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Classifying Historic Images to Quantify Spatial and Temporal Changes in Tree Mortality at Horseshoe Lake (Mammoth Mountain, California)

USGS science for a changing world

NAGT

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1) BACKGROUND

- Since 1990, researchers have noted areas of tree kill at Horseshoe Lake (HSL) located southeast of Mammoth Mountain, a Quaternary dacitic volcano in eastern California (Farrar et al, 1995).
- The dieoff has been attributed to the release of magmatic CO_2 into the soil through bedrock fractures, stimulated by the intrusion of a basaltic dike beneath Mammoth and accompanying earthquake swarms in 1989 (Sorey et al, 1993).
- Historical aerial photos provide a potentially rich dataset that allows us to compare the state of vegetation before and after CO_2 emissions are thought to have begun.
- Image classification also allows us to make the assessment of bare ground vs vegetated ground automated, empirical, and consistent.

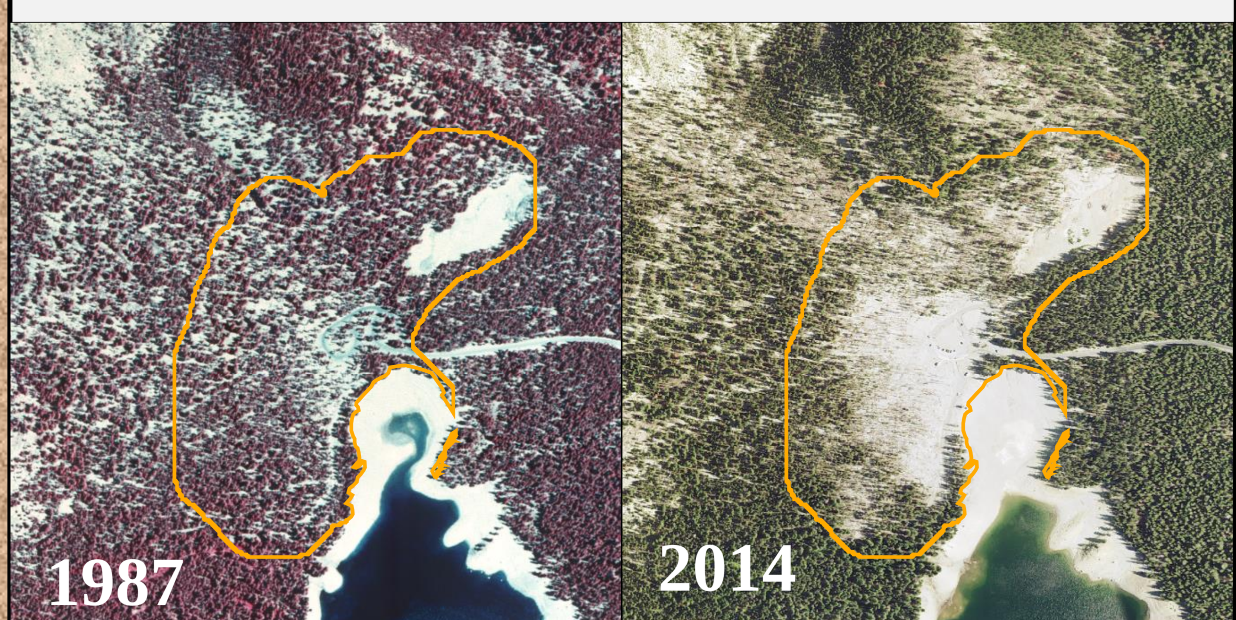


Figure 1: Our area of interest beside HSL, outlined in orange, in 1987 and 2014.

2) RESEARCH OBJECTIVES

Use historical aerial photography and automated image classification to calculate past and contemporary surface areas of bare ground at HSL. We may then compare the spatial distribution of these areas to existing CO_2 flux maps to see how reliably these bare areas serve as an indirect measure of CO_2-related tree mortality.

3) DATA & METHODS

We acquired and georeferenced twenty-four summertime aerial photos of the HSL region (EROS, UC Santa Barbara). Photos varied in spatial and spectral resolution. We then classified each image into *bare* and *vegetated* pixels using a maximum likelihood supervised classification in ArcMap 10.4. The tool sorts each pixel in the image into a pre-established category based on its similarity to a standard spectral signature.

