Post-Fire Burn Assessment by Remote Sensing on National Park Service Lands

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Abstract:

This project is currently ongoing, in the first year of three funded by the Park Oriented Biological Support program of the National Park Service.

The study addresses assessment of wildfires and fire use on National Park Service lands through remote sensing of burn severity. We consider severity as a measure of effect, based on conditions and ecological impacts following fire. Recognizing a need to standardize methodologies and provide comparable results between Parks over time, strategies previously developed at Glacier National Park are being tested in Yosemite, Bandelier and Everglades. In addition, we are working with Fire Monitors at Yukon-Charlie, Grand Tetons, and at Yellowstone, where a Masters thesis has tested our methods on five fires occurring in 1994 and 1997. At Glacier, recent burns in 1998, 1999, and 2000 are also being investigated to broaden sample size and enhance results in that area. In such cases, the Normalized Burn Ratio (NBR) is calculated and differenced between pre- and post-fire Landsat TM/ETM+ scenes. The Composite Burn Index (CBI) is then used to quantify severity on the ground, and correlation is made to the differenced NBR. By working with knowledgeable individuals in targeted Parks, we hope to ascertain the suitability of the CBI in different ecosystems, particularly whether field attributes and criteria are appropriate. We also test robustness of differenced NBR, and determine what calibration requirements may be needed across regions. The objective is a transferable approach that is not dependent on particular site or Landsat image characteristics, one that demonstrates reasonable feasibility on regional-to-national levels. Ultimately, such efforts may lead to implementing a national protocol for standardized post-fire assessment, to monitor and compare burns across NPS lands.

The Normalized Burn Ratio is a difference ratio, similar to NDVI, but uses *Reflectance* of TM Band 4 and Band 7.

$$NBR = (R4 - R7) / (R4 + R7)$$

We found NBR optimum for burned areas:

> Testing showed selected bands had strongest signal, ***R7*** increased while ***R4*** decreased most after burning.

> NBR had highest correlation to field-estimated burn severity, was more robust than NDVI late in the growing season, and less influenced by haziness.

> Change in NBR after burning yielded greater amplitude (more range) than other indices tested. Thus, ability to stratify levels of severity was improved.

> Image products had greater contrast within burns, and best distinction between burned and unburned areas.

Important steps to burn remote sensing:

> Suitable pre- and post-fire Landsat TM/ETM+ scenes.

> "Tight" co-registration and geo-rectification of scenes.

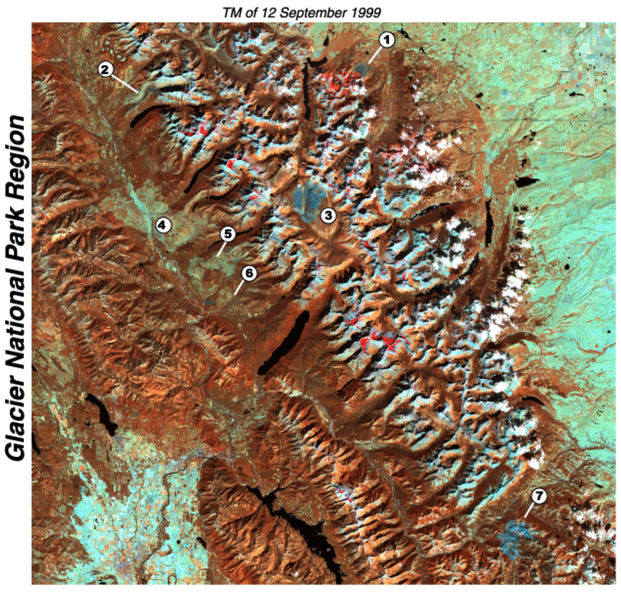
> Normalization of raw bands to account for solar, atmospheric, and topographic effects.

> NBR is calculated for pre-fire and post-fire dates, and differenced: **(prefire NBR) - (postfire NBR)**

Our hypothesis: ***Differenced NBR corresponds to severity in a consistent way from place to place, and over time, i.e. a particular range of values represents the same degree of severity on one burn as on another.*** Though still in progress, results indicate numeric thresholds between perceived levels of severity are similar among burns. This suggests differenced NBR may be an important way to quantify and compare burns regionally or nationally.

