Mt. Hood and Badger Creek Wilderness (zone of heavy prior defoliation) from Flag Point, OR, October 2009

Using LandTrendr remote sensing to monitor insect effects on tree mortality and surface fuels in Oregon forests

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Wood boring beetle galleries on a charred log, Gnarl Ridge Fire, north of Mt. Hood, OR, November 2009

Research objectives

1. Characterize insect activity with field, aerial, and satellite obs.
2. Map insect activity for Oregon Cascades
3. Use maps to explore insect-fire interactions

Satellite tools

LandTrendr: Landsat based detection of Trends in Disturbance and Recovery

A powerful new tool for change detection
- Detects both abrupt events and long-term processes
- Leverages the free Landsat data archive
- Improves detection of subtle change, including insects, thinning, drought, encroachment, growth

How it works:
- Mathematically observe the "life of a pixel" for 20+ years
- Automatic segmentation smoothes out year-to-year noise
- Maps are derived from start, end, and slope of segments

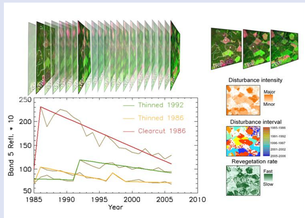

Figure 1. LandTrendr schematic adapted from Kennedy et al. 2007

Field sampling

Two zones in the Oregon Cascades
- Mt. Hood, affected predominantly by western spruce budworm (WSB; *Chonistoneura occidentalis*)
- Cascade Lakes, affected predominantly by mountain pine beetle (MPB; *Dendroctonus ponderosae*)

Stratified sampling
- aerial survey and LandTrendr
- defoliator (WSB) vs. bark beetle (MPB)
- early (1980s) vs. late (2000s)

Field methods
- fixed and variable radius plots
- standard fuels transects
- n = 38 plots
- ~3000 georeferenced photos

Aerial Detection Survey (ADS)

- annual flights of OR and WA, digitized since 1980
- identify all known disturbance agents
- new "cumulative mortality tool" summarizes all tree mortality in one GIS layer, used for MPB here
- additional "cumulative defoliation" layer developed in the IDL language, used for WSB here (Figs. 2,3)

Study areas

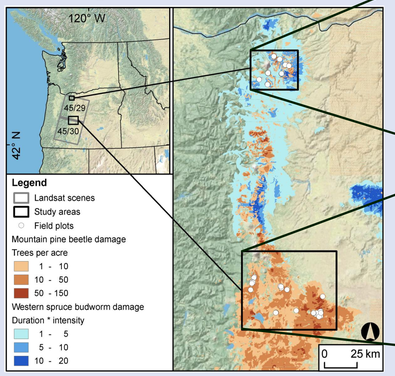

Figure 2. Study area locations within the Pacific Northwest Region (Landsat scenes 45/29 and 45/30). Insect damage represents cumulative impacts mapped by aerial detection surveys (ADS) from 1980 to 2009. Base map: World Physical Map from ESRI: http://server.arcgisonline.com. Source: USDOI National Park Service. Projection: Albers NAD83.

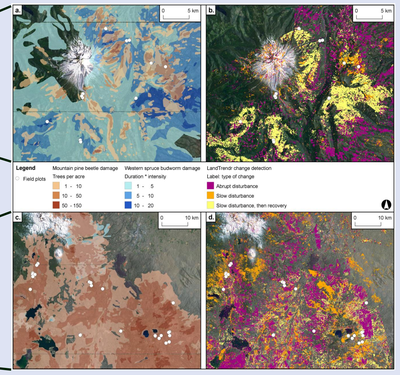

Figure 3. Aerial detection survey and LandTrendr maps of forest disturbance across study landscapes. Note different spatial extents in two study areas. Panels (a) and (c) show cumulative damage from mountain pine beetle (red/brown) and western spruce budworm (blue) from 1980-2009. Panels (b) and (d) show LandTrendr (Kennedy et al. 2010) Base map: ESRI Imagery World 2D from http://server.arcgisonline.com

