

Assessing Center-Pivot Irrigation Status and Patterns in the La Plata Basin, South America, Using Remote Sensing and Statistical Methods

Colton Ward¹, Soheil Nozari², Aiden Camargo², Ryan Smith²

¹Department of Mathematics, Colorado State University

²Department of Civil and Environmental Engineering, Colorado State University



COLORADO STATE UNIVERSITY

I. Motivation

- Irrigation status and pattern data are critical for understanding agricultural water use, crop production, and water resource management.
- Existing global irrigation maps lack the spatial and temporal resolution needed for tropical and subtropical regions.

II. Objectives

Our goal is to produce a comprehensive dataset of irrigated and non-irrigated center-pivot irrigation systems across the Río de la Plata Basin. Our approach seeks to:

- Develop a statistical framework for detecting irrigation status using **Normalized Difference Vegetation Index (NDVI)** and **Land Surface Temperature (LST)**
- Quantify differences between center-pivot irrigation systems and surrounding non-irrigated areas.
- Apply this framework consistently across multiple years and subregions to characterize irrigation patterns throughout the basin.

III. Study Area

- Río de la Plata Basin**, covering approximately 3.17 million km²
- 38,520 center-pivot irrigation systems, covering 16,730.41 km²
- Study period: 2004–2024
- No basin-wide ground-truth irrigation dataset available.

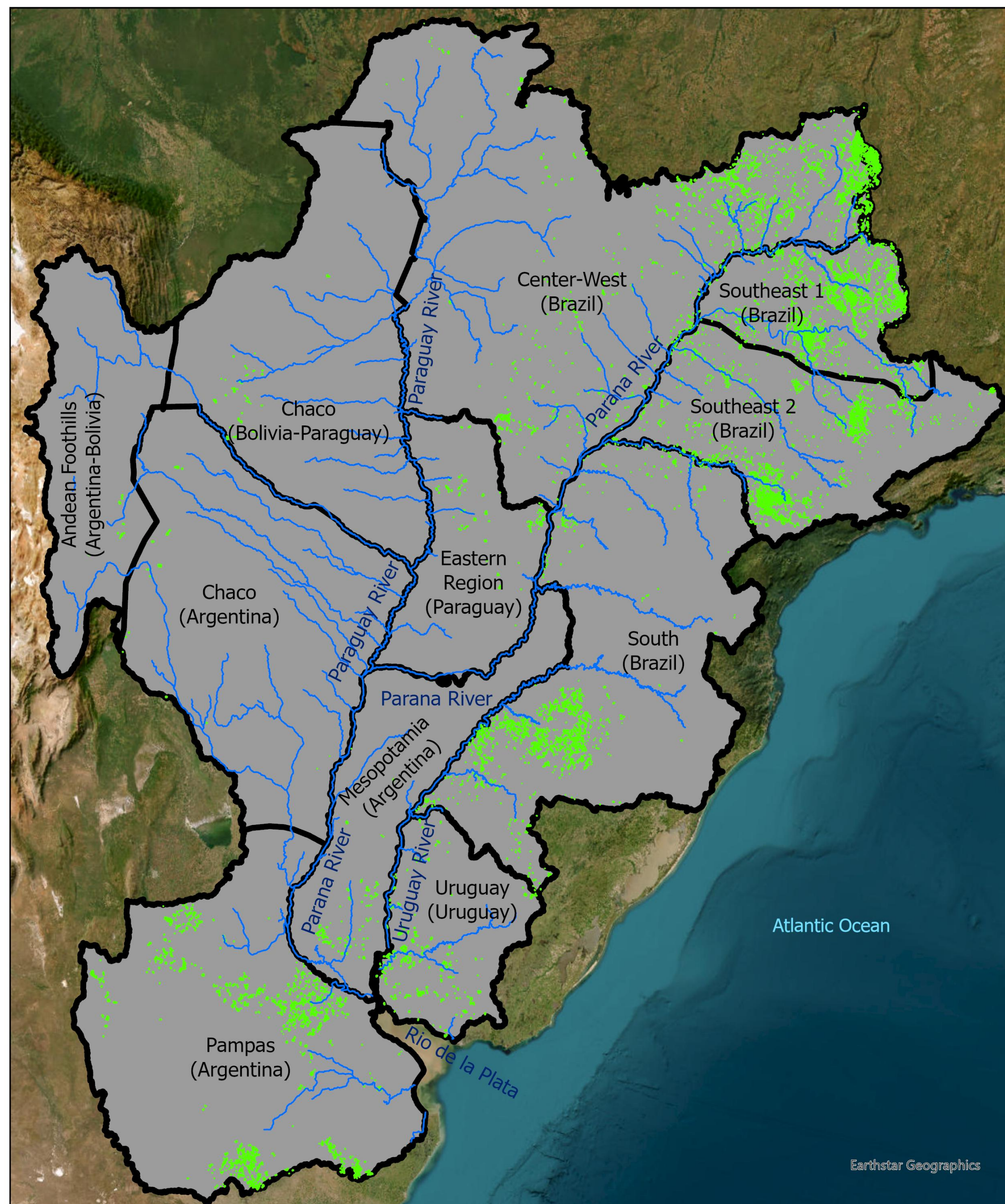
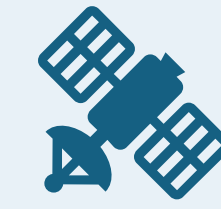


