The US Forest Service Embraces Landsat: A Success Story

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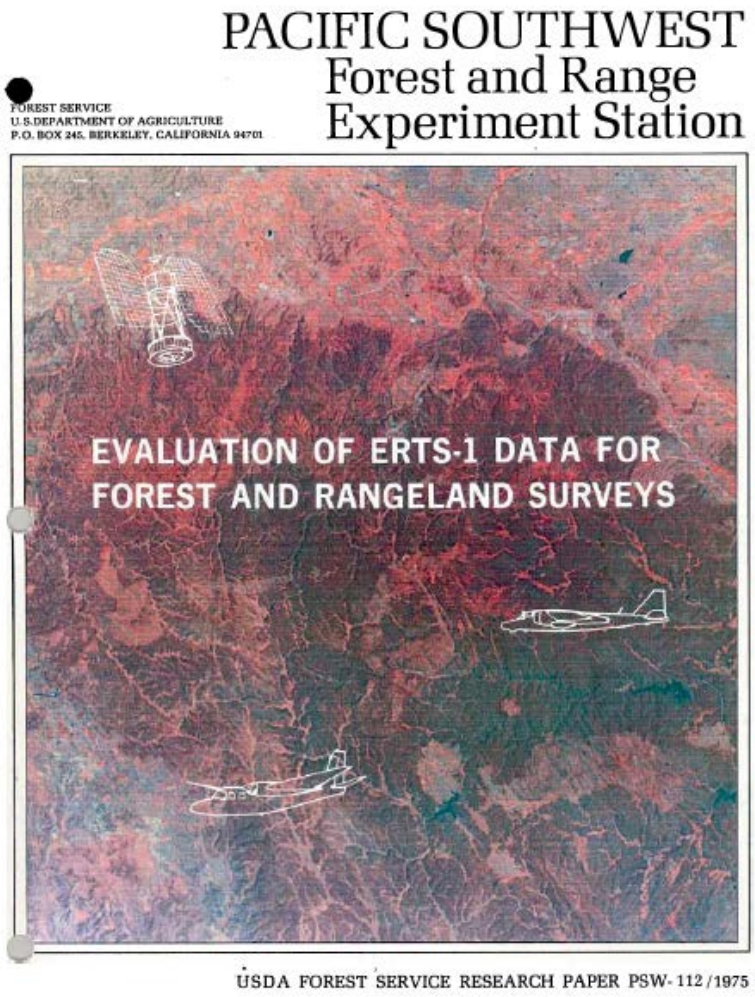
Final Landsat Science Team Meeting, 16-18 August 2011, Sioux Falls, SD

A modern story; but, for historical context…initially, a few pockets of activity; e.g.

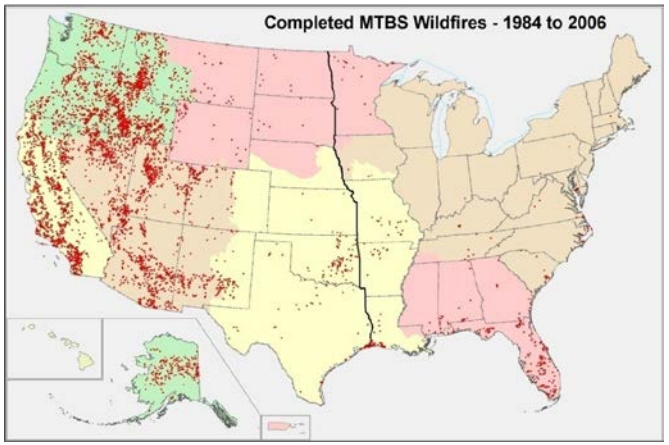


The CALVEG ("Classification and Assessment with Landsat of Visible Ecological Groupings") system – initiated 1978 by Region 5 (California) of the U.S. Forest Service – Woodcock & Strahler, major influences

USDA FOREST SERVICE
REMOTE SENSING LAB
SACRAMENTO, CA

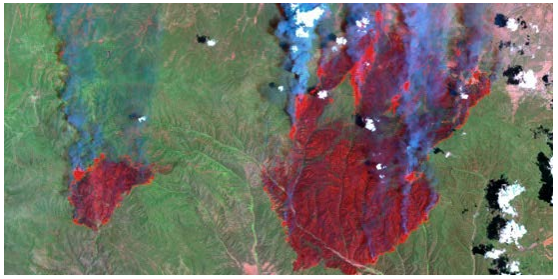
More Recent (80s-mid 00s) Landsat Happenings in the US Forest Service with Partners (examples)

- Fire mapping & modeling
- Insect & disease
- Wildlife habitat
- Statistical estimation of forest conditions
- Regional assessments
- Much of the work led by Remote Sensing Applications Center (RSAC) in Salt Lake City
  - But increasingly, various research labs took up the work
  - Other than MTBS, LandFire, and related, no/few operational products



Monitoring trends in burn severity

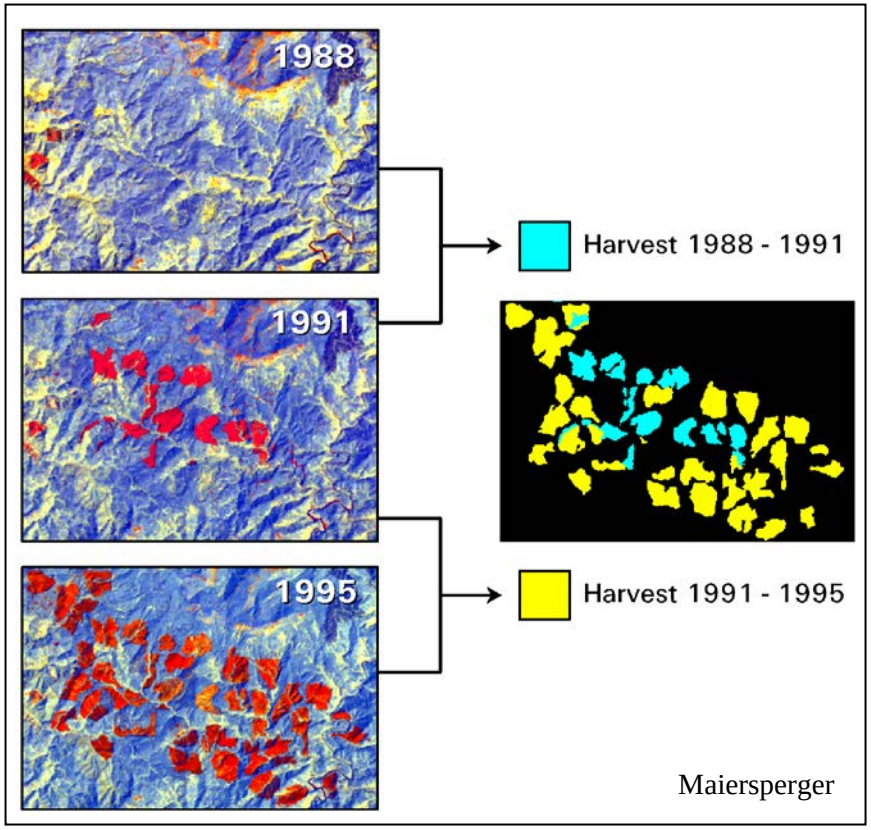
Remote Sensing Applications Center

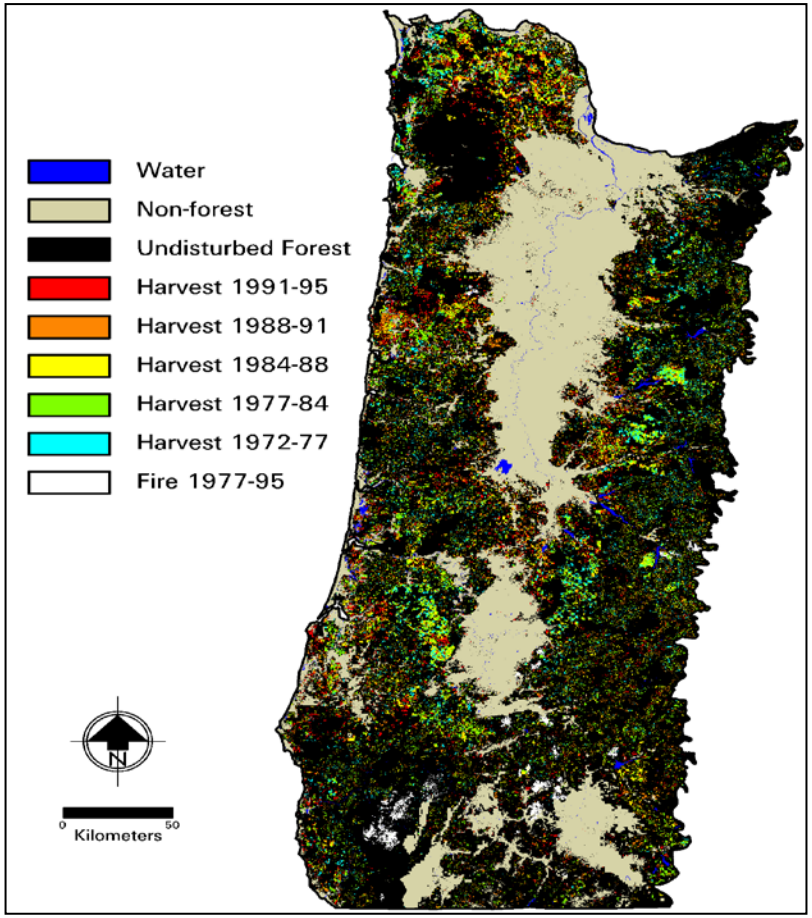


Rodeo and Chedeski fires in Arizona on June 21st, 2002 as seen by the Landsat 7 satellite.

