

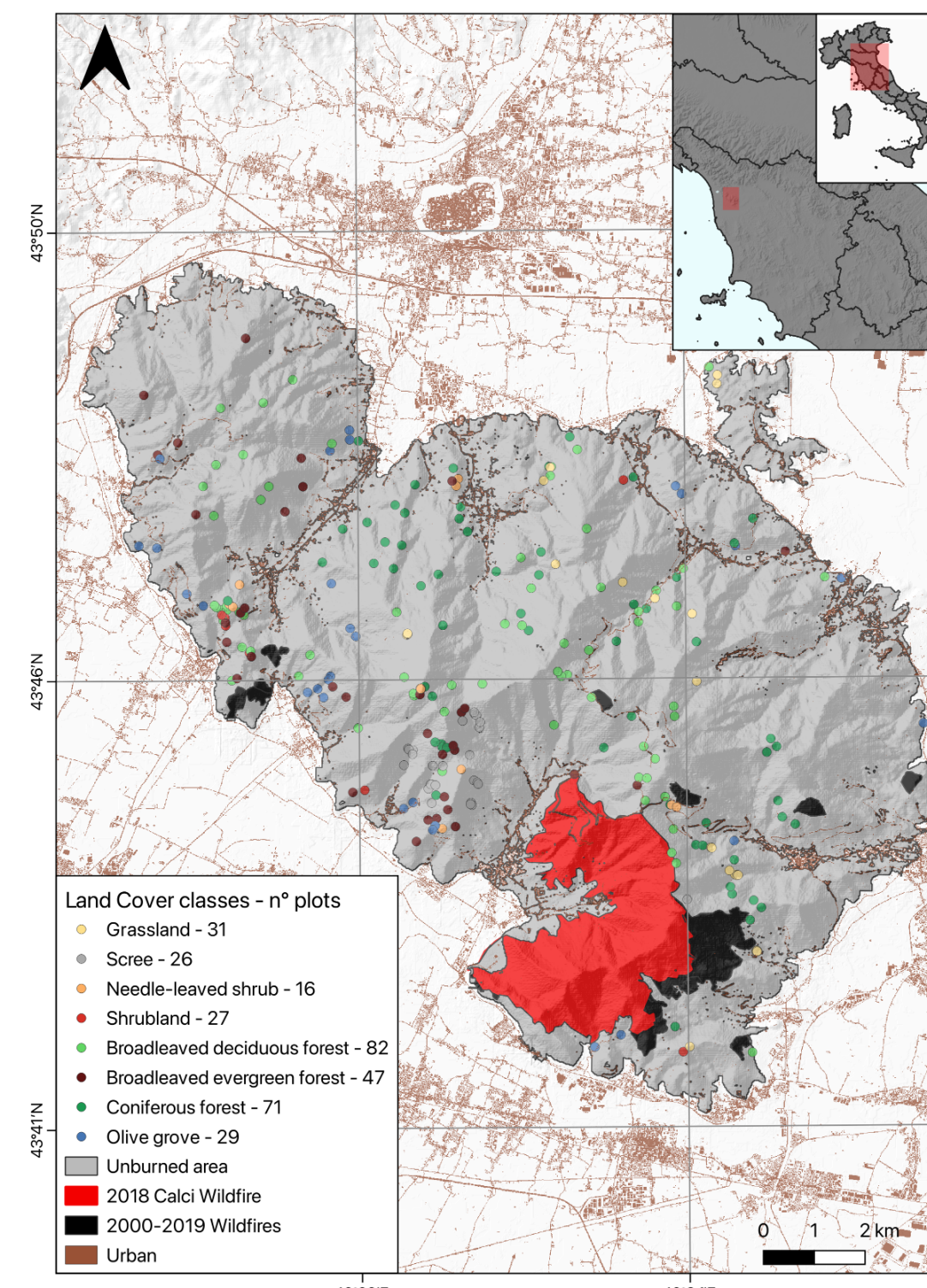
Problem Definition and Contribution

Goal: Assessing post-fire vegetation recovery trajectories in Mediterranean ecosystems (2017–2024) by integrating Random Forest modeling with Sentinel-2 satellite time series.

