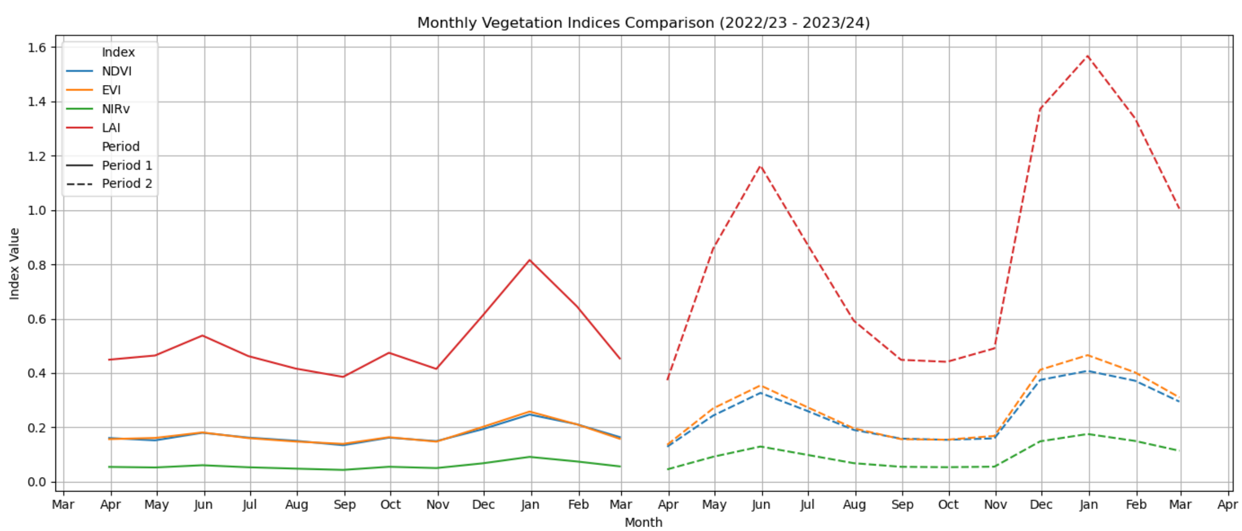
Phenology and Productivity Analysis

To assess inter-annual variability in vegetation dynamics, I analyzed monthly time series of four vegetation indices, NDVI, EVI, NIRv, and LAI. These indices were derived from Sentinel-2 SR data, spatially averaged over the region of interest, and used to quantify both seasonal productivity and phenological timing.