Standard, long-standing change detection method

Bi-temporal contrast:
example from western OR





- Analyses by interval
- Given “noise” signal limited to mid & higher intensity changes (e.g., near-stand replacement disturbances)

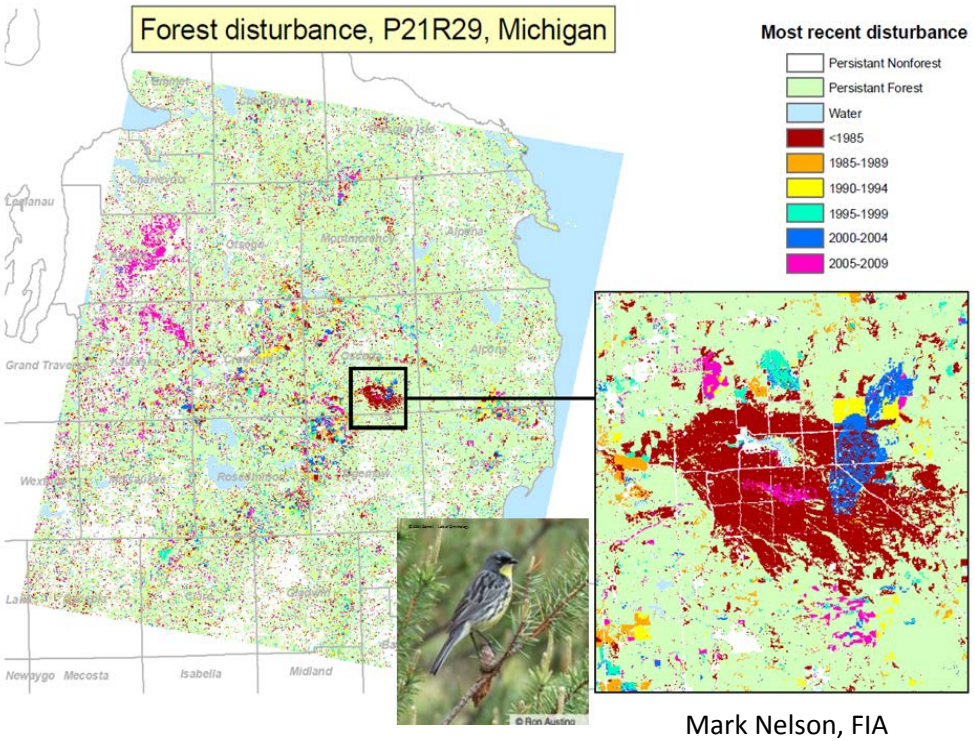
…Then, two parallel processes converged

1. Goward's NAFD (North American Forest Dynamics)project, funded by NASA Terrestrial Ecology & Applications Programs (~2003-present)
   - ✓ TEP: Push trend-based **annual time series analyses** to characterize disturbance rates nationally for NACP

2. USFS Forest Inventory & Analysis (FIA)/RSAC significantly broaden interest in Landsat for change detection (~2005-present)
   - ✓ Beyond MTBS/LandFire towards other operational apps
   - ✓ NAFD (Apps) offers collaboration; FIA/RSAC accepts

- Report on the status and trends of America's forest
- Long history of plot-based measurements
- Large client base beginning to demand map-based estimates of forest condition and change, difficult to provide with plots alone
- Progress in change mapping and estimation lagging behind demand
- Timing of NAFD applications initiative and FIA needs highly compatible

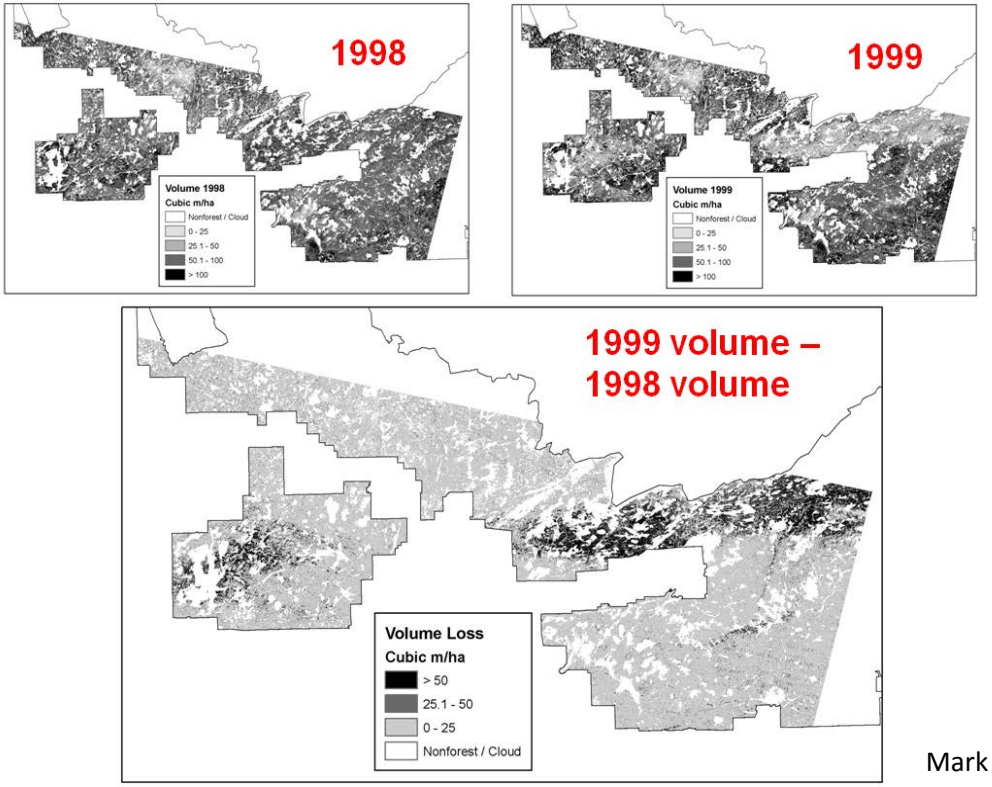
Example FIA Apps of NAFD products…



Mark Nelson, FIA

- Disturbed forests mapped in Michigan using the Vegetation Change Tracker (VCT, Huang et al.)
- Recently disturbed sites likely to have characteristics suitable for the Kirtland's warbler

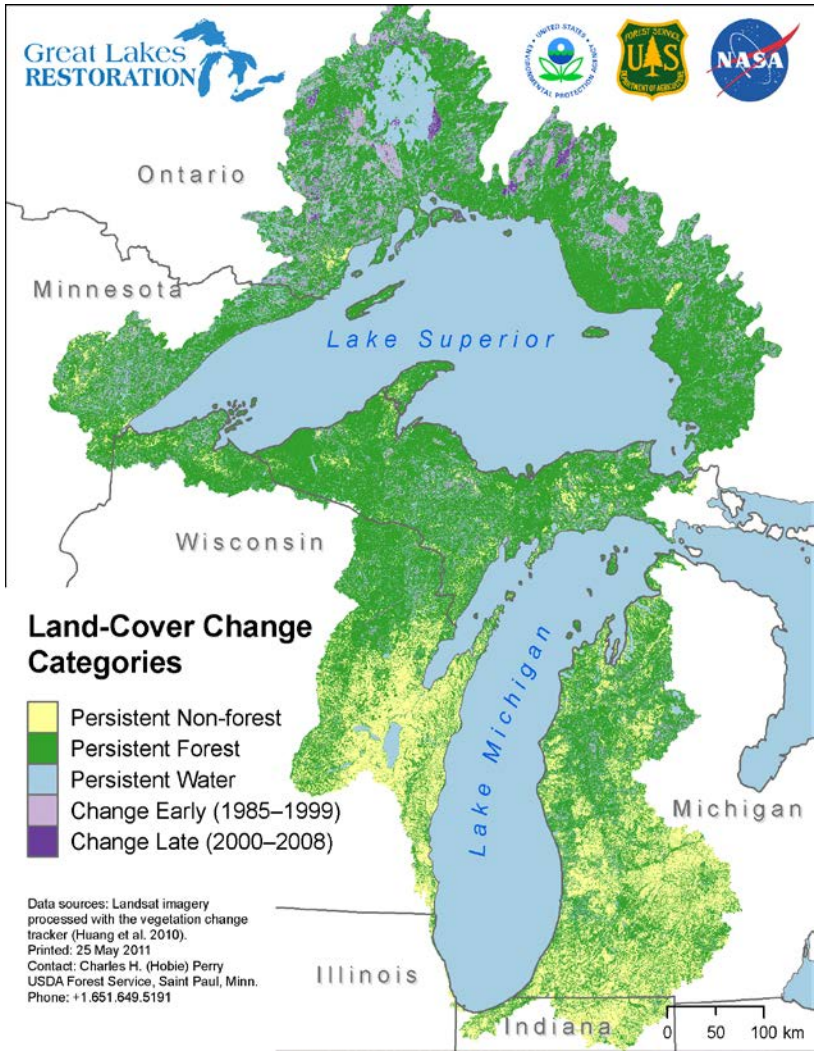
Example FIA Apps of NAFD products…



Mark Nelson, FIA

- Rapid estimates of disturbance area from VCT
- Volume loss by differencing pre- and post-storm forest volume maps, based on FIA ground data and Landsat

