EGU26-16930

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EGU26 GENERAL ASSEMBLY

Estimating & Predicting Post-Fire Forest Recovery Using Satellite-Derived Vegetation Indicators

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1 Problem

- **Wildfires are a major disturbance to forest ecosystems** causing significant losses in ecosystem services and carbon storage capacity
- **Post-fire recovery is critical for climate regulation** understanding recovery speed and completeness is key to assessing long-term resilience
- **Robust large-scale quantification methods remain limited** few established frameworks integrate multiple complementary indicators across European forests
- **This study addresses the gap using five satellite-derived indicators over Europe:**

Canopy Structure (LAI)

Greenness (NDVI,EVI)

Photosynthetic Activity (GPP, FPAR)

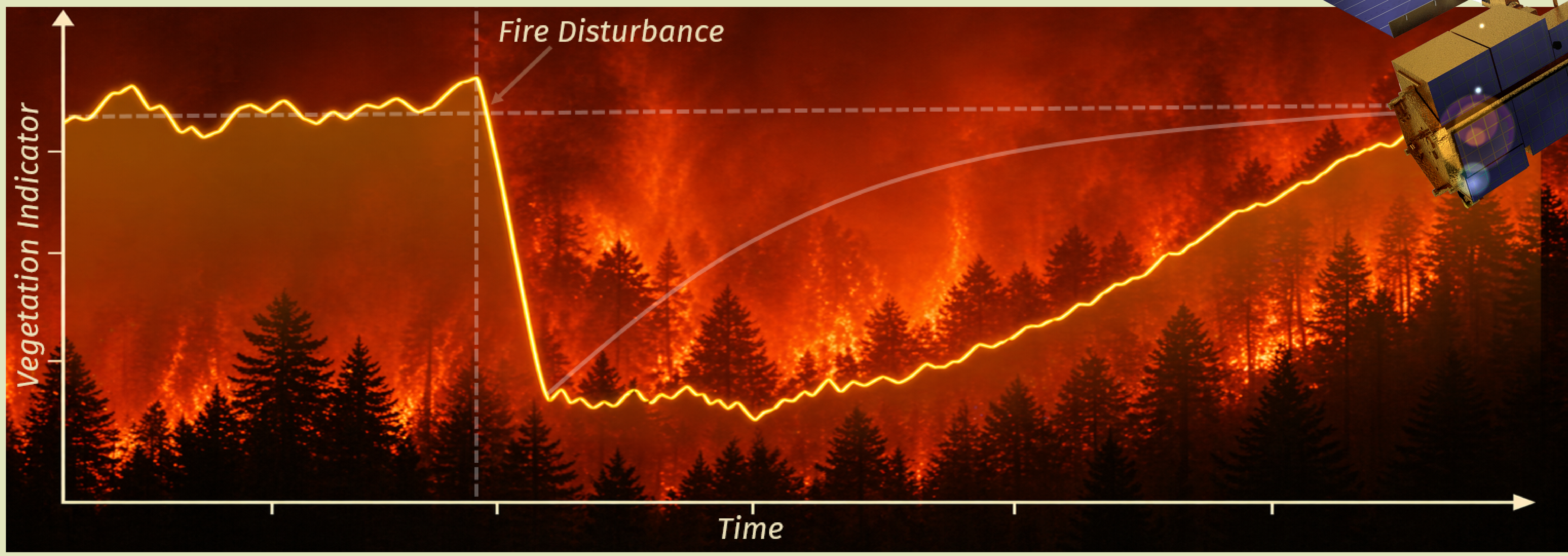

Figure 1: Schematic representation of an exponential recovery model fit to the timeseries of a satellite derived vegetation indicator over a burned forest including the used MODIS-Terra Satellite

5 Conclusions

This study presents a scalable framework to quantify post-fire forest recovery using satellite-derived vegetation indicators. Key findings include:

- **Consistent recovery within a few years**, confirming overall ecosystem resilience
- **Strong parameter differences**, with NDVI indicating slower recovery due to saturation effects
- **Higher regime shift detection in LAI**, reflecting delayed structural recovery compared to rapid greenness recovery
- **Validation of CSD theory**, enabling prediction of recovery rate magnitude from pre-fire dynamics

Although demonstrated for Europe, the approach is globally transferable, offering a powerful tool for large-scale ecosystem resilience assessment.

