

El Nino Effect on Agriculture in Andhra Pradesh: Rainfall Variability, Crop Production and Adaptation Measures

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ABSTRACT

The El-Nino Southern Oscillation (ENSO) is one of the major large scale climate phenomena affecting the rainfall variability over the Indian subcontinent. Andhra Pradesh, with its large area under rainfed agriculture and heavily reliant on the southwest and northeast monsoons, is particularly susceptible to the variations in rainfall and temperature associated with El Niño events. In this paper we examine the effect of El Nino on agricultural production in Andhra Pradesh with a special emphasis on rainfall variability, crop productivity, cropping systems and farm level vulnerability. The study is based on secondary data and review of empirical studies relating ENSO and rainfall and agricultural performance in the state of Andhra Pradesh. Evidence indicates that El Niño tends to be associated with deficient southwest monsoon rainfall, although the magnitude and spatial distribution of the effect varies greatly across regions and seasons. The historical records reveal that the 2002 El Nino event was related to large rainfall deficit and a decline in the yield of rice in Andhra Pradesh. Studies have also reported declines in area, production and productivity of Kharif rice in El Nino years. Rainfed crops like groundnut, pigeonpea, maize, pearl millet and other dryland crops are facing particular problems of dry spells and moisture stress. However, the links between El Niño and agricultural output are not deterministic, as irrigation, crop choice, soil condition, technological adoption and the northeast monsoon can moderate its impacts. The paper calls for ENSO-informed agricultural planning, drought-resilient varieties, diversification, supplemental irrigation, weather-based advisories, crop insurance and district-specific contingency planning. Andhra Pradesh must develop climate resilient agriculture to safeguard farm incomes and food security.

Keywords: El Niño, ENSO, agriculture, Andhra Pradesh, rainfall variability, crop production, drought, climate resilience, rainfed agriculture, adaptation.

INTRODUCTION

Agriculture in Andhra Pradesh is heavily dependent on variability of Indian monsoon. Irrigation has increased considerably, but rainfall still has a significant influence on the area that is sown, crop establishment, productivity and farm incomes, especially in drought-prone areas and areas that depend on rain. The southwest monsoon is most important for Kharif agriculture. The north east monsoon gives substantial rainfall to some parts of south and coastal Andhra Pradesh.

El Niño is the warm phase of the El Niño-Southern Oscillation. It is characterized by anomalous warming of the central and eastern tropical Pacific Ocean. El Niño can affect the Indian summer monsoon through atmospheric teleconnections. The relationship is strong at the broad seasonal scale but is not perfectly deterministic; not every El Niño produces drought in every part of India. This qualification is underscored by research specifically commissioned for Andhra Pradesh which nevertheless found a significant link between El Niño events, rainfall variability and agricultural performance.

Its importance has increased as agricultural systems are confronted with climate variability, rising temperatures, groundwater stress and a higher frequency of extreme weather events at the same time. Recent

studies in semi-arid Andhra Pradesh indicate that the timing and duration of dry spells could have significant impact on the productivity of major rainfed crops like groundnut, pigeonpea, maize and pearl millet.

Objectives of the Study

The specific objectives of the study are:

- To study the association between El Nino events and rainfall variability in Andhra Pradesh.
- To investigate the effect of El Niño related climatic variability on major agricultural crops
- To assess the vulnerability of rain-fed and irrigated agricultural systems.
- To investigate the implications of El Niño for crop production, productivity and farm incomes.
- To review existing adaptation measures and suggest appropriate policy strategies for climate-resilient agriculture in AP.

LITERATURE REVIEW

The ENSO and Indian monsoon rainfall relationship has been extensively investigated in the climatological and agricultural research. Previous studies have shown that El Niño events are generally associated with below-normal southwest monsoon rainfall over large parts of India, but regional differences are large. The relation thus gives a useful source of seasonal climate information but is not to be treated as a deterministic predictor of drought. (ResearchGate)

Rao et al. (2011) undertook a specific study on El-Nino impacts on climatic variability and crop production in Andhra Pradesh. Their analysis considered seasonal and annual rainfall, temperature, and production of key crops, and considered the potential of using El Niño information for strategic agricultural planning. The study highlighted that the effect varied by region and season, with the northeast monsoon having the potential to decrease the vulnerability in certain areas of the state. (Scribd)