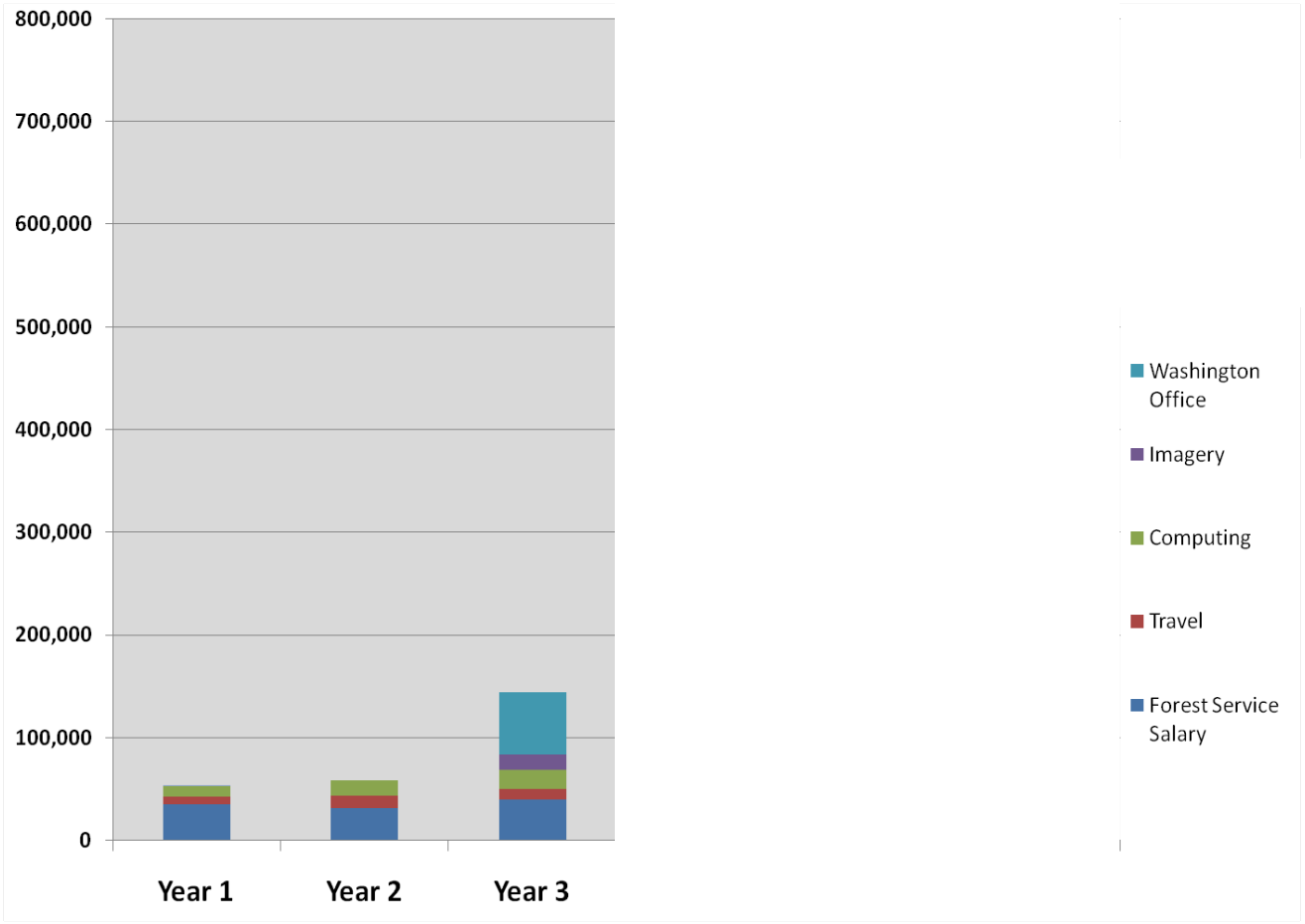
Example FIA Apps of NAFD products…



- Great Lakes Restoration Initiative—11 federal agencies working together to improve the health of the Great Lakes ecosystems
- FIA's contribution is the production of reports documenting status and trends of forest resources
- Included use of VCT to derive disturbance maps
  - ✓ Algorithm run by the Forest Service

Hobie Perry, FIA

USFS Investments in NAFD-based products



- Primary Forest Service expenditures (US $) on projects related to NAFD (2005-2010)

Then, 2008, a key puzzle piece fell into place:

- Access to free, high quality data

Free Access to Landsat Imagery

Free image. This Landsat 5 image of the southeastern corner of the Black Sea is part of the general U.S. archive that will be accessible for free under the new USGS policy.

WE ARE ENTERING A NEW ERA IN THE LANDSAT Program, the oldest and most venerable of our Earth-observing satellite programs. With little fanfare, the U.S. Geological Survey (USGS) has begun providing imagery for free over the Internet. Throughout the history of the Landsat Program, the cost and access to imagery has always limited our ability to study our planet and the way it is changing. Beginning with a pilot program to provide "Web-enabled" access to Landsat 7 images of the United States that were collected between 2003 and this year, the USGS now plans to provide top-quality image products for free upon request for the entire U.S. archive, including over 2 million images back to Landsat 1 (1972) [for details and schedules, see (*1*)]. The release by NASA and the USGS in January 2008 of a new Landsat Data Distribution Policy (*2*) was a key step to this goal. Free imagery will enable reconstruction of the history of Earth's surface back to 1972, chronicling both anthropogenic and natural changes during a time when our population doubled and the impacts of climate change became noticeable.

THE LANDSAT SCIENCE TEAM: CURTIS E. WOODCOCK,[1*] RICHARD ALLEN,[2] MARTHA ANDERSON,[3] ALAN BELWARD,[4] ROBERT BINDSCHADLER,[5] WARREN COHEN,[6] FENG GAO,[3] SAMUEL N. GOWARD,[7] DENNIS HELDER,[8] EILEEN HELMER,[9] RAMA NEMANI,[10] LAZAROS OREOPOULOS,[5] JOHN SCHOTT,[11] PRASAD S. THENKABAIL,[12] ERIC F. VERMOTE,[13] JAMES VOGELMANN,[14] MICHAEL A. WULDER,[15] RANDOLPH WYNNE[16]

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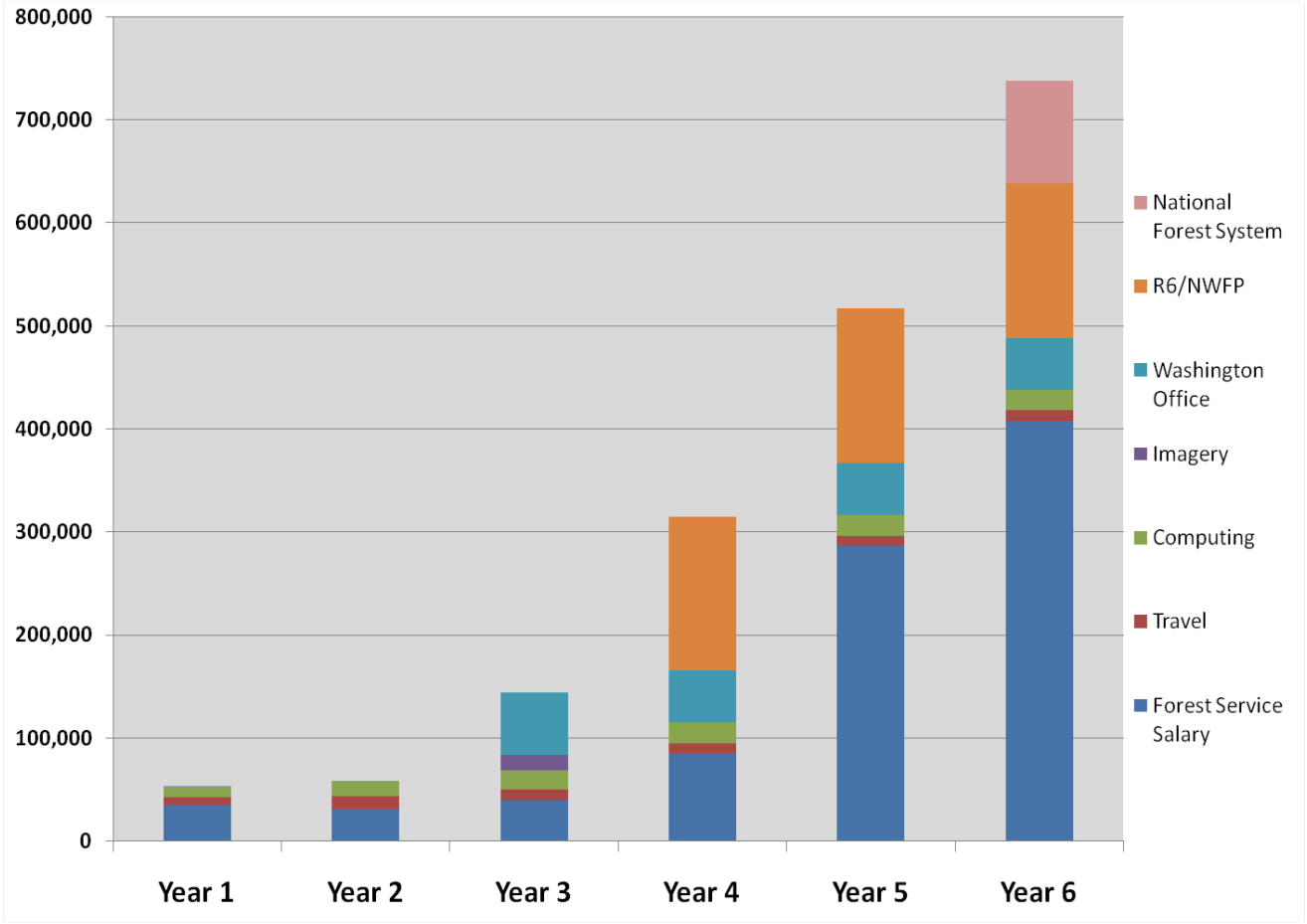
USFS Investments in NAFD-based products