Figure 1. Río de la Plata Basin split into 11 subregions

IV. Methodology

Prepare data

1 Remote sensing data preparation



Landsat pixels receiving >1 mm of rainfall on the observation date are masked. Valid observations are aggregated into monthly composites (mean NDVI, max NDVI, LST sum and LST count) for each September–August crop year, resulting in 12 composites per year.

2 Phenology analysis and time window selection



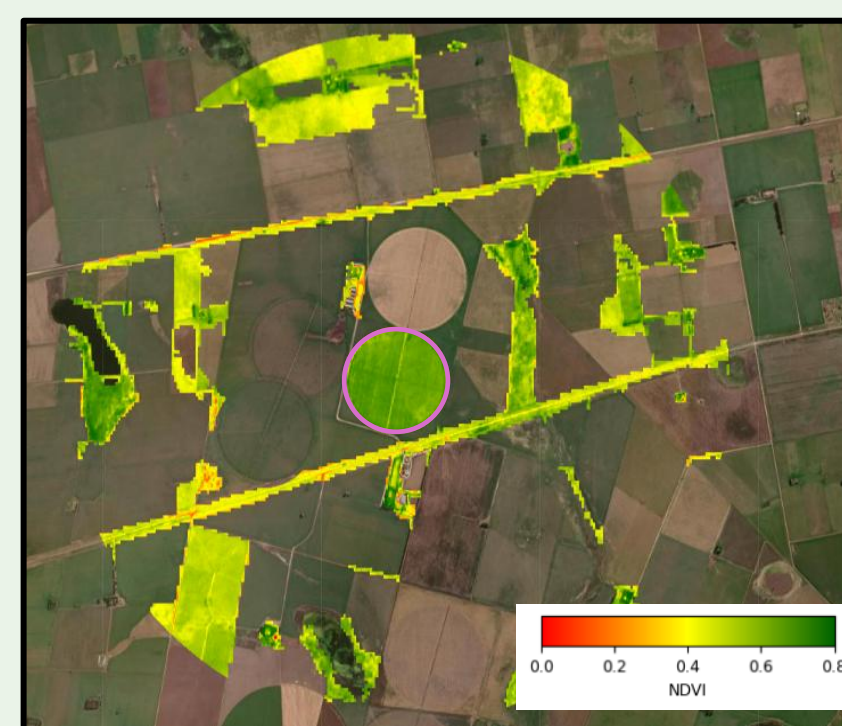
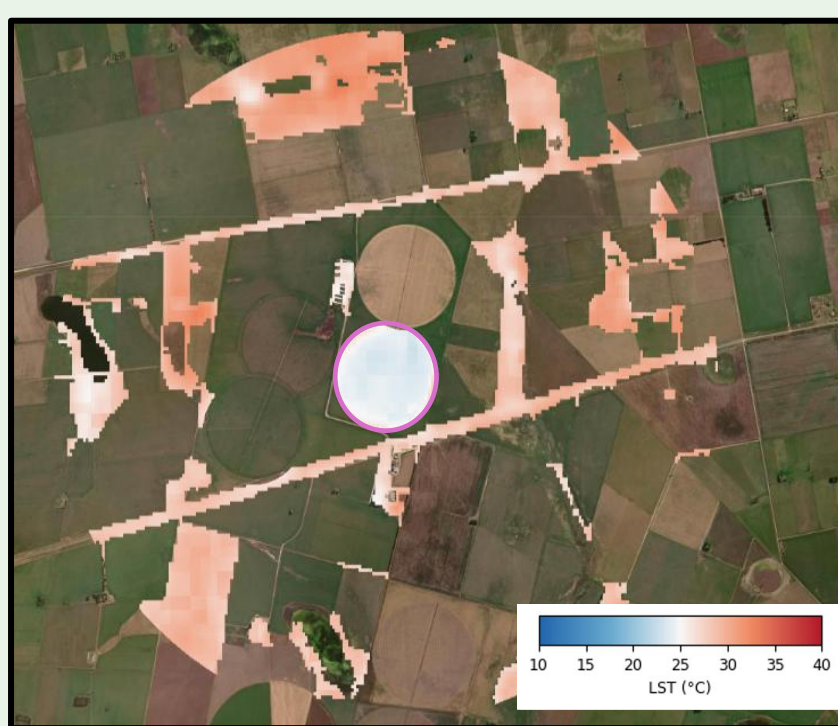
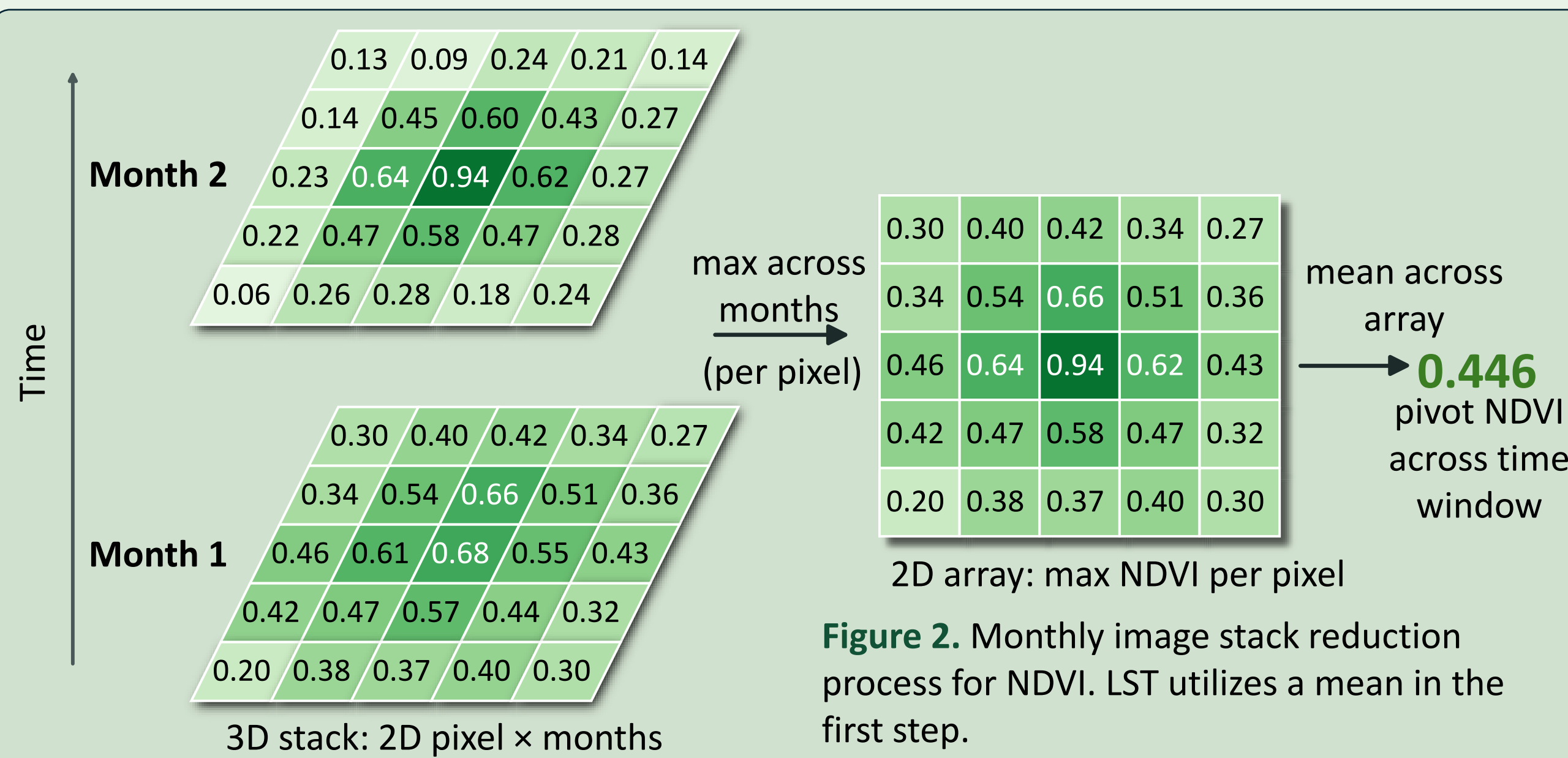
K-means clustering on monthly mean NDVI groups pivots of similar phenology into 3 or 6 clusters per subregion. Candidate time windows are constructed from the combination of each peak month and single months before and after where NDVI is greater than 0.25.

