Ethiopia Ecological Forecasting

Mapping Four Decades of Fire History for Targeted Conservation in the South-Central Highlands of Ethiopia

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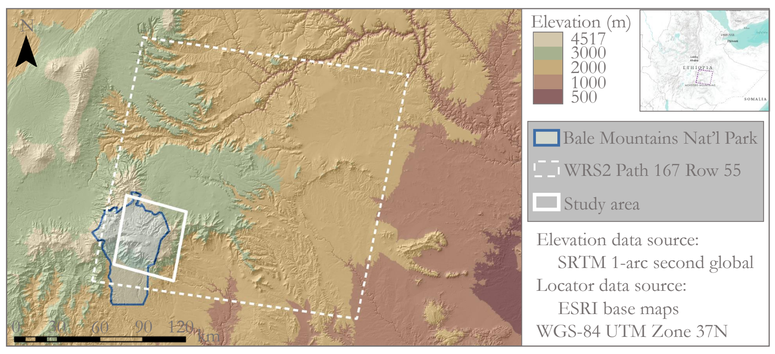
Abstract

The Bale Mountains of south-central Ethiopia comprise one of the largest and least studied mountain systems in Africa. An internationally recognized biodiversity hotspot, the region is home to Bale Mountains National Park and the Sanetti Plateau, which provide critical alpine habitat for numerous endemic and endangered species, such as the mountain nyala. Ethiopian agro-pastoralists in the region practice intentional burning to clear land for grazing and planting; however, pressures related to climate change and increasing populations have made understanding the frequency and extent of burning a top priority for conservationists and land managers seeking to balance conservation goals with the needs of local communities. To address this need, we mapped historical fire extent and frequency in the unique, high-altitude Ericaceous shrublands of Bale, using all available dry-season scenes from 42 years (1973-2015) of the Landsat record. We spatially and spectrally linked imagery within the LandsatLinkr R package to visualize landscape disturbances with a tasseled cap time series. A quantitative assessment of burned areas derived from the normalized burn ratio found that nearly all Ericaceous vegetation in the study area has burned since 1995, but with few repeated fires in the same location. Our results were not only in agreement with two MODIS Burned Area products and fire records compiled from the literature, but also improved upon their spatial resolution and augmented their temporal record. Maps and spatial data of fire date, extent, and frequency were disseminated to partners working in Ethiopia. These will support detailed studies of fire ecology in Bale and inform management approaches that ensure the preservation of the region's natural resources and the social-ecological systems they support.

Objectives

- **Quantify** fire extent and distribution in the Bale Mountains over a 42-year time period
- **Identify** spatial, temporal, and ecological patterns of burning
- **Provide** land managers in the region with the most detailed and complete record of fires to date
- **Demonstrate** a reproducible methodology applicable in Ethiopia and around the globe

Study Area



Methodology

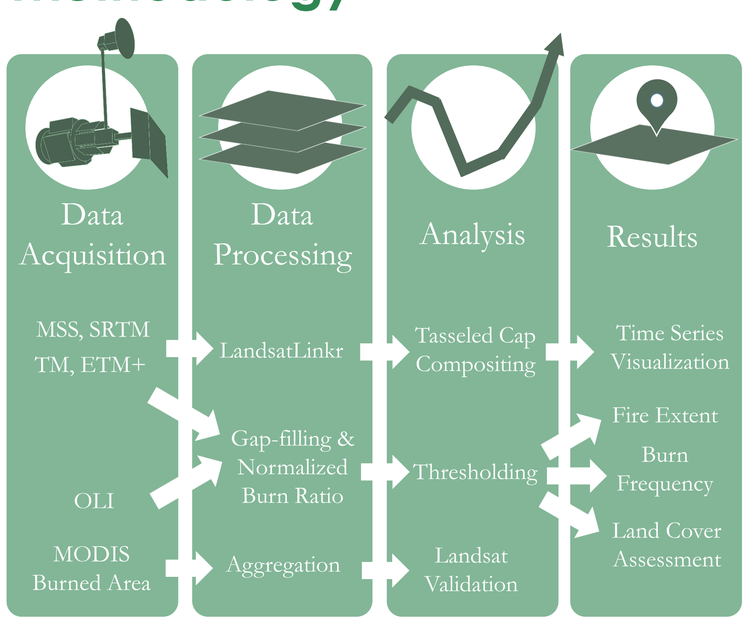


Figure 1. Generalized workflow for the study methods. This can be broken into four main stages: data acquisition, processing, analysis, and generation of results.