Glacier National Park Region

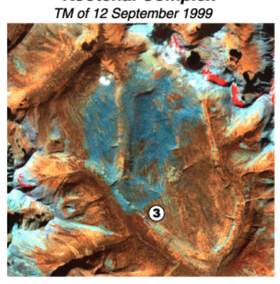
TM of 12 September 1999



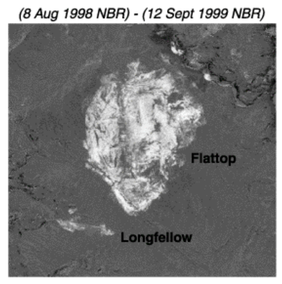
Eleven burns/complexes from 1994-present have been mapped, ranging in size from 50-10,000 ac., including: 1) Sofa, Alberta 1998; 2) Starvation, 1994; 3) Kootenai Complex 1998; 4) Red Bench*, 1988; 5) Adair Complex, 1994; 6) Anaconda, 1999 in progress on this image; and 7) Challenge, 1998. * For reference only, mapped previously (White, et al. 1996). Plans to reassess older burns with our methods are being considered.

Kootenai Complex

TM of 12 September 1999

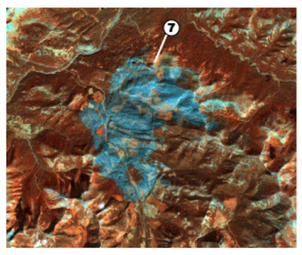


(8 Aug 1998 NBR) - (12 Sept 1999 NBR)

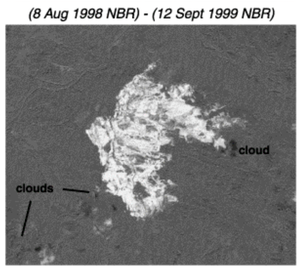


Challenge

TM of 12 September 1999

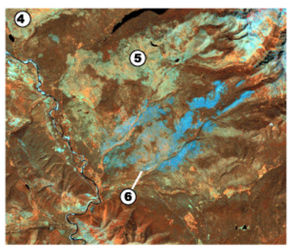


(8 Aug 1998 NBR) - (12 Sept 1999 NBR)

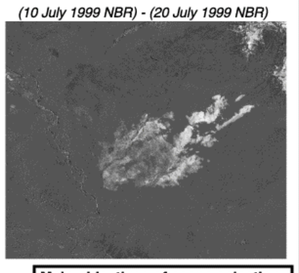


Anaconda

ETM+ of 20 July 2000



(10 July 1999 NBR) - (20 July 1999 NBR)



Left and Center. **Kootenai Complex** and **Challenge** were high elevation fires, with heavy snow pack the following winter. Late-season images, and almost a month difference between years, were needed to balance phenological conditions. Differenced NBR did a good job identifying **Longfellow** which was virtually undetectable in false color. *Right.* **Anaconda** was at low elevation. Images earlier in the season were selected. A May NBR difference (not shown) had slightly improved results.

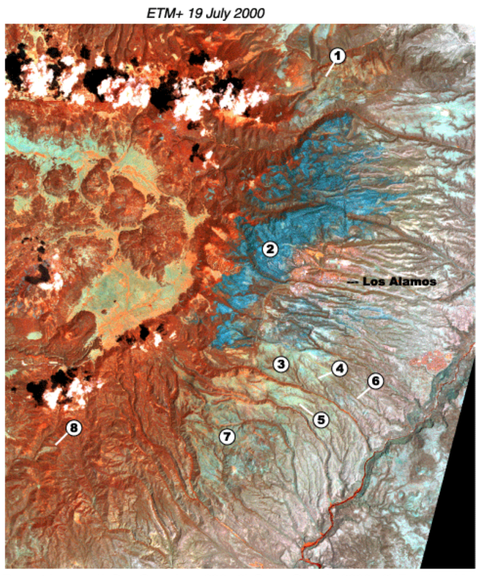
Main objectives of scene selection:

> acquire post-fire scene after time for regeneration of surviving plants.

> match pre- and post-fire dates for similarity of phenology and moisture.

