

Impact of climate change on paddy yield in rainfed agriculture system

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A Block-Level Analysis of Climate–Yield Relationships in Odisha, India (1995–2023)

1 Background & Objectives

Monsoon-dependent rice systems face intensifying hydroclimatic and thermal stress, yet how moisture persistence, temperature extremes, and their interactions shape yield risk remains poorly resolved at fine spatial scales. Most existing studies rely on linear, seasonally aggregated models that overlook threshold effects, non-stationary sensitivities, and spatial heterogeneity — limiting their value for targeted adaptation planning.

Odisha's strong physiographic diversity — coastal plains, central plateaus, eastern ghats, and western uplands — combined with recurring drought and heat events, makes it an ideal natural laboratory for studying spatially differentiated climate–yield responses at the administrative block level.

Study Objectives

The study provides the relative importance of

→moisture persistence, temperature extremes and their spatiotemporal interconnections with paddy productivity at subdistrict scales in Odisha

Study design: 298–314 blocks across Odisha, annual paddy yield 1995–2023, integrated with IMD rainfall and temperature indices at the block scale.

2 Study Area, Data & Methods

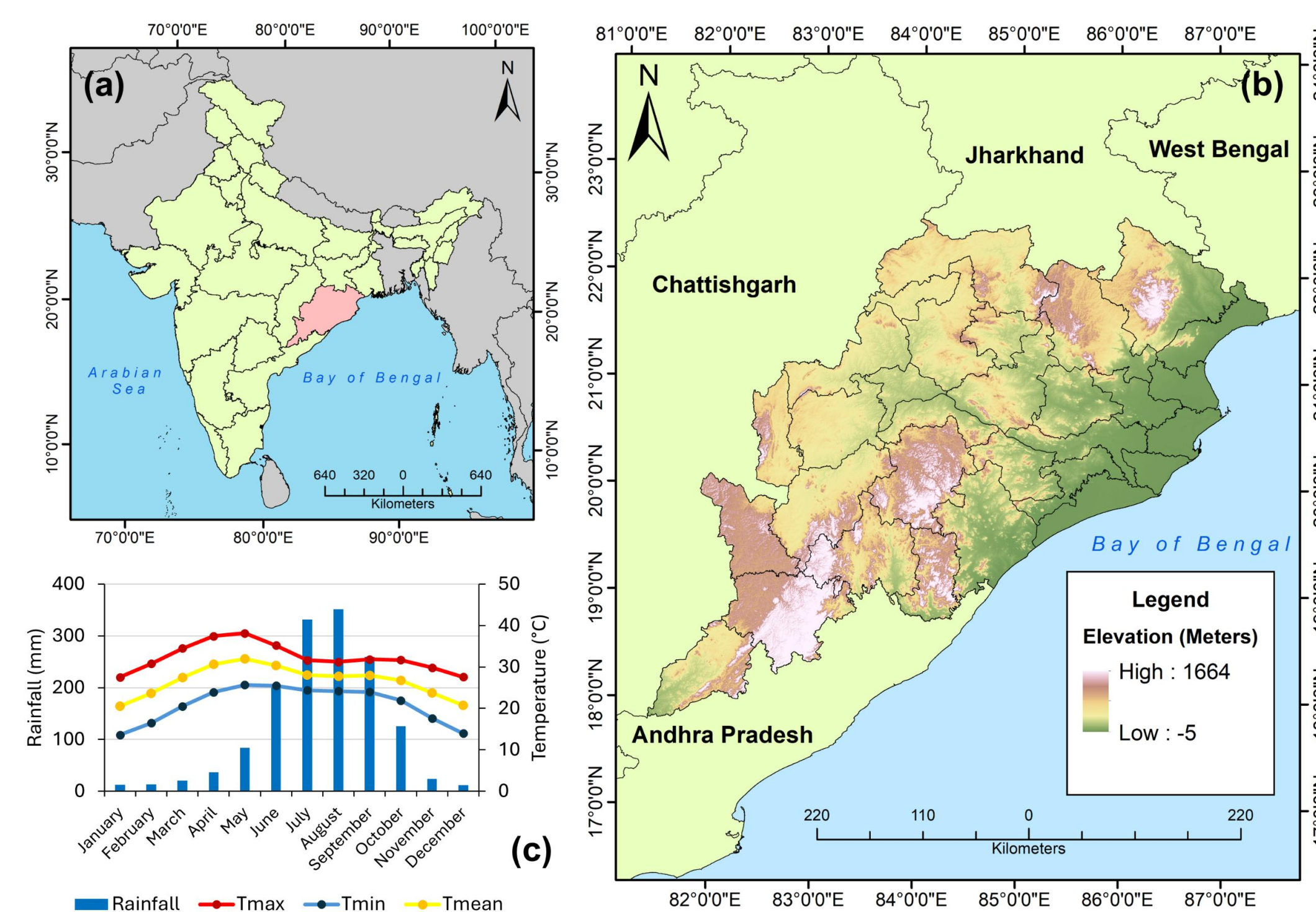


Fig. 1 Study area: (a) location within India, (b) elevation, (c) seasonal rainfall & temperature of Odisha.

Data

→Block-level annual paddy yield, 1995–2023 (Directorate of Agriculture & Food Production, Odisha)

→IMD gridded rainfall & temperature indices (ETCCDI-based), harmonized to the block scale

Analytical Approach

→Yield normalization & detrending (z-score SCY)

→Lag diagnostics & inter-variable dependence screening

→Two-way fixed-effects panel regression

→Non-linear (piecewise) threshold modeling

→Rolling-window sensitivity analysis

→Composite Climate Vulnerability Index (CCVI) construction

6 Compound Climate Stress Index (CSI)

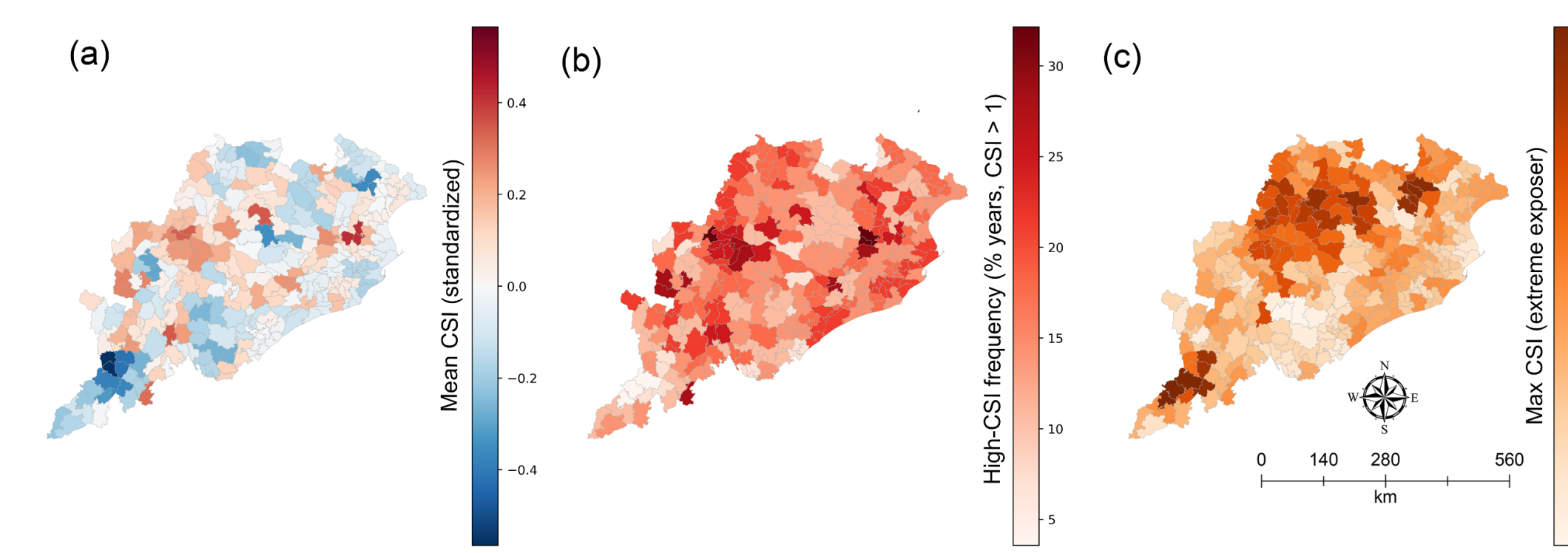


Fig. 5 (a) Mean standardized CSI, (b) frequency of high-CSI years, (c) maximum CSI (extreme exposure) by block.

