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Interannual Bare Ground Dynamics at SRER Beyond Climate

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INTRODUCTION

In Rangelands, bare ground is considered a vital gauge of the ecosystem health, soil stability and land degradation and therefore its monitoring helps to pinpoint the hotspots for soil erosion, tracking the long-term effects of climate variability, livestock grazing and other disturbances. This study uses bare ground ratio (Pred_BGR) for the Santa Rita Experimental Range (SRER) developed from 40 years (1984-2025) of Landsat imagery using Gradient Tree Boost models trained on 5-cm UAS imagery and 12 Landsat derived spectral and topographic predictors. By integrating interannual variability in precipitation and climate conditions in SRER, we hypothesize that climate is the dominant driver in determining changes in bare ground. Therefore, to disentangle the influence of climate from other potential drivers, we used SPEI3 as an indicator of water availability for vegetation growth and thus reduction in bare ground from May to September of each year.

OBJECTIVE OF THE STUDY

To quantify the relationship between interannual climate variability and bare ground dynamics in the Santa Rita Experimental Range (SRER).

METHODOLOGY

Interannual climate variability: We selected SPEI3 based on correlation analysis between a range of SPEI ending months and timescales and Pred_BGR

Climate-driven bare ground response: We modeled the relationship between SPEI3 and Pred_BGR across 40 years

Remove climate signal: Bare Ground Reduction = Pred_BGR_May – Pred_BGR_Sep

Climate-adjusted residual: The residual represents variation in bare ground that remains after accounting for the modeled effect of climate