Bandelier National Monument Region

ETM+ 19 July 2000

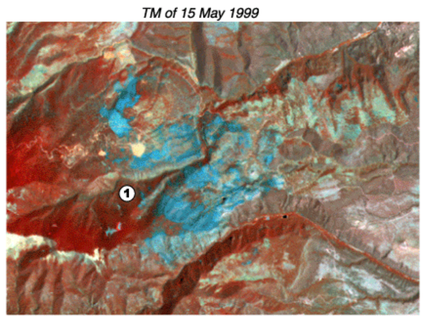


Recent burns: 1) Oso Complex 1998; 2) Cerro Grande 2000; 3) Escobas Mesa 1998; 4) Burnt Mesa 1999; 5) Lummis 1997 (3,4, and 5 overlay the 1977 La Mesa burn); 6) Entrance Station 2000; 7) Dome 1996; and 8) Nicole 1996.

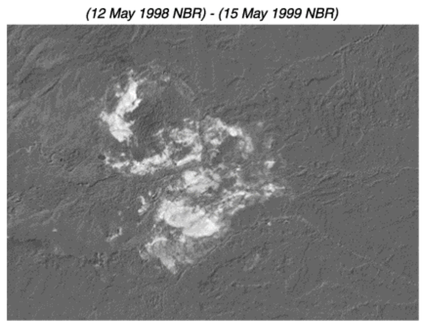
Below, **To gauge burn severity, which relates to fire effects on vegetation, post-fire NBR should be obtained from the growing season after fire. Then, surviving plants have had time to recover. However, this scene acquired soon after fire still provides good representation of fire perimeter (i.e. burned area) and indicates severity, although effects may be somewhat exaggerated.**

Oso Complex

TM of 15 May 1999



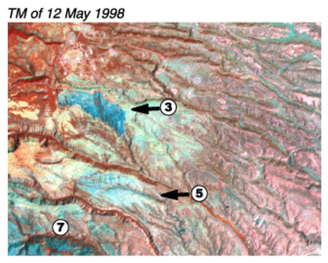
(12 May 1998 NBR) - (15 May 1999 NBR)



Incidental to burns within National Parks, burns occurring anywhere in a Landsat scene of a given fire year can be mapped at no additional effort or cost. Patches of moderate-high to high severity are indicated by differenced NBR in the Oso burns.

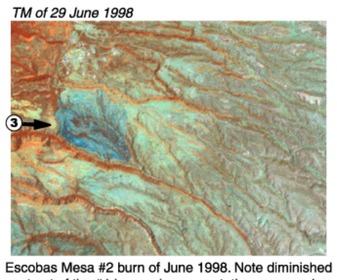
Management Ignited and Prescribed Natural Fires from 1998, 1999 and 2000

TM of 12 May 1998



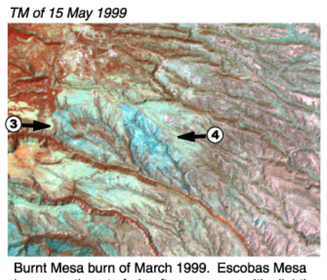
Top, Escobas Mesa #1 burn of April-early May 1998. *Mid*, Lummis burn of June-July 1997. *Lower left corner*, signal persists from the Dome burn of 1996.

TM of 29 June 1998



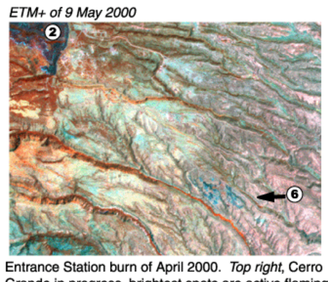
Escobas Mesa #2 burn of June 1998. Note diminished contrast of the #1 burn, where vegetative recovery has progressed for about 6 weeks.

TM of 15 May 1999



Burnt Mesa burn of March 1999. Escobas Mesa burns continue to fade after one year, with slightly stronger signal registered from Escobas #2.

ETM+ of 9 May 2000



Entrance Station burn of April 2000. *Top right*, Cerro Grande in progress, brightest spots are active flaming. Little detectable in false color from 1997-1999 burns.

Differenced NBR is a continuous variable, typically ranging between -1.0 and +1.0 (+ 0.2).

For image processing purposes differenced NBR is scaled by 1000, so values range between -1000 and +1000.