Key Contributions:

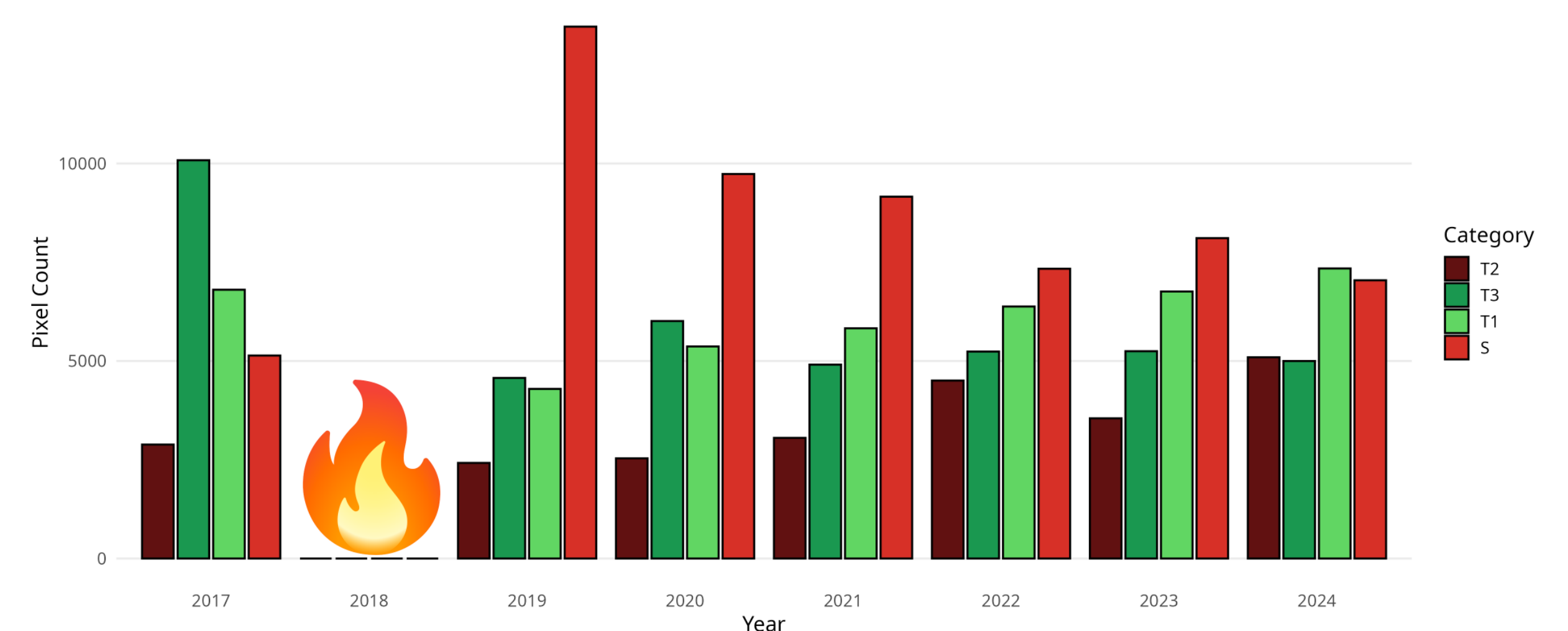
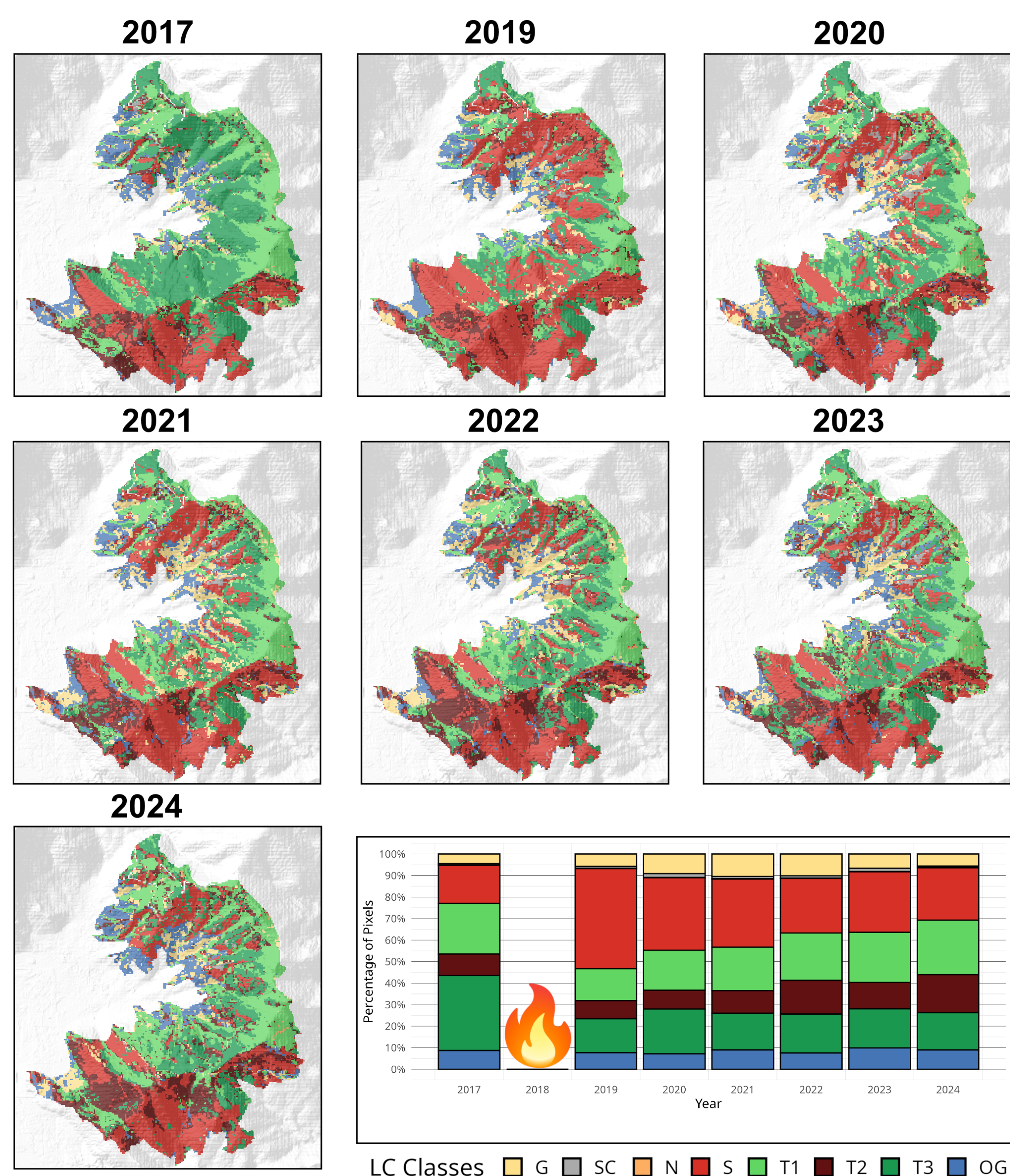
- **Machine Learning Framework:** A Random Forest (RF) based classification approach (78–82% accuracy) to map multi-year land-cover transitions across native forest and shrubland classes.
- **ΔNDVI Dynamics:** Implementation of $\Delta\text{NDVI} = \text{NDVI}_{\text{pre-fire}} - \text{NDVI}_{\text{post-fire}}$ to identify spectral breakpoints and quantify the recovery of photosynthetic vigor per plant functional type.
- **Statistical Rigor:** Use of non-parametric Mann-Whitney U tests on bootstrapped distributions (1,000 iterations) to validate the significance ($p < 0.05$) of recovery patterns between burned and unburned reference areas.
- **Ecological Insights:** Spatially explicit quantification of recovery trajectories, distinguishing between the rapid resilience of broadleaf resprouters and the slower recovery rates of coniferous stands.