Extract features

3 Pivot–annulus comparisons

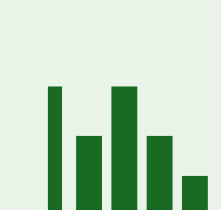


Maximum NDVI and mean LST are aggregated temporally for every candidate time window. Each pivot generates a 2500 m annulus, excluding other pivots and limited to pasture and grassland. Mean NDVI and mean LST are reduced spatially for each pivot and its annulus in every window.



Figures 3 & 4. LST (left) and NDVI (right) raster layers with selected pivot highlighted in pink. Surrounding pixels classified as pasture or grassland are used for comparison.

4 Window selection and feature construction



For each peak, separation between pivot and annulus observations is quantified using Cohen's d :

$$d = \frac{\bar{x}_{\text{pivot}} - \bar{x}_{\text{annulus}}}{s_p}$$

Where $\bar{x}$ is the mean LST or NDVI of each distribution and s_p is the pooled standard deviation. The LST window maximizing pivot cooling relative to annuli (lowest Cohen's d) is selected. NDVI uses the full peak range to capture seasonal grassland and pastureland response. From the resulting pivot and annulus distributions, z-score and percentile features are computed, quantifying how much cooler or greener a pivot is relative to surrounding annuli.

V. Results

Selected Results from Pampas Argentina and Center-West Brazil Subregions

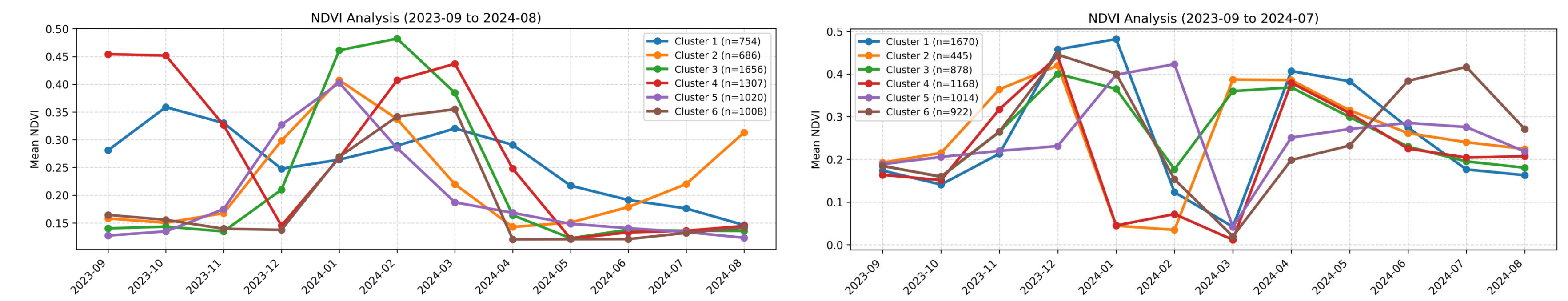


Figure 5. 2024 NDVI trend for Pampas Argentina (left) and Center-West Brazil (right) subregions

