A sea change on land: New insights into terrestrial processes facilitated by the open Landsat archive

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Landsat Science Team Meeting, Sioux Falls, August 2011

Contributions

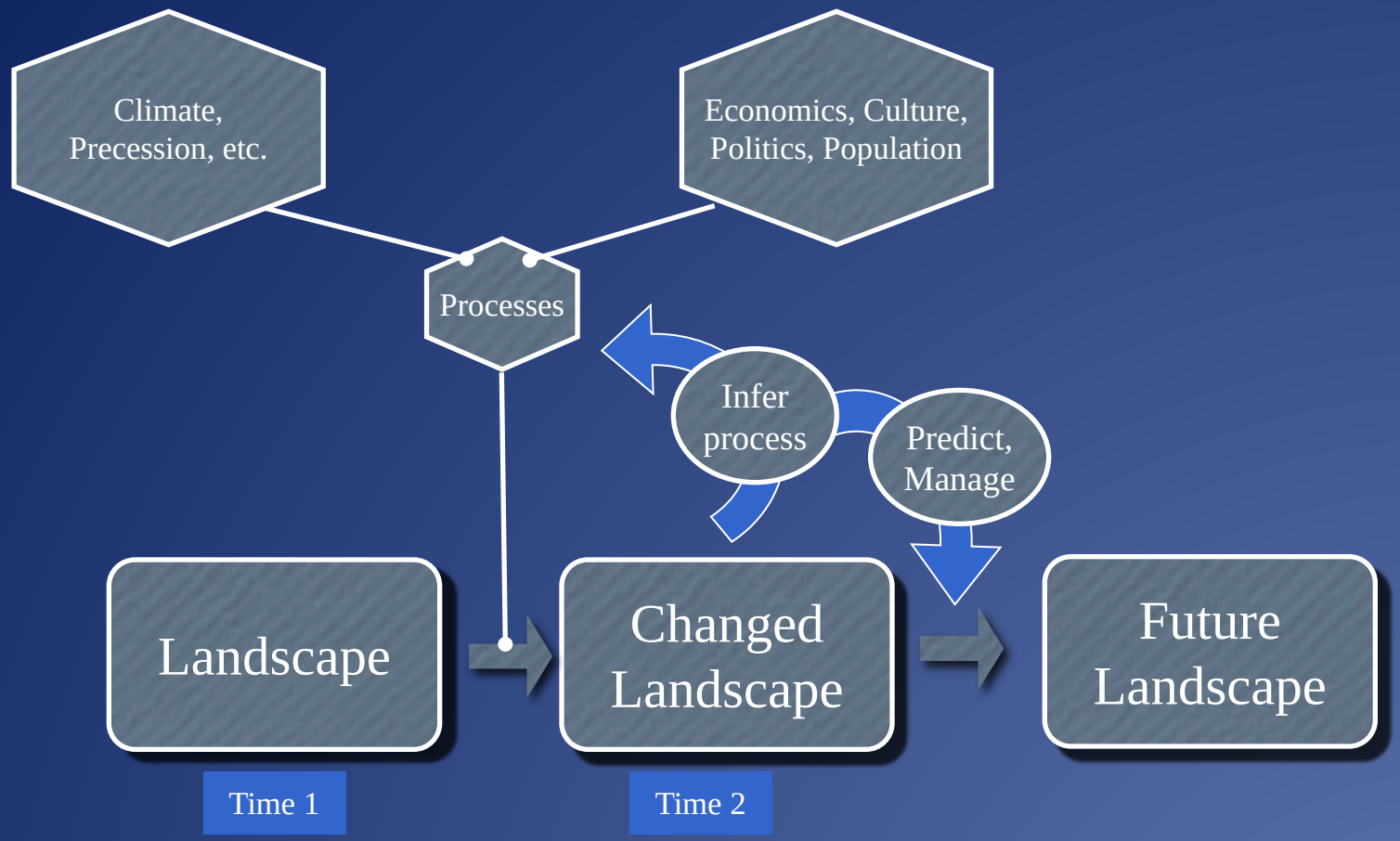
Agency support:

- USDA Forest Service Effectiveness Monitoring Program
- National Park Service Inventory and Monitoring Program
- NASA New Investigator Program and Carbon Cycle Science Program
- National Marine Fisheries Service

Slide contributions

- Dr. Rob Fraser: Canada Centre for Remote Sensing, Natural Resources Canada
- Patrick Griffiths: Geomatics Lab, Geography Department, Humboldt-Universität zu Berlin
- Dr. Martin Hais: Department of Ecosystem Biology, University of South Bohemia
- Dr. Eileen Helmer: USDA Forest Service, International Institute of Tropical Forestry
- Mitchell Lyons; Dr. Stuart Phinn: Centre for Spatial Environmental Research School of Geography, Planning and Environmental Management, The University of Queensland
- Dr. Todd Schroeder: USDA Forest Service, Rocky Mountain Research Station
- Dr. Peter Scarth: Queensland Department of Environment and Resource management
- Dr. Jim Vogelmann: USGS Earth Resources Observation and Science (EROS) center

Terrestrial processes: Who cares?



The better we characterize change, the better we can understand the processes

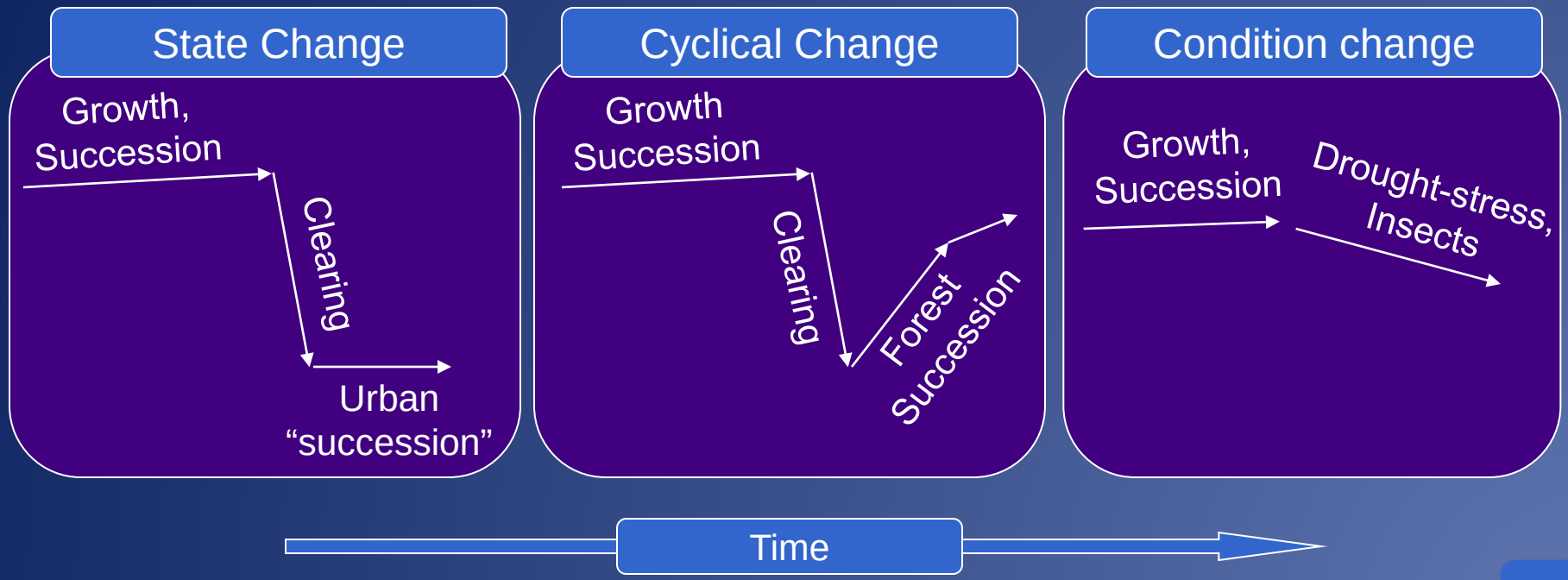
Changes in how detect change

- Open access has allowed maturation of two components in change detection:

	Then	Now
Analysis	Scene-based analysis, one image at a time	Pixel-based analysis, across the entire archive
Philosophy	Change is a big difference between two points in time	Change involves both trends and abrupt events

Underlying principles

- Change occurs *all the time*
  - Internal and external processes
  - Variable velocities and magnitudes: Vectors
- What matters is when the *processes change*
  - Result: Shift in direction of change vectors



Emerging themes

- These changes in analysis and philosophy are leading to three themes in how change information is used to better understand terrestrial processes:

  1. Track change at more appropriate time steps
  2. Observe trends over many time steps
  3. Use all time steps to better characterize current status

1. Track change at appropriate time steps

- A year has real meaning
  - Climate, water, biological cycles
  - Social/economic cycles
  - Policy implementation
- Examining impacts of those processes on landscapes requires annual map resolution
- Some foundational papers:

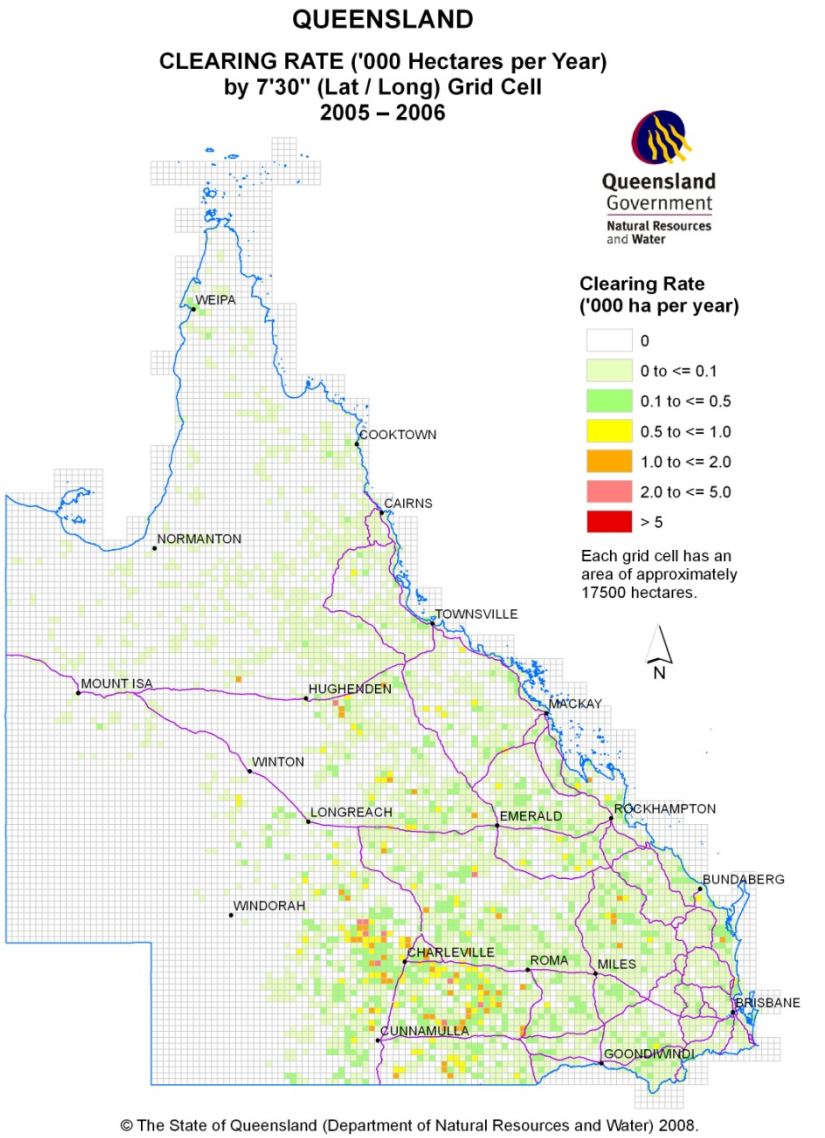
- Cohen, W. B., Harmon, M. E., Wallin, D. O., & Fiorella, M. (1996). Two decades of carbon flux from forests of the Pacific Northwest. *BioScience, 46, 836-844*
- Sader, S. A., Bertrand, M., & Wilson, E. H. (2003). Satellite change detection of forest harvest patterns on an industrial forest landscape. *Forest Science, 49, 341-353*