Research on rice in Andhra Pradesh reveals that the effects of climate are heterogeneous across agro-climatic zones and yield levels. Barnwal and Kotani show that the effect of temperature and precipitation is considerably different in agro-climatic zones and crop seasons. The monsoon-dependent Kharif rice is more susceptible to climatic changes than the winter rice. (ScienceDirect)

A more comprehensive study on ENSO and rice production reported that El Niño years were associated with below normal southwest monsoon rainfall in Coastal Andhra Pradesh and Rayalaseema. It also reported decreases in Kharif rice area, production and productivity in Andhra Pradesh during El Niño years. (MDPI)

Singh et al. used crop simulation and long-term weather data to examine alternative cropping systems for Nandyal in Andhra Pradesh. They found that ENSO information could be used to assess alternative cropping strategies and possibly reduce climatic risk in rainfed agriculture. (ICRISAT@OAR)

More recent work has moved away from total seasonal rainfall to the distribution of rainfall and dry spells. In semi-arid Andhra Pradesh, studies showed large negative relationships between the intensity of dry spells and yields of groundnut, pigeonpea, maize and pearl millet. This finding is important because El Niño impacts may not be operating through seasonal rainfall totals but the timing and persistence of moisture deficits. (Wiley Online Library)

METHODOLOGY

The present study is mainly based on secondary data and published research. The data was collected from published scientific studies, institutions of agricultural research and climate related literature on Andhra Pradesh.

The analysis is both descriptive and analytical. The study considers:

- El Niño and SW Monsoon rainfall;
- irregularities of rainfall during selected El Niño years;
- production and productivity of crops;
- vulnerability of rainfed agriculture;
- difference between Kharif and Rabi crops;
- irrigated against rainfed farming differences;
- possible options for adaptation

The published results of Andhra Pradesh specific studies are interpreted according to the ENSO-agriculture relationship. Because El Niño does not impact each district equally in each year, the paper does not treat all El Niño years as equivalent drought years.

El Niño and Rainfall Variability in Andhra Pradesh

Rainfall variability is the main agricultural route through which El Niño impacts Andhra Pradesh. Weak or erratic southwest monsoon can delay sowing, reduce soil moisture and increase chances of long dry spells.

Inter-annual variability of summer monsoon rainfall over Andhra Pradesh has been studied. Historical analysis of monsoon rainfall indicated that 2002 experienced especially adverse rainfall conditions and the year was associated with moderate drought situation over the state. The study also showed that the rice yield in 2002 was much lower than that in 2001. (ResearchGate)

Table 1 Selected Climatic and Agricultural Effects Associated with El Niño in Andhra Pradesh

El Niño-related effect	Agricultural implication
Deficient southwest monsoon rainfall	Reduced soil moisture
Delayed monsoon onset	Delayed sowing and crop establishment
Longer dry spells	Moisture stress during critical crop stages
Higher temperatures	Increased evapotranspiration
Reduced reservoir inflows	Lower irrigation availability
Decline in groundwater recharge	Increased irrigation costs

The relationship is not uniform across the state. The impact is geographical, crop season, availability of irrigation, soil characteristics and dependency on rainfall.

Effect on Agriculture Production

Effect on rice

Rice is very important in Andhra Pradesh and is closely related to monsoon and irrigation conditions. Kharif rice is more sensitive to rainfall variability than irrigated Rabi rice.

A study based on 34 years data on Andhra Pradesh rice yields showed that climatic variables had heterogeneous effects across yield distributions and agro-climatic zones . Kharif rice was more sensitive to temperature and precipitation than the winter rice. (ScienceDirect)

Research on ENSO further indicates that Kharif rice production suffers during El Nino years. In Andhra Pradesh during El-Niño episodes, there were declines in rice area, production and productivity. (MDPI)

Table 2. Reported Effects of El Niño on Kharif Rice in Andhra Pradesh

Indicator	Reported effect during El Niño years
Area under Kharif rice	−9.3%
Production of Kharif rice	−12.6%
Productivity of Kharif rice	−3.6%

Source: Based on published ENSO–rice analysis reported in the literature.

