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EL NIÑO AND THE CLIMATE PARADOX IN TIRUCHIRAPPALLI, TAMIL NADU: IMPLICATIONS FOR RAINFALL, AGRICULTURE, AND WATER RESOURCES

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ABSTRACT
El Niño, the warm phase of the El Niño–Southern Oscillation (ENSO), is generally associated with weakened Indian Summer Monsoon Rainfall (ISMR) across much of India. However, Tamil Nadu, including Tiruchirappalli district, often exhibits a contrasting climatic response. While El Niño may reduce Southwest Monsoon rainfall during June–September, it can simultaneously enhance Northeast Monsoon rainfall during October–December, creating a climatic paradox. This study reviews the influence of El Niño on Tiruchirappalli's rainfall distribution, temperature patterns, agricultural productivity, and water resource management. The findings suggest that El Niño alters seasonal rainfall timing rather than uniformly reducing annual precipitation. Understanding this paradox is critical for climate-resilient agriculture and water management in central Tamil Nadu.

Keywords: *El Niño, ENSO, Tiruchirappalli, Northeast Monsoon, Climate Variability, Agriculture, Tamil Nadu.*

1. INTRODUCTION
The El Niño–Southern Oscillation (ENSO) is one of the most influential climate phenomena affecting global weather patterns. During El Niño events, sea surface temperatures in the central and eastern tropical Pacific Ocean become warmer than normal, altering atmospheric circulation and influencing rainfall and temperature patterns worldwide.

India traditionally experiences below-normal Southwest Monsoon rainfall during El Niño years. However, Tamil Nadu presents a unique case because it receives a significant proportion of its annual rainfall from the Northeast Monsoon (NEM), unlike most Indian states that depend predominantly on the Southwest Monsoon. Tiruchirappalli, situated in the central region of Tamil Nadu, experiences climatic impacts from both monsoon systems, making it particularly vulnerable to ENSO-induced variability.

2. THE CLIMATE SETTING OF TIRUCHIRAPPALLI
Tiruchirappalli district lies in the semi-arid tropical region of Tamil Nadu and receives an average annual rainfall of approximately 800–900 mm. Rainfall is distributed through: Southwest Monsoon (June–September): 25–35%, Northeast Monsoon (October–December): 45–55%

Agriculture in the district relies heavily on Cauvery River irrigation and seasonal rainfall. Major crops include paddy, maize, sugarcane, black gram and groundnut.

3. THE EL NIÑO CLIMATE PARADOX

3.1 Reduced Southwest Monsoon Rainfall
During El Niño years, weakened Walker Circulation suppresses convection over the Indian subcontinent, often resulting in below-normal Southwest Monsoon rainfall. Consequently, Tiruchirappalli may experience: Delayed monsoon onset, Reduced early-season rainfall, Increased summer temperatures and Moisture stress in rainfed crops

Many El Niño events have historically coincided with monsoon deficits across India. Scientific studies indicate that ENSO significantly influences dry and wet spells throughout the country.

3.2 Enhanced Northeast Monsoon Rainfall
Paradoxically, several studies have found that El Niño years are frequently associated with enhanced Northeast Monsoon rainfall over Tamil Nadu. Research analyzing more than a century of rainfall data showed that most ENSO years corresponded with wet or flood years during the Northeast Monsoon season (De and Mukhopadhyay, 1999).

For Tiruchirappalli, this can lead to: Intense rainfall events during October–December, Urban flooding risks, Waterlogging in agricultural lands, Improved reservoir storage and groundwater recharge

Thus, El Niño may create both drought-like conditions during the Southwest Monsoon and excessive rainfall during the Northeast Monsoon.

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4. IMPACTS ON AGRICULTURE

4.1 Negative Effects

The early growing season may suffer from: Soil moisture deficits, Delayed sowing operations, Reduced germination rates and Increased irrigation demand

Heat stress associated with El Niño can further reduce crop productivity and increase evapotranspiration rates. Recent climate assessments indicate that El Niño often intensifies heat conditions across India while weakening seasonal rainfall.

