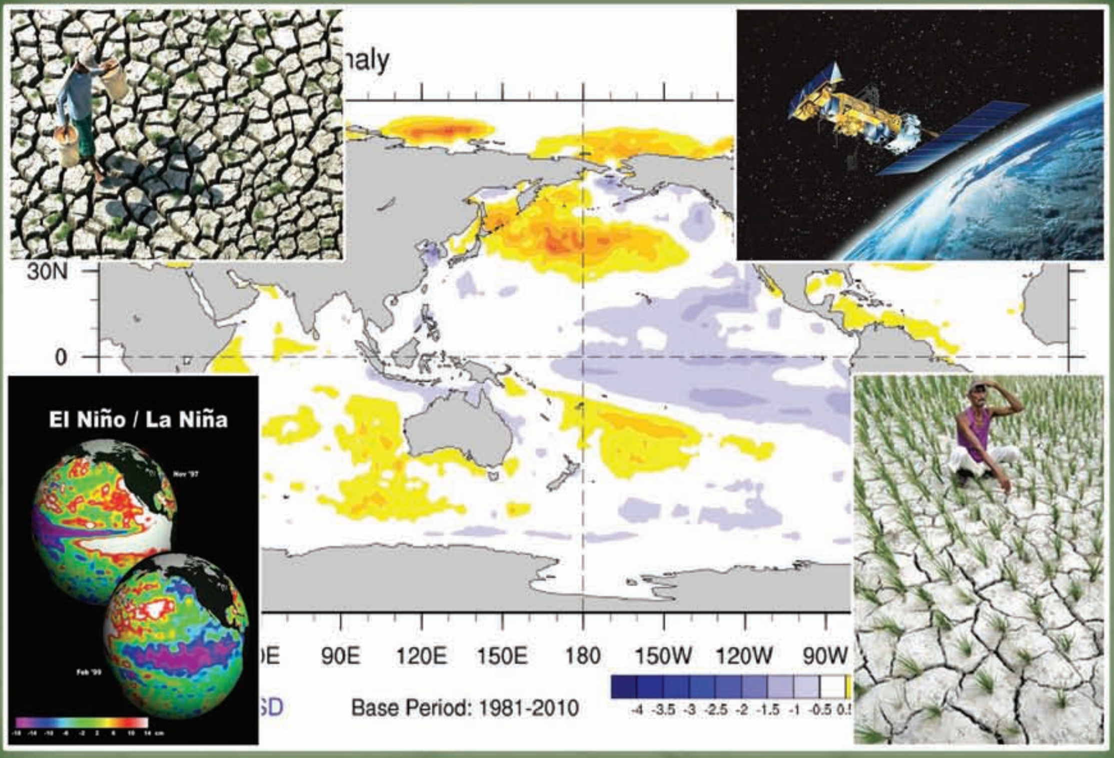
Res. Bull. No. 2/2011

El Niño Effect on Climatic Variability and Crop Production :
A Case Study for Andhra Pradesh

V.U.M. Rao
A.V.M. Subba Rao
B. Bapuji Rao
B.V. Ramana Rao
C. Sravani
B. Venkateswarlu



हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

National Initiative on Climate Resilient Agriculture (NICRA)
All India Coordinated Research Project on Agrometeorology
Central Research Institute for Dryland Agriculture
Santoshnagar, Saidabad, Hyderabad – 500 059, A.P., India

Res. Bull. No. 2/2011

El Niño Effect on Climatic Variability and Crop Production :

A Case Study for Andhra Pradesh

V.U.M. Rao
A.V.M. Subba Rao
B. Bapuji Rao
B.V. Ramana Rao
C. Sravani
B. Venkateswarlu

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

भाकृअनुप
ICAR

National Initiative on Climate Resilient Agriculture (NICRA)
All India Coordinated Research Project on Agrometeorology
Central Research Institute for Dryland Agriculture
Santoshnagar, Saidabad, Hyderabad – 500 059, A.P., India

Citation :
Rao, V.U.M., Subba Rao, A.V.M., Bapuji Rao, B., Ramana Rao, B.V., Sravani, C. and Venkateswarlu, B. (2011). El Niño Effect on Climatic Variability and Crop Production : A Case Study for Andhra Pradesh, Research Bulletin No. 2/2011. Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh, India. 36 p.

