Plant Archives Vol. 26, Supplement 1, 2026 pp. 1699-1708 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.229

CLIMATE CHANGE, LAND DEGRADATION, AND SOIL HEALTH IN TELANGANA: SHIFTING TRENDS AND ADAPTATION OVER TWO DECADES

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(Date of Receiving : 05-10-2025; Date of Acceptance : 08-12-2025)

ABSTRACT

Over the past two decades, Telangana has witnessed profound climate shifts marked by rising temperatures, erratic rainfall, and intensifying extreme events. Average temperatures across the state have risen steadily, with Hyderabad recording a 0.07 °C increase alongside declining rainfall (–22.1%) and humidity (–6.7%). Heat waves are becoming harsher, peaking at 48.9 °C in Nalgonda (2015), while winters are warming with fewer cold-wave days, altering seasonal dynamics. Rainfall patterns show high variability. The state's wettest years were 2020–22, exceeding long-term averages by 30–53%, while 2023–24 remained slightly above normal. However, regional disparities persist: southern districts show rainfall gains, whereas northern and eastern districts face declines up to 157 mm. Telangana is also recording more extreme events 517.5 mm fell in Wazeedu (2013) in a single day, while October 2023 was the driest in six decades. Climate change, combined with intensive agriculture, is accelerating land degradation. About 57% of Telangana's area faces moderate to severe soil erosion, with districts like Adilabad, Karimnagar, and Warangal showing acute risks. Soil studies reveal widespread nitrogen deficiency and localized imbalances in phosphorus and potassium, with variability across districts and cropping systems. Adaptation responses include large-scale afforestation (Haritha Haram), agroforestry, soil conservation, and land degradation neutrality planning. These strategies enhance resilience, restore soil fertility, and sustain agriculture in the face of climate stress. Long-term monitoring, sustainable land management, and farmer-focused climate services remain critical to safeguarding Telangana's food, water, and ecosystem security.

Keywords **:** Rising Temperatures, Erratic Rainfall, Extreme Weather Events, Land Degradation, Adaptation Strategies

Introduction

Over the past two decades, Telangana has witnessed profound climate shifts marked by rising temperatures, erratic rainfall, and intensifying extreme events. Average temperatures across the state have risen steadily, with Hyderabad recording a 0.07 °C increase alongside declining rainfall (–22.1%) and humidity (–6.7%). Heat waves are becoming harsher, peaking at 48.9 °C in Nalgonda (2015), while winters are warming with fewer cold-wave days, altering seasonal dynamics.

Rainfall patterns show high variability. The state's wettest years were 2020–22, exceeding long-term averages by 30–53%, while 2023–24 remained slightly above normal. However, regional disparities persist: southern districts show rainfall gains, whereas northern and eastern districts face declines up to 157 mm. Telangana is also recording more extreme events 517.5 mm fell in Wazeedu (2013) in a single day, while October 2023 was the driest in six decades. Climate change, combined with intensive agriculture, is accelerating land degradation. About 57% of Telangana's area faces moderate to severe soil erosion, with districts like Adilabad, Karimnagar, and Warangal showing acute risks. Soil studies reveal widespread nitrogen deficiency and localized imbalances in

phosphorus and potassium, with variability across districts and cropping systems.

Adaptation responses include large-scale afforestation (Haritha Haram), Agroforestry, soil conservation, and land degradation neutrality planning. These strategies enhance resilience, restore soil fertility, and sustain agriculture in the face of climate stress. Long-term monitoring, sustainable land management, and farmer-focused climate services remain critical to safeguarding Telangana's food, water, and ecosystem security.

KEY CLIMATE CHANGE TRENDS OBSERVED IN TELANGANA (PAST 20 YEARS)

I. Temperature Change Patterns in Telangana (Last ~20 Years)

Escalating Temperature & Heat waves:

Notable temperature increases are evident across the state. For instance, Hyderabad has seen average temperatures rise by approximately 0.07 °C, alongside a –22.1% drop in annual rainfall and –6.7% decline in humidity, giving it a "High" climate severity score of 43/100. Heat waves are also intensifying. In April 2022, Hyderabad experienced 10 days of temperatures above 40 °C, starkly up from just one day in 2021. Telangana recorded its hottest day in the past decade: 48.9 °C in Narketpally, Nalgonda, on May 22, 2015.

Recent extremes in 2025: In the latest heat waves, 22 of Telangana's 33 districts recorded maximum temperatures above 40 °C, with Asifabad topping at 42.4 °C.

Warmer winters and Fading Cold Waves:

Decline in cold wave occurrences: Telangana has seen winters warming significantly, with a rise of 0.5 °C to 1 °C annually. Cold wave days dropped from 7–8 days in 2018–2019 to just one in 2023.

Milder winter of 2024: Winter temperatures in 2024 were 2–3 °C higher compared to 2022 and 2023. Night temperatures hovered around 13 °C to 15 °C in Hyderabad, with fog becoming more common a shift linked to global warming and urban factors.

II. More Extremes and Erratic Rainfall:

Rainfall change patterns in Telangana over the past ~20 years (2004–2024):

1. Overall Annual Rainfall Variability & Recent Extremes

Since becoming a state in 2014, Telangana's wettest years were 2020–21 and 2021–22—recording 1,322.4 mm (+46%) and 1,180.6 mm (+30%) rainfall respectively, against a long-term average of ~905 mm. The year 2022–23 has recorded peak annual rainfall of 1,387.8 mm, approximately 53% above normal. Rainfall received during 2023–24, was 994.8 mm and it is slightly above the historical average.

