Integrated Monitoring of Forest Life Cycle Using Time Series Landsat Observations and Field Inventory Data

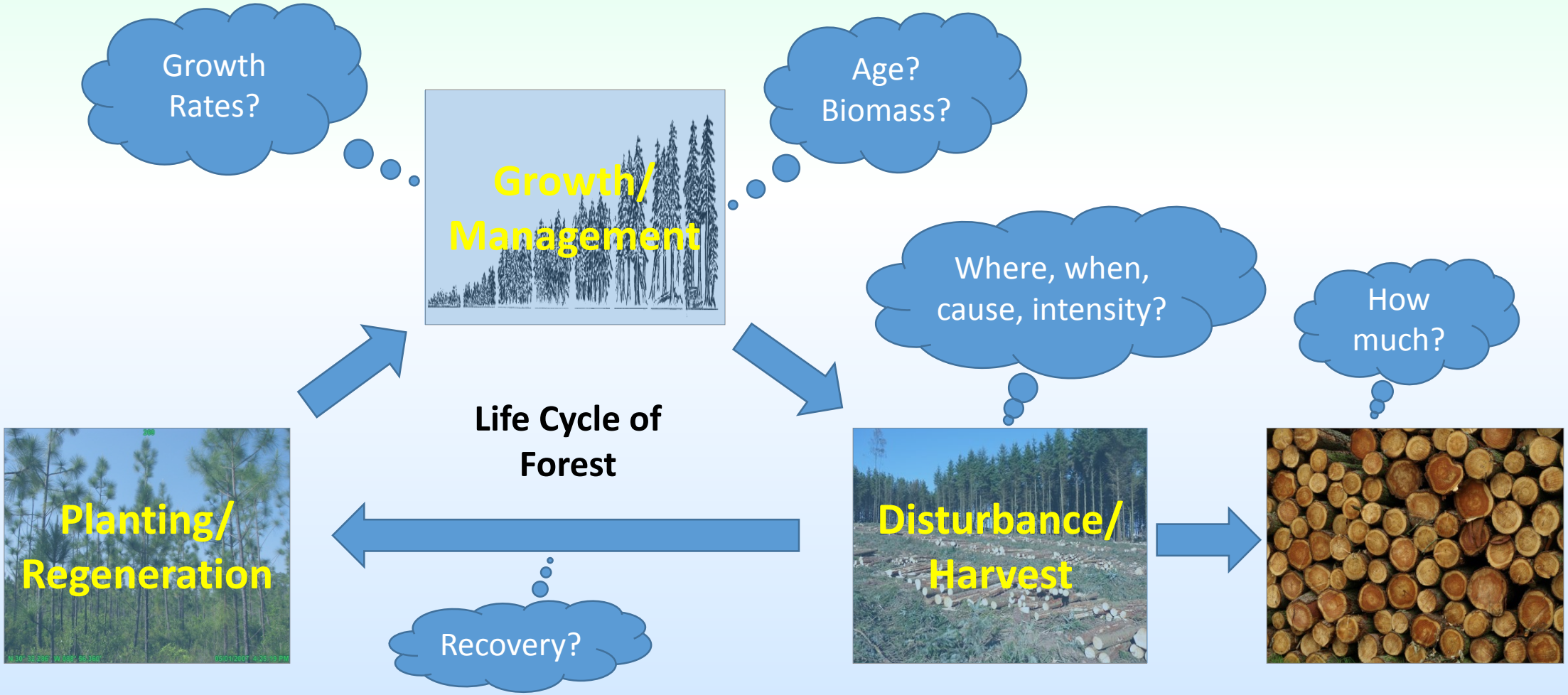
Chengquan Huang, Xin Tao, Feng Aron Zhao, Karen Schleeweis, Pui-Yu Ling, Feng Robin Zhao, Jeffrey Masek, Zhiliang Zhu, Jennifer Dungan, and Samuel Goward

Department of Geographical Sciences, University of Maryland
USDA Forest Service Rocky Mountain Research Station
NASA Goddard Space Flight Center
NASA Ames Research Center
US Geological Survey

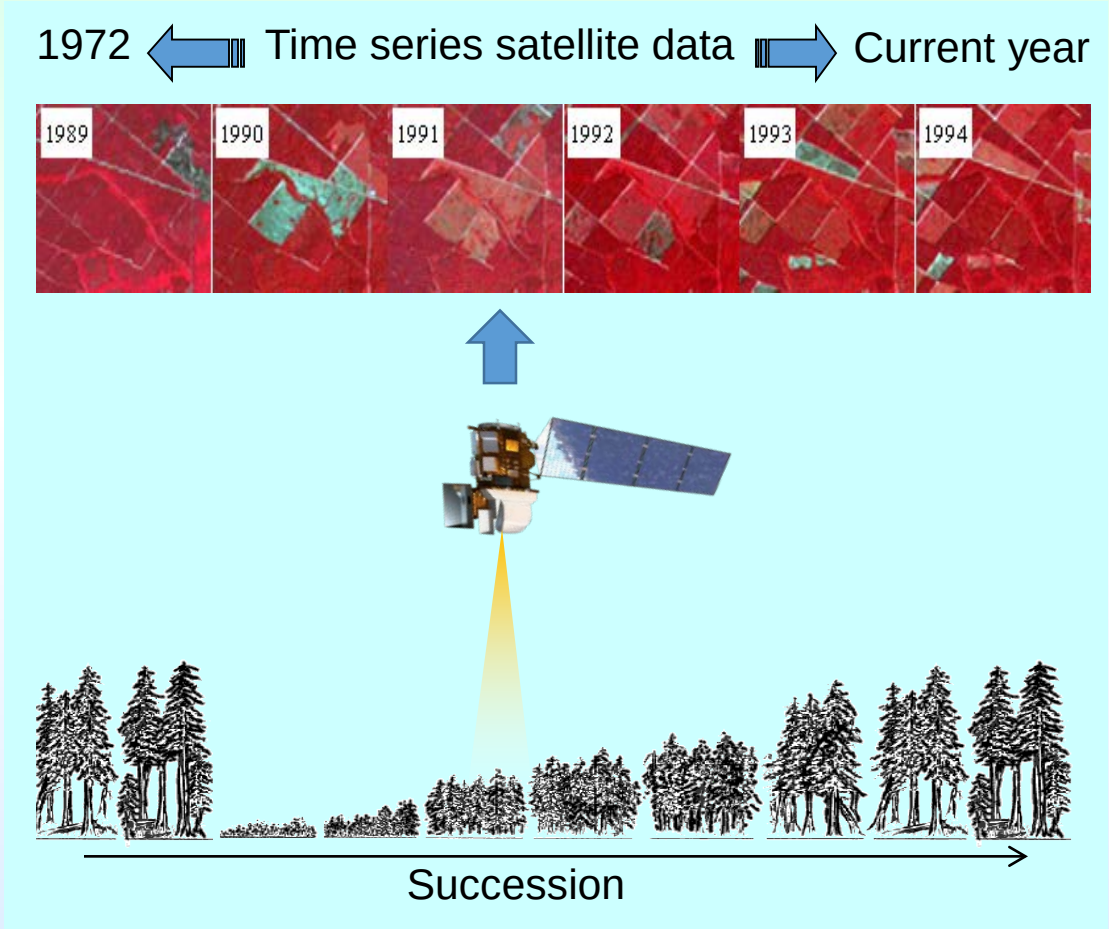
Contact: cqhuang@umd.edu

LCLUC SARI International Regional Science Meeting in South/Southeast Asia, Chiang Mai, Thailand
July 17-19, 2017

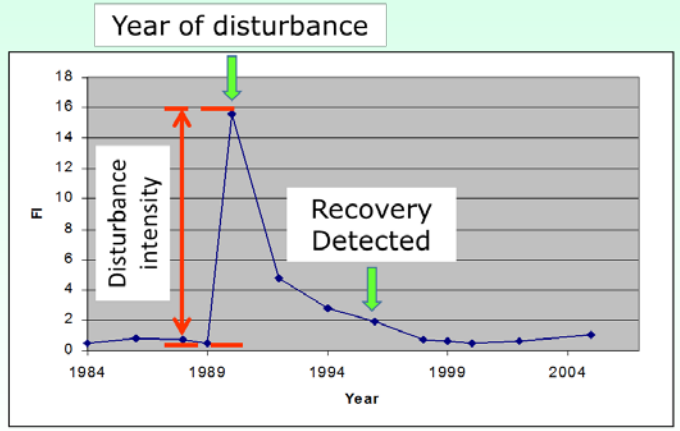
Many Important Questions About Forest Life Cycle



