Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 05, Issue: 05 (SEP-OCT, 2025)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Climate Change and Agro-Climatic Realities: A Data-Driven Lens on Indian Agriculture

*Guhan V
Project Scientist II, Meteorological Centre, India Meteorological Department, Hyderabad, Telangana, India
*Corresponding Author's email: guhanthiran@gmail.com

India's agricultural backbone has long been synchronized with the rhythms of nature, monsoon onset, seasonal temperature shifts, and predictable rainfall patterns have historically guided sowing dates, irrigation cycles, and crop choices. However, these rhythms are now in flux. Climate change is no longer a distant projection; it is a lived reality for millions of farmers across the country. Over the past few decades, rising temperatures, erratic rainfall, and shifting seasonal boundaries have begun to disrupt traditional farming calendars. Crops that once thrived under stable climatic conditions are now facing shortened growing periods, increased water stress, and unpredictable yield outcomes. The implications are profound, not just for food production, but for rural livelihoods, water resource management, and long-term agricultural sustainability. This disruption is especially pronounced in agro-climatic zones of Tamil Nadu and Telangana, where diverse topography and rainfall regimes demand highly localized strategies. In Tamil Nadu, for instance, semi-arid regions are experiencing longer dry spells and higher evapotranspiration rates, while coastal zones face intensified rainfall events and salinity intrusion. Telangana's transitional zones, on the other hand, are grappling with increased drought frequency and rainfall variability, complicating irrigation planning and crop selection.Against this backdrop, scientific studies and data-driven models offer critical insights. By analyzing water requirements, yield responses, and rainfall patterns across these zones, researchers are helping farmers and planners adapt to the new climate reality. This article draws from a series of such studies, spanning Bengal gram, sugarcane, tomato, and urban rainfall extremes, to highlight the emerging challenges and propose actionable solutions for climate-resilient agriculture.

Crop Water Requirement Under Climate Stress

Climate change is exerting a profound influence on crop water dynamics across Tamil Nadu's agro-climatic zones. Recent modeling efforts using CROPWAT and AquaCrop have revealed that even traditionally resilient crops like Bengal gram are now facing elevated water stress. Under projected climate scenarios, Representative Concentration Pathways (RCP) 4.5 and 8.5, the water requirement for Bengal gram increased by 8–12%, particularly in semi-arid regions such as Dharmapuri and Tiruchirapalli. These zones experienced shortened growing periods due to rising temperatures and delayed monsoon onset, leading to reduced pod formation and lower harvest index [1].Sugarcane, a water-intensive crop cultivated extensively in western Tamil Nadu, showed even sharper declines in yield. Simulations indicated a 10–15% reduction in productivity, primarily driven by elevated evapotranspiration during peak summer months. The western agro-climatic zone, encompassing districts like Erode and Coimbatore, recorded higher vapor pressure deficits and reduced effective rainfall, which compounded irrigation demand and stressed canal-fed systems [2]. These findings underscore the vulnerability of perennial crops to thermal stress and the need for recalibrating irrigation schedules.Tomato cultivation, especially in coastal and transitional zones such as Cuddalore and Villupuram, faced a 20% surge in water requirement under future climate projections. The crop's sensitivity to both temperature and moisture stress resulted in significant yield variability. Coastal zones, while receiving higher rainfall, also experienced increased runoff and reduced infiltration, limiting soil moisture availability during critical growth stages. Transitional zones, with their erratic rainfall patterns, showed the highest inter-annual yield fluctuations, making tomato cultivation increasingly risky without supplemental irrigation and mulching strategies [3].These crop-specific insights highlight the urgent need for zone-specific water budgeting, dynamic irrigation advisories, and cultivar selection tailored to emerging climate realities. Integrating these findings into district-level contingency planning and farmer advisories can help mitigate yield losses and optimize water use efficiency.

Rainfall Extremes and Drought Risk

In Telangana's Adilabad district, dry and wet spell probabilities were modeled using Markov Chain techniques. The results indicated a rising trend in dry spells and declining rainfall reliability over the past two decades [4]. Complementary analysis using meteorological drought indices (SPI, SPEI, RDI) confirmed increasing drought severity and spatial variability [5].Urban centers like Hyderabad showed alarming rainfall shifts. A 42-year statistical analysis revealed increasing rainfall extremes and seasonal displacement, complicating water harvesting and urban flood management [6].

Machine Learning for Climate Forecasting

Advanced machine learning models were deployed to forecast temperature and rainfall trends using historical IMD datasets. These models demonstrated high accuracy in predicting Tmax, Tmin, and rainfall anomalies across India, offering scalable tools for agro-advisory systems [7]. A pan-India study on urban precipitation trends used statistical and ML techniques to unravel rainfall behavior in major cities. The findings highlighted intensifying rainfall bursts and shifting monsoon windows, with implications for urban agriculture and water resilience [8].