2011

500 copies

Published by

The Director
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059
Ph : 040-24530177 Fax : 040-24531802
website : http://www.crida.ernet.in E-mail : director@crida.ernet.in

Printed at : **Sree Ramana Process Pvt. Ltd.**
1-7-267, S.D.Road, Secunderabad - 500 003. Ph : 040-27811750

CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

Though agriculture is the backbone of India's economy, the contribution from farm sector is declining constantly from 57 per cent in 1950-51 to 17.2 per cent in 2008-09. This decline will have a direct impact on the employment opportunities and livelihoods in rural areas. National food security in the backdrop of climate change is a concern for everyone in the society. Extreme weather conditions such as floods, droughts, heat and cold waves, cyclones and hail storms cause huge losses to crop production, but even more subtle fluctuations in weather during critical phases of crop can also have a substantial impact on the ultimate yields. Some of these fluctuations may go unnoticed on a regional scale but the science of Agricultural Meteorology has established that the performance of southwest monsoon in the country has a tele link with El Niño phenomenon. Thus information on the anticipated fluctuations in both monsoon rainfall and the resultant agricultural production prior to the start of the growing season has wider implications for decision making at the farm and policy levels. Regional scenarios anticipated in the event of El Niño help the state administration to mobilize resources and inputs like seeds, fertilizers etc. Therefore an attempt has been made to examine the possibility of using El Niño factor as a signal for climatic variability which can help in moderating any likely adverse effects on crop production with better planning and management. I sincerely hope that there is an urgent need to carry out analogous studies for all those regions where the impact of climatic variability on crop production is significant.

(B. Venkateswarlu)

Hyderabad
11.11.2011

Summary

During the recent years, the inter-seasonal and intra-seasonal variability in weather is believed to outsmart the abilities of climatologists and statisticians in defining the limits within which these variabilities can be observed. This has lead the weather experts to realize and convince themselves that the global climate is changing due to enhanced human activities detrimental to natural environment. Therefore, the meteorologists are now required not only to predict weather on short term basis but also climate on long term basis as many critical decisions in agriculture are required to be made well ahead of the season before those weather conditions are realized. Such predictions offer the potential for farmers and other decision makers to predict crop responses to expected climate, and modify decisions to decrease unwanted impacts or take advantages of expected favourable conditions.

El Niño is fundamentally a warming of the surface waters of the tropical eastern Pacific Ocean from South American coast to the International Date Line that persists for three or more seasons. El Niño is a pervasive climatic phenomenon which was found to be associated with regional climatic variations throughout the world.

Analysis of long term data suggests an inverse relationship between El Niño and southwest monsoon rainfall in India. However, there is no one to one relationship as El Niño years have not always produced severe droughts. Studies on the effect of El Niño either on crop production or productivity at regional level were not so far carried out in India.

Therefore, an attempt has been made to examine the effect of El Niño for

- identifying changes in seasonal rainfall as well as annual rainfall in different districts of Andhra Pradesh,
- quantifying the changes in annual temperature at some selected locations in the state for which records are available,
- assessing the changes in total food grain production as well as production of some of the crops rice, groundnut, castor, pigeonpea, chickpea and pearl millet and
- suggesting the possible strategies to enhance agricultural production in the event of adverse climate situations.

The study brought out some of the interesting findings as detailed below:

The average southwest monsoon rainfall received during the years with El Niño was found to be less compared to normal years and the average rainfall during the northeast monsoon is higher in coastal Andhra Pradesh. In general, it was observed that either the southwest monsoon rainfall or the annual rainfall will be less during the years with El Niño.

The mean annual temperature was found not to vary much during El Niño years. The diurnal range in temperature was also found not to vary drastically during El Niño years.

