

Applying the Landsat Archive to Detect Ecological Thresholds in the West African Tropical Forests

Landsat Science Team meeting 28 July, 2016

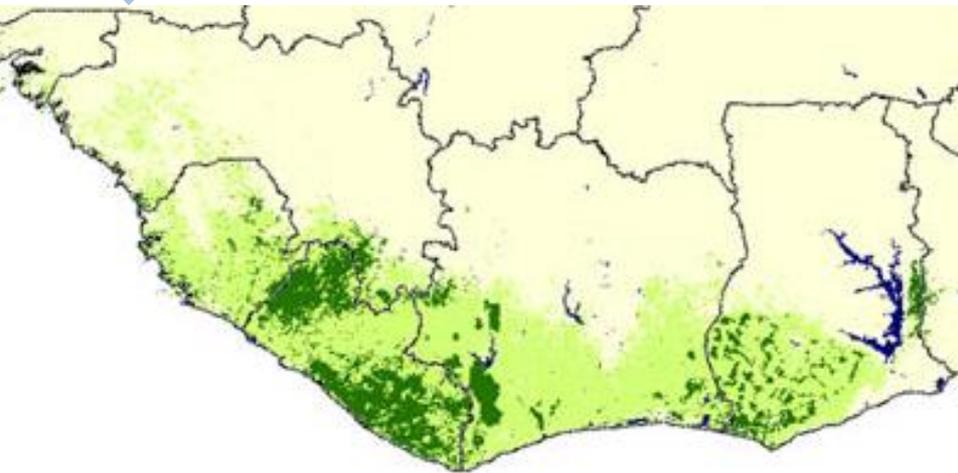
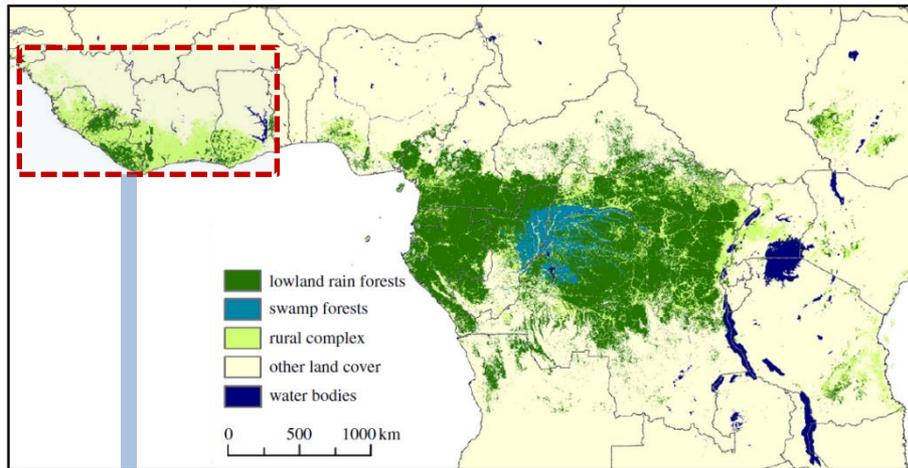
Francis Dwomoh & Michael Wimberly

Geospatial Sciences Center of Excellence

South Dakota State University



Upper Guinean Forest of West Africa



- West African tropical forest (Upper Guinean forest)
 - ≈ 10.9 million ha
 - a globally significant biodiversity hotspot
 - vital resource for region's wellbeing
 - Also under intense stress due to land use and climatic pressures

Upper Guinean Forest

- Remaining remnants contained in protected areas, which are embedded in a hotspot of climate stress & land use pressures, increasing their vulnerability to fire