2. Shift from Deficit to Excess Rainfall

In 2014–15, rainfall was just 682 mm, marked 24.7% below average. Post-2019, trend reversal was observed with rainfalls having consistently skewed above average, signaling a shift toward wetter years.

3. Spatial Variability: Regional Disparities in Rainfall Trends

Southern districts (Hyderabad, Warangal Urban, Bhadradri Kothagudem, Jogulamba Gadwal, Wanaparthy, Mulugu, Narayanpet) have seen annual rainfall increases between 25 mm to 75 mm over the last 30 years. Northern and eastern districts (Nirmal, Mancherial, Kamareddy, Siricilla, Suryapet) show declines ranging from 110 mm to 157 mm.

4. Increase in Extreme Rainfall Events

Wet spells increasing: From 2004 to 2020, Telangana recorded 432 wet spells ($\geq$ 2.5 mm/day) 162 of them occurred in the last five years. A 24-hour rainfall record of 300 mm in Hayathnagar (Hyderabad) and an even more extreme 517.5 mm in Wazeedu (Mulugu) on July 19, 2013, highlights the intensifying extreme downpours-emphasizing volatility Driest October in six decades: October 2023 recorded just 6.5 mm of rainfall versus an expected 89.2 mm, a -93% deviation lowest since 1965.

III. Shifting Monsoon Systems, Rainfall Patterns and Environmental Degradation:

Climate change is altering monsoon trajectories. Instead of moving northeast, more low-pressure systems are tracking westward from the Bay of Bengal, bringing intense rains to Telangana's northern regions. Experts warn of more incessant and erratic rainfall events in the future, particularly during the latter monsoon months (October–November), along with doubling of heat wave days in cities like Hyderabad by 2030. Heavy pesticide and fertilizer usage: Between 2015–16 and 2021–22, paddy production surged by 342%, but so did pesticide and fertilizer use. Telangana ranks third-highest nationwide in pesticide usage raising concerns about soil degradation and long-term resilience

IV. Adaptation Initiatives:

Telangana's afforestation drive Haritha Haram, launched in 2015, has planted millions of saplings across diverse landscapes road sides, institutional areas, and community lands boosting green cover for

ecological balance, environmental stability and support agriculture. Agroforestry & greening efforts: Telangana is promoting agroforestry (integrating trees with crops), which enhances soil nutrition, retains moisture, sequesters carbon, boosts biodiversity, and improves resilience yielding 20–50% yield increases and multiple income streams (timber, fruits, nuts).

IMPACT OF CLIMATE CHANGE ON LAND DEGRADATION INDIA & TELANGANA

- Climate change accelerates land degradation through higher temperatures, more frequent/intense droughts and heavy rains, shifting monsoon patterns, and increased wildfire risk all of which increase soil erosion, desertification, salinization and loss of vegetation/soil organic matter.
- Roughly ~25–30% of India's land shows signs of degradation (varying by data source and method); water erosion of rainfed agricultural land is the dominant cause.
- Telangana is already experiencing more dry days, erratic monsoon timing and local hotspots of forest loss and land degradation; these trends increase vulnerability of agriculture, water security and livelihoods in the state.

IMPACT OF LAND DEGRADATION ON PEOPLE AND ECOSYSTEMS:

1. Food & water security: Yield volatility, higher irrigation demand, siltation of reservoirs, and declining water regulation services.
2. Biodiversity & ecosystem services: Habitat loss and fragmentation reduce resilience; restoration can reverse some losses if done at scale.
3. Health & livelihoods: Dust, heat, fire smoke, and income loss in dryland agriculture; migration rises where repeated droughts and land degradation co-occur.

MECHANISMS OF CLIMATE CHANGE THAT DRIVES LAND DEGRADATION:

1. Altered rainfall patterns & extremes—longer dry spells punctuated by intense downpours increase runoff and soil erosion, reduce groundwater recharge, and raise flash-flood risk.
2. Rising temperatures—increase evapotranspiration, reduce soil moisture and organic matter, and speed up decomposition and nutrient loss.
3. Increased drought frequency/intensity—leads to vegetation loss, reduced ground cover and wind/water erosion.
4. Compound stress with land-use change—deforestation, overgrazing, unsustainable cultivation and urban expansion interact with climate stress to magnify degradation.

MEASURING & MONITORING DEGRADATION UNDER CLIMATE CHANGE:

1. Remote sensing & national atlases: Trends in vegetation (NDVI), bare soil, burn scars, salinity proxies, and erosion modeling; India's Desertification & Land Degradation Atlas (2021) is a leading national example.
2. Soil/land health indicators: SOC, aggregate stability, infiltration, salinity/sodicity, compaction, and erosion rates—paired with weather and hydrology to separate climate signals from management effects.

SOLUTIONS: WHAT WORKS (AND WHERE):

1. Avoid–Reduce–Restore is the consensus framing across IPCC/ UNCCD:
   - Avoid degradation: keep natural cover (forest, grassland, wetlands); climate-smart spatial planning to prevent new conversion in high-risk areas.
   - Reduce ongoing degradation (SLM): conservation agriculture (reduced tillage, residue retention, rotations), contour/graded bunds, check dams, mulching, diversified agroforestry, improved pasture management, efficient/deficit irrigation, and salinity control (drainage + gypsum + salt-tolerant crops). Co-benefits include carbon gains and microclimate buffering.
   - Restore degraded land: assisted natural regeneration, re/afforestation where ecologically suitable, revegetation of dunes and gullies, peatland and wetland re-wetting, and soil carbon rebuilding via organic inputs. Programmatic evidence shows strong returns on investment when targeted to hotspots.
2. Risk management & early warning: drought/heat/fire early-warning systems tied to farm advisories; climate services guiding sowing windows and input use.
3. Governance & finance: Land Degradation Neutrality (LDN) targets, payment for ecosystem services, and policies aligning agriculture, forestry, and water with restoration outcomes.