Residual reflects potential effects of grazing, wildfire or noise

RESULTS

Comparison of bare ground in May and September

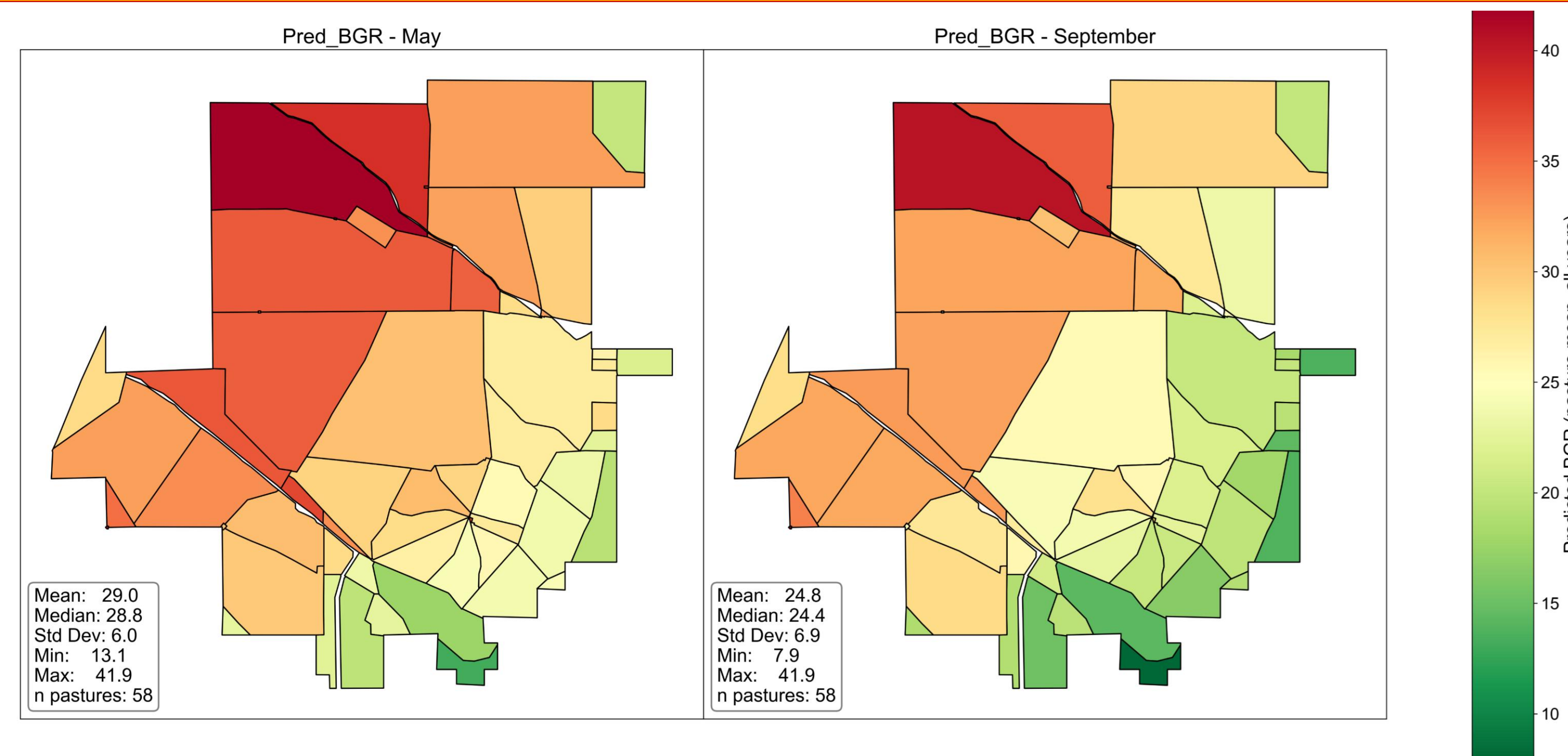


Figure 1: Reduction in predicted bare ground from May to September across SRER in 40 years where green represents less bare ground and red indicates more bare ground. A clear reduction in predicted bare ground is seen from May to September in the pastures.

Bare ground Reduction = Pred_BGR_May – Pred_BGR_Sep

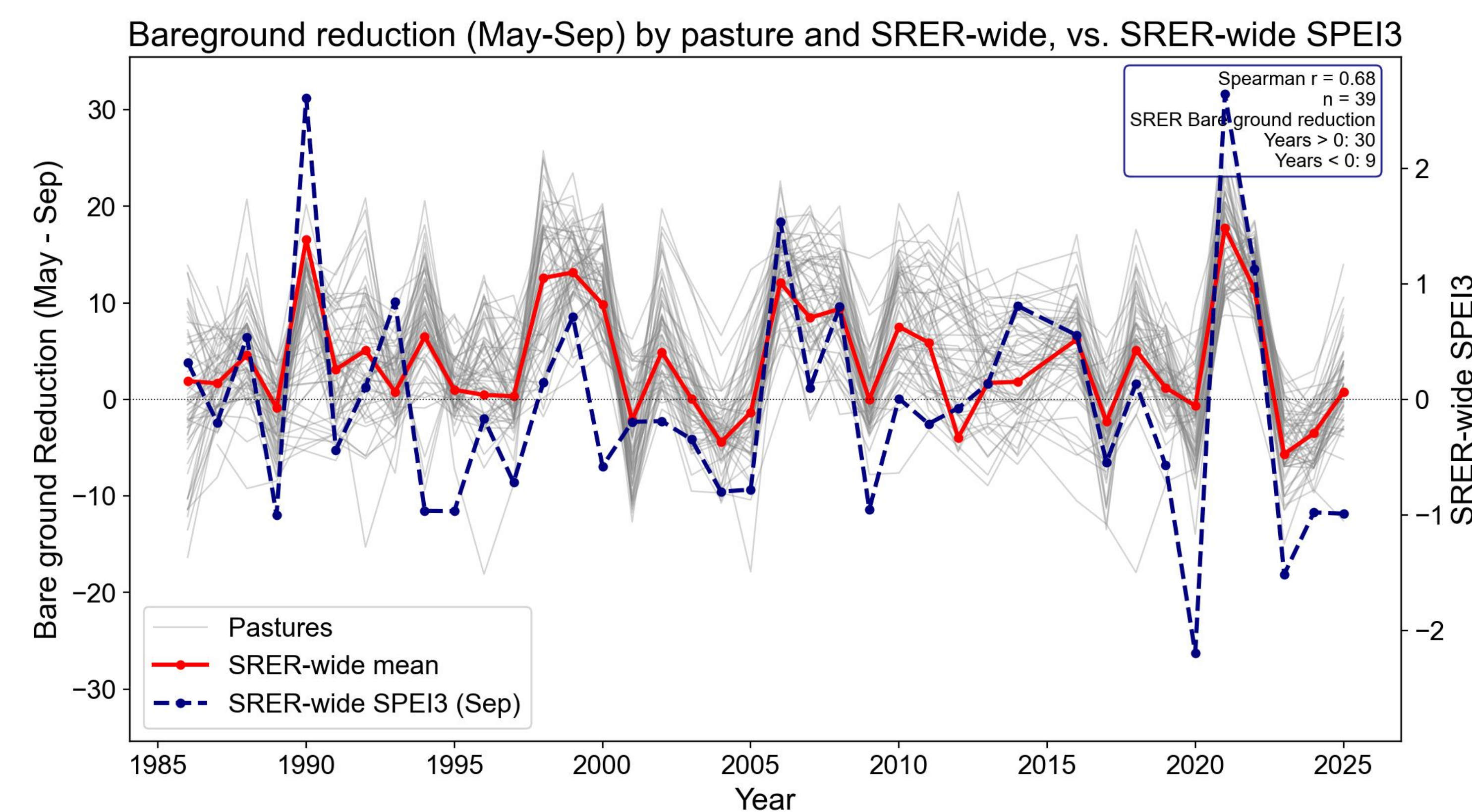


Figure 2: Timeseries of bare ground reduction in pastures and SRER along with SPEI3 across 40 years.