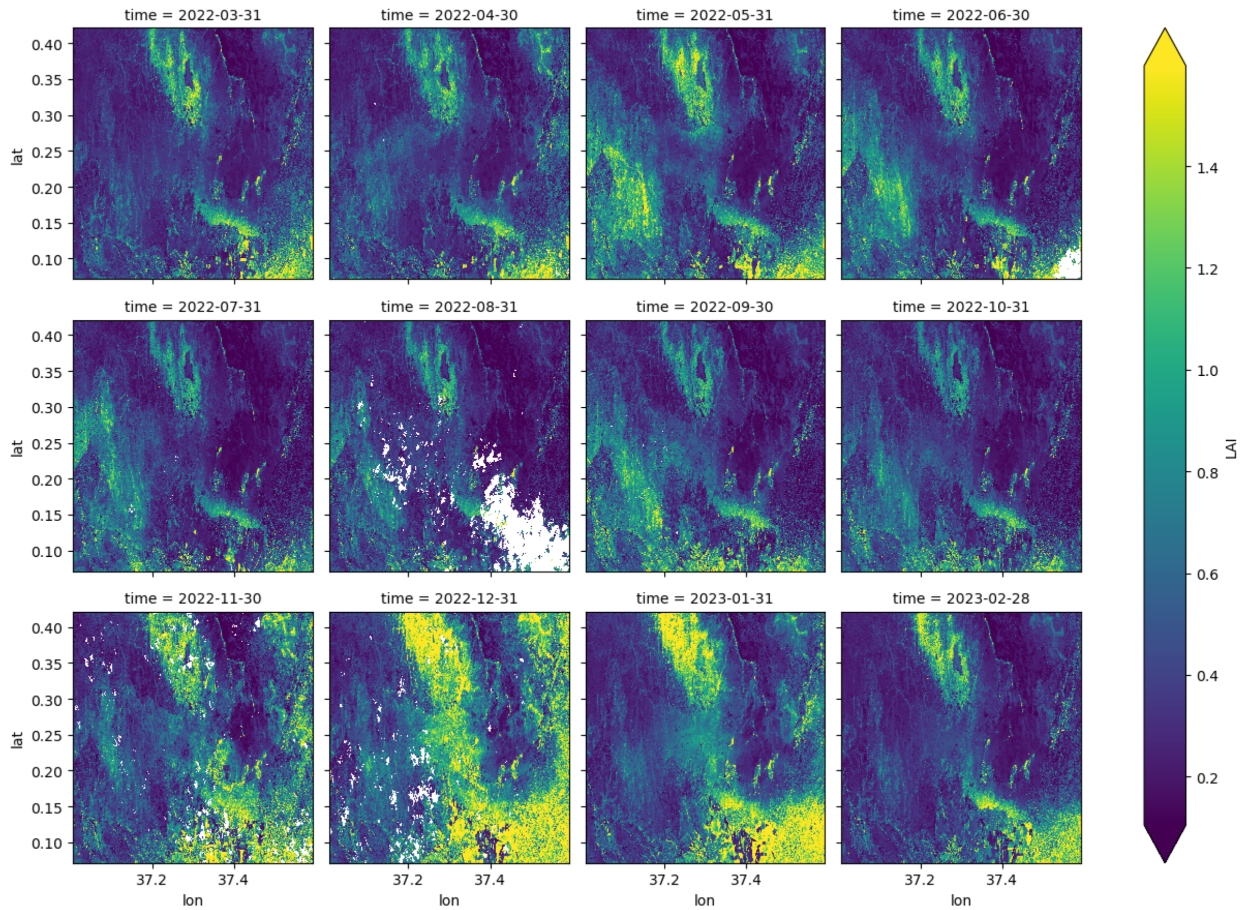
I computed summary statistics (mean, max, standard deviation) for each index and derived phenological metrics—onset, offset, and growing season duration using a hybrid thresholding method. Each index's threshold was defined as the maximum of a relative threshold (20% of seasonal amplitude) and an index-specific absolute minimum (NDVI ≥ 0.2, EVI ≥ 0.1, LAI ≥ 0.5).

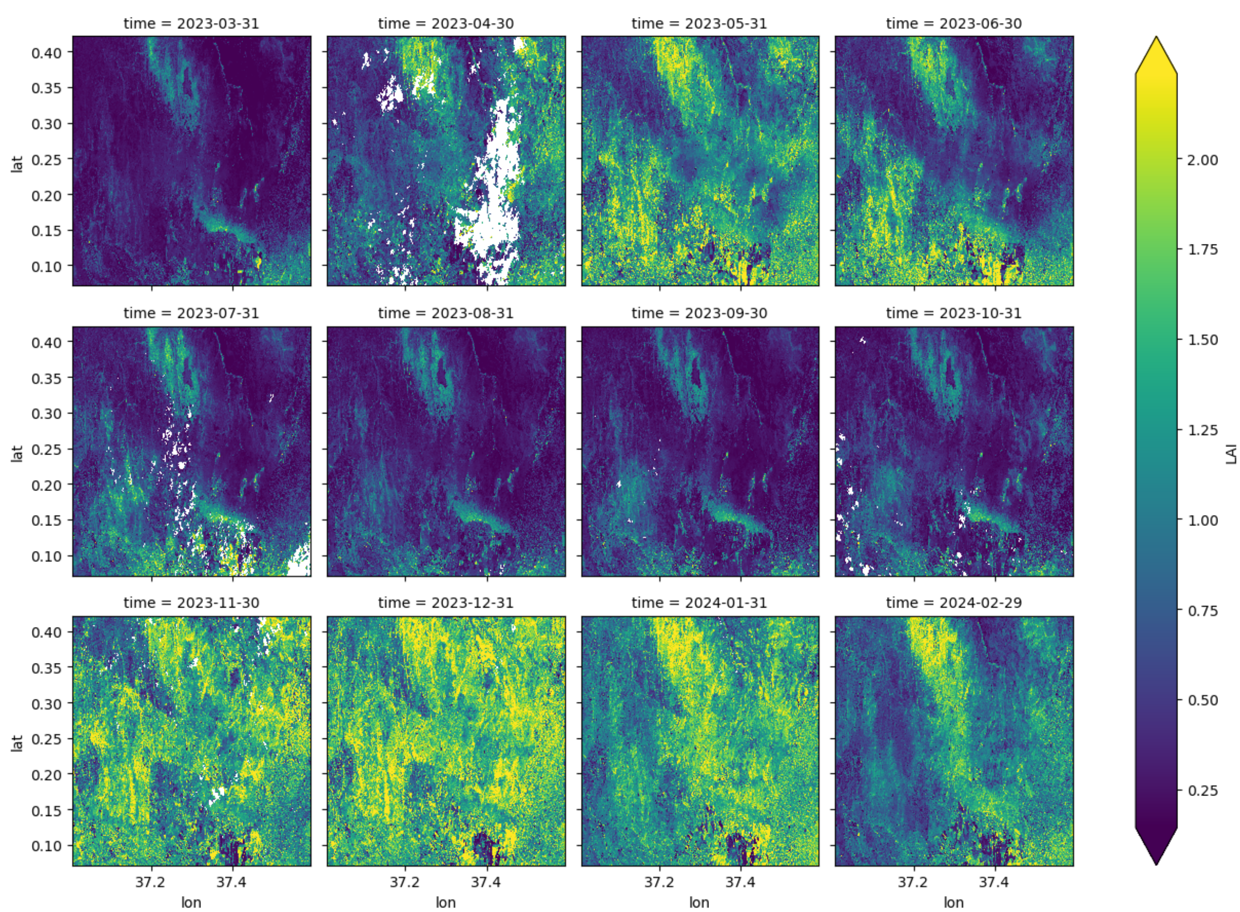
The comparison revealed substantial increases in productivity and growing season length in Period 2 relative to Period 1:

- **NDVI** mean increased by 49%, with the growing season length increasing from 1 month to 10 months.
- **EVI** and **LAI** also showed significant increases in both amplitude and duration, indicating enhanced canopy vigor and structural biomass.
- **NIRv** was consistently above its threshold in both years but increased by 68% in mean value from p1 to p2.



These results indicate that Period 2 experienced more intense and prolonged vegetation activity, likely due to an earlier, more sustained, and spatially extensive rainy season. In contrast, Period 1 showed weak NDVI response, with only a brief greening episode in late 2022, pointing to below-average or delayed rainfall.


time = 2022-03-31
time = 2022-04-30
time = 2022-05-31
time = 2022-06-30
time = 2022-07-31
time = 2022-08-31
time = 2022-09-30
time = 2022-10-31
time = 2022-11-30
time = 2022-12-31
time = 2023-01-31
time = 2023-02-28
lat
0.40
0.35
0.30
0.25
0.20
0.15
0.10
37.2
37.4
lon
LAI
1.4
1.2
1.0
0.8
0.6
0.4
0.2


time = 2023-03-31
time = 2023-04-30
time = 2023-05-31
time = 2023-06-30
time = 2023-07-31
time = 2023-08-31
time = 2023-09-30
time = 2023-10-31
time = 2023-11-30
time = 2023-12-31
time = 2024-01-31
time = 2024-02-29
lat
0.40
0.35
0.30
0.25
0.20
0.15
0.10
37.2
37.4
lon
LAI
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25

It is important to note that all metrics were spatially averaged over the region, which may mask sub-regional phenological heterogeneity. Localized dynamics such as soil variation, topography, and land use, can drive significant variation in green-up timing and productivity. For example, areas under community-based rangeland management, such as conservancies or rotational grazing schemes, may exhibit greater resilience to climatic extremes and faster recovery post-drought.

Because rainfall is the dominant control on phenology in this ecosystem, isolating the influence of conservation or grazing management requires disentangling climatic and anthropogenic effects. One promising strategy is to statistically model the vegetation index response as a function of rainfall, using historical precipitation data (e.g., from CHIRPS). The residuals from this model—areas where vegetation performs better or worse than expected—can then be interpreted as potential signals of land degradation or effective management.

This residual-based approach can help identify:

- Positive anomalies, indicating successful interventions such as grass banks, or rotational grazing efforts.
- Negative anomalies, pointing to areas where overgrazing or land degradation may be limiting productivity despite adequate rainfall.