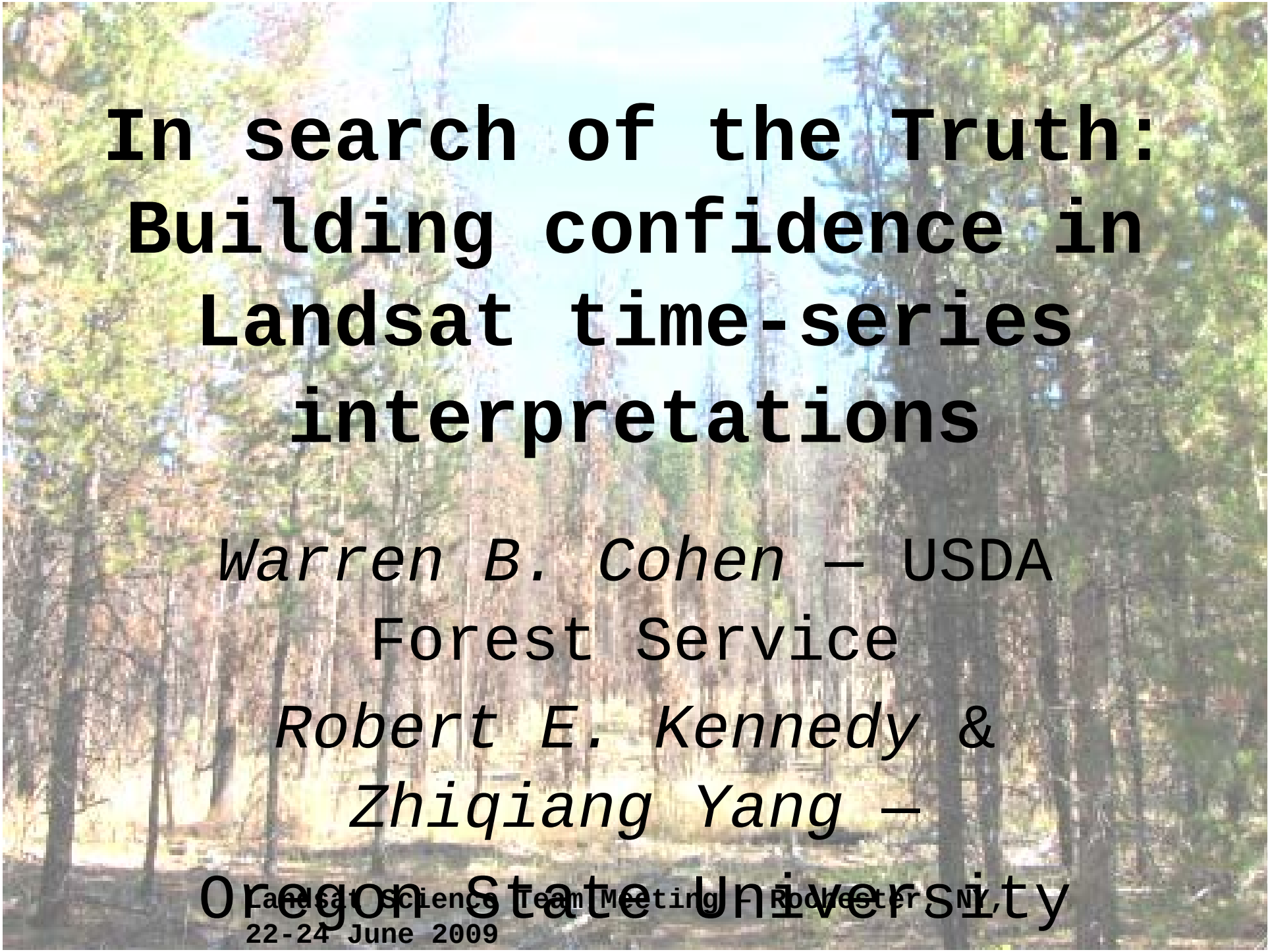


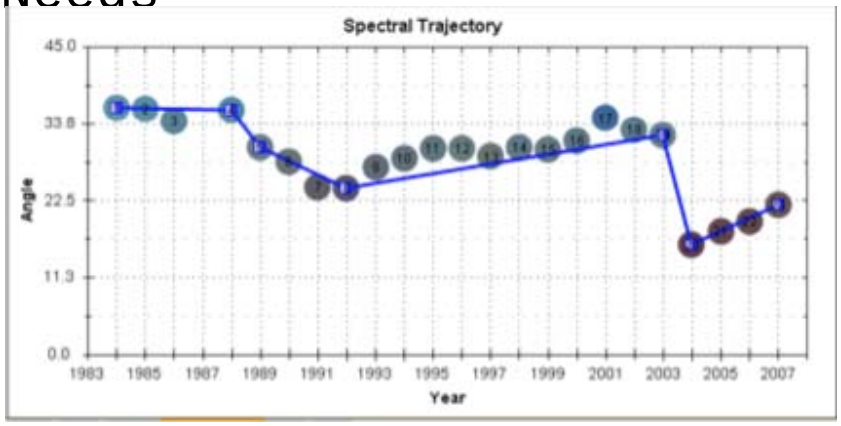
In search of the Truth: Building confidence in Landsat time-series interpretations

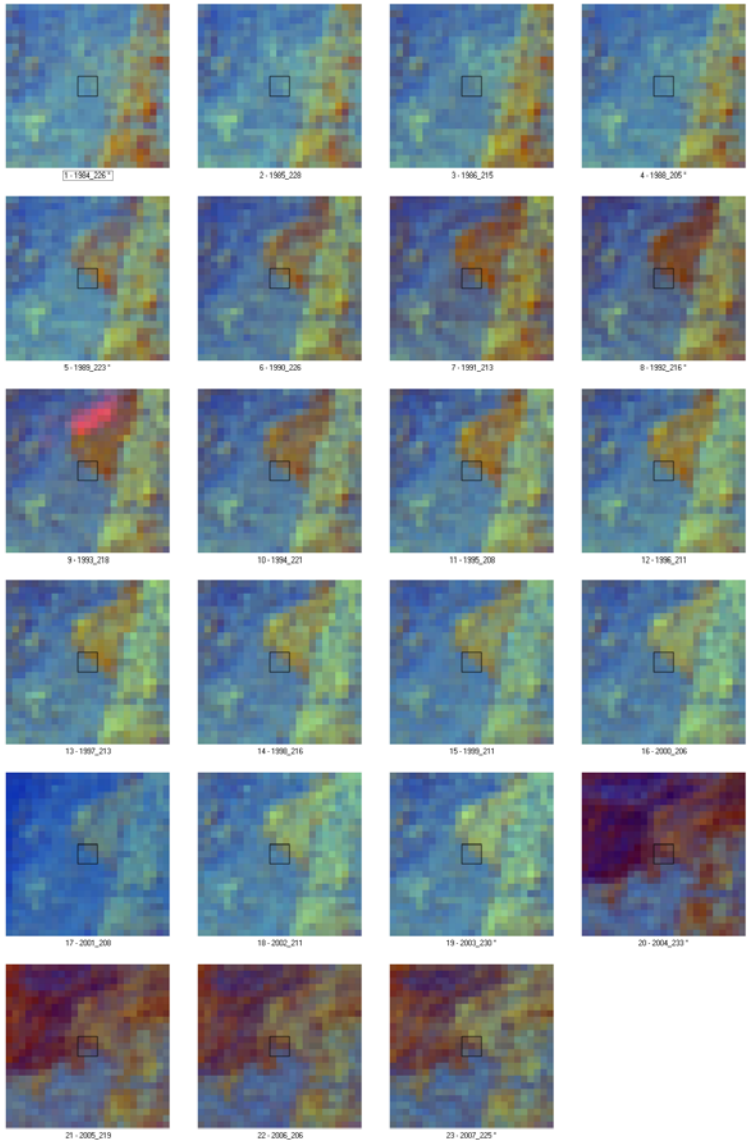
Warren B. Cohen – USDA Forest Service

Robert E. Kennedy & *Zhiqiang Yang* – Oregon State University

Monitoring with Landsat: New Opportunities/Challenges

- Opening of the US Archive, single recipe, time to use orders of magnitude more data to do what only Landsat can do
- E.g., cover change at annual time step, nearly 40 years – management relevant grain
- Regional, continental, global scales (international archives)
- Needs

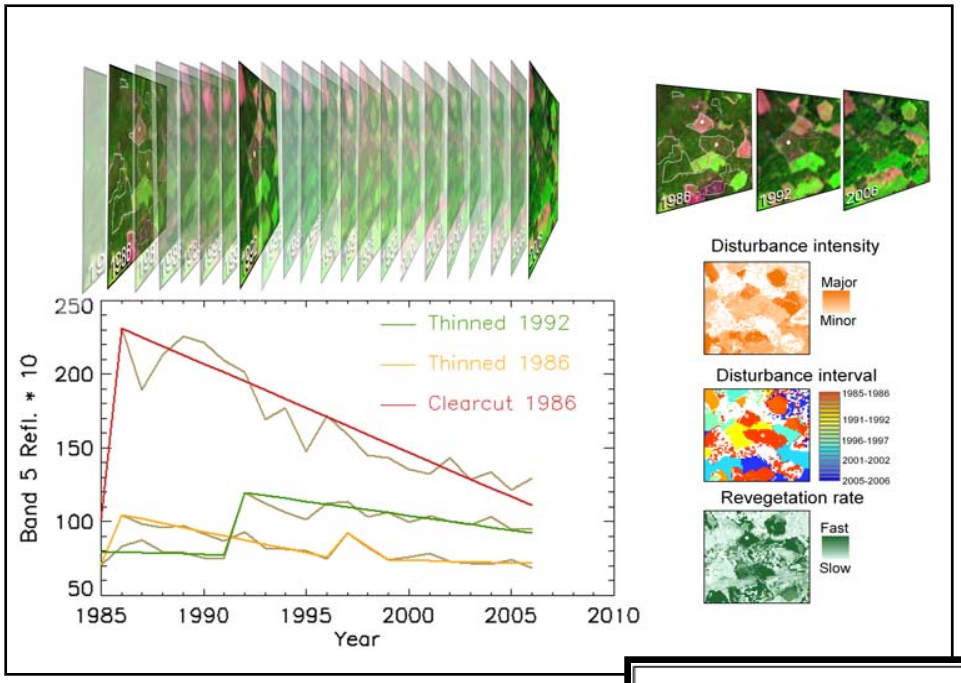




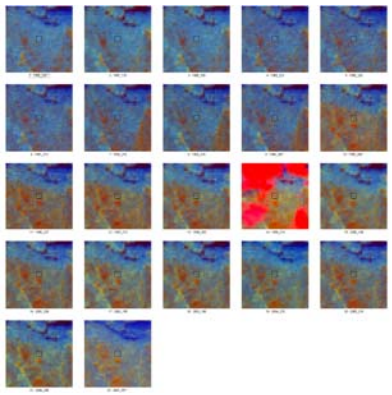
In search of the Truth about land cover change

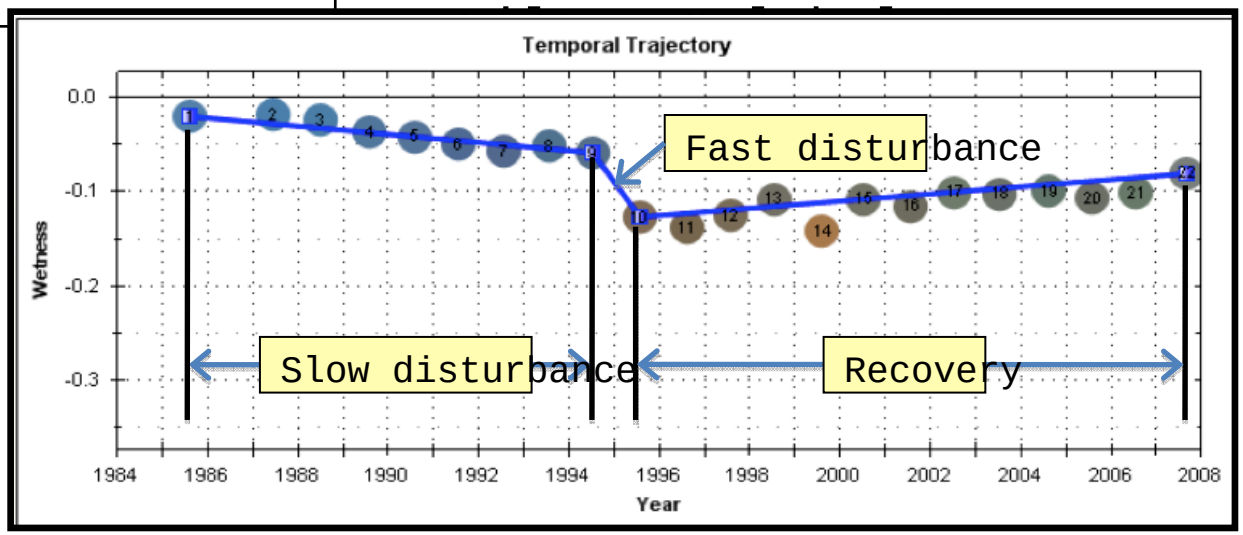
- Multiple models of reality
  - Maps from automated Landsat time-series algorithms
    - E.g., VCT (Huang, Goward, Masek et al.); LandTrendr - Landsat-based Detection of Trends in Disturbance and Recovery (Kennedy, Yang, Cohen)
  - Enhanced photo-interpreted assessments of Landsat time series at specific locations
    - TimeSync – Syncing automated and human interpretation of Landsat times series (Cohen, Yang, Kennedy)
  - Independent database
    - MTBS (fire), FHM (pathogens), management records (prescriptions/activities)
- Which can we believe?
  - Are any free of errors?
  - Is one more correct than another?
  - Disagreement at least as important as agreement

The Skinny on LandTrendr (Kennedy et al.)



- Calibrated annual time series stack – compositing (gap- and cloud-filling, as needed)
- Statistical & knowledge-based rules to identify salient features of each pixel's trajectory



