Forest Insect Defoliation and Carbon Dynamics: Linking Remote Sensing with Simulation Modeling

NASA LCLUC Meeting

April 20, 2010

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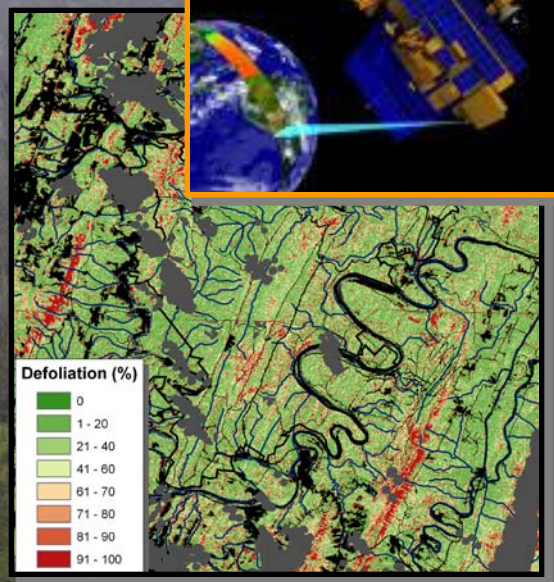
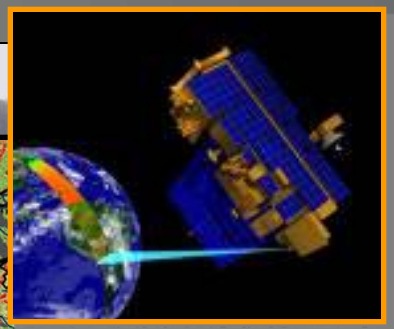
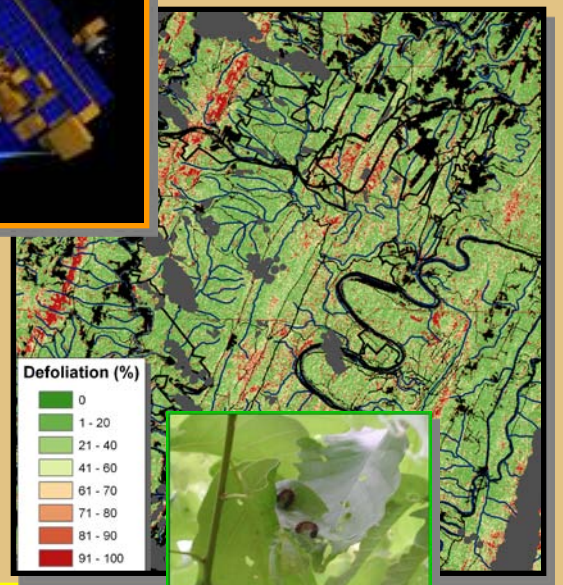
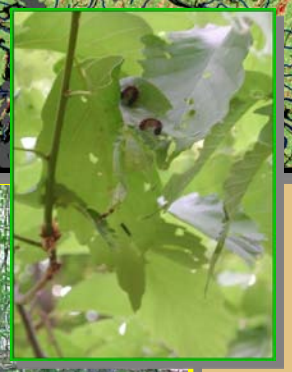
and David Mladenoff





NASA Carbon Project – Monitoring and Modeling Insect Defoliation Outbreaks





Multi-investigator effort:

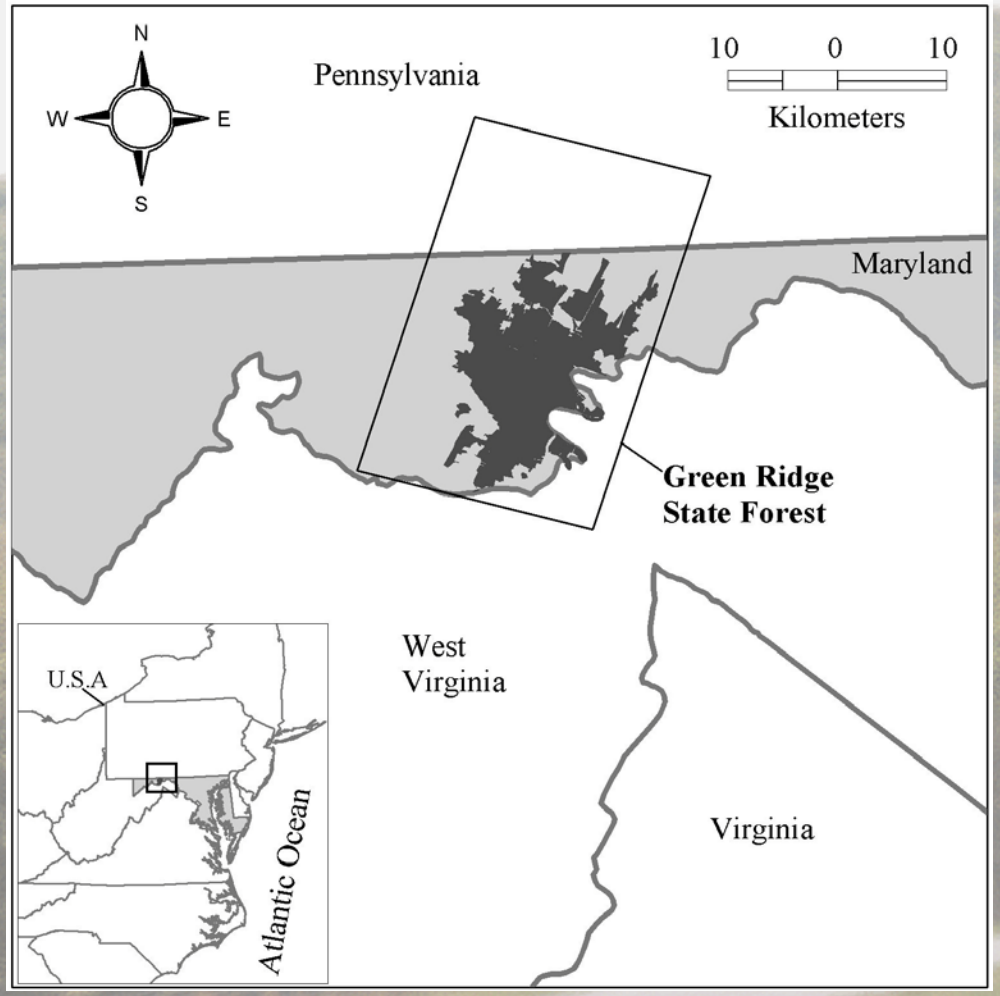
1: Map defoliation at multiple scales using satellite data.

2: Model long-term effects of defoliation on aboveground carbon in forest landscapes.

