Uncovering spatiotemporal trends in fire activity in pastoralist southern Ethiopia using satellite remote sensing

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References:

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Project summary and aims

Introduction

- Recent studies suggest burned area is on the decline across North and East Africa (Andela et al., 2017). However, these trends are spatially heterogeneous and, particularly in pastoral regions, their human and biophysical drivers are not fully understood. Remote sensing can offer important insights into past and present fire regimes in the face of significant climate, ecological and social changes occurring across rural East Africa.

Aims

- To investigate fire regime trends in the Lower Omo valley and across Ethiopia, the drivers of these changes and the impacts on local livelihoods and protected area conservation.

Approach

- This study uses satellite remote sensing to investigate trends at the national and regional level to uncover drivers of fire regime change. This will be used in combination with participatory mapping to understand how different perceptions, fire management practices and systems of governance are influencing fire regimes in East African drylands.

Background

Fire in the grasslands

- Fire is essential for maintaining open ecosystems, which together cover a quarter of the Earth's terrestrial land surface (Bond, 2019) and contain unique biodiversity, including the majority of the world's remaining megafauna.
- Fire is an essential livelihood practice, used to maintain expanses of open grassland, provide new forage for grazing, clear and prepare agricultural lands alongside varied cultural reasons. These ecosystems account for 75% of total annual burned area (Archibald, 2016).

Study Region

- The Lower Omo Valley (Figure 1) is home to eight agro-pastoralist groups including the Mursi and Me'en (Bodi).
- There are two distinct fire seasons, and a high frequency burning regime (often twice per year).
- New community-based conservation in the region (Tama CCA – Figure 1) is raising questions over conflicts between traditional burning and wildlife conservation.

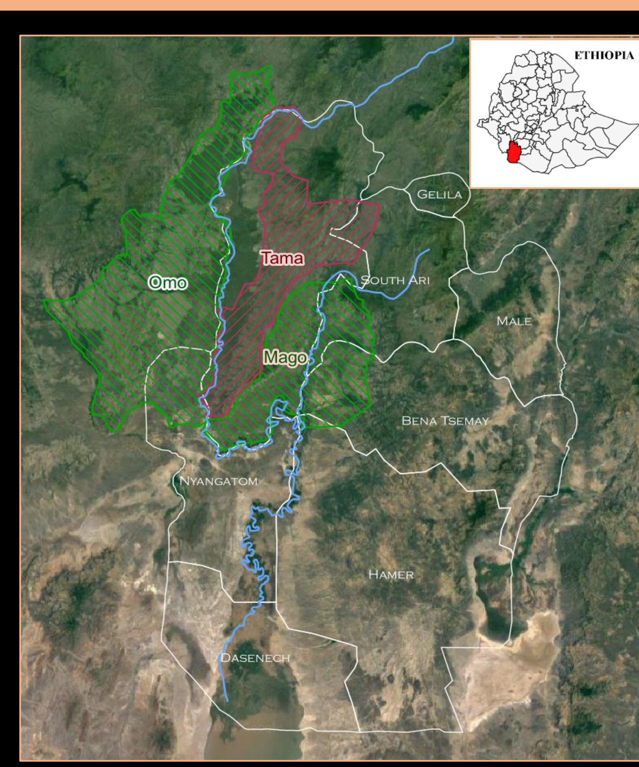


Figure 1: Map of the Lower Omo Zone. The Omo and Mago National Parks and the Tama Community Conservation Area (CCA) are presented.

Methods

Remote Sensing of Fire

- Satellite remote sensing offers the ability to detect and monitor complex spatiotemporal patterns of burning at multiple scales.
- Developments in satellite sensors allow detection of fires at high temporal resolutions (MODIS) and spatial resolutions (Landsat, Sentinel-2).

Modelling drivers of fire regime change

- This study will investigate multiple components of the fire regime covering three dimensions:

Spatial	Burned Area
	Active fire density
Temporal	Fire frequency
	Fire seasonality
Magnitude	Fire radiative power

1. Time-series analysis used to detect spatiotemporal patterns of fire trends over the previous 20 years.
2. Residual trend (RESTREND) analysis used to remove the influence of climate variability and reveal underlying trends.
3. Breakpoint analysis used to distinguish long-term trends from sudden "shocks" (e.g., from rapid development and land-use change).
4. Satellite and geospatial data will be used to develop a model of fire regime components in relation to climatic, biophysical and socioeconomic drivers.