- Primary Forest Service expenditures (US $) on projects related to NAFD (2005-2010)

2010: Emergence of An Operational Change Detection Framework – Monitoring Trends in Landcover Change (MTLC)

- Goal: Promote interagency coordination in monitoring landcover change (leader, Brewer USFS) – tie together multiple existing efforts; all lands all the time

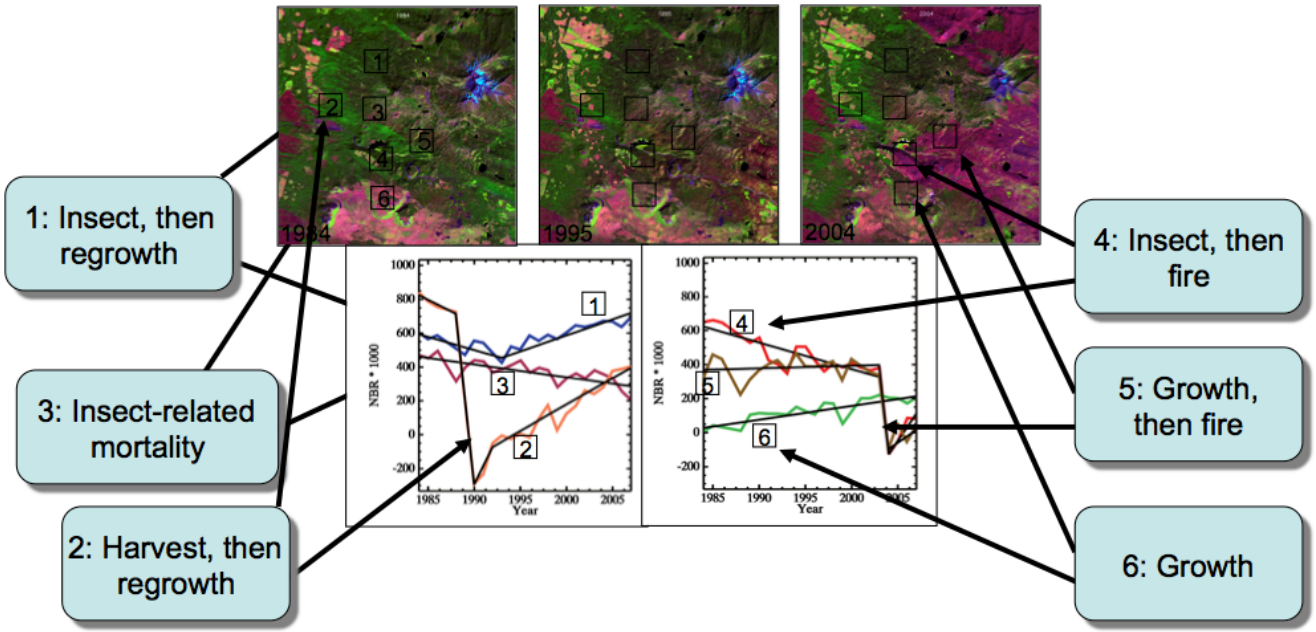
- 1st step: develop the foundation for Landsat-based analytical engine as key component designed to meet USFS and partner needs for monitoring carbon and other resource dynamics (LCMS: leader, Healey FIA)

- Objectives:
  1. Information needs assessment involving key agency representatives from managerial and science entities (RSAC)
  2. Integrate current change approaches (VCT, LandTrendr, TimeSync, others) to provide more broad change detection options for use in characterizing land cover and use dynamics (PNW, RM, OSU, UMD)
  3. Develop flexible statistical change estimation procedures to address diverse user needs (RM)
  4. Transfer technology to, and share data with, a FIA and other clients (RSAC)
  5. ***Maintain partnership between science & applications/operations…***

Science Pathfinding for LCMS: Time series analyses

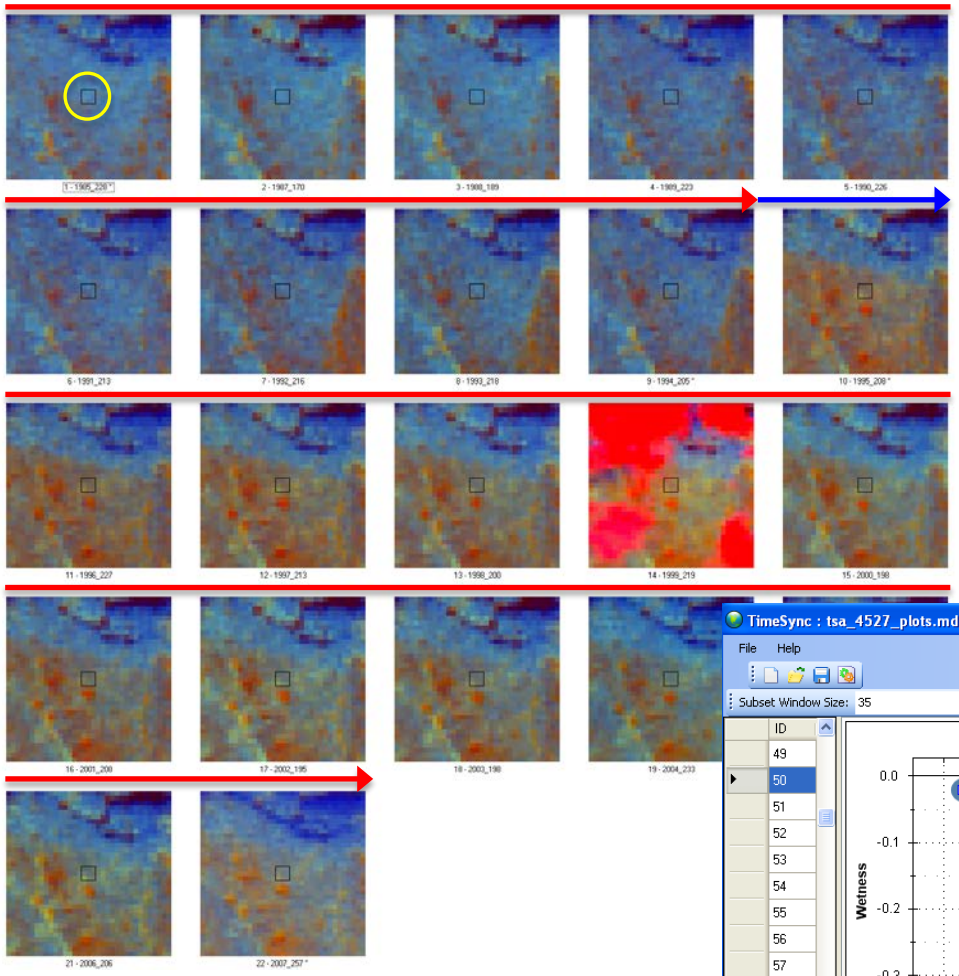
- Context: NAFD (VCT), Northwest Forest Plan (LT), others

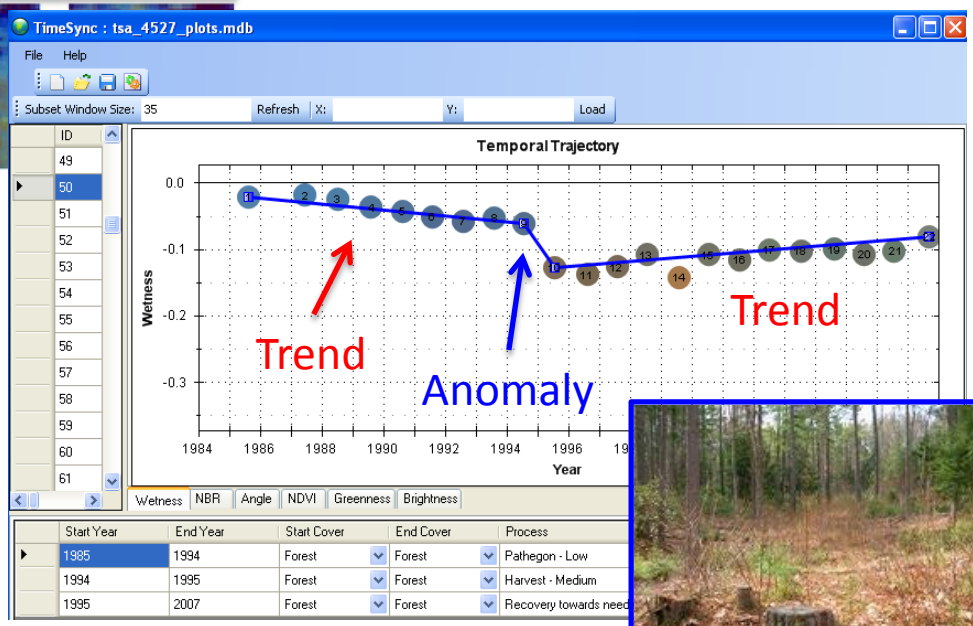
Disturbance year, magnitude, agent, regrowth rates



Example from LandTrendr – Kennedy et al.