Barring S.P.S Nellore district, the average total food grain production throughout the state was found to decline during El Niño years. The decrease in production was found to be more than 10 per cent in several districts in the state. The average productivity of total food grains was found to be less in all the districts barring S.P.S Nellore and West Godavari although there is variation in magnitude geographically. The shortfall in production and productivity can be attributed to decreasing southwest monsoon rainfall in the state. However the yields were above average during the weak El Niño years 2004 and 2006, but fell short of preceding higher yield points.

The average groundnut productivity and yield during El Niño years were not affected for the state as a whole although there is a decline in the productivity by more than 10 per cent in Anantapur district where crop is sown usually during second fortnight of July to first week of August.

Pearl millet is grown mostly in shallow soils and *alfisols* during the southwest monsoon season. The average production and productivity were found to decrease during El Niño years thereby indicating the risk associated with short duration crops grown under rainfed conditions during *kharif* season.

On annual basis, the average production and productivity of rice during El Niño years was not affected. During *kharif* season, there was a decline in average production of rice by 12 per cent in the state. Rice being predominantly an irrigated crop in the district, El Niño effect was marginal when the state as a whole was considered. However, when the total food grain production excluding rice was examined, the decline in production and productivity appeared to be more than 25 per cent thereby indicating the vulnerability of dryland crops during the years particularly with moderate and strong El Niño. It will be a difficult task to achieve increased growth rate in total food grain production during El Niño years. Yields of long duration *kharif* crops like pigeonpea and crops like chickpea grown under residual soil moisture during *rabi* season were comparitively less affected during the El Niño years.

Therefore, there is need to enhance the agricultural production and productivity during the years with El Niño and the possible strategies are as follows:

- As the southwest monsoon rainfall is likely to be less and the northeast monsoon is likely to be more than normal in Nalgonda and Mahabubnagar districts in Telangana and entire coastal Andhra Pradesh barring Vizianagaram, intercropping systems with long duration base crop and short duration intercrop can be adopted in traditional rainfed mono-cropping areas.
- As the northeast monsoon rainfall is likely to be more than normal in some of the districts, the productivity of *rabi* crops can be improved by judicious use of fertilizers and adoption of pest and disease control during the early stages of its growth.
- In those districts wherever rice yields are likely to decline, rice may be cultivated under system of rice intensification (SRI) method particularly during *kharif* season.
- Plantation crops like mango, cashew and coconut are likely to yield less wherever pre-monsoon rainfall has a tendency to decrease and therefore moisture conservation practices need to be adopted.
- Vegetable production during summer season is likely to get affected and production can be sustained by promoting peri-urban olericulture and use of shadenets.

The authors consider that the study may not be very exhaustive and is only intended to enlighten the utility of using signals like El Niño as a possible option to understand climate variability and use it for taking strategic decisions for enhancing agricultural production during the seasons with adverse climate to a certain extent.

Although, El Niño phenomena may provide signal only for few of the years, it indicates the possibility to identify some more critical parameters to cover as many years as possible in the near future.

CHAPTER-1
Introduction

Everyone in India is aware that agriculture and associated industries are the primary source of food and the major employment sector. The agriculture sector contributed 17.2 per cent; industry contributed 18.5 per cent while the service sector had a contribution of 64.5 per cent of the GDP according to 2008-09 estimates (Das *et al.*, 2011). Among several factors that govern agricultural production, weather appears to be the most critical factor as the farmers have no control over it and its inter and intra seasonal variabilities are difficult to predict with greater reliability and confidence. So, the farmers generally believe that the weather in the coming year will be different from what they were aware in the past. Contingency crop planning strategies were evolved to address the problem with delayed start of the farming season through adoption of short duration crops/varieties and mid-season corrections (Singh and Ramana Rao, 1988) were advocated as a short term measure to cope with aberrant weather conditions after initial establishment of the crop. During the recent years, the inter-seasonal and intra-seasonal variability in weather are believed to outsmart the abilities of climatologists and statisticians in defining the limits within which these variabilities are likely to be observed. This has lead to the Weather Experts to realize and convince themselves that the global climate is changing due to enhanced human activities detrimental to natural environment. Rapid industrialization, increased use of chemicals, deforestation, burning of fossil fuels etc., are contributing to increased concentrations of the so called green house gases in the atmosphere, which will in turn contribute to global warming, changes in general circulation in the earth's atmosphere leading to climate change and / or climate variability. The meteorologists are now required not only to predict weather on short term basis but also climate on long term basis. Until the last two decades of 20th century, there was no sound scientific basis for believing that climate predictions might be possible.