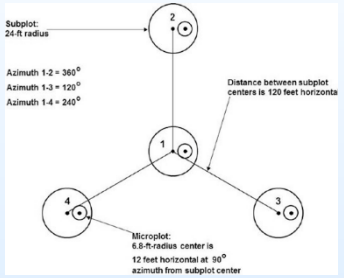
Overall Approach



Remote Sensing



Inventory Survey

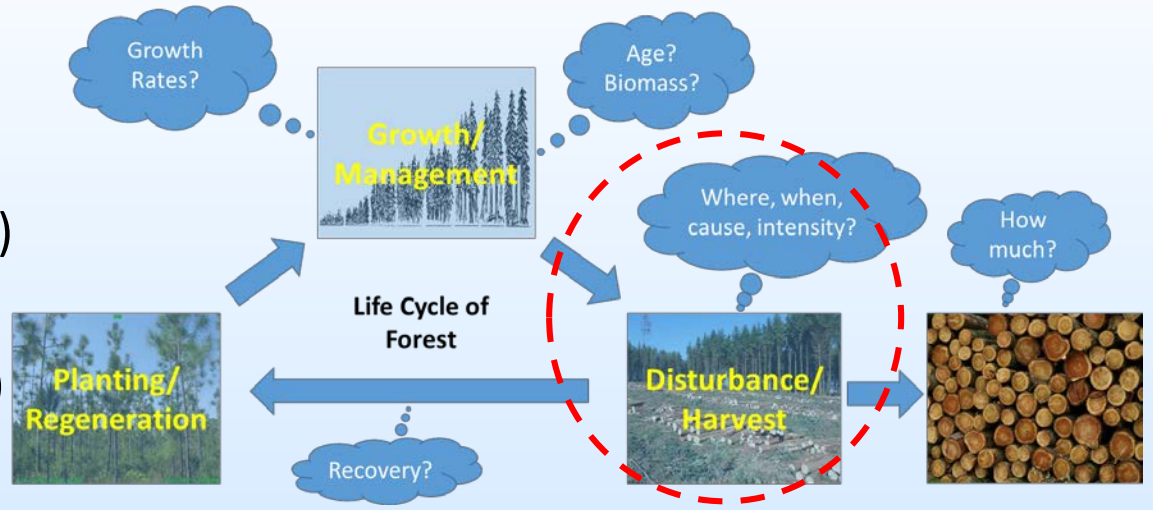


FIA Data

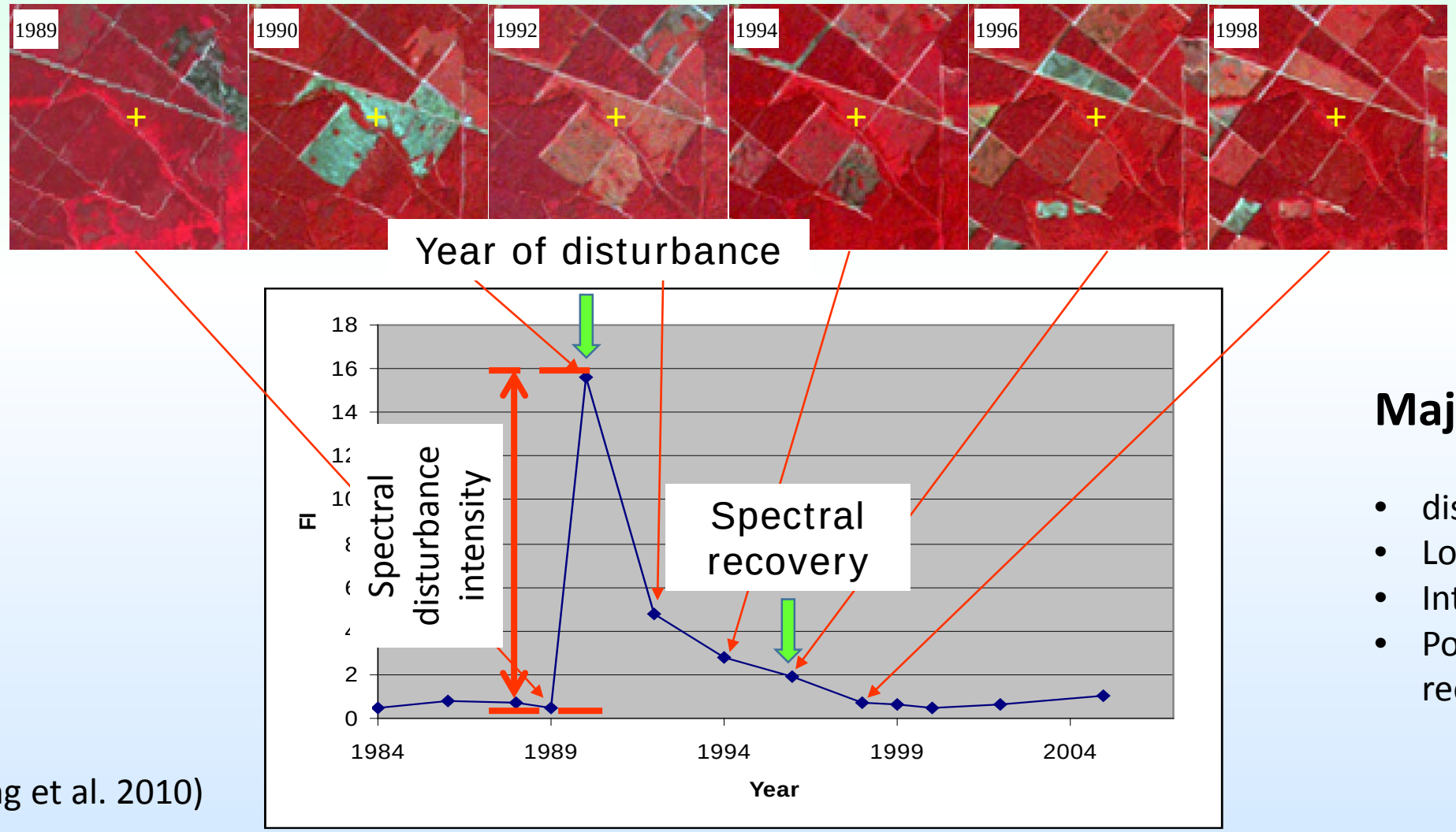
Timber Product Output

Booming of Time Series Methods for Disturbance Mapping

- Trajectory based
  - LandTrendr (Kennedy et al. 2007, 2010)
  - Vegetation change tracker (VCT) (Huang et al. 2010)
  - UBC-CFS (Univ. of British Columbia-Canadian Forest Service) (White et al. 2014, Hermosilla et al. 2015a, b)
  - Image Trends from Regression Analysis (Vogelmann et al. 2012)
- Classification/machine learning based
  - Hansen-Potapov (Hansen et al. 2008, Potapov et al. 2012)
  - Multi-index Integrated Change Analysis (Jin et al. 2013)
- Deviation from model prediction
  - Continuous change detection and classification (CCDC) (Zhu et al. 2014)



Forest Disturbance Mapping Using Vegetation Change Tracker (VCT)

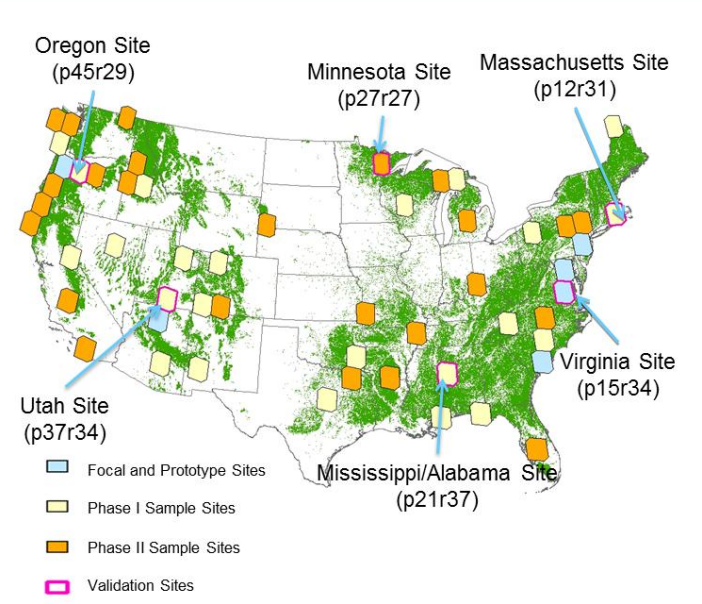


Major outputs

- disturbance year
- Location
- Intensity
- Post-disturbance recovery

(Huang et al. 2010)

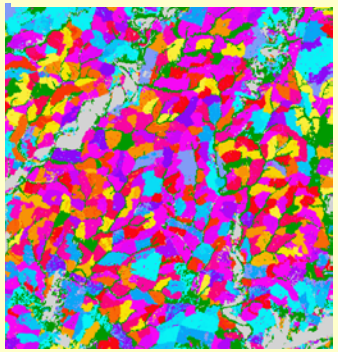
VCT Validated Across the US



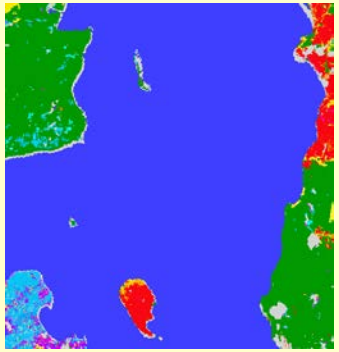
WRS2 Path/row	*Location (State)*	Overall accuracy	Average producer's accuracy	Average user's accuracy
12/31	Massachusetts	0.87	0.60	0.62
15/34	Virginia	0.84	0.67	0.78
21/37	Mississippi/Alabama	0.84	0.64	0.79
27/27	Minnesota	0.82	0.64	0.80
37/34	Utah	0.86	0.31	0.50
45/29	Oregon	0.86	0.57	0.72
16/35	North Carolina	0.87	0.82	0.83
47/27	Washington	0.94	0.92	0.92
42/29	Idaho	0.91	0.83	0.82

(Huang et al. 2009, 2010, 2011, 2015; Thomas, Huang et al. 2011)