TELANGANA: LAND DEGRADATION & SOIL EROSION STATISTICS

The total geographical area of Telangana is 112,077 square kilometers and is equivalent to

3.41% of India's total geographical area and is the 12th largest state in India by area

Landform: Telanagan lies on the Deccan Plateau in the central part of India and is characterized by ancient igneous rocks like basalt and granitic intrusions with a general elevation of 300-600 meters. The general slope of the plateau is from West to East, which influences the direction of the major rivers.

"Land degradation" is a long-term decline in land condition—loss of biological productivity, ecological integrity, or value for people—driven by human activities (e.g., land use) and aggravated by anthropogenic climate change.

District-wise observations of Soil Erosion Risk in Telangana:

1. Soil erosion is extensive in Telangana, over half of the state's area faces moderate to severe soil-loss pressures. Approximately 37% of Telangana's total geographical area (TGA) experiences moderate erosion rates of 5–10 Mg/ha/year, while about 20% of the TGA is prone to erosion exceeding 10 t/ha/year.
2. Adilabad, Karimnagar, Khammam, Nizamabad and Warangal each have >20% of their area subjected to erosion rates exceeding 10 Mg/ha/year, totaling around 0.25 million hectares, with these three districts representing roughly 83% of that severely eroded land
3. Ranga Reddy (56%), Khammam (46%) and Medak (44%) have significant proportions of land in the moderate erosion category (5–10 Mg/ha/year), suggesting priority zones for conservation.
4. The land degradation neutrality planning demonstrates a structured response allocating large tracts (over ~2.3 million ha combined) for restoration, afforestation, agroforestry, and drainage yet leaving about 1,40,000 ha without targeted action.

Note: A "Megagram" (Mg) is a unit of mass equal to 1,000 kilograms or 1 metric ton

KEY SOIL QUALITY INDICATORS STUDIED IN TELANGANA:

1. Mahabubnagar Groundnut Belt (Soil pH & Fertility)

- pH ranges between 7.5 and 8.5 (slightly alkaline).
- Electrical conductivity (EC) is low (< 0.25 dS/m).
- Organic carbon is high (> 0.75%).
- Nitrogen is acutely deficient (< 100 kg/ha), while phosphorus is high (> 24.6 kg/ha), and potassium is medium (108–280 kg/ha).
- Micronutrients: Zinc, manganese, and copper are sufficient; iron remains low (<4 mg/kg).

2. Warangal & Nalgonda Districts (Soil Quality Index)

Composite SQI mapping using GIS shows spatial variations across districts with the contributing factors such as

- Available phosphorus: 25.5%
- Organic carbon: 23.6%
- Soil moisture retention at 15 bar: 18.1%
- Cation exchange capacity (CEC): 16.9%
- Carbon mineralization: 8.7%
- Mean weight diameter of aggregates: 4.3%

3. Jagityal District (Rice-Growing Areas Fertility)

- Soil texture: sandy clay loam, sandy loam, and loamy sand (sand: 44–80%).
- pH: neutral to slightly alkaline (6.8–8.2).
- EC: non-saline (0.23–0.69 dS/m).
- Organic carbon: low to medium (0.3–0.6%).
- Nitrogen: low (101–195 kg/ha).
- Phosphorus: high (26.8–61.5 kg/ha).
- Potassium: medium to high (120–449 kg/ha).
- Sulfur: medium to high (10–26.8 mg/kg)

4. Warangal District (Fertility Constraints)

- pH: 6.16–8.34 (slightly acidic to slightly alkaline).
- EC: non-saline (0.14–1.00 dS/m).
- Organic carbon: 0.12–1.14%.
- Nitrogen: low (136–231 kg/ha).
- Phosphorus: 14–166 kg P_2O_5/ha.
- Potassium: medium to high (199–997 kg K_2O/ha).
- Micronutrients show wide variability: Zinc, iron, copper, manganese all range from low to sufficient—highlighting areas needing targeted fertilization.

5. Central Telangana Zone (Red Soils–Paddy Soils)

- pH: 6.65–7.78 (neutral to slightly acidic–alkaline).
- EC: 0.02–0.72 dS/m.
- Organic carbon: 0.19–0.51%.
- Nitrogen: 50–314 kg/ha (low).
- Phosphorus: 17–147 kg P_2O_5/ha (high).
- Potassium: 72–627 kg K_2O/ha (high).
- Micronutrients: Iron: 0.58–5.92 mg/kg; Zinc: 0.06–4.81 mg/kg

Notably, 97% of samples were low in nitrogen, while 90% had high phosphorus, and 47% had high potassium.

6. Sangareddy District (Bengal Gram Areas – Particle & Nutrient Status)

- Soil texture by productivity:
- High productivity: sand 32.1%, silt 26.7%, clay 41.1%.
- Medium: sand 33.7%, silt 26.1%, clay 40.1%.
- Low: sand 37.4%, silt 25.1%, clay 37.2%.
- Nutrient availability: Nitrogen: average ~224 kg/ha; Phosphorus: ~32 kg/ha; Potassium: ~316 kg/ha.
  Lower productivity zones had higher sand content—indicating impacts on soil aggregation and fertility.