→Interior and western blocks show both higher mean compound stress and a greater frequency of high-CSI years

→Extreme-exposure (max CSI) hotspots concentrate in the same interior tableland corridor identified by the CCVI

→Spatial convergence across CSI metrics strengthens confidence in the identified vulnerability hotspots

→Effects of moisture-stress indicators are consistent in direction across zones, but vary substantially in magnitude

→Pooled, weighted coefficients confirm dry-day frequency and consecutive dry days as robust statewide drivers of yield loss

→Zone-level heterogeneity in effect size reinforces the case for spatially targeted, rather than uniform, adaptation responses

3 Key Results

±50%+

Detrended yield anomalies despite long-term yield gains

9–10%

Median drought-year yield loss, interior plateau vs. 2–4% in coastal plains

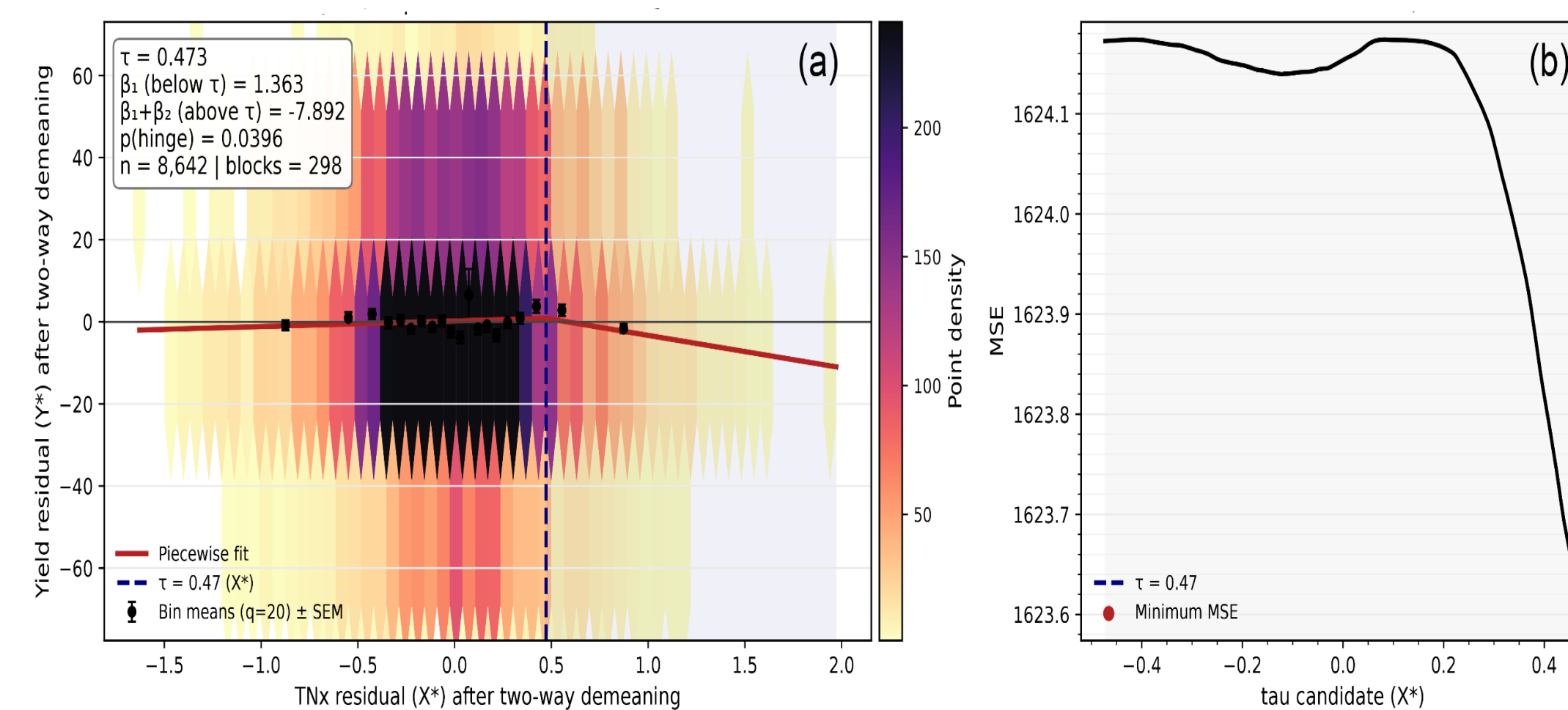


Fig. 2 Piecewise threshold response of yield to warm-night extremes (TNx); yield declines sharply beyond $\tau \approx 0.47$ ($\sim 28.7^\circ\text{C}$).

Findings

→Moisture persistence — dry-day frequency and consecutive dry days — is the dominant statewide yield control, with both contemporaneous and lagged effects

→Mean temperature shows weak linear effects, but warm-night extremes (TNx) drive a sharp non-linear yield decline beyond a critical threshold

→TNx sensitivity has intensified since ~ 2015 , coinciding with more frequent compound warm-dry conditions

7 Temporal Non-Stationarity of TNx Sensitivity

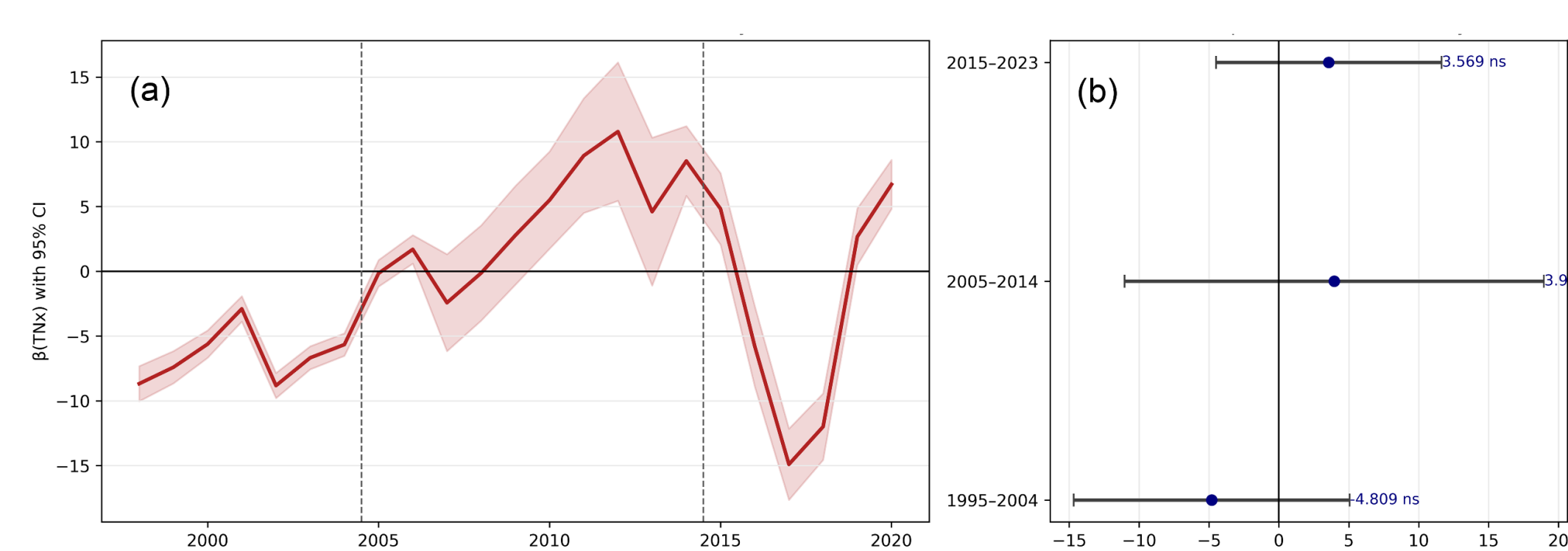


Fig. 6 (a) Rolling-window TNx sensitivity, 1995–2023; (b) sensitivity by sub-period, with 95% CI.