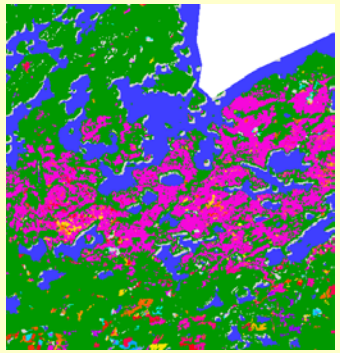
Little left undisturbed



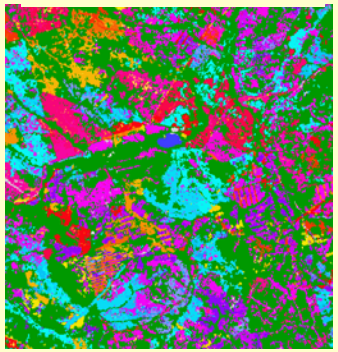
Whole Island burned



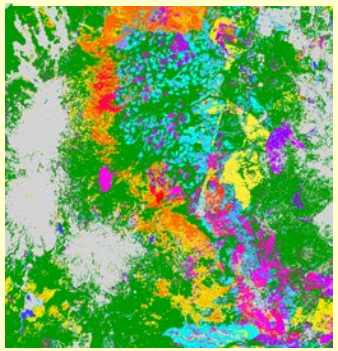
Severe wind blow-down

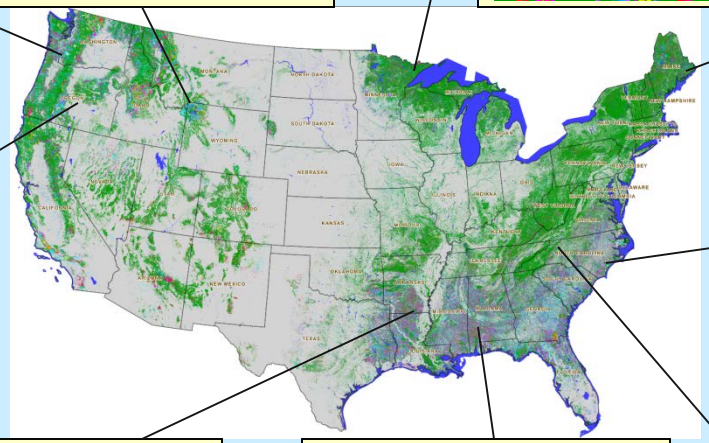


Logging industry

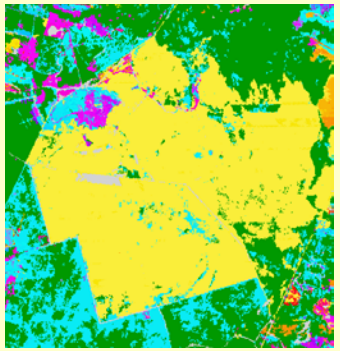


Fires and insects





Lightening induced fire



No change classes

- Persisting Nonforest
- Persisting Forest
- water

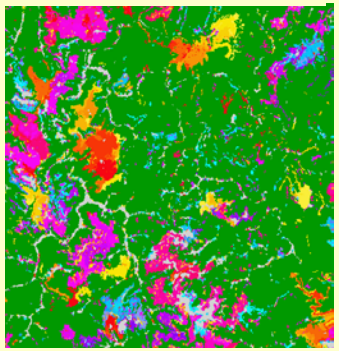
Disturbance year classes

- Pre-observation
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011

Parallel tornados tracks

Intensive logging

Mountain top mining

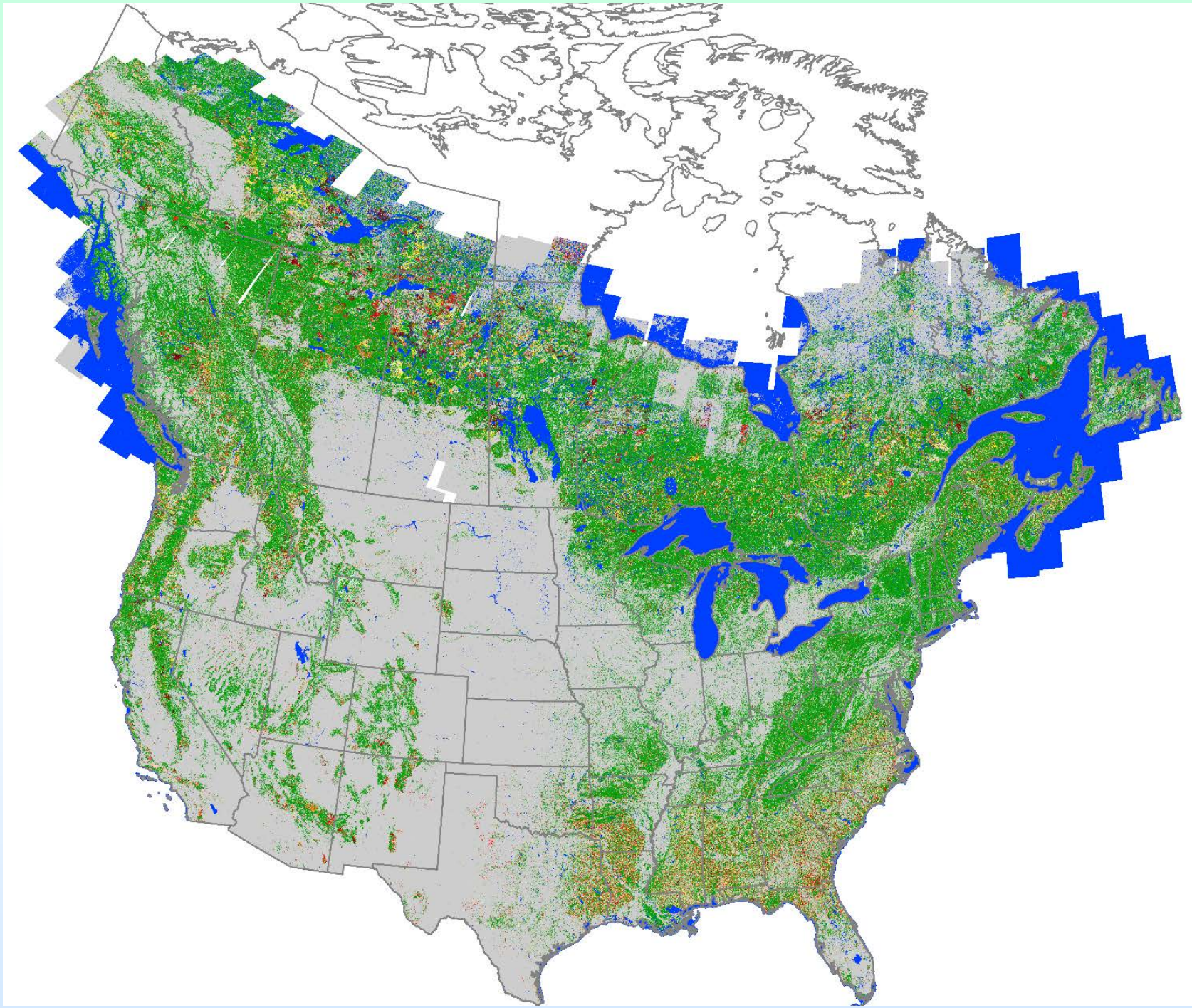


The NAFD-NEX Product: A 25-year History of US Forest Disturbances from VCT

Distributed at ORNL DAAC

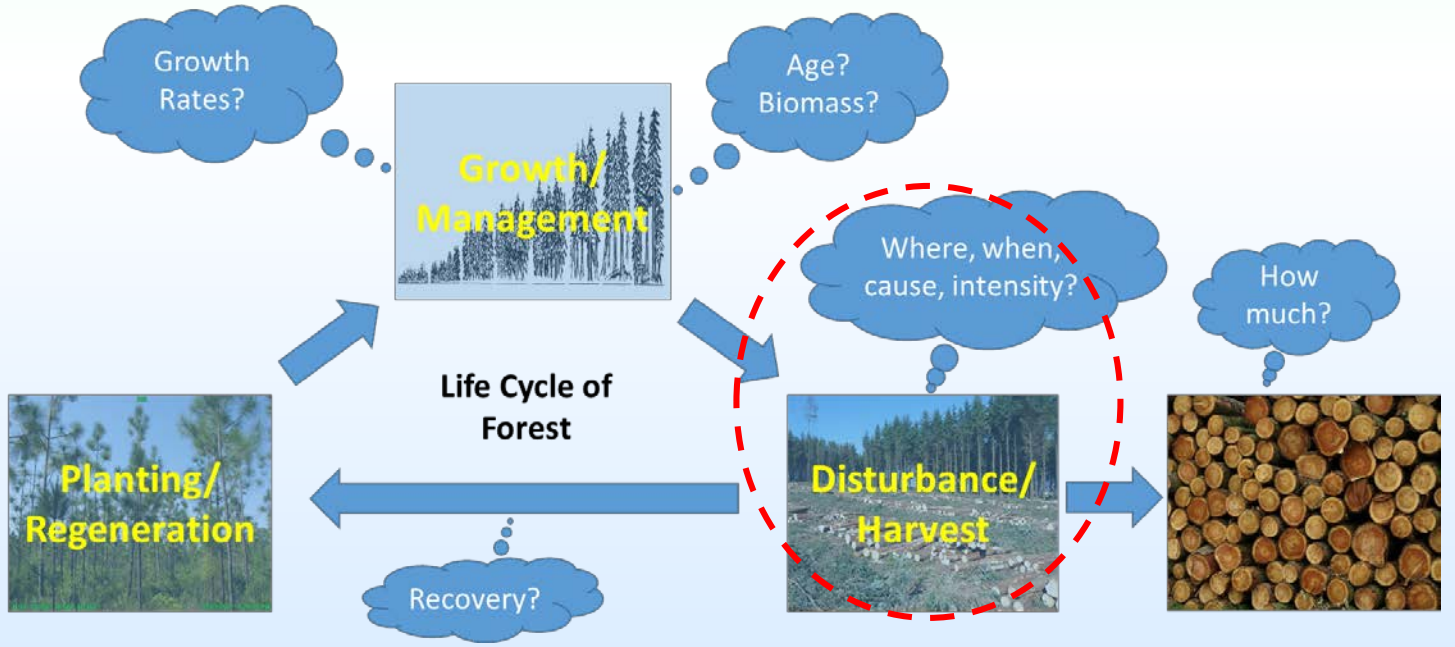
https://daac.ornl.gov/NACP/guides/NAFD-NEX_Forest_Disturbance.html

A 30-Year Annual Disturbance Record for US and Canada



More About Disturbance

- Attributes provided by VCT
  - Disturbance location
  - Timing
  - Spectral based intensity
- Other desirable details
  - Disturbance agent
  - Physically based disturbance intensity
  - Harvested timber volume



Disturbance Agent

Response Classes:

- Harvest
- Wind
- Fire
- Stress *
- Conversion
- Other

Predictor Variables

- VCT outputs
- Temporal profile shapes & related metrics (Meyer 2008; Moisen et al. 2016)
- Ancillary data

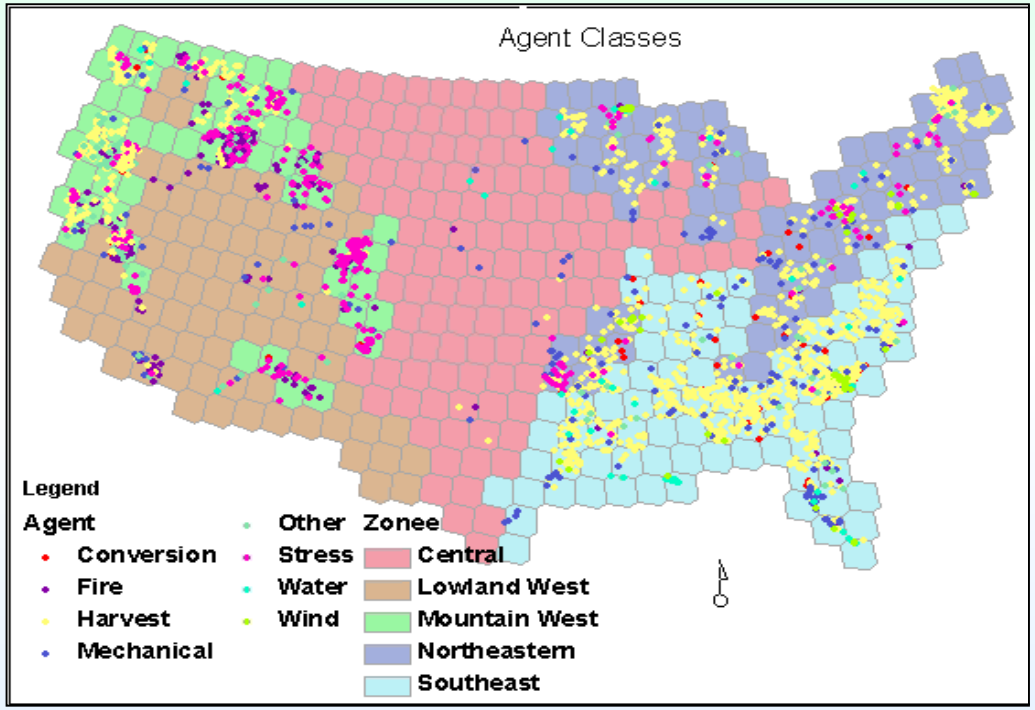
Random Forest Classification

Overall Accuracy = 75%

Harvest:

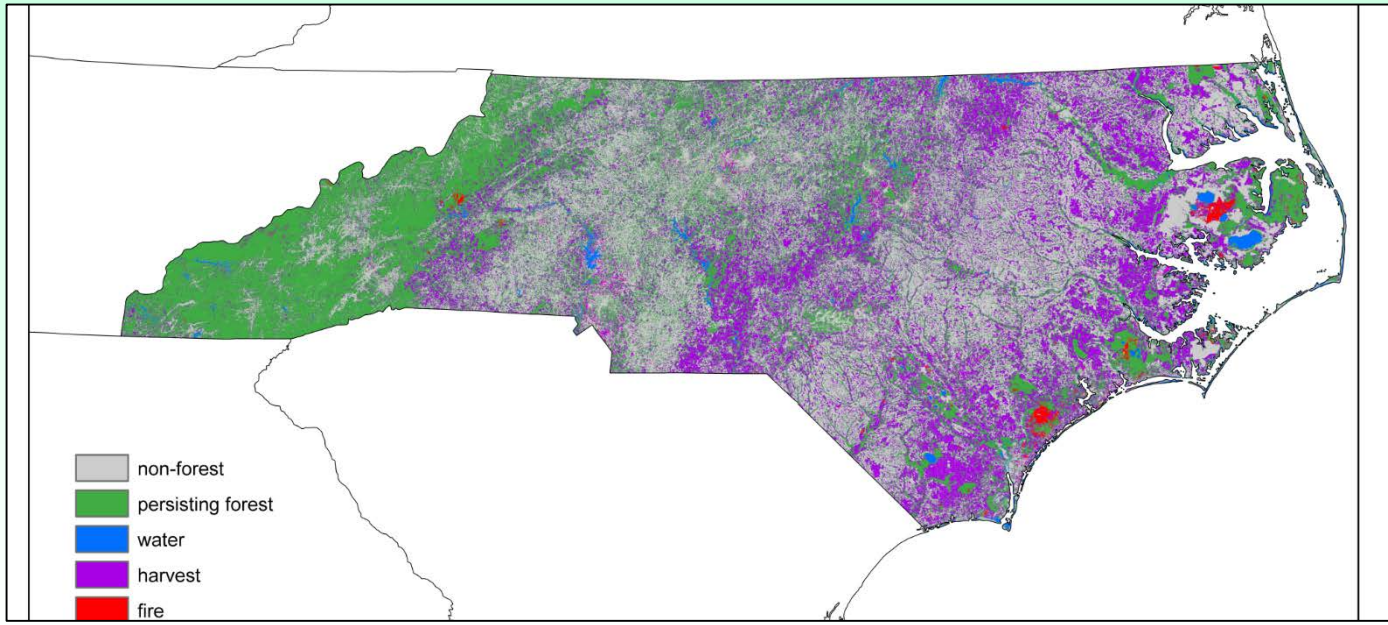
Commission/omission rates: ~25%

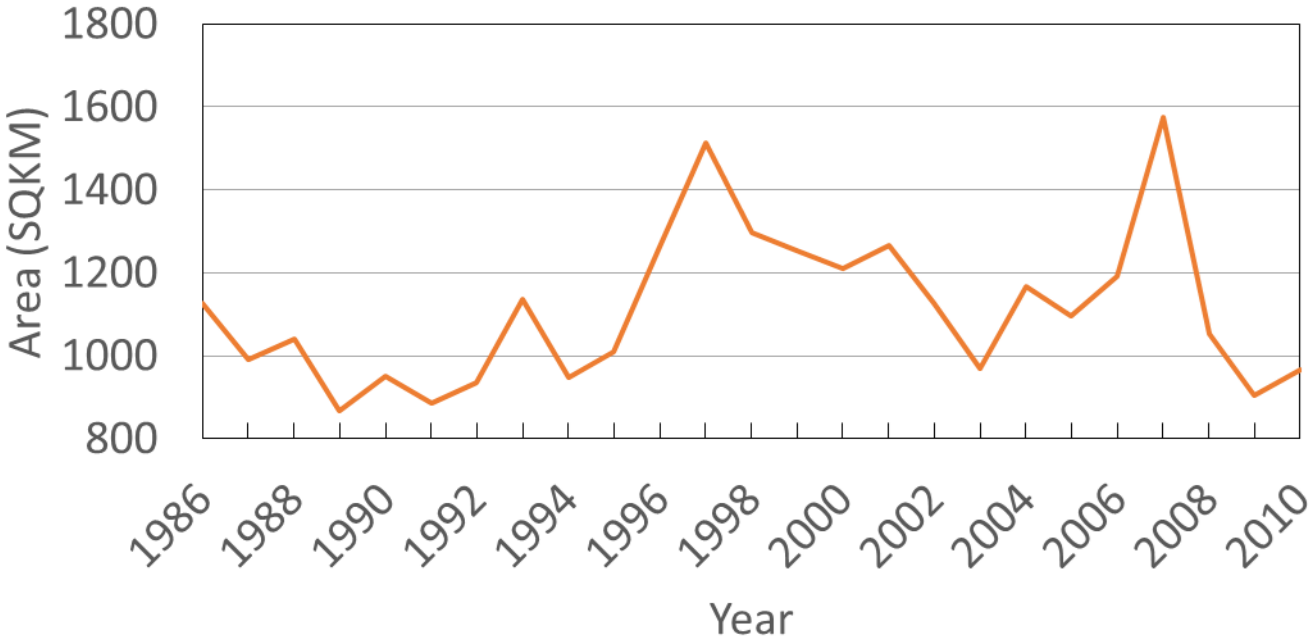
Training data



(Moisen et al. 2016; Schroeder et al. accepted)

Forest Harvest Area in NC



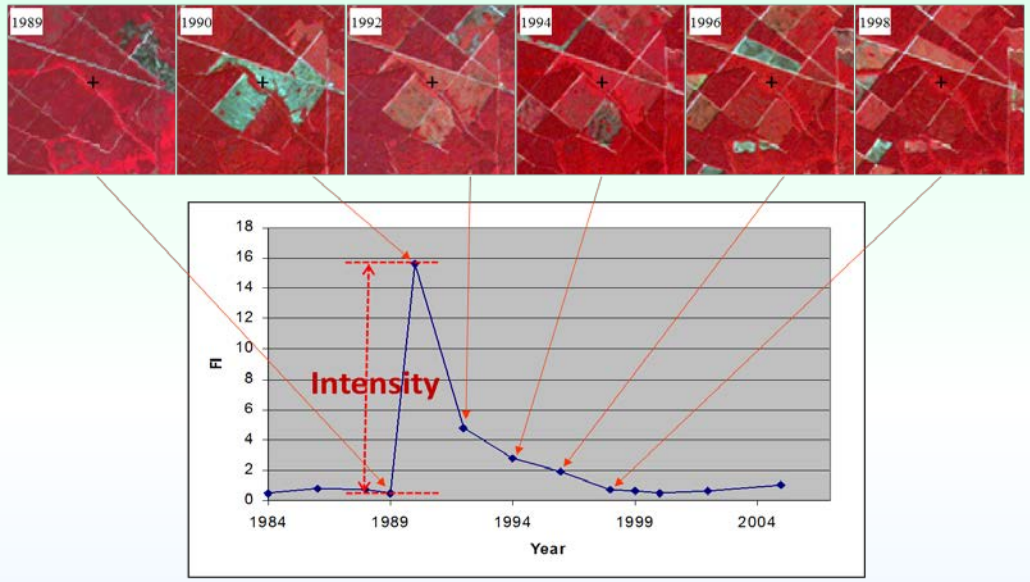


Average annual harvest area: 1110 km^2

~1.5% of forest land in NC

Harvest Intensity

Vegetation Change Tracker (VCT)



USFS Forest Inventory and Analysis (FIA) plot data

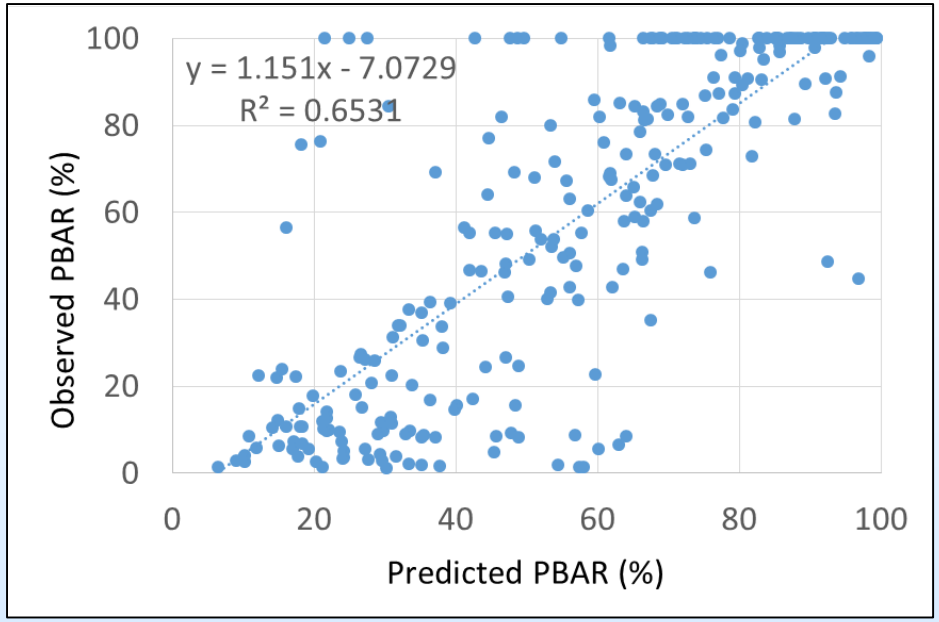
- One plot every 5 km
- Measure and track each tree
- Revisit every 5-10 years

Percent basal area removal (PBAR)

Percent basal area removal (PBAR)

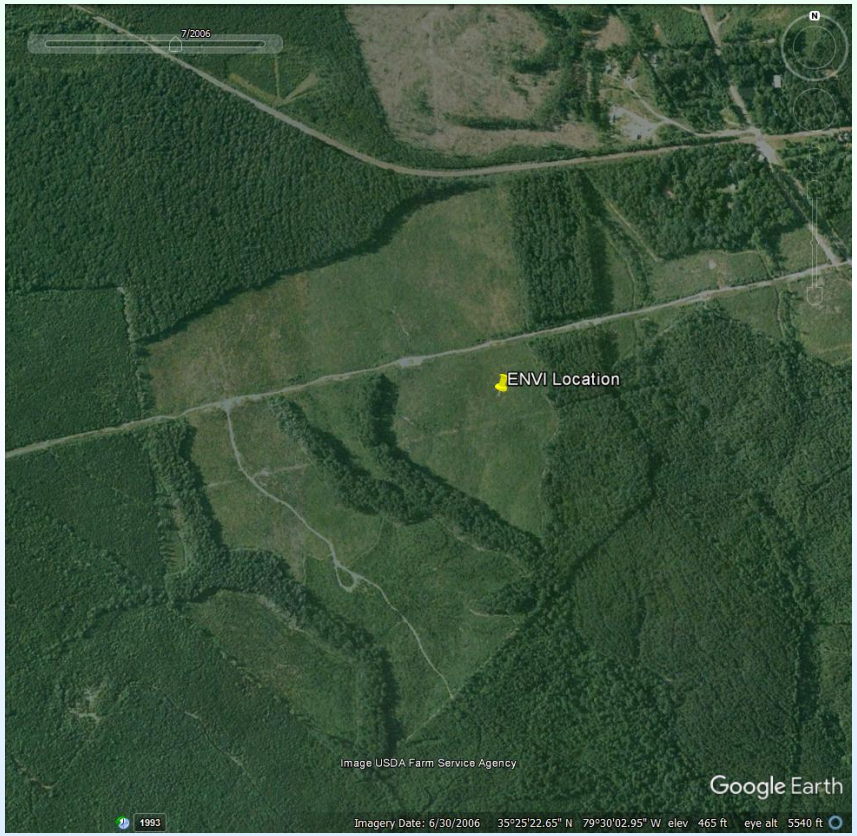
~

spectral disturbance intensity

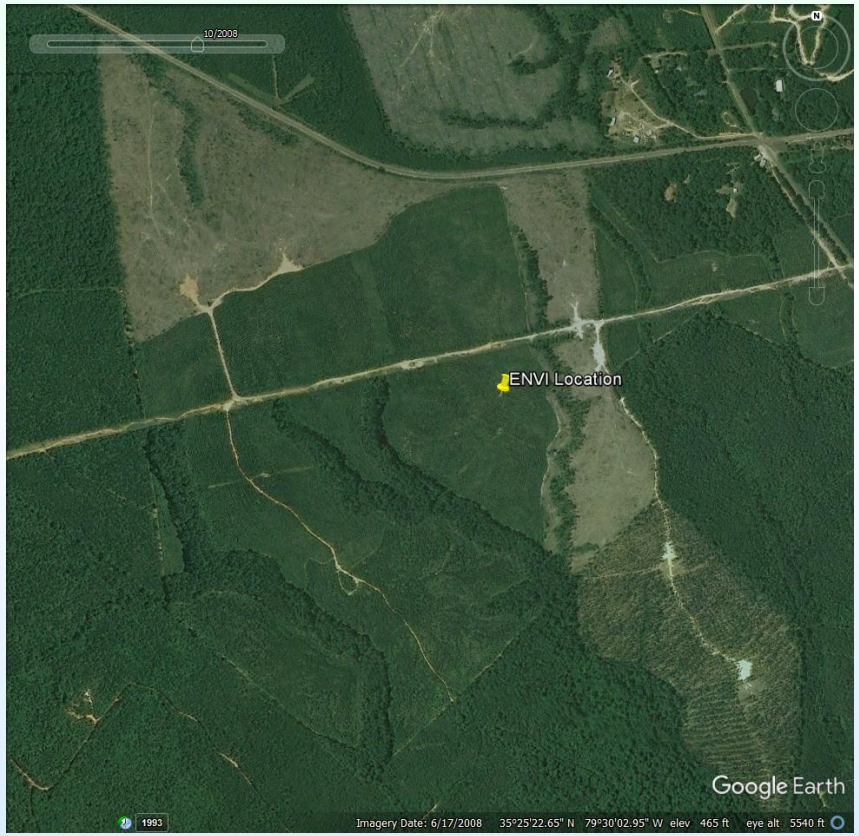


(Tao, Huang et al., in preparation)