Removing climate signal from Bare Ground Reduction

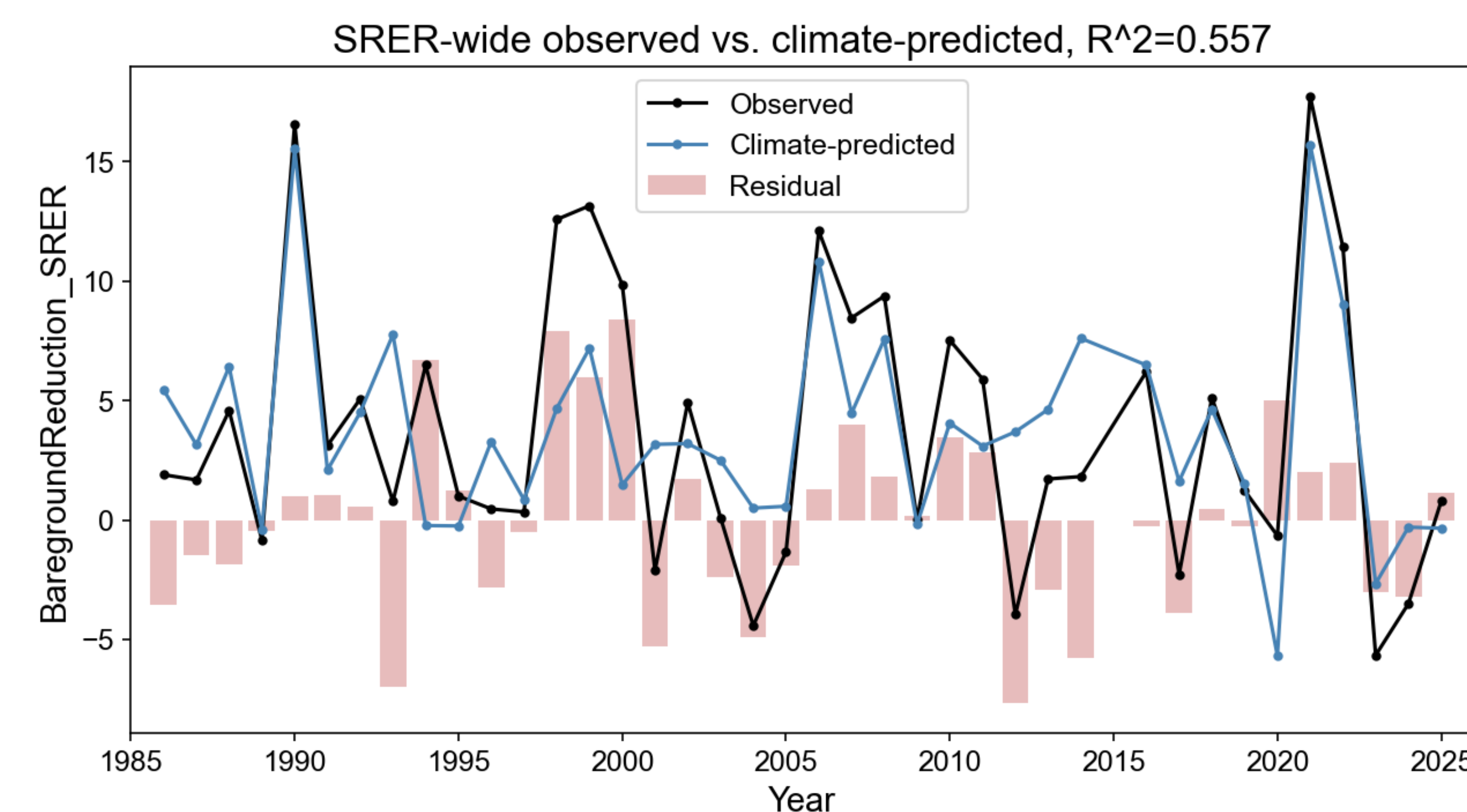


Figure 3: Timeseries of observed vs climate-predicted bare ground reduction and residual across 40 years.