Intact closed forests less susceptible to fire

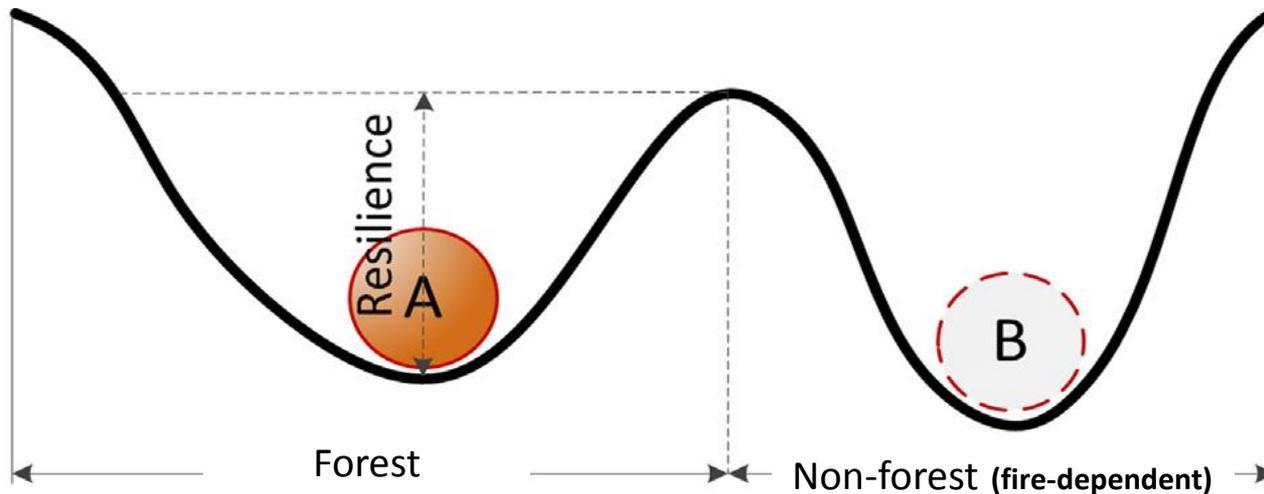


Fragmented & disturbed forests susceptible to fire



Hypothesis

In the semi-deciduous tropical forest zone, increased fire activity has compromised forest resilience by pushing the system past a tipping point to an alternative stable state in which a novel ecosystem with low tree density is maintained by fire.