2 Method

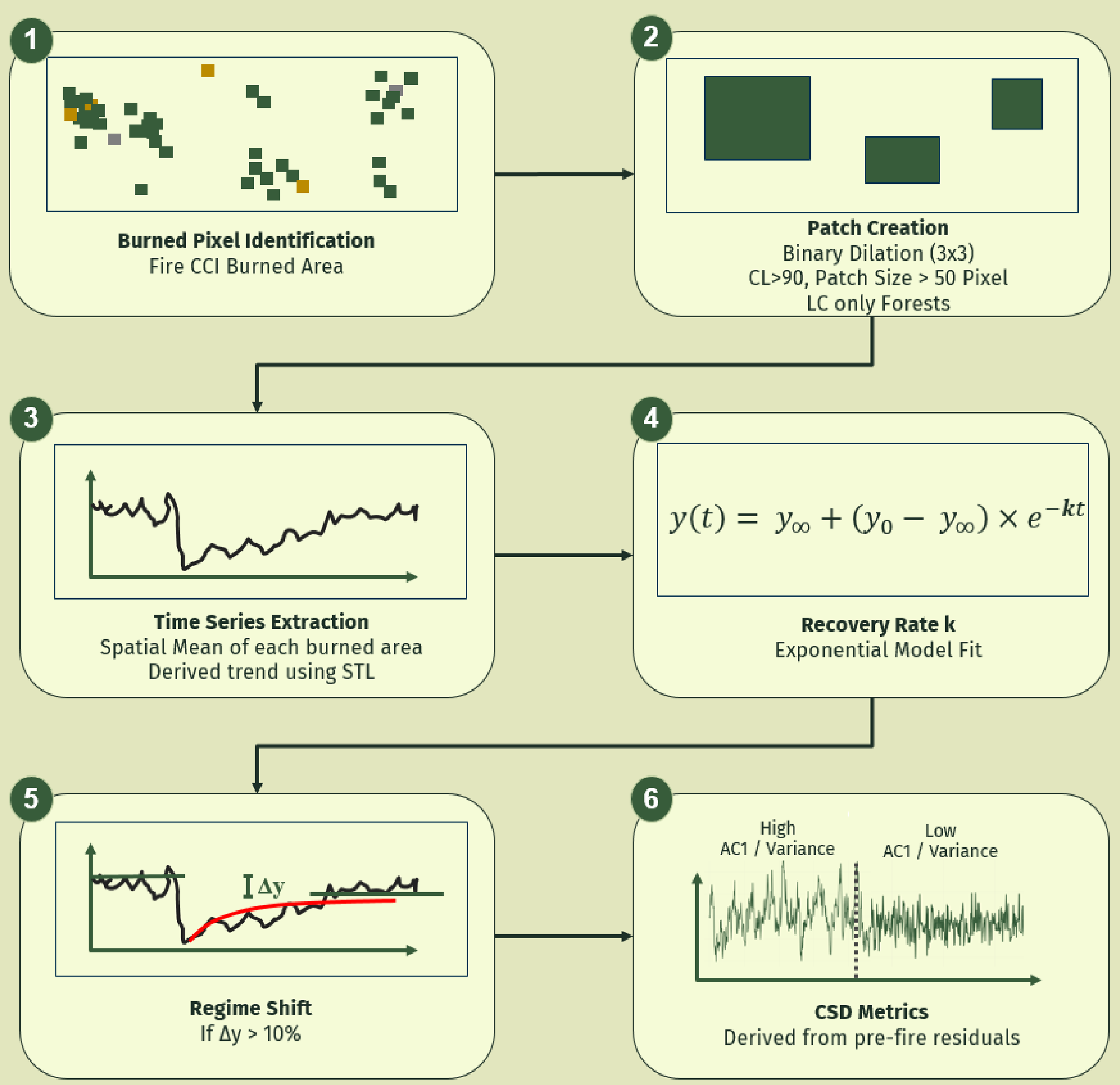

Figure 2: Schematic Illustration of the applied methodology, including burned pixel identification, patch creation, spatial time series extraction, estimation of the empirical recovery rate, classification of a regime shift and derivation of CSD Metrics AC1 and variance