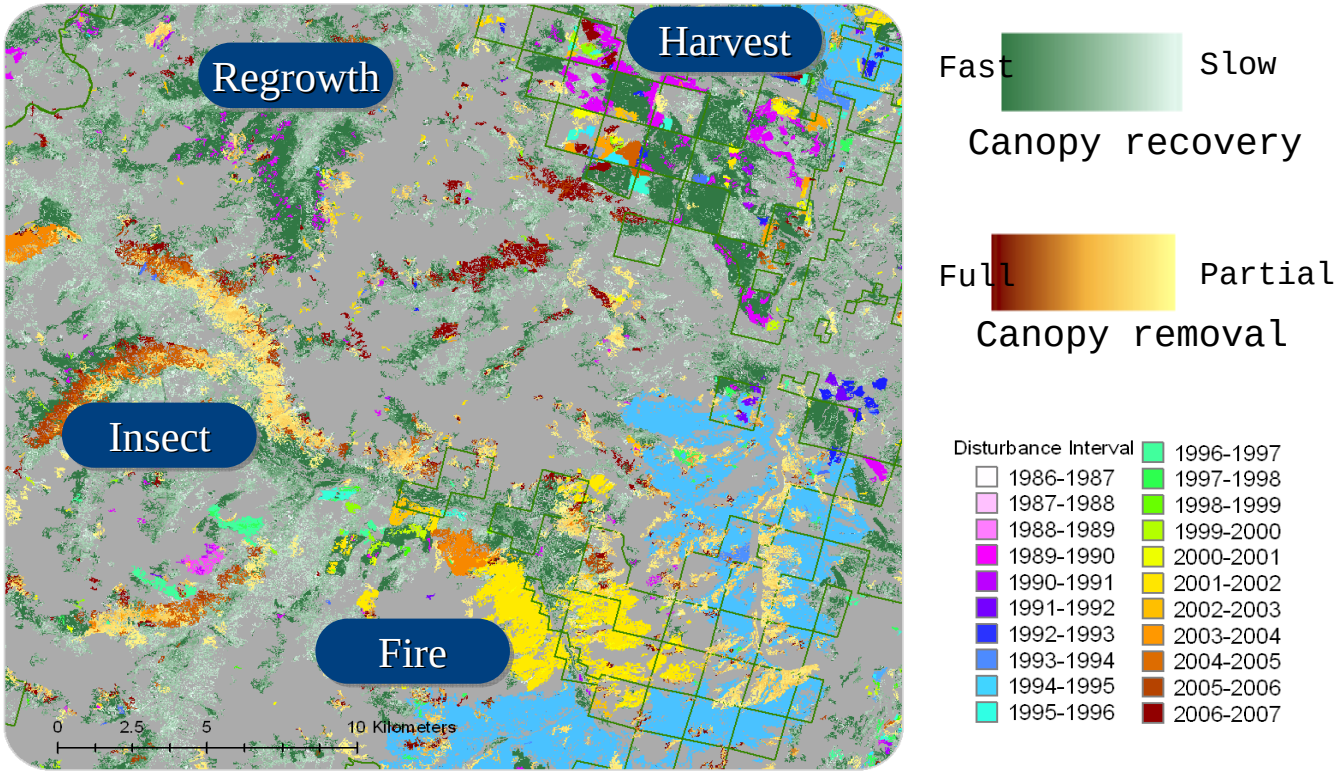


Time Series Change Maps (e.g., LandTrendr): Advantages

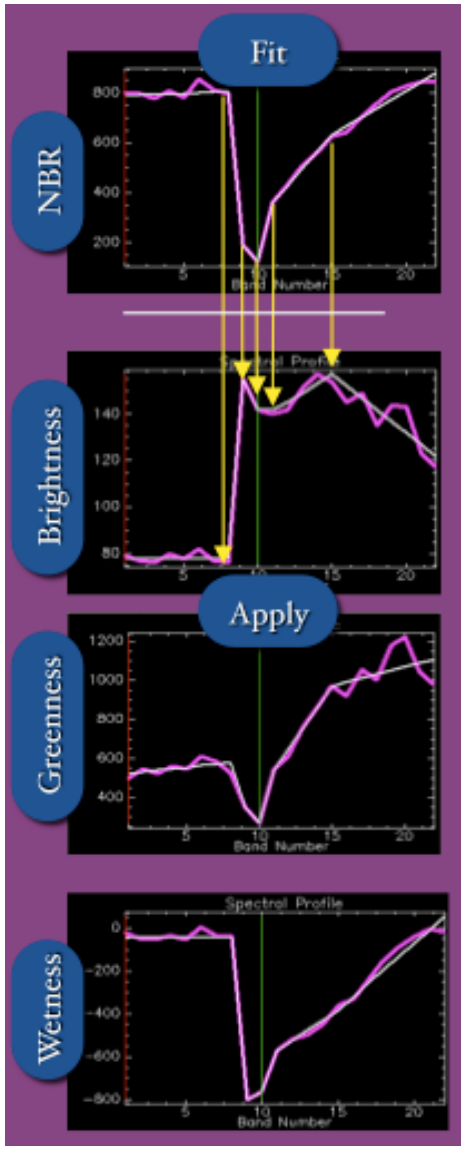
1. Dramatic events as with earlier, interval-based approaches (clearcuts, high intensity fires), but now more often (yearly)
2. More subtle events than before (thinning, lower intensity fires)
3. Slower, multi-year disturbance processes such as insects and other pathogens

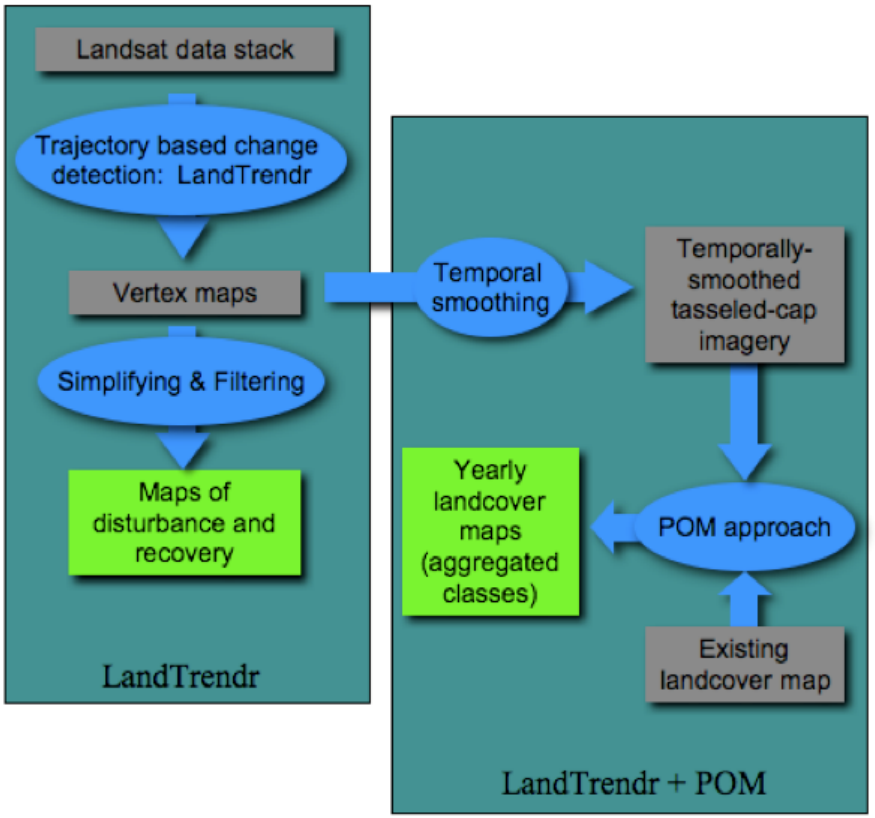
4. Recovery and regrowth after disturbance in terms of magnitudes and rates

5. More ecological information: how vegetation change varies across a region and as function of disturbance type and severity

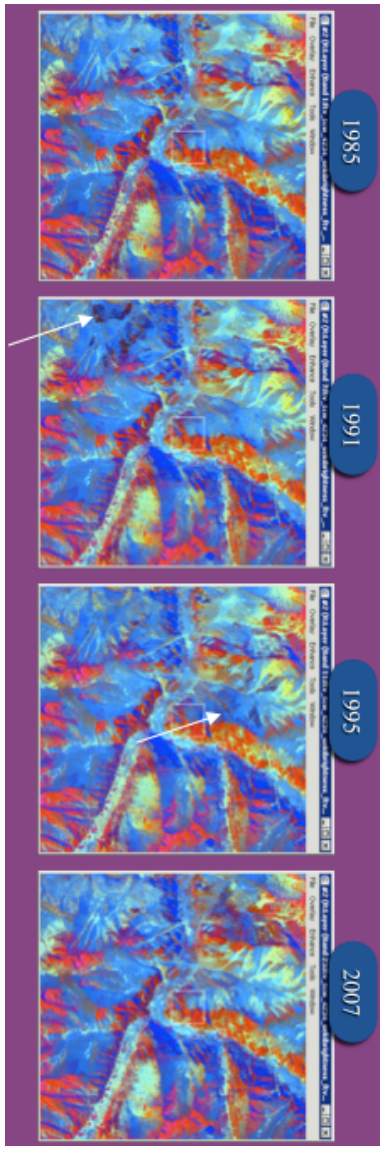


LandTrendr Byproducts



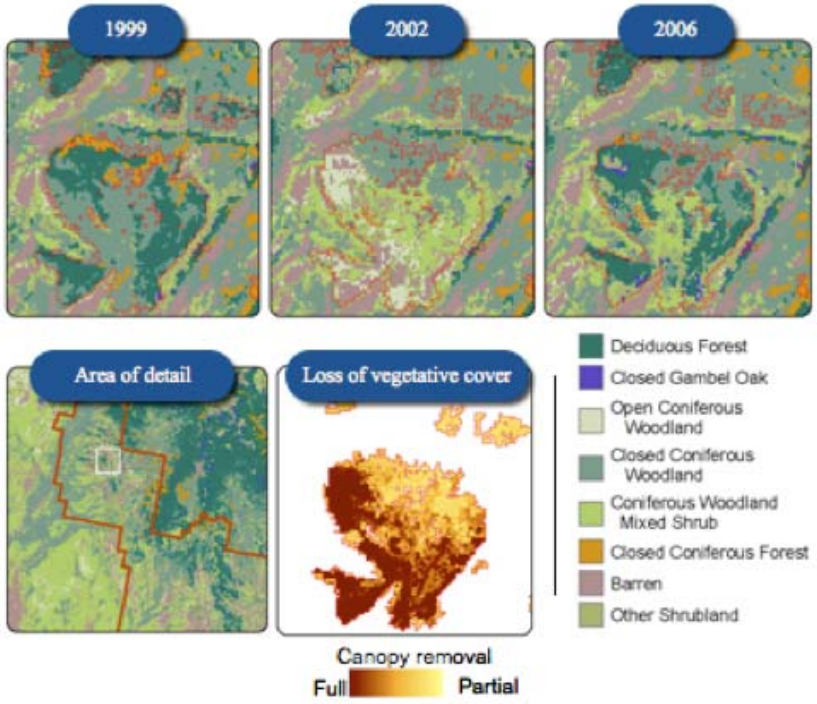


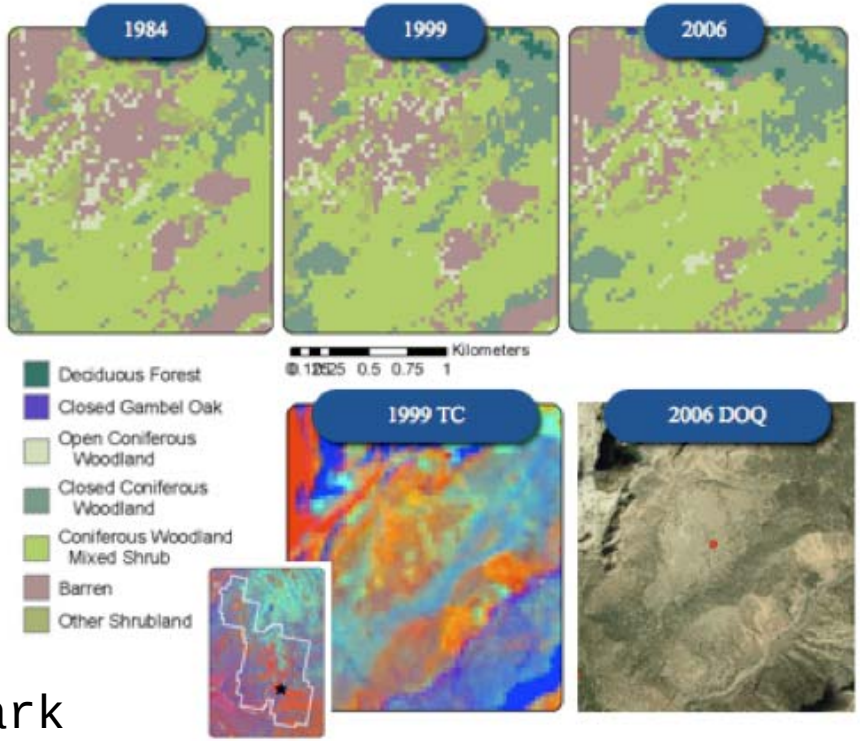
- Gap-filled imagery
- Temporally fitting at pixel-level based on change vertices



Land Cover Trends

- Apply classification rules across time series
- Stable areas remain stable in terms of class
- Changed areas more likely to have true