Number of images	24
Year of exposure	1951 - 2014
Image resolution (meters)	0.263 – 3.502

Table 1: Descriptive details of data imagery.

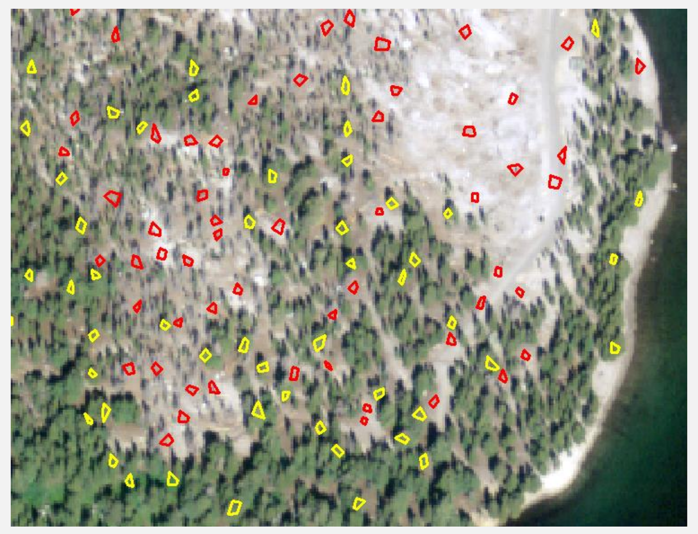


Figure 2: Detail image of training polygons (2005).

To train the classifier tool, polygons were hand-drawn atop each image identifying known areas of vegetated and bare ground within our area of interest. These spectral signatures were used as inputs for the classification.

3a) COMPARING TWO CLASSIFICATION METHODS

For the years 1987, 1994, and 2001-2014, 600 training polygons were drawn for each image and 1000 subsets of 60 polygons each were randomly selected using a Python script. All other years were manually classified 2-3 times with hand-drawn polygons. The amount of classified bare ground from each classification was then averaged together to arrive at a total "bare ground" measurement for that photo.