Australia: Monitoring woody cover

Provides accurate statistics to support Government legislation

Contributor: Dr. Peter Scarth, Queensland Department of Environment and Resource management

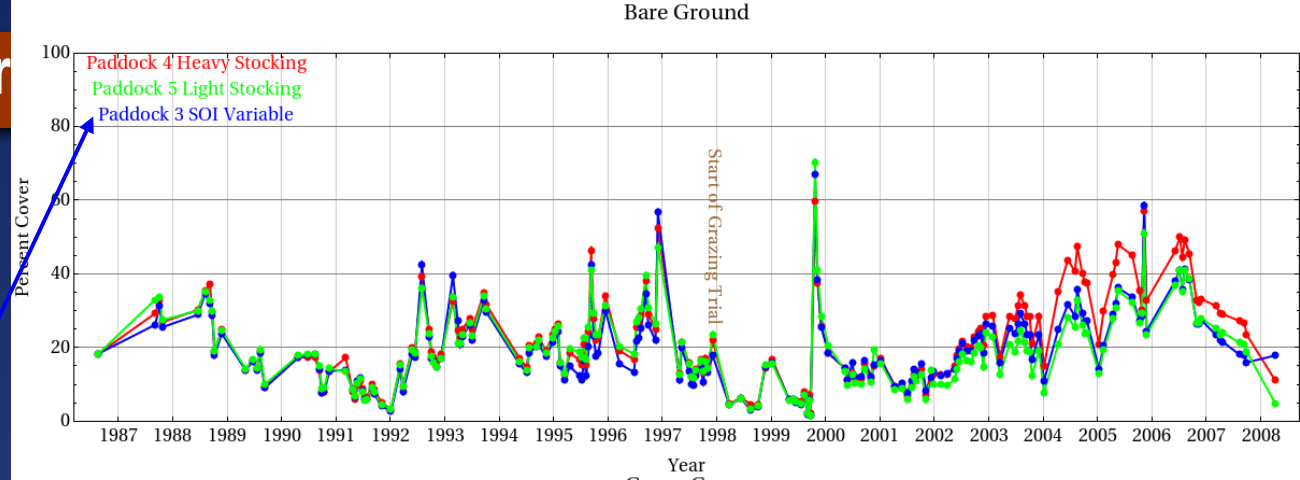
200

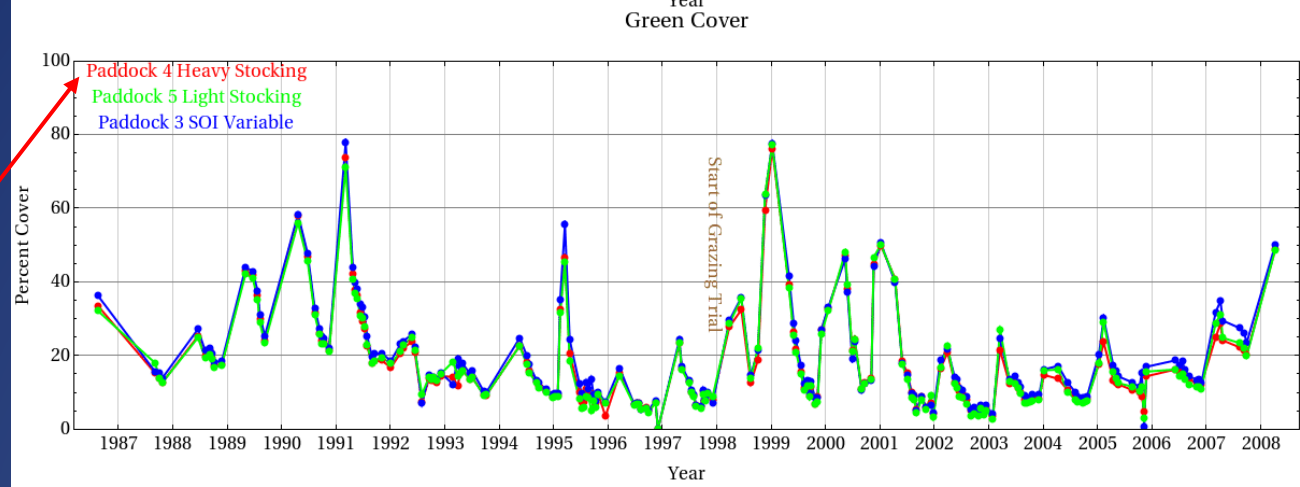


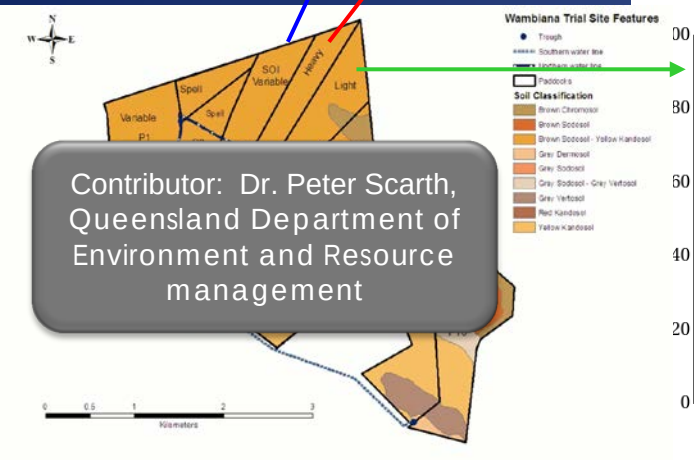
2005-2006

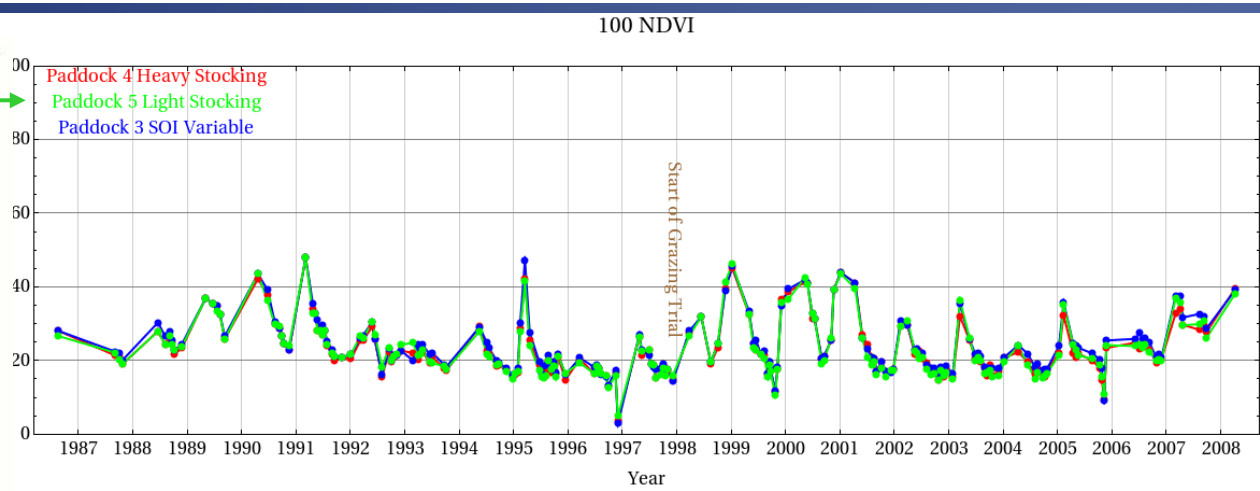
Landsat Cover

- Application of fractional cover model to long term grazing trial
  - Paddock differences in **Dead** and **Bare** cover are related to grazing pressure, but **Green** cover and NDVI are not good indicators of grazing pressure









