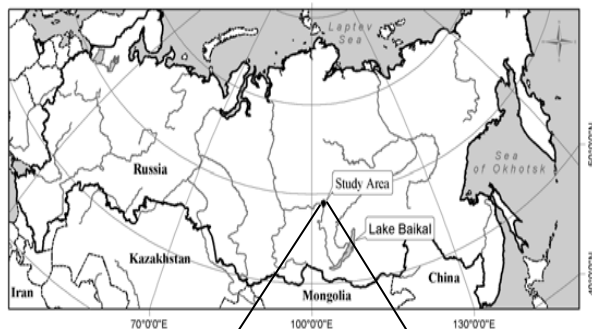
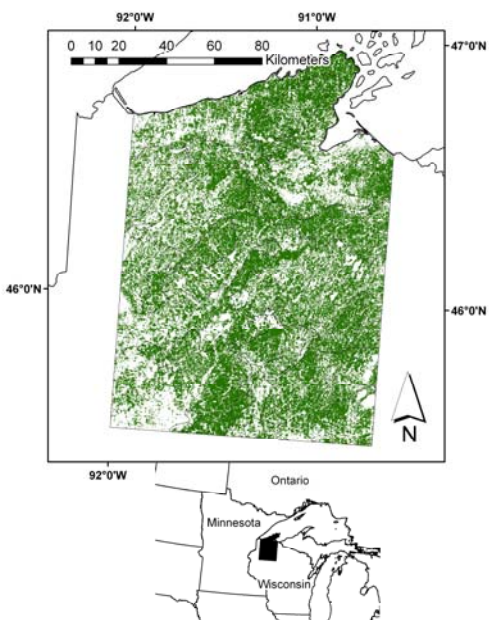
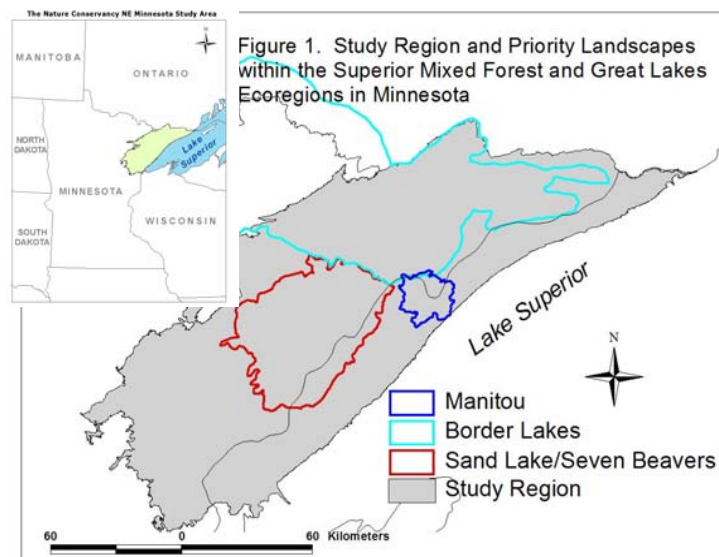
Case Studies of Forest Change Under a Changing Climate

10.08.2004 15

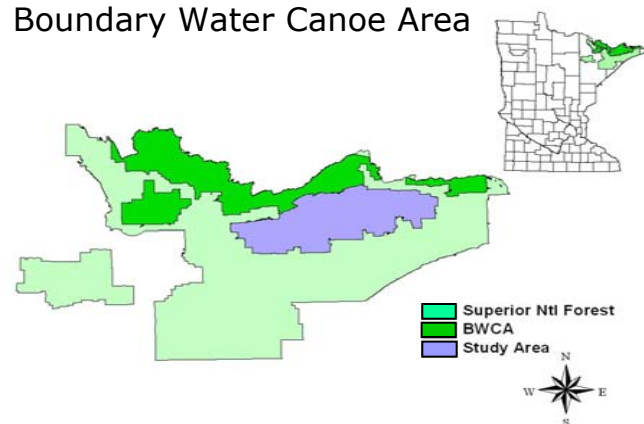
Case Studies: How Will Climate Change Affect Northern Forest Ecosystem Functioning?

- Ravenscroft, Scheller, White, and Mladenoff. In press. *Ecological Applications*.
- Gustafson et al. In press. *Ecological Applications*
- Xu, Gertner, and Scheller. 2009. *Global Change Biology*.
- Scheller and Mladenoff. 2008. *Climate Research*.
- Xu, Gertner, and Scheller. 2007. *Global Change Biology*.
- Scheller and Mladenoff. 2005. *Global Change Biology*.
- Scheller and Mladenoff. 2004. *Ecological Modelling*.

Study Areas



Boundary Water Canoe Area



A Complex Suite of Processes

Climate change is only one of many important drivers of forest change.

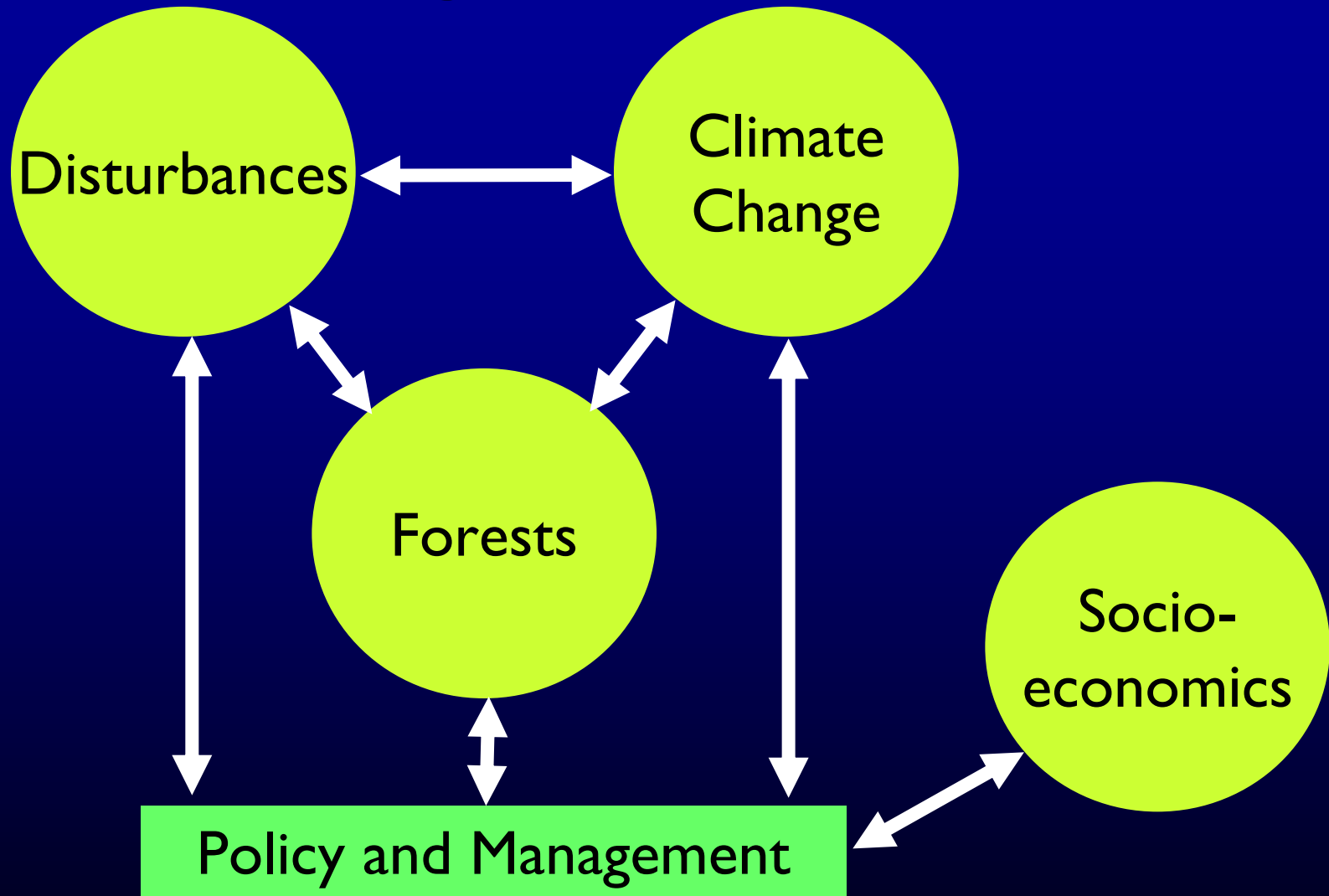
Key spatial processes:

Fire is the dominant process in boreal or near-boreal forests.

Harvesting is the most important disturbance in temperate northern forests.

The rate of tree species migration will likely lag behind the rate of climate change.