4.2 Potential Benefits

Enhanced Northeast Monsoon rainfall may provide: Adequate water for samba paddy cultivation, Reservoir replenishment, Improved groundwater recharge and Increased availability of irrigation water

Therefore, the net agricultural impact depends on rainfall timing, intensity, and distribution rather than annual rainfall totals alone.

5. RAINFALL VARIABILITY IN TIRUCHIRAPPALLI (1981–2025)

5.1 Long-Term Rainfall Characteristics

Tiruchirappalli district lies in the semi-arid zone of central Tamil Nadu and receives rainfall from both the Southwest Monsoon (SWM) and Northeast Monsoon (NEM). Historical rainfall studies indicate that annual rainfall averages approximately 850–900 mm, though considerable year-to-year fluctuations occur due to large-scale climate drivers such as ENSO. The Northeast Monsoon contributes nearly half of the annual rainfall and is therefore the dominant rainfall season in the district.

Table 1. Analysis of long-term rainfall records reveals:

Season	Contribution to Annual Rainfall (%)
Southwest Monsoon (Jun–Sep)	25–35
Northeast Monsoon (Oct–Dec)	45–55
Summer (Mar–May)	10–15
Winter (Jan–Feb)	2–5

These seasonal proportions make Tiruchirappalli climatically distinct from much of India, where the Southwest Monsoon dominates annual rainfall.

5.2 Rainfall Behaviour During El Niño Years

A comparison of major El Niño years (1982, 1987, 1997, 2002, 2009, 2015, 2023) demonstrates a recurring pattern in Tiruchirappalli:

1. Deficient Southwest Monsoon rainfall.
2. Above-normal temperatures.
3. Enhanced Northeast Monsoon activity in several El Niño years.
4. Increased occurrence of heavy rainfall events during October–December.

Studies conducted by the India Meteorological Department found that among 22 ENSO years examined, 18 were associated with wet or flood years during the Northeast Monsoon season over Tamil Nadu (De and Mukhopadhyay, 1999).

5.3 Decadal Rainfall Trends

Table 2. The rainfall record for Tiruchirappalli may be broadly divided into four periods:

Period	Characteristics
1981–1990	Moderate variability; strong influence of 1982–83 and 1987 El Niño events
1991–2000	High rainfall variability; extreme 1997–98 El Niño associated with enhanced NEM rainfall
2001–2010	Frequent drought episodes; 2002 and 2009 monsoon deficits
2011–2025	Increased frequency of intense rainfall events and greater seasonal variability

Recent climate assessments suggest increasing rainfall variability across Tamil Nadu due to rising temperatures and changing moisture dynamics.

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6. STATISTICAL RELATIONSHIP BETWEEN EL NIÑO AND TIRUCHIRAPPALLI RAINFALL

ENSO affects Tiruchirappalli through two contrasting mechanisms:

Negative Relationship with Southwest Monsoon

As Pacific Ocean temperatures increase during El Niño, convection shifts eastward, weakening monsoon circulation over India. This often results in reduced rainfall during June–September.

Positive Relationship with Northeast Monsoon

El Niño conditions enhance sea-surface temperatures over the Bay of Bengal and Arabian Sea, favouring cyclonic activity and increased rainfall over Tamil Nadu during October–December (De and Mukhopadhyay, 1999).

This dual response explains why annual rainfall totals in Tiruchirappalli may remain near normal even when the Southwest Monsoon fails.

7. CASE STUDIES OF MAJOR EL NIÑO EVENTS

1987 El Niño

1. Severe all-India monsoon drought.
2. Reduced SWM rainfall in Tiruchirappalli.
3. Partial recovery through NEM rainfall.

1997–98 Super El Niño

1. One of the strongest ENSO events of the twentieth century.
2. Enhanced Northeast Monsoon rainfall across Tamil Nadu.
3. Significant reservoir recharge and groundwater recovery (De and Mukhopadhyay, 1999).

2015 El Niño

1. Record warming in the Pacific Ocean.
2. Exceptional rainfall and flooding in several parts of Tamil Nadu during the Northeast Monsoon season.
3. Demonstrated the paradoxical impact of El Niño on southeastern India.

2023–24 El Niño

1. Elevated temperatures and delayed monsoon conditions.
2. Spatially uneven rainfall distribution across Tamil Nadu.
3. Continued evidence of ENSO-related climate variability (Lakshmi *et al.* 2025).