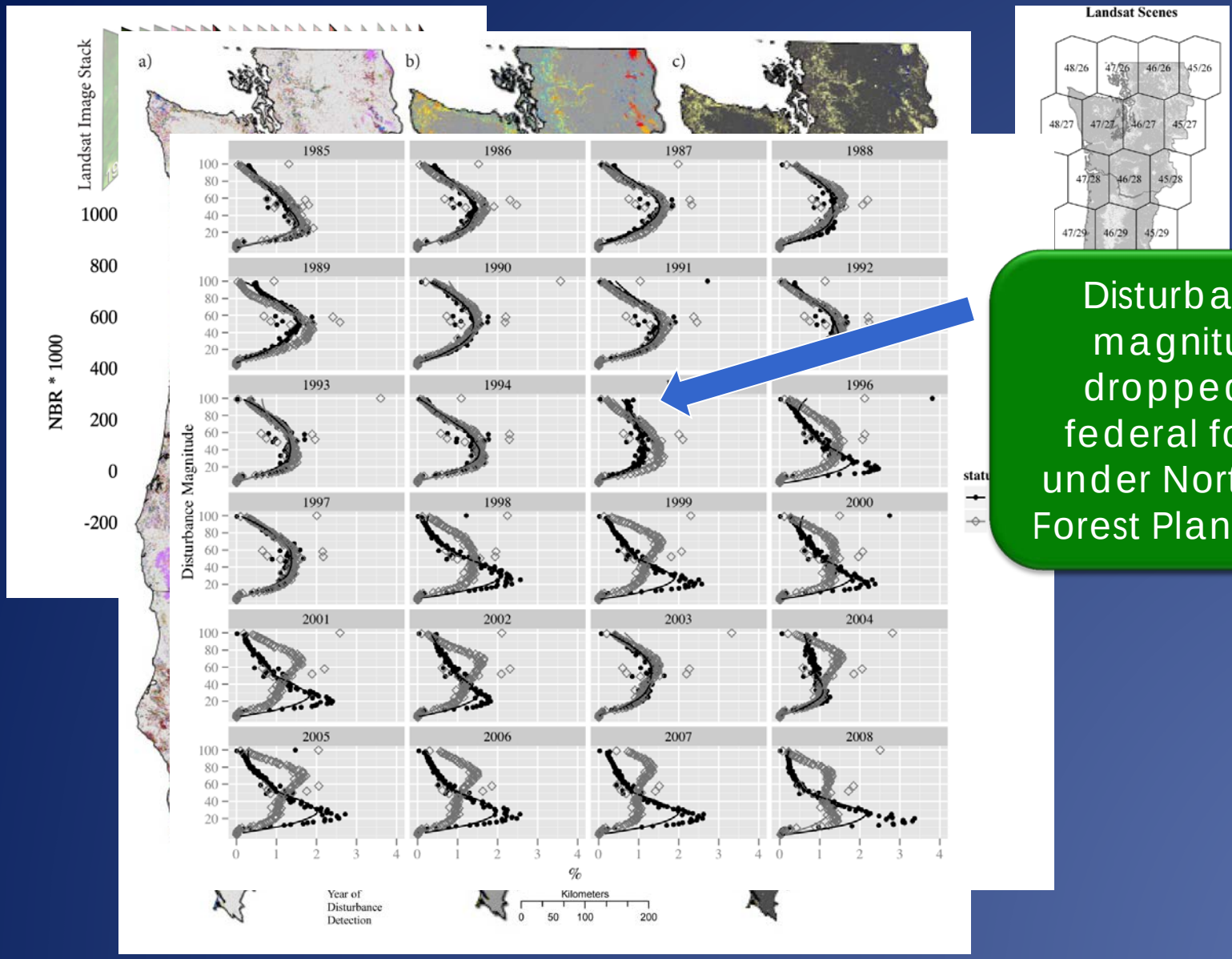
Contributor: Dr. Peter Scarth, Queensland Department of Environment and Resource management

Rumania: Forestland Restitution

- Landsat data used to track response to various phases of forestland return to private ownership

Contributor: Patrick Griffiths, Geomatics Lab, Geography Department, Humboldt-Universität zu Berlin

US Pacific Northwest: Forest policy change



Disturbance magnitude dropped on federal forests under Northwest Forest Plan (1994)

And many more…

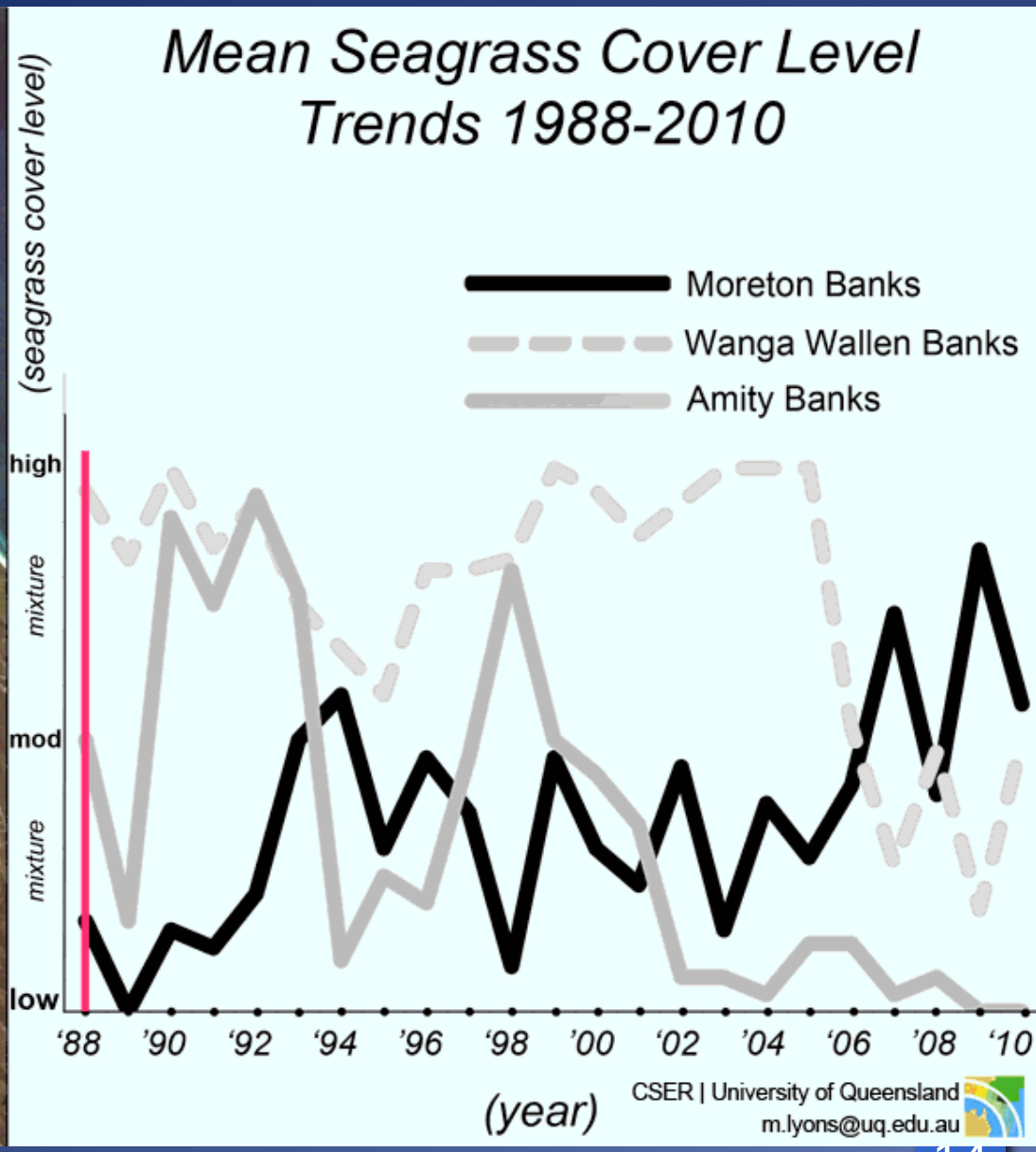
- Other relevant examples…
- Huang, Chengquan, Goward, Samuel N., Masek, Jeffrey G., Thomas, Nancy, Zhu, Zhiliang, & Vogelmann, James E. (2010). An automated approach for reconstructing recent forest disturbance history using dense Landsat time series stacks. *Remote Sensing of Environment, 114, 183-198*
- van Lier, O. R., Luther, J. E., Leckie, D. G., & Bowers, W. W. (2011). Develpment of large-area land cover and forest change indicators using multi-sensor Landsat imagery: Application to the Humber River Basin, Canada. *International Journal of Applied Earth Observation and Geoinformation, 13, 819-829*
- Potapov, Peter V., Turubanova, Svetlana, & Hansen, Matthew C. (2011). Regionals-scale boreal forest cover and change mapping using Landsat data composites for European Russia. *Remote Sensing of Environment, 115, 548-561*
- *Etc….*

Moving toward annual land cover

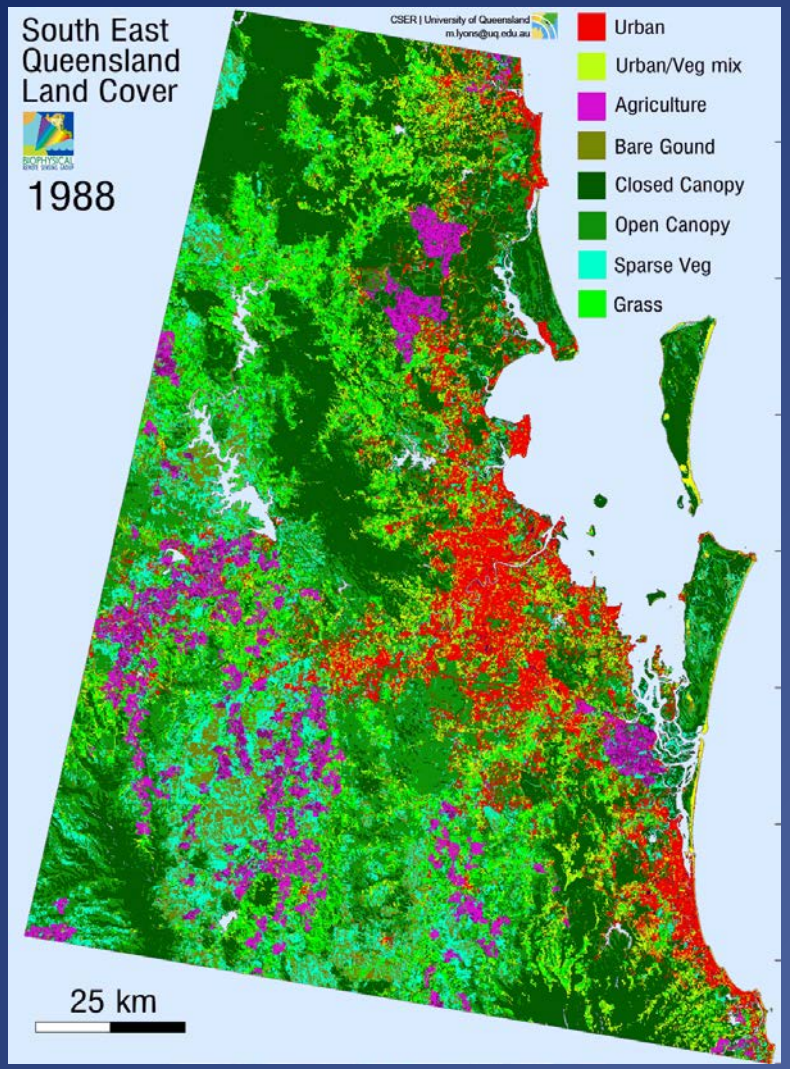
- Annual land cover mapping is a logical extension of single-date mapping
- Key challenges:
  - Ensuring consistency across time
  - Validating across time
  - Appropriately labeling post-disturbance

Australia: Seagrass cover

Contributor: Mitchell Lyons, Centre for Spatial Environmental Research School of Geography, Planning and Environmental Management, The University of Queensland