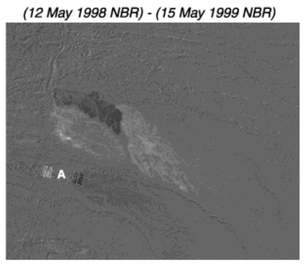
The B&W images are grayscales of that range.

Unchanged pixels have values between approximately -100 and +100 (medium gray).

Pixel value and brightness increases in the positive, and decreases (becomes darker) in the negative direction.

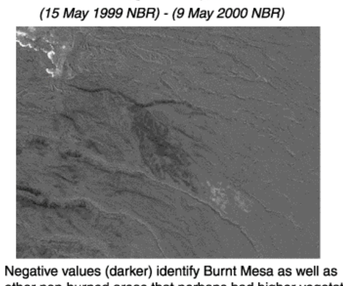
The brightness of pixels, we believe, relates to burn severity, or the degree of ecological change caused by fire.

(12 May 1998 NBR) - (15 May 1999 NBR)



Differenced NBR

(15 May 1999 NBR) - (9 May 2000 NBR)



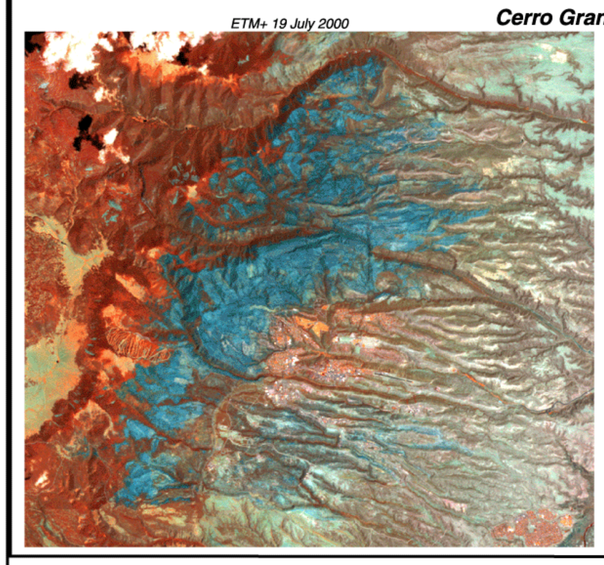
Escobas Mesa #2 and Burnt Mesa burns show positive (lighter) values of differenced NBR, since both burned after the pre-fire image of 12 May 1998. Escobas Mesa #1 has negative (darker) values, indicating vegetative recovery since 12 May 1998. The Lummis burn is also faintly darker. (A - rectangular patches result from anomalies in the original Landsat data.)

Negative values (darker) identify Burnt Mesa as well as other non-burned areas that perhaps had higher vegetative productivity in the 9 May 2000 scene. Entrance Station burn shows up slightly lighter than surroundings. Little signal is registered from Escobas Mesa.

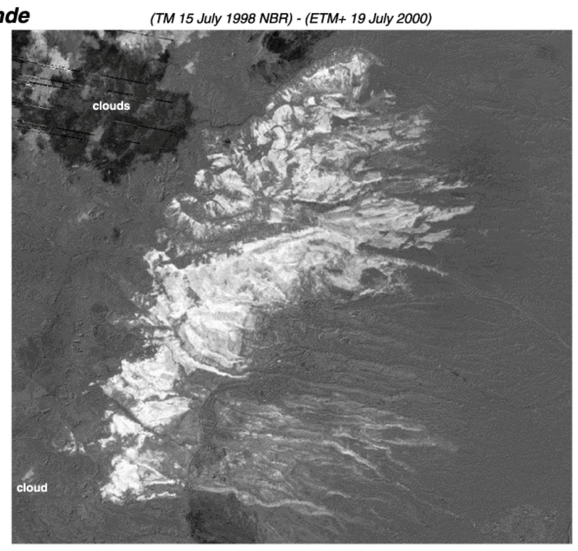
Differenced NBR in above cases indicates relatively low severity and ephemeral impacts.