Climate Change Effects on Forests



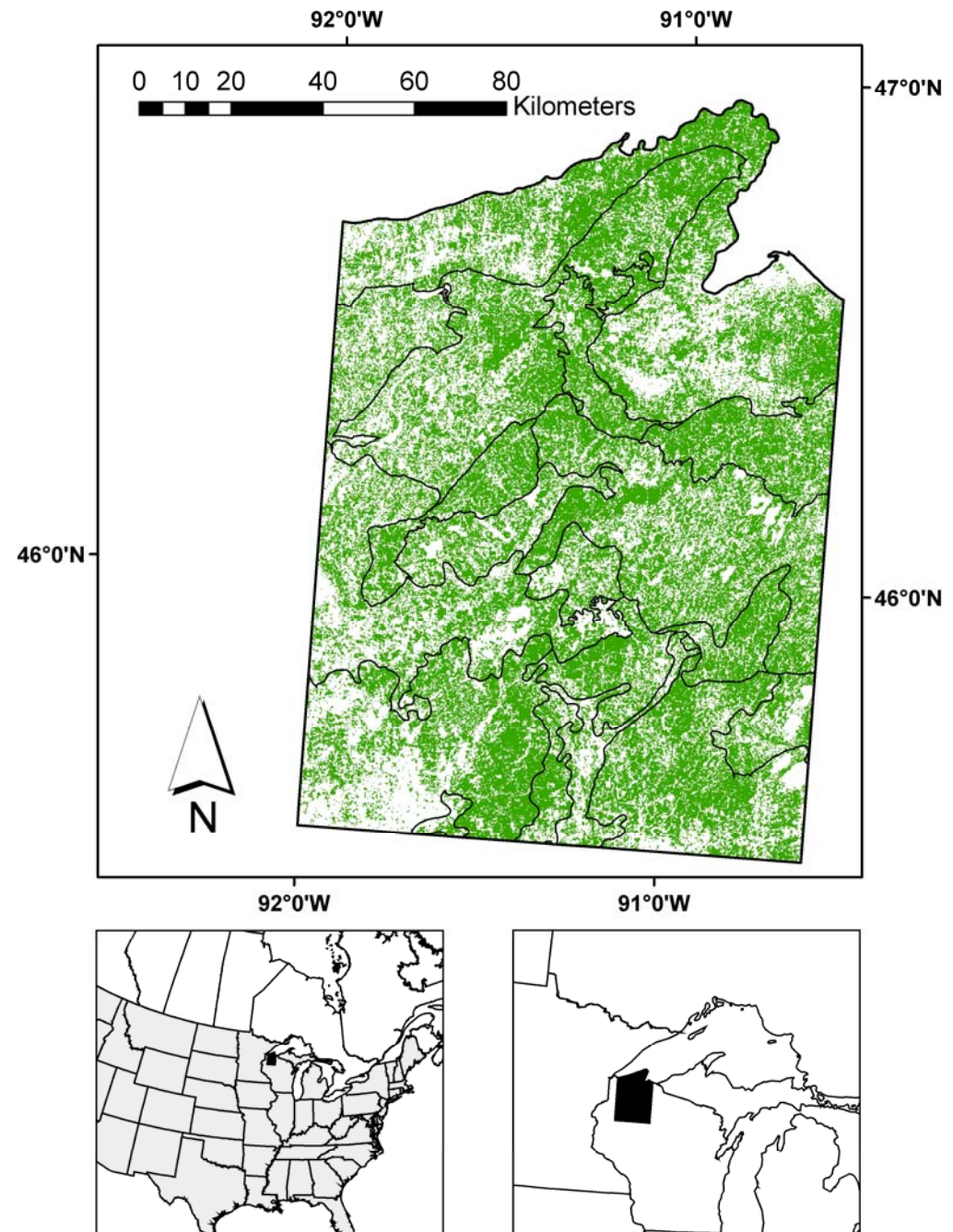
Study Area

Dry conifer and mesic
northern hardwoods

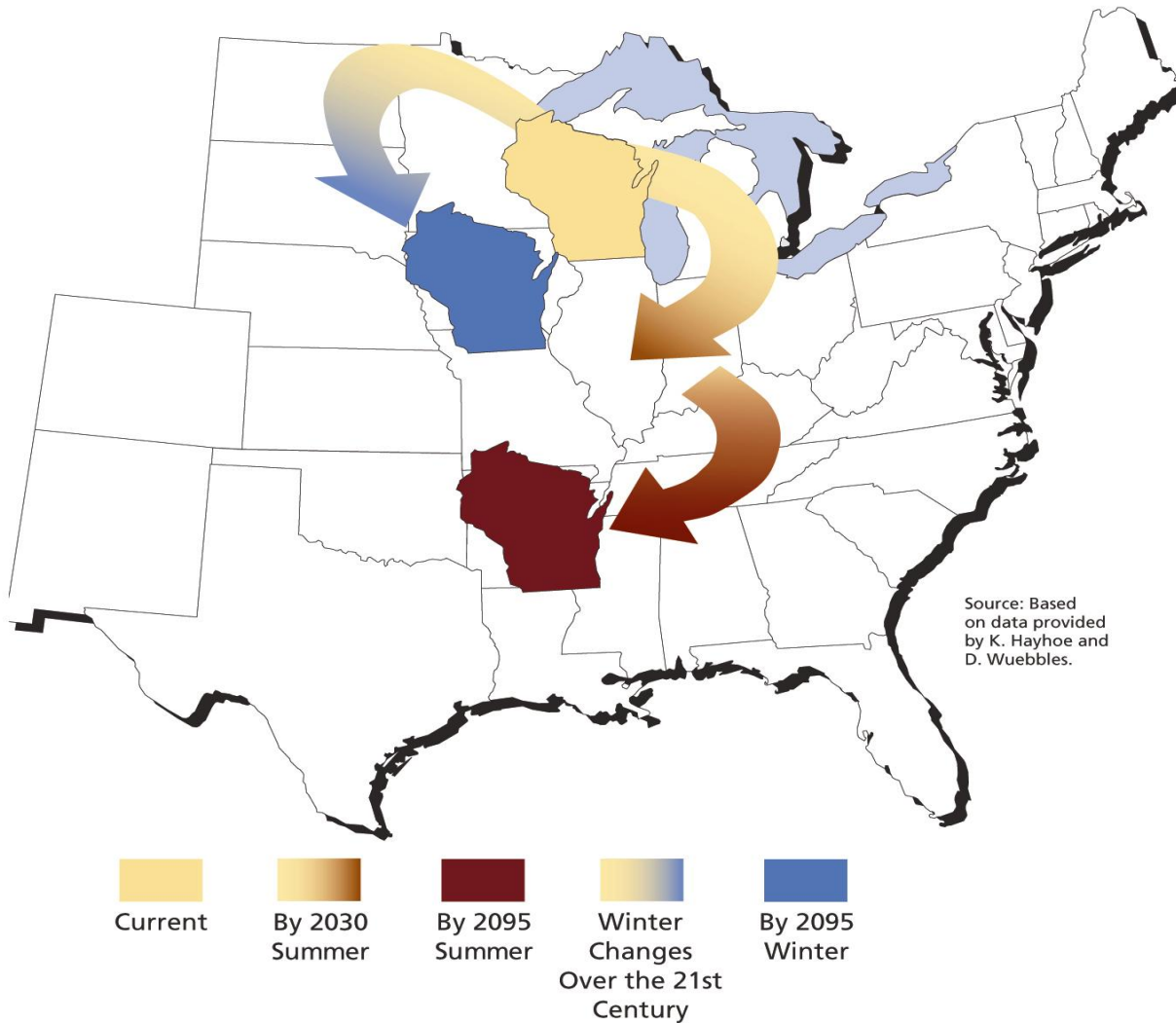
Lies along an transitional
zone with:

- boreal species
- southern oaks
- maples, white pine,
aspen

Divided into 10 land
units



Climate Change Effects



Our Approach: Landscape Simulation Models

Provide estimates of forest landscape change and ecosystem functioning

Experimentation

- replicated experimentation at broad scales is impossible
- create artificial *in silico* experiments

Heuristic value

- synthesize multi-scalar data
- formalize ideas
- evaluate importance of various drivers