Australia: Yearly land cover

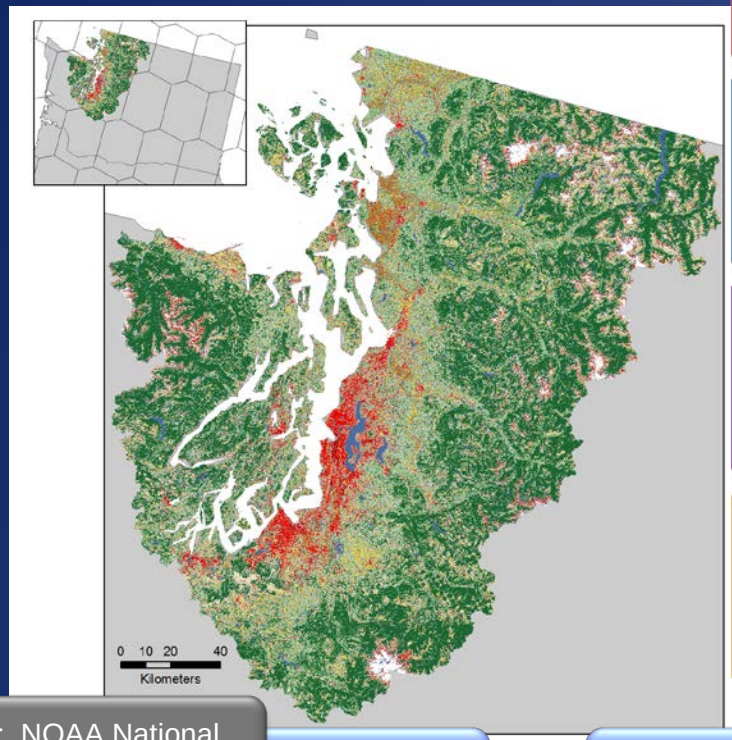


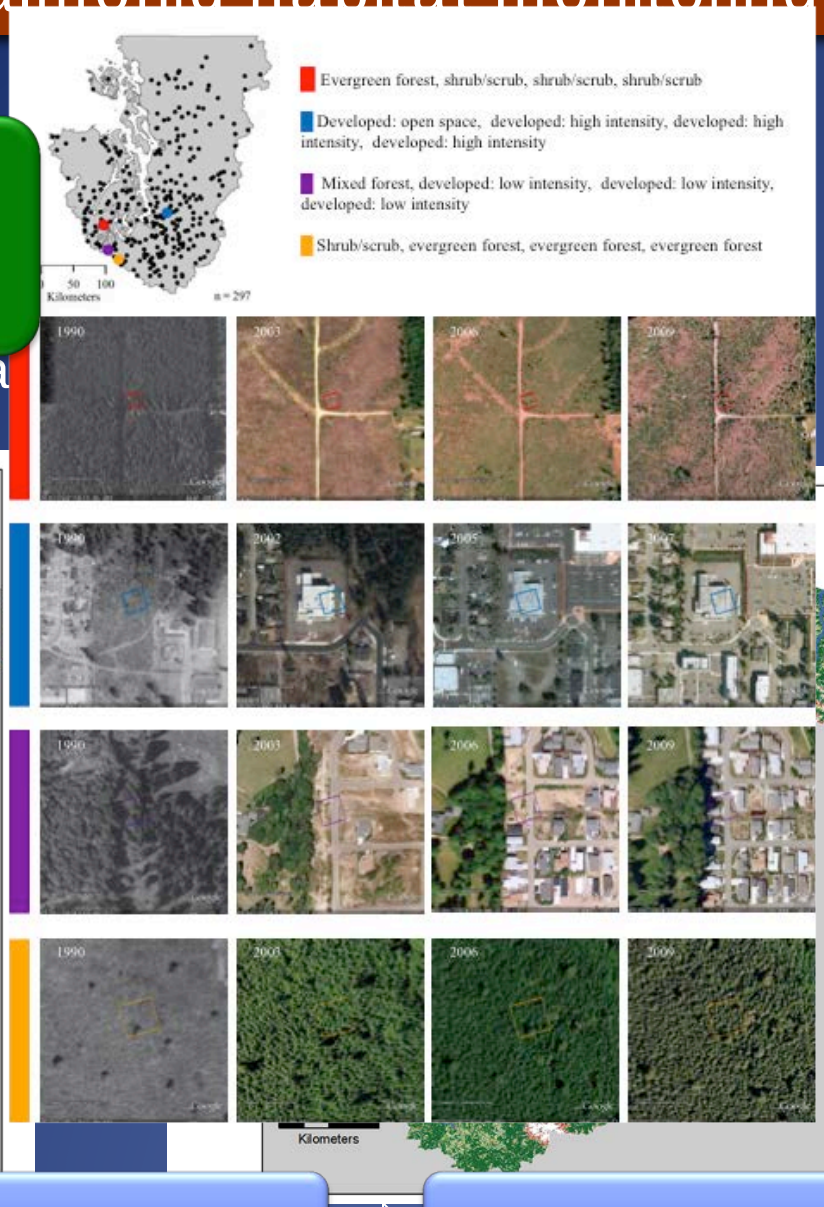
Contributor: Mitchell Lyons, Centre for Spatial Environmental Research School of Geography, Planning and Environmental Management, The University of Queensland

Pacific Northwest: Salmonid habitat monitoring

Retrospective validation is necessarily opportunistic

– Be consistent across a





Support: NOAA National Marine Fisheries Service

LCD^{LT} ⇨ Yearly NLCD^{LT} ⇨ 2005 NLCD^{LT}

Pacific Northwest: Yearly NLCD-like land cover

Cons: Maps must be based primarily on spectral properties

Emerging themes

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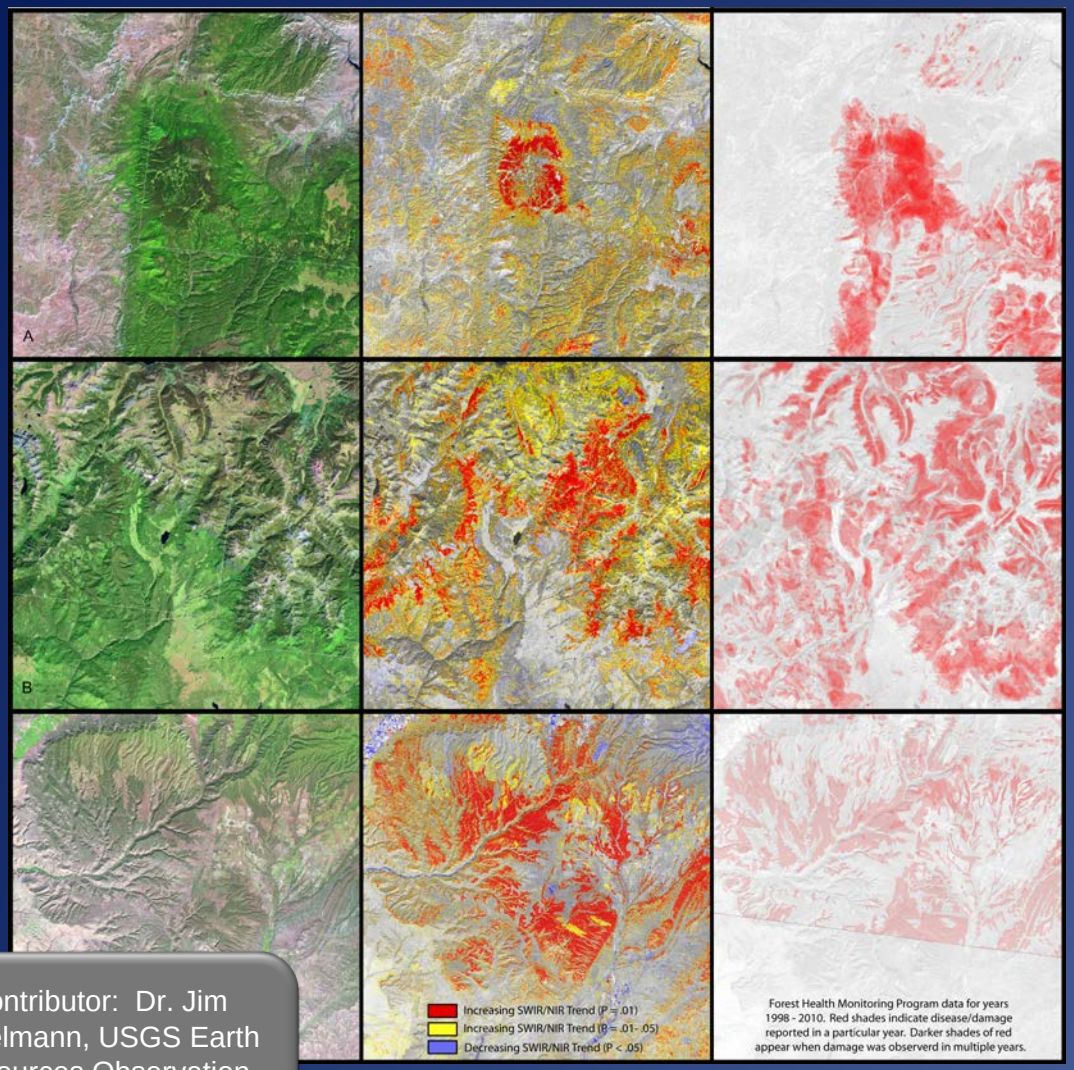
  3. Use all time steps to better characterize current status

2. Observe trends over many time steps

- Many predicted effects of climate change are subtle and long-term
- Considering each pixel's life history allows detection of long-term trends
- Some foundational papers:

- Viedma, O., Meliá, J., Segarra, D., & García-Haro, J. (1997). Modeling rates of ecosystem recovery after fires by using Landsat TM data. *Remote Sensing of Environment, 61, 383-398*
- Hostert, P., Roder, A., & Hill, J. (2003). Coupling spectral unmixing and trend analysis for monitoring of long-term vegetation dynamics in Mediterranean rangelands. *Remote Sensing of Environment, 87, 183-197*
- Schroeder, Todd A., Cohen, Warren B., & Zhiqiang, Yang (2007). Patterns of forest regrowth following clearcutting in western Oregon as determined from a Landsat time-series. *Forest Ecology and Management, 243, 259-273*

Southwest US: Chronic forest mortality



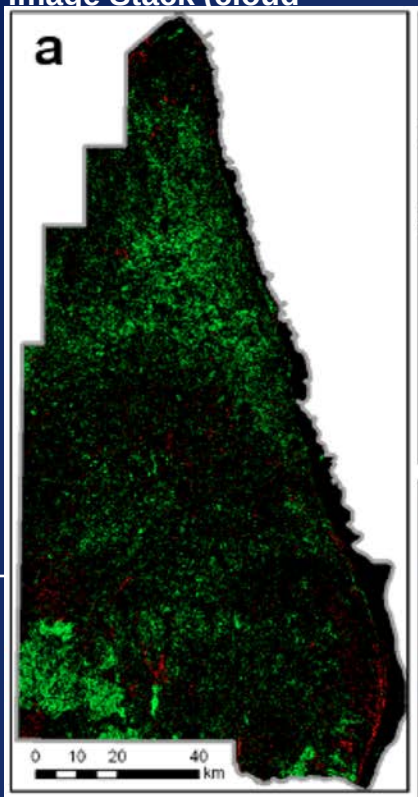
Contributor: Dr. Jim Vogelmann, USGS Earth Resources Observation and Science (EROS) center