Residual in pastures affected by wildfire in 1994 and 2017

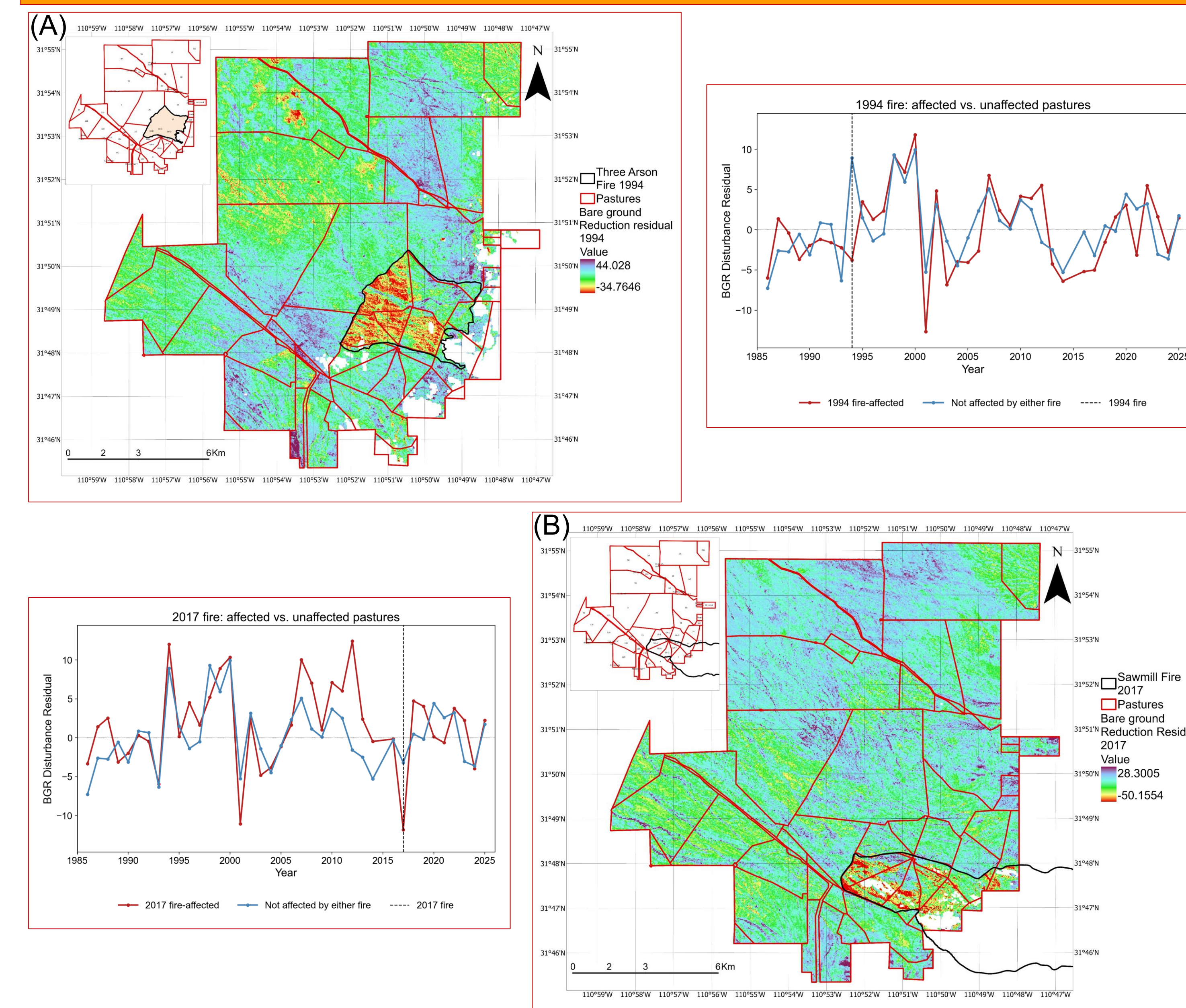


Figure 4: Distribution of bare ground reduction residual shown for two fire events; Three Arson Fire in 1994 (A) and Sawmill Fire in 2017 (B) along the residual timeseries for affected and not affected pastures by either fire.