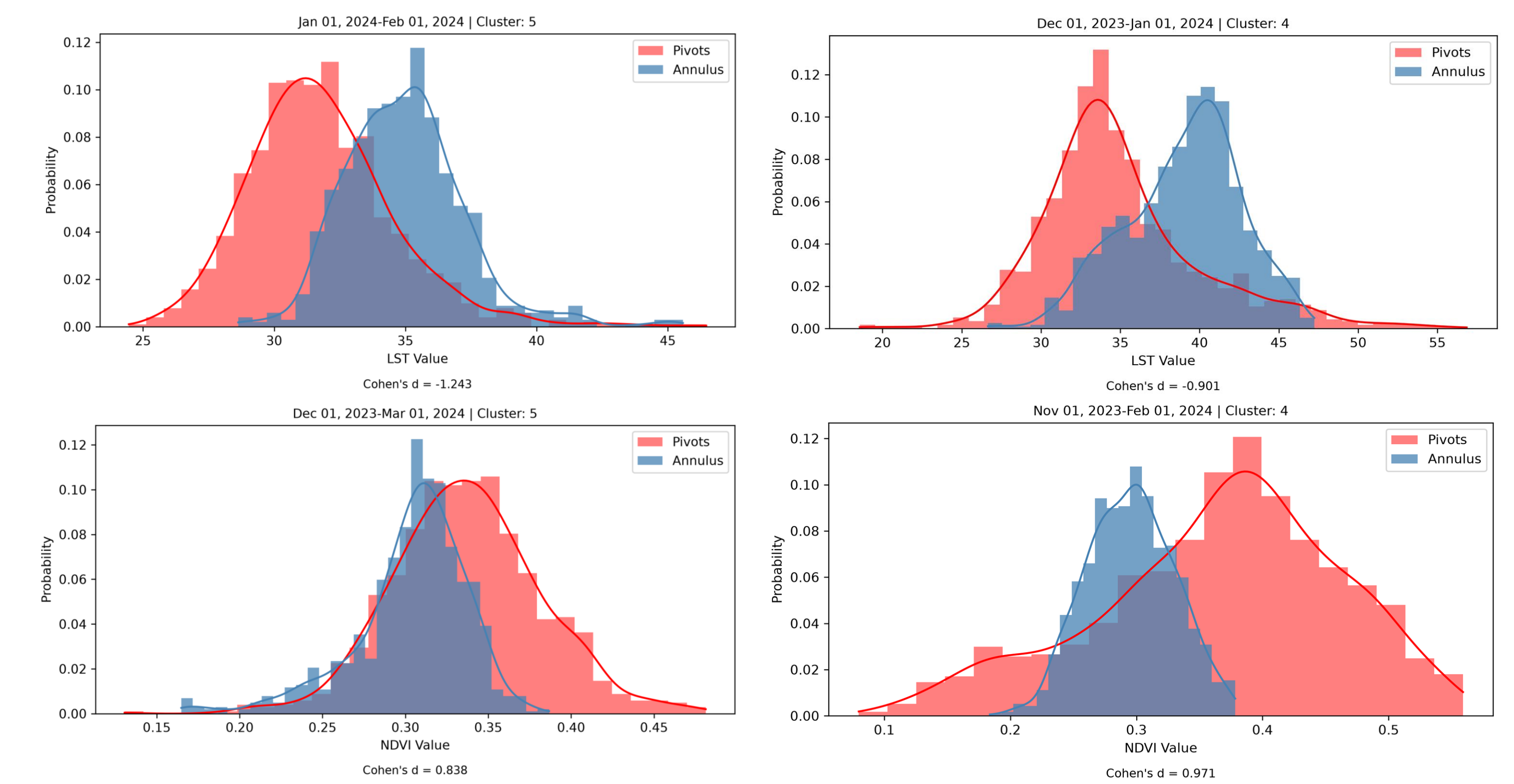


Figure 6. LST and NDVI histograms for Cluster 5 of Pampas Argentina (left) and Cluster 4 of Center-West Brazil (right)