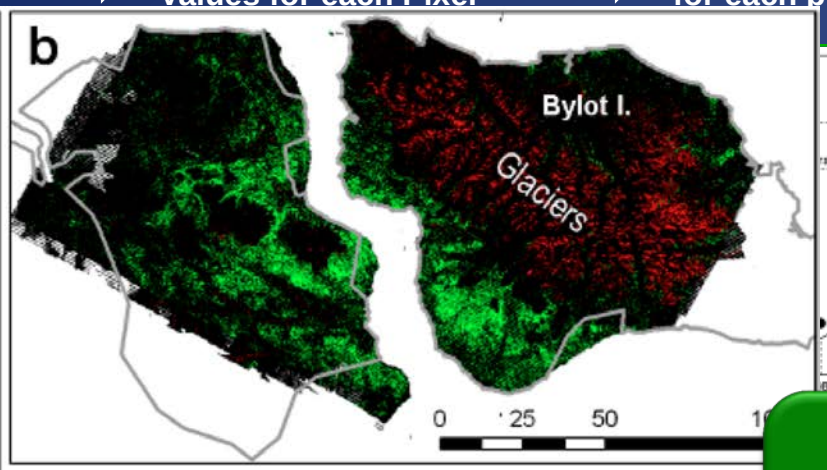
Canada: Increasing greenness

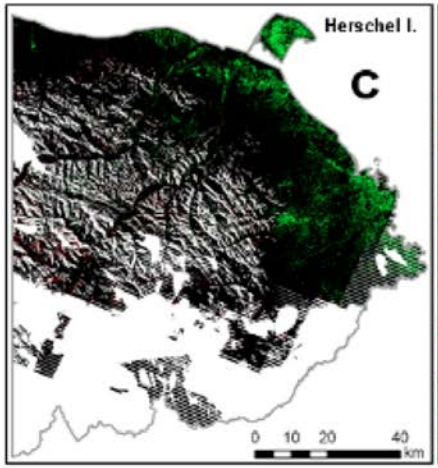
1. Build 25-year Landsat Image Stack (cloud-

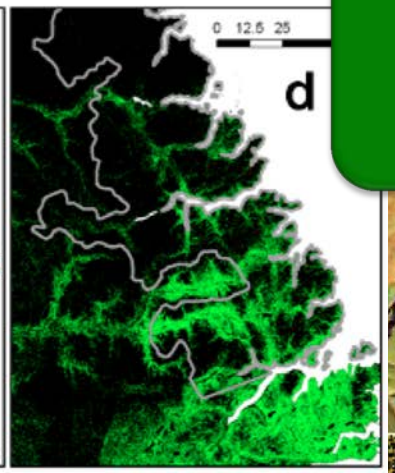
2. Extract Time Series Values for each Pixel

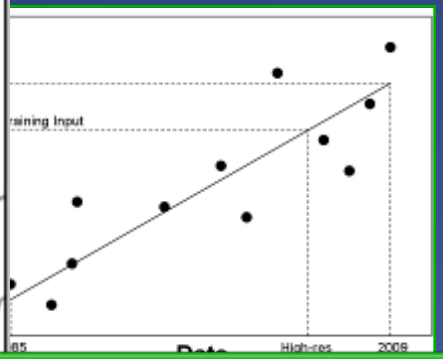
3. Derive Linear Trends in Landsat indices for each pixel using Robust Regression



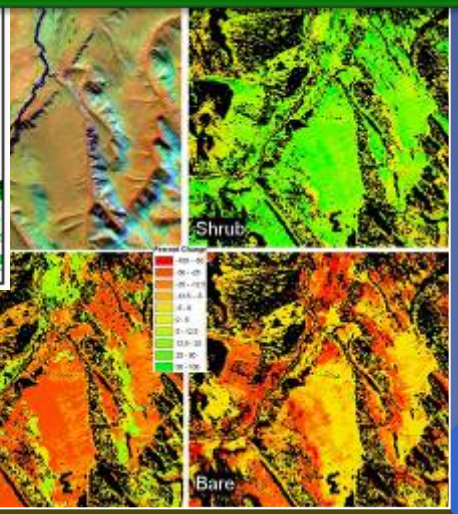






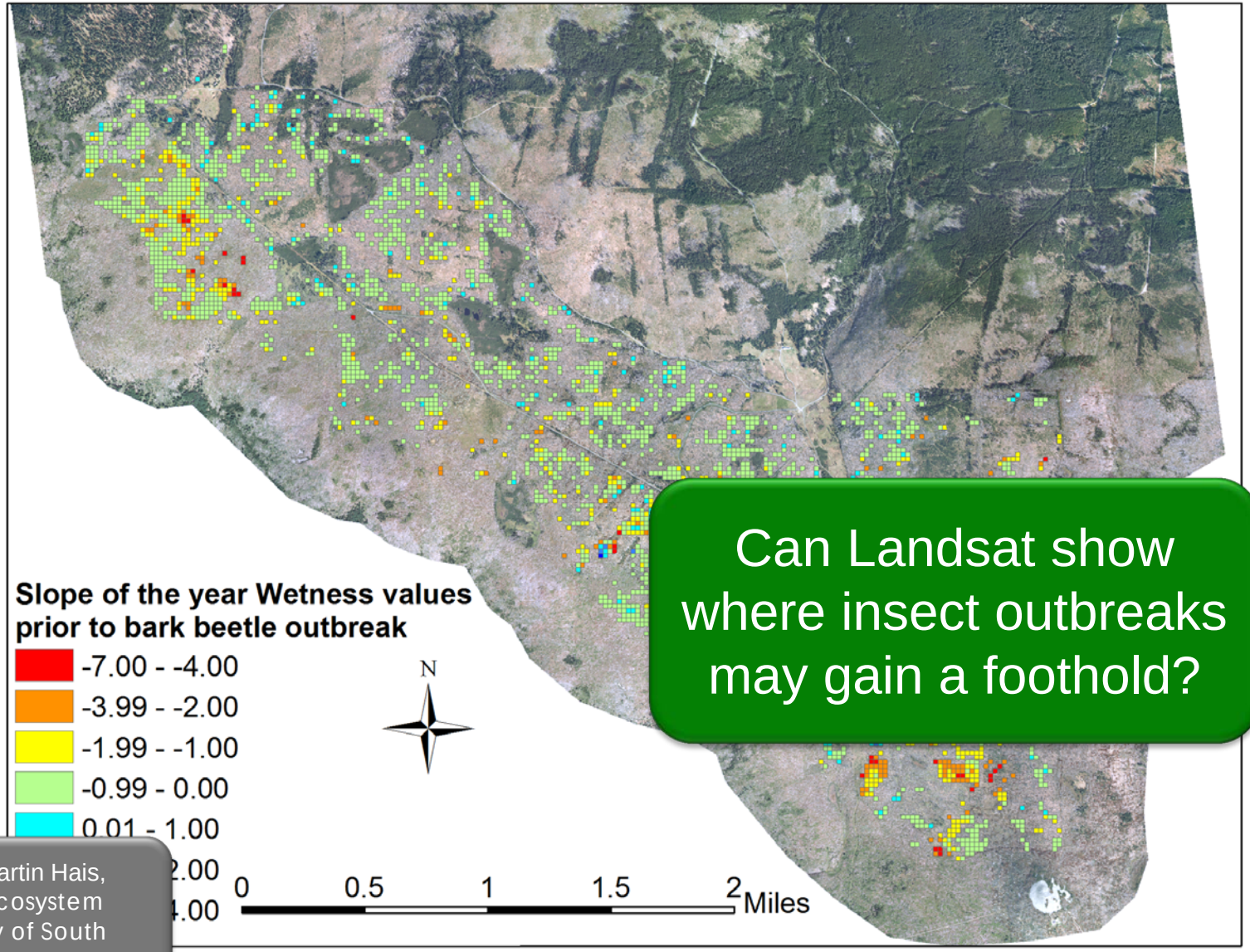


ParkSPACE Canada



Contributor: Dr. Rob Fraser, Canada Centre for Remote Sensing, Environment Canada

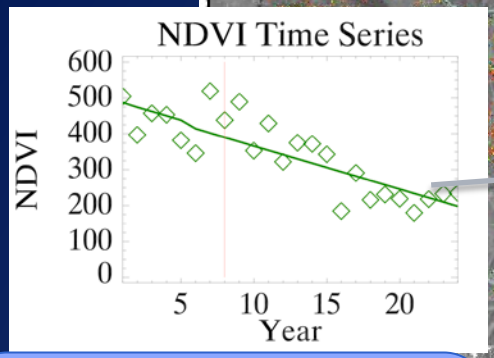
Czech Republic: Forest mortality from bark beetle