LANDIS-II: Forest Landscape Simulator

LANdscape DIsturbance and Succession

- simulates succession and disturbance interactions

Spatially Dynamic

- emphasis is on spatial processes and spatial context

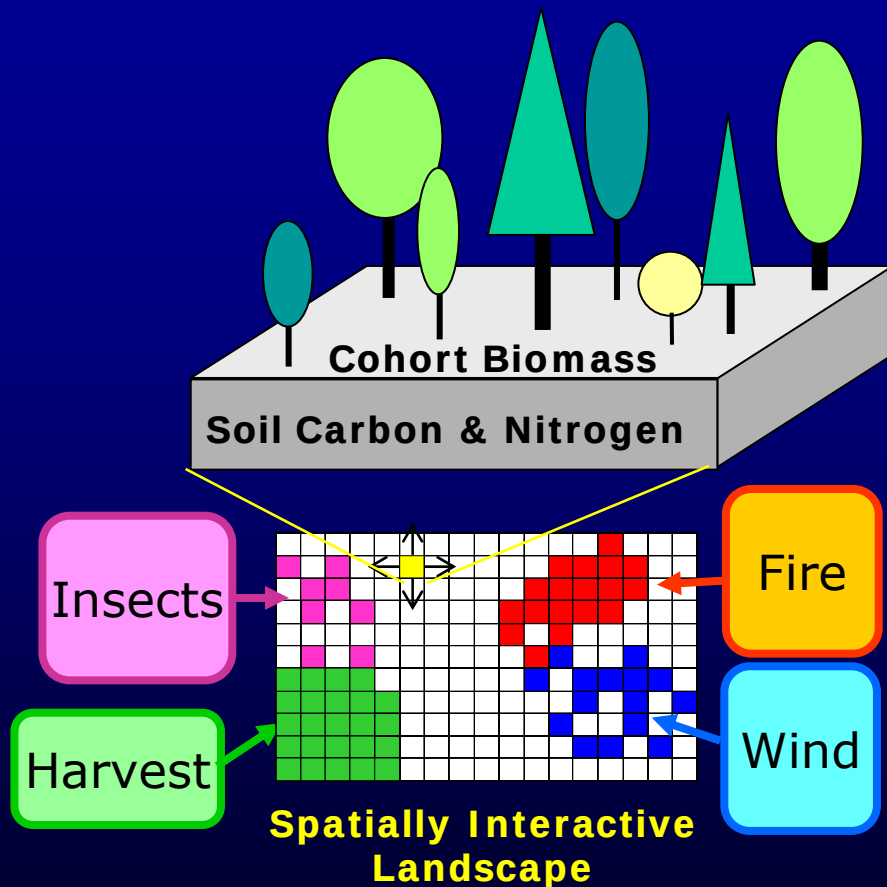
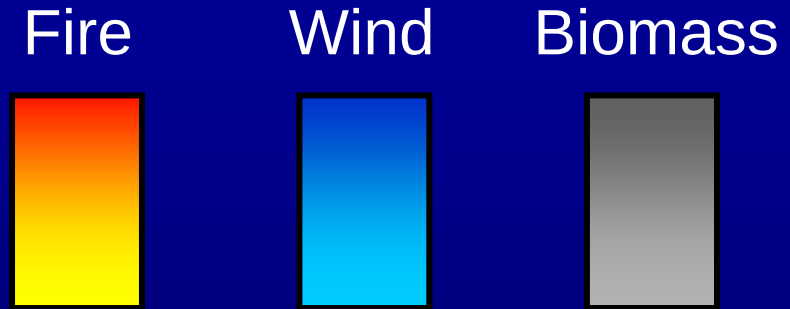
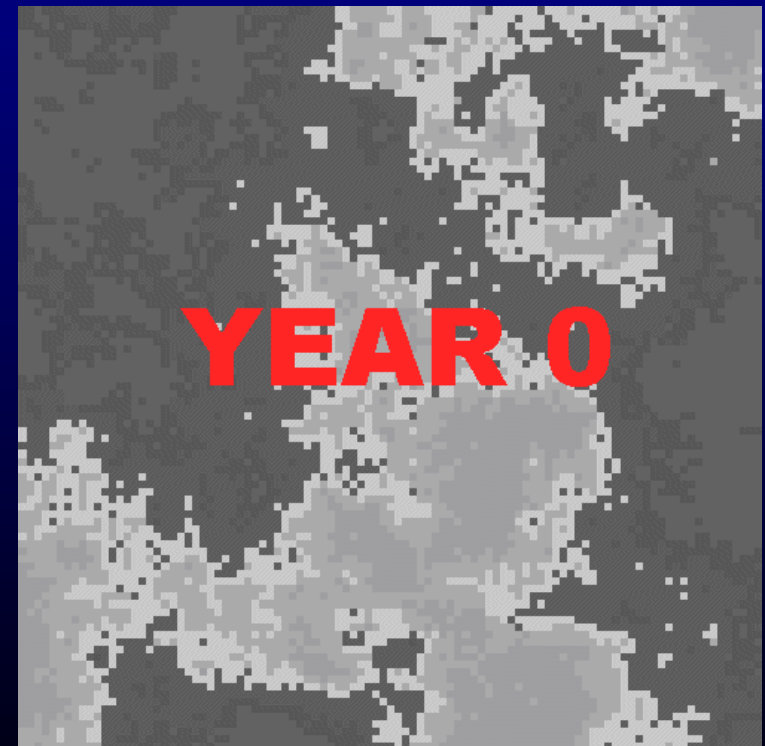
Species-centric

- tree species with unique life history attributes
- provides an important connection to management

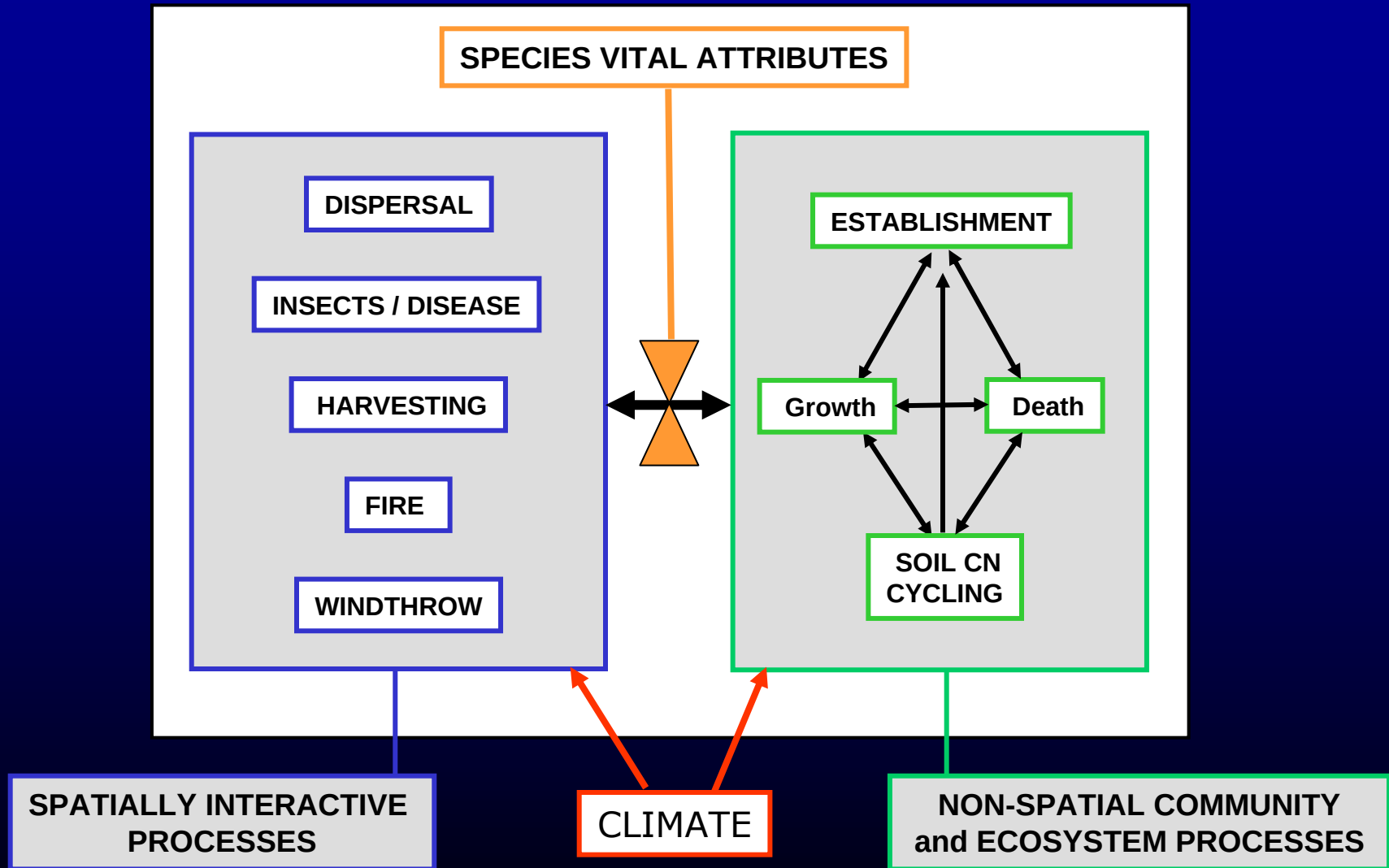
Stochastic

- probabilistic disturbance and reproduction

LANDIS-II: Forest Landscape Simulator



LANDIS-II: Forest Landscape Simulator



Known LANDIS-II Applications



Forest landscape change:

- Climate change
- Harvesting
- Wildfire
- Fuels management
- Insect defoliation
- Fragmentation

Consequences:

- C cycling
- Biomass
- Composition
- Diversity

LANDIS-II

Features

Optimized for Spatial Processes

- structure emphasizes neighborhood interactions
- efficiently manages $>10^6$ interacting cells

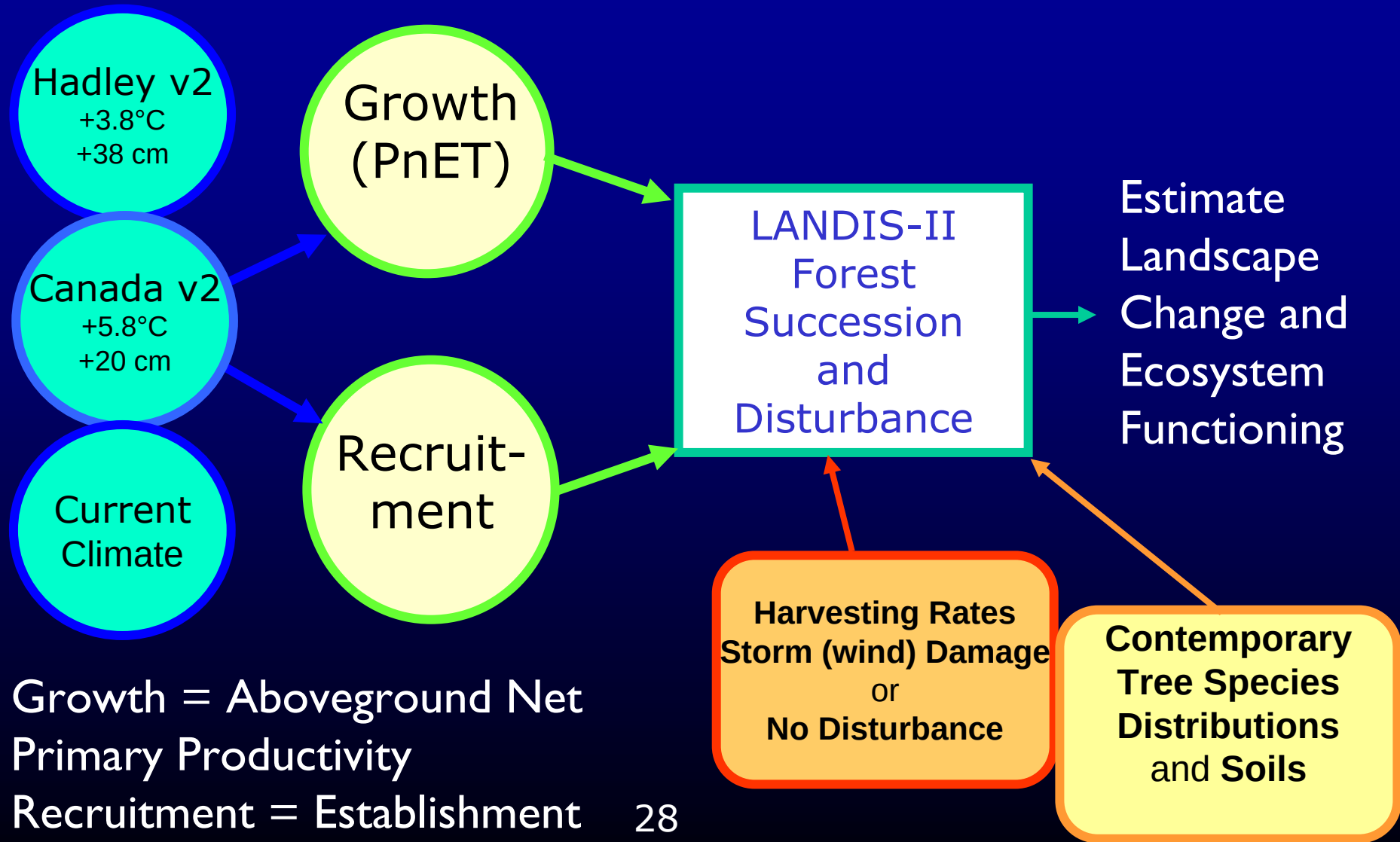
Spatial and Temporal Flexibility

- variable time steps for each ecological process
- variable spatial resolution and extent