According to Cane and Arkin (2000) some of the year to year variations in climate are the result of random sequences of events, just as a series of coin flips will occasionally produce long run of either heads/tails. In tropical countries like India, a region may experience a dry spell because no storms happen to pass that way for a time. Prediction of such stochastic events is not possible. Climatologists, now see, however, that many climatic variations are part of large scale, slowly evolving patterns.

Many critical agricultural decisions from farm to policy level must be made several months before those weather conditions are experienced. Hansen and James (2000) observed that recent advances in atmospheric and oceanic research, much of it focusing on El Niño -Southern oscillation and its teleconnections made it possible to forecast climate with useful skill with lead times of several months. Such predictions offer the potential for farmers and other agricultural decision makers to predict crop responses to expected climate, and modify decisions to decrease unwanted impacts or take advantages of expected favourable conditions. According to Wilby and Wigley (2000), even if global climate models in the future are run to high resolution, there will remain the need to 'downscale' the results from such models to individual sites or localities or regions for impact studies. Downscaling methodologies are still under development and more work needs to be done in inter-comparing these methodologies and quantifying the accuracy of methods.

Not long ago, the term El Niño was seldom seen or heard outside ivied wall of acadamecia and research laboratories. In the last two decades, it has been brought to the attention of every one, in every country and is probably here to stay. The ENSO (El Niño – Southern Oscillation Index) is a pervasive climate phenomenon which has been found to be associated with regional climatic variations throughout the world. These are three phases: Warm-El Niño, Cold-La Niña and other (non El Niño or La Niña), generally referred to as neutral.

What are El Niño / La Niña / Southern Oscillation?

The term El Niño (Spanish for "the Christ Child") was originally used by fishermen along the coasts of Ecuador and Peru to refer to a warm ocean current that typically appears around Christmas time and lasts for several months. Fish are less abundant during these warm intervals, so fishermen often take a break to repair their equipment and spend time with their families. In some years, however, the water is especially warm and the break in the fishing season persists into May or even June. Over the years, the term "El Niño" has come to be reserved for these exceptionally strong warm intervals that not only disrupt the normal lives of the fishermen, but also bring heavy rains.

El Niño normally occurs around Christmas and usually lasts for a few weeks to a few months. Sometimes an extremely warm event can develop that lasts for much longer time periods. In the 1990s, strong El Niños developed in 1991 and lasted until 1995, and from fall 1997 to spring 1998.

The formation of an El Niño is linked with the cycling of a Pacific Ocean circulation pattern known as the southern oscillation. In a normal year, a surface low pressure develops in the region of northern Australia and Indonesia and a high pressure system over the coast of Peru (Figure 1). As a result, the trade winds over the Pacific Ocean move strongly from east to west. The easterly flow of the trade winds carries warm surface waters westward, bringing convective storms to Indonesia and coastal Australia. Along the coast of Peru, cold bottom water wells up to the surface to replace the warm water that is pulled to the west.