Results: Example spectral trajectories

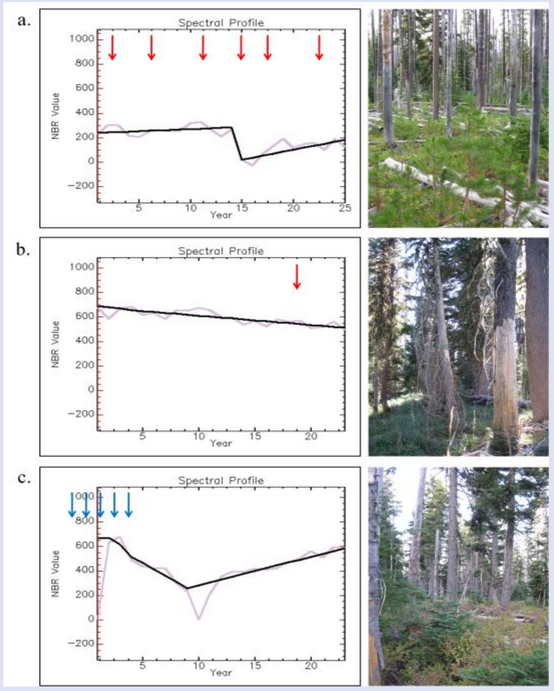

Figure 4. Example spectral trajectories and plot photographs. NBR: Normalized Burn Ratio derived from Landsat bands 4 and 7 (Key and Benson 2006). Vertical arrows indicate aerial detection of insect activity:
- red: mountain pine beetle
- blue: western spruce budworm.

Results: Relation to field data

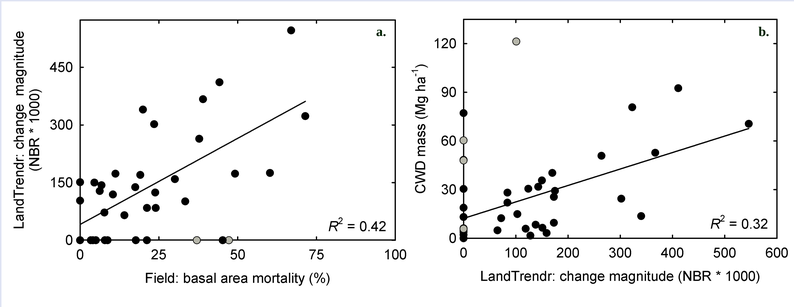

Figure 5. LandTrendr linear relationships with tree mortality (A) and fuels (coarse woody detritus; B). LandTrendr disturbance magnitude from slow and abrupt disturbance identified by aerial detection survey and field observations as defoliator (western spruce budworm) and/or bark beetle (mountain pine beetle). Gray points indicate plots not included in regression because tree mortality and CWD recruitment occurred outside of LandTrendr temporal coverage.

References

- Kennedy RE, Cohen WB, Schroeder TA (2007).Trajectory-based change detection for automated characterization of forest disturbance dynamics. *Remote Sensing of Environment, 110, 370-386.*
- Kennedy, R.E., Yang, Z.G., & Cohen, W.B. (2010). Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr - Temporal segmentation algorithms. *Remote Sensing of Environment, 114*, 2897-2910.
- Key, C.H., & Benson, N.C. (2006). Landscape assessment: Ground measure of severity, the Composite Burn Index; and remote sensing of severity, the Normalized Burn Ratio. In FIREMON: Fire effects monitoring and inventory system. USDA Forest Service General Technical Report RMRS-GTR-164-CD. Fort Collins, CO.

Discussion: Spectral trajectories

Although spectral trends exhibited variability from site to site, insect-affected sites generally conformed to four spectral trajectories (three shown to left in Figure 4 plus an additional trajectory of abrupt followed by slow disturbance).

Budworm trajectories appeared to show a consistent temporal evolution of gradual spectral decline and recovery (Figure 4c) .

Mountain pine beetle sites exhibited both abrupt and gradual spectral declines and variable recovery rates.

Discussion: Relation to field data

The linear fits (Figure 5) provide compelling evidence of relationships between LandTrendr disturbance magnitude and field estimates of tree mortality (% basal area) and surface fuels (coarse woody detritus).

Comparing satellite and ADS data with field measurements of insect impacts, we found that spectral changes were related to mass-based estimates (percent change in tree basal area mortality and coarse woody detritus) whereas ADS changes were related to count-based estimates (trees per acre).

Future studies will improve on these relationships by leveraging multi-date, regional-scale inventory data (*i.e.,* Region 6 Current Vegetation Survey).

Implications

These results demonstrate diverse spectral and physical manifestations of insect activity in conifer forests, highlighting the utility of insect mapping methods that capture a wide range of spectral signals.

This study also confirms the key role that satellite imagery can play in understanding the interactions among insects, fuels, and wildfire.

We welcome collaboration with researchers and managers across the region!

"Red stage" lodgepole pine on fire!

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