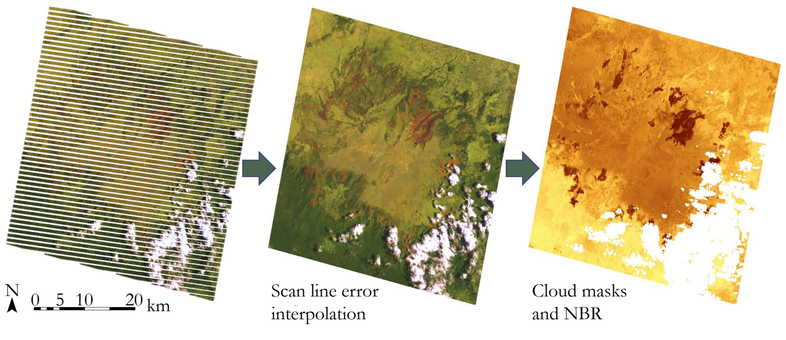


Figure 2. For Landsat imagery, we interpolated scan line errors, masked clouds, and calculated and thresholded the normalized burn ratio (NBR) for each scene.

Results

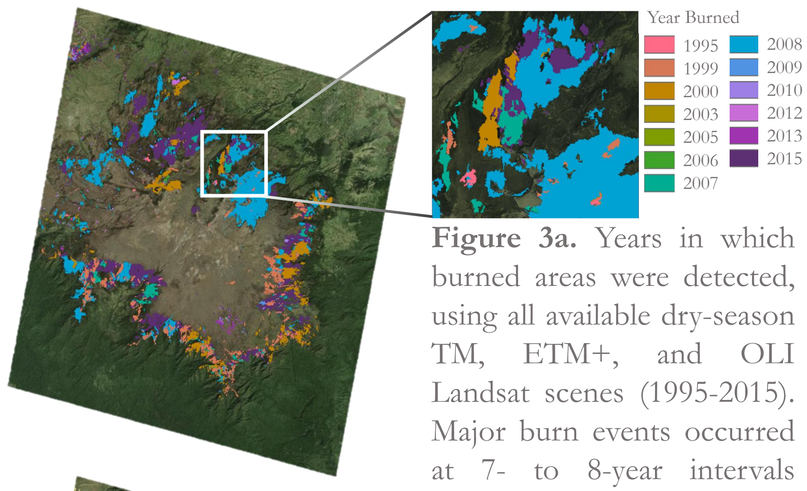


Figure 3a. Years in which burned areas were detected, using all available dry-season TM, ETM+, and OLI Landsat scenes (1995-2015). Major burn events occurred at 7- to 8-year intervals (2000, 2008, 2015).

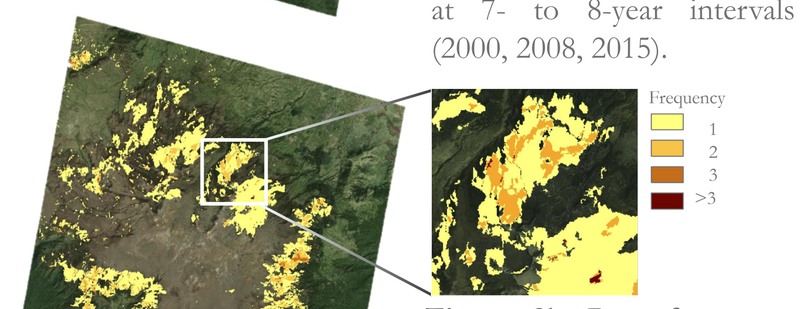


Figure 3b. Burn frequency (number of times each pixel burned). The "jigsaw" pattern of fires across years (Fig. 3a) indicates that, within the study period, the same locations tended not to burn more than 1-3 times.