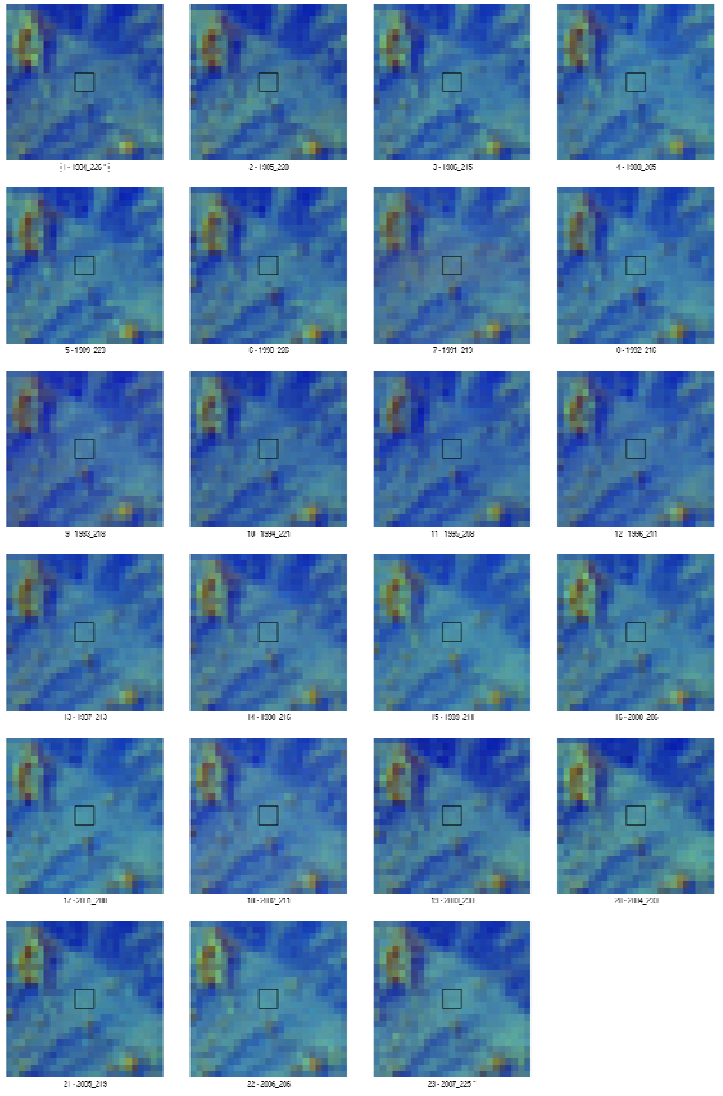




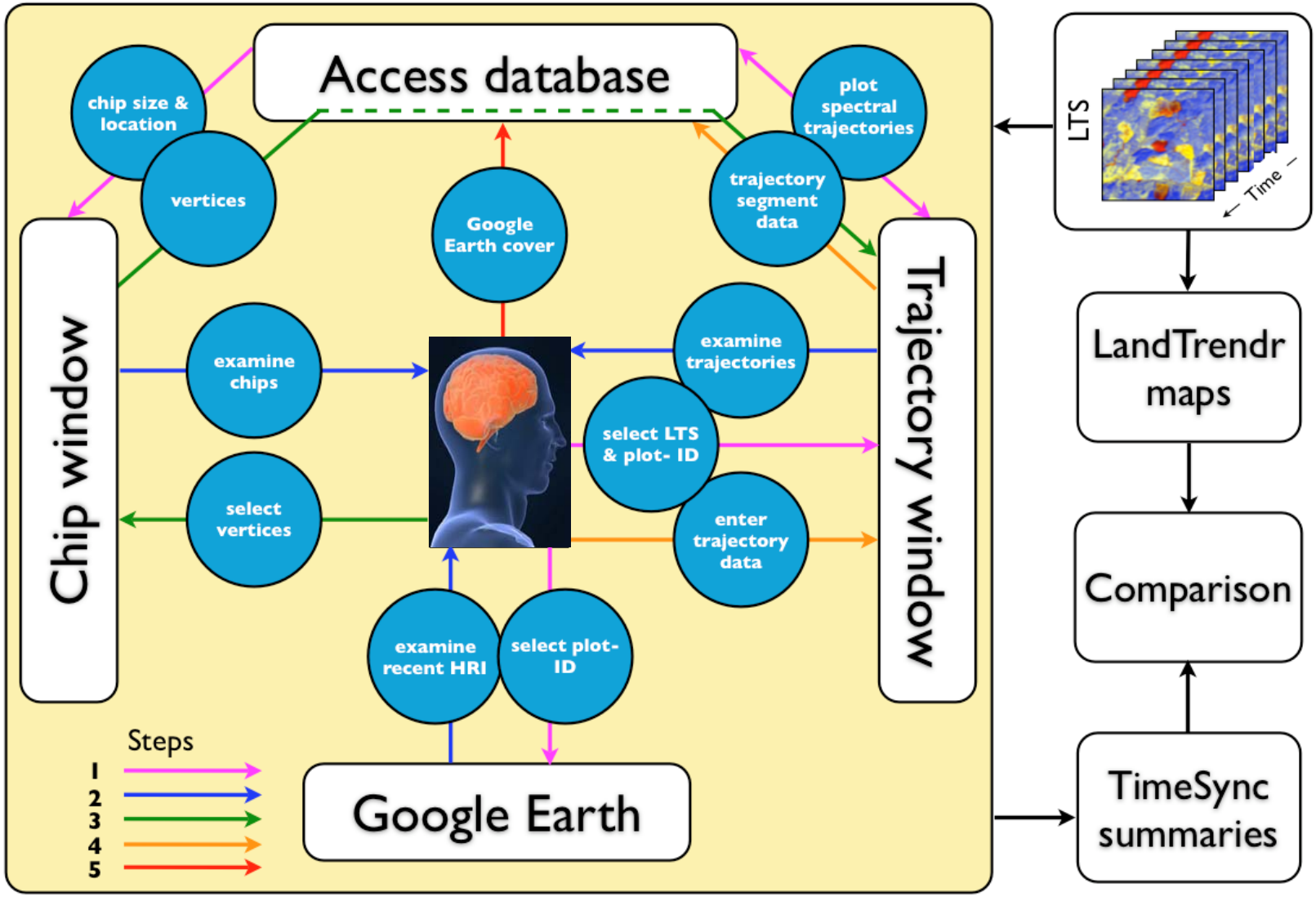
Zion National Park

In Search of the Truth

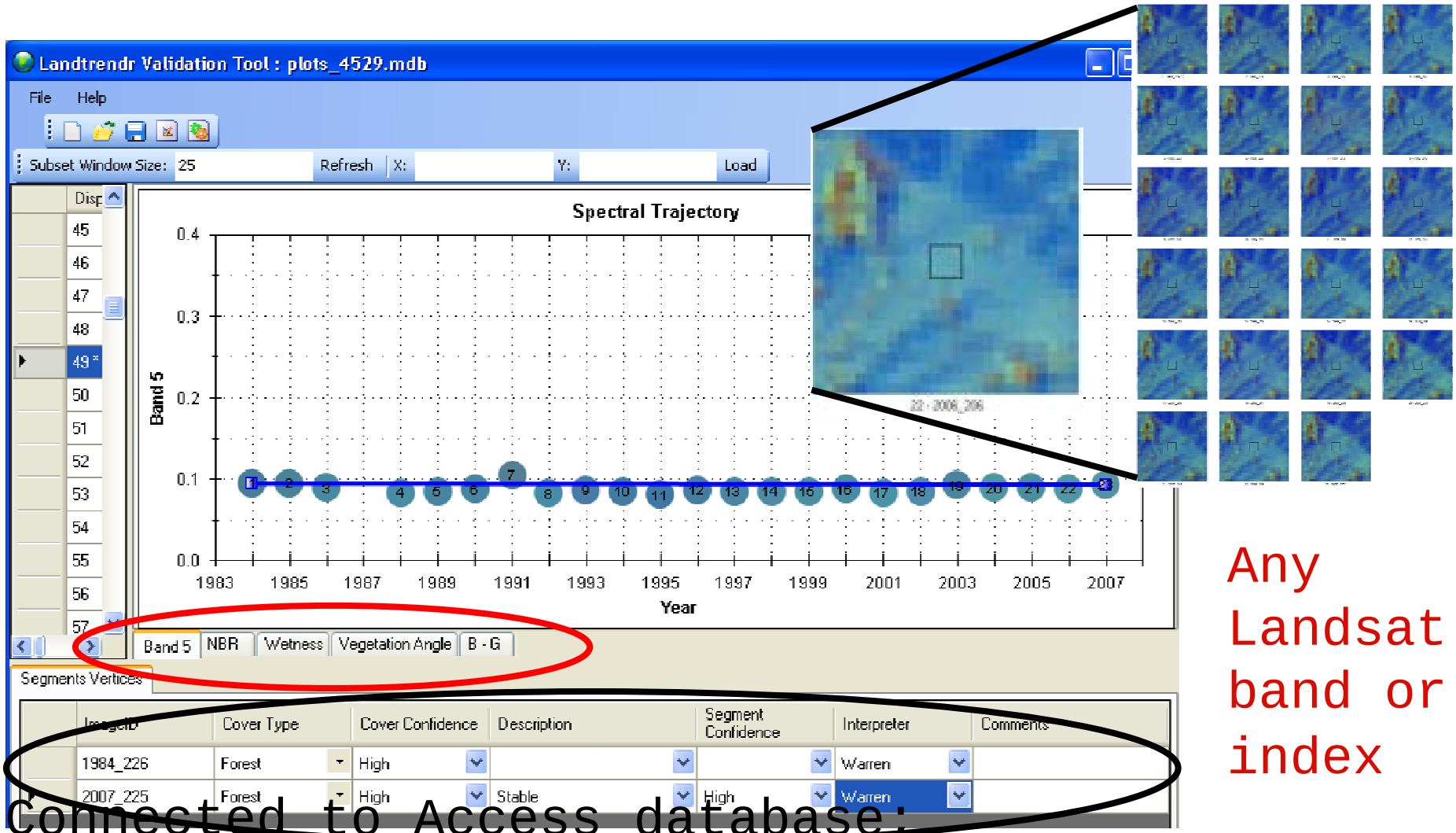
- How to validate LandTrendr & related maps with their rich spatial and temporal detail?
  - *Extant databases are limited in spatial and temporal coverage, and therefore statistical power*
  - *New methods required*
- Type 1. TimeSync: Synching human and automated interpretations of



TimeSync & Cal/Val of LandTrendr



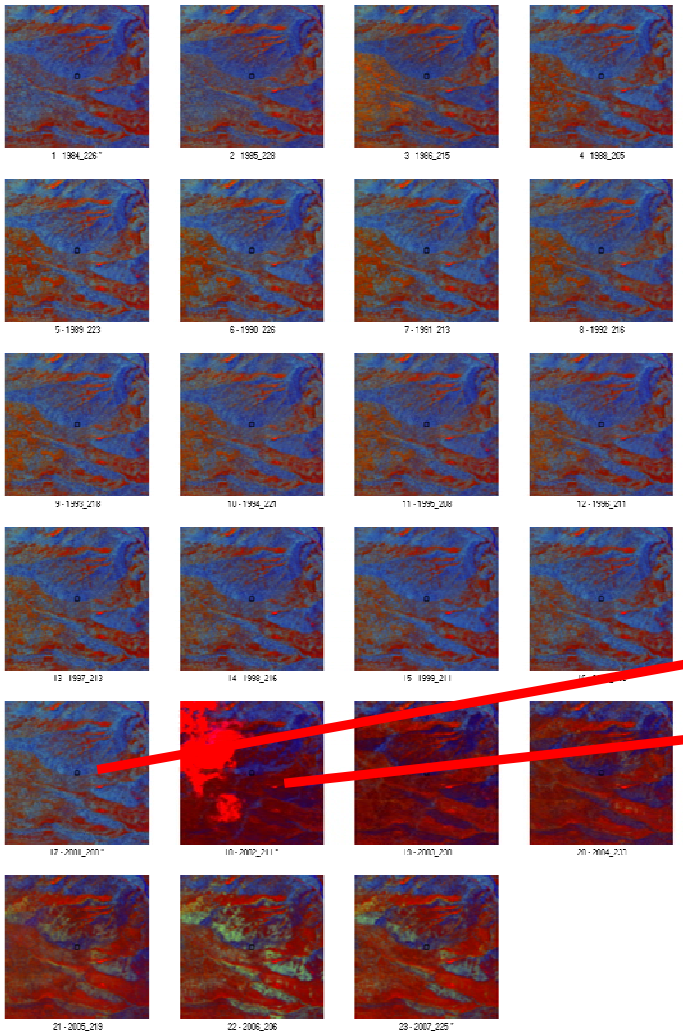
Timesync: Enhancement #1

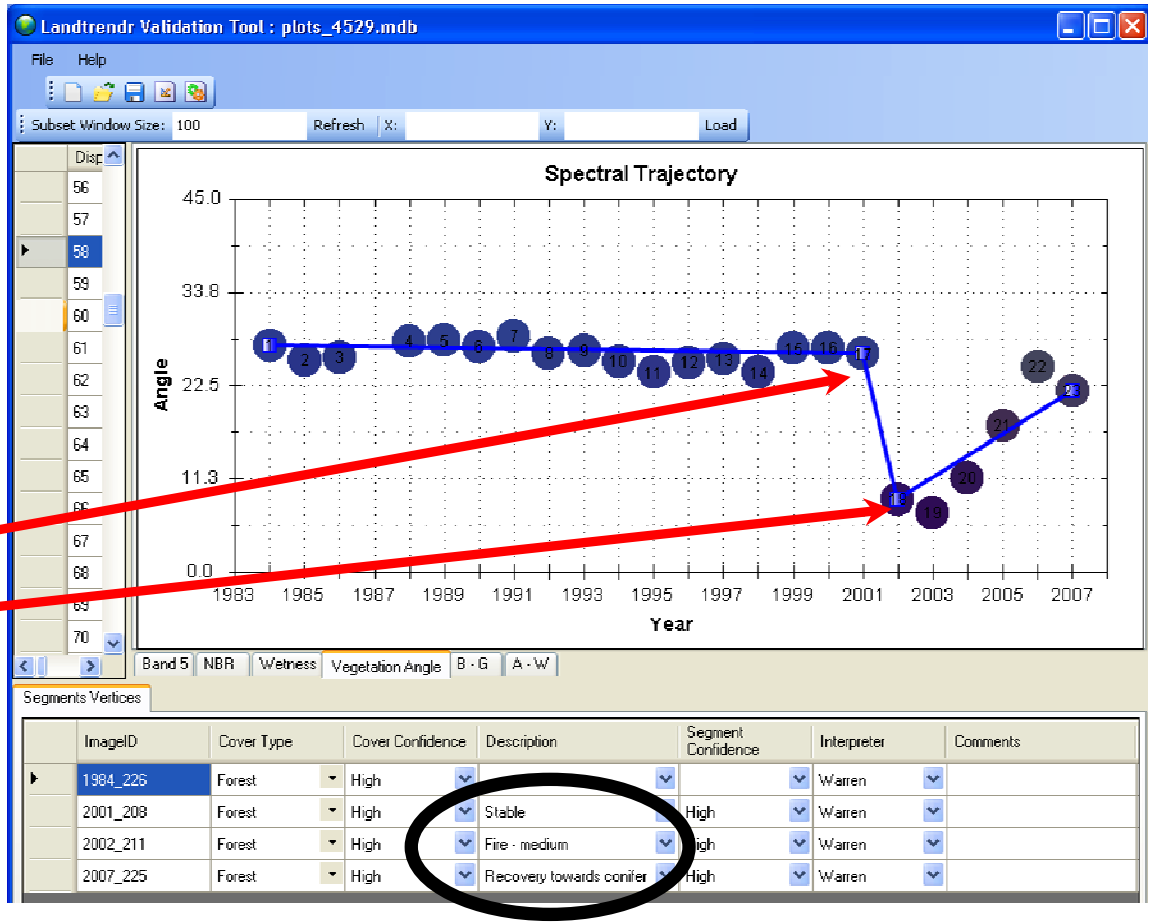


Any Landsat band or index

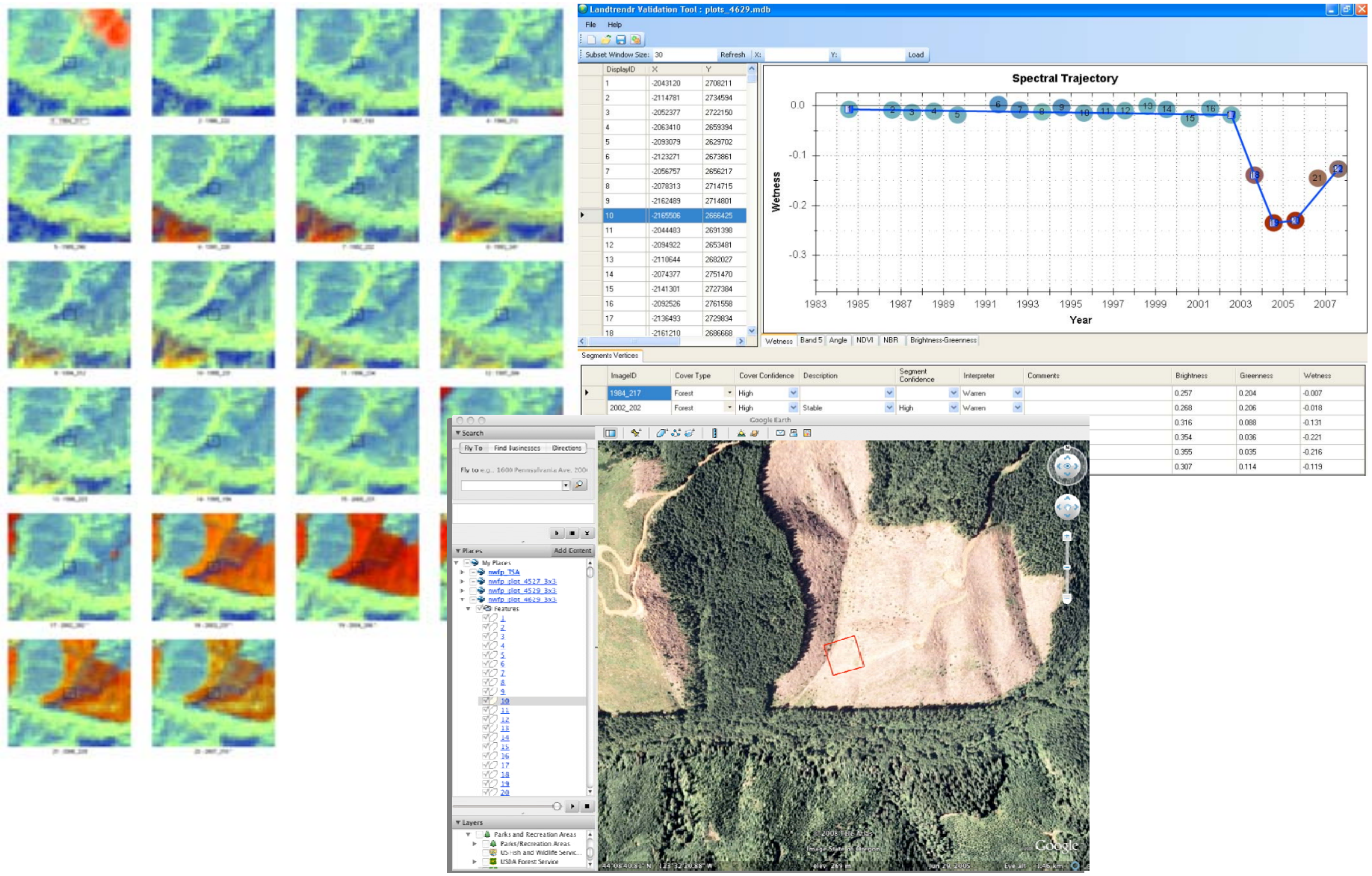
Connected to Access database; picklists, comments

TimeSync: Example ~~Stable-fire-~~ recovery

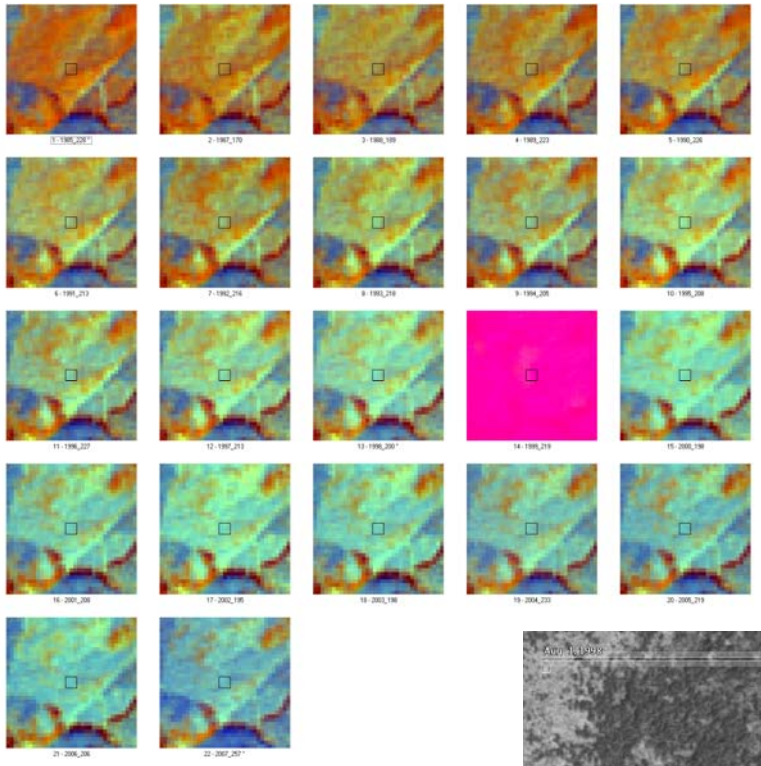


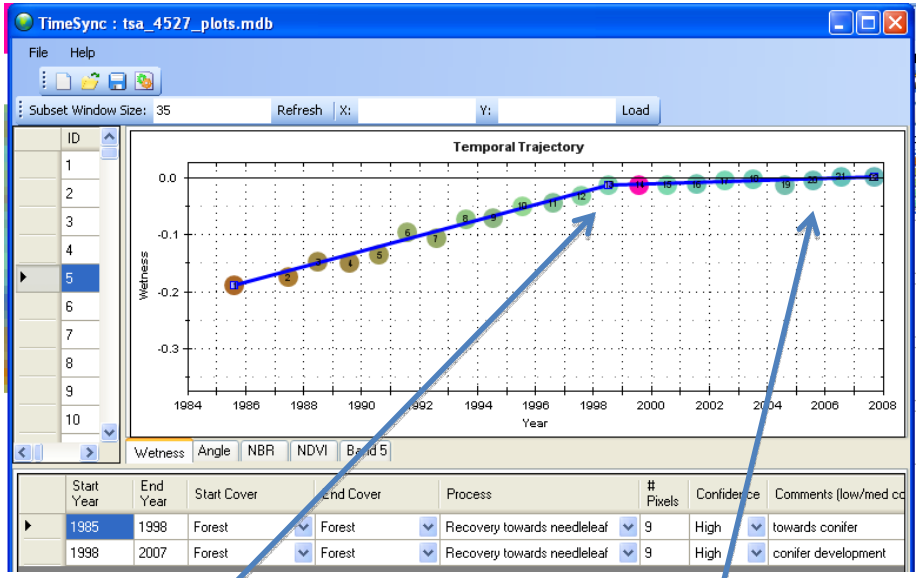


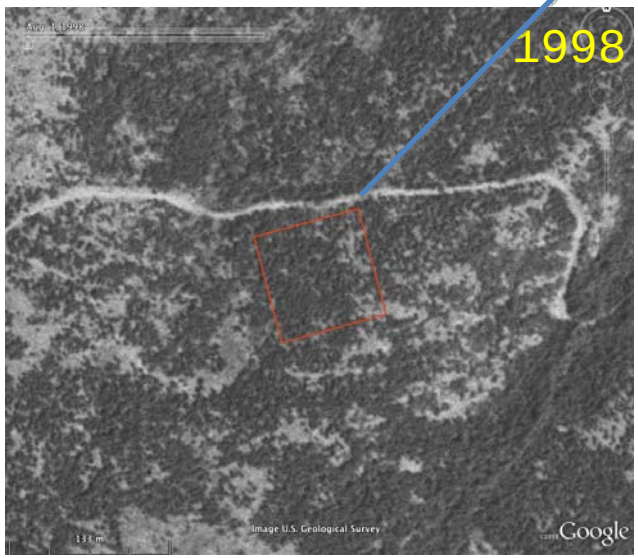
TimeSync Enhancement #2: Google Earth interface