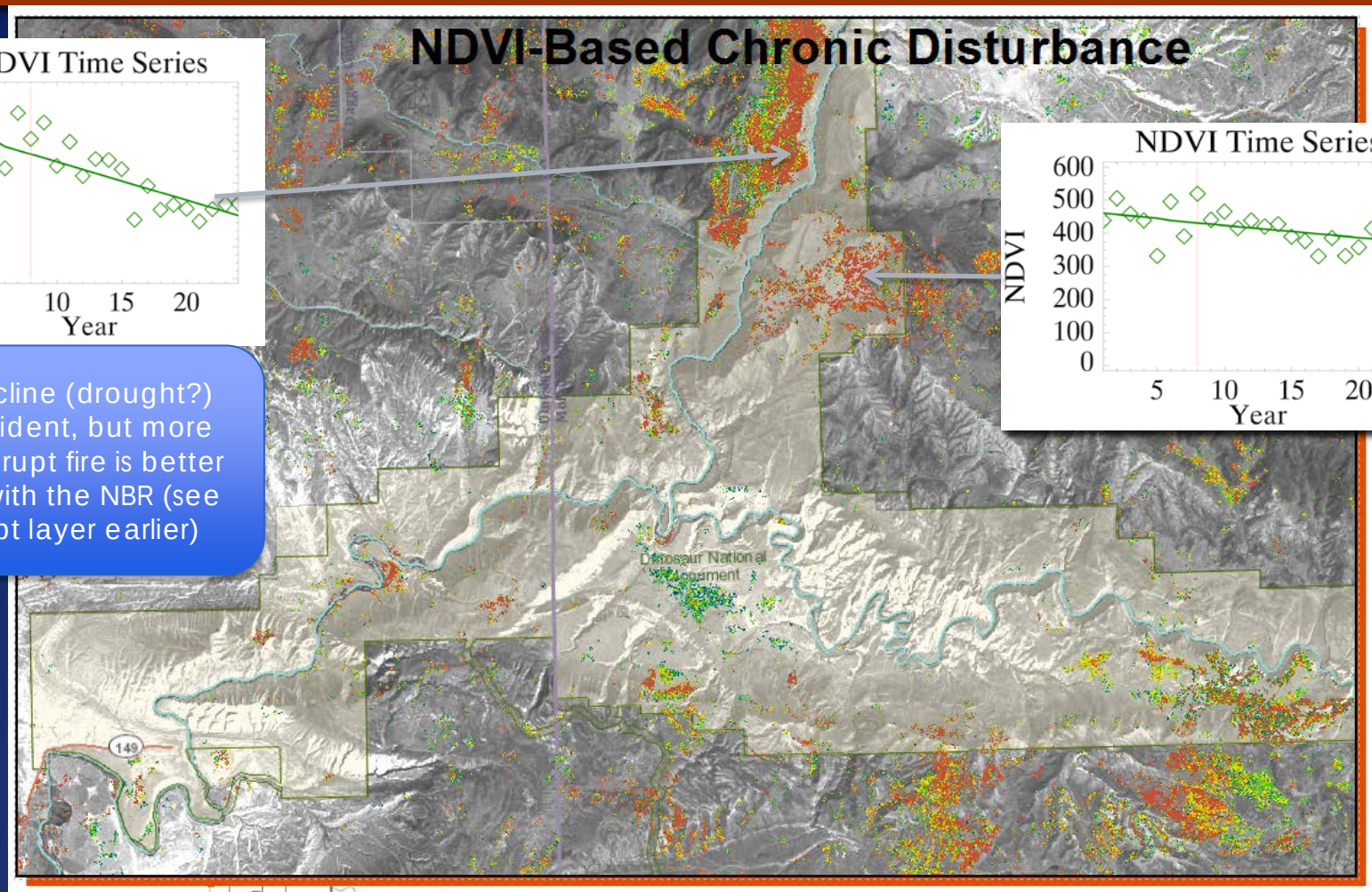


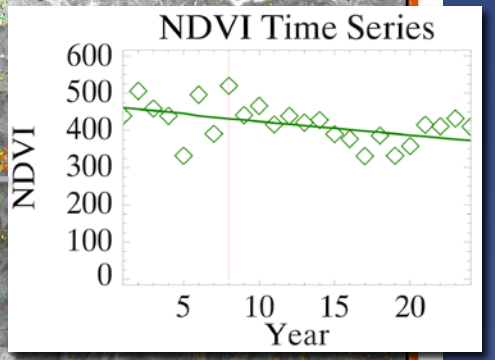
Can Landsat show where insect outbreaks may gain a foothold?

Contributor: Dr. Martin Hais, Department of Ecosystem Biology, University of South Bohemia

Dinosaur National Monument: Growth and mortality







Pre-fire decline (drought?) may be evident, but more likely this abrupt fire is better captured with the NBR (see NBR abrupt layer earlier)

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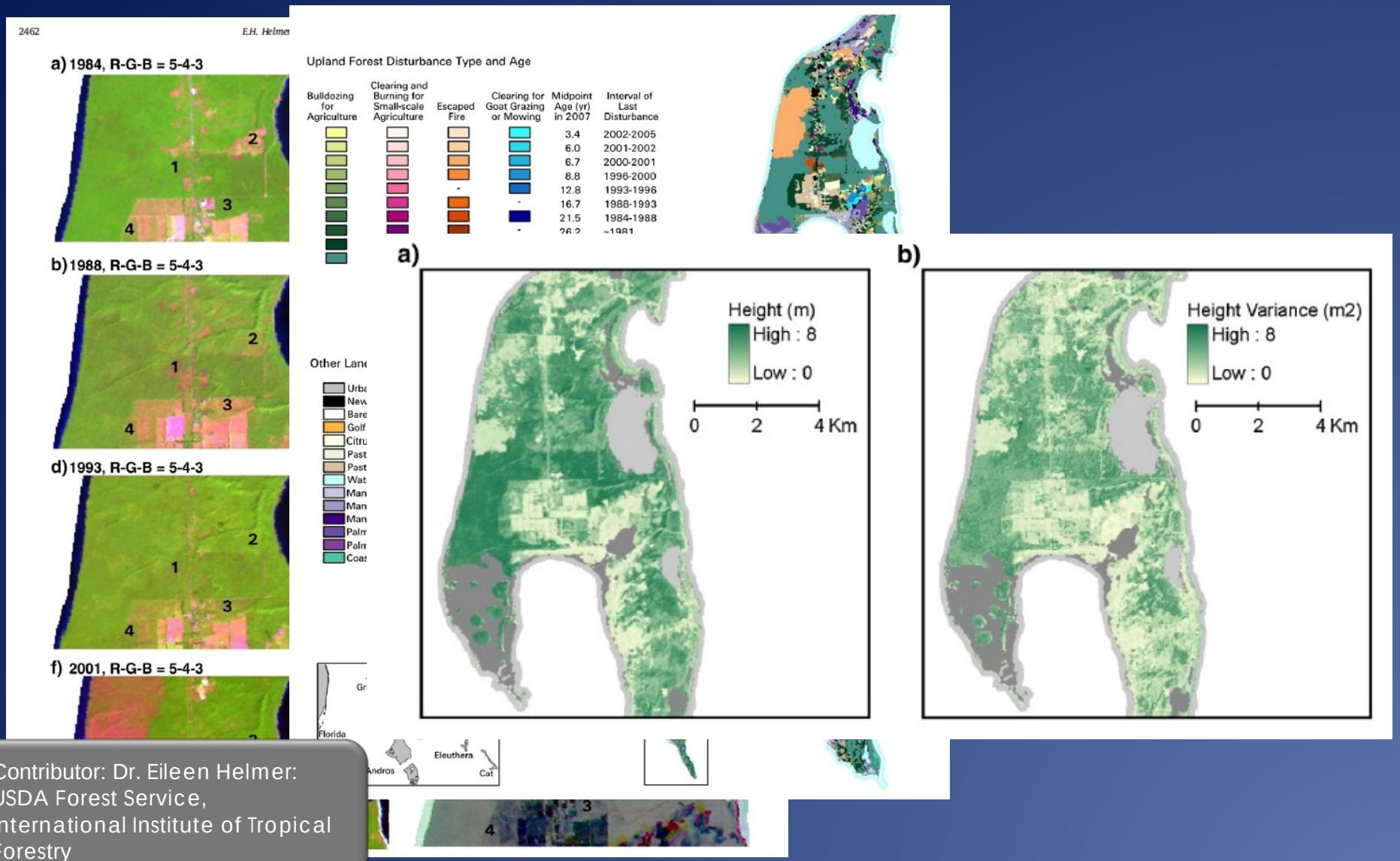
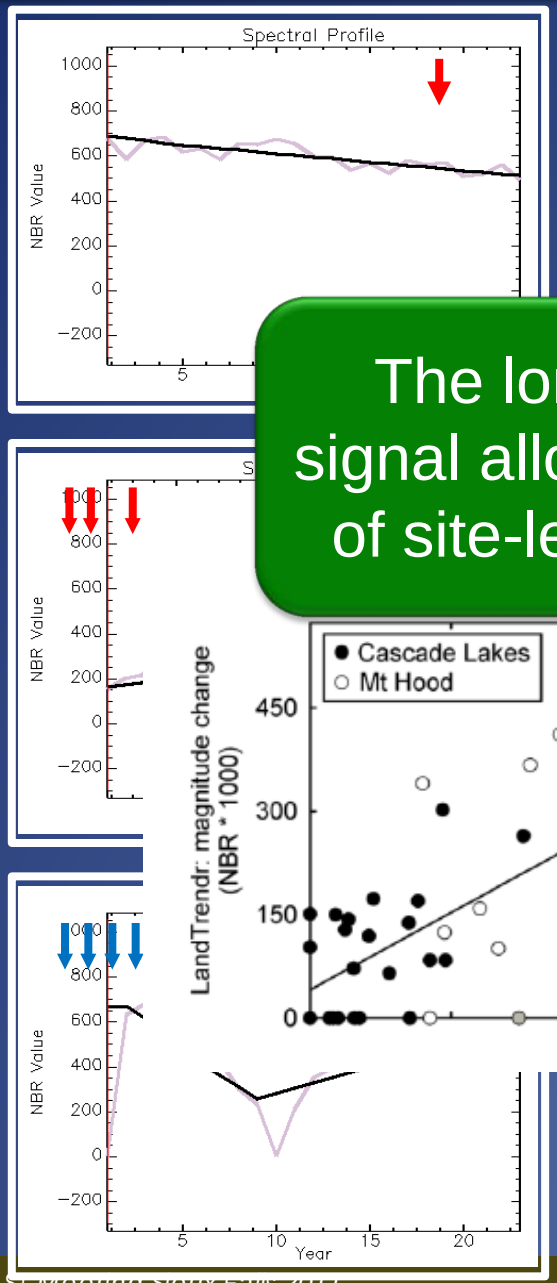
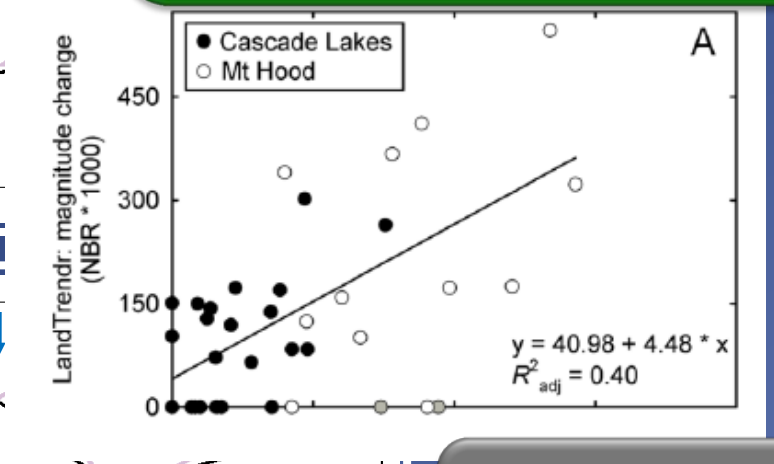
Bahamas: Land cover, height, biomass



Contributor: Dr. Eileen Helmer: USDA Forest Service, International Institute of Tropical Forestry