Built for Collaboration

- a core model with extensions ('plug-ins')
- on-line database of open-source extensions
- flexible model architecture

Simulation of Climate Change Effects

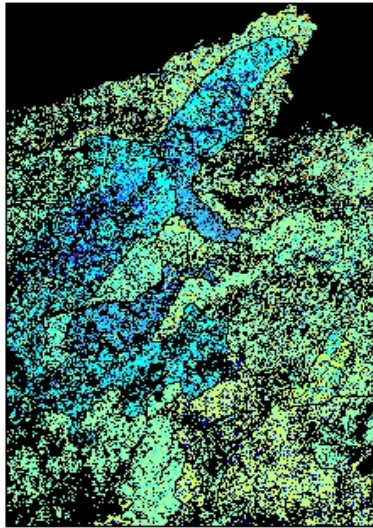


Effects of Climate Change on Northern Wisconsin

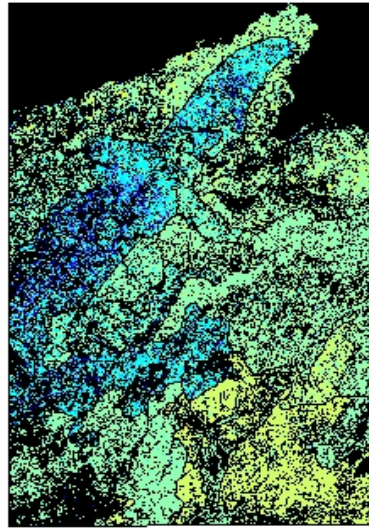
Results

Year 2100

**Initial Biomass
Year 1990**

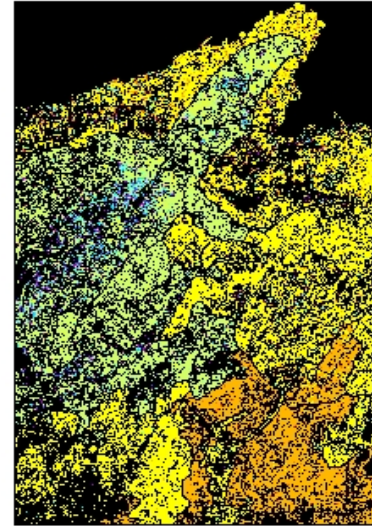


Current Climate

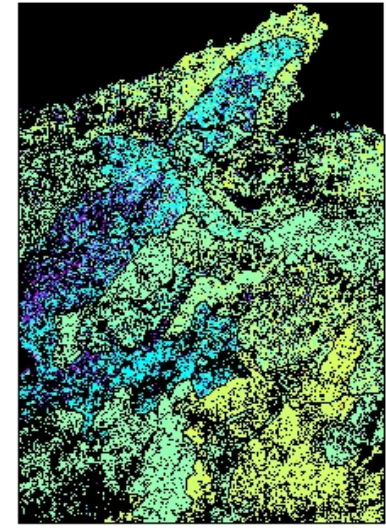


No Disturbance

**Hadley Climate
Centre**



**Canadian Climate
Center**



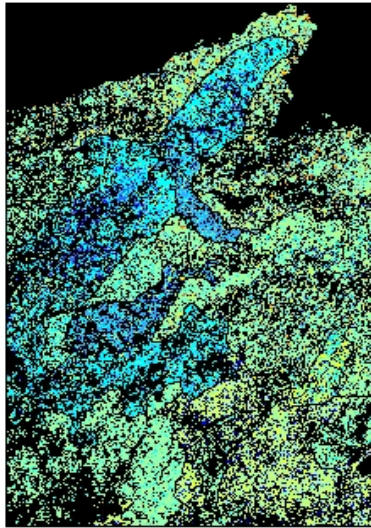
**Aboveground Live
Biomass (Mg/ha)**

Value

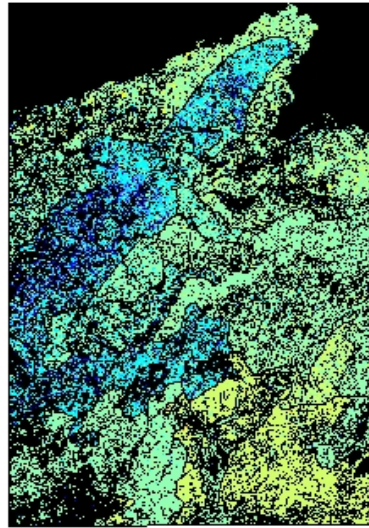


Year 2100

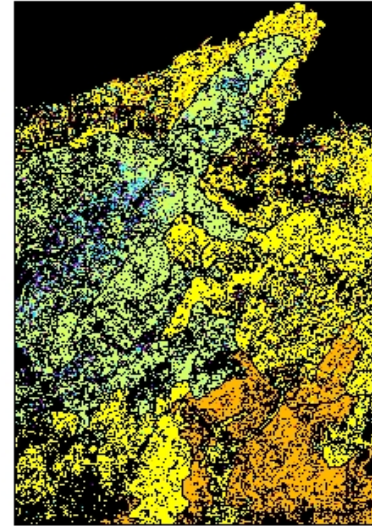
**Initial Biomass
Year 1990**



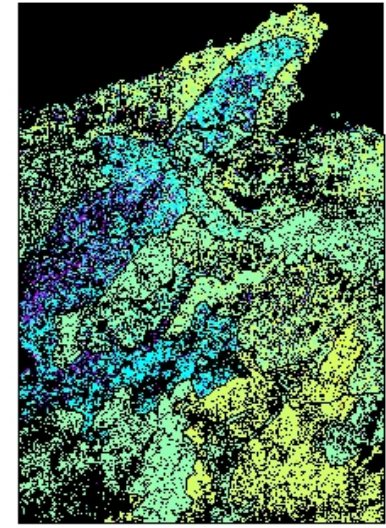
Current Climate



**Hadley Climate
Centre**



**Canadian Climate
Center**



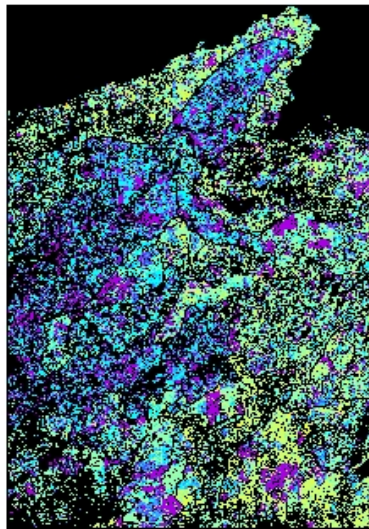
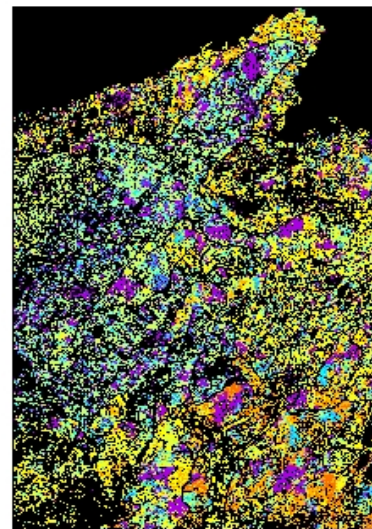
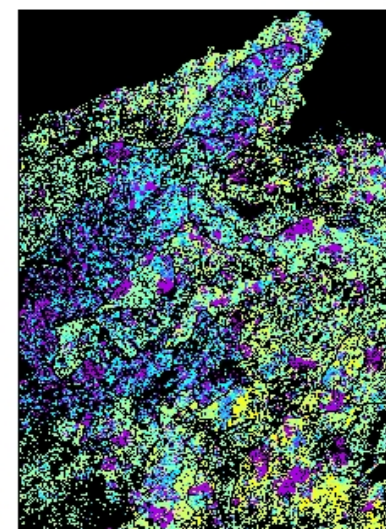
No Disturbance