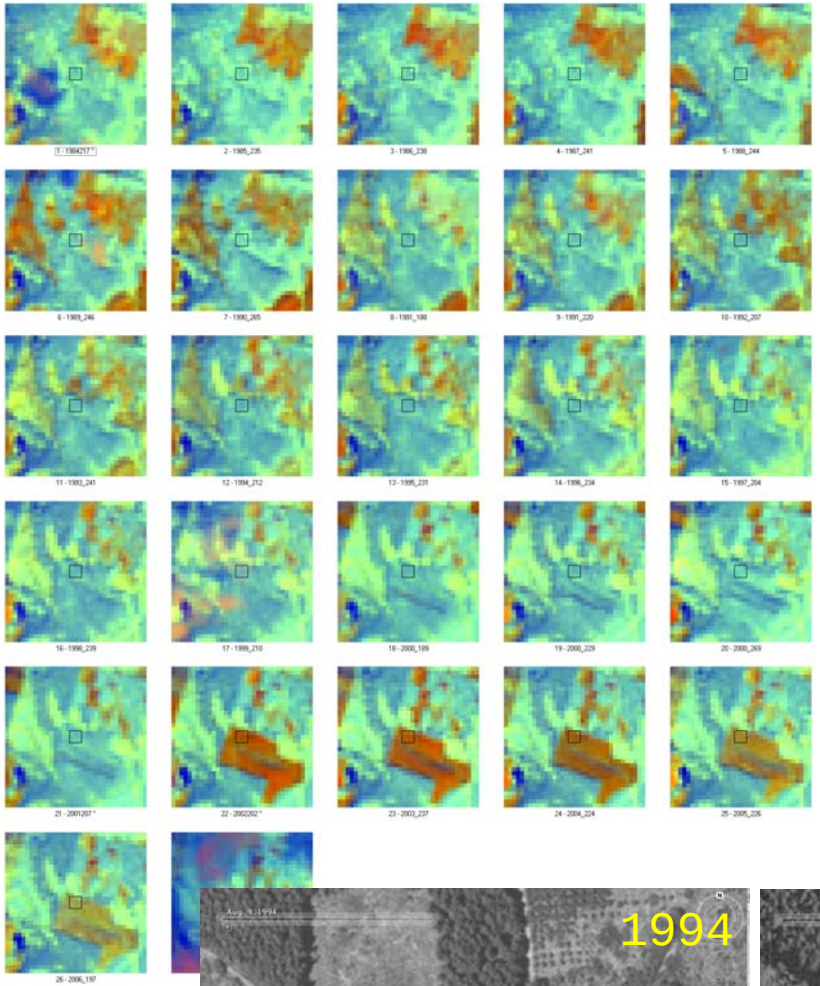
TimeSync: More Examples

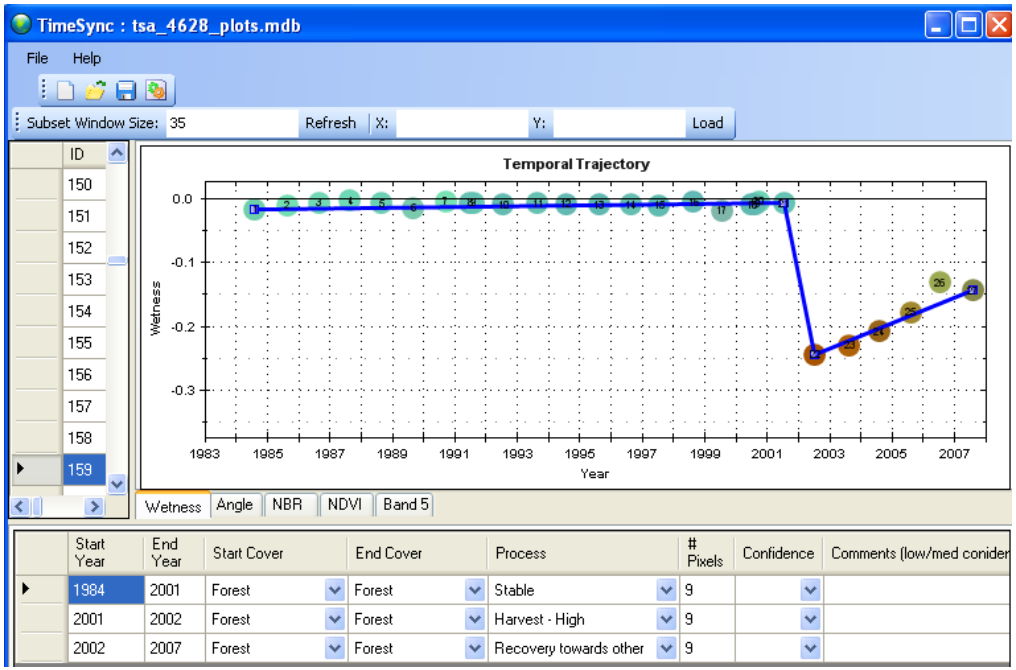




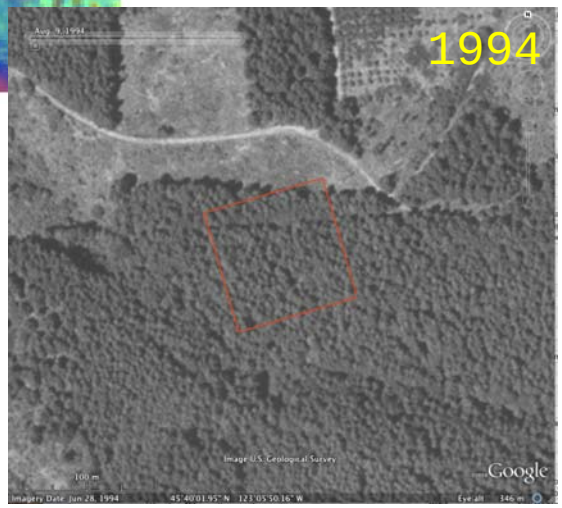


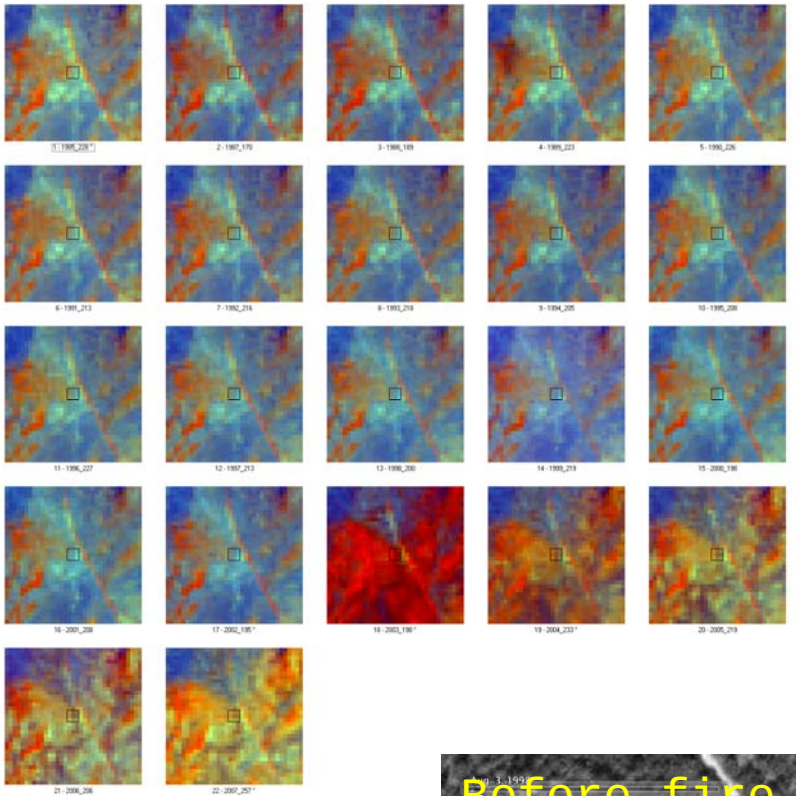
Recover
y only

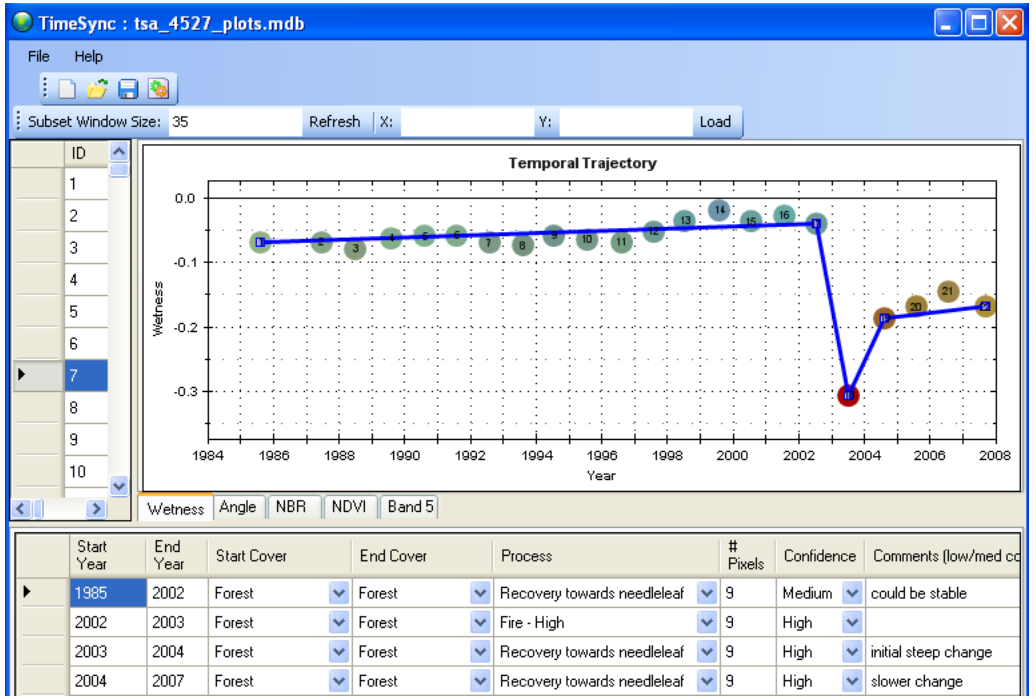




Stable, clearcut, recovery

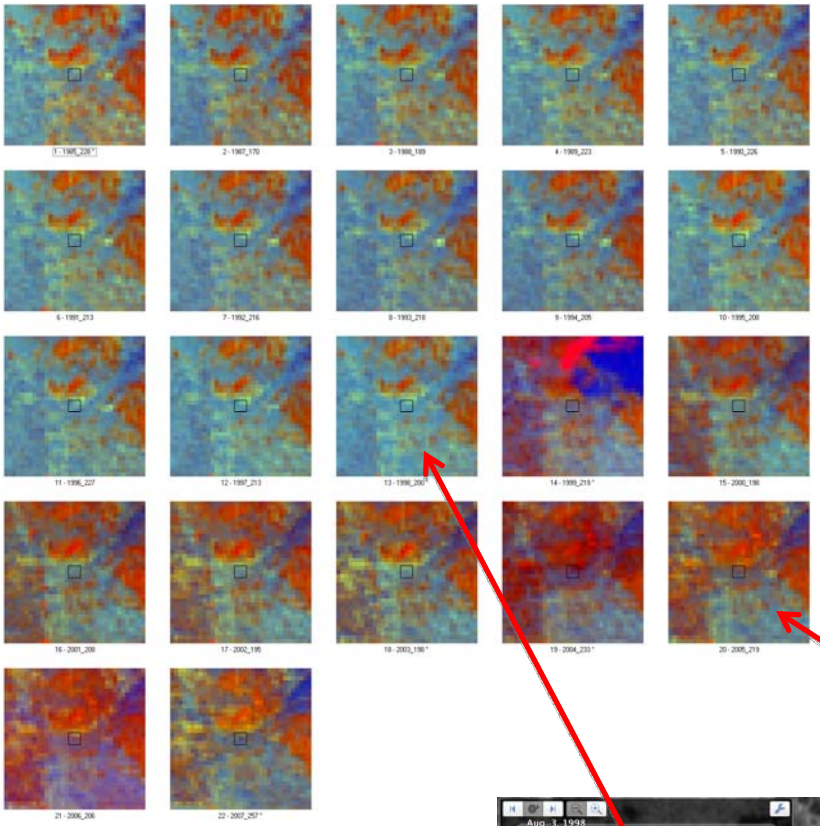


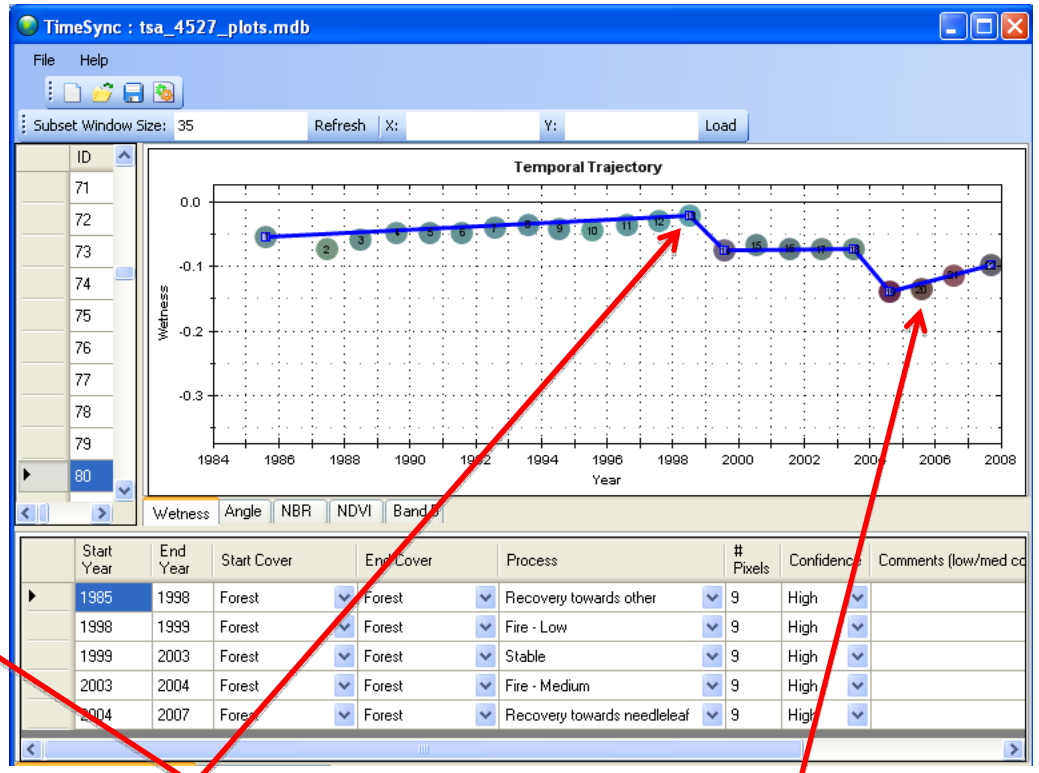


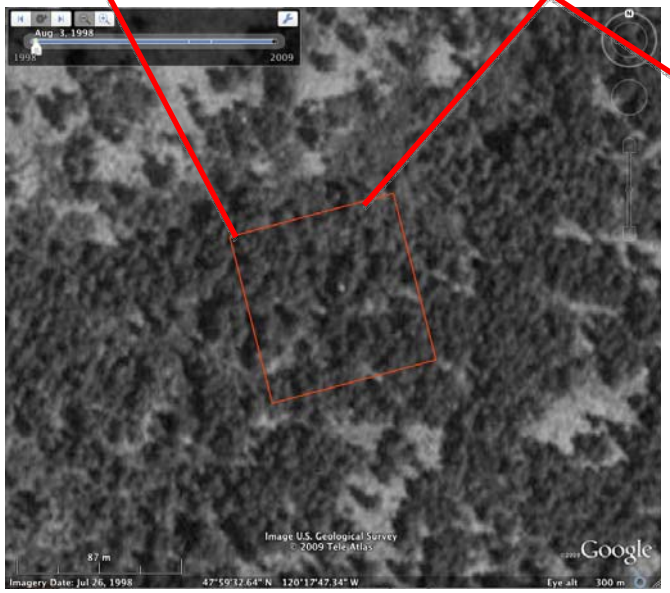


Start Year	End Year	Start Cover	End Cover	Process	# Pixels	Confidence	Comments (low/med cc
1985	2002	Forest	Forest	Recovery towards needleleaf	9	Medium	could be stable
2002	2003	Forest	Forest	Fire - High	9	High	
2003	2004	Forest	Forest	Recovery towards needleleaf	9	High	initial steep change
2004	2007	Forest	Forest	Recovery towards needleleaf	9	High	slower change