Contributions:

- Locally validated medium resolution Landsat maps of burned area to capture the up to 40% of fires undetected by coarse spatial resolution global products (Figure 2).
- Local knowledge and perceptions through participatory mapping (Figure 3)

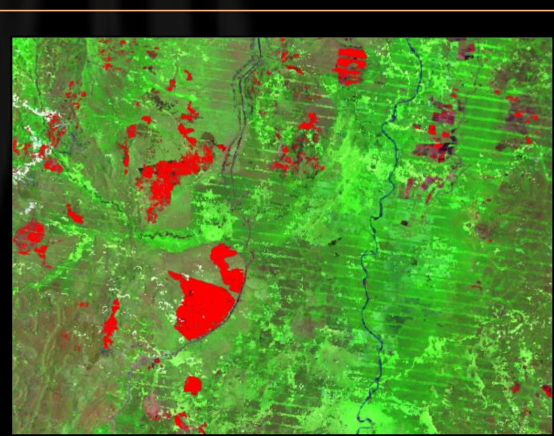
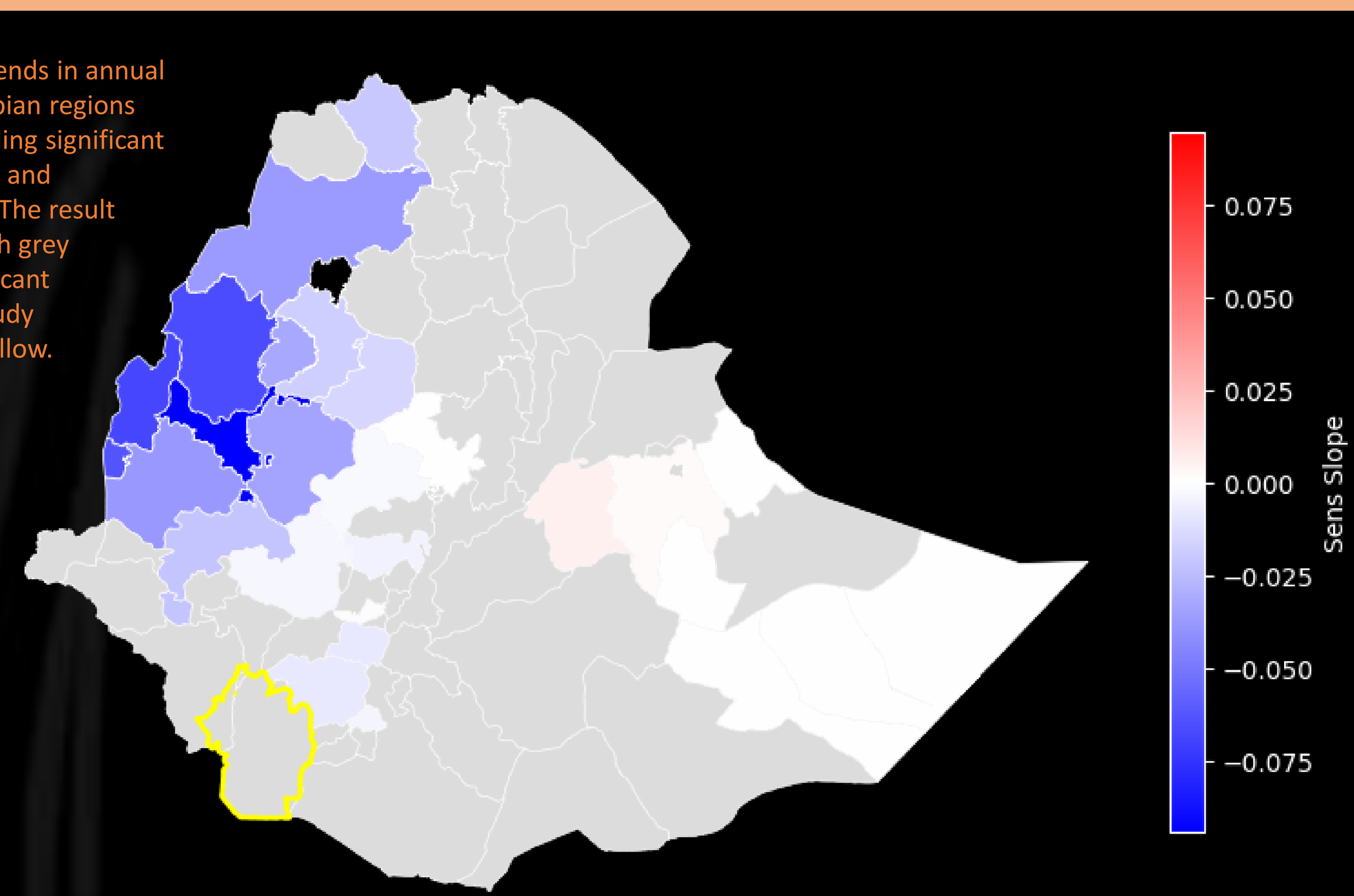