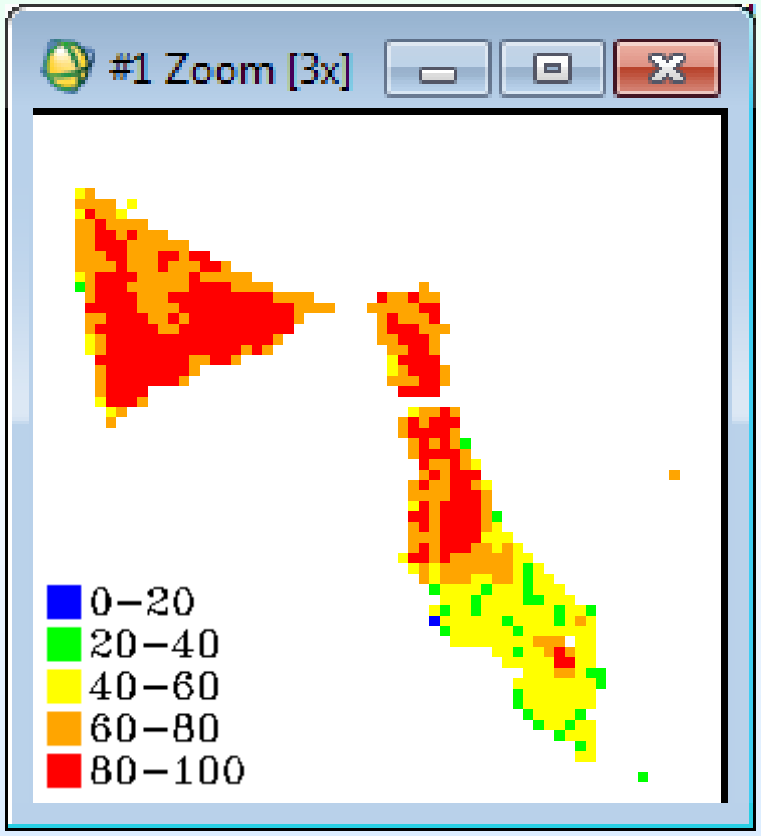
Verification of Disturbance Intensity Using Available GoogleEarth Images