Temporal segmentation



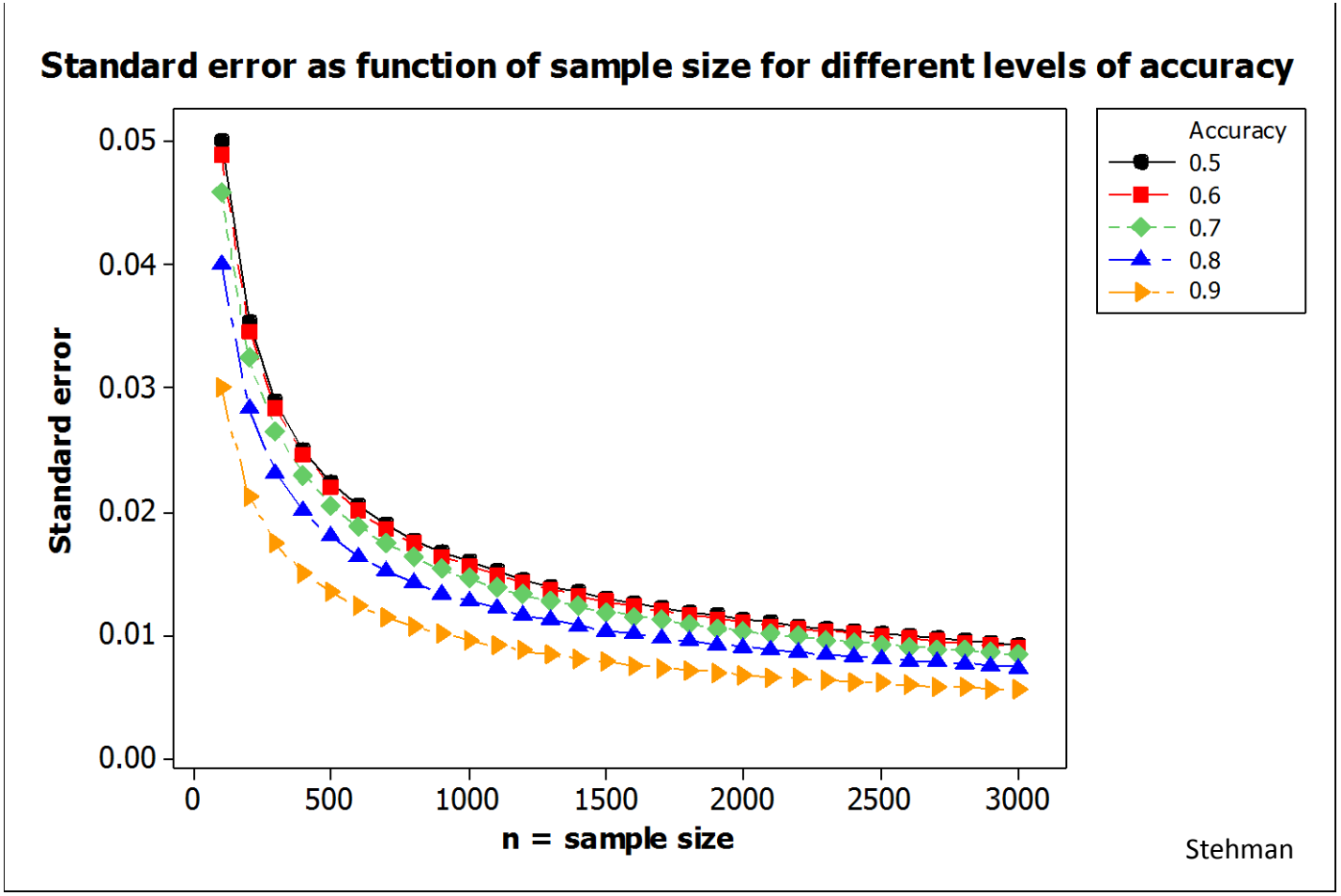


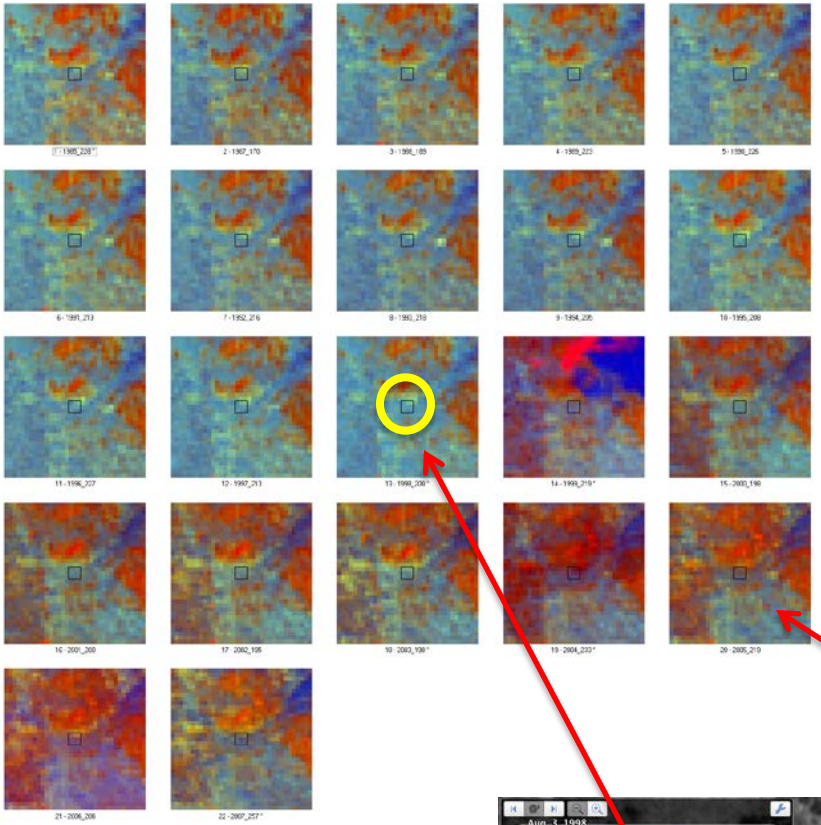
Tracking reflectance history increases signal to noise and allows detection of subtle, long-term trends in addition to anomalies