Figure 2: Landsat (30m) burned area maps offer increased sensitivity to small agricultural fires and reveal spatial patterns of burning in greater detail to global MODIS (500m) products.

Figure 3: Participatory mapping, Lower Omo, August 2022, used to qualitatively discuss fire changes and drivers and to produce localised GIS data for use in remote sensing analysis.

Burned area trends across Ethiopia

Figure 4: Magnitude of trends in annual burned area within Ethiopian regions (zones) 2001-2021, revealing significant ($p < 0.05$) increasing (red) and decreasing (blue) trends. The result of Mann-Kendall test, with grey zones indicating no significant trend. The Lower Omo study region is highlighted in yellow.



- Declining trends in burned area, are most strongly detected in North and East Africa (24% in the period 1998–2015 - Andela, 2017).
- Significant decreasing trends are seen in the west of Ethiopia, contrasting with slight increases in some eastern regions (Figure 4).
- Investigations into fire regimes at the national scale can be limited in their ability to detect key localised spatiotemporal processes. There is a need for multi-scale analysis.

Regional trends in the Lower Omo

- Trend analysis was performed on $5km^2$ grid-cells across the region to investigate trends in burned area (Figure 5).
- Future work will used RESTREND to account for high climate variability (Figure 6) and uncover emerging spatiotemporal patterns.