**Aboveground Live
Biomass (Mg/ha)**

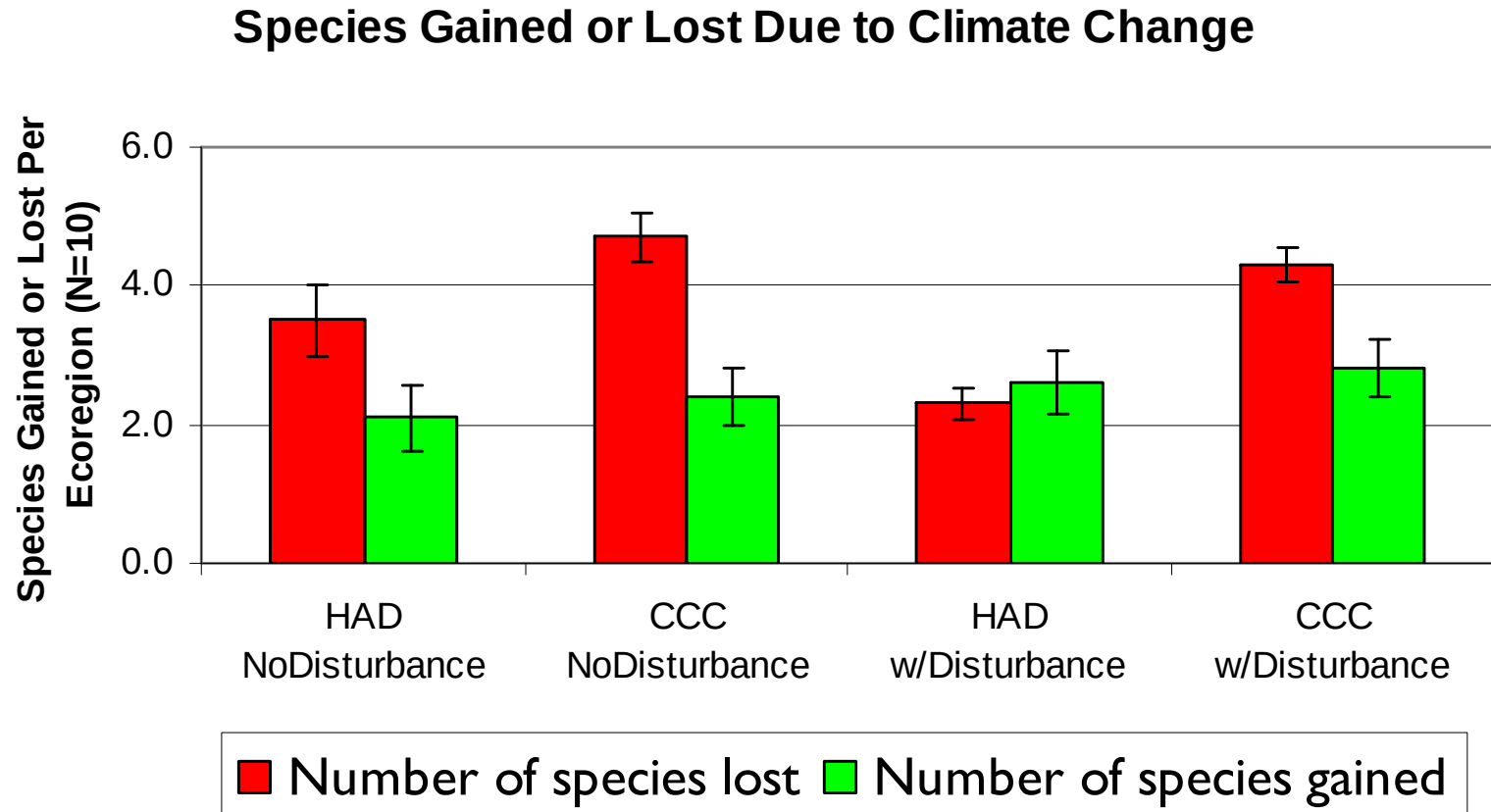
Value



Harvesting



Results: Species Composition and Diversity



Results: Species Composition

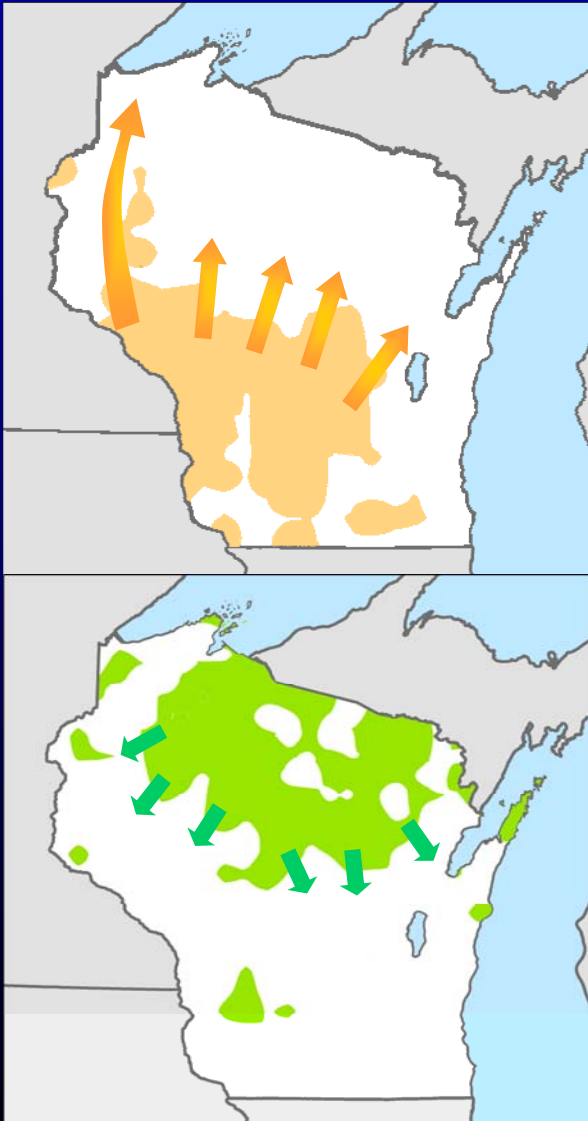
Climate change and disturbance interact and significantly alter tree species composition.

Under all climate change scenarios, species near the southern edge of their historic distribution (boreal species) are lost as dominants.

Overall simplification of community structure and reduction in diversity.

How Might Tree Species Migration Interact with Climate Change?

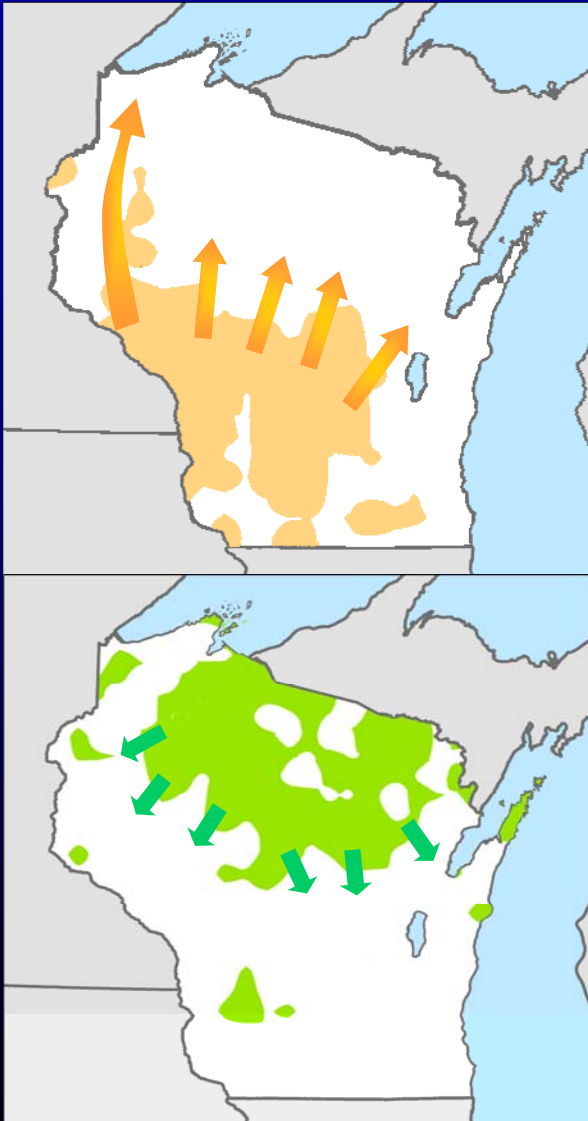
What Limits Tree Species Migration?



Tree species migration is limited by:

- seed dispersal
- generational lags

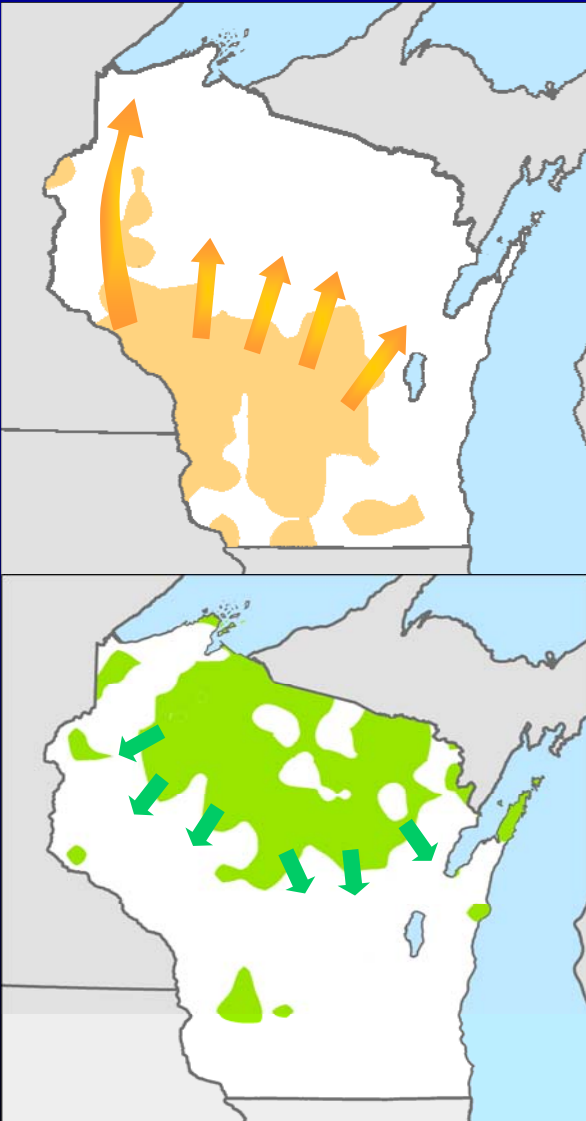
What Limits Tree Species Migration?