8. WATER RESOURCE IMPLICATIONS

Key El Niño Impacts for Trichy

Pre-Monsoon & Heat Stress: The initial phase brings intense heat waves to South India, frequently pushing temperatures 3°C to 4°C above normal. This can cause a deficit in the Southwest Monsoon and strain groundwater levels.

Extreme Rainfall: By the latter half of the year, El Niño tends to augment rainfall extremes during the Northeast Monsoon (October–December). Trichy and the surrounding delta regions often experience sudden deluges, flooding, and cyclonic circulations rather than steady, uniform rainfall.

Agricultural & Local Concerns

Kuruvai (Early) Season Risk: The delayed or weak Southwest Monsoon affects surface water inflows into the Cauvery River, causing agricultural departments in districts like Trichy and Thanjavur to advise farmers to rely heavily on groundwater and early sowing to mitigate risks.

Crop Vulnerability: The elevated temperatures (potentially rising above normal) paired with uneven precipitation can threaten paddy and sugarcane yields.

Tiruchirappalli depends on the Cauvery River system, tanks, reservoirs, and groundwater resources. El Niño-induced variability can produce contrasting hydrological outcomes:

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Drought Risk
Lower inflow during Southwest Monsoon months, Increased groundwater extraction and Reduced tank storage

Flood Risk
Heavy Northeast Monsoon rainfall, Urban flooding in low-lying areas, Reservoir management challenges and River overflow during extreme rainfall events.

This dual risk necessitates adaptive water resource planning.

The rainfall analysis indicates that El Niño does not necessarily reduce total annual rainfall in Tiruchirappalli. Instead, it redistributes rainfall seasonally:

1. Reduced rainfall during crop establishment stages.
2. Increased risk of heat stress.
3. Higher irrigation demand during kharif season.
4. Potentially beneficial water availability during samba paddy cultivation.
5. Greater flood risk during intense NEM events.

This seasonal redistribution creates significant challenges for agricultural planning and water management

9. CLIMATE CHANGE AND FUTURE CONCERNS

Recent studies suggest that the relationship between ENSO and Indian monsoon rainfall is evolving under climate change. While ENSO remains a strong driver of climate variability in southern India, rising temperatures and changing ocean conditions may amplify extreme weather events (Athira *et al.* 2023)

For Tiruchirappalli, future El Niño events may result in: More frequent heatwaves, Greater rainfall variability, Increased occurrence of extreme rainfall events and Higher agricultural vulnerability.

The interaction between ENSO and climate change may therefore intensify the climate paradox already observed in Tamil Nadu.

10. ADAPTATION STRATEGIES

To reduce vulnerability, the following measures are recommended:

1. Climate-informed crop planning.
2. Promotion of drought-tolerant crop varieties.
3. Expansion of rainwater harvesting structures.
4. Strengthening tank and reservoir management.
5. Improved seasonal climate forecasting.
6. Adoption of precision irrigation technologies.
7. Development of district-level climate risk management plans.

11. CONCLUSION

The analysis of rainfall variability in Tiruchirappalli from 1981–2025 demonstrates that El Niño produces a distinctive climatic paradox. While Southwest Monsoon rainfall generally declines during El Niño years, Northeast Monsoon rainfall often increases, offsetting seasonal deficits. The district therefore experiences both drought and flood risks within the same climatic cycle. Long-term rainfall trends also indicate increasing variability and more frequent extreme rainfall events, highlighting the need for climate-resilient agricultural practices, improved seasonal forecasting, and adaptive water-resource management strategies (De and Mukhopadhyay, 1999).

El Niño presents a distinctive climatic paradox for Tiruchirappalli. While it often weakens Southwest Monsoon rainfall and increases heat stress, it can simultaneously enhance Northeast Monsoon rainfall, which is the primary source of precipitation for Tamil Nadu. This dual influence creates both drought and flood risks within the same year. Consequently, understanding ENSO-driven climate variability is essential for sustainable agriculture, water management, and climate adaptation planning in Tiruchirappalli district. Future research should focus on district-scale climate modeling and impact assessments to improve resilience against increasingly variable climatic conditions.

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