July 2006



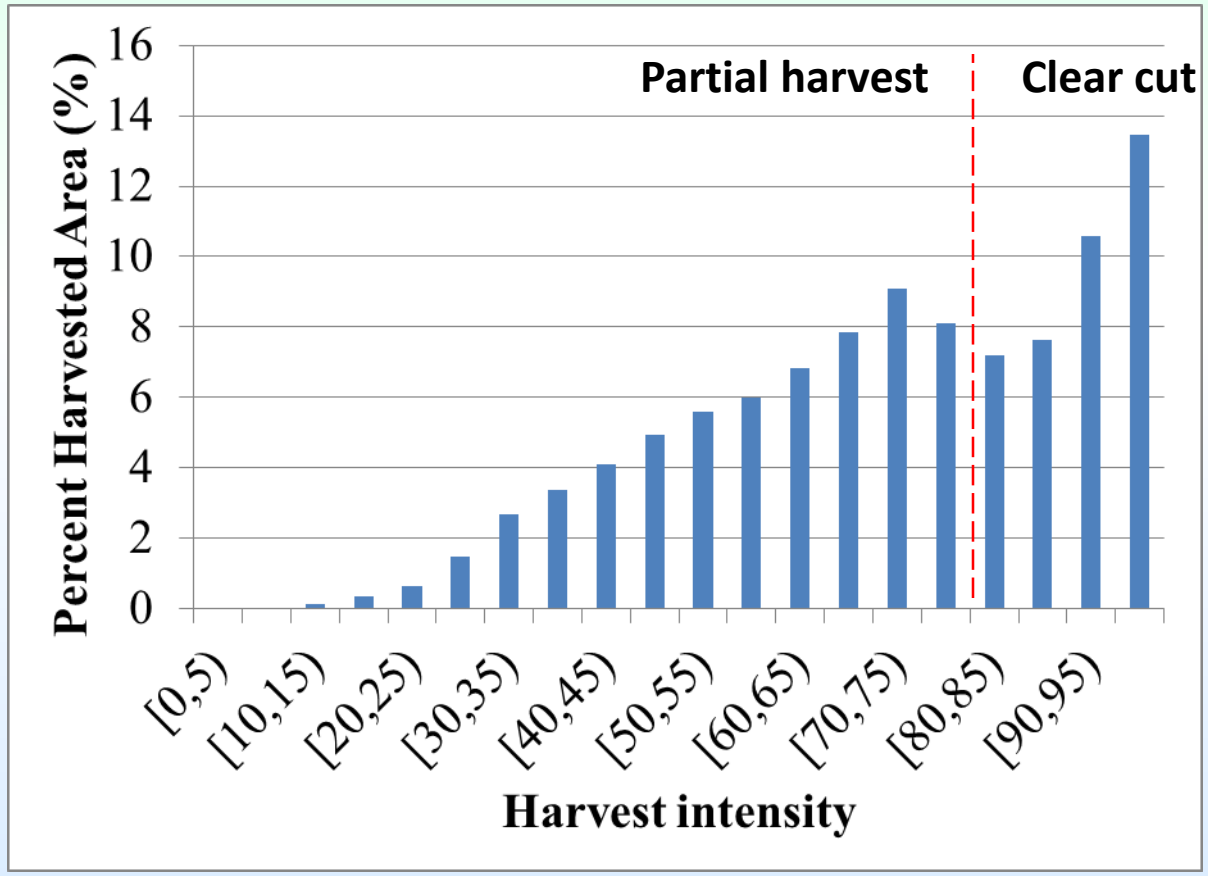
October 2008

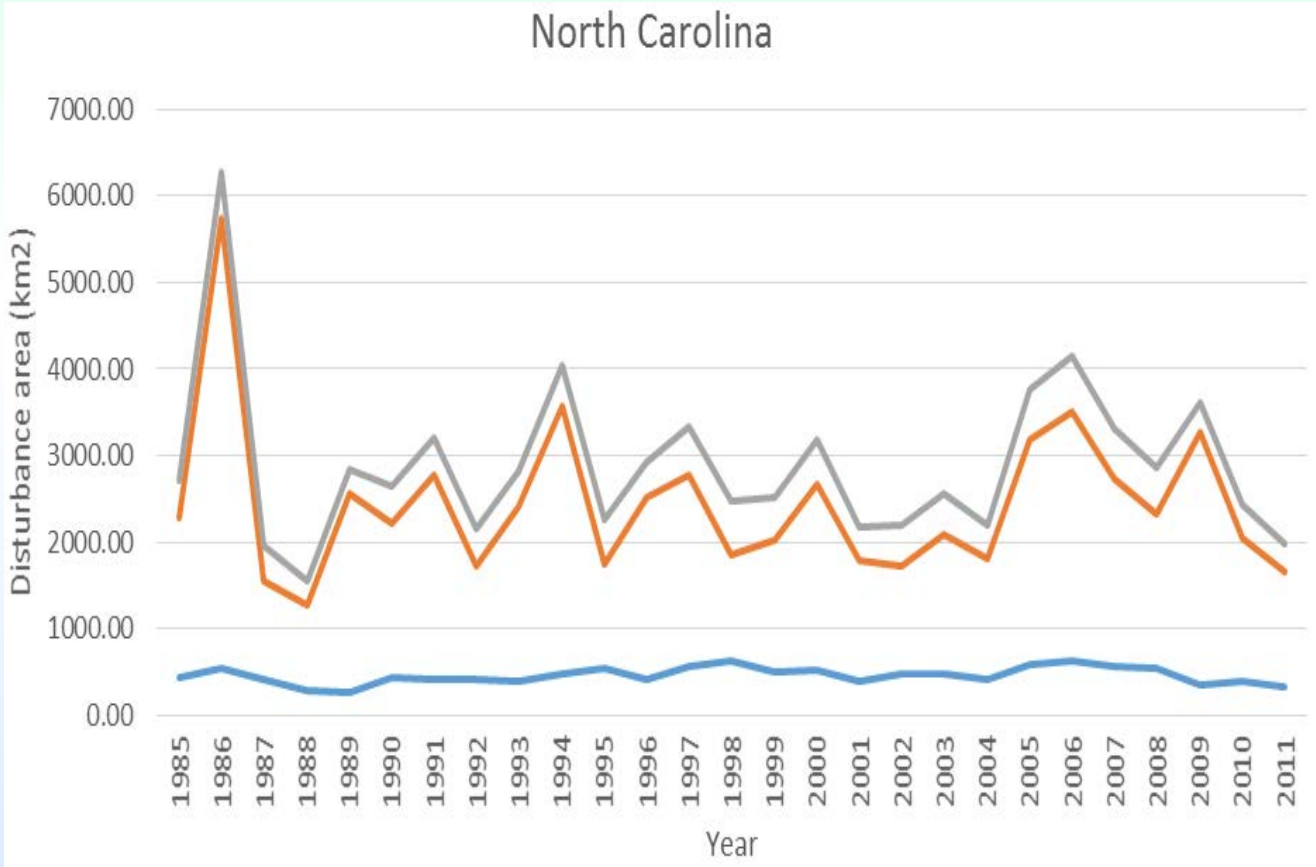


Percent Basal Area Removal

Distribution of Disturbance Intensity in North Carolina

Disturbance Intensity Histogram

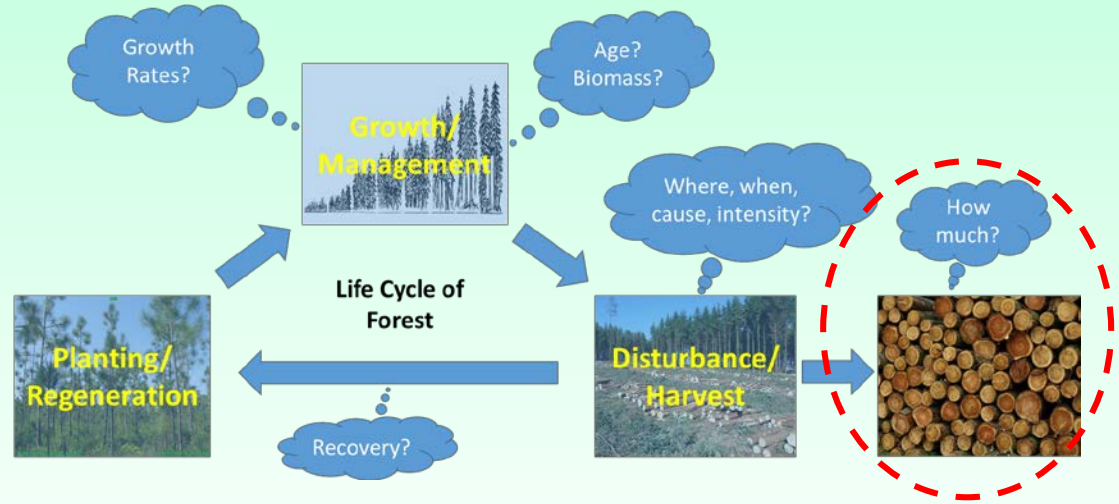


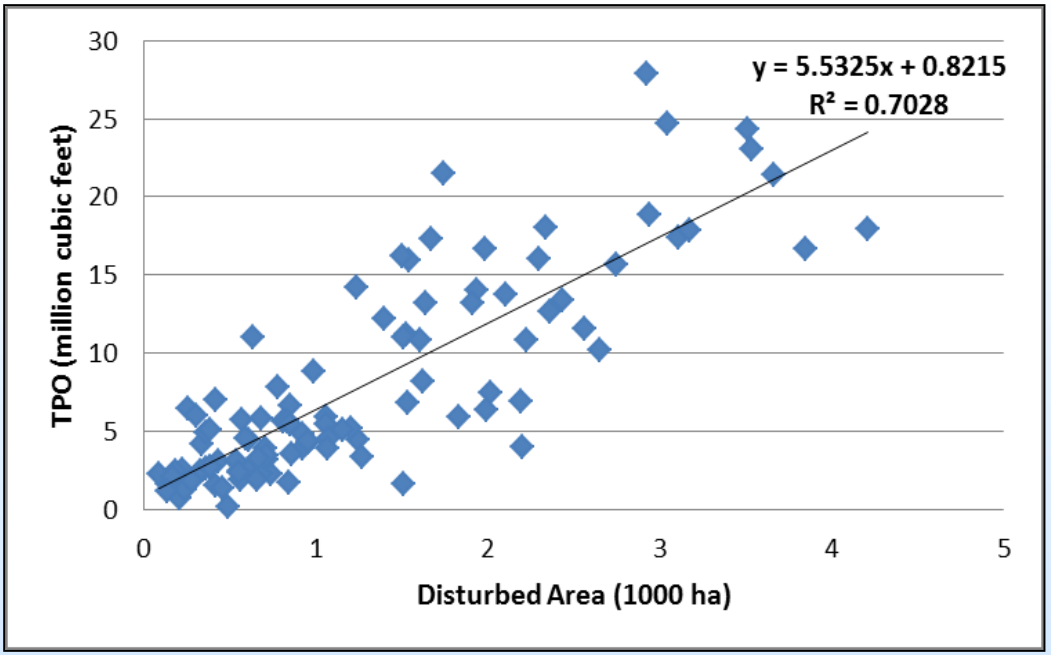


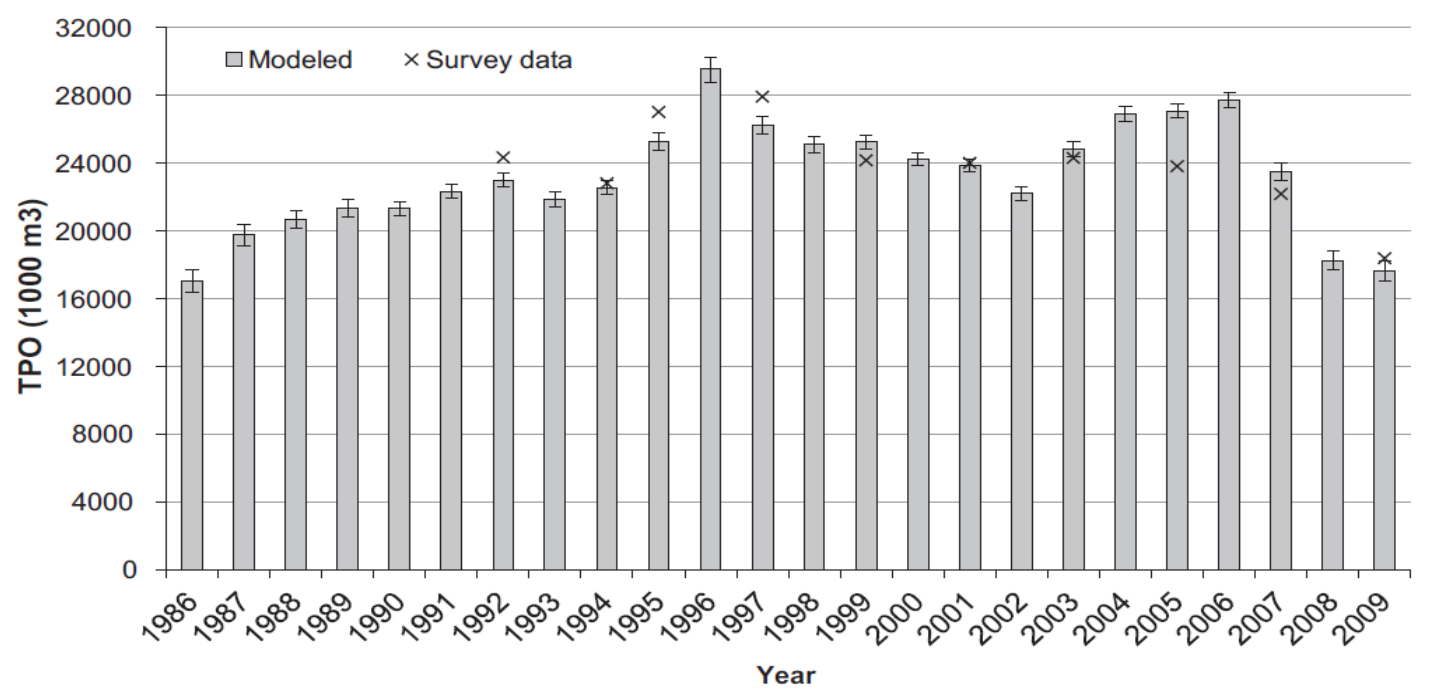
According to USFS/FIA (Smith et al. 2009), clear cut accounted for 41% of total harvest area.

Timber Product Output (TPO)

- Target: survey estimation of timber product output (TPO)
- Predictor variables: disturbance area, type, intensity, forest type, etc.
- Methods: Stepwise linear regression; panel based modeling





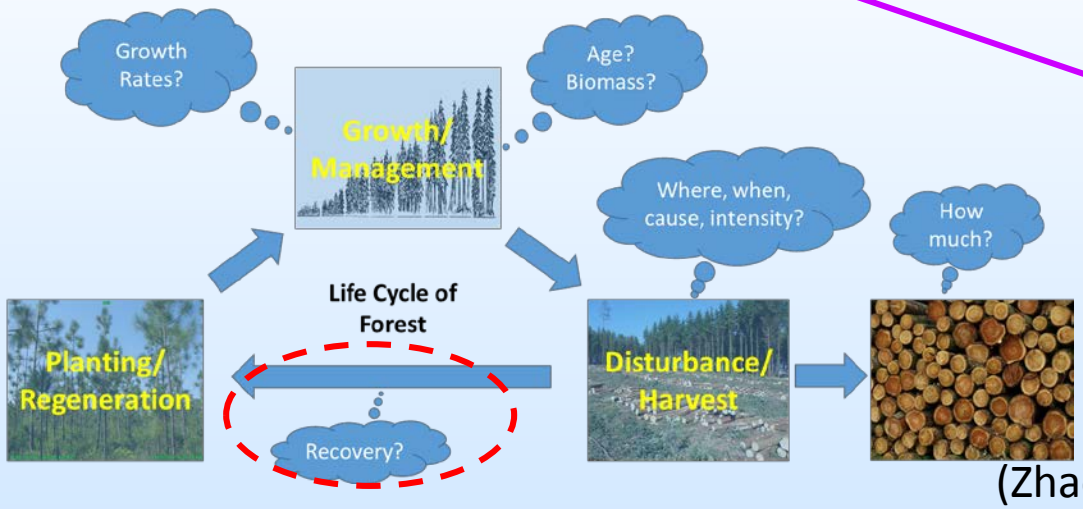


(Huang et al. 2015; Ling, Huang et al. 2016)

Validation of VCT Post-Disturbance Recovery Detection

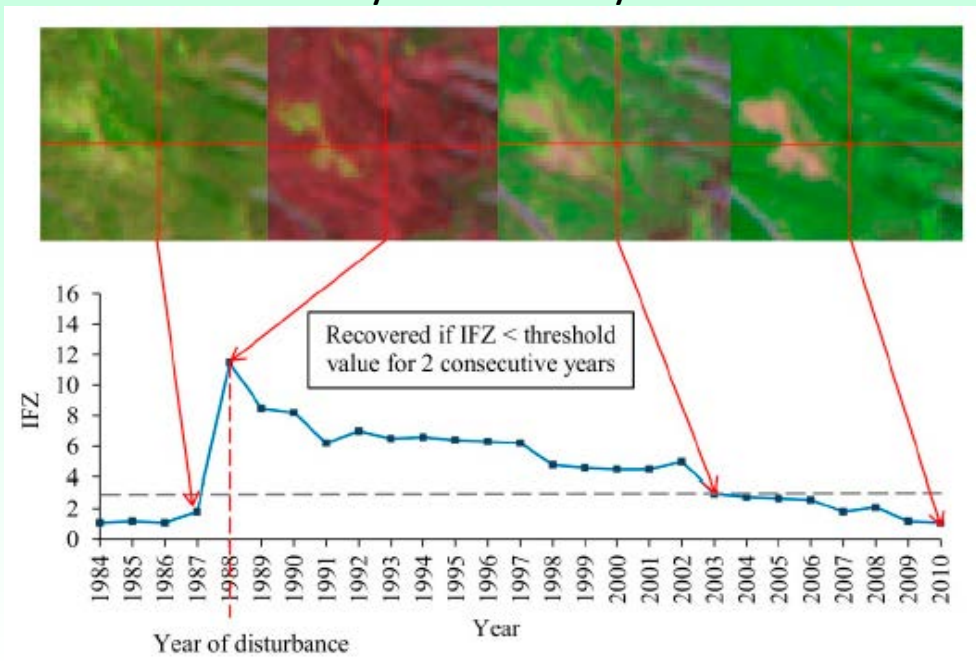
Circa 2010 GoogleEarth Images

Figure 3. Examples of Google Earth validation of recovered and non-recovered pixels in 5 by 5 grids: (**a**) non-recovered; (**b**) recovered; and (**c**) recovered.

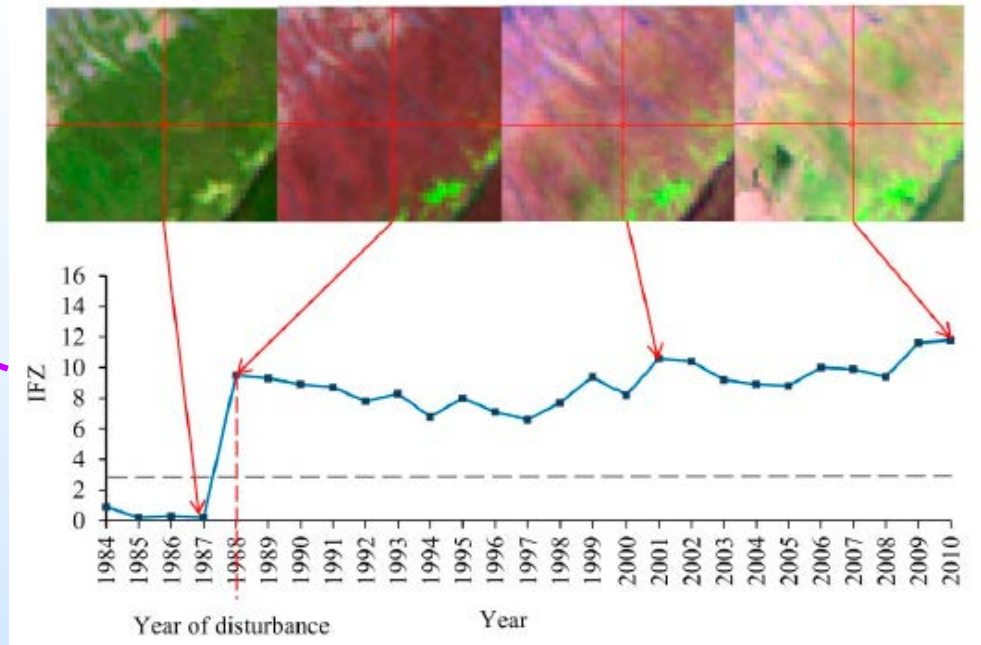


(Zhao. Huang et al., 2016)