4 Spatial Vulnerability & Conclusion

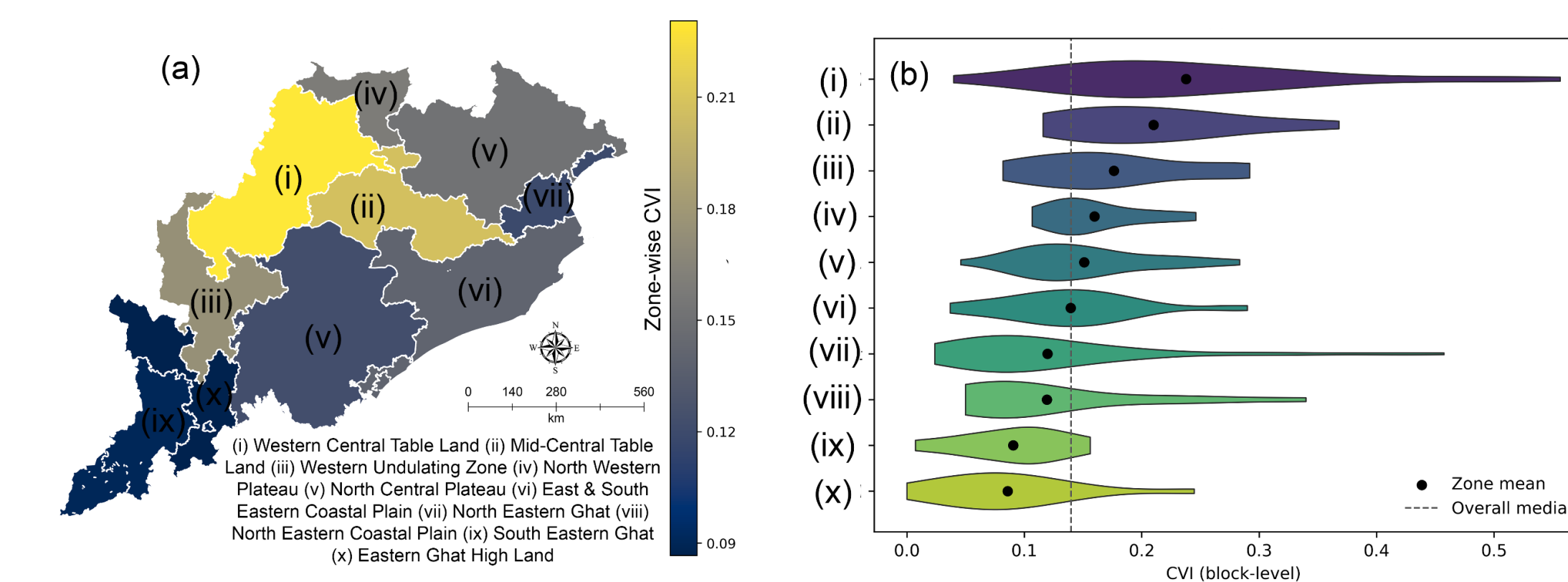


Fig. 3 Agro-climatic zone-wise Composite Climate Vulnerability Index (CCVI); zone-level distributions (right).

Vulnerability Hotspots

→Persistent hotspots in western & interior tableland zones: WCTL (CCVI ≈ 0.24), MCTL (≈ 0.21), WUZ (≈ 0.18)

→Coastal plains comparatively buffered (CCVI ≈ 0.12 – 0.14) via better irrigation and soil-moisture retention

→Substantial within-zone heterogeneity supports block-level, rather than zone-level, targeting

Conclusion & Policy Implications

Region-specific adaptation is essential: heat- and drought-tolerant rice varieties, phenology-based and supplemental irrigation, and soil-moisture conservation for interior rainfed zones; and thermal-tolerant cultivars paired with reliable irrigation in coastal systems as nighttime warming continues.