Assessing spatial autocorrelation of mean residual across SRER

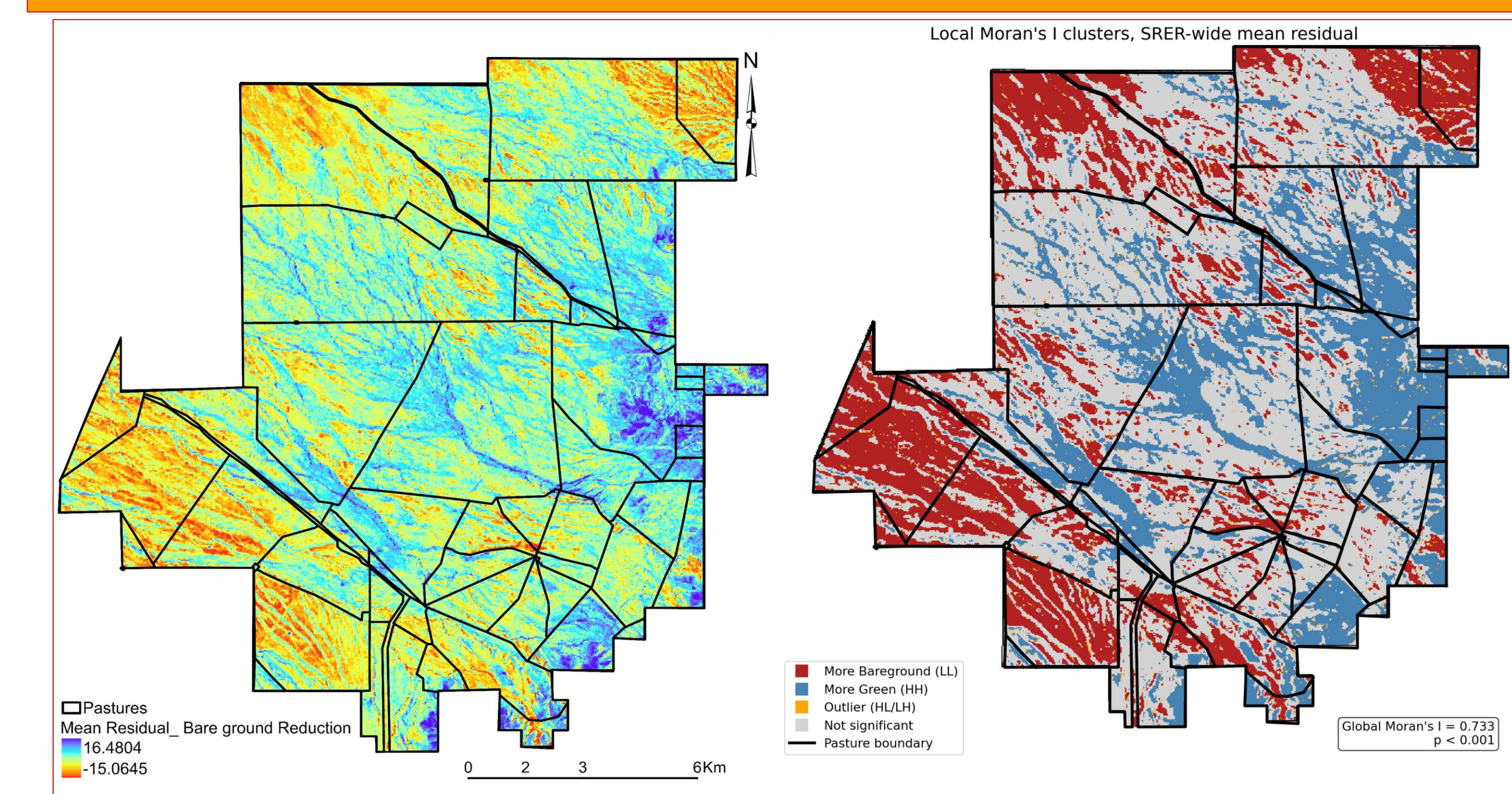


Figure 5: Comparison between mean residual and bare ground hotspots derived from Moran's I across SRER. There is a strong positive spatial autocorrelation in the residuals ($I = 0.73$, $p < 0.001$) and Local Moran's I identified 5,008 ha (23.3% of SRER) as chronic bare ground hotspot (LL) and 4929 ha (23.0%) as green hotspots (HH).

SUMMARY

- Climate (SPEI3_Sep) explains only about 56% of year-to-year bare ground variability across Santa Rita Experimental Range, and the unexplained "residual" is not random noise but significantly spatially clustered across the SRER based on Moran's I.
- Both fire events show up clearly in the residual: the 2017 fire produces a sharp dip to the most extreme negative values (~-12 to -15) in the entire 40-year record across all five affected pastures, and the 1994 fire shows a similar dip.