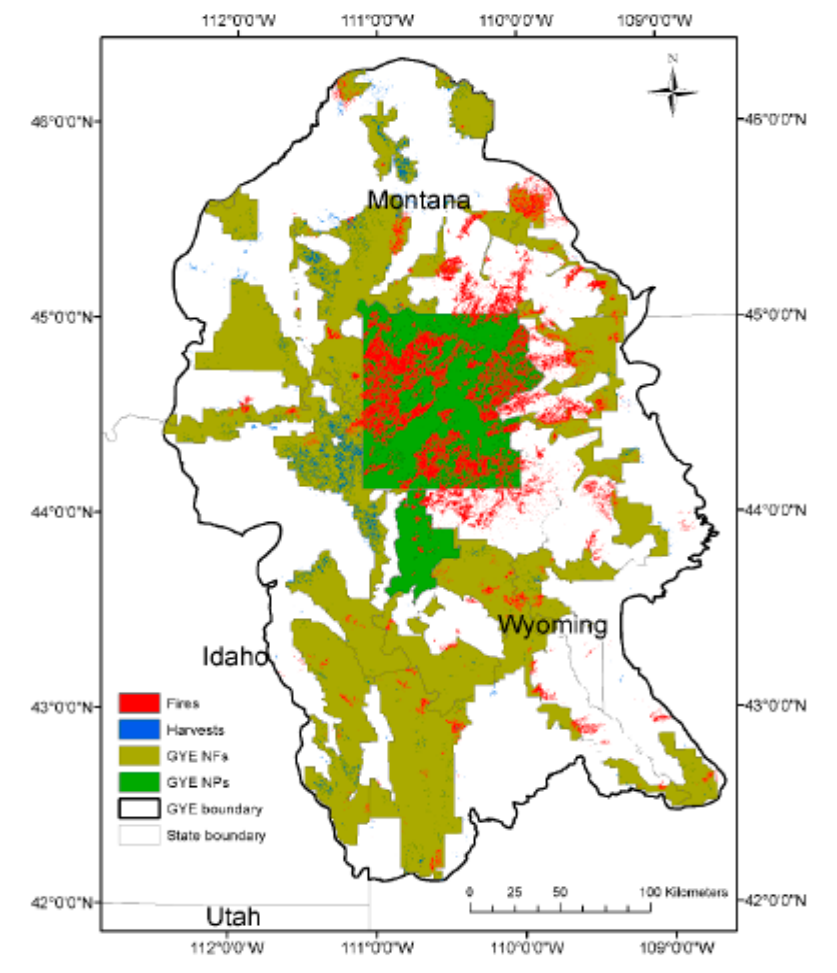
Recovery detected by 2010



No detectable recovery by 2010



Validation of Recovery Mapping over Yellowstone



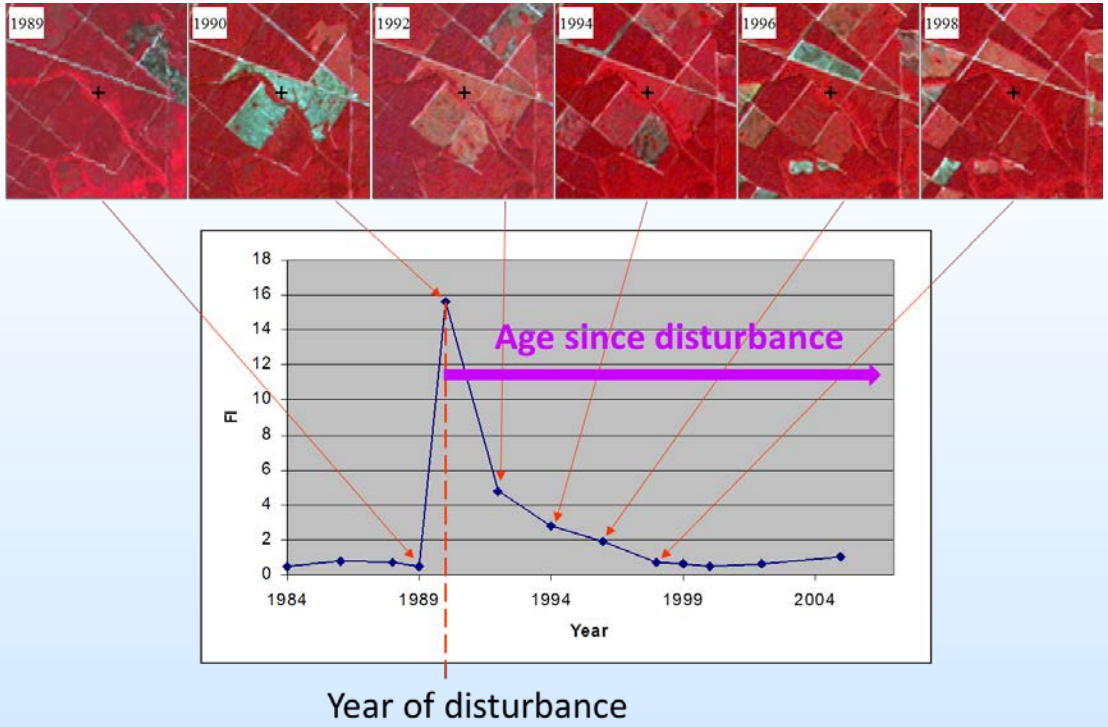
Post-Fire Spectral Recovery Validation Results					
		Reference			
		Recovered (Tree Cover > 10%)	No-Detectable-Recovery (Tree Cover ≤ 10%)	Row Total	User's Accuracy
Map	Spectrally recovered	0.19	0.07	0.26	0.75
	No-detectable-recovery	0.13	0.61	0.74	0.82
	Column total	0.32	0.68	1.00	
	Producer's Accuracy	0.59	0.90		
	Overall Accuracy		0.80		

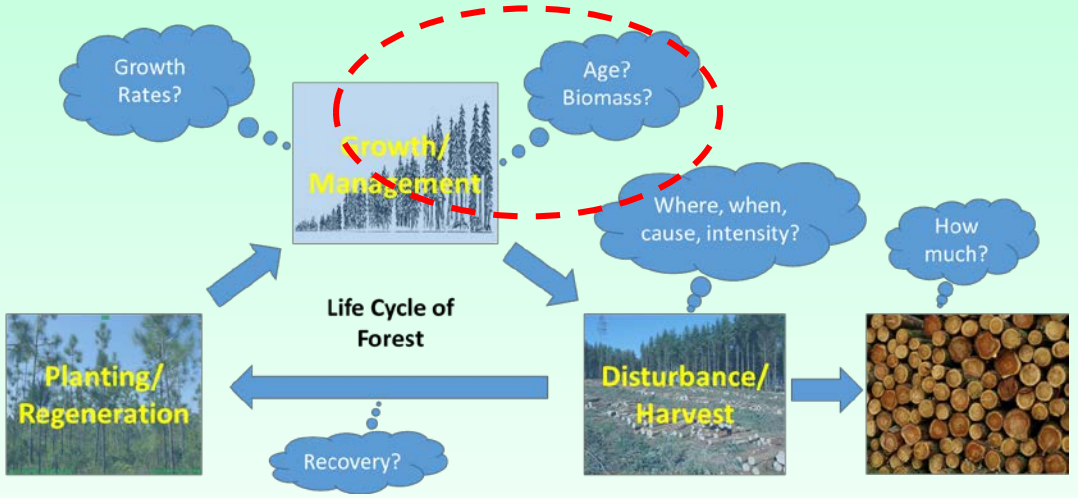
Post-Harvest Spectral Recovery Validation Results					
		Reference			
		Recovered (Tree Cover > 10%)	No-Detectable-Recovery (Tree Cover ≤ 10%)	Row Total	User's Accuracy
Map	Spectrally recovered	0.69	0.02	0.71	0.97
	No-detectable-recovery	0.12	0.17	0.29	0.58
	Column total	0.81	0.19	1.00	
	Producer's Accuracy	0.85	0.89		
	Overall Accuracy		0.86		

(Zhao. Huang et al., 2016)

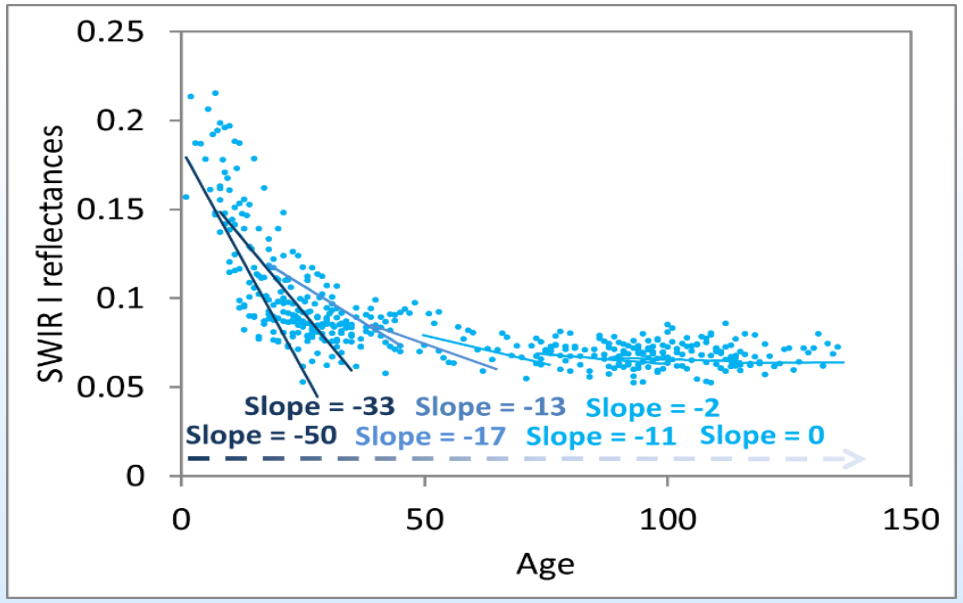
Forest Age

- Forest regenerating from a previous disturbance
  - Age since disturbance





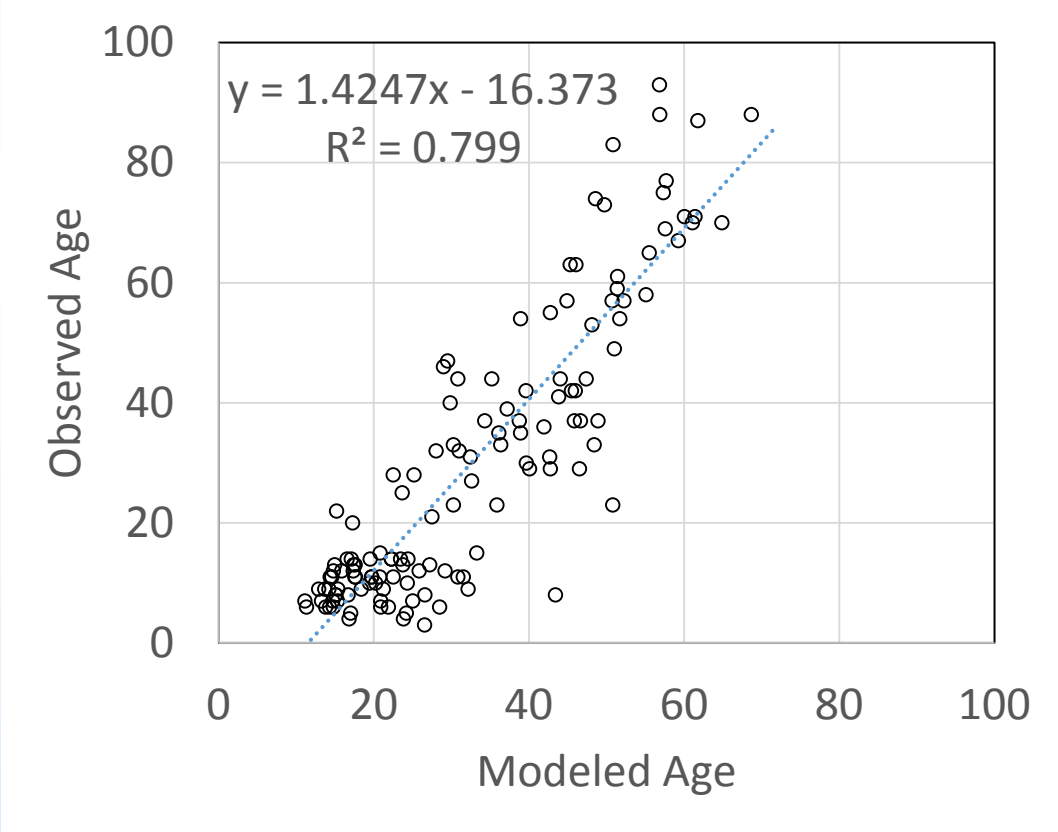
- Undisturbed forest
  - 30+ year Landsat observations indicative of age