These numbers suggest that the effect is mediated by more than one mechanism. The area planted could be affected first by decreased rainfall and then the yield is affected by moisture stress.

Impact on Rainfed Crops

El Niño is more directly associated with rainfall variability which affects rainfed agriculture. Andhra Pradesh has large rainfed production of groundnut, pigeonpea, maize, pearl millet and other crops.

Research in the semi-arid areas of Andhra Pradesh revealed that the intensity of dry spells was negatively associated with the yields of groundnut, pigeonpea, maize and pearl millet. It was found that Anantapur was especially susceptible to dry-spell conditions. (Wiley Online Library)

Table 3. Vulnerability of Major Crops to El Niño-Related Moisture Stress

Crop	Major climate sensitivity	Relative vulnerability
Groundnut	Soil-moisture deficiency during establishment and reproductive stages	High
Pigeonpea	Prolonged dry spells	High
Maize	Moisture stress during vegetative and reproductive stages	High
Pearl millet	Rainfall deficiency and high temperature	High
Kharif rice	Deficient rainfall and inadequate water availability	High
Chickpea	Residual soil moisture and temperature	Moderate
Cotton	Rainfall distribution and moisture stress	Moderate–High
Rabi rice	More dependent on irrigation	Relatively lower

Source: Synthesized from published Andhra Pradesh climate–crop studies. (OAR@ICRISAT)

Regional Differences in Andhra Pradesh

The agricultural impact of El Niño varies considerably across Andhra Pradesh.

Coastal Andhra

Coastal agricultural systems are characterized by large areas of rice cultivation and dependence on irrigation and river water resources. However, the impact of a weak southwest monsoon may be mitigated in areas where irrigation water is available. However, inadequate reservoir inflows and rainfall deficits may still affect Kharif crop establishment.

Rayalaseema

Much more vulnerable is Rayalaseema, because of its semi-arid climate and high dependence on rainfed agriculture. Groundnut and other dryland crops are very sensitive to prolonged dry spells.

Southern and southeastern Andhra Pradesh

In many localities the influence of the northeast monsoon is great. This is an important distinction: a weak southwest monsoon does not necessarily translate into an equally weak annual rainfall deficit. Thus, agricultural planning needs to take into account both monsoon systems, and not only the June-September rainfall.

Table 4. Major Pathways Through Which El Niño Affects Agriculture

Climatic pathway	Immediate effect	Agricultural consequence
Reduced SW monsoon	Lower rainfall	Delayed sowing
Rainfall breaks	Longer dry spells	Crop moisture stress
Higher temperature	Increased evapotranspiration	Greater water requirement
Low reservoir inflow	Reduced irrigation supply	Reduced cropped area
Poor groundwater recharge	Falling water availability	Higher irrigation costs
Delayed sowing	Shortened growing period	Lower productivity
Crop failure	Reduced output	Lower farm income
Fodder shortage	Reduced livestock feed	Livestock income loss
Reduced production	Lower market supply	Possible price increases

El Niño and Farm Income

The economic consequences of El Niño extend beyond crop yields. A reduction in agricultural production can result in lower farm income, higher expenditure on irrigation, greater dependence on credit and increased risk of distress migration. Small and marginal farmers are particularly vulnerable because they often have limited irrigation facilities, smaller financial reserves and restricted access to climate-risk management instruments.

The impact can therefore be conceptualized as:

El Niño → rainfall deficiency → moisture stress → lower cropped area/productivity → lower output → lower farm income → increased indebtedness and livelihood vulnerability.

However, the strength of this chain varies according to irrigation access, crop choice, farm size, access to institutional credit, crop insurance and government support.

Adaptation Strategies

The evidence suggests that El Niño should not be treated simply as a disaster after it occurs. Instead, ENSO forecasts should be incorporated into **pre-season agricultural planning**.

Climate-informed crop planning

Farmers should be encouraged to select crops according to anticipated rainfall conditions. If seasonal forecasts indicate elevated drought risk, less water-intensive crops can be promoted.

Crop diversification

Diversification reduces dependence on a single crop. The use of millets, pulses, oilseeds and drought-tolerant crops can provide alternatives during moisture-deficit years.

Drought-resistant varieties

Greater adoption of short-duration and drought-tolerant varieties can help farmers escape terminal drought and reduce water requirements.