Tree species migration may be further limited by:

- land use change (fragmentation)
 - *less suitable habitat*
 - *fewer seed sources*
- competition from existing species

What Are the Potential Effects of Limited Migration?



Reduced or limited migration will reduce aboveground live biomass (*'biomass'*) and species diversity.

Why? The best-adapted species are not broadly distributed, generating sub-optimal ANPP.

How to Measure the Effects of Limited Migration?

Compare estimated actual biomass to the potential biomass.

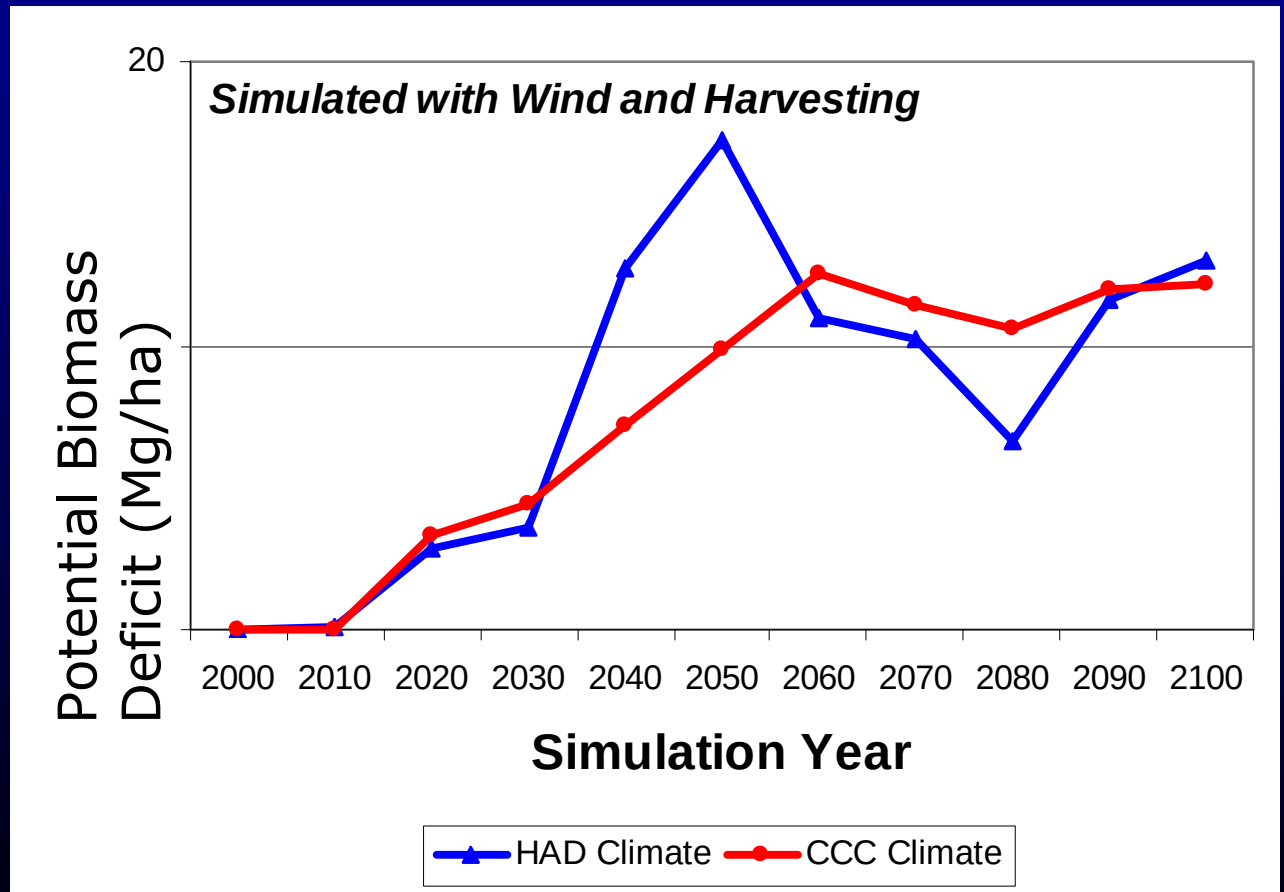
Actual Biomass = simulated biomass, limited by migration

Potential Biomass = duplicate scenarios, removing migration limits

$$\text{Potential Biomass} - \text{Actual Biomass} = B_{\text{MIGRATION EFFECT}}$$

Reduction of Aboveground Carbon Storage Due to Limited Migration

Temporal Change of $B_{\text{MIGRATION EFFECT}}$ in northern Wisconsin

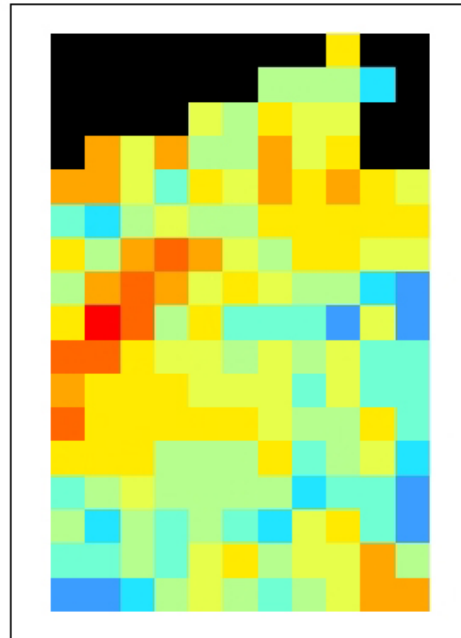


Compared the spatial distribution of $B_{\text{MIGRATION EFFECT}}$ to the spatial distribution of:

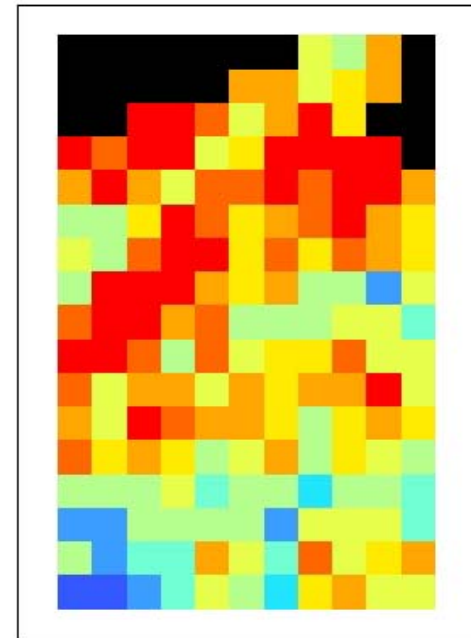
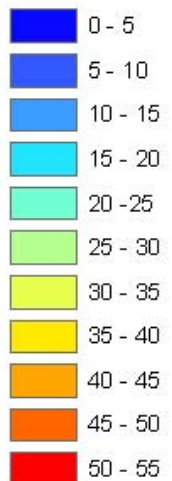
- Fragmentation
- Potential competitors

Potential Biomass Deficit (Mg/ha) 2100

HAD with wind and harvest



CCC with wind and harvest



Results: Limited Migration

Fragmentation due to land use change and competitive barriers decrease the ability of tree species to migrate.

Individual tree species migration $\sim f(\text{life history attributes, biotic interactions, landscape modification, harvesting})$

Limited migration reduces ecosystem function: tree species richness and the ability to store carbon.



Overall Conclusions: Climate Change in Northern Forests

Restoration of pre-settlement disturbance regimes is not possible and therefore forest management is critical to maintaining diversity.

Management planning based on natural disturbance patterns can increase diversity and productivity.

However, in areas which were previously unmanaged (eg Siberia), the effect of introducing extensive/intensive management overwhelms the effects of climate change.

Overall Conclusions: Climate Change in Northern Forests

We need to work with climate change:

- assisted migration?
- as southern forests expand, ensure they are diverse and resilient.

Given the uncertainty associated with climate change, ensuring a diversity of species and conditions within forested landscapes may be the most effective means of ensuring sustainability.

Overall Conclusions: Climate Change in Northern Forests

There remain significant uncertainties:

- CO₂ fertilization, ozone effects
- Forest management policy, land use change
- Deer browsing, other invasive or over-abundant spp.

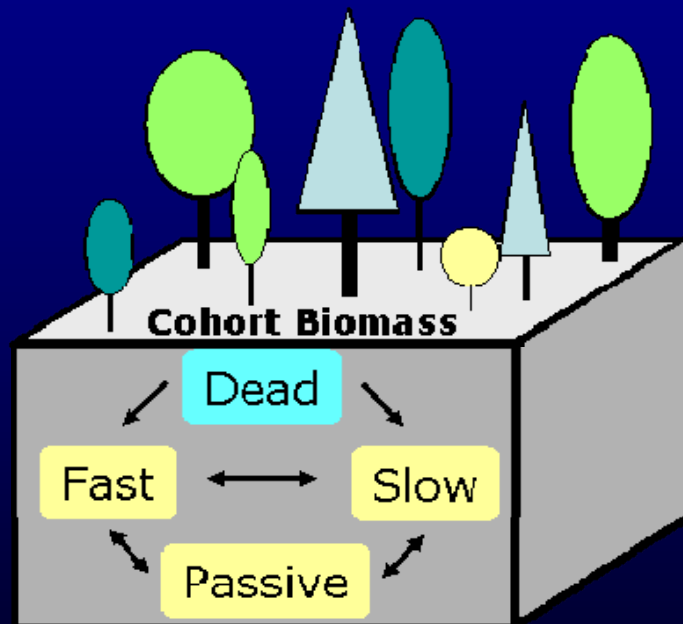
Are Northern Forests Sustainable?