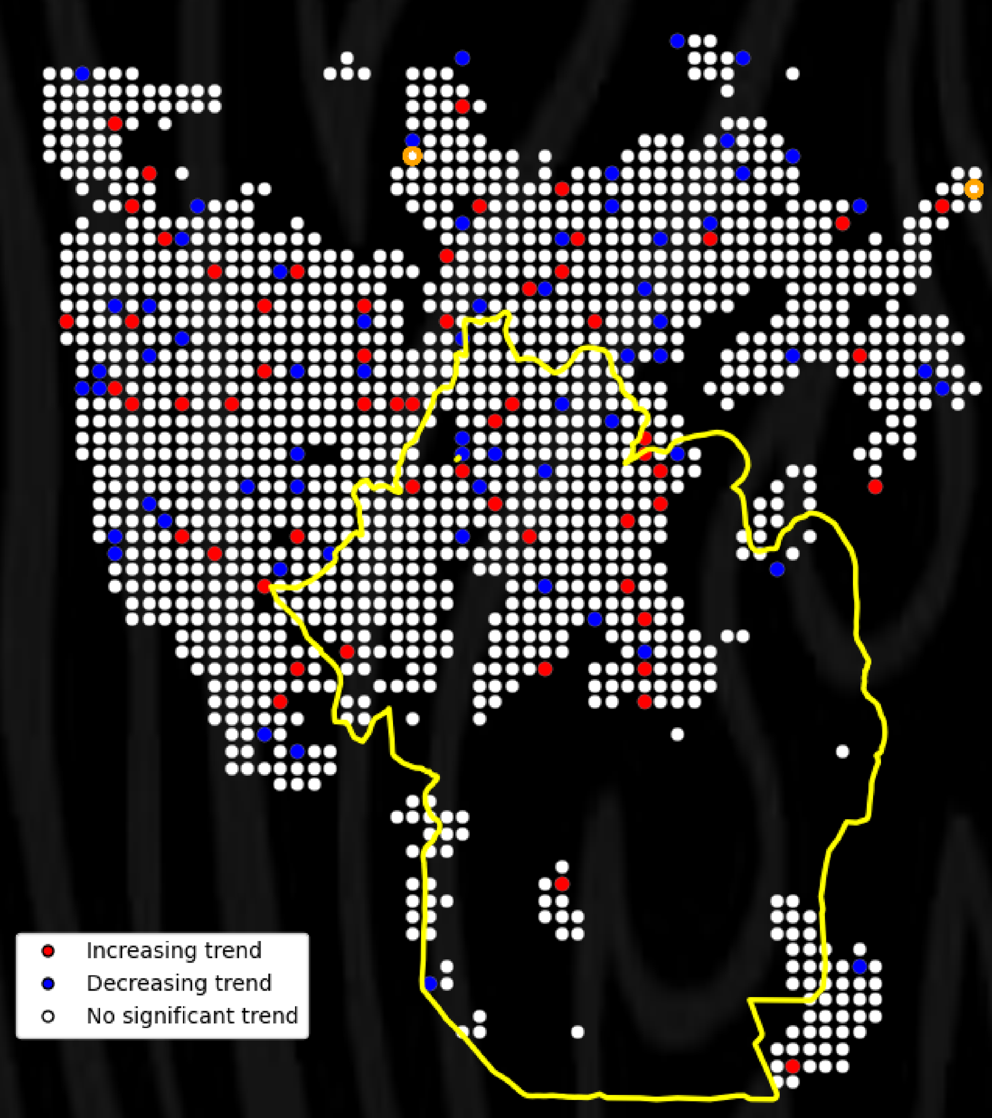
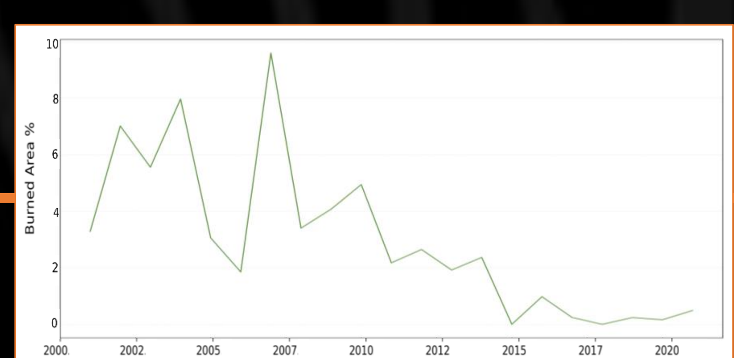


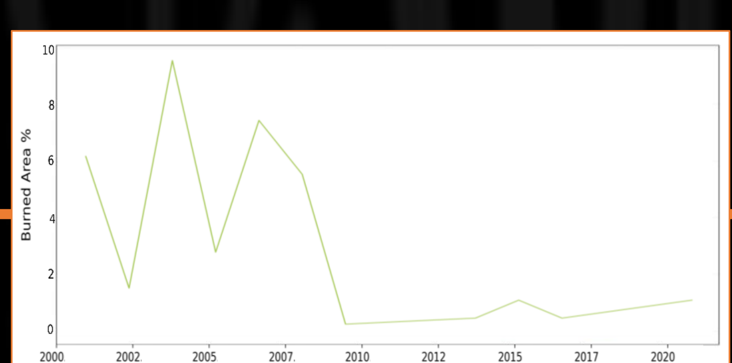
Figure 5: Results from Mann-Kendall trend analysis performed on $5km^2$ flammable grid-cells (dots). Results reveal regions with significant ($p < 0.05$) increasing (red) and decreasing (blue) trends or no significant trend (white). The Lower Omo study region is highlighted in yellow.

Trends...



- Longer-term, gradual changes to fire regime e.g., due to climate change gradual land-use, livelihood and demographic changes.

Shocks...



- Sudden changes which alter the fire regime e.g., due to large-scale land acquisitions (LSLA), commercial agriculture and hydro-electric projects.