Supplemental irrigation

Farm ponds, check dams, watershed development and efficient irrigation technologies can provide critical water during dry spells.

Weather-based advisories

Village-level weather advisories should provide information on:

- sowing dates;
- crop choice;
- fertilizer application;
- pest management;
- irrigation scheduling;
- harvesting decisions.

Crop insurance

Crop insurance should be strengthened in areas exposed to recurrent rainfall variability. Faster assessment and settlement of claims is essential.

ENSO-based contingency planning

Particularly important is the availability of El Niño contingency plans district-wise. At present, ICAR's agricultural advisory system provides El Niño advisories and district level contingency plans including for Andhra Pradesh. (ICAR-Indian Institute of Maize Research)

DISCUSSION

The evidence presented in this paper substantiates that El Niño is an important source of agricultural risk in Andhra Pradesh. However, its impact should not be taken as a straightforward one-to-one El Niño to drought relationship.

Three main observations are discussed.

First, rain is the main transmission mechanism. El Niño can affect the southwest monsoon, and hence the availability of agricultural water. Rainfall variability has a strong association with agricultural performance studies in Andhra Pradesh. (ResearchGate)

Secondly, rainfed agriculture is more vulnerable than well irrigated agriculture. Recent evidence from semi-arid Andhra Pradesh suggests that dry spell frequency and persistence may be more informative for crop production than seasonal rainfall totals alone. (Wiley Online Library)

Third, the effects depend on space and season. Monsoon rice is typically more exposed than irrigated Rabi crops, and areas receiving the northeast monsoon could have a different risk profile. Similarly, rice research in Andhra Pradesh also showed variations across agro-climatic zones and seasons. (From ScienceDirect)

So agricultural policy should shift from a uniform state-level response to crop-specific, district-specific and season-specific climate-risk management.

CONCLUSION

El Niño is an important climatic factor affecting the agriculture performance of Andhra Pradesh. The dominant agricultural impact is through changes in monsoon rainfall, dry spell occurrence, soil moisture and water availability. Historical evidence indicates that El Niño years may be correlated with below-average rainfall and lower agricultural production, particularly in rainfed farming systems. Moisture stress is a special problem for Kharif rice and dryland crops like groundnut, pigeonpea, maize and pearl millet.

But El Niño is not always an agricultural catastrophe. Irrigation, access to groundwater, crop diversification, better varieties, good sowing decisions and effective agricultural advisories can greatly reduce its impacts. The experience of Andhra Pradesh also indicates the need to consider the northeast monsoon and regional climatic differences in the agricultural risk assessment.

Hence, the future agriculture strategy of Andhra Pradesh should be climate intelligence and not climate reaction. Systematic integration into crop planning, water management, extension services, insurance and agricultural credit is needed for El Niño forecasting. The combination of scientific climate forecast information with local knowledge and district-level contingency planning can be extremely effective in improving farmers' resilience to ENSO-related climate shocks.

Policy Recommendations

Based on the analysis, the following policy measures are recommended:

The following policy measures are recommended based on the analysis:

- Incorporate ENSO forecasts in agricultural planning: Seasonal El Niño forecasts should be used for developing district specific agricultural advisories.
- Prepare district level crop contingency plans: Each district should prepare plans for delay in monsoon, extended dry spells and rainfall deficiency.
- Promote drought resilient crops: Groundnut, pulses, millets and other suitable crops should be promoted in vulnerable rainfed areas.
- Expand micro-irrigation Water-use efficiencies can be enhanced by drip and sprinkler irrigation.

- Strengthening watershed development: Priority should be given to farm ponds, check dams and groundwater recharge structures in drought-prone mandals.
- Promote short-duration varieties Short-duration varieties may decrease exposure to late-season moisture stress.
- Improve weather advisory services Mobile phones, farmer groups, extension workers and local institutions should be used to disseminate advisories to farmers.
- Strengthen crop insurance: The insurance cover should be expanded among small and marginal farmers.
- Improve access to institutional credit: In times of climate shocks, timely credit can prevent farmers from turning to expensive informal credit.
- Develop climate-resilient agricultural extension. Extension workers need specialized training on ENSO-informed agricultural management.

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