Develop a defoliation disturbance extension for Landis-II

Green Ridge State Forest, MD

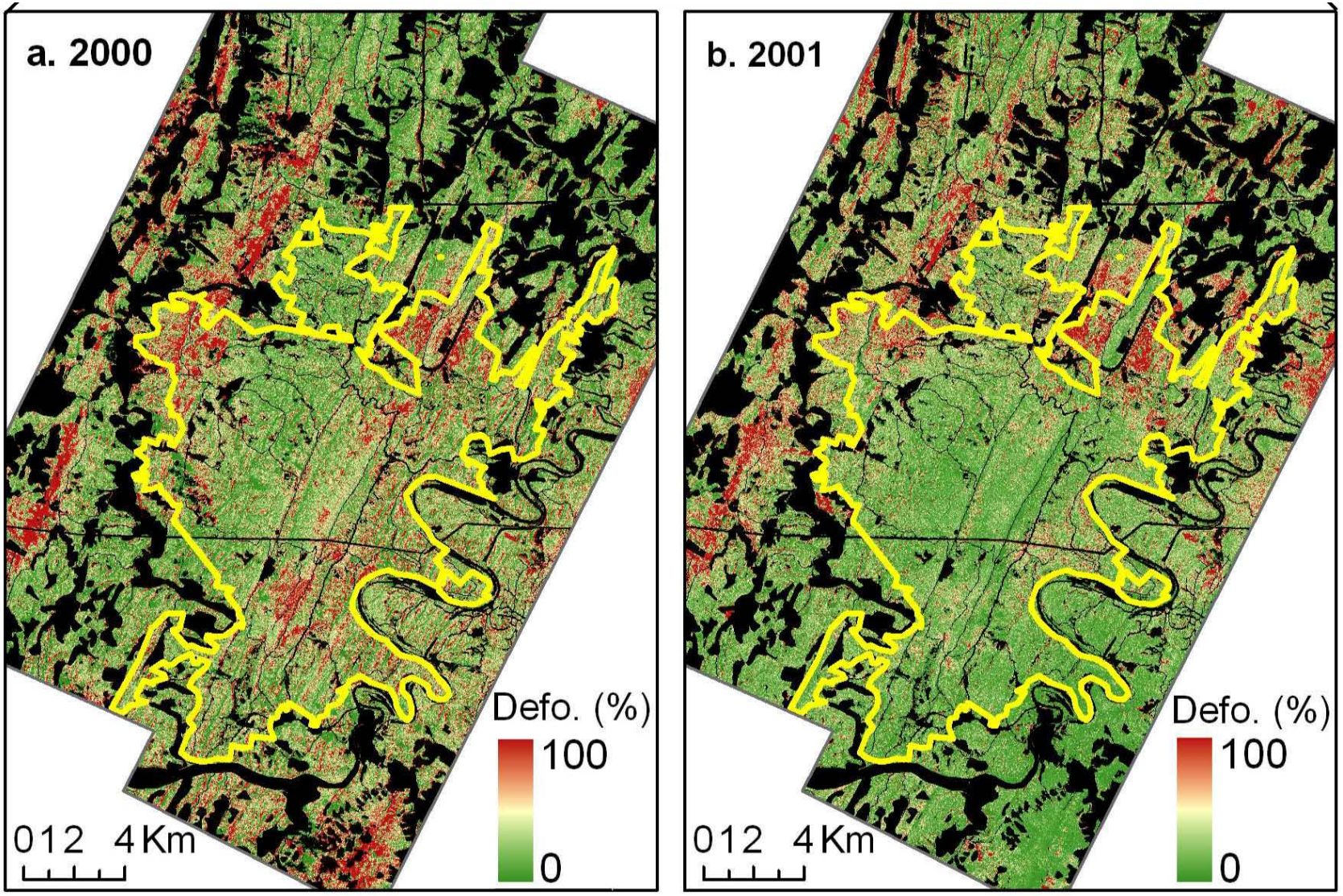
Mixed deciduous study area.



Green Ridge Landscape

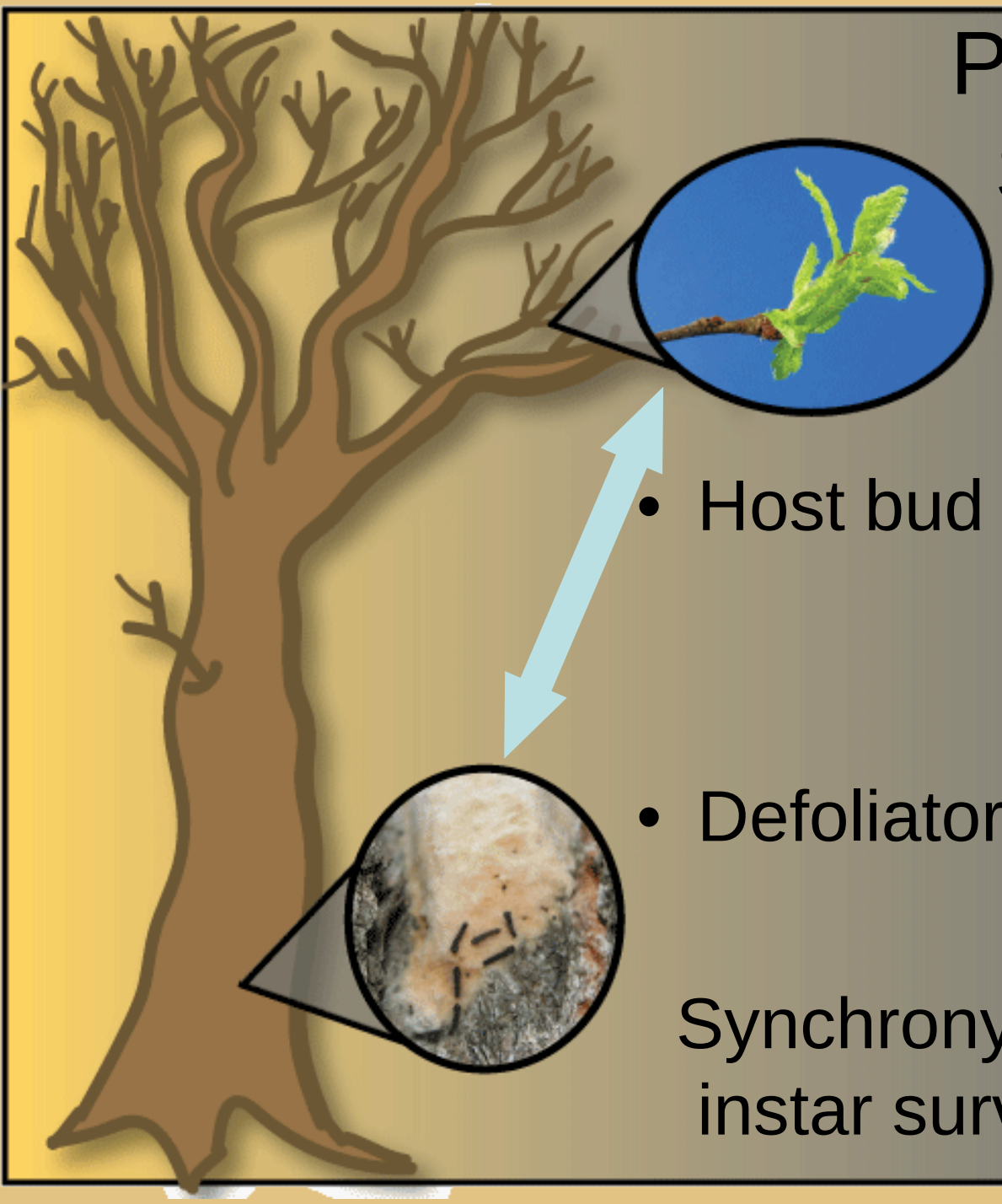
European Gypsy Moth (*Lymantria dispar* L.) invaded this area in 1980's and has recurring outbreaks.

May 4th, 2002



Defoliation maps created from empirical relationships between frass fall, canopy biomass, and changes in satellite reflectance (Phil Townsend et al. UW-Madison).