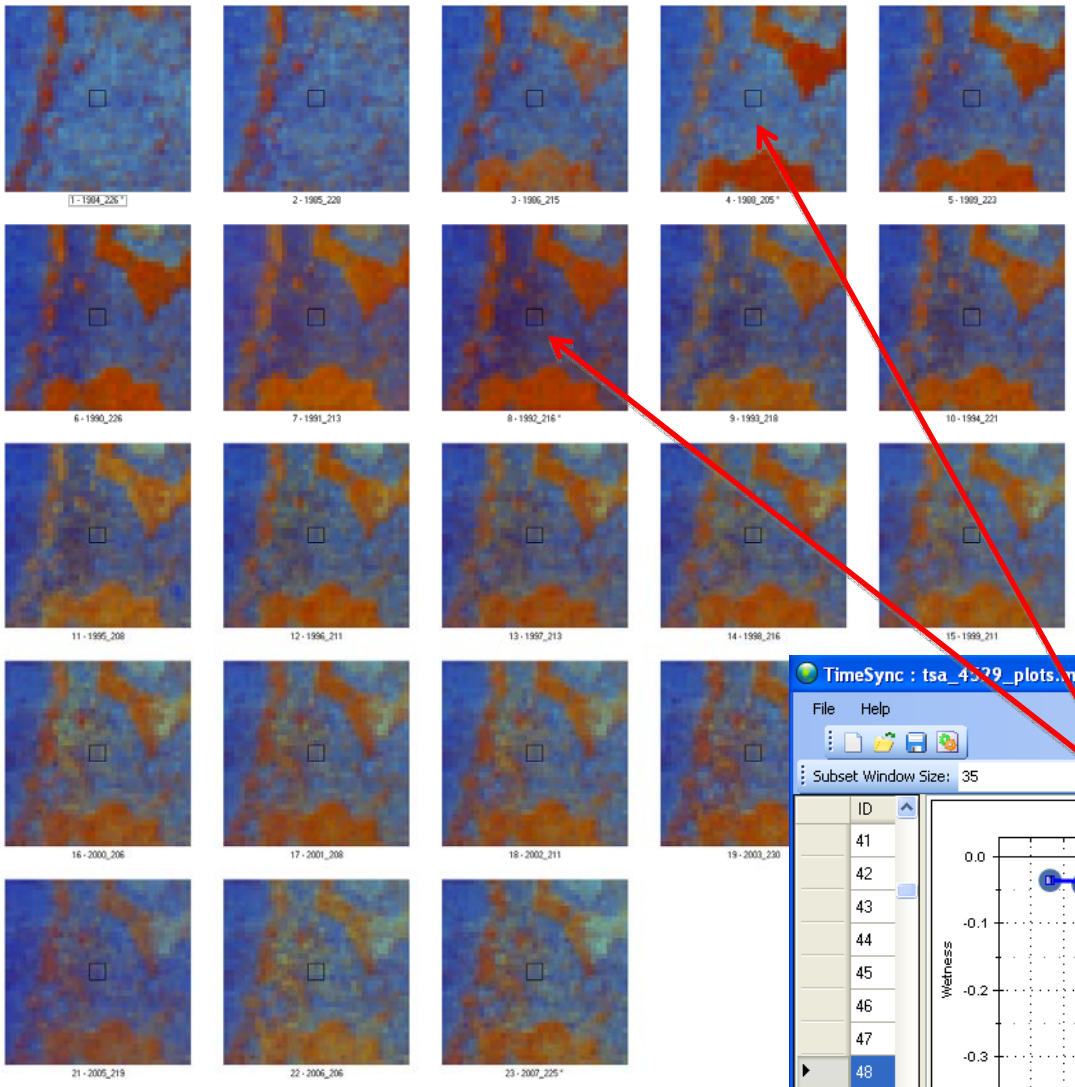
Recovery, hi. int. fire, recovery

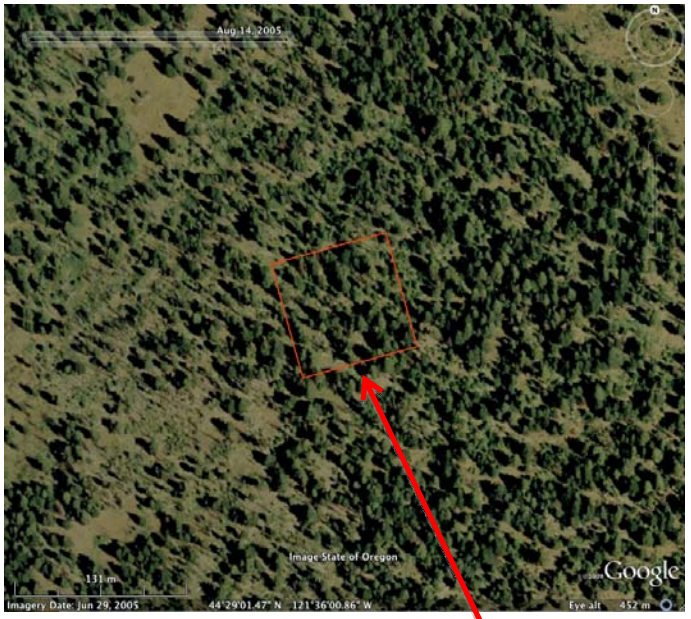


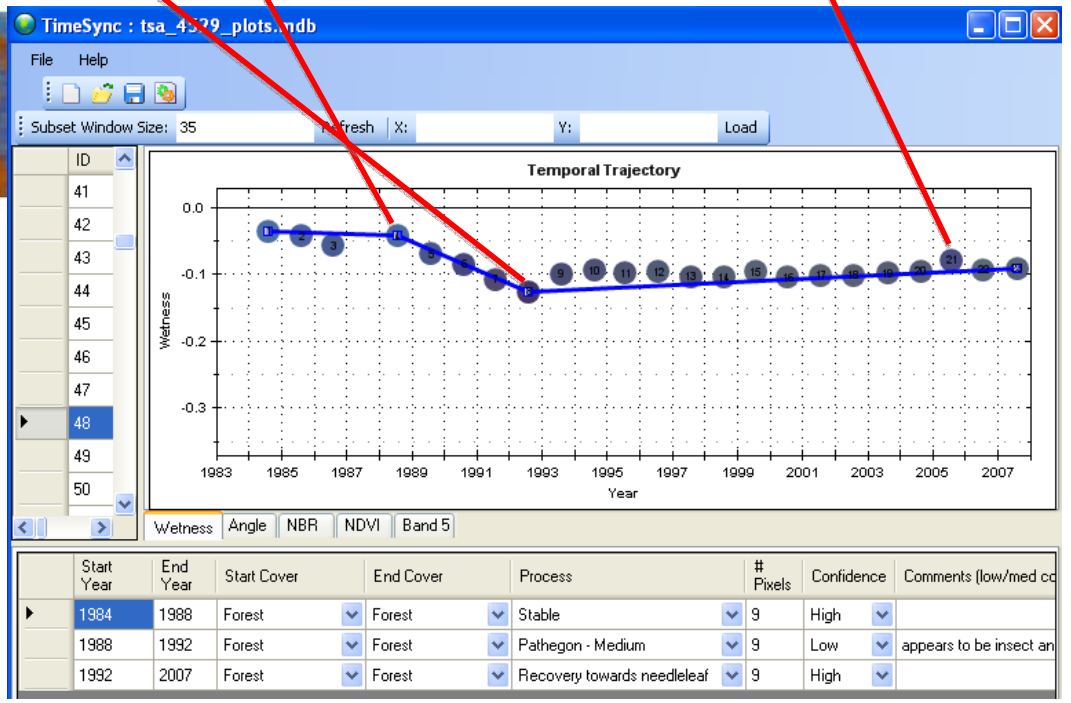




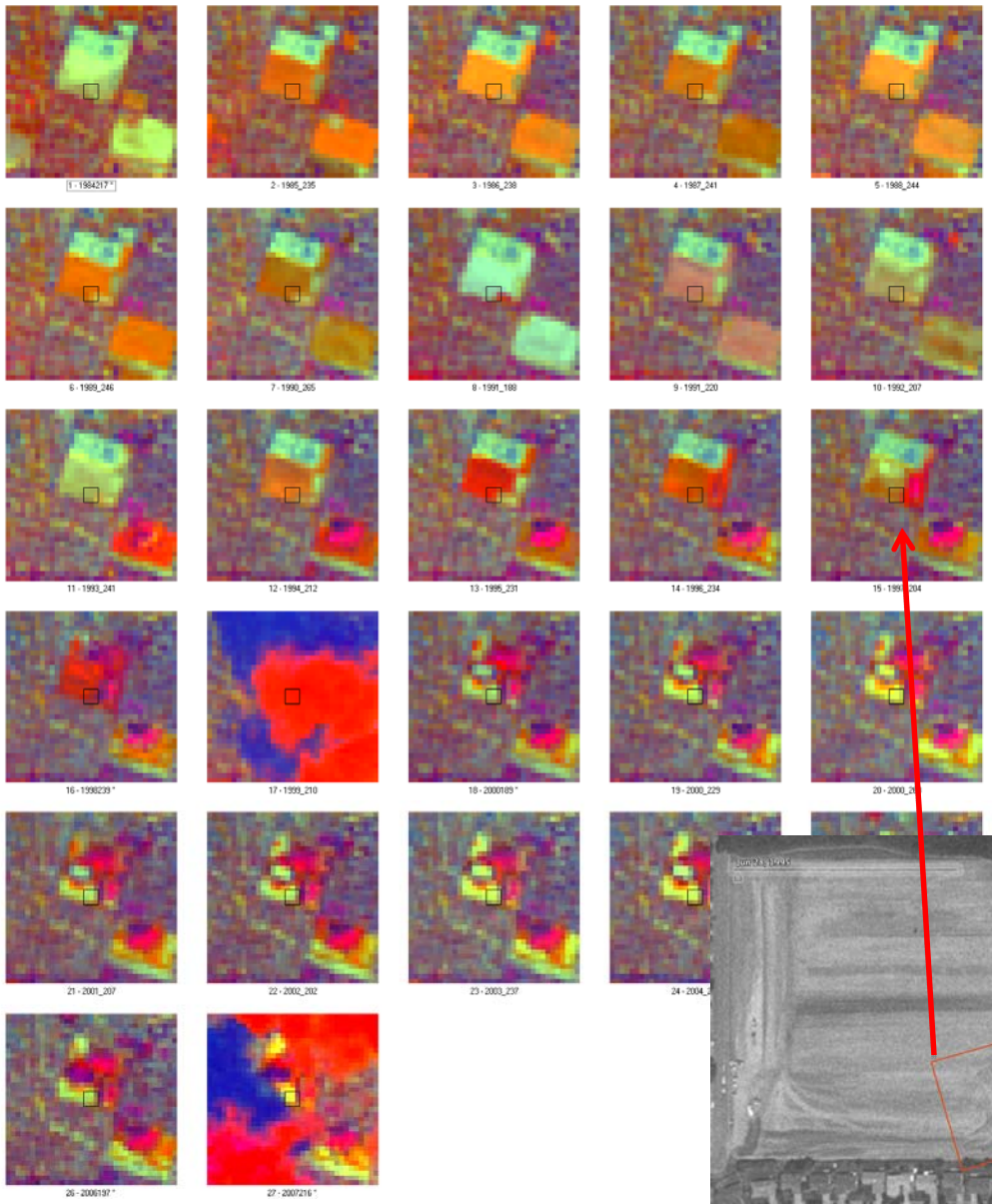
Recovery, low int. fire, stable, mod int. fire,