Potential drivers of fire regime change

Environmental drivers

- Temperature and precipitation: Globally, higher temperatures, reduced fuel moisture and longer fire weather windows are leading to larger and hotter fires.
  - Cumulative rainfall and temperature over the previous two years are key controls of burned area.
- Drought: Increased climate variability in parts of East Africa is leading to greater drought frequency and intensity (Figure 6).
  - Satellite-derived soil moisture and drought severity indices.

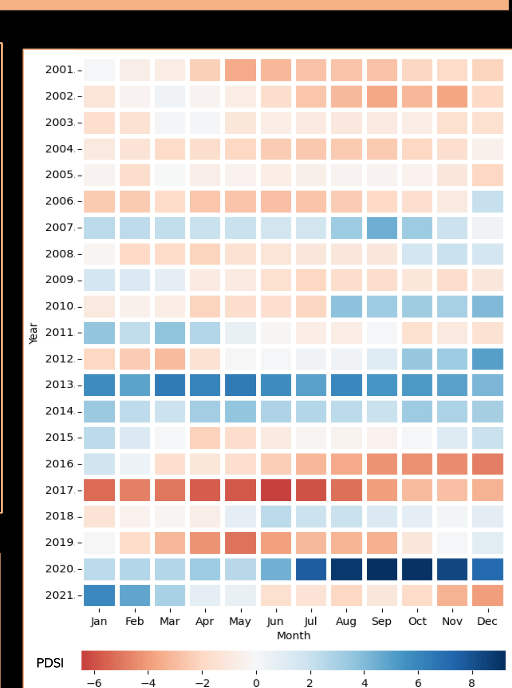


Figure 6: Mean monthly Palmer drought severity index (PDSI) in the Lower Omo Zone shows climate variability and frequent droughts over the last 20 years.

Socio-economic drivers

- Social and demographic changes: Population increase leads to resource pressure, changes to traditional fire management and governance and reductions in burned area.
- Land-use/cover change (LUCC): Conversion of grasslands to agriculture leads to significant changes in size and timing of fires (Figure 7).
- Infrastructure development: Road and urban development fragments the grasslands, leading to reduced fuel continuity and burned area.

Large Scale Land Acquisitions (LSLA)

- Africa's tallest hydro-electric dam, the Gilgel-Gibe III, began construction in the Lower Omo in 2006.
  - Fire suppression policies lead to gradual declining burned area around the site of the Dam.
  - 100,000 ha of pastoral grasslands converted to commercial sugar cultivation resulting in the loss of grazing lands and disruption to traditional fire management systems.
  - Damming of the Omo river leads to loss of the annual flood, relied upon for flood-recession cultivation and leading to widespread alteration of livelihoods.
  - Sedentarisation of mobile pastoralists leading to increasingly uneven and intensive patterns of grazing and burning, which have been associated with rangeland degradation and large-scale bush encroachment.

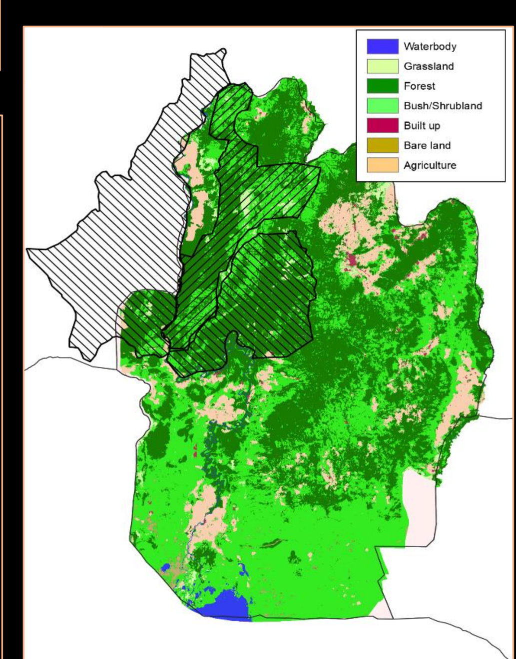


Figure 7: Land-use/Land-cover (LULC) map of the Lower Omo region showing large areas of new commercial agriculture (figure provided by Hailemariam Atinaf at the University of Arba Minch).