Phenological Synchrony

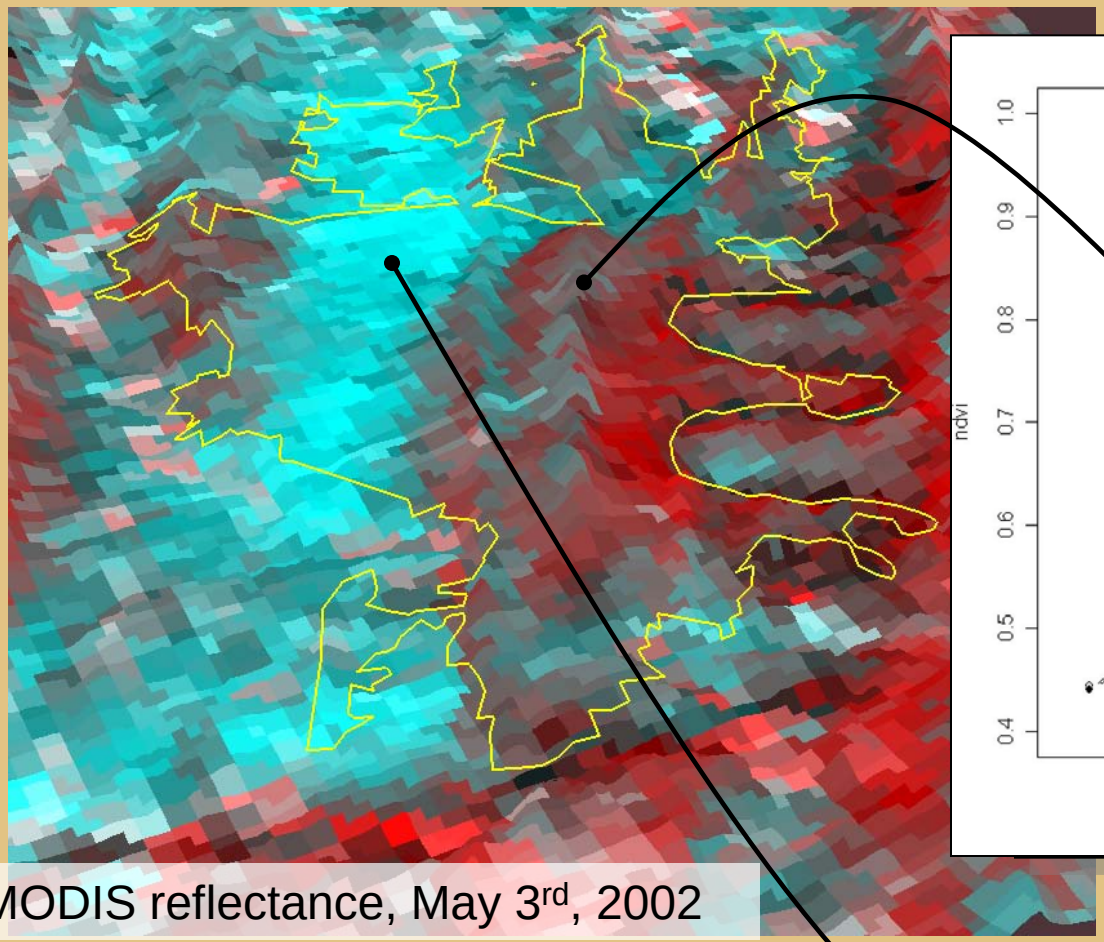


- Host bud burst
- Defoliator egg hatch

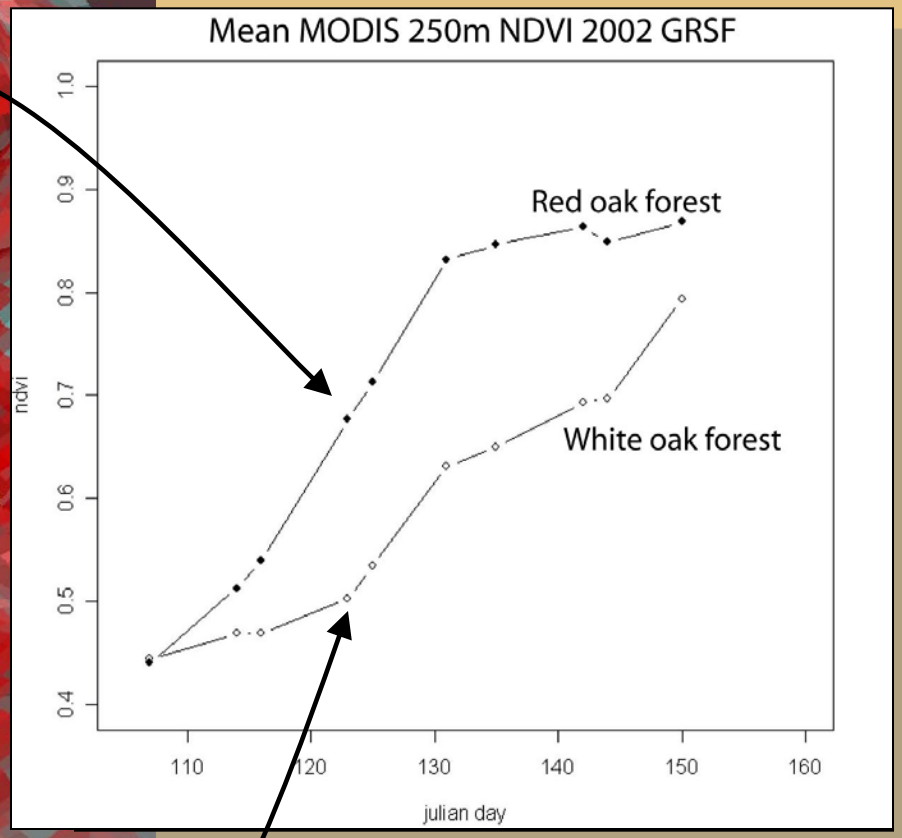
Synchrony is key for early instar survival.

Leaf-out Phenology

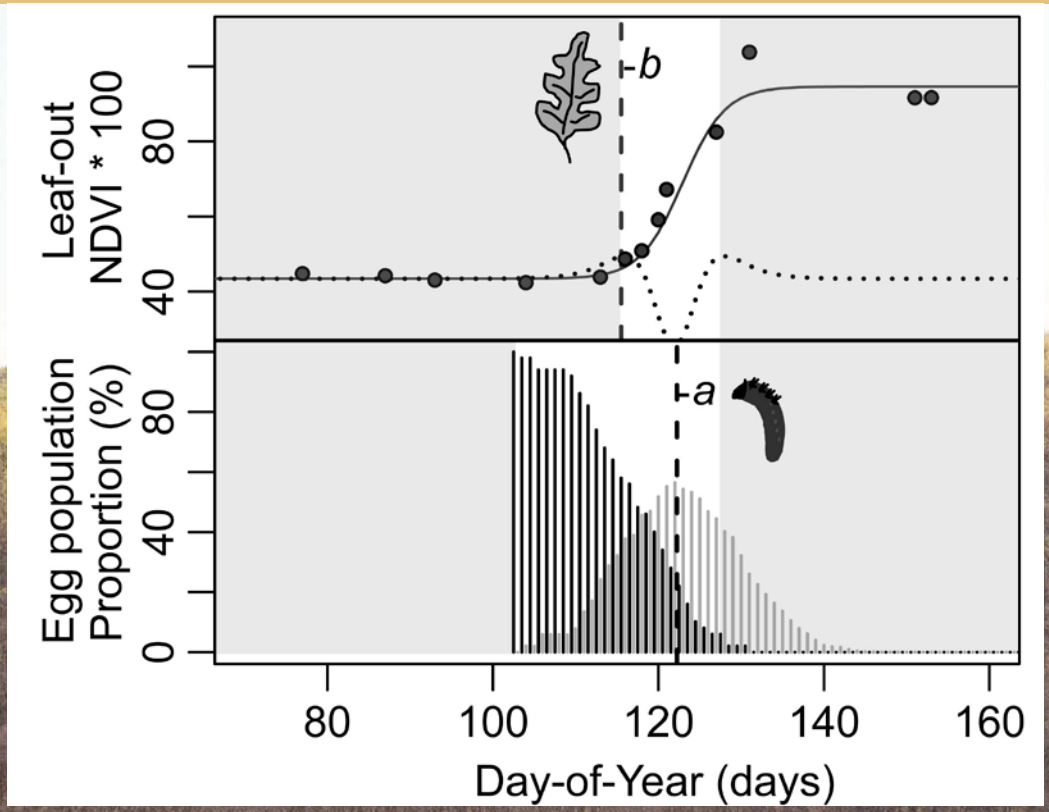
Measured with NDVI time-series of MODIS daily data (MOD09GQK) (250 m) from 2000 to 2007.