4) RESULTS

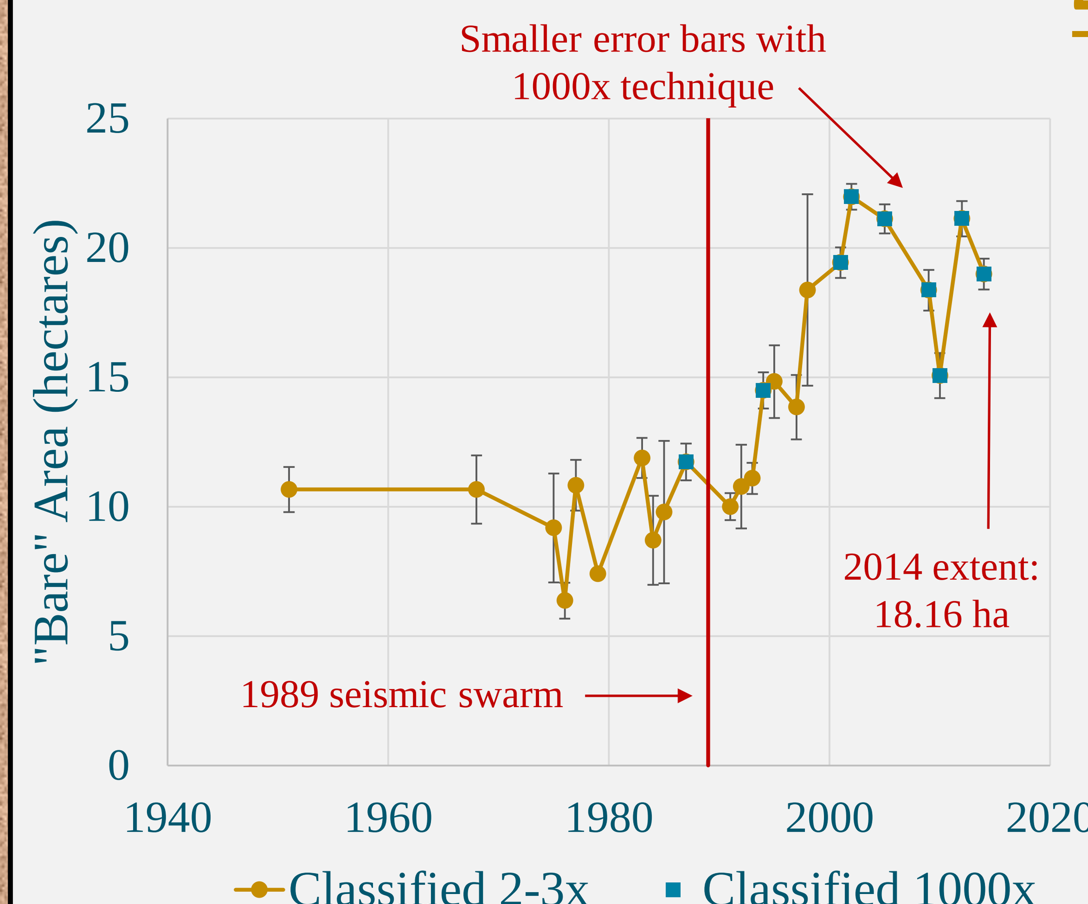
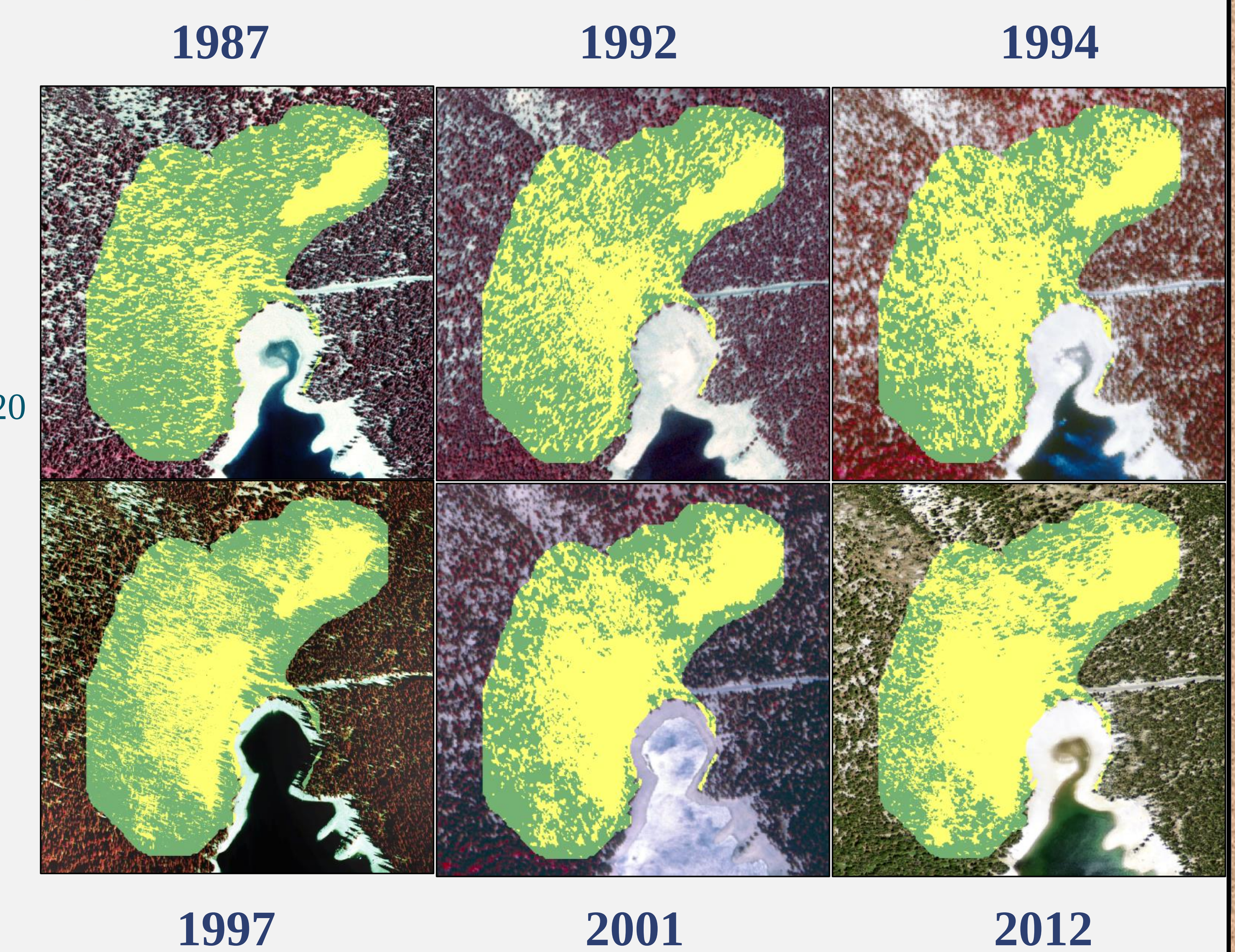