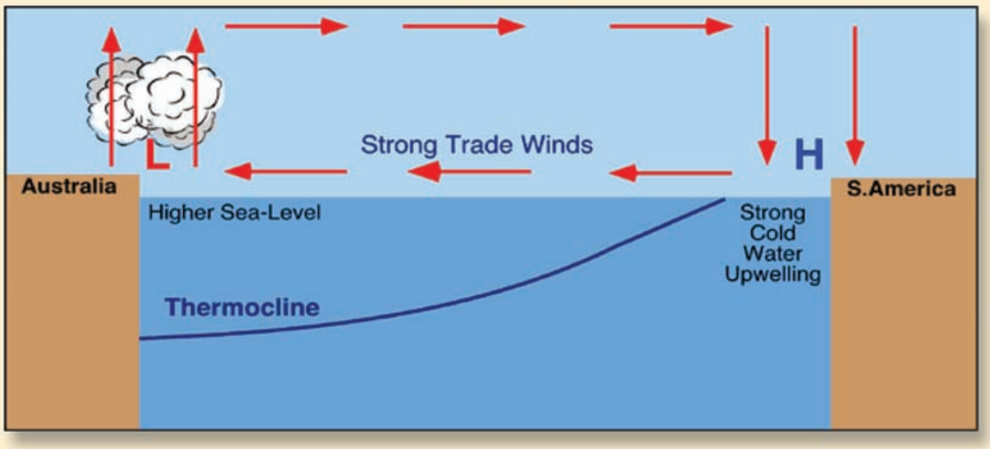


Figure 1. A cross-section of the Pacific Ocean, along the equator, depicting the pattern of atmospheric circulation typically found at the equatorial Pacific in normal years

In an El Niño year, air pressure drops over large areas of the central Pacific and along the coast of South America (Figure 2). The normal low pressure system is replaced by a weak high in the western Pacific (the southern oscillation). This change in pressure pattern causes the trade winds to be reduced. This reduction allows the equatorial counter current (which flows west to east) to accumulate warm ocean water along the coastlines of Peru and Ecuador. This accumulation of warm water causes the thermocline to drop in the eastern part of Pacific Ocean which cuts off the upwelling of cold deep ocean water along the coast of Peru. Climatically, the development of an El Niño brings drought to the western Pacific, rains to the equatorial coast of South America, and convective storms and hurricanes to the central Pacific.

After an El Niño event weather conditions usually return back to normal. However, in some years the trade winds can become extremely strong and an abnormal accumulation of cold water can occur in the central and eastern Pacific. This event is called a La Niña. A strong La Niña occurred in 1988 and scientists believe that it might have been responsible for the summer drought over central North America. The most recent La Niña began developing in the middle of 1998 and was persistent into the winter of 2000. During this period, the Atlantic Ocean has seen very active hurricane seasons in 1998 and 1999. In 1998, ten tropical storms developed of which six became full-blown hurricanes. One of the hurricanes that developed, named Mitch, was the strongest October hurricane ever to develop in about 100 years of record keeping (Pidwiry, 2010). Some of the other weather effects of La Niña include abnormally heavy monsoons in India and Southeast Asia, cool and wet winter weather in south-eastern Africa, wet weather in eastern Australia, cold winter in western Canada and north-western United States, winter drought in the southern United States, warm and wet weather in north-eastern United States, and an extremely wet winter in south-western Canada and north-western United States.