MODIS reflectance, May 3rd, 2002



Calculating Phenological Asynchrony



←*MODIS*

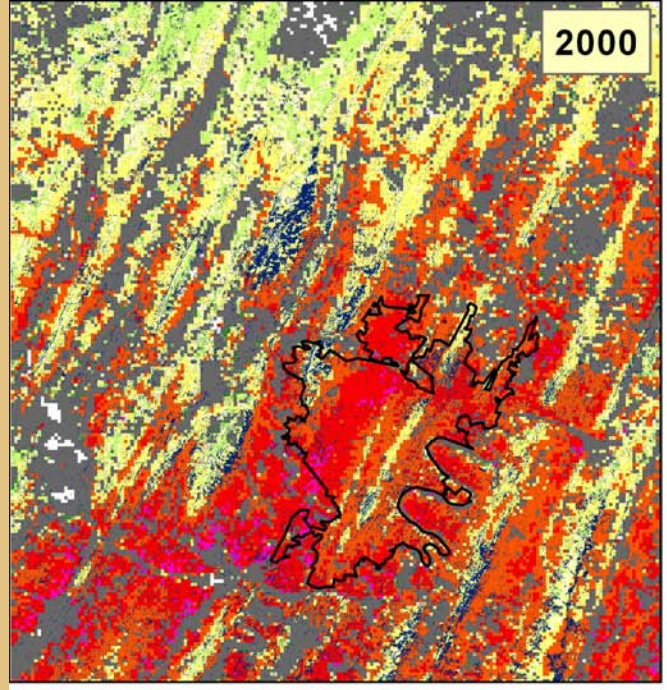
←*BioSIM*

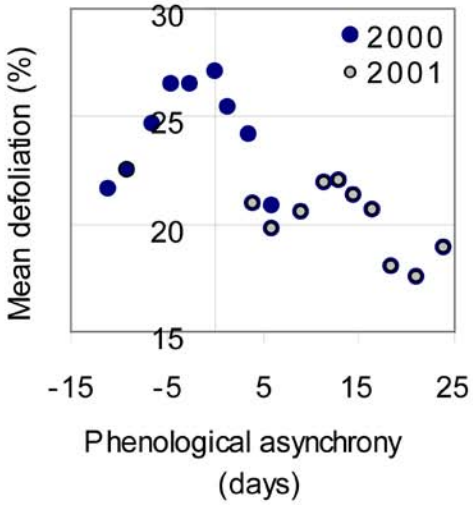
<u>Phenological Asynchrony (days)</u> = timing GM emergence (*a*) - timing of local leaf-out (*b*)

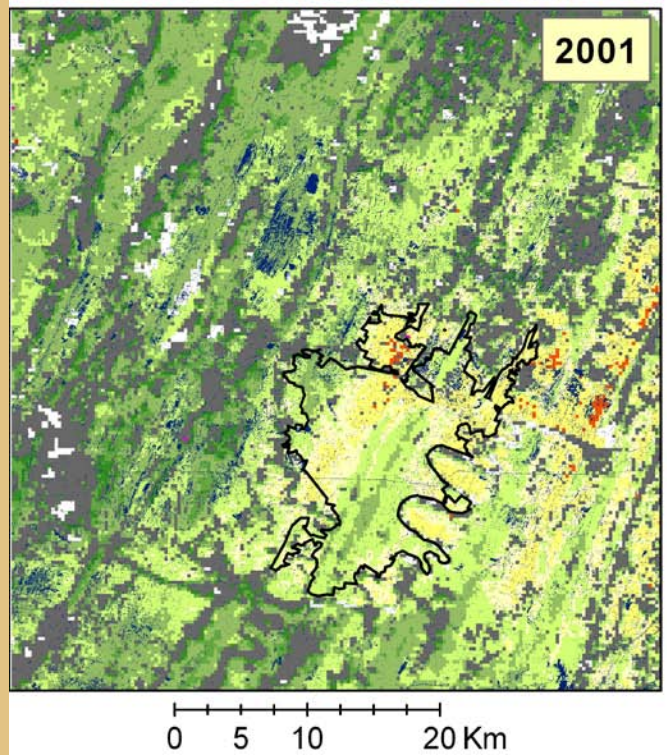
* for each pixel on the landscape!

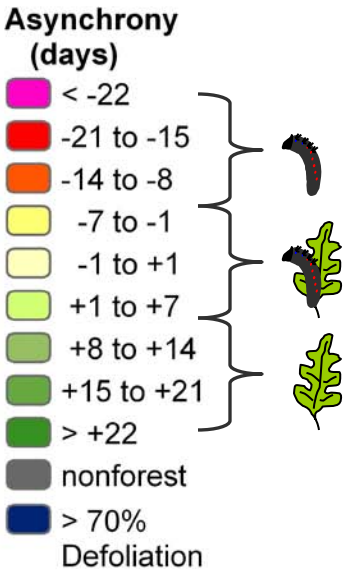
May 4th, 2002

Results: Patterns of Asynchrony







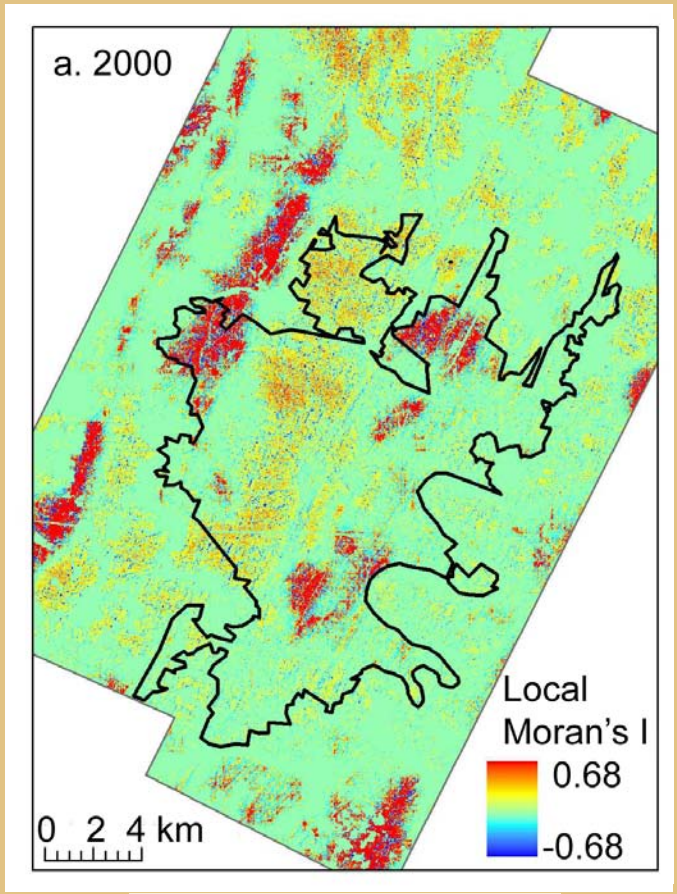


Mean defoliation decreased as asynchrony increased.