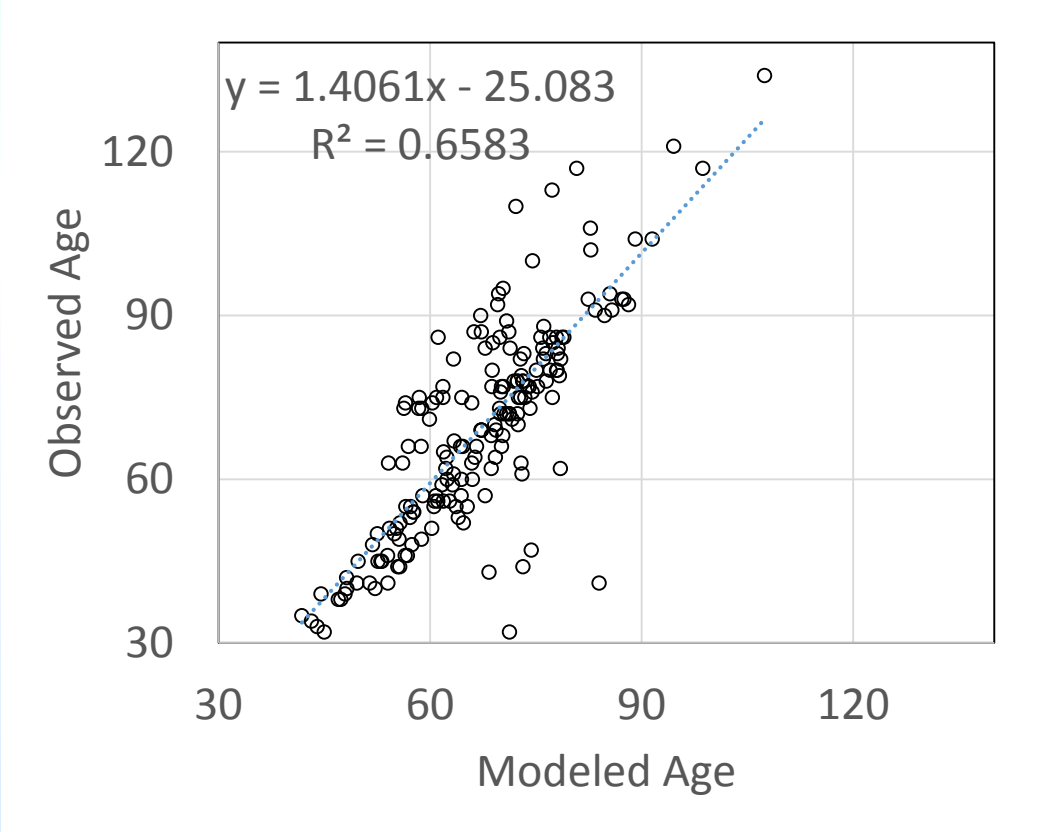
Reflectance trajectories of Doug. Fir forests of different ages

Assessment of Age Modeling Over North Carolina

Forest regenerating from a previous disturbance



Undisturbed forest

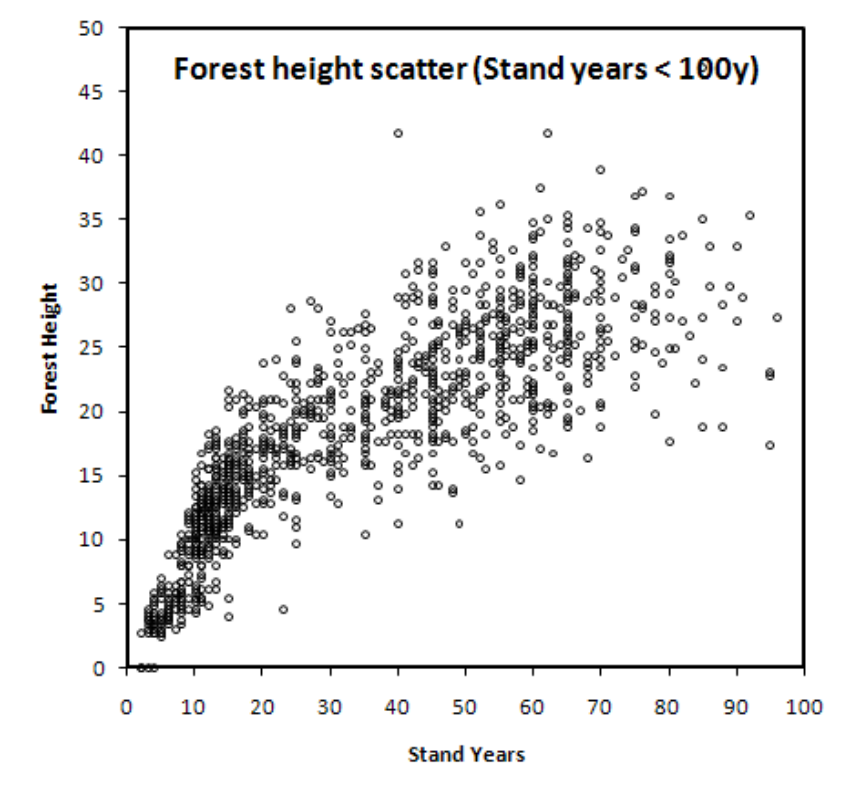


(Tao, Huang et al., in preparation)

Height and Biomass

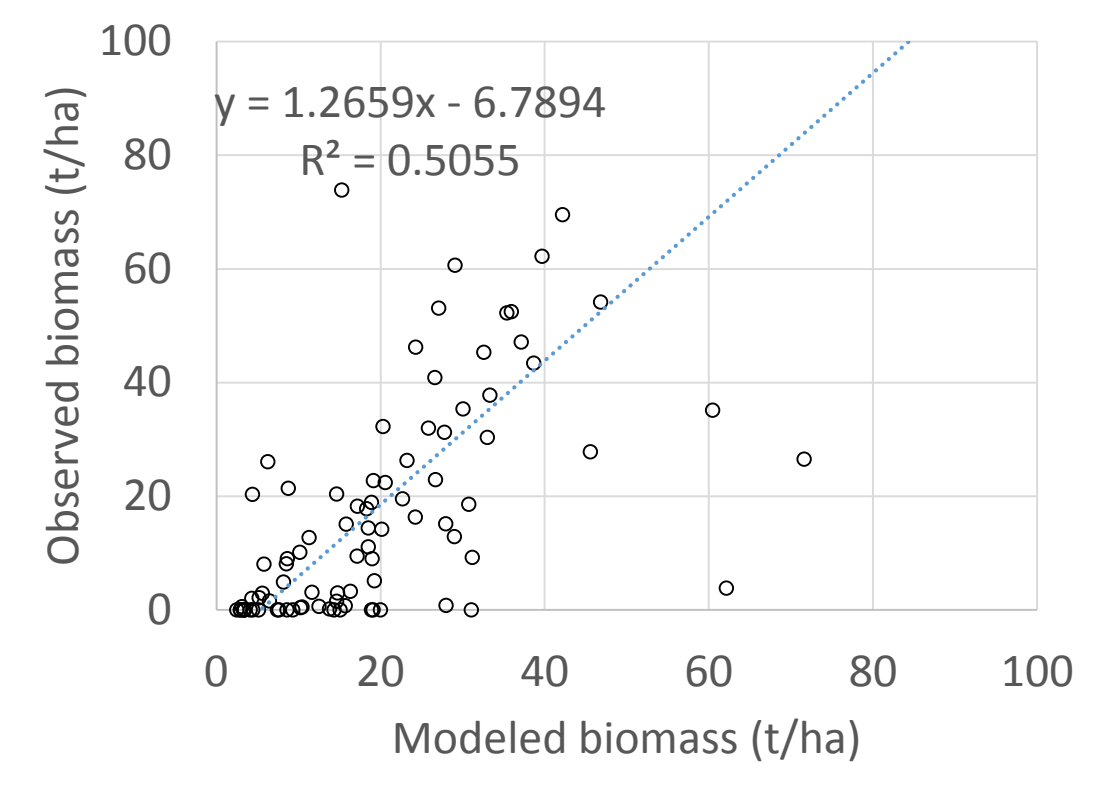
H, Biomass = f(age, species, local environment and climate conditions)

- Widely used in forestry for individual forest areas
- Large area use difficult
  - Required inputs not available
  - Spectral trajectory of growth could be used as surrogates
    - Biomass = f(age, spectral data)

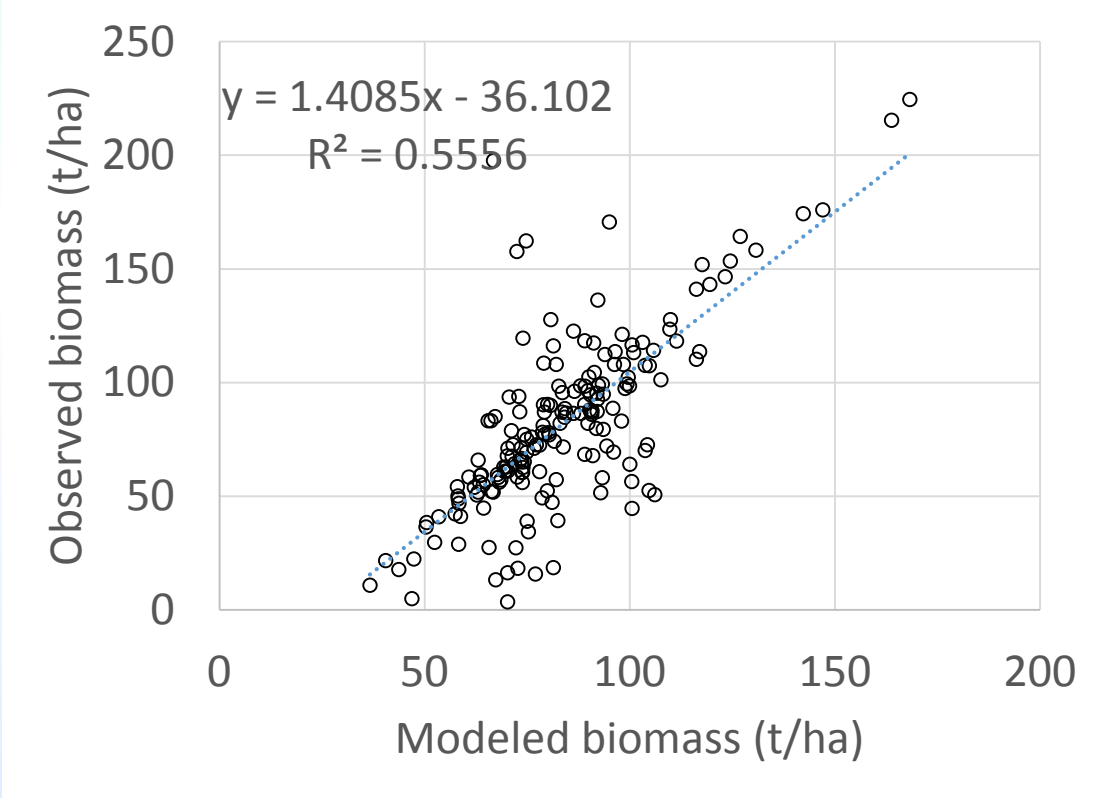


Assessment of Biomass Modeling Over North Carolina

Forest regenerating from a previous disturbance



Undisturbed forest



(Tao, Huang et al., in preparation)

Landsat Time Series + Inventory -> Characterization of Forest Life Cycle

Contact
cqhuang@umd.edu