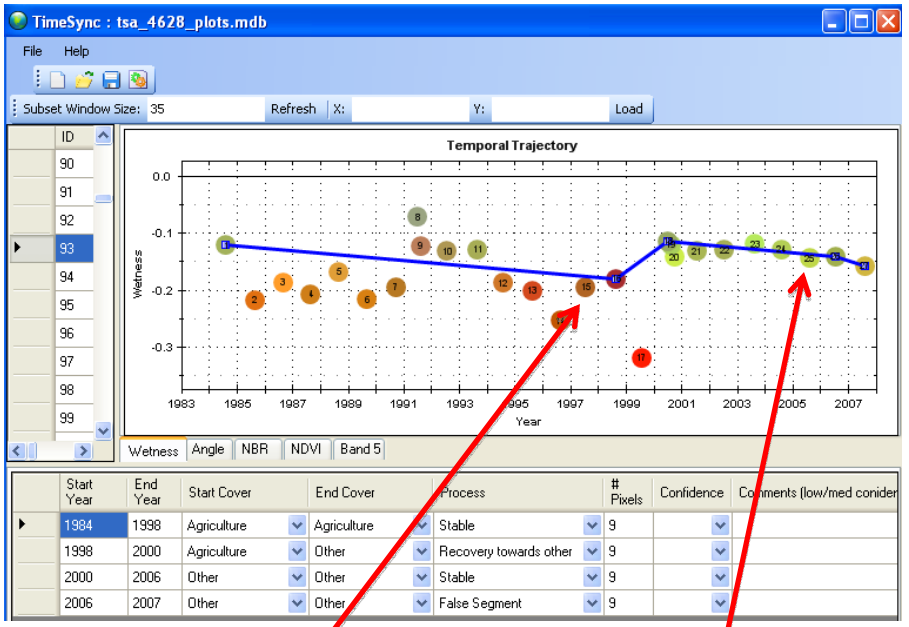




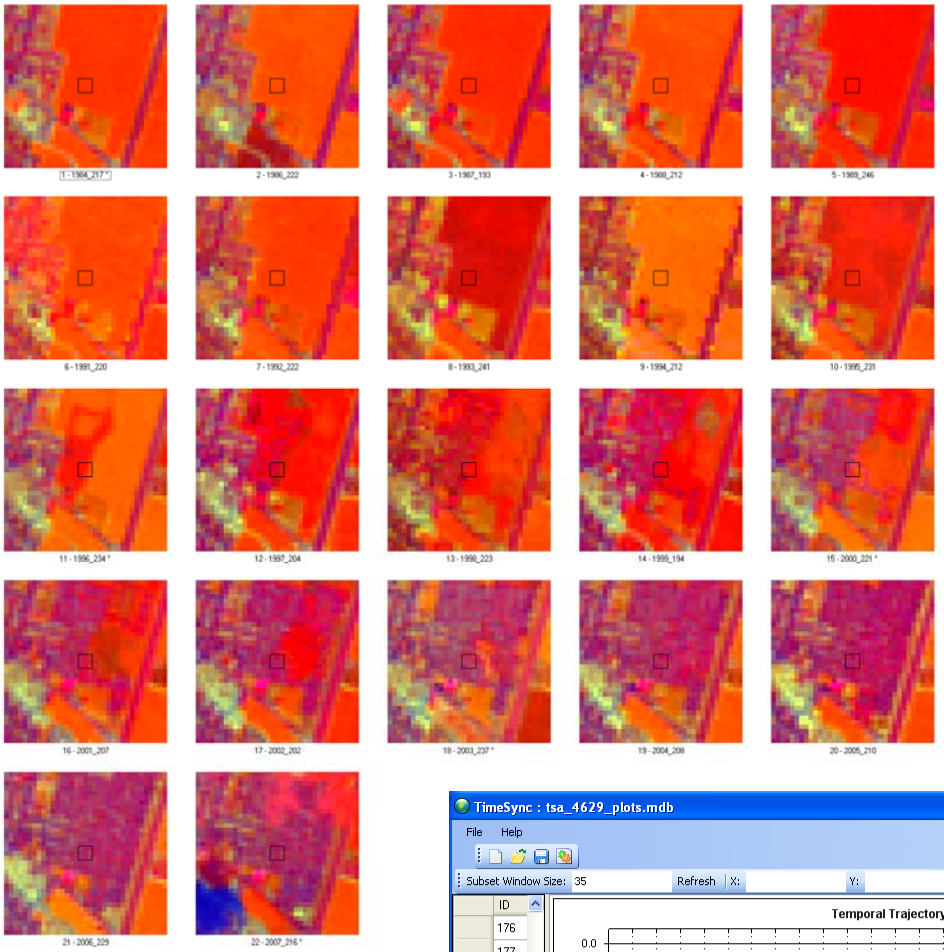


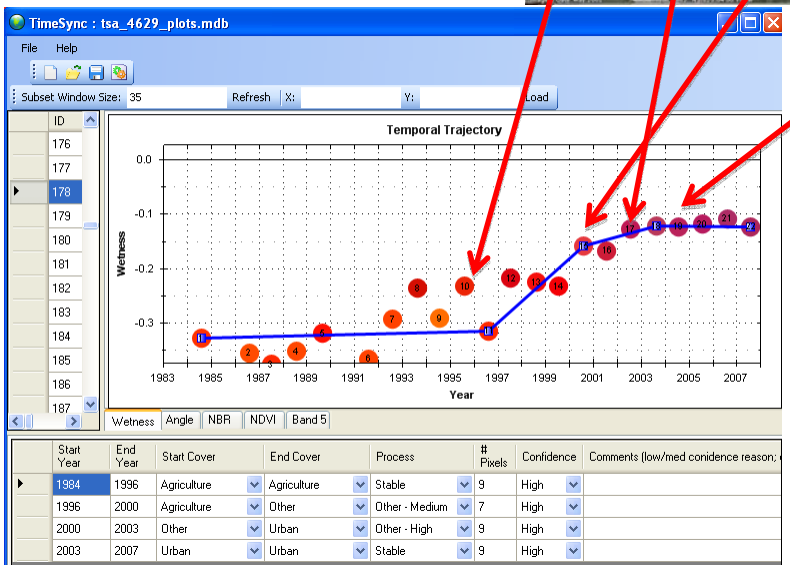
Stable, pathogen, recovery





Agriculture to ball field



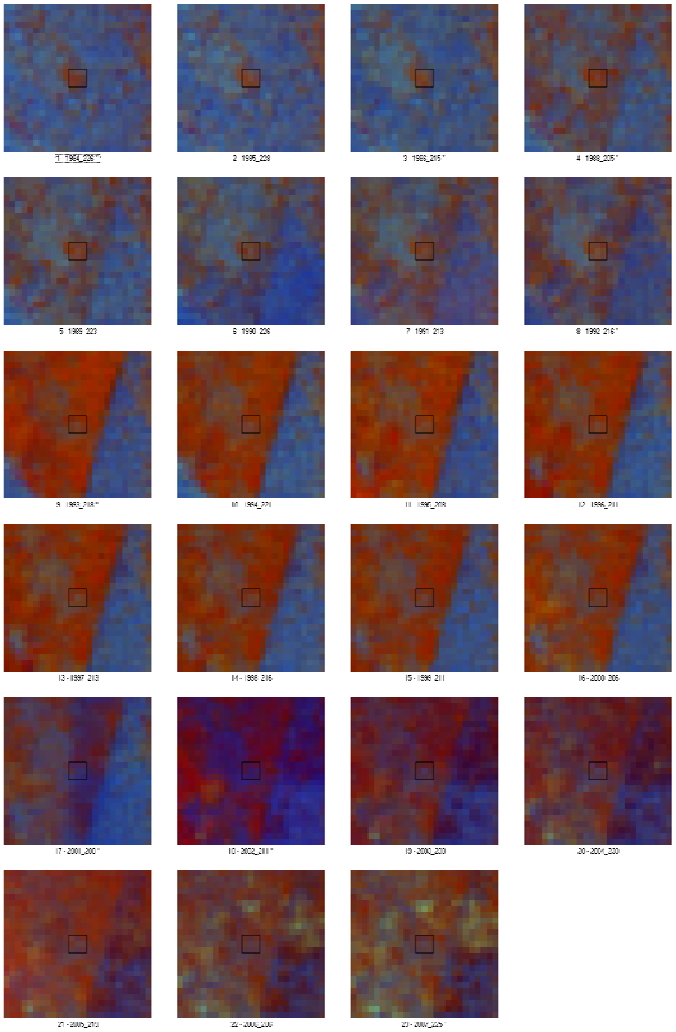


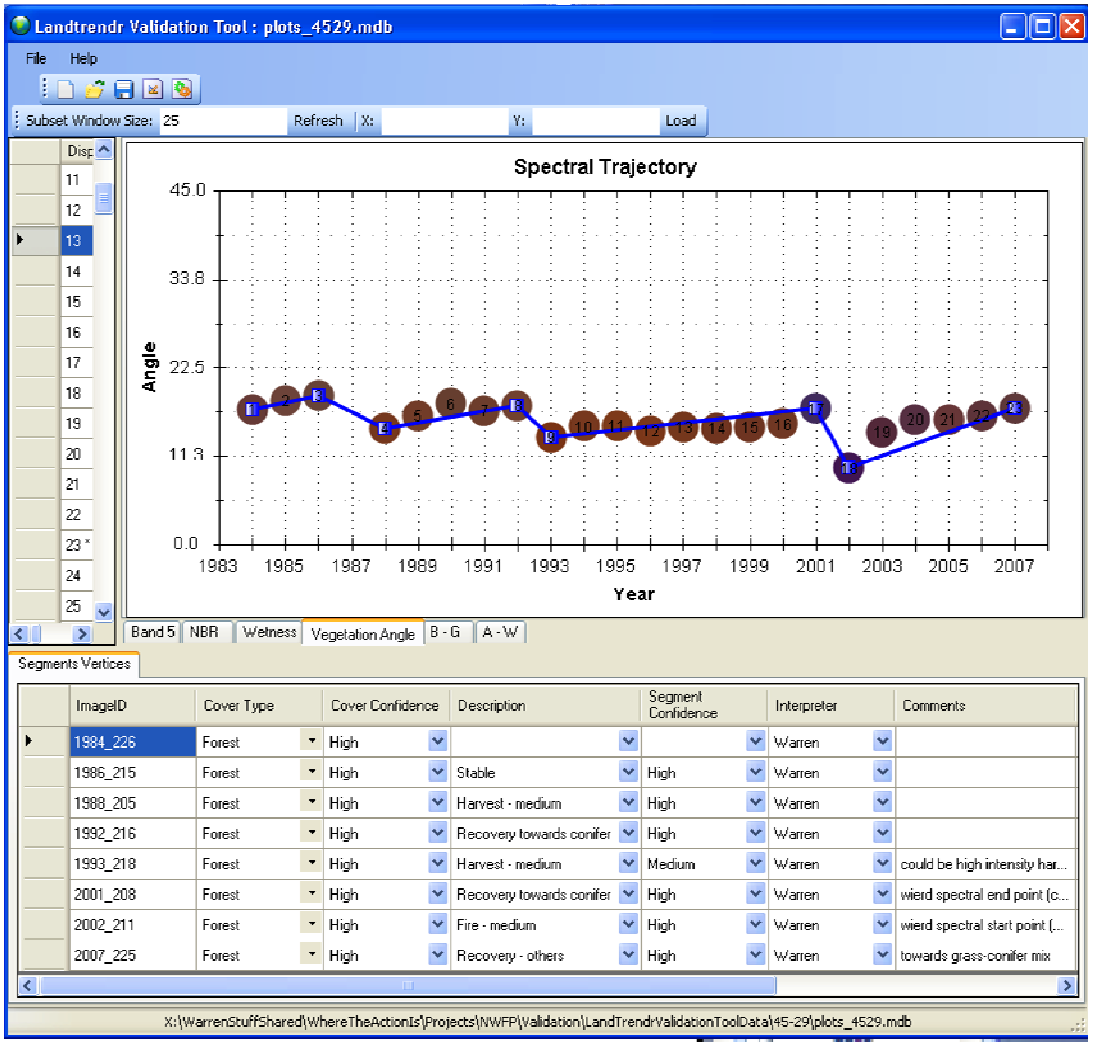
Start Year	End Year	Start Cover	End Cover	Process	# Pixels	Confidence	Comments (low/med conidence reason;
1984	1996	Agriculture	Agriculture	Stable	9	High	
1996	2000	Agriculture	Other	Other - Medium	7	High	
2000	2003	Other	Urban	Other - High	9	High	
2003	2007	Urban	Urban	Stable	9	High	

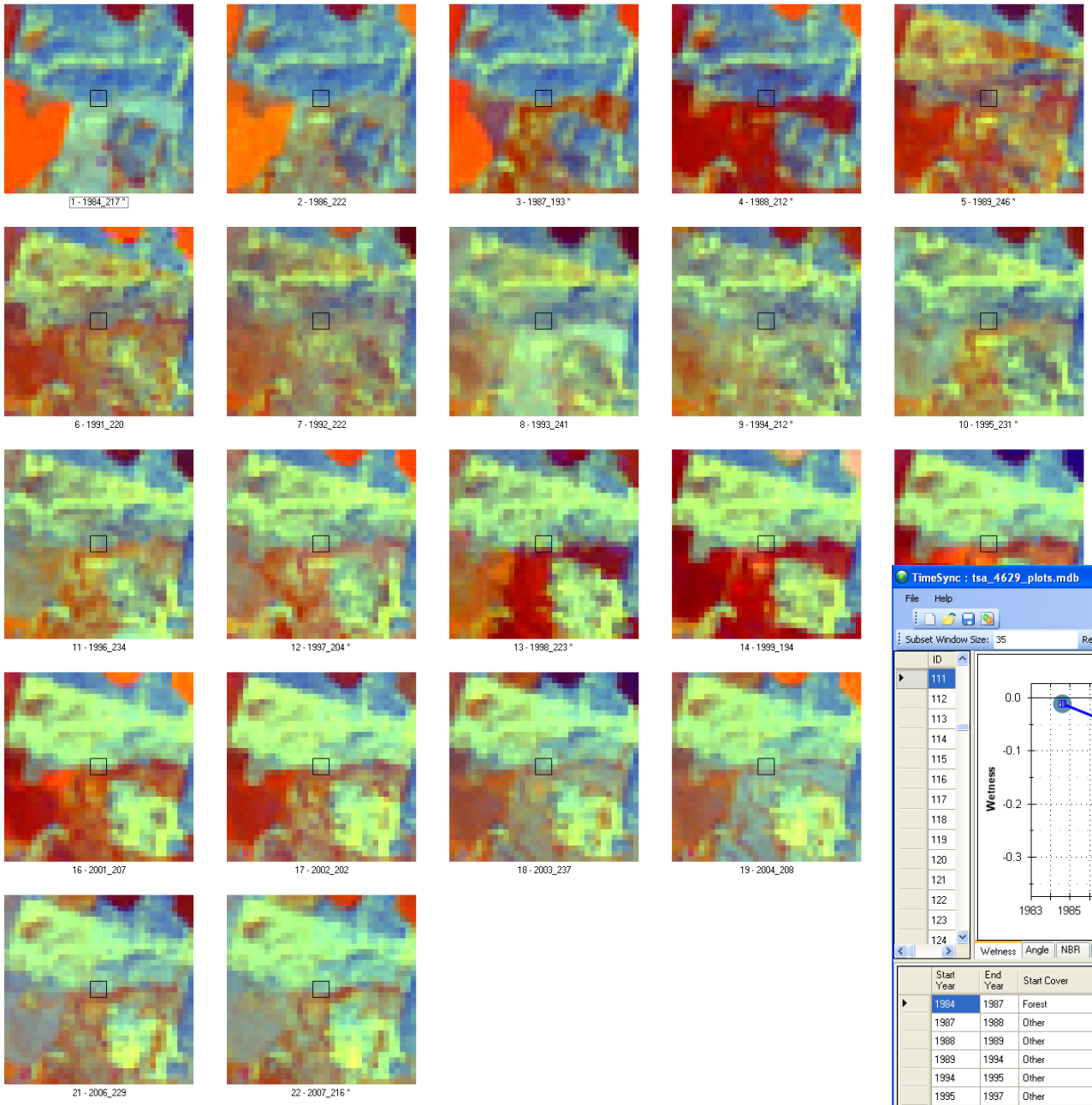
Agriculture to urban in stages

get?

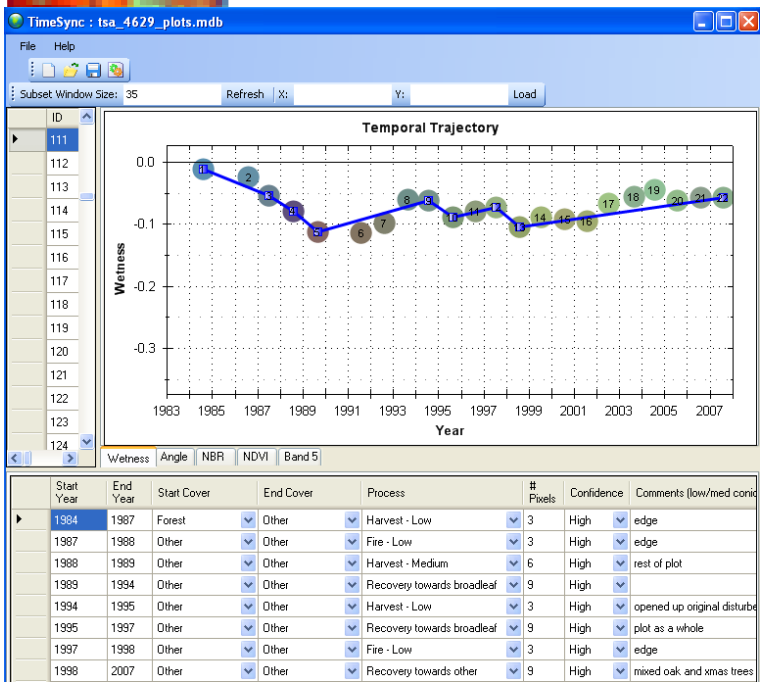
partial harvest, clearcut harvest, wildfire



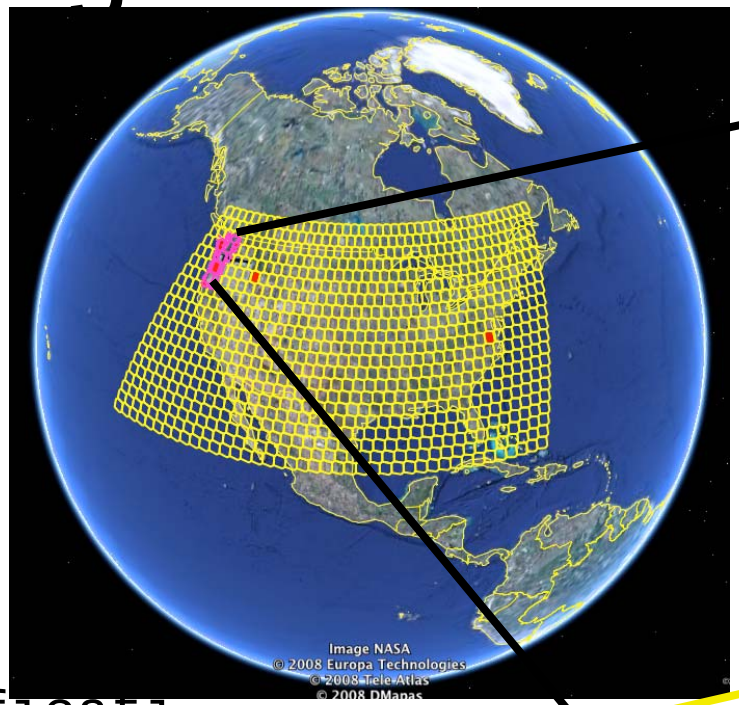



1 - 1984_217 *
2 - 1986_222
3 - 1987_193 *
4 - 1988_212 *
5 - 1989_246 *
6 - 1991_220
7 - 1992_222
8 - 1993_241
9 - 1994_212 *
10 - 1995_231 *
11 - 1996_234
12 - 1997_204 *
13 - 1998_223 *
14 - 1999_194
16 - 2001_207
17 - 2002_202
18 - 2003_237
19 - 2004_208
21 - 2006_229
22 - 2007_216 *