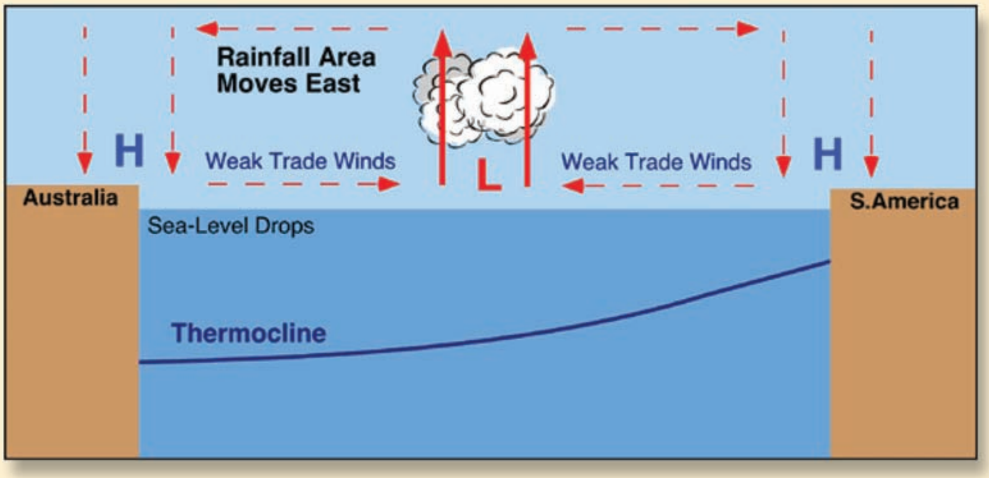


Figure 2. The cross-section of the Pacific Ocean, along the equator, illustrates the pattern of atmospheric circulation that causes the formation of the El Niño. The shift in the position of the thermocline may be noted from **Fig 1**

Prior to the 1980s and 1990s, strong El Niño events occurred on an average every 10 to 20 years. In the early 1980s, the first of a series of strong events developed. The El Niño of 1982-83 brought extreme warming to the equatorial Pacific. Surface sea temperatures in some regions of the Pacific Ocean rose by 6° Celsius above normal. The warmer waters had a devastating effect on marine life existing off the coast of Peru and Ecuador. Fish catches off the coast of South America were 50% lower than the previous year. The 1982-83 El Niño also had a pronounced influence on weather in the equatorial Pacific region and worldwide. Severe droughts occurred in Australia, Indonesia, India and southern Africa. Dry conditions in Australia resulted in a 2 billion dollar loss in crops, and millions of sheep and cattle died from lack of water. Heavy rains were experienced in California, Ecuador, and the Gulf of Mexico.

Scientific understanding of the processes responsible for the development of El Niño is still incomplete. Scientists are able to predict the future development of an event by noting the occurrence of particular weather precursors. Researchers also now have a pretty complete understanding of the global weather effects caused by the formation of an El Niño (Figure 3) (Pidwiry, 2010).

Figure 3. Global climatological effects of the El Niño (after Pidwiry, 2010)

El Niño (Stefhen Zebiak, 1999) is fundamentally a warming of the surface waters of the tropical eastern Pacific Ocean- from South American coast to the International Date Line – that persists for three or more seasons. But it is far more than an oceanographic peculiarity. Closely linked to these systematic ocean warnings are major swings in atmospheric conditions on nearly global scale, which in turn invoke seasonal and long-term changes in earth's climate.

Quinn and Neal (1987) pointed out that strong ENSO event occurred every 42-45 years during the period 1525 to 1983 but recently stronger El-Niños appear to be occurring more frequently. The ENSO events have been found to influence regional weather and, in turn, crop yields (Nicholas, 1986 and Leglar, 1999). The changes in crop yields have obvious economic implications. Mc. Carl *et al.,* (2000) reviewed the economic implications of using information on El Niño in agriculture decision making. In terms of aggregate U.S. and World Economic Welfare, the estimates of using ENSO forecast information in agricultural decision making have been in excess of $300 million annually.

A Significant finding of the study by Gadgil and Gadgil (2006) is the observed asymmetry in the response to monsoon variation, the magnitude of the impact of deficit rainfall on Gross Domestic Product (GDP) and Food Grain Production (FGP) in India being larger than the impact of surplus rainfall. The study reveals that despite a substantial decrease in the contribution to GDP over the five decades, the impact of severe droughts has remained between 2 and 5 per cent of GDP throughout.