Figure 3 (above): Bare area at HSL over time. Error bars represent one standard deviation of repeat classifications. The "present day" (2014) extent of the tree kill is 18.16 ha, compared to the average of 9.74 ha before the 1989 swarm.

Figure 4 (below): Six of our twenty-four classified images, showing the advancement of the tree kill area (yellow) over time.



5) CONCLUSIONS

- Images between 1951 and 1987 exhibit relatively constant canopy until bare area begins to increase in 1992.
- The onset of the dieoff followed the 1989 seismicity within three years.
- Averaging 1000 classifications improved the precision of each area measurement.
- Though ground observations suggest the dieoff stabilized by 2005, we see more fluctuation in bare ground than expected after this time.
- Large excursions in bare area could be due to environmental factors (i.e. a large windstorm in 2012) or the angle/time of day of the photograph (i.e. large shadows in 2010 mask the bright soil, resulting in an erroneously low classification of bare ground).

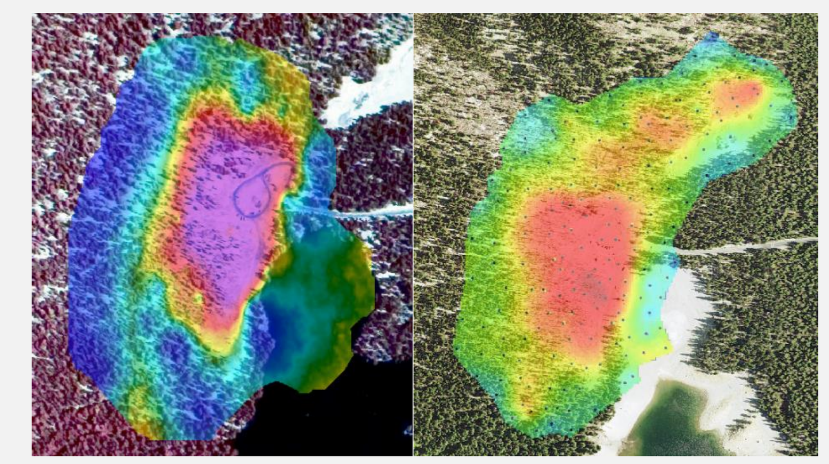


Figure 5: CO_2 flux maps overlaid atop images from 1995 and 2014; warm colors indicate higher flux of tons/day.

- Overlays of CO_2 flux maps (Werner et al, 2014) align well with our classified bare areas, supporting bare area in this zone serving as an indicator for CO_2 emission.

REFERENCES

Farrar, C. D., et al. "Forest-killing diffuse CO2 emission at Mammoth Mountain as a sign of magmatic unrest." *Nature* 376.6542 (1995): 675-678.

Sorey, M. L., et al. "Helium isotope and gas discharge variations associated with crustal unrest in Long Valley Caldera, California, 1989–1992." *Journal of Geophysical Research: Solid Earth* 98.B9 (1993): 15871-15889.

Werner, Cynthia, et al. "Decadal-scale variability of diffuse CO2 emissions and seismicity revealed from long-term monitoring (1995–2013) at Mammoth Mountain, California, USA." *Journal of Volcanology and Geothermal Research* 289 (2014): 51-63.