Ecological thresholds (Regime shifts) : Ball-and-valley diagram

  Alternative ecosystem states

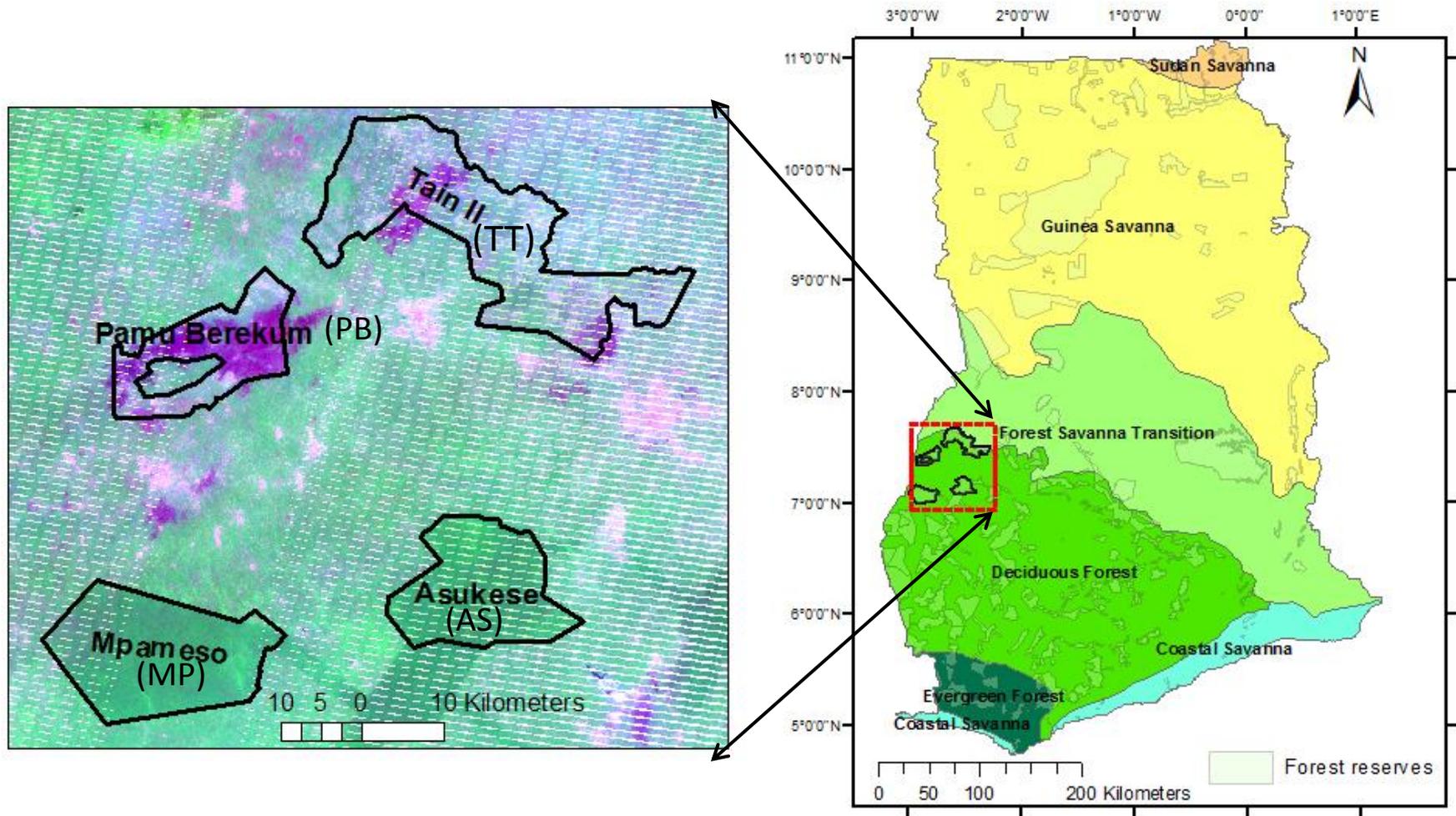
 Ecosystem regime

Using Landsat data to detect regime shifts

Look for components underlying regime shifts:

- 1. *Trigger*:** Detect sudden large disturbances that directly affect ecosystem states;
- 2. *Positive feedbacks*:** Map vegetation changes and identify novel feedbacks which reinforce new vegetation states; &
- 3. *Hysteresis*:** Map to demonstrate that alternative vegetation states exist under similar environmental conditions.