Edginess

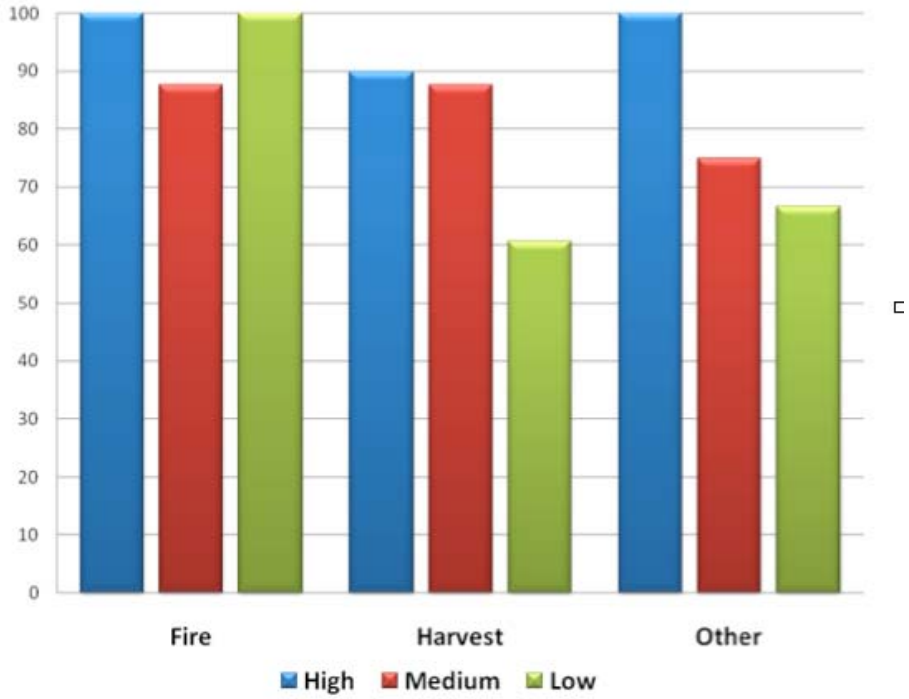

TimeSync : tsa_4629_plots.mdb
File
Help
Subset Window Size: 35
Refresh
X:
Y:
Load
ID
111
112
113
114
115
116
117
118
119
120
121
122
123
124
Temporal Trajectory
Wetness
0.0
-0.1
-0.2
-0.3
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
Wetness
Angle
NBR
NDVI
Band 5
Start Year
End Year
Start Cover
End Cover
Process
Pixels
Confidence
Comments (low/med conic
1984 1987 Forest Other Harvest - Low 3 High edge
1987 1988 Other Other Fire - Low 3 High edge
1988 1989 Other Other Harvest - Medium 6 High rest of plot
1989 1994 Other Other Recovery towards broadleaf 9 High
1994 1995 Other Other Harvest - Low 3 High opened up original disturbe
1995 1997 Other Other Recovery towards broadleaf 9 High plot as a whole
1997 1998 Other Other Fire - Low 3 High edge
1998 2007 Other Other Recovery towards other 9 High mixed oak and xmas trees

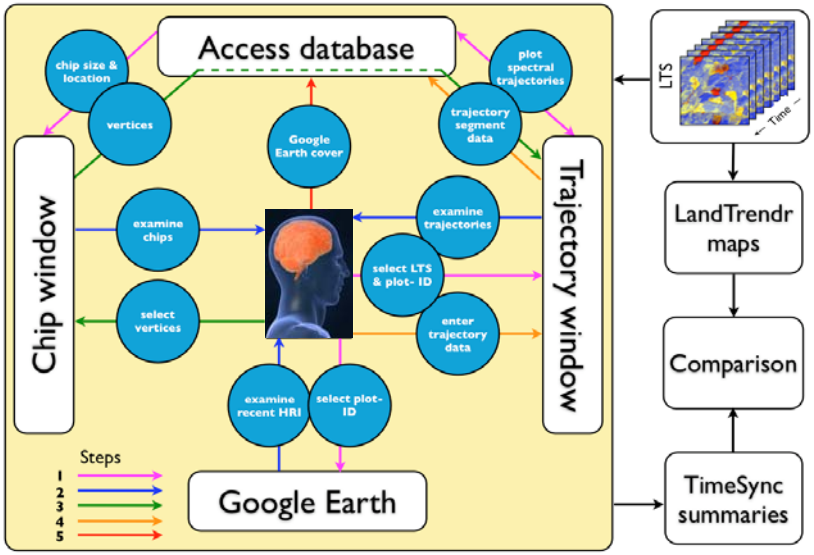
TimeSync: Sample Design.....



- Stratification by TSA
- Randomly located plot list
- Interpret ~ 200 per full TSA

LandTrendr





Example: Percent agreement—*disturbance agent* and *relative*

Type 2. Can We Trust TimeSync Interpretations?

- Intersect TimeSync plots with USFS FACTS and FHM, BLM, and MTBS databases
- Derive agreement matrices
- Explore/explain disagreements
- Caveats
  - FACTS and BLM databases are from only portions of the land base
    - Most of the forest management activity since early 90s has been on private lands for which databases not available
    - Databases are in various degrees of completeness and usability
  - MTBS is fire only

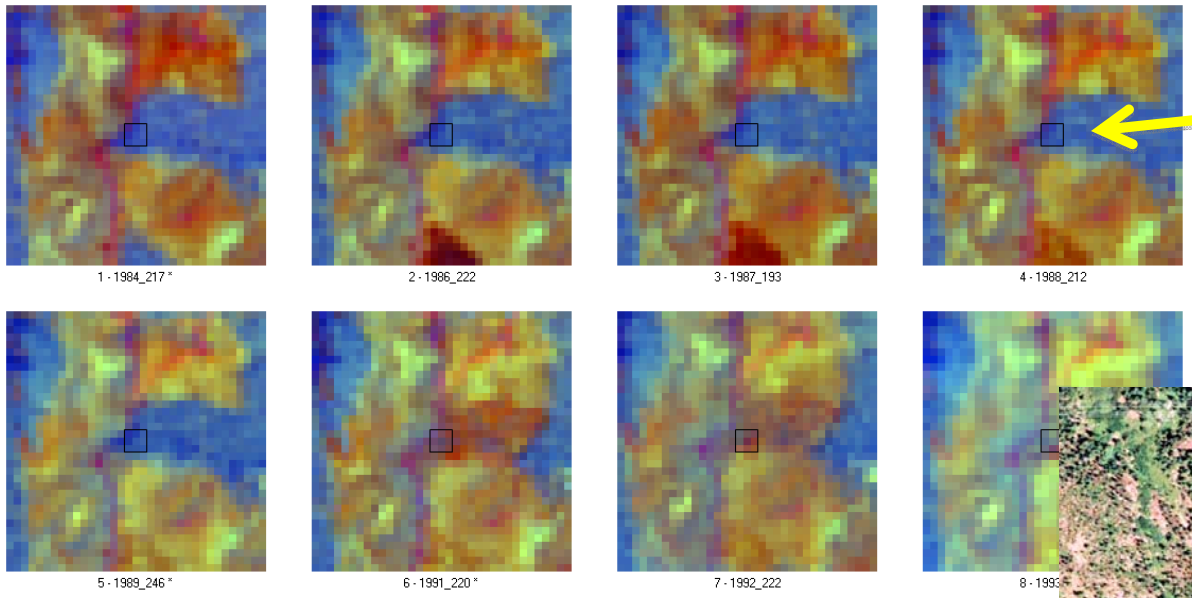
Initial Results (from 4 TSAs)

	MTBS Burn Intensity (weighted mean) + R. Davis						
TimeSync	**V.Low (0-0.5)**	**Low (0.51-2.5)**	**Medium (2.51-3.5)**	**High (3.51-4)**	**R. Davis**	**Not Disturbed**	**Notes**
Harvest		1					plot 45-27: 29 (very edge of Hatchery fire, near housing, I
Fire		**8**	**10**	**4**	**4**	1	plot 45-27: 84 (2004, I think MTBS missed it)
Not Disturbed						**517**	
Totals	0	9	10	4	4	518	**545**
Agreement	**0.996**						

	Integrated FACTS-FOI						
TimeSync	**Harvest (C)**	**Harvest (PC)**	**Fire**	**Insect**	**Road**	**Not Disturbed**	**Notes**
Harvest	**8**	**2**				10	8 of 10 not disturbed are real changes, 2 are tough calls
Fire						11	all confirmed by MTBS
Insect						8	7 confirmed by FHM
Road						3	all real
Not Disturbed	1	7	2			**143**	(1) salvage after high intensity fire, (7) pre-commercial thin, (2) low intensity prescribed burn
Totals	9	9	2	0	0	175	**195**
Agreement	**0.785**		***TS accuracy***	***0.933***			

Disagreement: Which is correct?

- FACTS says not harvested

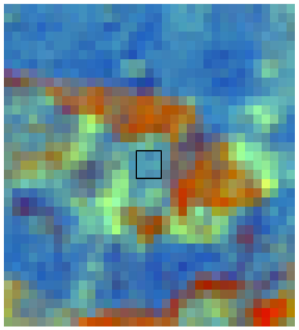


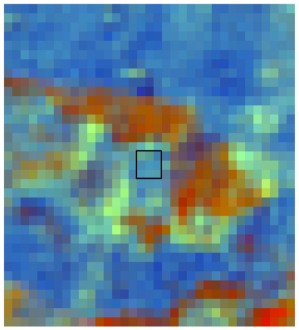
Area of interest

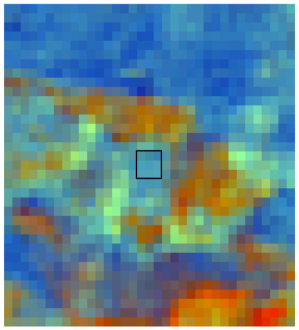
46-29 plot 172

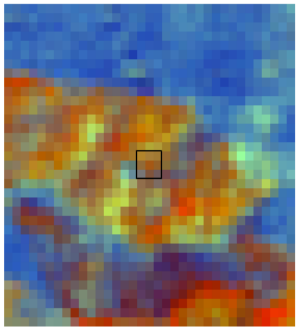
Disagreement: Which is correct?