7. Agroforestry Impacts on Soil Fertility– Warangal Region

- Compared across land-use types: agroforestry systems (e.g. eucalyptus, teak, mango + teak) significantly improved soil fertility over barren land
- At 0–20 cm depth, highest values recorded: Organic carbon: 5.12 g/kg, CEC: 18.3 cmol(p+)/kg, Available nitrogen: 198 kg/ha; Phosphorus: 69 kg/ha; Potassium highest in teak (530 kg/ha);
- Positive correlations: OC with CEC (r=0.839), available N (r=0.900), P (r=0.408), K (r=0.521)—pointing to healthy soil structures under agroforestry.

Literature review — Climate change and land degradation (global → India → Telangana)

1. The relationship between climate change and land degradation is well established: land use and land-management practices both drive greenhouse-gas emissions and suffer back-effects from altered climate (temperature rise, shifting precipitation, more extremes). The IPCC Special Report Climate Change and Land (2019) synthesizes evidence that land contributes ~20–25% of anthropogenic greenhouse-gas emissions, and that climate change, interacting with land-use change, exacerbates soil carbon loss, erosion, desertification and reduced productivity.
2. UNCCD's Land Degradation Neutrality (LDN) framework operationalizes targets to "avoid-reduce-restore" land degradation and links land targets to national planning and financing instruments; its technical guidance describes indicators and the target-setting steps used by countries.
3. ISRO/SAC's Desertification and Land Degradation Atlas of India (2021) uses multi-temporal satellite data (NDVI, bare-soil indices, erosion proxies) to map degradation across administrative units — a leading national dataset for India.
4. Field metrics such as soil organic carbon (SOC), aggregate stability (mean weight diameter), infiltration rate, CEC, salinity, and nutrient status are used in district-level assessments and to build composite Soil Quality Indices (SQI). IPCC and UNCCD guidance encourage integrated indicator suites tied to functional ecosystem services.
5. The ISRO Atlas of 2021and related SAC products show ~25–30% of India's land with some degree of degradation, with water erosion the dominant proximate driver in many agricultural landscapes. These national maps are widely cited for planning and LDN target setting. [Research Gate], [UNCCD Catalogue].
6. Regional focus — Telangana & Hyderabad: Set of state and city-level reports and peer-reviewed work document trends and event case studies for Telangana: State hydromet & planning sources (Telangana Development Planning Society / TGDPS) provide recent annual rainfall and seasonal diagnostics used to map district-level wet/dry anomalies and post-2019 shifts toward some wetter years in parts of the state. ([Telangana GPDPS]
7. Urban-flood case studies (Hyderabad, Oct 2020): [Mausam Journal], [Research Gate].
8. Several recent reports and studies document of high pesticide and fertilizer consumption in Telangana [The Times of India], [Research Gate], [The New Indian Express]