Study area



Four forest reserves in the semi-deciduous tropical forest zone of Ghana

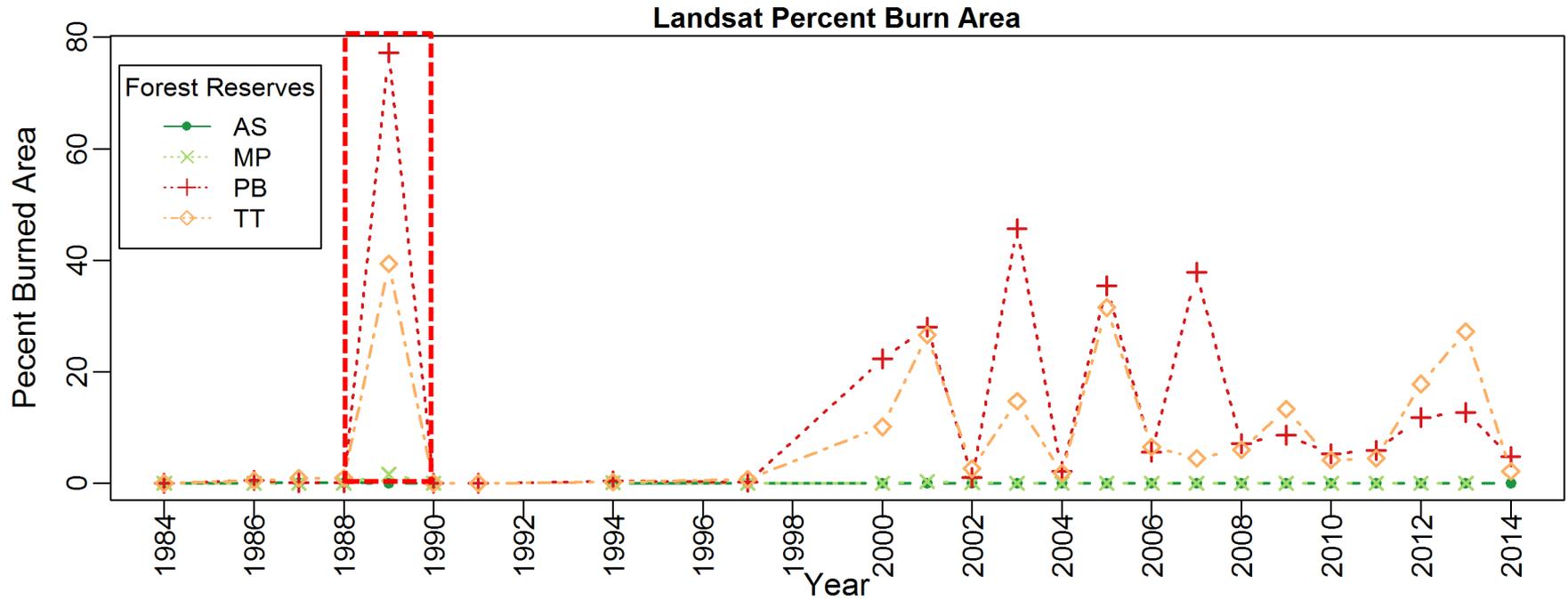
Data

- 26 Landsat images, p/r =195/55, 1984 – 2015
 - Landsat TM/ETM+ imagery , surface reflectance
 - Source: USGS-EROS
 - Spatial resolution 30m
- Precipitation
 - Historical precipitation data from 3 weather stations in Ghana, 1976-2013
 - Source: Ghana Meteorological Service
- Field-based datasets
 - Forest inventory data in the 4 forest reserves:
 - Historical: 1986–1990
 - Current: March 2014
- Field points of current land cover, 2013-2014

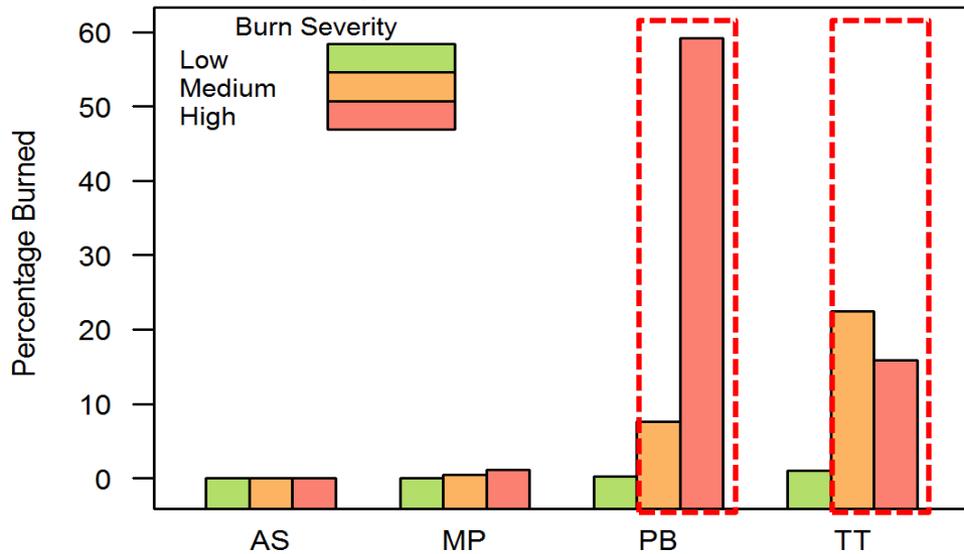
Methods

- Generate time series:
 - Tasseled Cap brightness, greenness & wetness indices
 - Disturbance index (DI, Healey, et al., RSE 2005)
 - the normalized spectral distance of a given pixel from a nominal “mature forest” class to a “bare soil” class.
 - Normalized burn ratio(NBR), dNBR & burned area
- Conduct time series analyses (trends and breakpoints)
- Summarize forest inventory data