Cerro Grande

ETM+ 19 July 2000



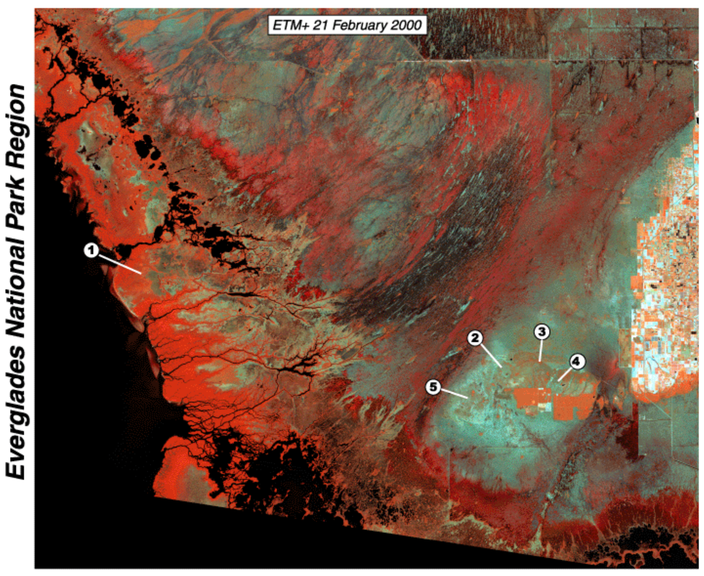
(TM 15 July 1998 NBR) - (ETM+ 19 July 2000)



Applications: **Differenced NBR quantifies post-fire effects, or burn severity, on vegetation, fuels, and soil:** 1) *Soon after* fire for burn area delineation and quick assessment; or 2) A *year after* for estimating long-term effects on existing vegetation. **>> Combine with other geo-spatial data:** verify burn predictions, provide input to existing models, or guide development of improved models in complex landscapes. **As a scaled spatial measure of severity:** assess impacts to habitat, watershed and wildlife; provide managers the size, distribution and composition of burned areas. Assist rehabilitation planning and evaluation. **As a standardized index:** enhance research and management across broad regions, or over long periods within a given area. Provide a framework for maintaining fire atlases, developing prescriptions, and monitoring results of prescribed fire. **Derived from Landsat TM/ETM+ with repetitive near-global coverage:** this is a moderate resolution (30 m) approach suited for landscape-scale projects. May be most useful on large burns (>1000 ac), especially in remote areas, but can detect small and low severity burns down to about 50 ac. Recent low pricing and overlapping coverage of Landsats 5 and 7 increases feasibility and cost effectiveness.

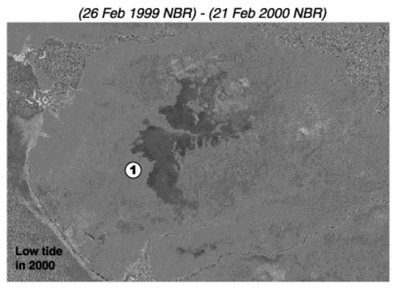
Everglades National Park Region

ETM+ 21 February 2000

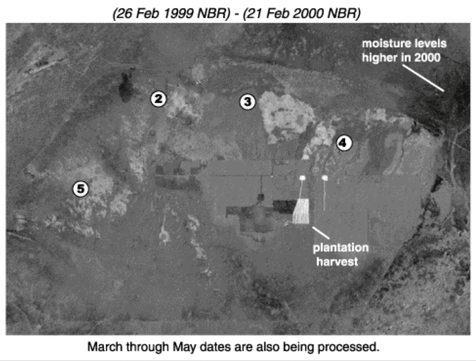


About 14 burns from 1999 are being investigated, including 1) Lostman; 2) Brown; 3) EDG #9966; 4) Aerojet; and 5) West A. 1) is in cord grass prairie where production was enhanced by fire after 1 year. 2-5) are in long needle pine and saw grass with NBR response similar to western forests. Unique factors influencing results here include wide fluctuations in moisture within short time frames, and rapid regrowth after only a few weeks.