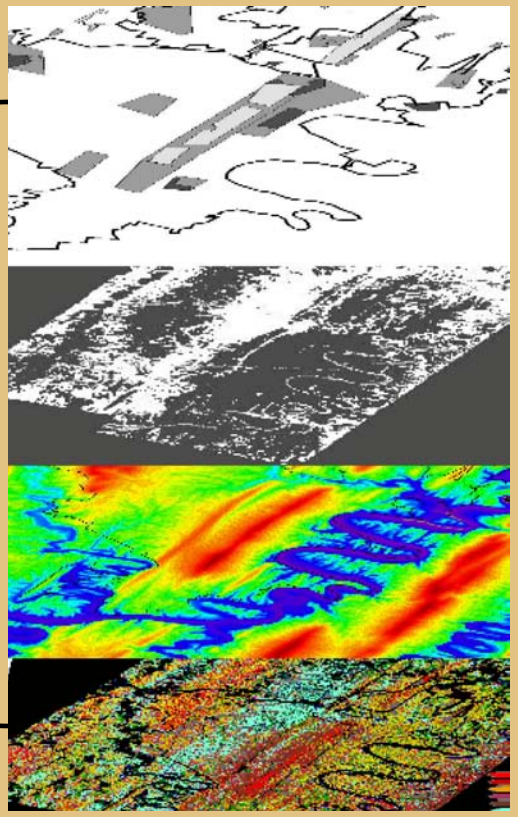
Asynchrony patterns extended ~ 3 to 5 km, well beyond typical GM dispersal (<1 km).

Explaining defoliation patterns - Spatial linear models

defoliation = f(forest composition + elevation + phenology + spray history)