Results: Burned area time series

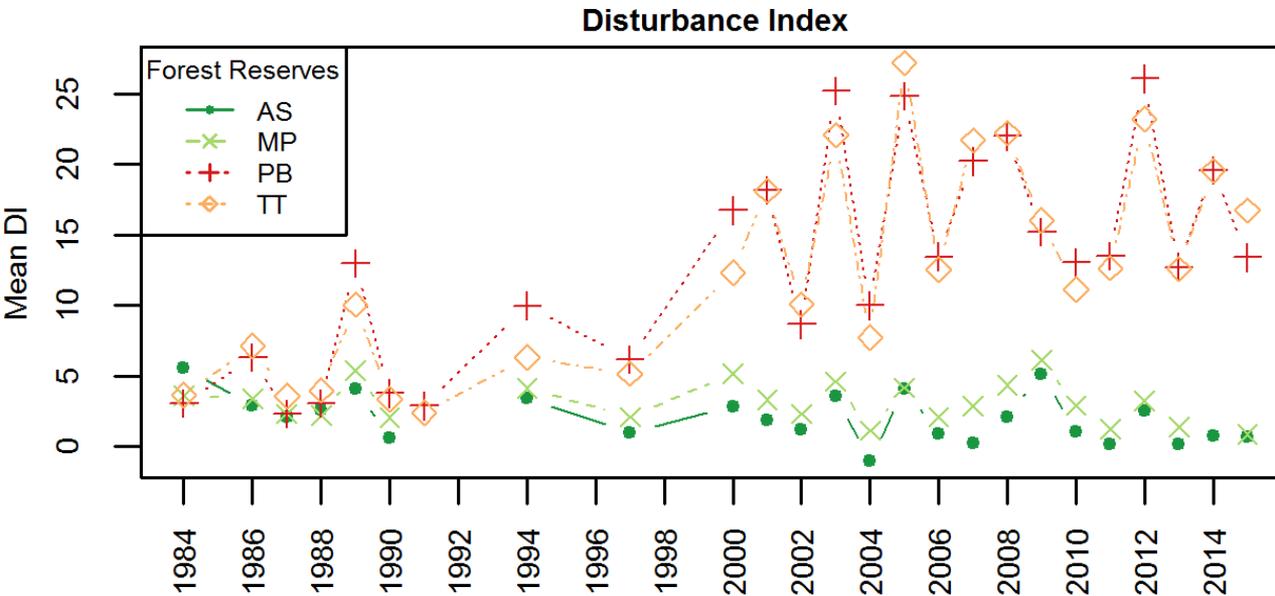


Immediate post-fire burn severity 1989

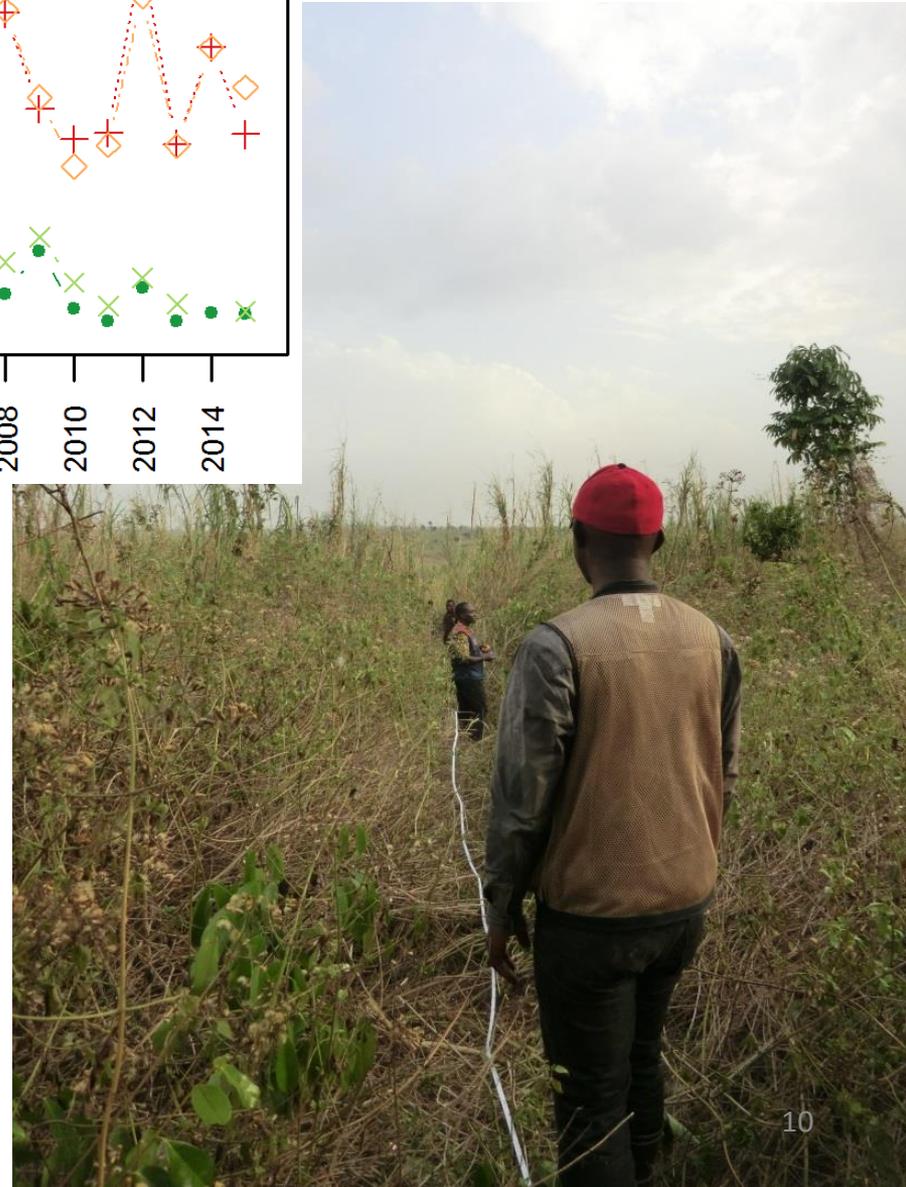


Trigger

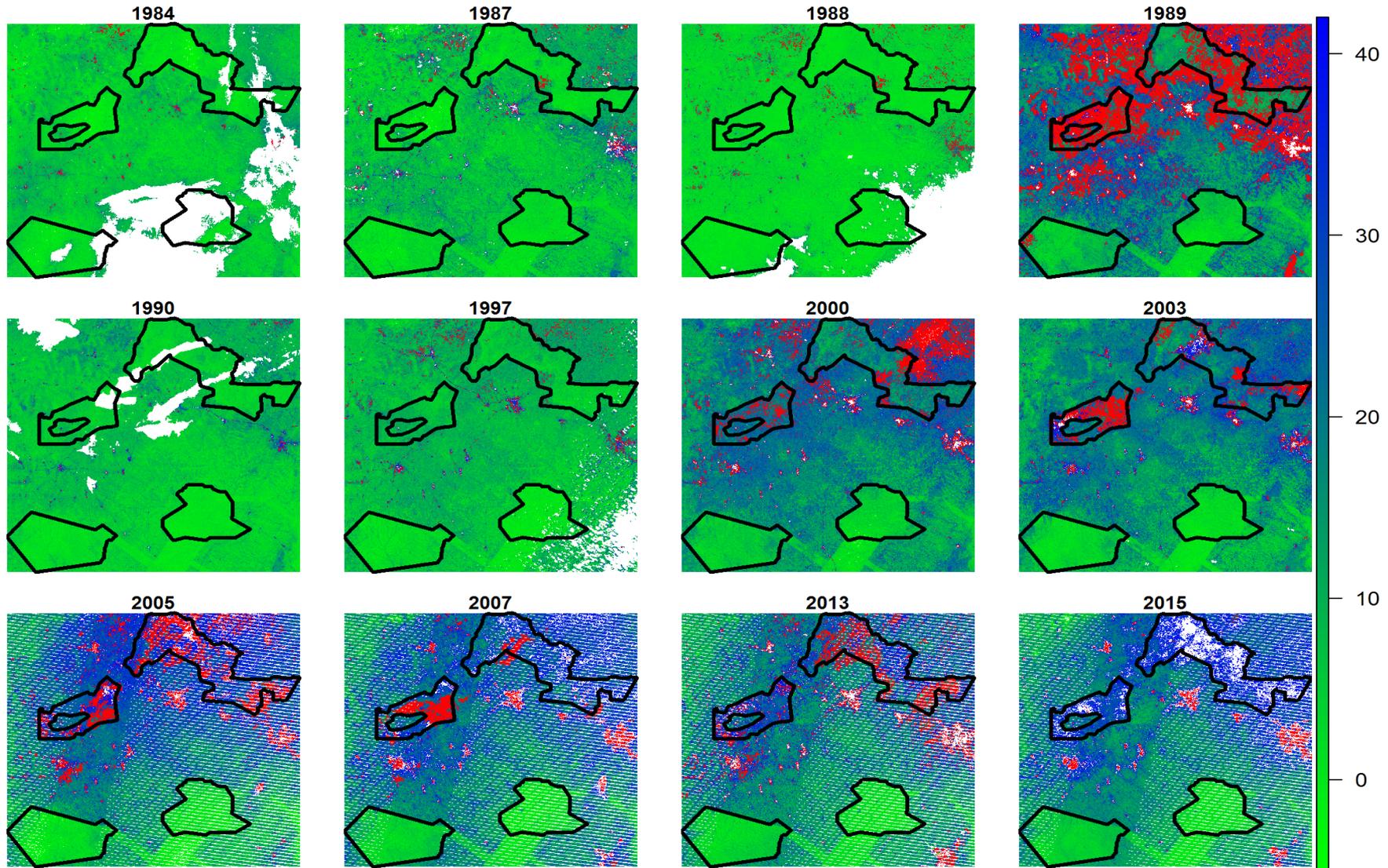
Feedbacks & hysteresis



- Pamu Berekum and Tain II have poor forest condition: low tree density, basal area, & canopy cover



Feedbacks & hysteresis: Disturbance index and burned area time series maps



Colors represent a gradient from closed forest (green) to degraded forests or low vegetation cover (blue). Red color represents recently burned sites; white spaces indicate non-vegetated surfaces or no data