(26 Feb 1999 NBR) - (21 Feb 2000 NBR)



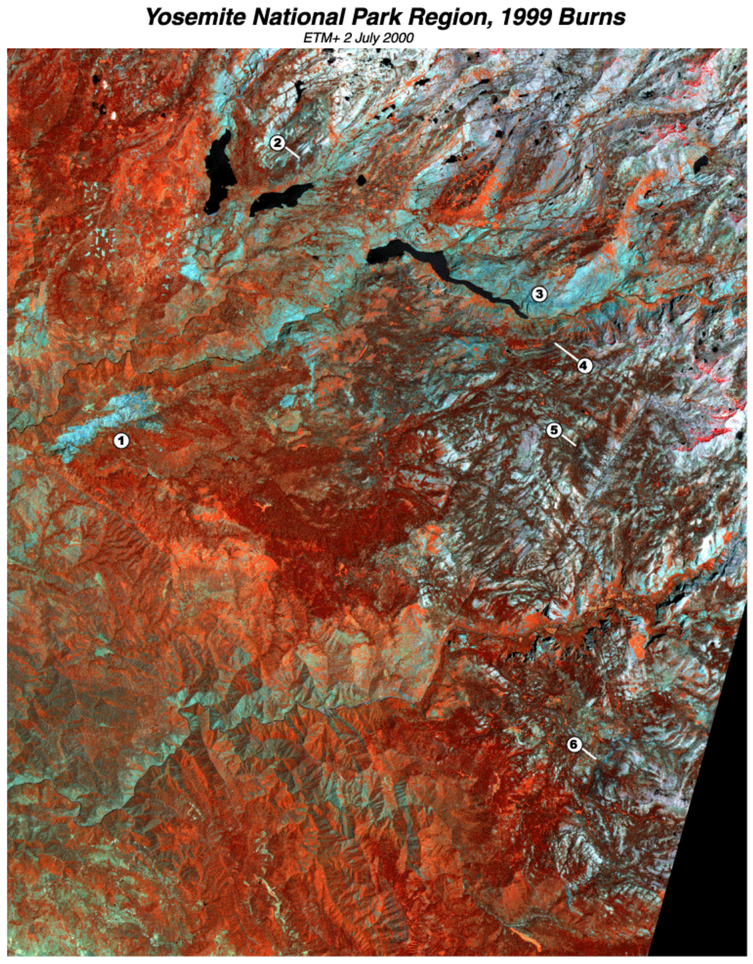
(26 Feb 1999 NBR) - (21 Feb 2000 NBR)



March through May dates are also being processed.

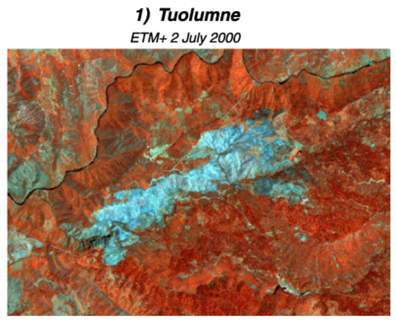
Yosemite National Park Region, 1999 Burns

ETM+ 2 July 2000

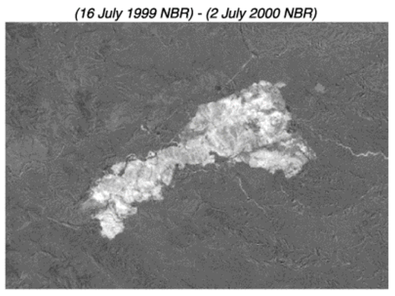


1) Tuolumne

ETM+ 2 July 2000

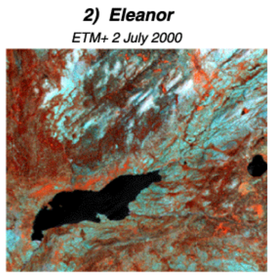


(16 July 1999 NBR) - (2 July 2000 NBR)

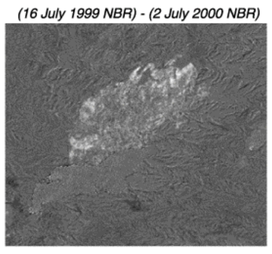


2) Eleanor

ETM+ 2 July 2000

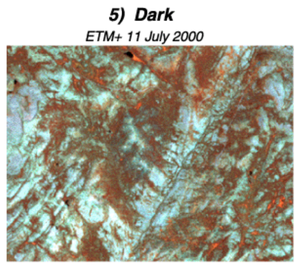


(16 July 1999 NBR) - (2 July 2000 NBR)