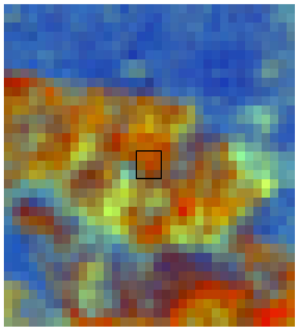
- FACTS says not harvested

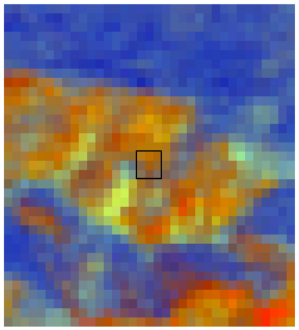






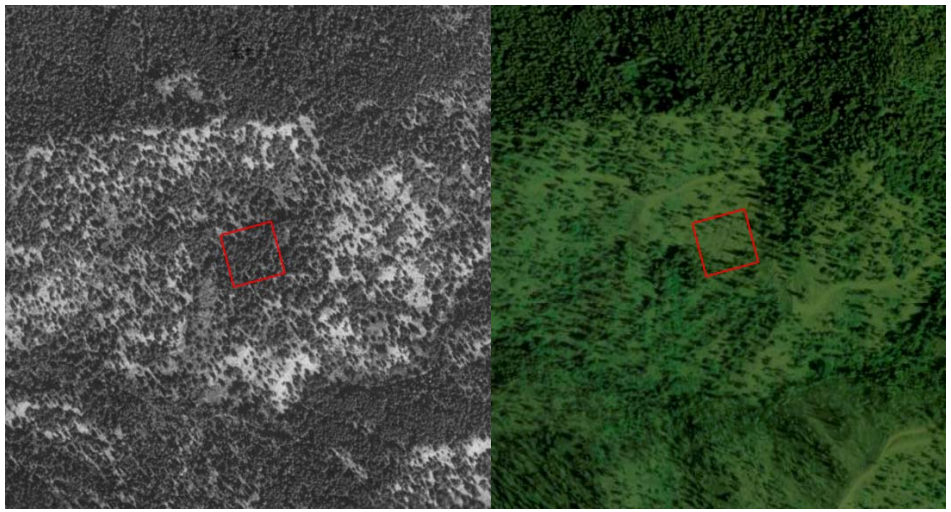






2006

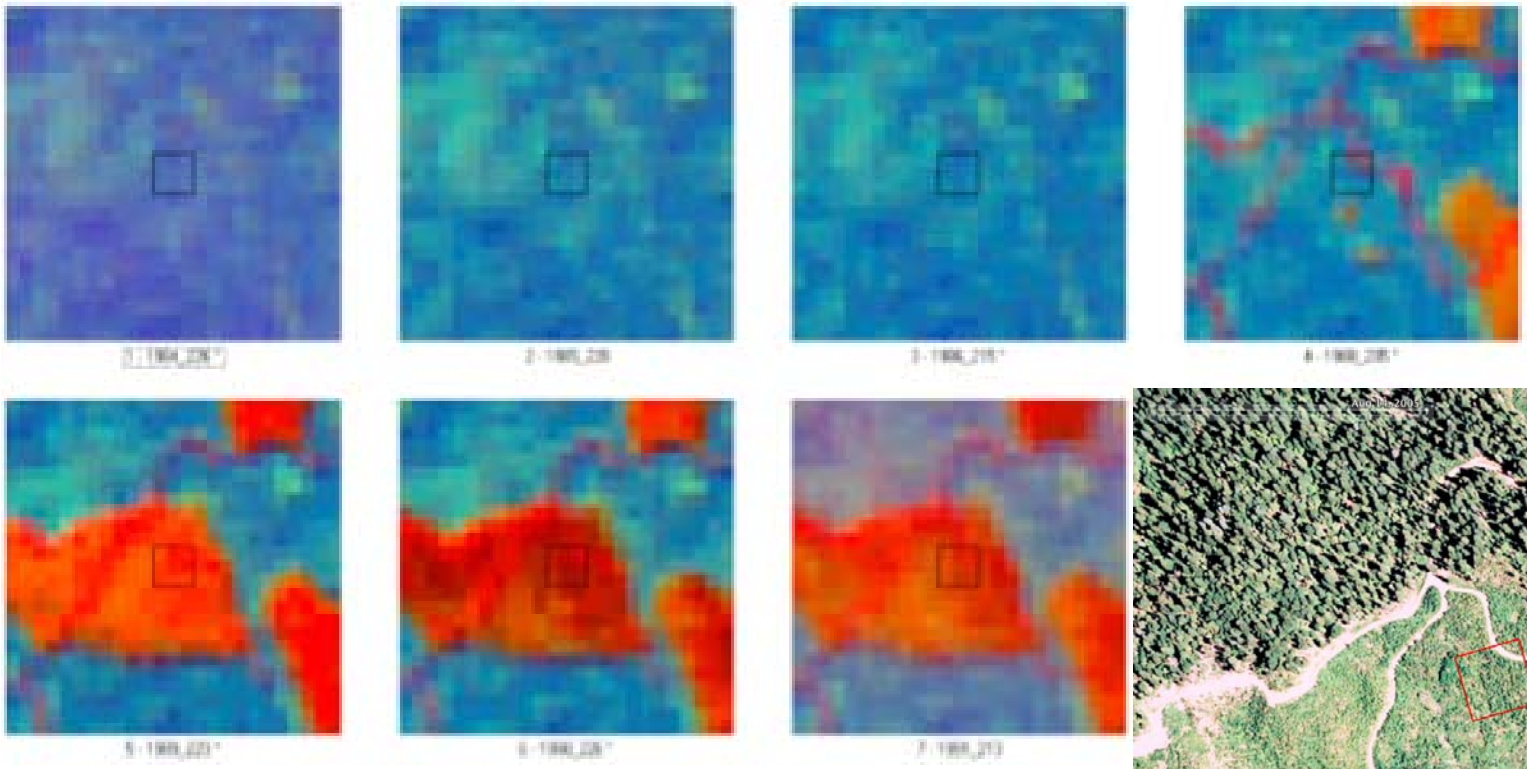
1998



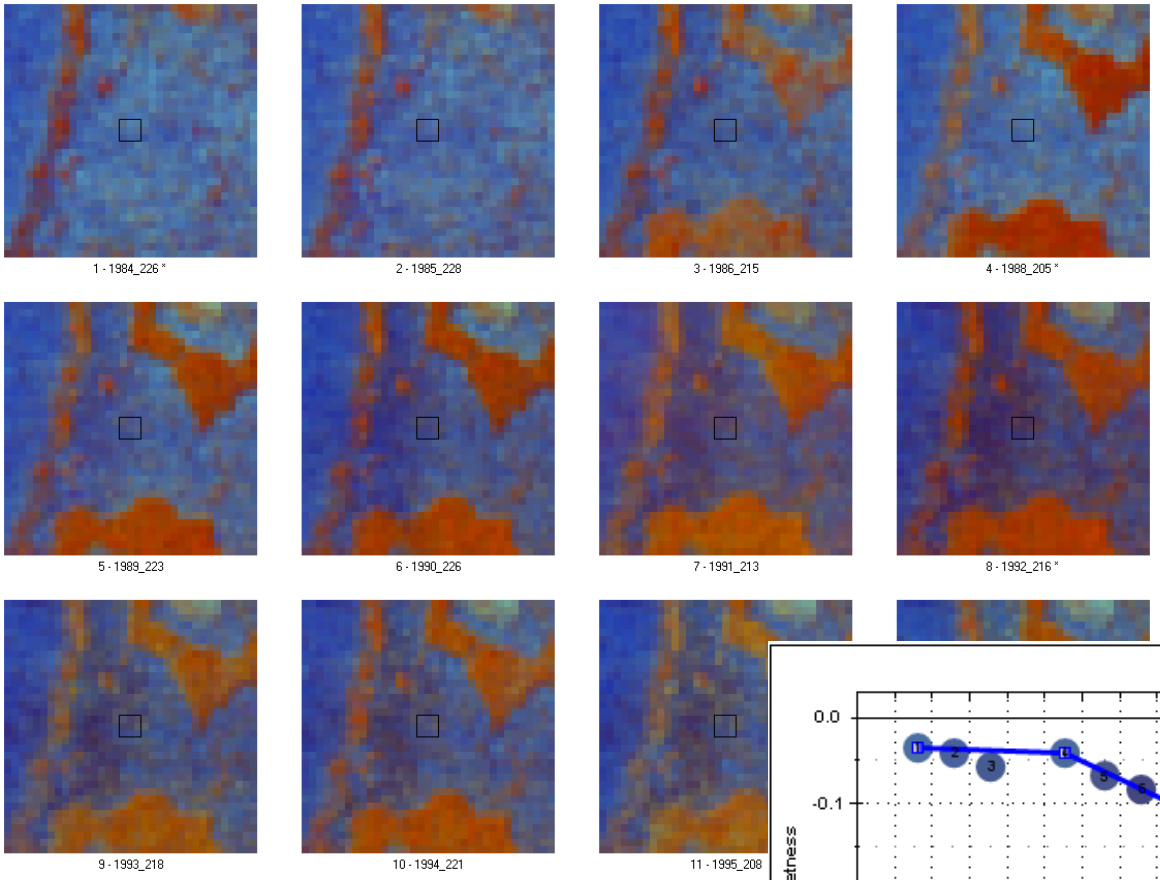
45-27 plot 38

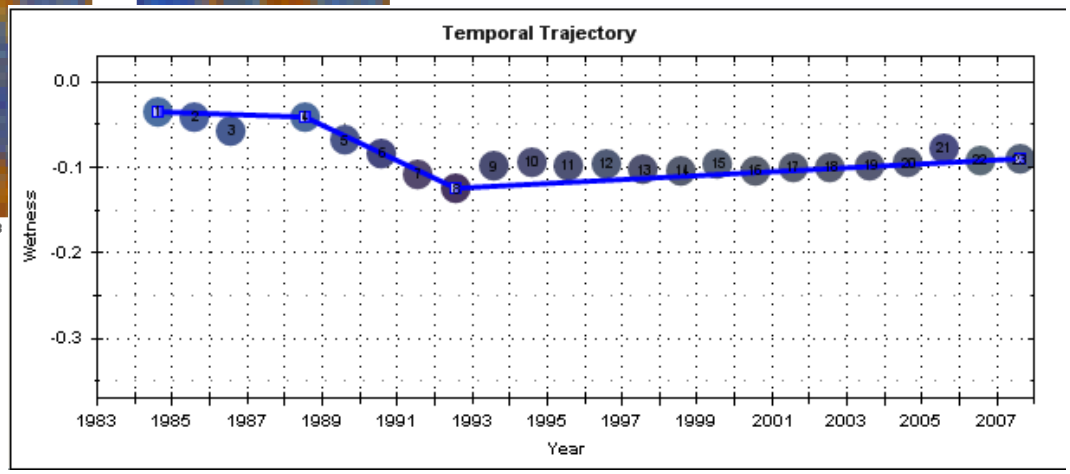
Disagreement: Which is correct?

- FACTS says no road



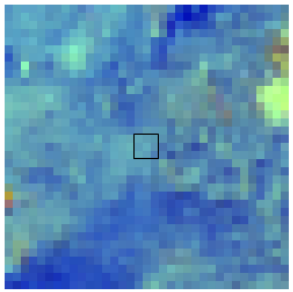
Not in FACTS (FHM confirms insects)

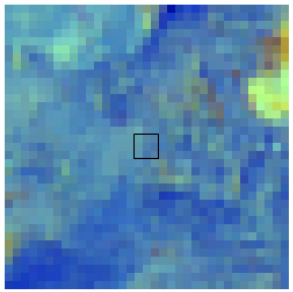


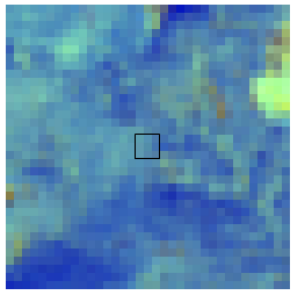


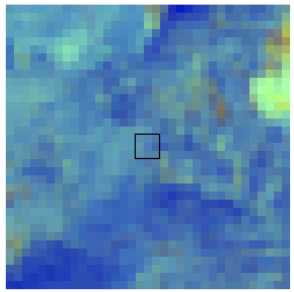
45-29 plot 48

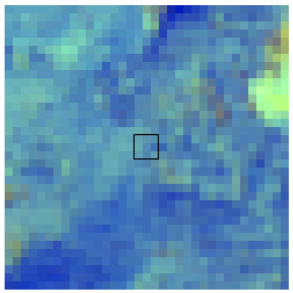
Not in FACTS (MTBS corroborates fire)

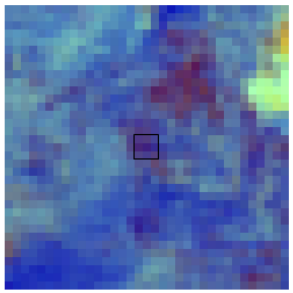

13 - 1998_223

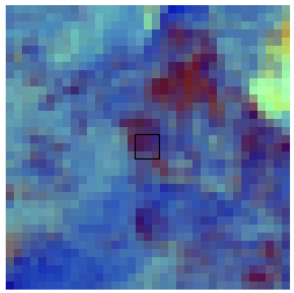

14 - 1999_194

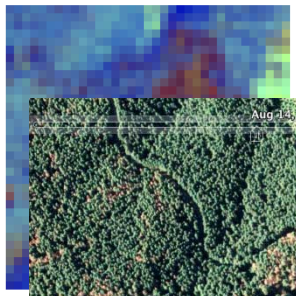

15 - 2000_221


16 - 2001_207


17 - 2002_202 *


18 - 2003_237

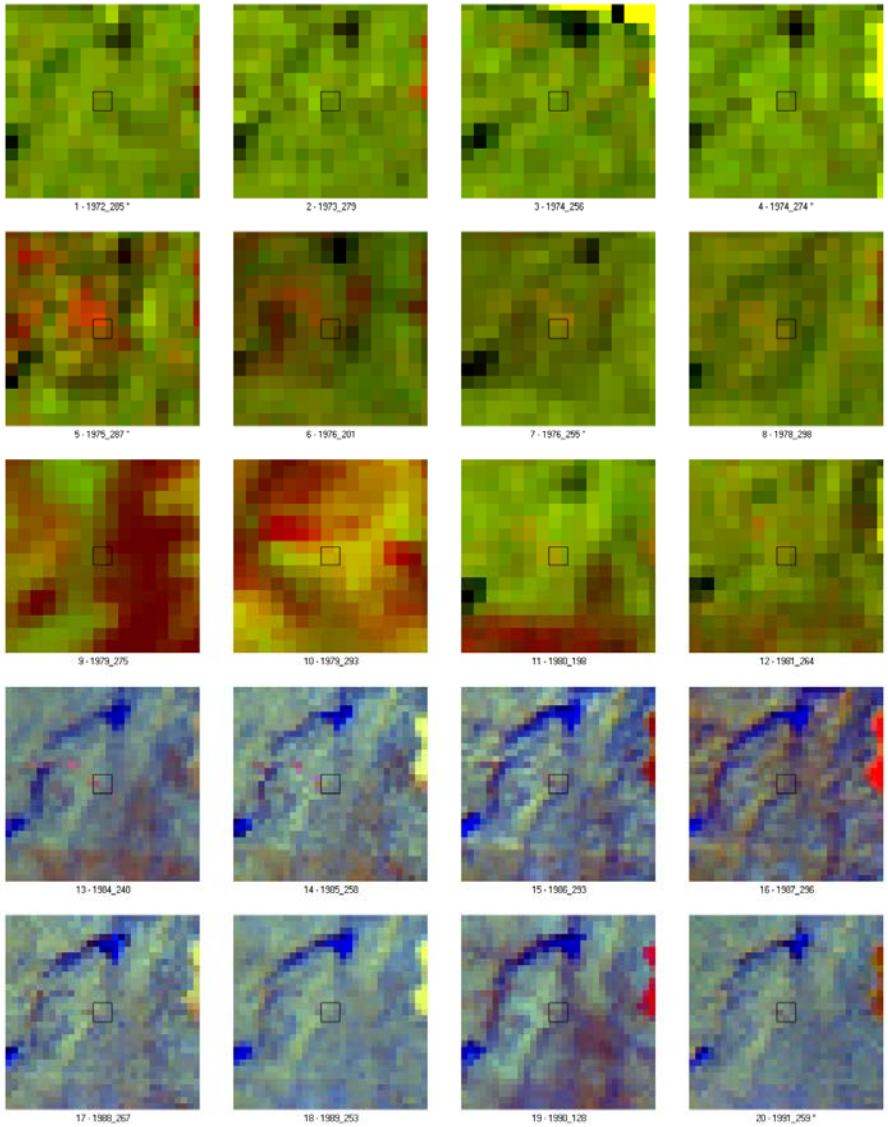

19 - 2004_208 *

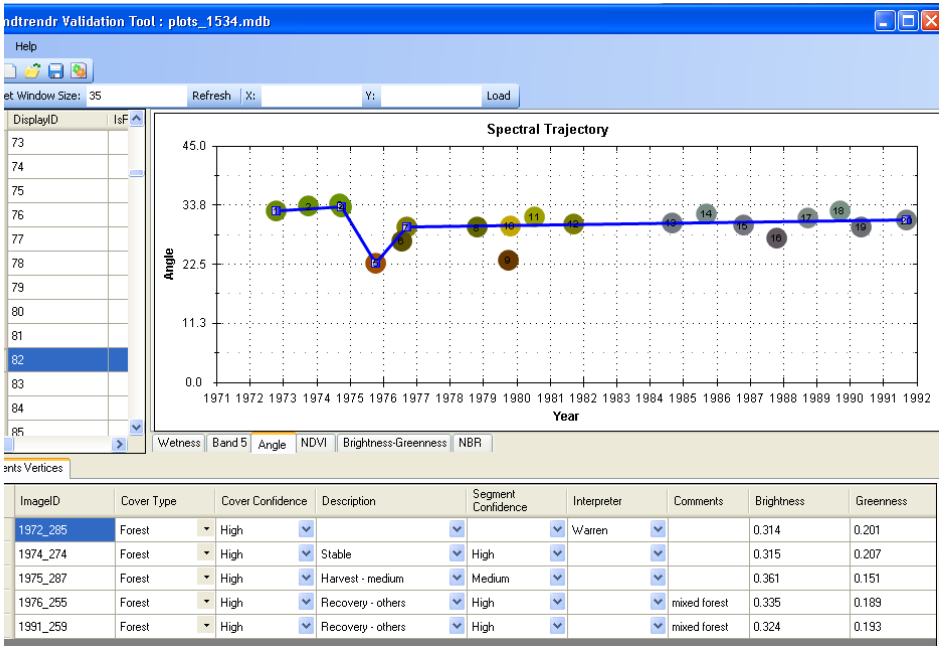


46-29 plot 5

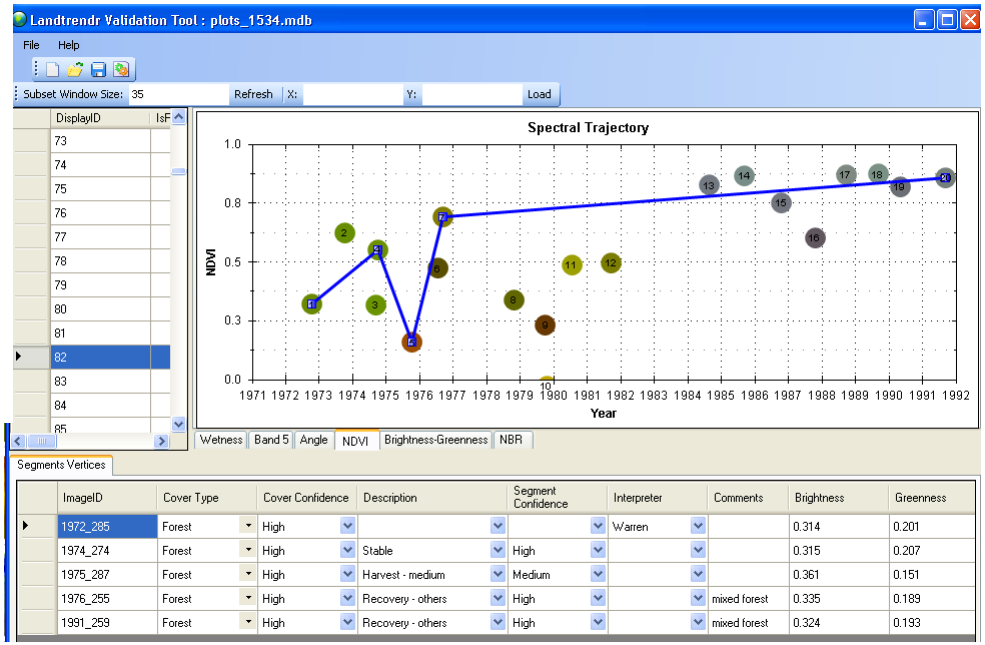
Summary: LandTrendr & TimeSync

- Opening of the archive = paradigm shift in Landsat change detection
- Automated algorithms (e.g., LandTrendr - Kennedy) already exploiting the archive regionally, nationwide, as well as internationally (plus: exploring MSS-ETM+)
  - LandTrendr composites to remove clouds and SLC-off gaps
  - Smooths time series between change vertices enabling functional linkage between spectral properties and map classifications through time
- Given temporal and spatial richness of change information from algorithms, paucity of independent data to conduct validation





ImageID	Cover Type	Cover Confidence	Description	Segment Confidence	Interpreter	Comments	Brightness	Greenness
1972_285	Forest	High			Warren		0.314	0.201
1974_274	Forest	High	Stable	High			0.315	0.207
1975_287	Forest	High	Harvest - medium	Medium			0.361	0.151
1976_255	Forest	High	Recovery - others	High		mixed forest	0.335	0.189
1991_259	Forest	High	Recovery - others	High		mixed forest	0.324	0.193



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Real change in MSS era, Angle v. NDVI