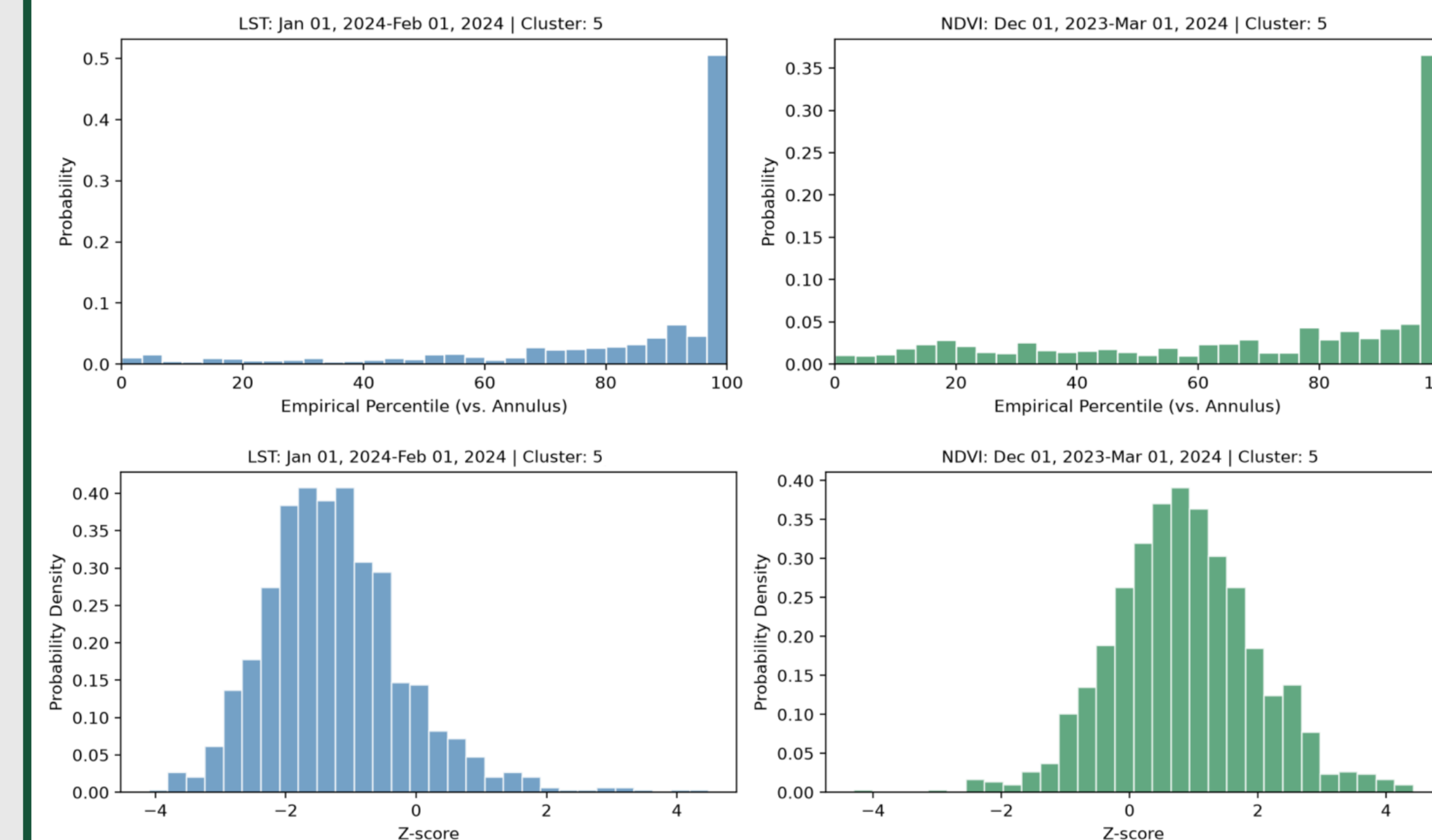


Figure 7. Selected results from **Cluster 5 of Pampas Argentina subregion** for crop year 2024. The empirical percentile histograms give the probability of a pivot being cooler or greener than a given percentile of surrounding annuli in the cluster.

Table 1. Annual average Cohen's d values across all subregions for all selected time windows and clusters.

Crop Year	Average LST Cohen's d	Average NDVI Cohen's d
2004	-0.749	0.958
2009	-0.669	0.836
2014	-0.618	0.580
2019	-0.435	0.447
2024	-0.594	0.771
All Years	-0.613	0.718

VI. Next Steps

- Train supervised classification and regression models on the derived NDVI and LST features to predict irrigation status.
- Apply these models to all 38,520 center-pivot irrigation systems across the study basin for crop years 2004–2024.
- Extend framework to all cropland polygons across the Río de la Plata Basin to produce basin-wide irrigation status maps and assess long-term irrigation patterns.

Acknowledgements

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