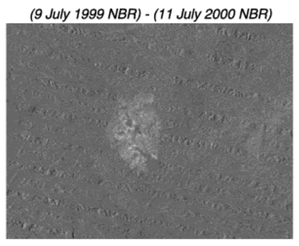


5) Dark

ETM+ 11 July 2000

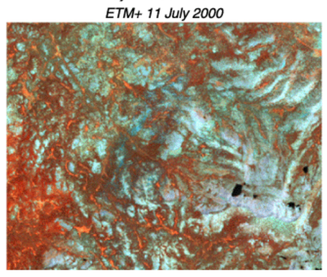


(9 July 1999 NBR) - (11 July 2000 NBR)

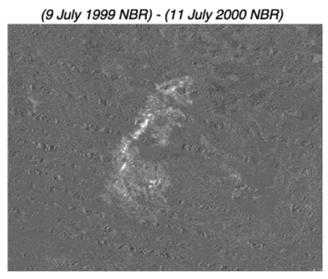


6) Lost Bear

ETM+ 11 July 2000



(9 July 1999 NBR) - (11 July 2000 NBR)



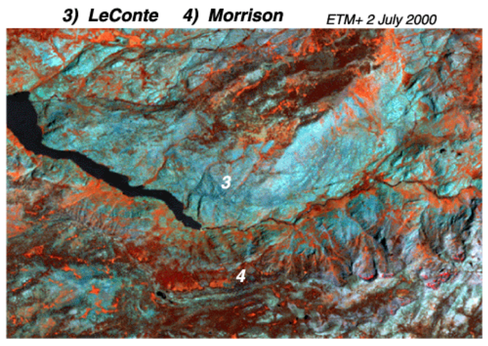
Mostly light intensity underburning is detected on 2, 5, and 6.

Illustrated results have generally similar characteristics to examples from Glacier National Park. Larger burns (1, 2, 3) show diversity of severity, a representative gradient from low to high.

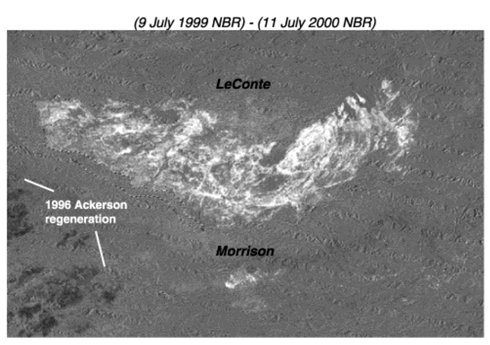
However, all burns except 1) occurred in very patchy forest within rocky terrain. Results did not seem adversely affected under these conditions. Even small burns and very low severities were detected (4, 5, 6).

3) LeConte 4) Morrison

ETM+ 2 July 2000



(9 July 1999 NBR) - (11 July 2000 NBR)



Attributes Promoting Standardized Use:

- Severity is defined; a multi-strata suite of criteria tailored to TM detection capability.
- Optimal TM band combination, ratios and normalization enhance spectral qualities.
- Broad testing in a variety of ecosystems nationwide.
- Severity is not discrete, but measured on a continuous scale (testing & modeling).
- Scale can be stratified to identify severity levels tailored to management needs.

Color images on this poster are false-color composites of Landsat TM/ETM+ Bands 4, 5, 7 (RGB). The blue signal results from most dramatic increase in Band 7, and decrease in Band 4 after burning. Hence, the derivation of our Normalized Burn Ratio.

Note: Visual discrimination of burn severity is reduced somewhat on paper, due to plotter limitations. Thresholds between burn levels, though subtile, are more distinct when viewed on a computer monitor.

Acknowledgements

We wish to thank several individuals for consultation, support, and effort in helping us at a number of Park areas, including: Jan van Wagtendonk and Andi Thode at Yosemite; Craig Allen, Kay Beeley and Laura Trader at Bandelier; Caroline Lansing and Dennis DiVoky at Glacier. Marilyn Blair has helped with many aspects of computer hardware, software, and networking.

We also thank several individuals who contacted us and endeavored to try our methods in their respective areas. We intend to support those projects and look forward to their results, including: Brian Sorbel and Mitch Burgard at Yellowstone; Diane Abendroth at Grand Tetons; Eric Lindquist at Bridger Teton National Forest, Marsha Lutz and Jan Passek from Alaska National Parks; Tim Hammond at the Alaska Northern Field Office of BLM; and Matt Macander at University of Alaska, Fairbanks.