Feedbacks & hysteresis: current alternative vegetation states in study area

A) Unburned forest



B) Recently (& frequently) burned



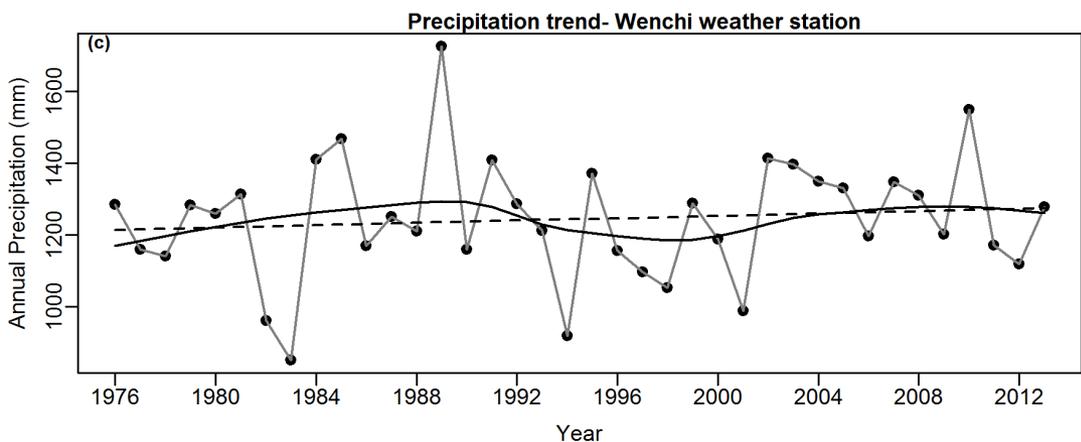
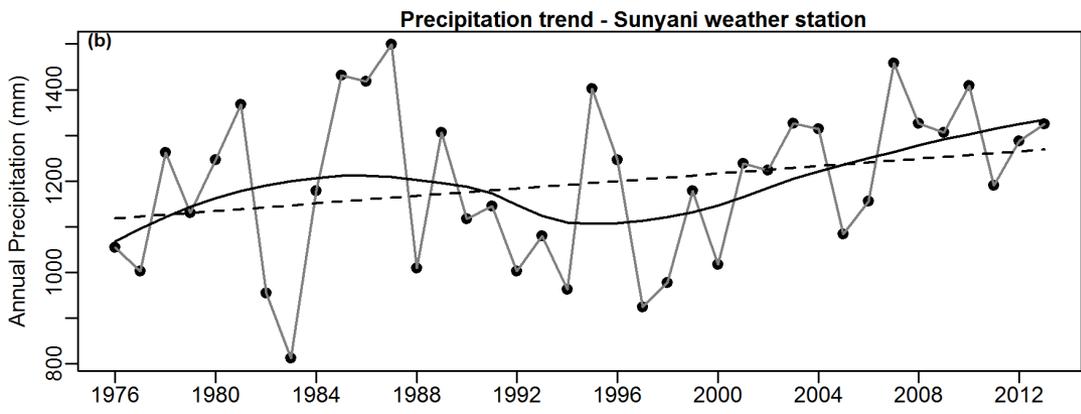
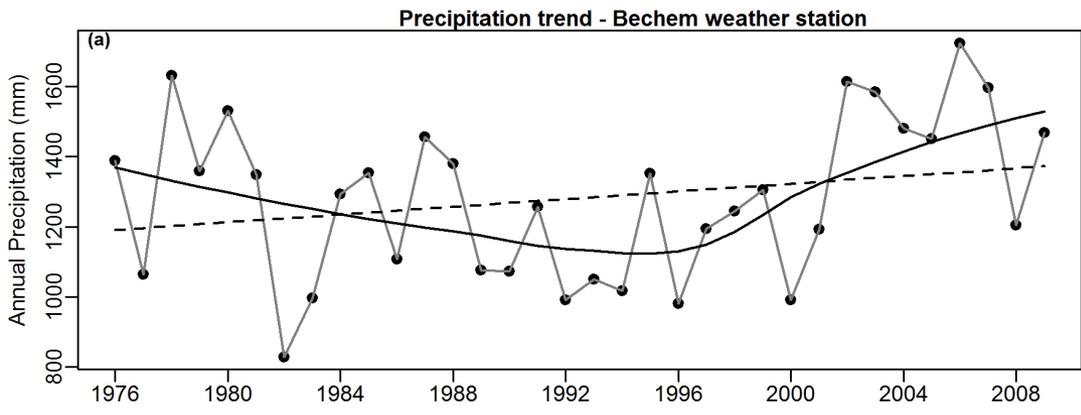
C) Transition to shrub-dominant vegetation



D) Transition to grass-dominant vegetation



Hysteresis: Precipitation trends



- Conditions have not become drier
- Northern and southern reserves have similar rainfall regime, but different fire regimes
- Increased fire activity in northern reserves not driven by drier climate

Summary of Results

- Late 1980's widespread and severe burning was a *trigger* for declining forest cover in the two northern reserves
- The disturbed reserves transitioned to pyrogenic grass and shrub dominated vegetation, maintained by fire-vegetation *positive feedbacks*
- Despite a generally increasing precipitation, non-forested conditions persist in burned forest, suggesting a *hysteresis* effect

Role of the Landsat archive

- Scarcity of data on large scale disturbances & long-term records have constrained empirical studies of fire-driven regime shifts in tropical forest
- By leveraging the Landsat archive (1984-present), we were able to explore an important ecological question on ecosystem regime shifts in the tropics that would not have been possible otherwise.

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