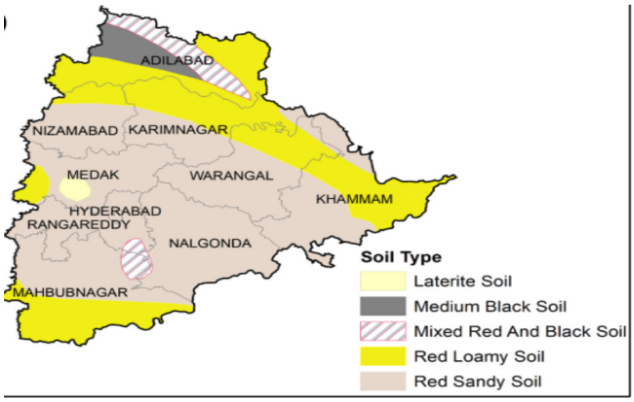

Image 1 : Types of Soils in Telangana

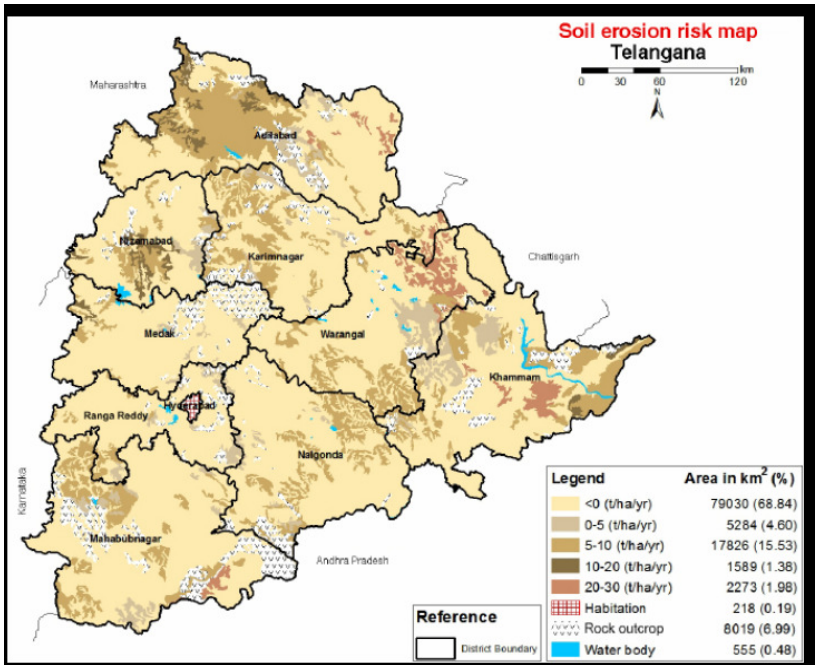

Image 2: Map illustrating soil erosion risk

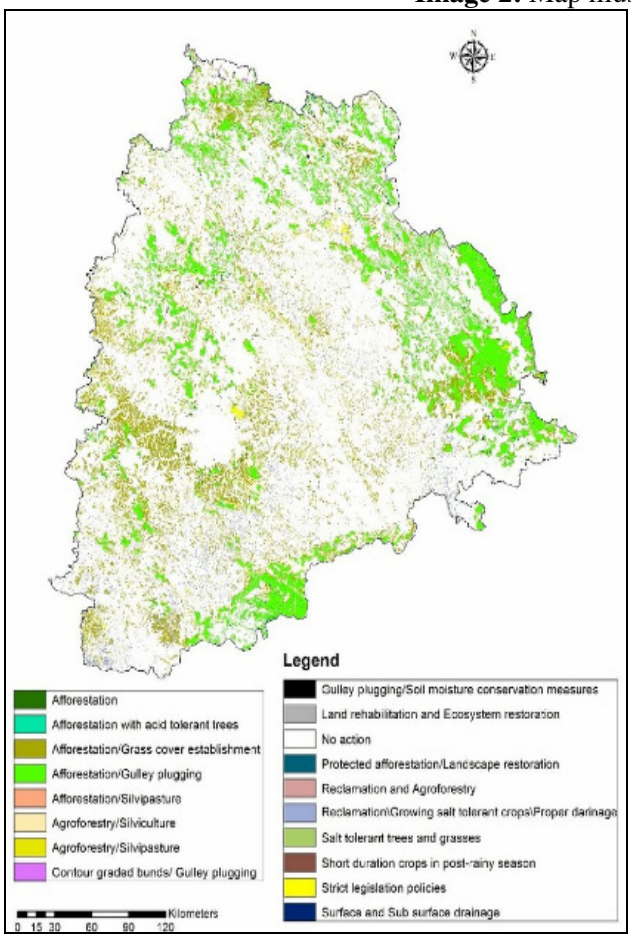

Image 3: Maps illustrating land-degradation action-plan zones for Telangana—highlighting areas most affected and targeted for restoration.