3 Results

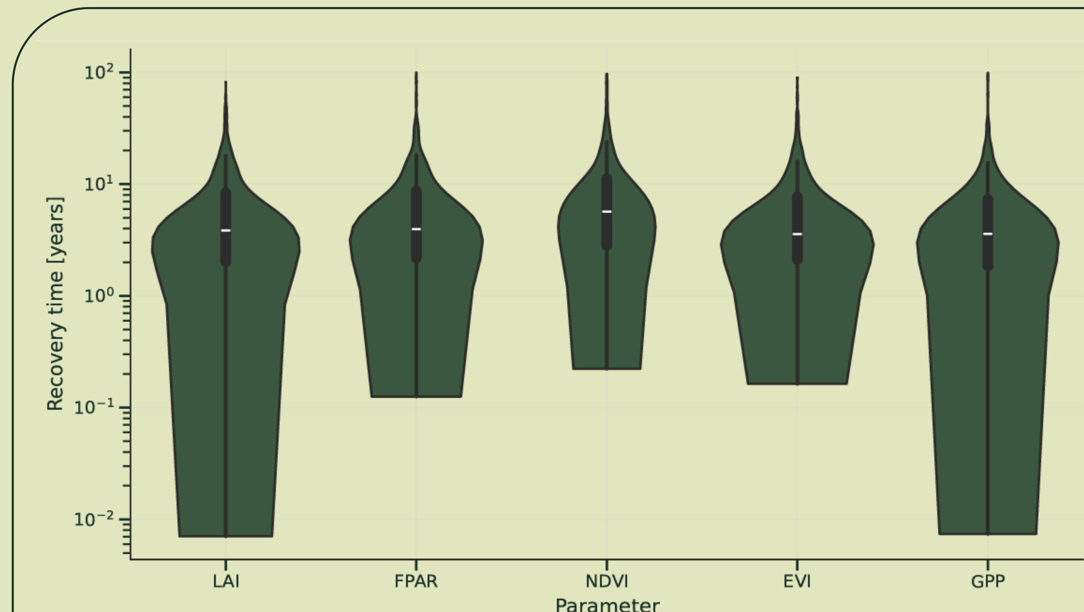

Figure 3: Distribution of patch-level recovery times (years to 95% recovery) across vegetation parameters. Recovery time is derived from an exponential recovery model. Violin width indicates data density; horizontal lines show medians.

- Median recovery times are ~3.6–4.0 years for EVI, LAI, FPAR, and GPP
- NDVI shows slower recovery (~5.7 years)
- Fastest recovery: GPP and LAI
- Highest variability: NDVI (σ ~14 years)

Differences arise from index sensitivity and saturation effects, with NDVI underestimating recovery in dense canopies.

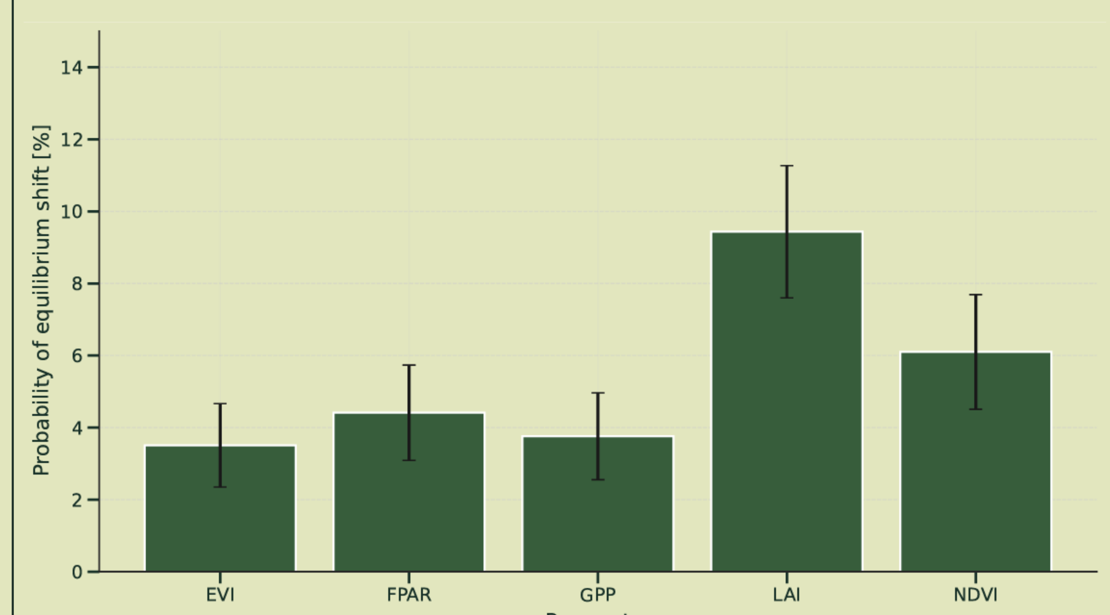

Figure 4: Probability of regime shifts per vegetation parameter, defined as the fraction of patches with >10% decline in post-fire equilibrium. Error bars represent 95% bootstrap confidence intervals.

- Highest regime shift probability: LAI (~9.4%)
- Moderate: NDVI (~6.1%)
- Lowest: EVI & GPP (~4.0%)
- Largest variability: LAI (σ ~30%)

Structural indicators (LAI) detect persistent changes more strongly than greenness-based indices.

4 Can we predict post-fire recovery rates?

Using Critical Slowing Down (CSD) theory, ecosystem resilience can be inferred from internal time-series properties:

Lag-One Autocorrelation | **Variance**

Lower values of these metrics indicate higher resilience and faster recovery. Results show a clear monotonic decrease of AC1 and variance with increasing recovery rates for LAI and FPAR and a weaker and inconsistent relationship for NDVI and EVI.