Study area



Map showing the 2018 Calci fire area (red), fires from 2000 to 2019 (black), and unburned area before the 2000 (grey). Dots indicate ground-truth observations for land-cover classes. Land-cover class acronyms are as follows: (G) grassland, (SC) scree, (N) needle-leaved shrub, (S) shrubland, (T1) broadleaved deciduous forest, (T2) broadleaved evergreen forest, (T3) coniferous forest, and (OG) olive groves.

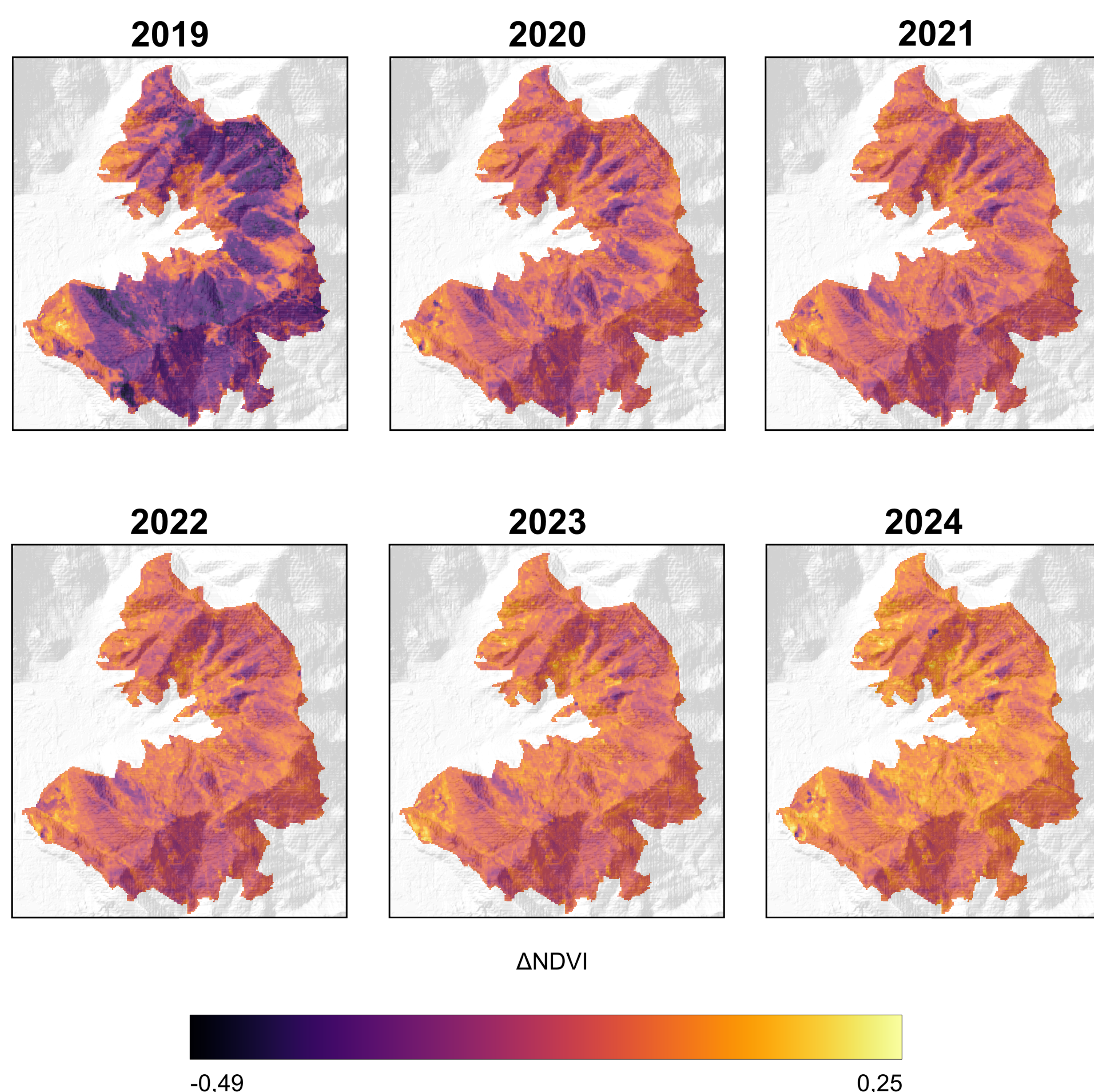
RF Model



Land-cover transition

- **Pre-fire Baseline:** Prior to the fire event, the landscape was dominated by coniferous forests in the central area, with deciduous forests prevailing at higher elevations. Shrubland ecosystems were primarily distributed in the southern sector and along the rural–urban interface.
- **Post-fire Shift:** Massive transition to shrubland (reaching +160% in 2019) immediately following the 2018 wildfire event.
- **Forest Decline:** Significant reduction in forest cover, with coniferous stands (*Pinus spp.*) showing the most severe loss (~55%) compared to broadleaf forests (16–35%).
- **Recovery Trends:** Bar charts showing yearly pixel count variation for forest and shrubland stands from 2017 to 2024, highlighting the gradual re-colonization of native species.

NDVI recovery



Recovery Trajectories

Burned areas exhibit pronounced interannual variability in NDVI, consistent with post-fire vegetation regrowth dynamics, whereas unburned areas remain comparatively stable over the study period, showing only minor fluctuations. Box-Whisker plots of NDVI distributions from 2017 to 2024 in the unburned (green) and burned (red) areas of the Monte Pisano study site; The symbol * below the years in the x axis denotes distribution difference statistical significance based on the Mann–Whitney U test ($p < 0.05$).