1. Sustainability is not preservation.
2. Forests and our expectations for ecosystem functioning constantly change through time.
3. As the rate of change accelerates, ecosystem management must intensify to maintain sustainability and resilience.

Challenges and Needs



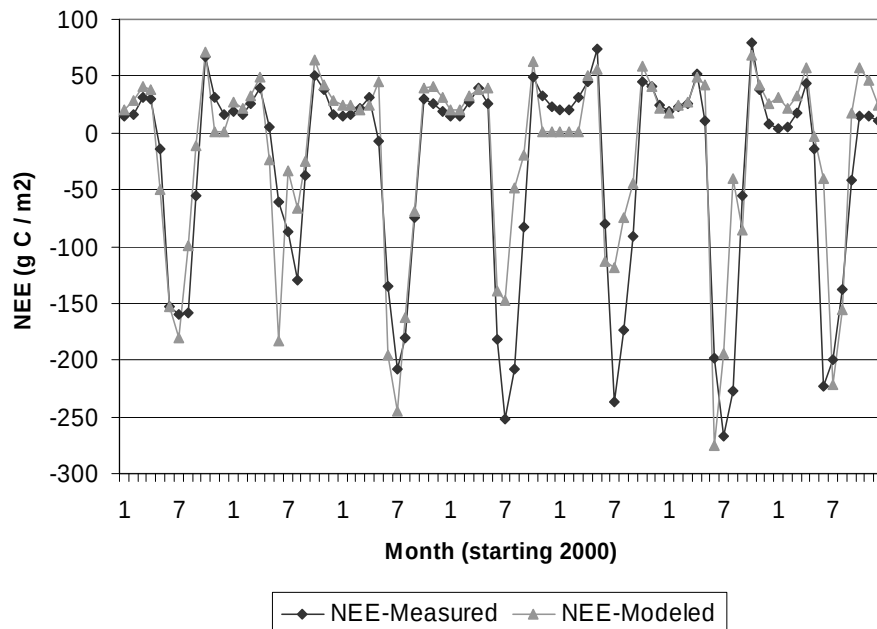
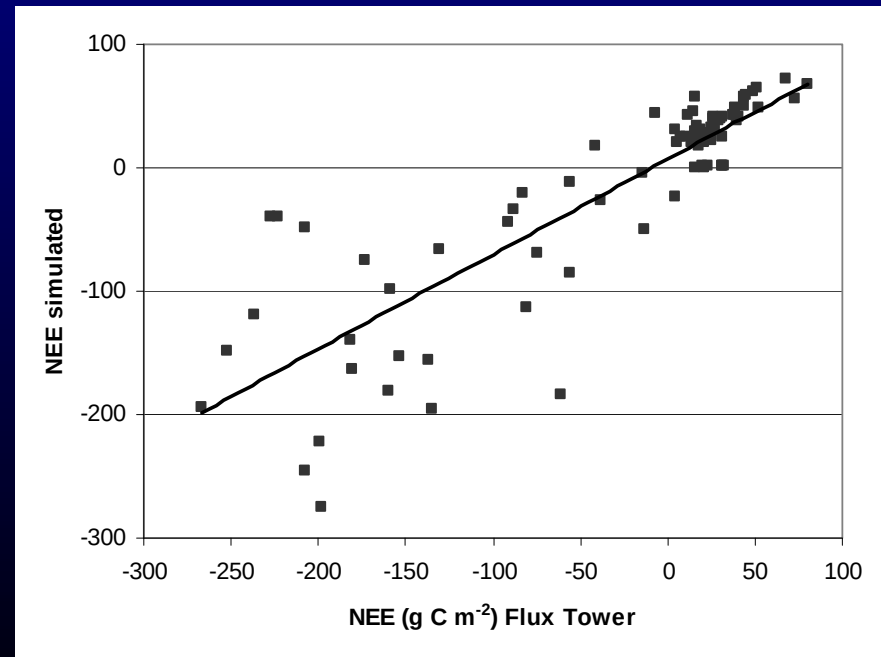
Future Research Directions



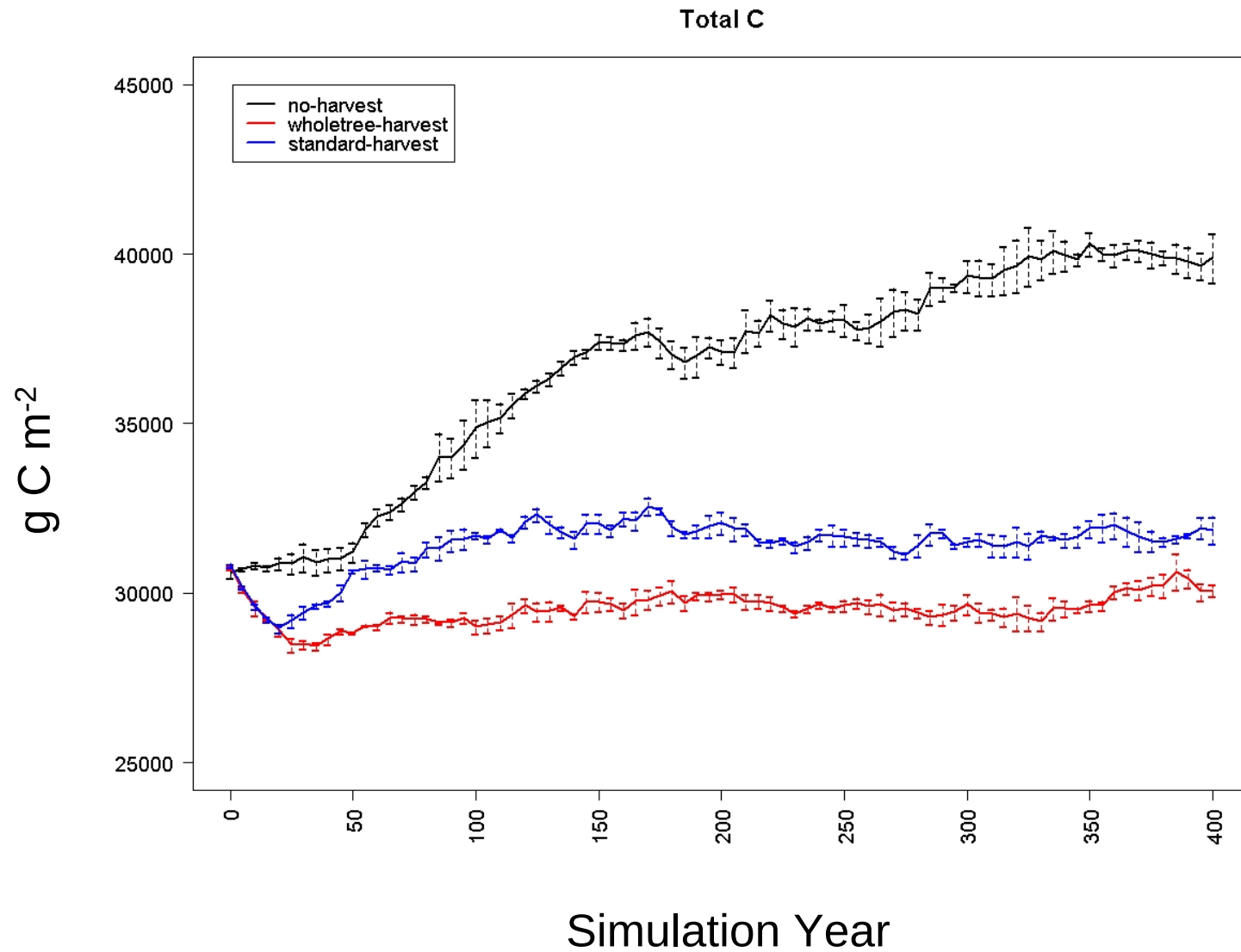
- Integrate complete soil C & N cycling
- Enable full C accounting due to climate change, disturbances, management

Future Research Directions

- Model parameterized for northern Wisconsin
- Calibrated against flux tower Net Ecosystem Exchange data