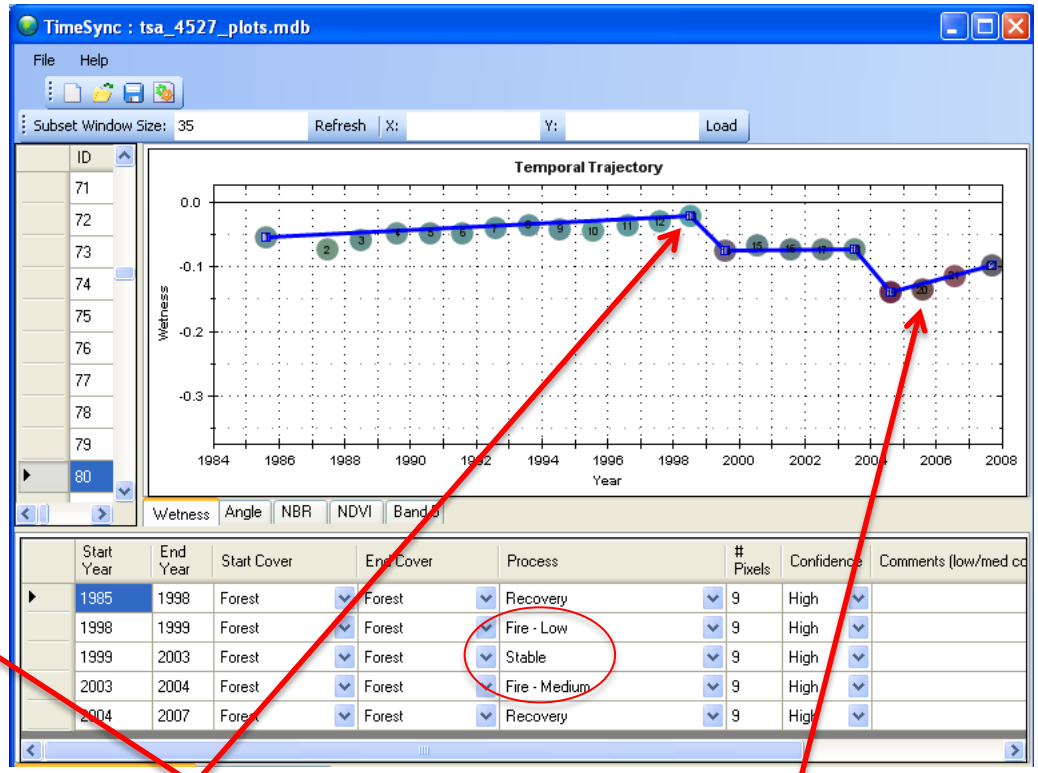
Photos: Garrett Meigs

Science Pathfinding for LCMS

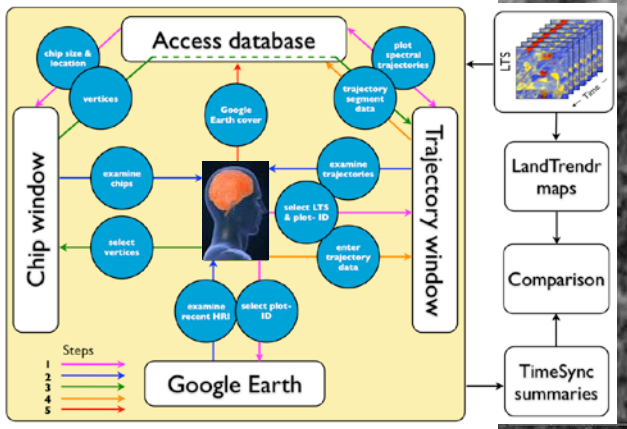
- Error assessment







TimeSync tool



LandTrendr maps

Comparison

TimeSync summaries

Science Pathfinding for LCMS

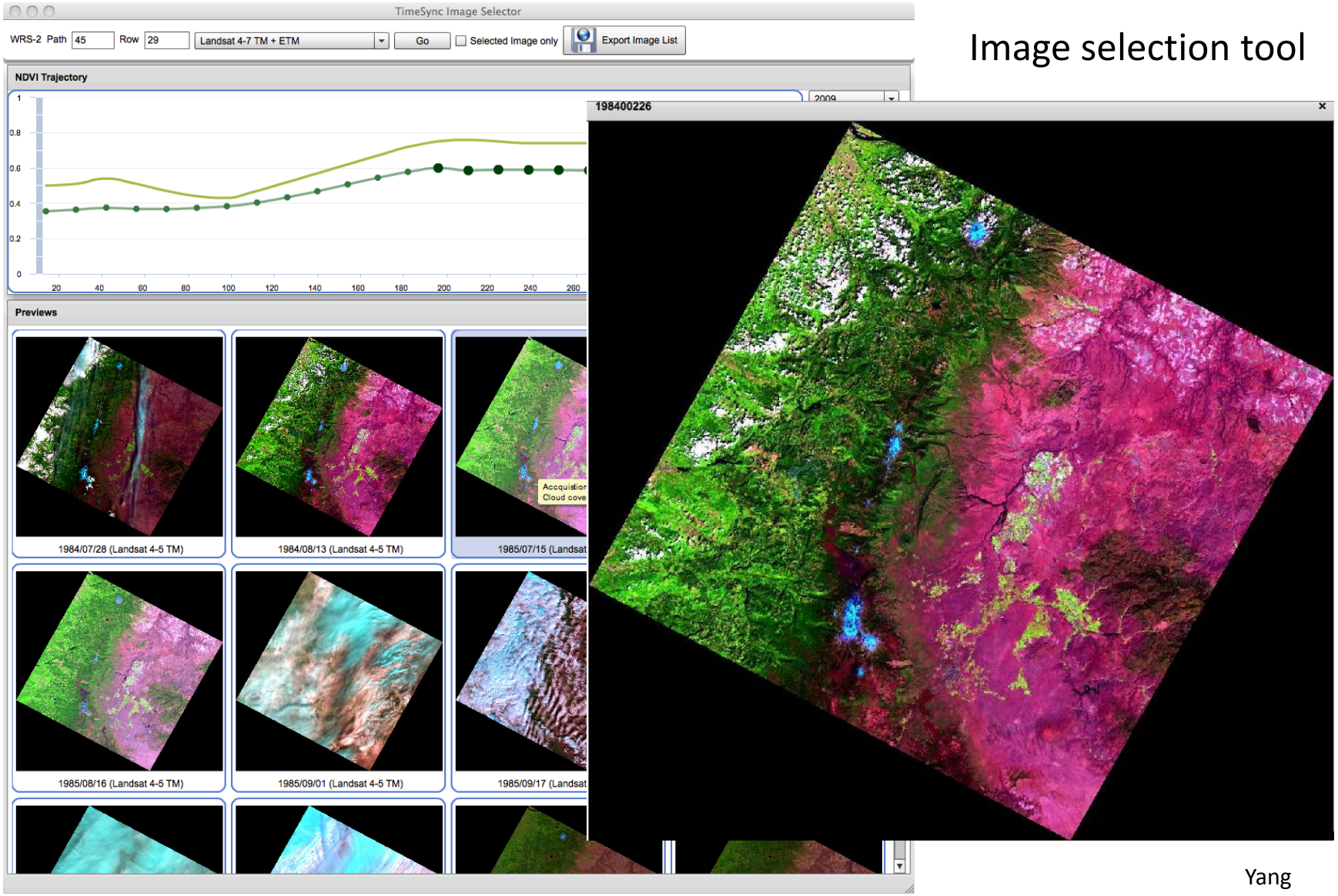


Image selection tool

Yang

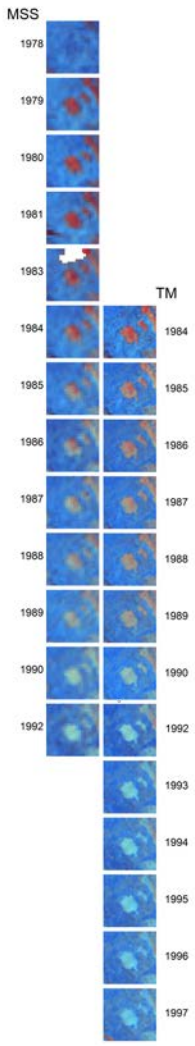
Science Pathfinding for LCMS

Title of my proposal to Join Landsat Science Team

Landsat and Vegetation Change: Towards 50 Years of Observation and Characterization

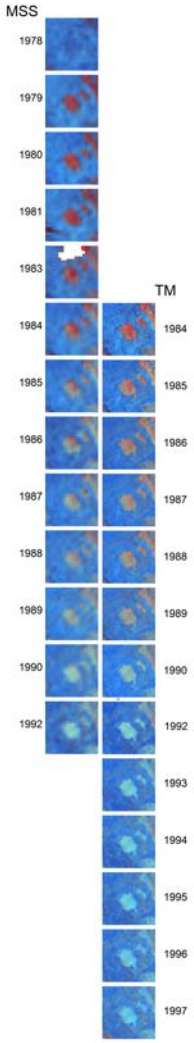
Science Pathfinding for LCMS

Year	Date	Satellite
1972	08/12	Landsat 1 MSS
1973	08/07	Landsat 1 MSS
1975	08/15	Landsat 1 MSS
1977	08/13	Landsat 2 MSS
1978	07/30	Landsat 3 MSS
1979	08/03	Landsat 2 MSS
1980	08/16	Landsat 2 MSS
1981	08/10	Landsat 2 MSS
1982	10/05	Landsat 4 MSS
1983	07/04	Landsat 4 MSS
1984	07/14	Landsat 5 MSS
1984	07/14	Landsat 5 TM
1985	07/17	Landsat 5 MSS
1985	07/17	Landsat 5 TM
1986	07/20	Landsat 5 MSS
1986	07/20	Landsat 5 TM
1987	08/08	Landsat 5 MSS
1987	08/08	Landsat 5 TM
1988	07/25	Landsat 5 TM
1988	08/10	Landsat 5 MSS
1989	07/28	Landsat 5 TM
1989	08/05	Landsat 4 MSS
1990	07/31	Landsat 5 MSS
1990	08/16	Landsat 5 TM
1991	07/18	Landsat 5 TM
1992	08/05	Landsat 5 MSS
1992	08/05	Landsat 5 TM
1993	08/08	Landsat 5 TM
1994	07/26	Landsat 5 TM
1995	08/14	Landsat 5 TM
1996	07/31	Landsat 5 TM
1997	08/03	Landsat 5 TM
1998	07/21	Landsat 5 TM
1999	07/08	Landsat 5 TM
2000	08/11	Landsat 5 TM
2001	08/06	Landsat 7 ETM+
2002	08/09	Landsat 7 ETM+
2003	08/20	Landsat 5 TM
2004	07/21	Landsat 5 TM
2005	07/24	Landsat 5 TM
2006	07/27	Landsat 5 TM
2007	07/30	Landsat 5 TM
2008	08/01	Landsat 5 TM
2009	07/19	Landsat 5 TM
2010	08/07	Landsat 5 TM



- **Integrate MSS and TM/ETM+ into a single time to <u>ready it for analyses</u>** (Pflugmacher)
  - ✓ Improve georegistration of MSS to TM/ETM+ using automated tie-point program
  - ✓ Cross-calibrate and normalize across sensors
    1. Derive LPGS-based MSS Tasseled Cap brightness and greenness coefficients based on new calibration data
    2. Cross-sensor, scene-level radiometric normalization of TasCap indices
    3. Bias adjustment to remove residual MSS-TM offset at the pixel level

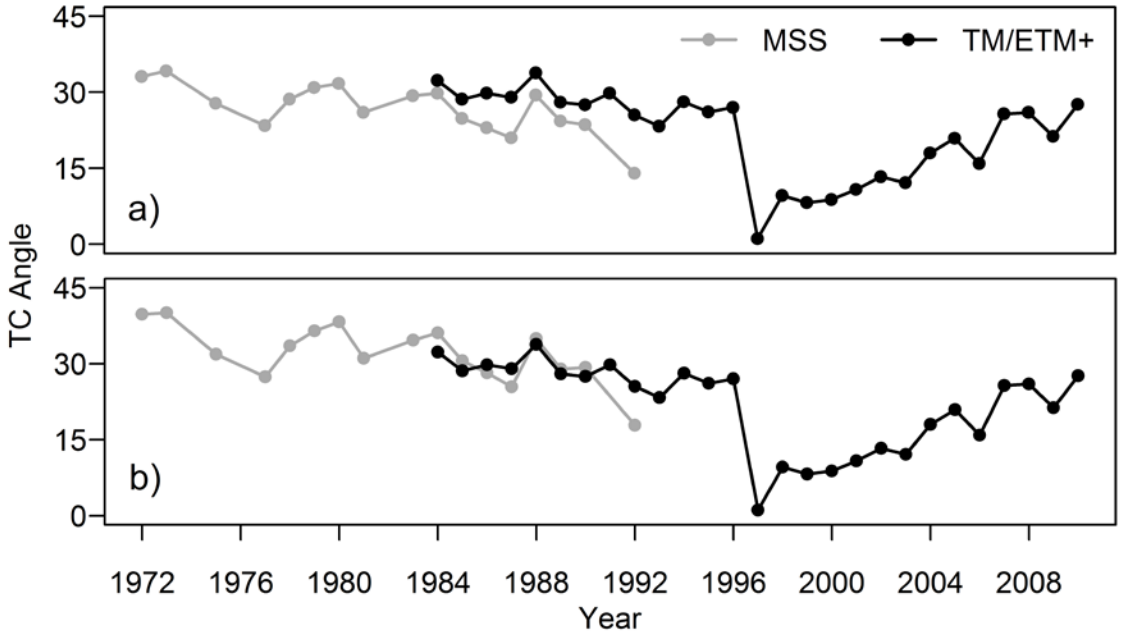
Science Pathfinding for LCMS



Bias adjustment to remove residual MSS-TM offset at the pixel level (brightness, greenness, and angle)