(i) CSD theory is applicable in real ecosystems
(ii) LAI and FPAR are robust indicators for resilience assessment
(iii) Post-fire recovery rates can be predicted from pre-fire system dynamics

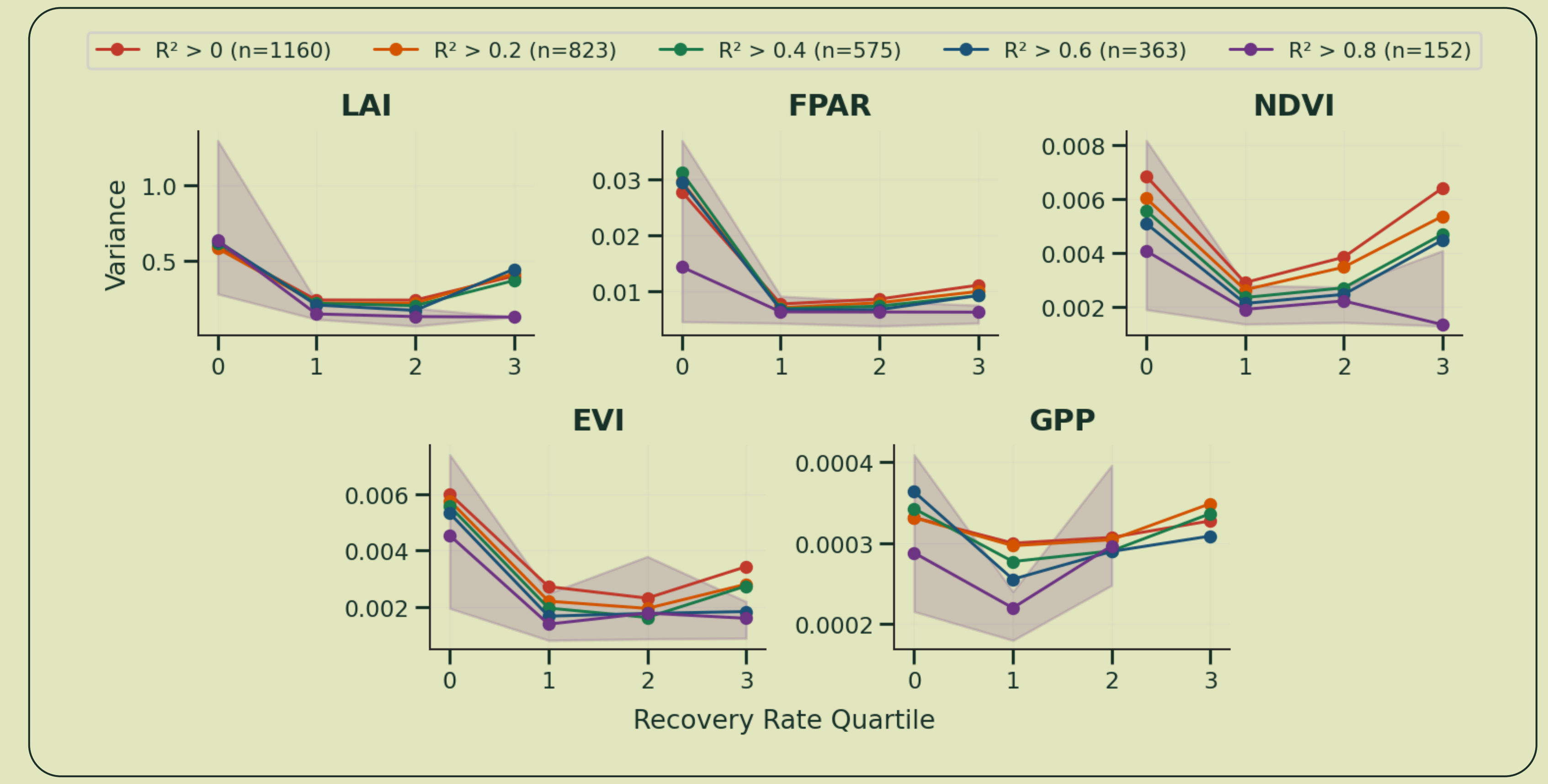

Figure 5: Median pre-fire lag-1 autocorrelation (AC1) and variance as a function of recovery rate quartiles (Q1 = slowest, Q4 = fastest). Decreasing trends indicate agreement with Critical Slowing Down theory. Strong relationships are observed for LAI, FPAR, and GPP, while NDVI and EVI show weaker patterns. Relationships improve with increasing model quality.

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Sharing is encouraged

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