defoliation intensity



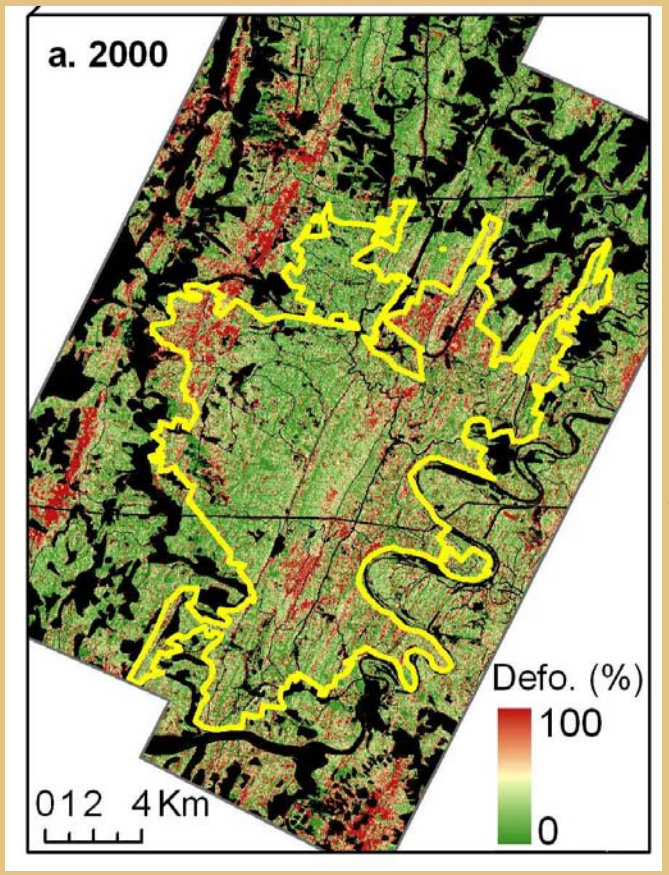
pesticide spray history

phenology

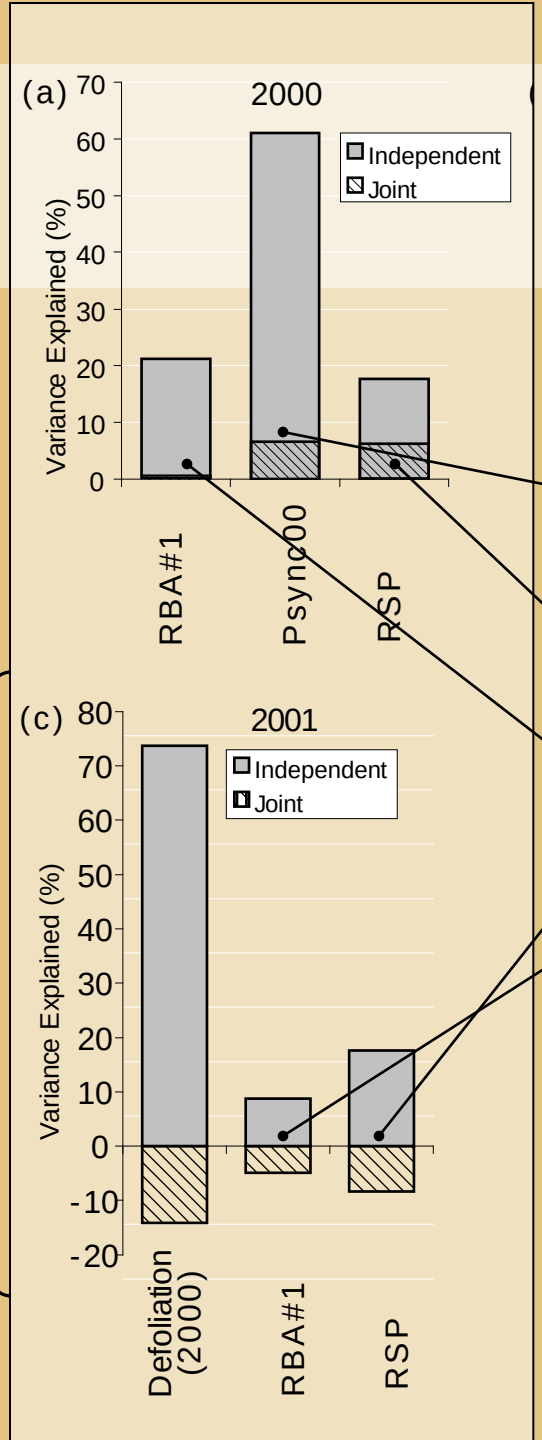
elevation

forest composition

Results



defoliation intensity



1st year

phenology

1st and 2nd year

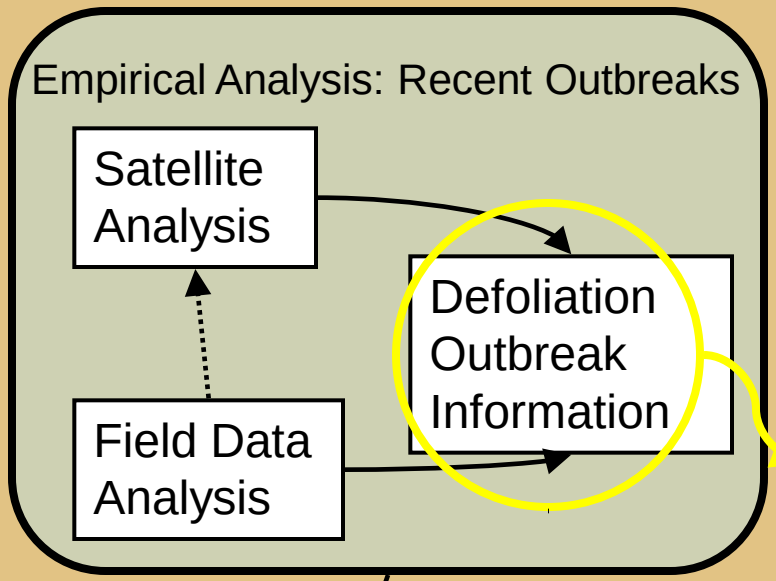
elevation

forest composition

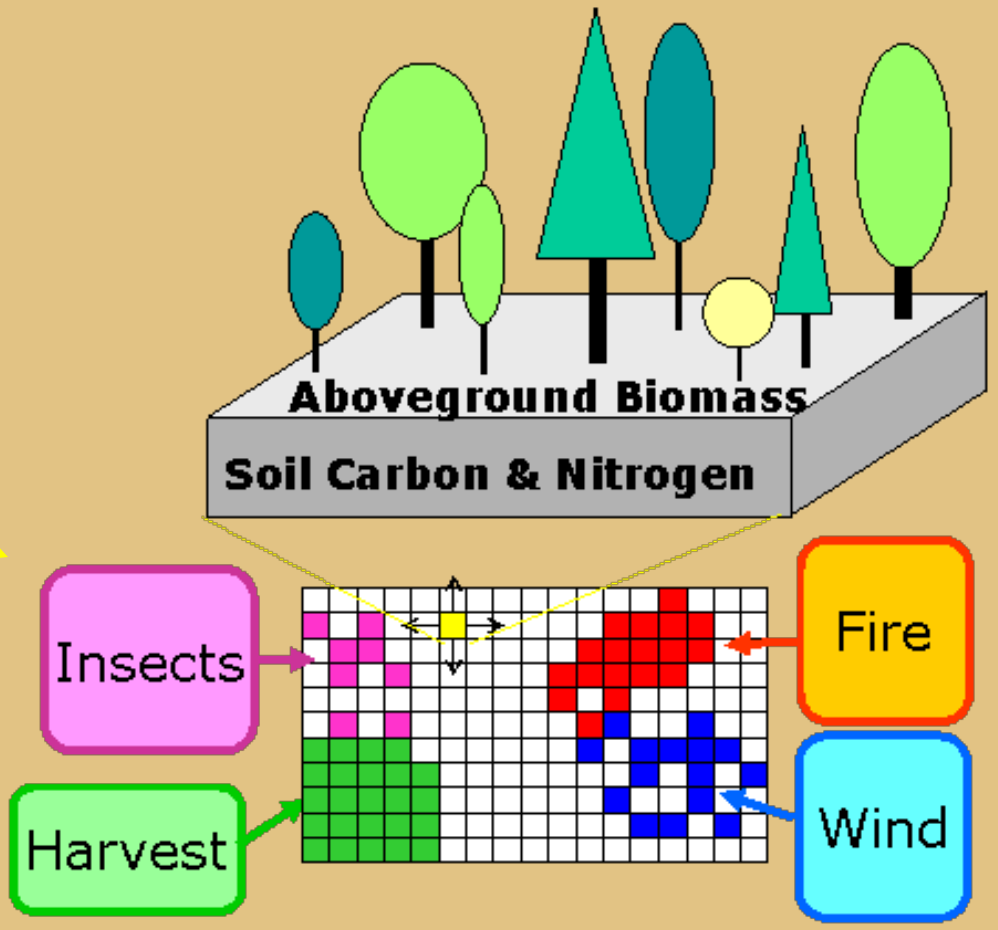
Not significant

pesticide spray history

LANDIS-II: Forest Landscape Simulator



- Disturbance characteristics
- Tree species response
- Spatial processes



Spatially dynamic landscape

Landis-II Simulation Disturbance Scenarios

Scenarios	GM	FTC	Harvest
1	–	–	*X*
2	*X*	–	*X*
3	–	*X*	*X*
4	*X*	*X*	*X*

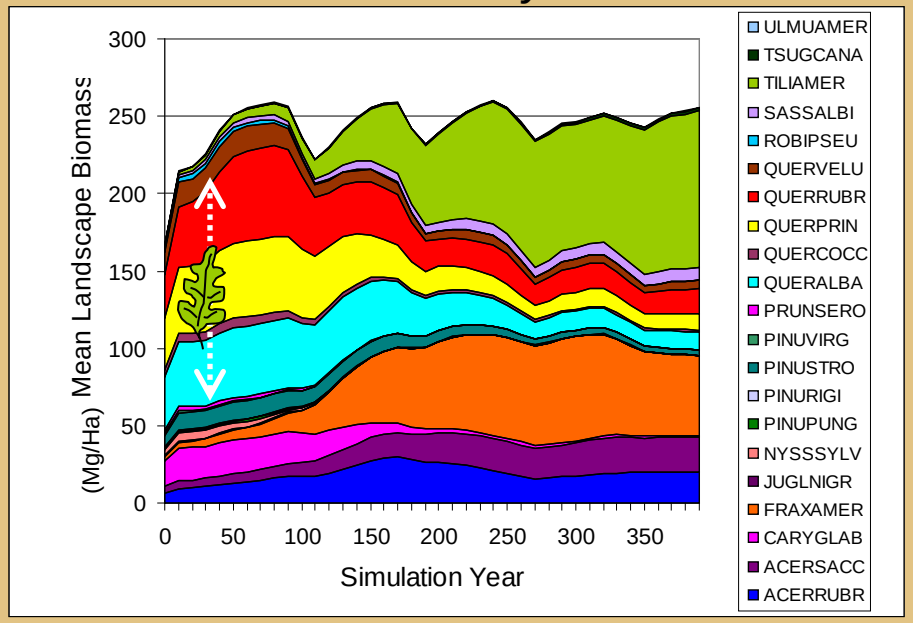
400 year simulations, annual timesteps.

* Baseline scenario includes current harvesting practices.

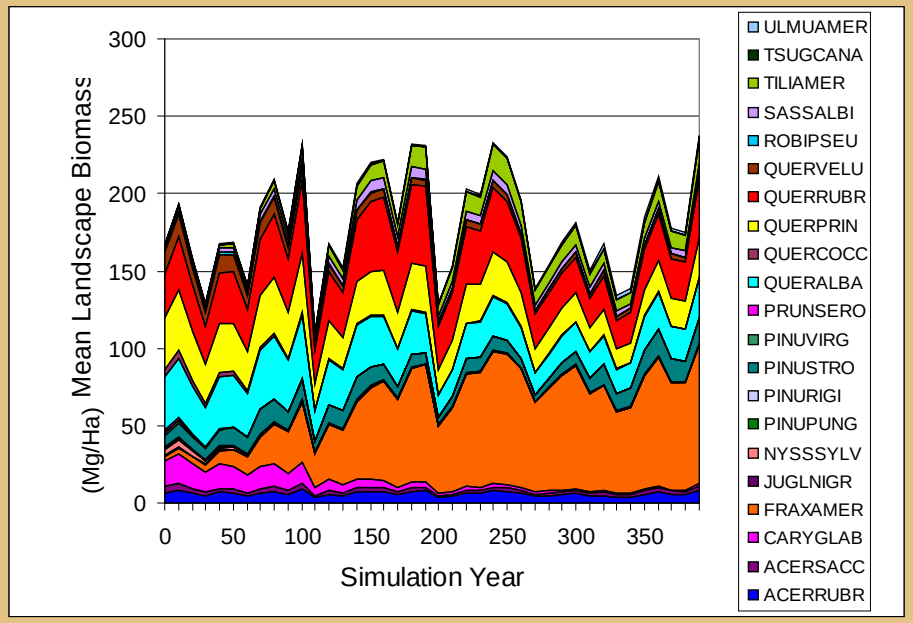
Photos:
GM: Jane Foster
FTC: Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org
Logging: Brian Lockhart, USDA Forest Service

Preliminary Results: Biomass and Species Composition

Harvest only



Harvest + FTC + GM

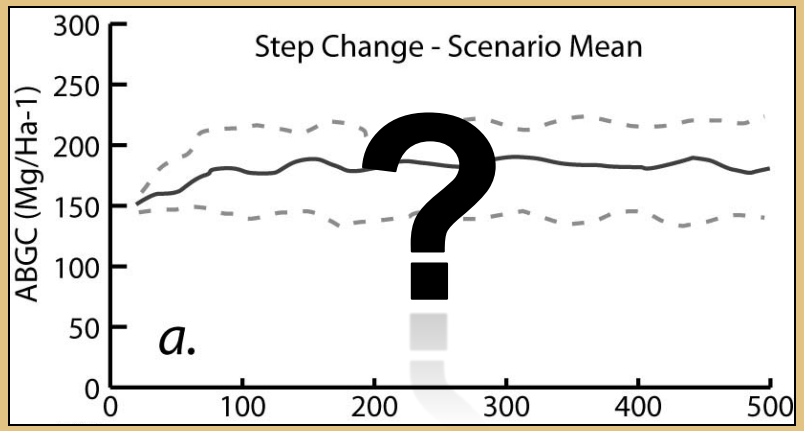


Biomass response of currently dominant species (oaks) varies between defoliated and undefoliated disturbance scenarios.