- TC angle = arctan (TCG/TCB)

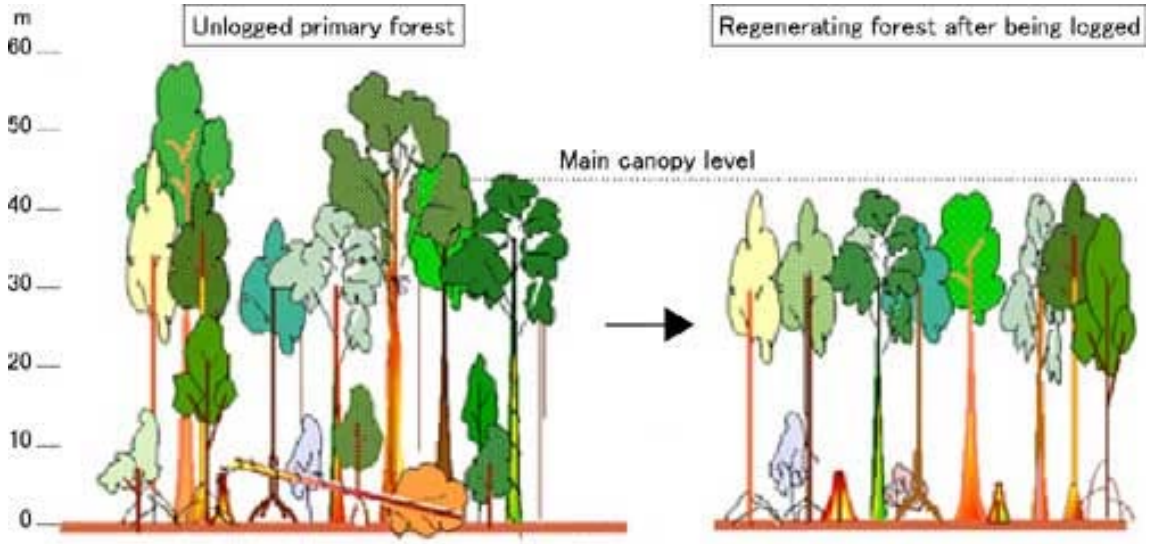
$$Bias = \frac{1}{N}\sum_{i=1}^{N} MSS_i - TM_i$$



$$MSS_i' = MSS_i - Bias$$

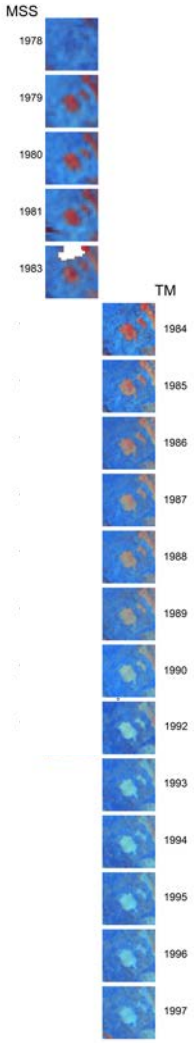
Analysis (Example): Current Forest Structure

- Goal: Map forest structure
- Concept: Current structural condition strongly influenced by disturbance history

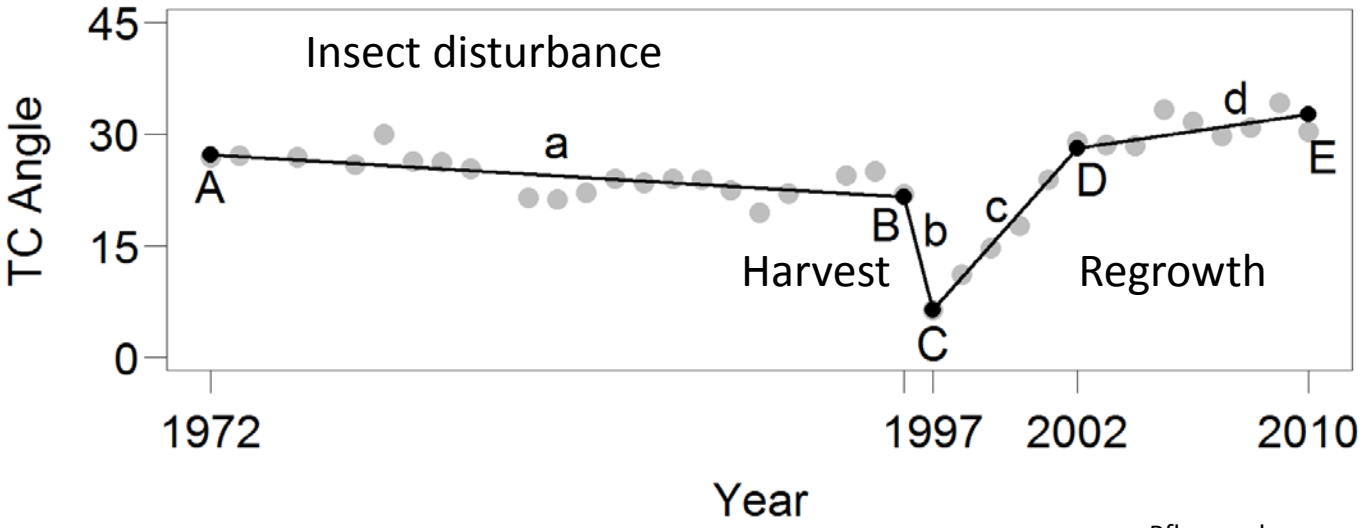


- Needed: Metrics of forest disturbance history derived from time series for each pixel

Analysis (Example): Current Forest Structure



- Remove redundant MSS data
- Segment time series (TimeSync, LandTrendr)
  - Identify relevant vertices (A,B,C,D,E)
    - Year, cover/use label
  - …and segments (a,b,c,d)
    - Process label



Pflugmacher

Analysis (Example): Current Forest Structure

Derive disturbance and regrowth metrics

Scope	Description	Parameter
Greatest disturbance (GD)	TC Angle before	$GDTCA_B$
	TC Angle after	$GDTCA_A$
	Duration	GDDUR
	Magnitude	GDMAG
	Relative magnitude (GDMAG/$GDTCA_B$)	GDRCH
	Rate (GDMAG/GDDUR)	GDROC
	Weighted Magnitude (GDMAG*GDDUR)	GDMXD
	Time since disturbance start	$GDTSD_S$
	Time since disturbance end (GDTSD-GDDUR)	$GDTSD_E$
Total disturbance (TD)	Magnitude	TDMAG
	Duration	TDDUR
	Rate (TDMAG/TDDUR)	TDROC
	Weighted Magnitude (TDMAG*TDDUR)	TDMXD
Total recovery (TR)	Magnitude	TRMAG
	Duration	TRDUR
	Rate (TRMAG/TRDUR)	TRROC
Total no change (TS)	Duration	TSDUR
Total all (TA)	Disturbance-recovery ratio (TDMAG/TRMAG)	TADRR
	Weighted MSE of fit	TAMSE
Last monotonic trend (LM)	Magnitude	LMMAG
	Duration	LMDUR
	Rate of change (LCMAG/LCDUR)	LMROC
	MSE of fit	LMMSE
Current condition	TC Brightness of 2008 image	LTCB
	TC Greenness of 2008 image	LTCG
	TC Wetness of 2008 image	LTCW

- Starting & ending values
- Magnitudes
- Durations
- Rates
- Interactions

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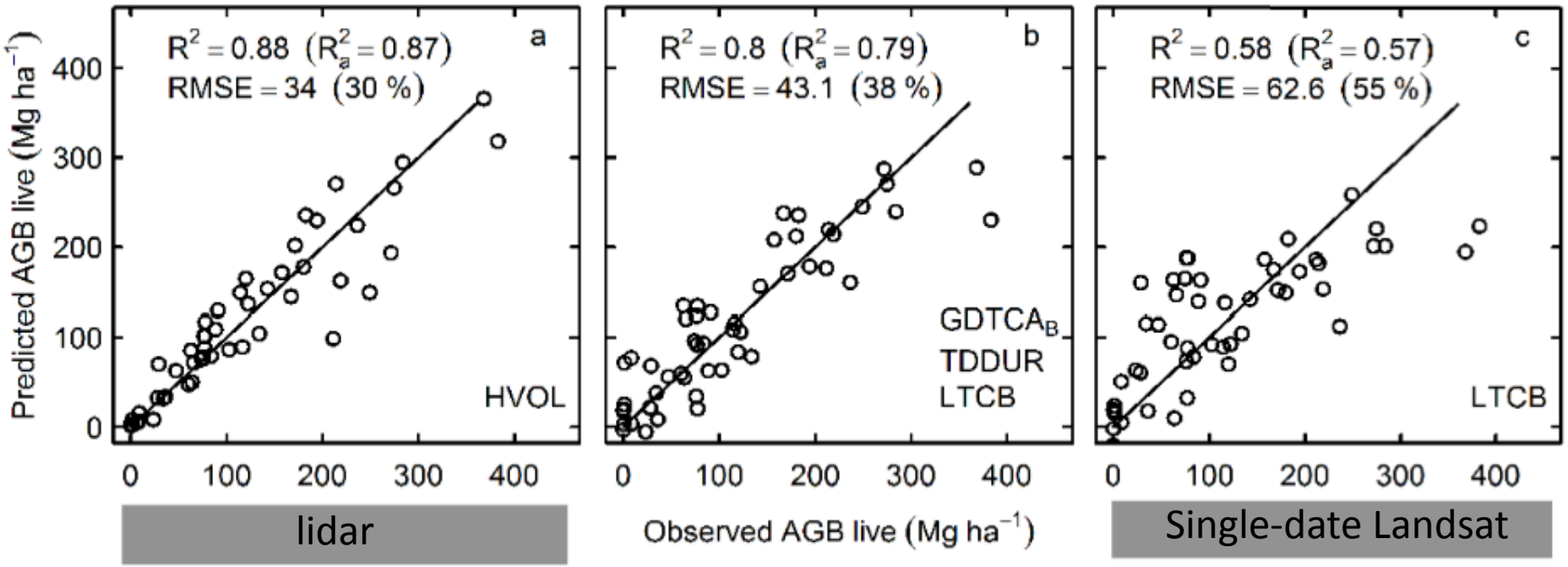
Analysis (Example): Current Forest Structure