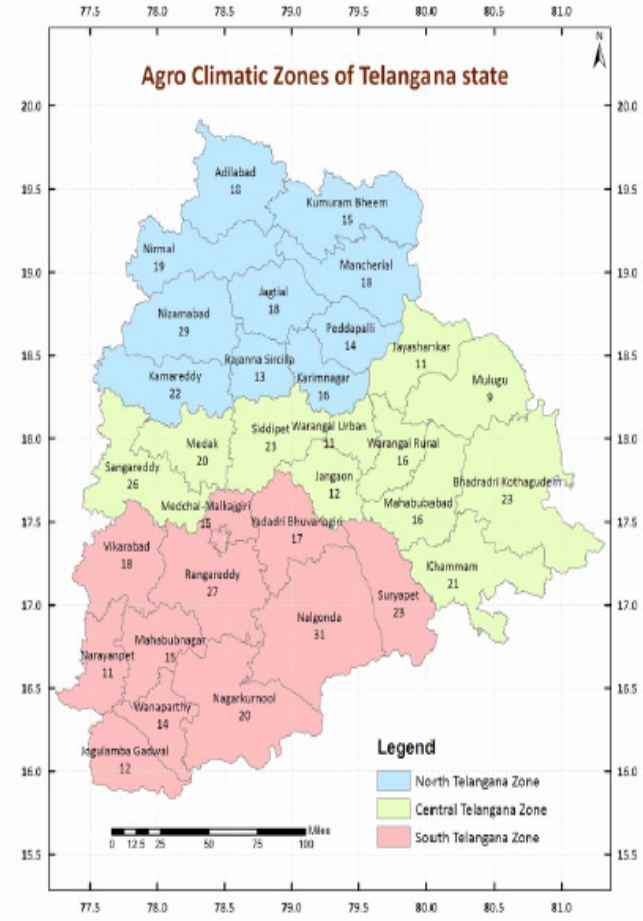

Image 4: Agro Climatic Zones of Telangana

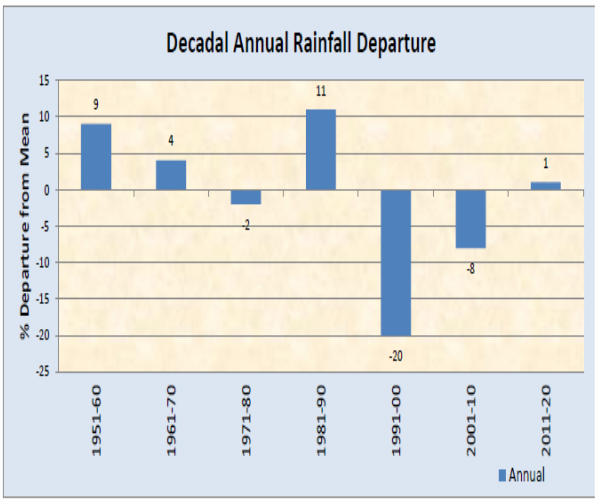

Fig. 1: Average Decade Annual Rainfall of Telangana

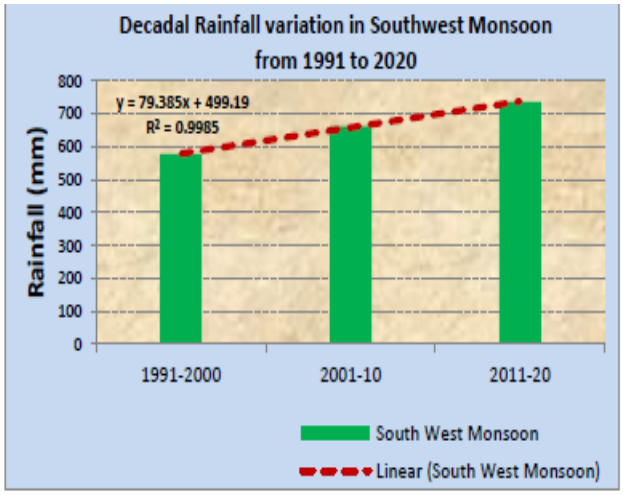

Fig. 2: Average Decade Annual Rainfall of Telangana

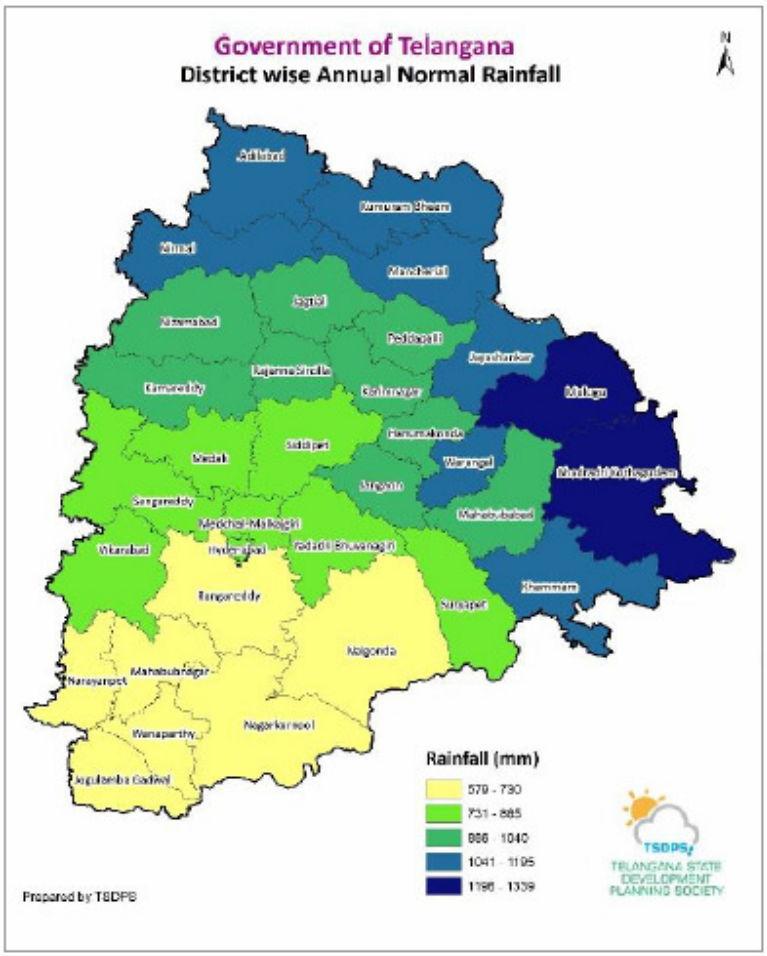

Image 5: District wise Average Annual Normal rainfall, Rainfall Deviation and Rainy Days

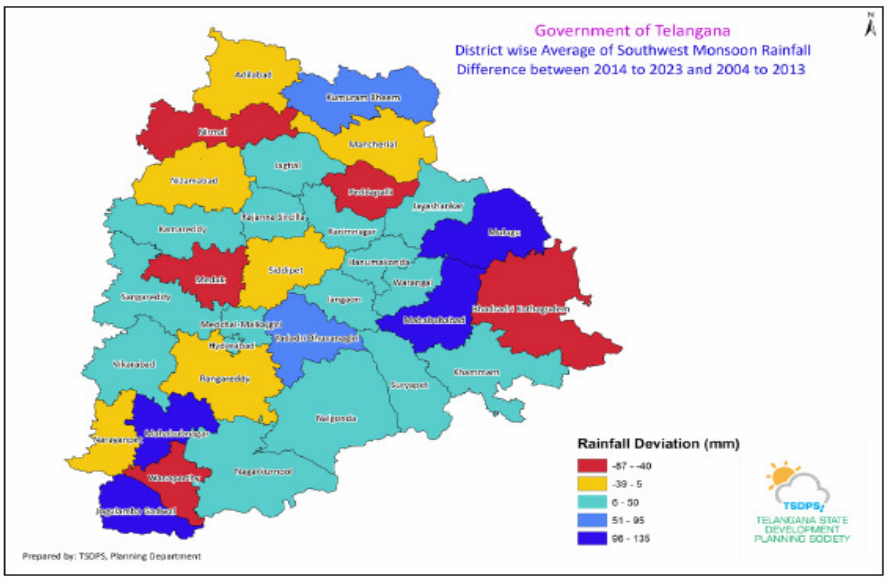

Image 6: District wise Average Annual Normal rainfall, Rainfall Deviation and Rainy Days