Oregon: Tree mortality from insects





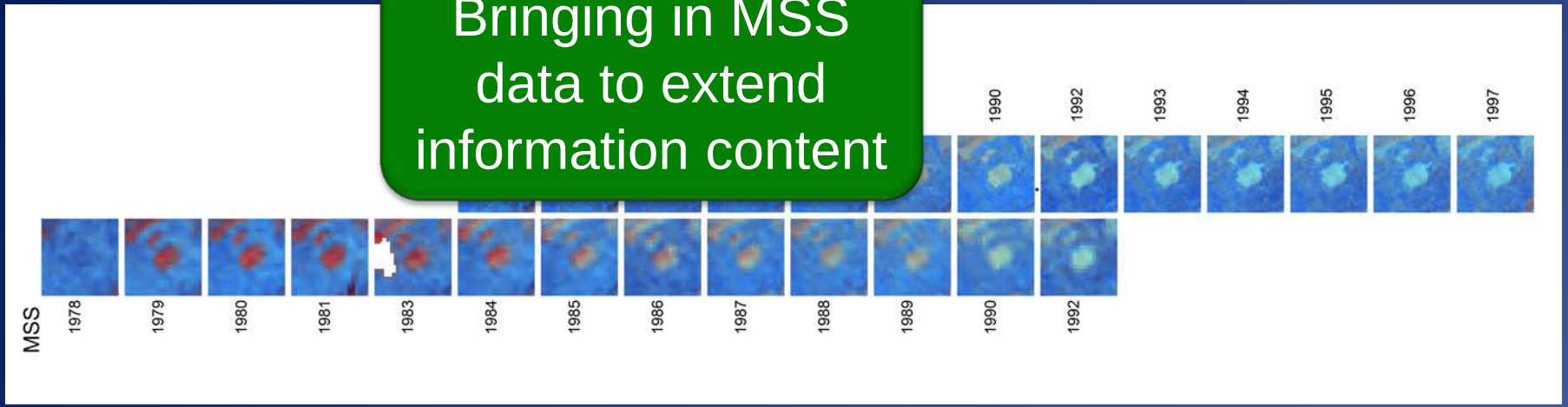
The long duration signal allows prediction of site-level mortality

Support: USDA Forest Health Technology Enterprise Team and Deschutes National Forest

Photos, graphs: Garrett Meigs, Department of Forest Ecosystem and Society, Oregon State University

Oregon: Biomass, Height prediction

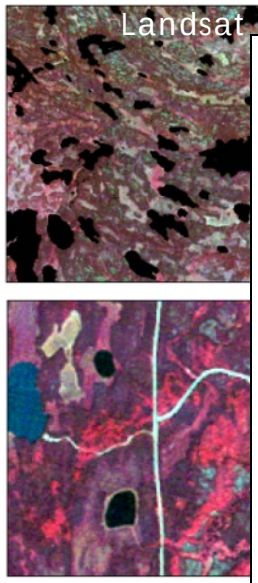
Bringing in MSS data to extend information content

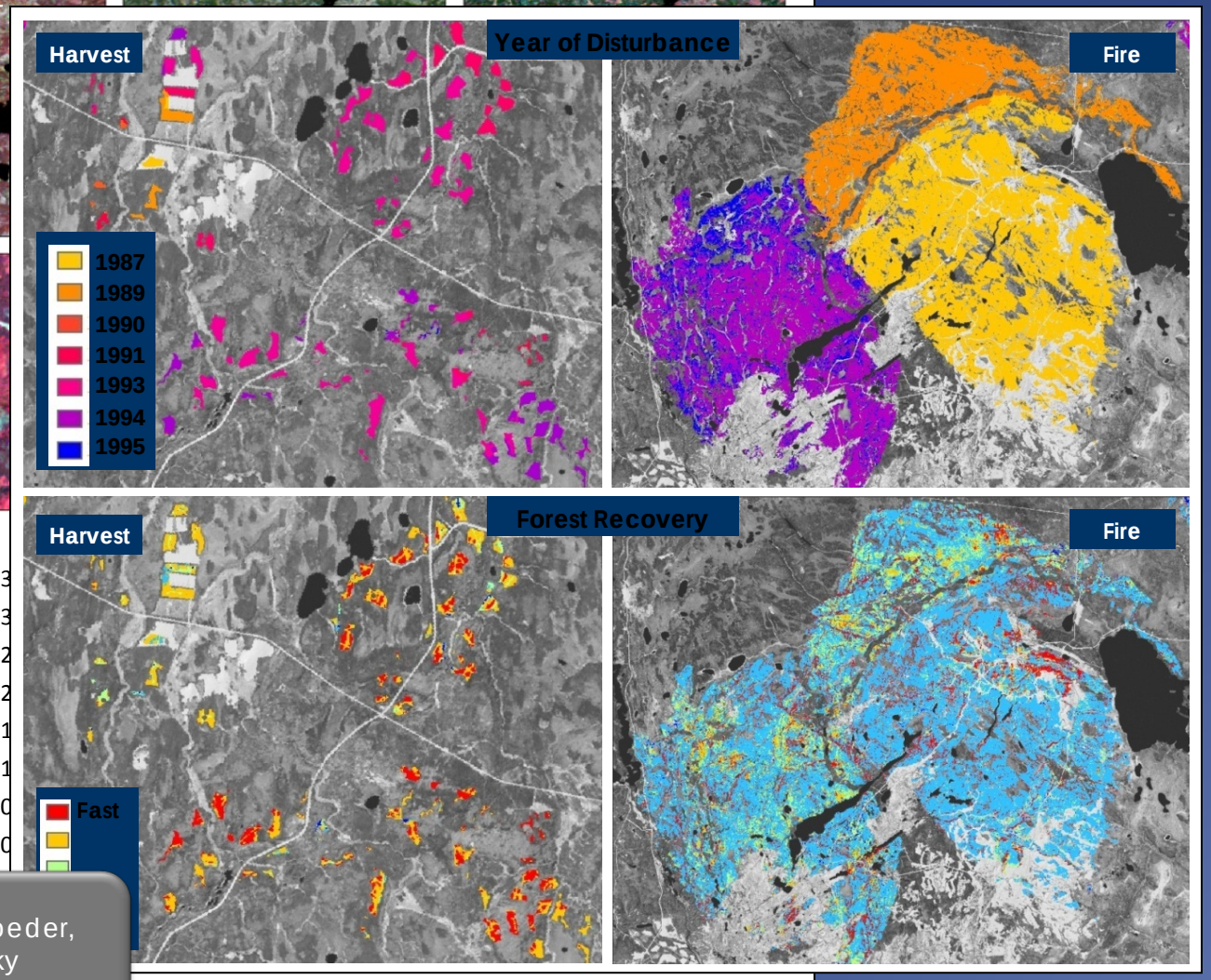


Support: Oregon Water Enhancement Board

Graphs: Dirk Pflugmacher, Department of Forest Ecosystem and Society, Oregon State University

Canada: Disturbance attribution

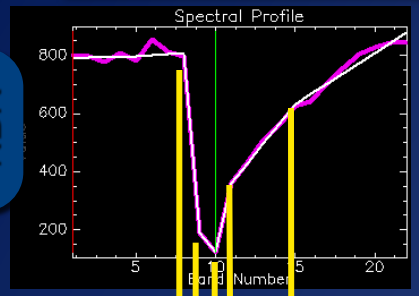




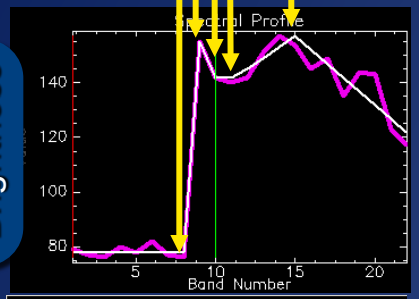
B5 Reflectance

Contributor: Dr. Todd Schroeder, USDA Forest Service, Rocky Mountain Research Station