- Improved prediction over a single date of Landsat
  - ✓ Lower RMSE throughout range
  - ✓ Increased asymptote by 50%
- Closer to lidar



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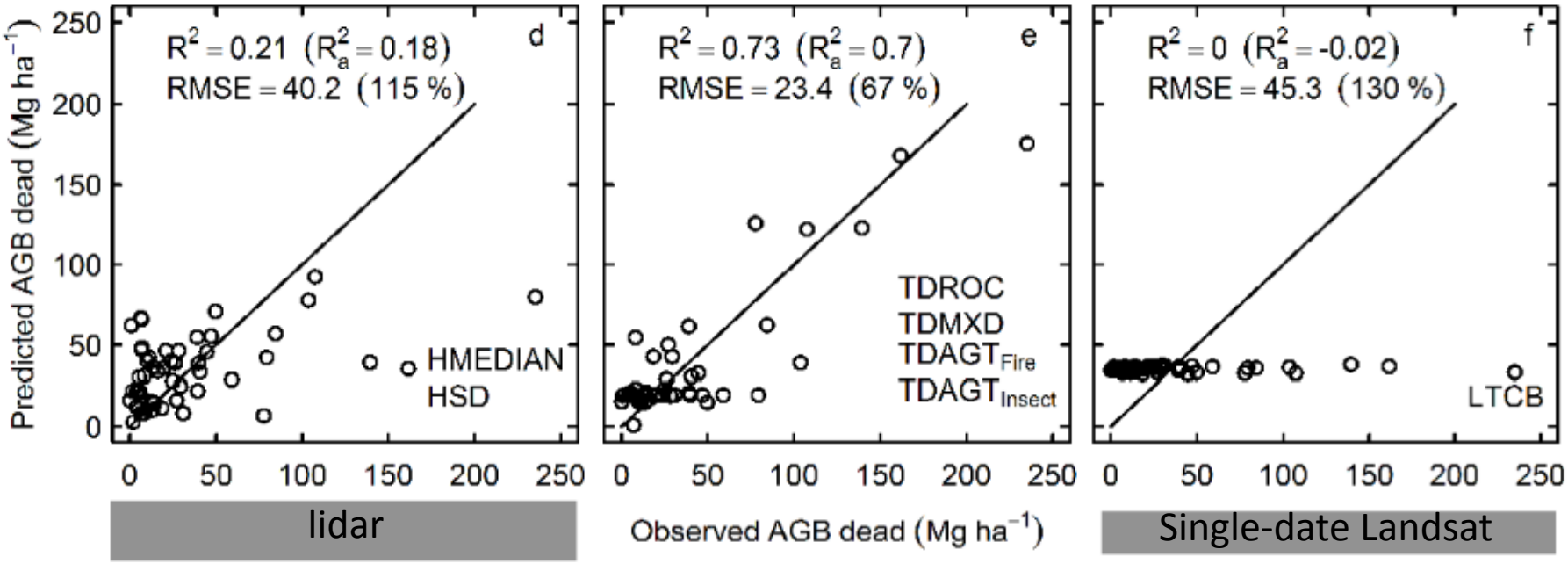
Analysis (Example): Current Forest Structure

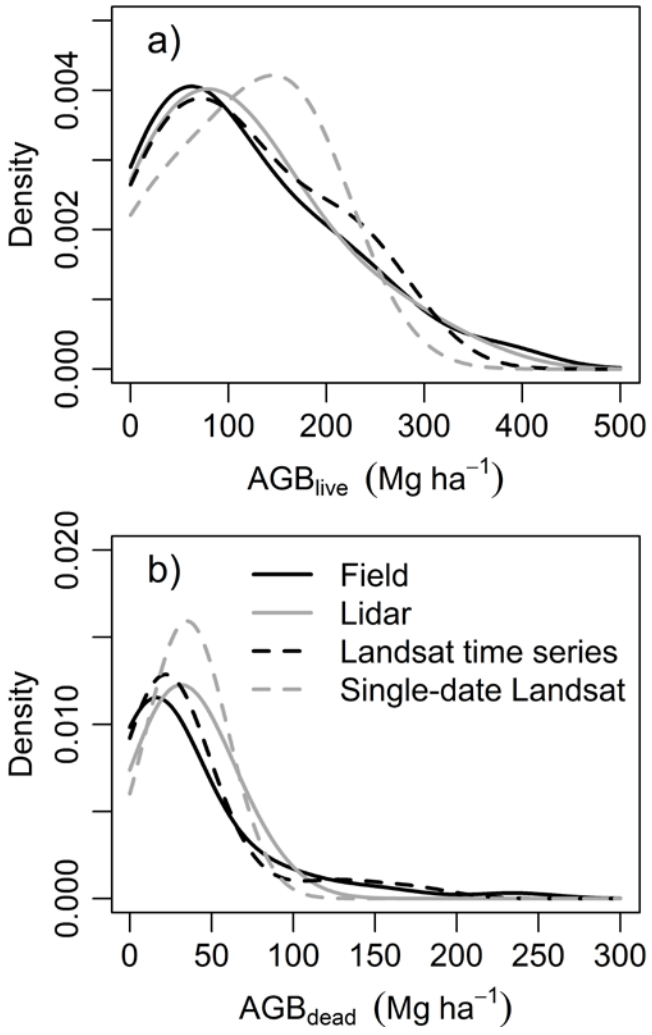
- Disturbance history should also inform models of dead wood (e.g., standing and downed)…

  ✓ Landsat time series has real potential



Pflugmacher

Analysis (Example): Current Forest Structure

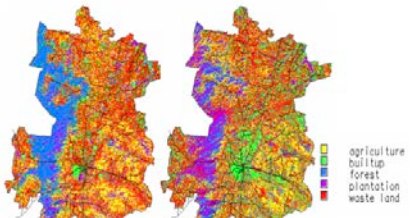


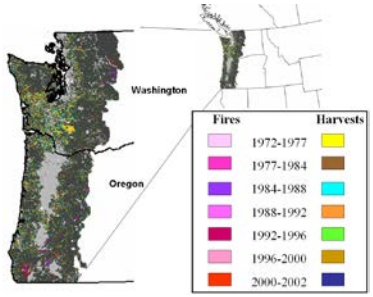
- Many map-based applications require accurate distributions
  - Non-linear functions of structure

Next: Extrapolate Forest Structure

- Space
  - Structure measurements needed
    - Not all field data equal for use with Landsat
    - Lidar, supported by limited field data
- Time
  - How many years of history needed?
  - If, e.g., 10, can possibly create structure maps back to ~1984 using MSS data

Change Detection: Where Do We Come From, Where Do We Go?





Healey et al. 2009

1972

1980

1990

2000

2008

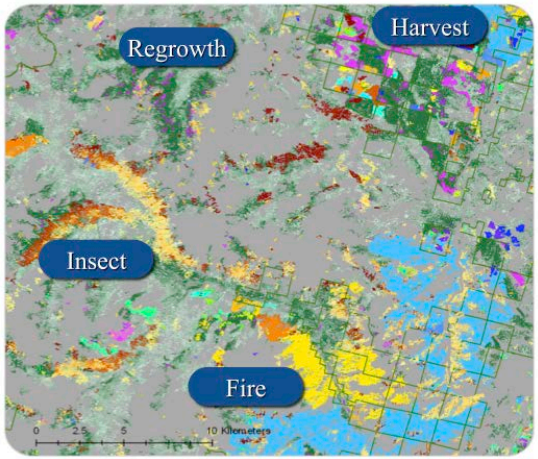
1 Landsat scene, 2 image dates

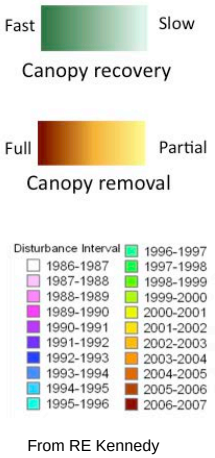
Slow, incremental progress

100s Landsat scenes, 2 image dates (Masek et al, LEDAPS) ***or*** handfuls of scenes and dates (eg, Healey et al)

A new frontier

2008 to present– 100s-1000s Landsat scenes ***and*** an ~annual or greater look at nearly 40 years of imagery = **more information & new opportunities for operational use**





From RE Kennedy

Institutional Awakening

- During the tenure of this Landsat Science Team
  - USFS (FIA, RSAC, research stations) has rapidly gravitated towards Landsat (NCLD also)
  - Now committed to complementing traditional plot-based data with critical and consistent Landsat-derived forest change information
  - Positive experiences + free Landsat data + MTLC/LCMS vision supported by production-science partnership =
- Major success for the USFS and the Landsat program!

…And extremely rewarding for me both personally and professionally