Basin-Level Hydrology and Extremes

Hydrological modeling using the SWAT framework in the Aliyar sub-basin revealed significant streamflow variability under changing climate inputs. These insights are vital for reservoir operations and downstream irrigation planning [9]. Further analysis of climate extremes over the Parambikulam Aliyar Project basin showed increasing frequency of high-intensity rainfall events and temperature spikes, demanding robust early warning systems and adaptive infrastructure [10].A national-scale study spanning 1980–2023 synthesized temperature and rainfall trends across India. It confirmed warming trends, increased rainfall variability, and regional disparities in climate impact, reinforcing the urgency of climate-smart agriculture [11].

Conclusion

The convergence of crop modeling, statistical analysis, and machine learning paints a compelling and urgent picture: Indian agriculture stands at a climate crossroads. Decades of stable seasonal patterns are giving way to unpredictability, water demand is rising across all major crops, rainfall is becoming increasingly erratic, and productivity is no longer uniform even within the same agro-climatic zone. This shift demands a fundamental rethinking of how we plan, cultivate, and manage agricultural systems. Blanket advisories and one-size-fits-all irrigation schedules are no longer sufficient. Instead, farmers and planners must adopt localized, data-driven strategies that reflect the unique climate sensitivities of each district, crop, and season. These strategies must integrate traditional wisdom, such as crop rotation, soil conservation, and indigenous water harvesting, with modern analytics, including satellite-based rainfall tracking, machine learning–driven yield forecasting, and dynamic water budgeting. The studies synthesized here, from Bengal gram in semi-arid Tamil Nadu to urban rainfall extremes in Hyderabad, demonstrate that climate-smart agriculture is not a theoretical ideal but a practical necessity. By embracing zone-specific interventions, climate-resilient crop varieties, and predictive decision-support tools, India can safeguard its agricultural future while empowering farmers to thrive in a changing climate.

References

1. Guhan, V., Arul Prasad, S., Easwaran, S., Annadurai, K., Marimuthu, M., Balu, D., Vigneswaran, S., Navin Kumar, C. (2024). Climate Change and its Impact on Water Requirement and Productivity of Bengal Gram. *Legume Research*. https://doi.org/10.18805/LR-5286
2. Guhan, V., Annadurai, K., Easwaran, S., Marimuthu, M., Balu, D., Vigneswaran, S., Navinkumar, C. (2024). Assessing the impact of climate change on water requirement and yield of sugarcane. *Scientific Reports*. https://doi.org/10.1038/s41598-024-58771-8
3. Guhan, V., Geethalakshmi, V., Bhuvaneswari, K., Kowshika, N., Vinothkumar, V., Nithila, S., Marimuthu, M. (2024). The Impact of climate change on water requirement and yield of tomato. *Current Science*. https://doi.org/10.18520/cs/v127/i11/1330-1334
4. Guhan, V., Sravani, A., Rao, L.V., Murali Krishna, A., Muralidhar, B. (2024). Dry and Wet Spell Probability by Markov Chain Model over Adilabad District of Telangana. *Madras Agricultural Journal*. https://doi.org/10.29321/MAJ.10.300007
5. Guhan, V., Sravani, A., Rao, L.V., Harshana, M. (2024). Comparative study of meteorological drought indices for Adilabad district, Telangana, India. *Journal of Agrometeorology*. https://doi.org/10.54386/jam.v26i3.2588
6. Velusamy, G., Akasapu, D.R., Kopparthi, N., Alanka, S. (2025). Climate Variability and Rainfall Patterns in Hyderabad: A 42-Year Statistical Analysis. *Madras Agricultural Journal*. https://doi.org/10.29321/MAJ.10.7000MA3
7. Guhan, V., Dharma Raju, A., Rama Krishna, K., Nagaratna, K. (2025). Evaluating weather trends and forecasting with machine learning. *Dynamics of Atmospheres and Oceans*. https://doi.org/10.1016/j.dynatmoce.2025.101562
8. Guhan, V., Dharma Raju, A., Sravani, A., Naga Ratna, K. (2025). Unraveling Rainfall Trends: A Comprehensive Study of Urban Precipitation. *Journal of Earth System Science*. https://doi.org/10.1007/s12040-025-02614-1
9. Guhan, V., Geethalakshmi, V., Raviraj, A., Bhuvaneswari, K., Kowshika, N., Marimuthu, M. (2025). Estimating Stream Flow Variability of Aliyar Sub Basin using Swat Model. *Environmental Engineering and Management Journal*. https://doi.org/10.30638/eemj.2025.013
10. Guhan, V., Geethalakshmi, V., Raviraj, A., Sankar, T. (2025). Extremities Analysis over Parambikulam Aliyar Project Basin of Tamil Nadu. *MAUSAM*. https://doi.org/10.54302/mausam.v76i2.6520
11. Guhan, V., Dharma Raju, A., Rama Krishna, K., Nagaratna, K. (2025). Exploring climate trends and extremes in India: A study of temperature and rainfall from 1980 to 2023. *Journal of Atmospheric and Solar-Terrestrial Physics*. https://doi.org/10.1016/j.jastp.2025.106596