The fastest-growing, non-host species increases in both scenarios at expense of oaks: *Fraxinus americana*

Next Steps…

- Finish calibrating model and disturbance regime behavior.
- Expand calibrated scenarios to entire GRSF landscape.
- Replicate scenario simulations and response to different disturbance regimes.
- Analyze output at multiple scales to understand long-term changes in above-ground C and species composition.



Acknowledgements

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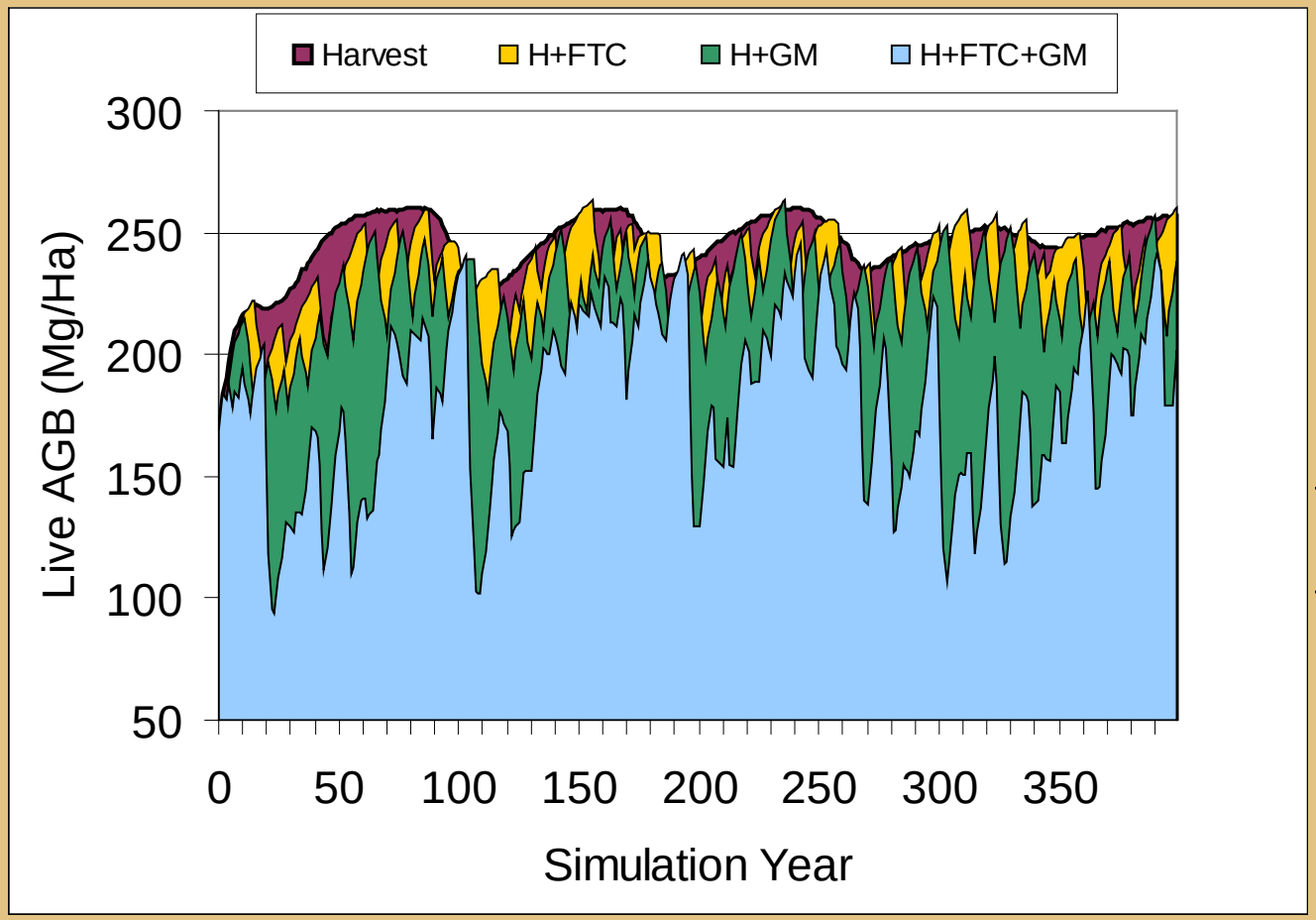
Collaborators: Brian Sturtevant, Peter Wolter and Kirsten DeBeurs

UW Forest Landscape Ecology Lab

Preliminary Results: Mean Biomass Response



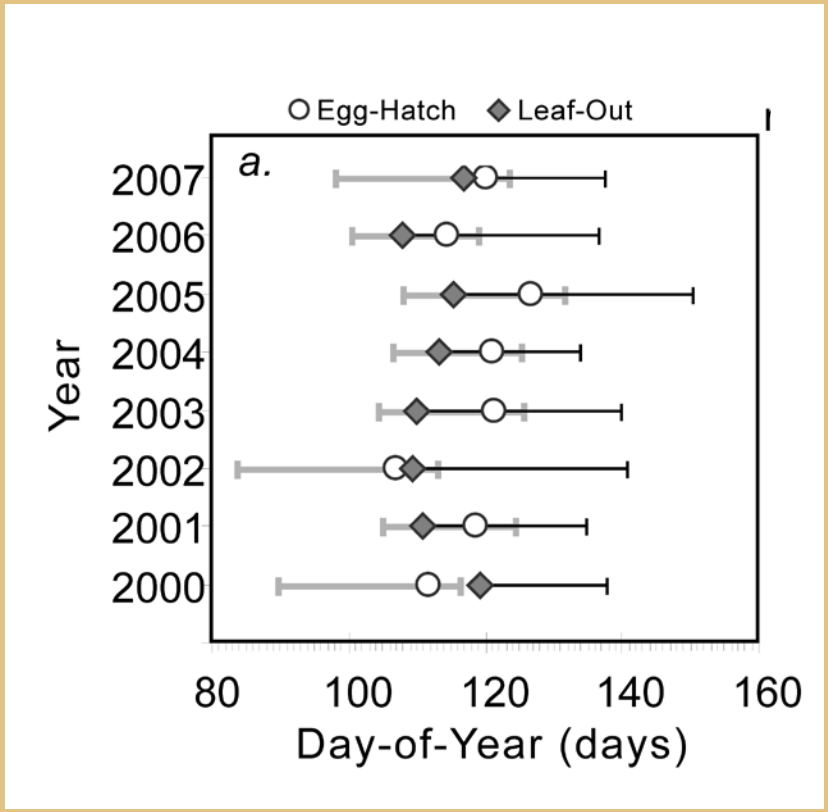
Harvest:

100 yr rotation

Defoliation:

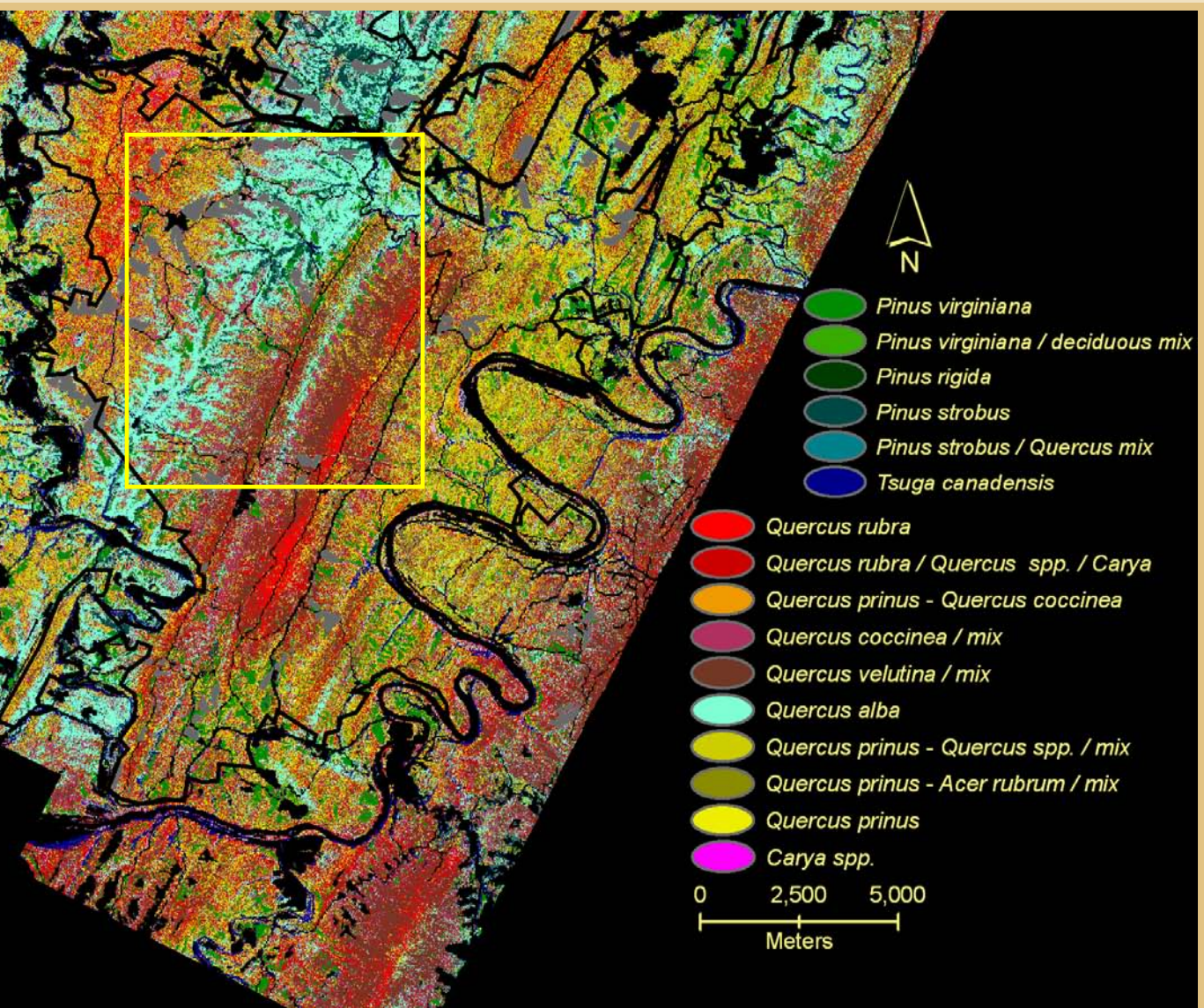
	Interval (yrs)	Duration (yrs)
FTC	10 (s=3)	2 (s=1)
GM	7 (s=2)	3 (s=1)

Interannual Variability



Temporal differences were sufficient (<-5 or > +10 days) to limit 1st instar survival in 2000, 2003, and 2005.

Model inputs: vegetation communities

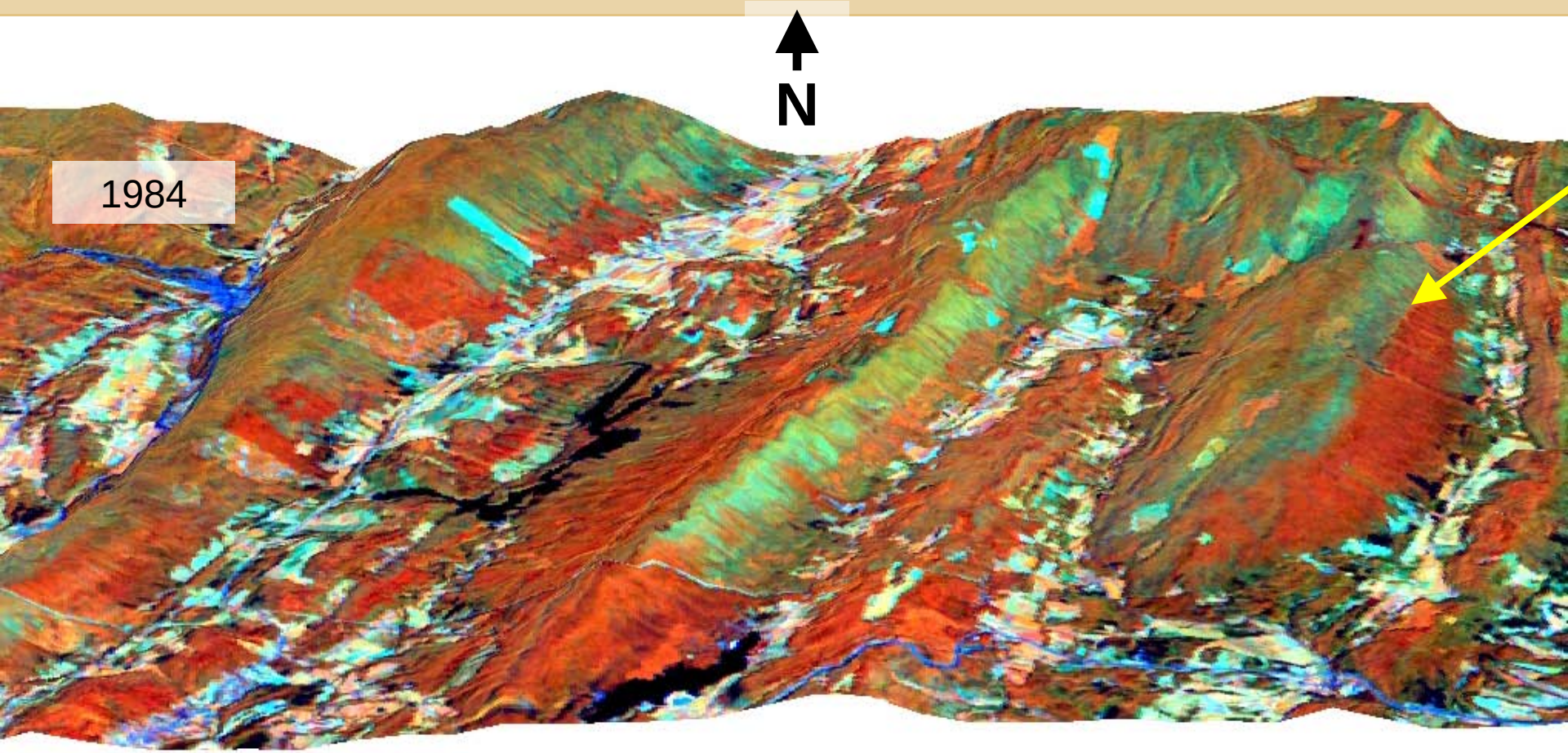


20 Community types from AVIRIS map and 430 inventory plots.

Cohort ages and species composition from plots.

Hosts #1 = 67% RBA

Defoliation Patterns in Study Landscape



Defoliation patches are often concentrated on ridges or certain aspects and may have sharp, distinct edges. The reasons for these patterns remain unclear. (Healthy green vegetation in red tones).