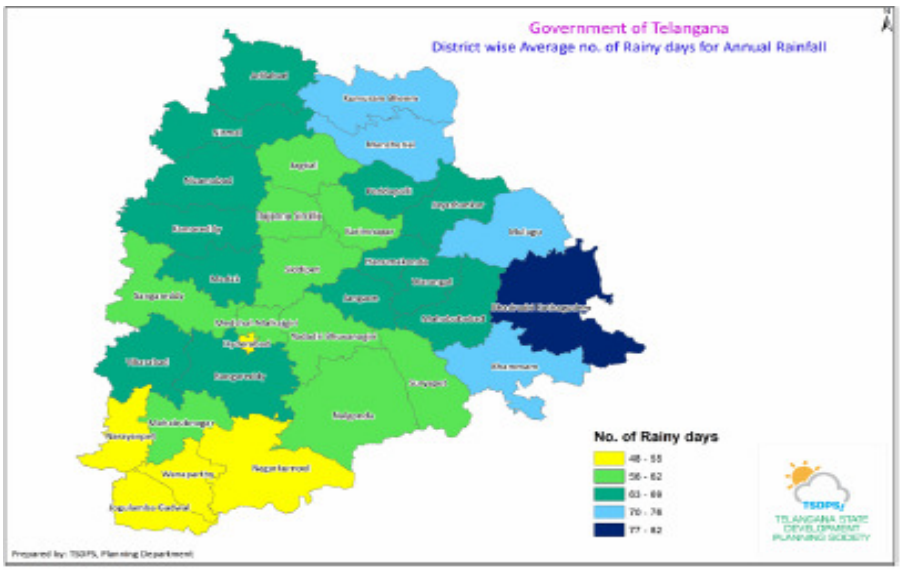

Image 7: District wise Average Annual Normal rainfall, Rainfall Deviation and Rainy Days

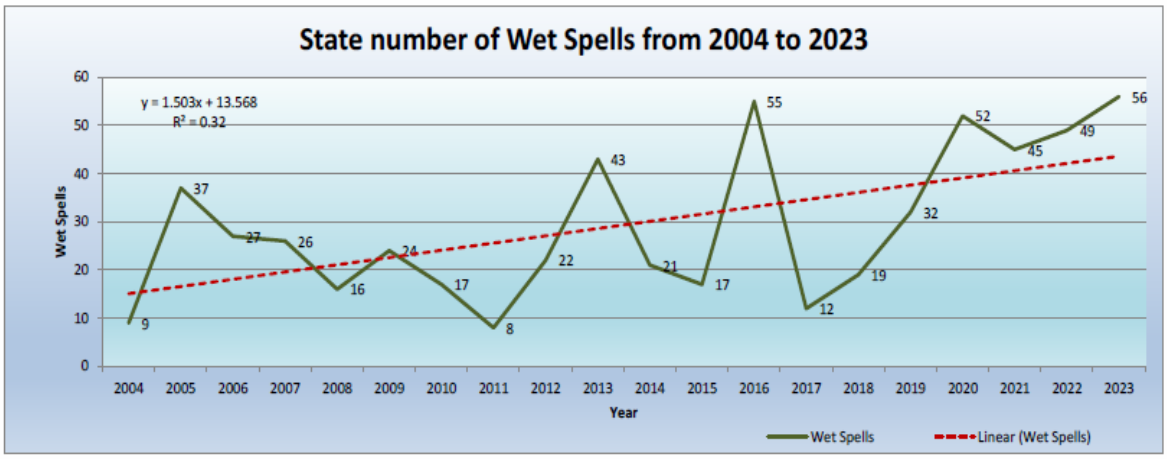

Fig. 3: Year wise number of wet spells from years 2004 to 2023

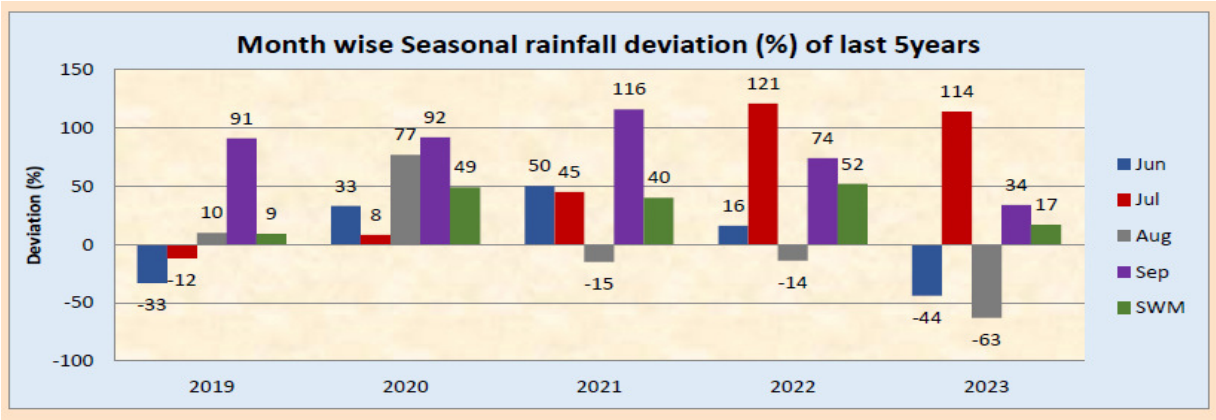

Fig. 4: Month wise seasonal rainfall deviation (%) of last 5 years of Telangana

Summer Tmax				
Year	Tmax	Normal	Anomaly	Rank
2016	40.6	38.9	1.7	1
2017	39.5		0.6	2
2019	39.5		0.6	3
2018	38.9		0.0	4
2015	38.4		-0.5	5
2014	38.1		-0.8	6
2022	37.9		-1.0	7
2020	37.9		-1.0	8
2021	37.1		-1.8	9
2023	37.0		-1.9	10

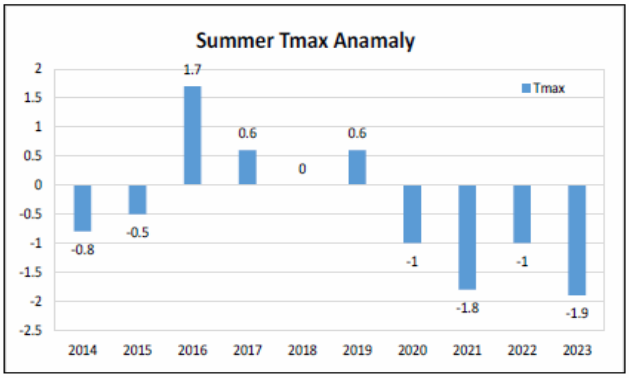

Fig. 5: Telangana state last 10 years (2014-2023) maximum Temperature during Winter