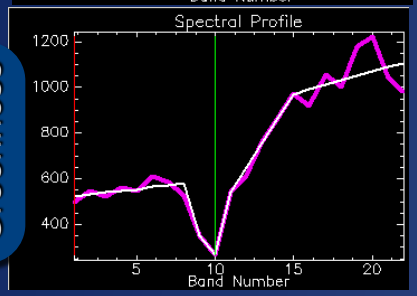
Spectral signals of change



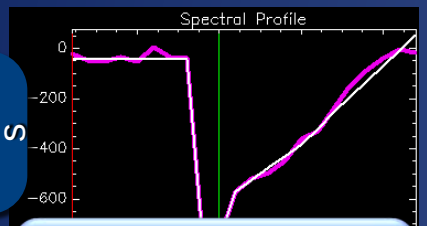
NBR



Brightness



Greenness



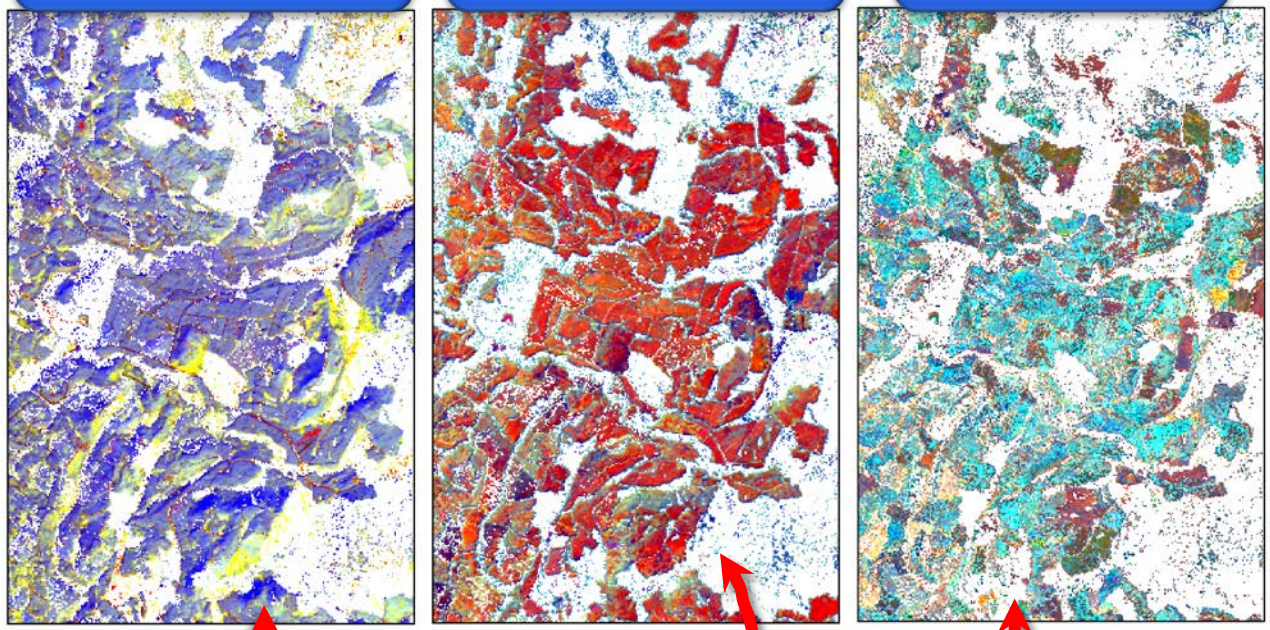
Wetness

Creating Fitted Multispectral

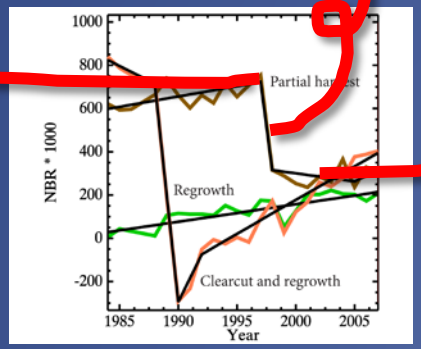
Pre-disturbance BGW*

Disturbance BGW

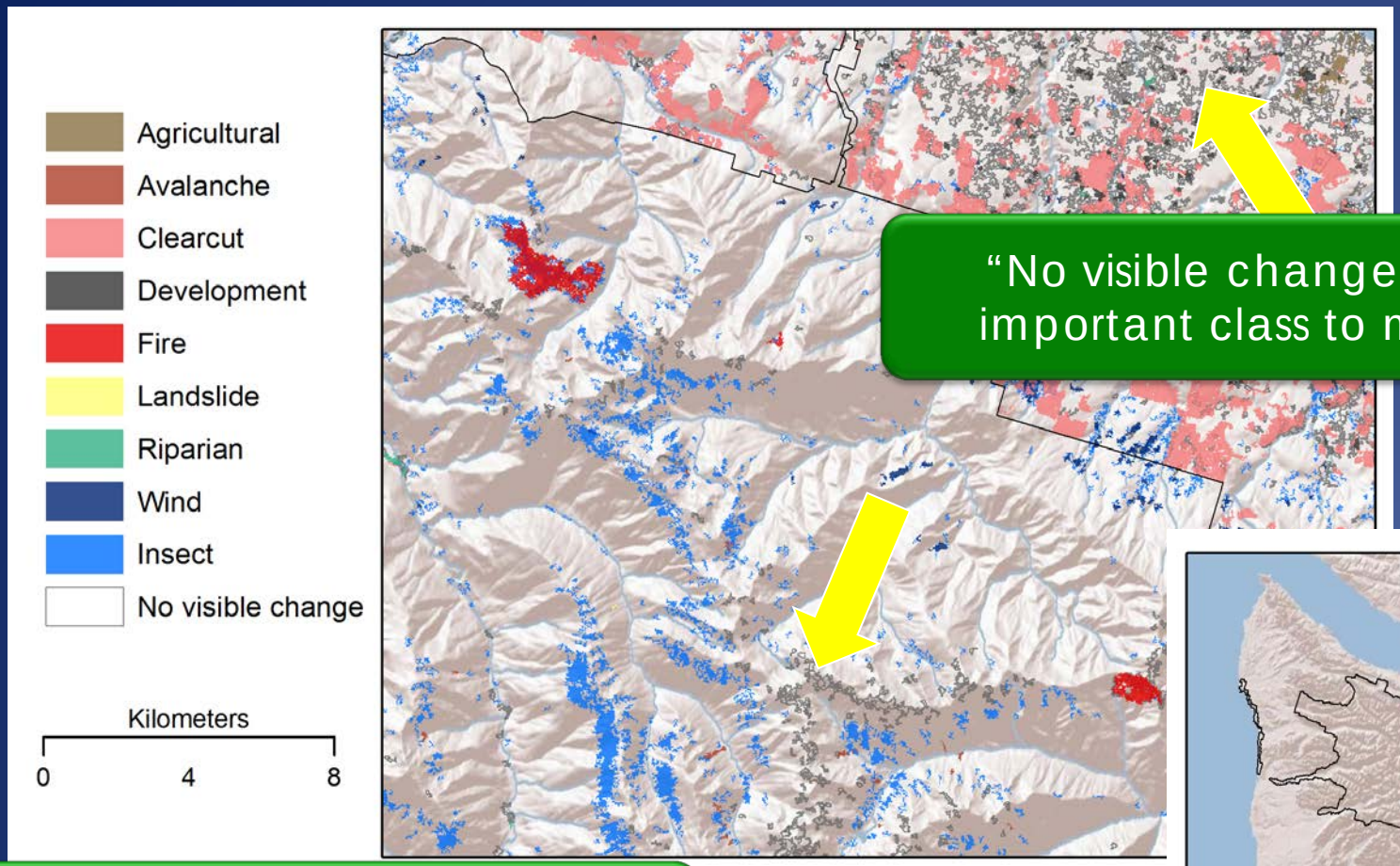
Regrowth BGW



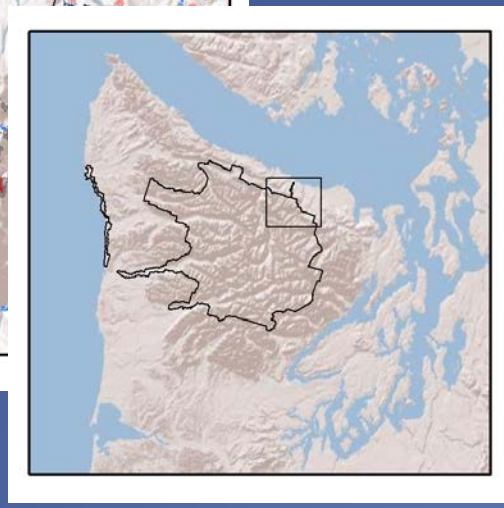
*BGW: Tasseled-cap Brightness, Greenness, Wetness



Pacific Northwest: Change attribution



"No visible change" is an important class to model!



Expert human interpretation from local park staff is critical

Pacific Northwest: Change attribution

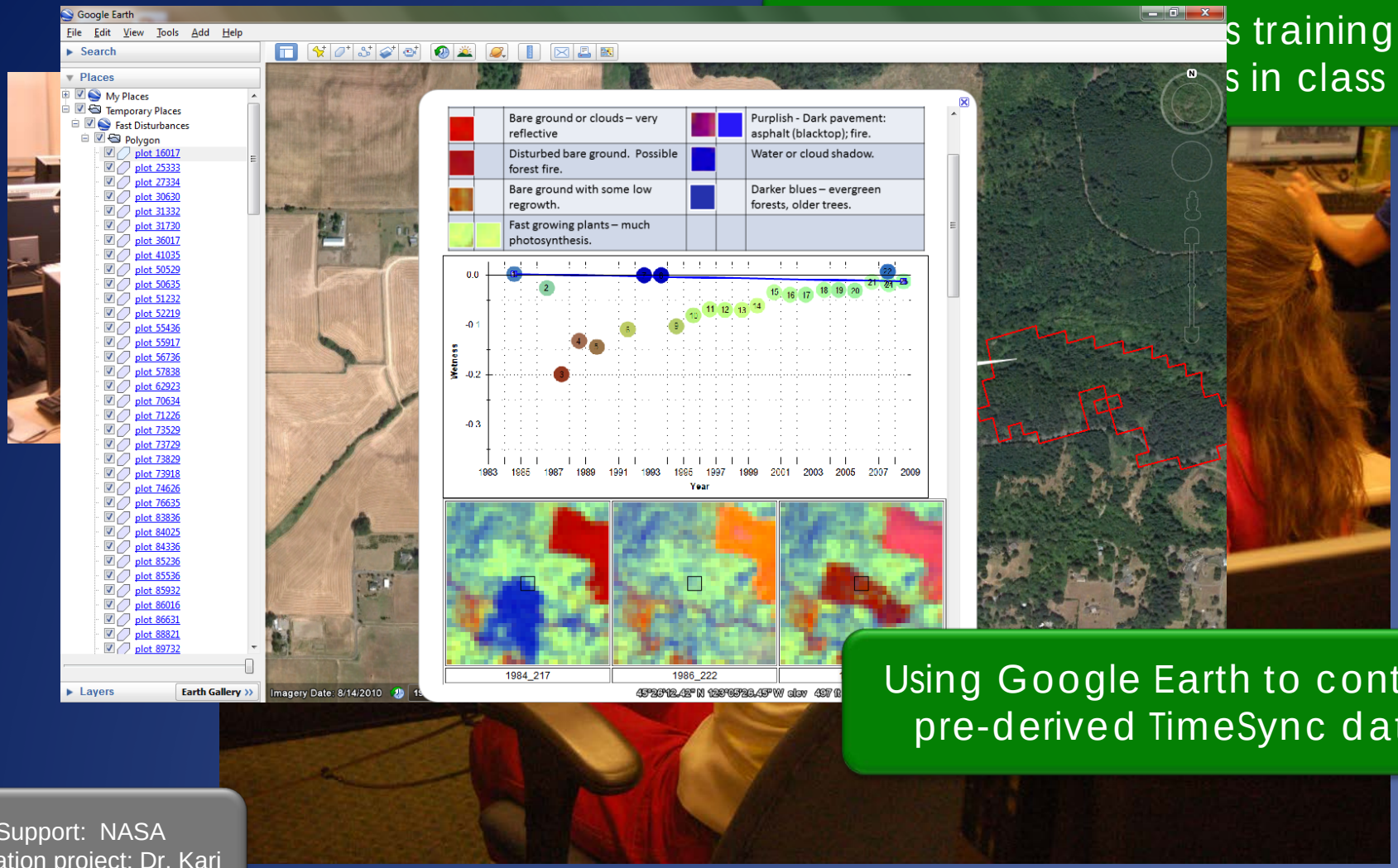
First crack at attribution across cover types

Support: NOAA National Marine Fisheries Service

Pacific Northwest: Change attribution

First crack at attribution across cover types

A new constituency?



s training
s in class

Using Google Earth to contain pre-derived TimeSync data

Support: NASA Education project; Dr. Kari O'Connell PI

Review: Key Themes

- We are now following the life history of pixels and objects
- That life history allows us to:
  - Match change temporally to drivers
  - Follow long-term trends
  - Better describe conditions now knowing what got us here

Summary: Interesting lessons

- Convergent evolution: The data have given rise independently to similar use strategies
  - Use of many images in time-series is being exploited to upper bounds of information content

- Leapfrogging: Information content may now be ahead of use, geographic analysis, and independent reference datasets
  - But these are rapidly catching up!

Where to go?

- Disturbance
  - Attribution improvement
    - Citizen science? Mob science?
  - Better linkage with ad hoc reference data
- Land cover
  - Better understand which spectral class groupings are best for yearly mapping
  - Determine whether conditions directly after disturbance are a fundamentally different case
  - Extend to MSS era
- Trends
  - Post-disturbance regrowth
  - Better linkage with situations on the ground
  - Better linkage with climate drivers

Thank you

- Thank yous…
  - For keeping this platform alive:
    - Jim Irons
    - Darrell Williams
    - Sam Goward
  - For leading this team:
    - Tom Loveland
    - Curtis Woodcock
  - The USGS and EROS
  - And YOU, the Landsat Science Team
    - We're spoiled