Results: Total C



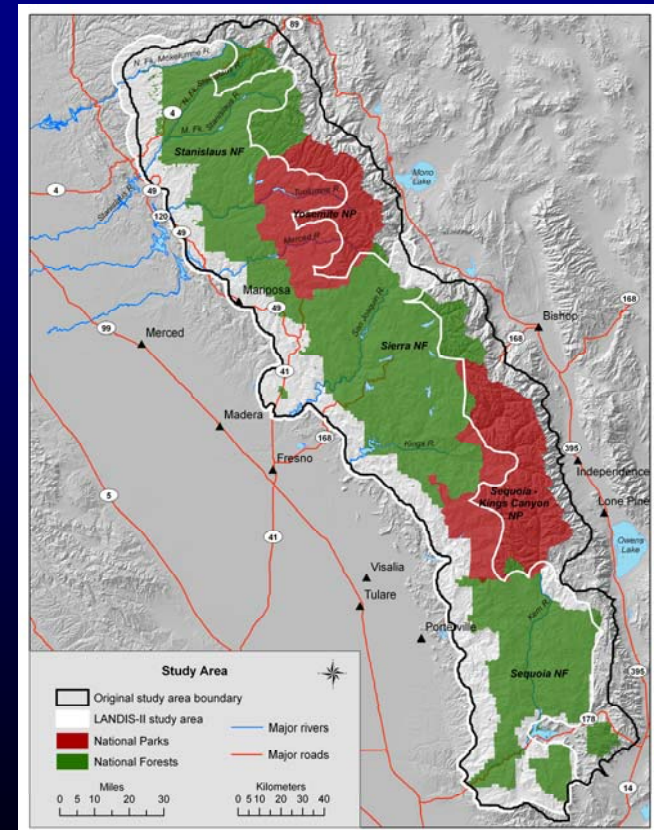
Future Research Directions

Climate Change Effects on Fire

Fire propagation $\sim f(\text{climate, fuels, topography})$

Baseline Fire = recent weather records

Climate Change Fire



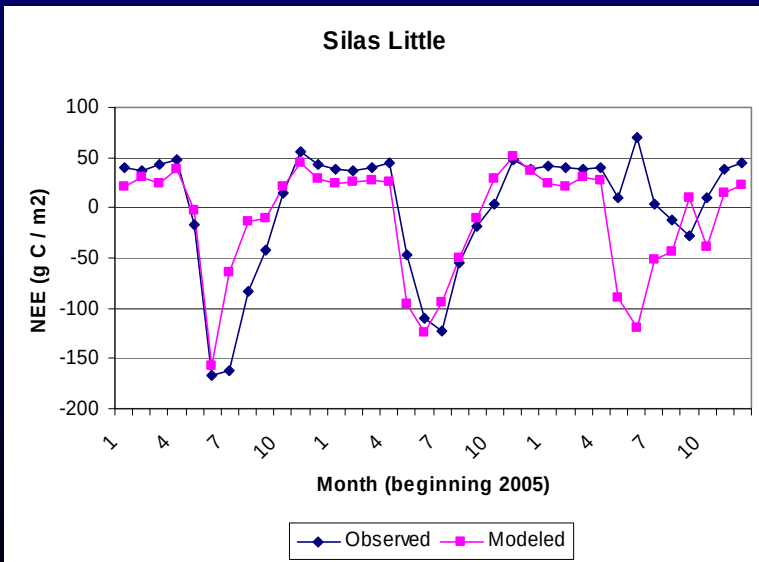
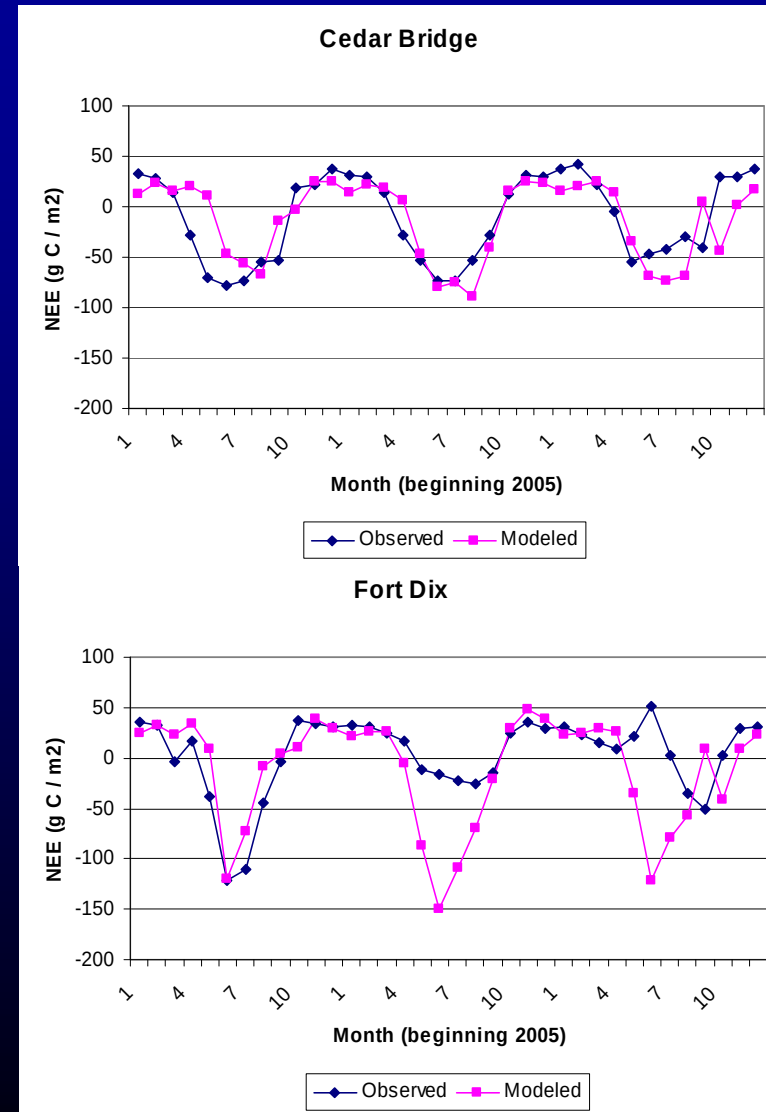
Future Research Directions

Climate change, fire,
insects and C dynamics in
the New Jersey Pine
Barrens



Future Research Directions

Climate change, fire, insects and C dynamics in the New Jersey Pine Barrens: **Net Ecosystem Exchange**



Future Needs for Climate Change Effects Research

- More mechanistic representation of reproduction
 - acclimation
 - fertilization and germination
- Drought related stress and mortality
- CO₂ fertilization



Model Validation: Promises, Challenges, and Perils

Promises:

- Improve model performance, representation
- Builds confidence in model results

Challenges:

- Acquisition of appropriate data
- You may need to alter your model to meet available empirical data

Model Validation: Promises, Challenges, and Perils

Perils:

In the end, you may still be confronted with the question:

If your model results are surprising, is it because your model is wrong or the future will be surprising?

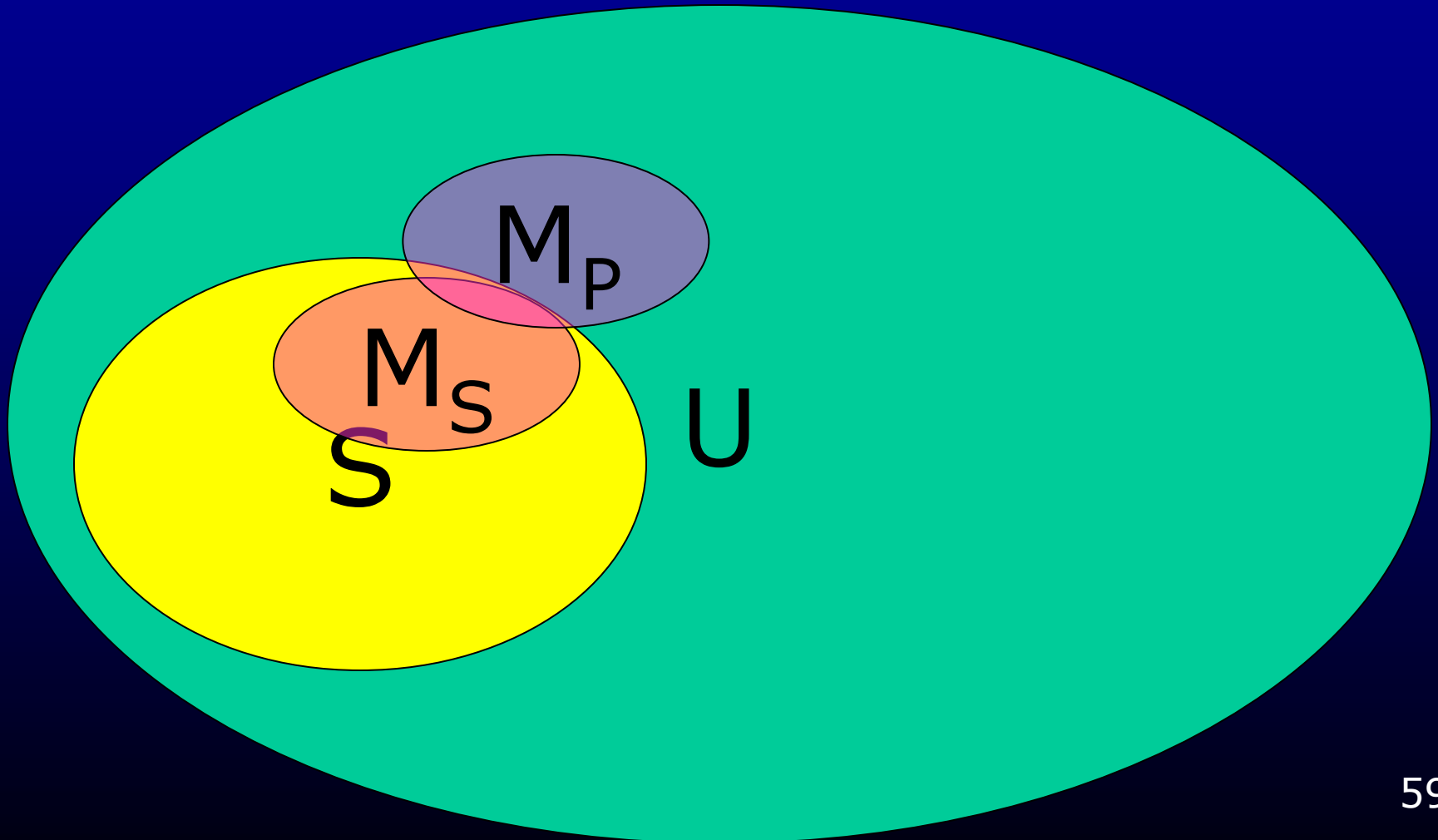
- The world is stochastic
- You can never include every process
- Therefore, models can only serve as guides, not oracles

Model Validation

The Central Conundrum of Validation

You are rarely funded to predict what is already known.

Statistical vs. Predictive Models



Model Validation

Other avenues for building confidence in model results include:

- Repeated application across diverse ecosystems
- Sensitivity testing
- Appropriate levels of software engineering and testing
- Transparency

Thank you!

Questions?

www.consbio.org
rmscheller@consbio.org

www.pdx.edu