Winter Tmin				
Year	Tmax	Normal	Anomaly	Rank
2020	17.6	16.4	1.2	1
2022	17.4		1.0	2
2019	17.4		1.0	3
2021	17.3		0.9	4
2016	17.0		0.6	5
2023	16.7		0.3	6
2018	16.5		0.0	7
2015	16.2		-0.2	8
2014	15.9		-0.5	9
2017	15.9		-0.5	10

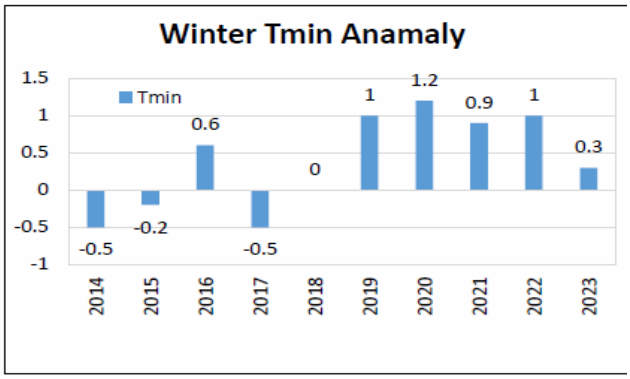

Fig. 6: Telangana state last 10 years (2014-2023) minimum Temperature during Winter

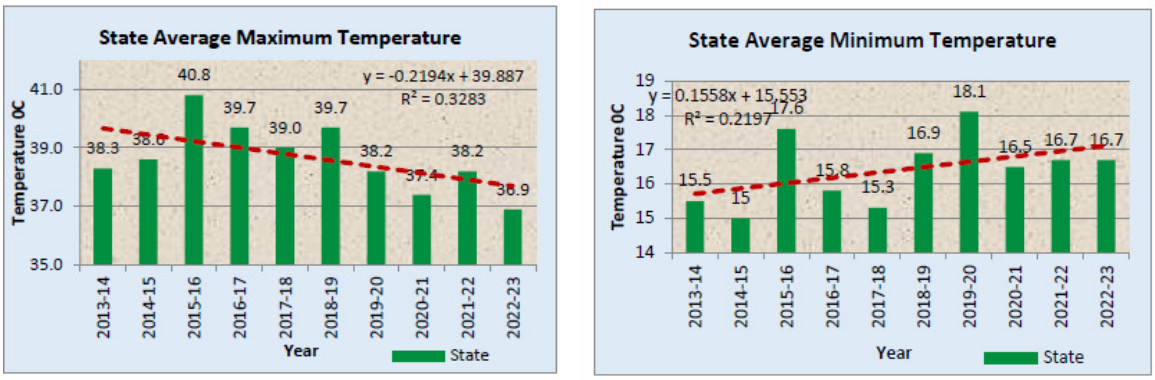

Fig. 7: Telangana state last 10 years (2014-2023) average maximum and minimum Temperature

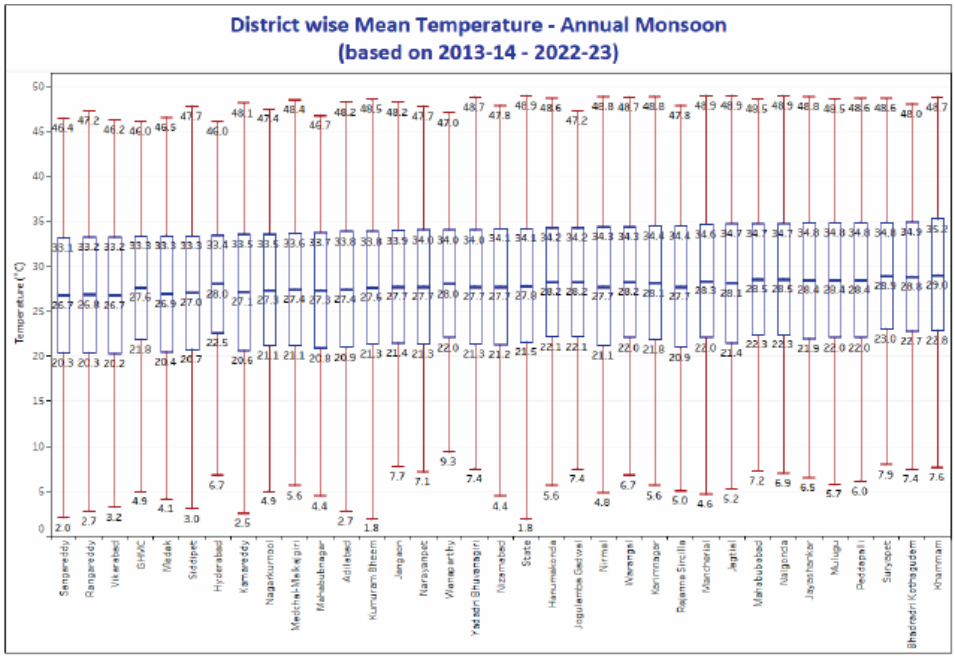

Fig. 8: Box plot representing the Annual Mean, maximum, minimum and Extreme maximum and Minimum temperatures (°C) based on 2013-2023 data of Telangana

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