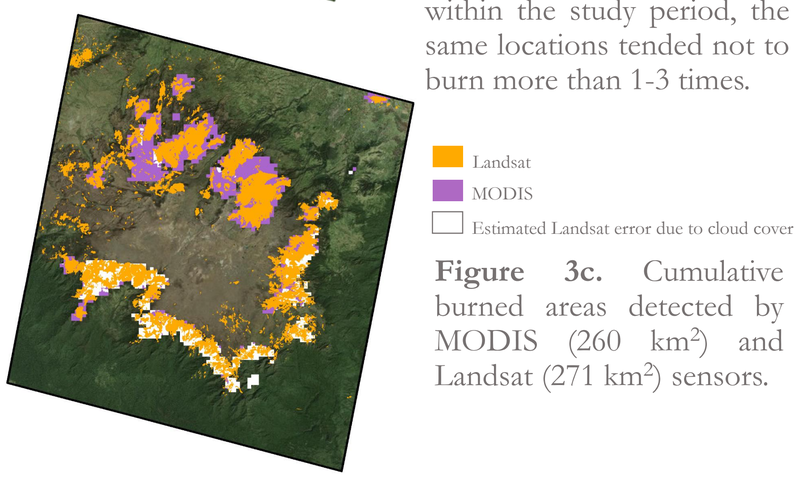


Figure 3c. Cumulative burned areas detected by MODIS (260 km^2) and Landsat (271 km^2) sensors.

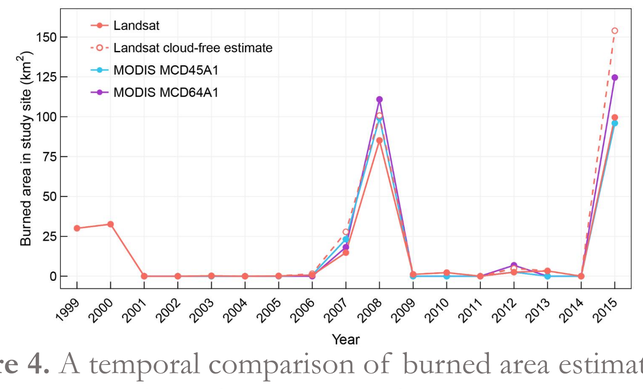


Figure 4. A temporal comparison of burned area estimates between our results and MODIS products.

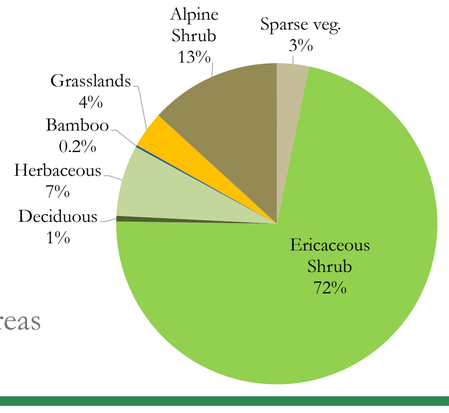
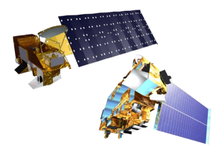


Figure 5. Proportion of burned areas within land cover classes.

Conclusions

- Between 1995-2015, 35% of the ericaceous vegetation of the Bale escarpment burned, but few areas experienced repeated fires.
- LandsatLinkr expedites pre-processing, but data gaps and cloud cover remain serious challenges for time series analysis in remote, tropical alpine regions.
- Final products for partners:
  - Maps and spatial data of fire extent and frequency (1995-2015)
  - Spectrally comparable and composited tasseled cap time series (1973-2015)

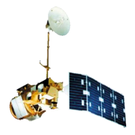
Earth Observations



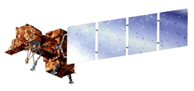
Terra/Aqua – MODIS

Shuttle Radar Topography Mission (SRTM)

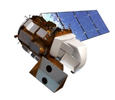
Landsat 1, 3 – Multispectral Scanner (MSS)



Landsat 5 – Thematic Mapper (TM)



Landsat 7 – Enhanced Thematic Mapper (ETM+)



Landsat 8 – Operational Land Imager (OLI)

Project Partners

- The Murulle Foundation
- Natural Resource Ecology Laboratory at Colorado State University

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Team Members

Team members (left to right): Kelly Hopping, Stephen Chignell, Chandra Fowler, Darin Schulte

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