Panel Regression & Zone Sensitivity

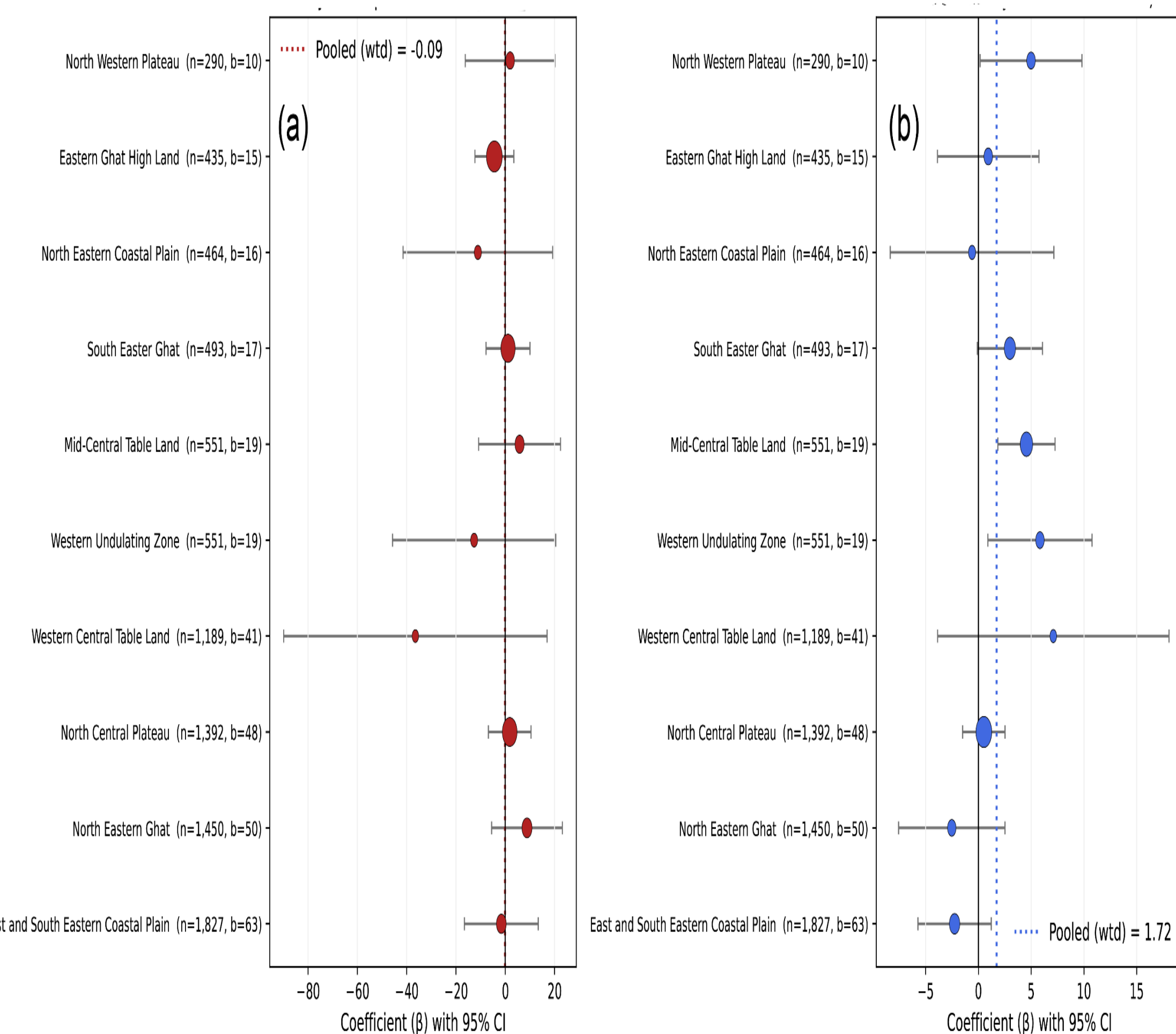


Fig. 4 Zone-wise fixed-effects coefficients (95% CI) for (a) dry-day frequency and (b) consecutive dry days, with pooled weighted means.

8 Limitations & Future Work

This analysis relies on annually aggregated climate indices and does not explicitly incorporate crop phenology, sowing-date variation, or farm-level management and adaptive capacity — all of which modulate realized climate risk. T

Priorities for Future Research

→Incorporate sub-seasonal and phenology-stage-specific climate data

→Integrate irrigation infrastructure and adaptive-capacity indicators into the CCVI

→Extend threshold analysis to other compound stress combinations (e.g., heat × drought co-occurrence)

Why it matters: This transferable, block-level framework helps prioritize heat-tolerant crop varieties, climate-sensitive early-warning systems, and adaptive irrigation investment where they will reduce risk most in monsoon-dependent rice systems.



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