The inter-annual variability of Indian Summer Monsoon rainfall has been linked to variations of sea surface temperatures over the Equatorial Pacific and Indian Oceans, Eurasian snow cover etc. (Sikka, 1980 and Gadgil *et al.,* 2004). Kesava Munty (1982) studied the sensitivity of the sea surface temperature anomalies over the central and west Pacific region using GFDL general circulation model. He concluded that the sea surface temperature anomalies over the central and general Pacific are more effective in making the influence on the atmospheric circulation. Analysis of long term data suggests there is an inverse relationship between El Niño events and the Indian Summer Monsoon Rainfall (ISMR). Most of the severe droughts over India occurred in association with El Niño events (Rajeevan and Pai, 2006). However, there is no one-to-one relationship as El Niño years have not always produced severe droughts. Victor *et al.* (1985) studied El Niño's effect on southwest monsoon rainfall in Andhra Pradesh. They examined the behavior of southwest monsoon rainfall in space and time in relation to El Niño event at district level in Andhra Pradesh during the years with long range forecast of both deficit and normal rainfall on All India basis. For the years with El Niño and forecast of deficit rainfall on All India basis, they observed that the rainfall was below normal in coastal Andhra Pradesh and Rayalaseema regions. Studies on the effect of El Niño either on crop productivity or production at regional level were so far not carried out in India. Therefore, an attempt has been made to examine the effect of El Niño for

- identifying changes in seasonal rainfall as well as annual rainfall in different districts of Andhra Pradesh
- quantifying the changes in annual temperature at some selected locations in the state for which records are readily available, and
- assessing the changes in total food grain production as well as production of rice, pearl millet and groundnut at district level, and
- suggesting the possible strategies to enhance the agricultural production in the event of adverse climate situations.

The authors wish to emphasize that the study may not be very exhaustive one and is only intended to enlighten the utility of using signals like El Niño as a possible option to understand climate variability and use it for taking strategic decisions for improving agricultural production during the seasons with adverse climate to a certain extent. Although, the El Niño phenomena may provide signal only for few of the years, it indicates the possibility to identify some more critical parameters to cover as many years as possible in the near future.

CHAPTER-2

Methodology

The district wise monthly rainfall data for all the districts of Andhra Pradesh recorded during the years 1971-2009, as available in the database at CRIDA, Hyderabad were used in the present study.

The rainfall totals for the summer (March to May), southwest monsoon (June-September), *rabi* (October-December) and winter (January-February) seasons were computed year wise for all the districts and state as well.

The monthly temperature data for all the years 1981-2009 recorded at 21 stations spread throughout the state (Fig. 4) as available with the Agromet Databank of the Central Research Institute for Dryland Agriculture, Hyderabad were analyzed to find the mean seasonal maximum and minimum temperature as well as average diurnal range of temperature during different seasons considered.

Figure 4. Location map of selected stations in Andhra Pradesh for which temperature data was considered in the present study

The area, production and productivity of total food grains, rice, pearl millet and groundnut in different districts of Andhra Pradesh for the years 1981 to 2009 were obtained from Directorate of Economics and Statistics, Government of Andhra Pradesh, Hyderabad. The year wise yields of castor, pigeonpea and chickpea in Andhra Pradesh for the years 1990 to 2007 were also considered.

According to Jan Null (2011), the Oceanic Nino Index (ONI) has become the de-facto standard that NOAA uses for identifying El Niño (Warm) and La Niña (Cool) events in the tropical Pacific for the Nino 3.4 region (i.e., 5°N to 5°6, 120°-170°W). Events are defined as five consecutive months at or above the +0.5 ° anomaly for warm (El Niño) events. The threshold is further broken down into weak with a 0.5 to 0.9 sea surface temperature anomaly, Moderate (1.0 to 1.4) and Strong (³ 1.5) events.

For the purpose of weak, moderate or strong, it must have equaled or exceeded the threshold for at least 3 months. Accordingly the El Niño years were classified from 1951 to 2010 as follows:

Intensity	Years
Weak	1951, 1963, 1968, 1969, 1976, 1977, 2004, 2006
Moderate	1986, 1987, 1994, 2002
Strong	1957, 1965, 1972, 1982, 1991, 1997, 2009

During the period considered for the present study from 1981 to 2009, there were 8 moderate and strong and two weak El Niño events out of 29 years.

CHAPTER-3

El Niño Effect on Rainfall and Thermal Regime

Rainfall

The average rainfall for the years with strong and moderate El Niño was calculated and compared with the normal rainfall for the years 1971 to 2009 during the four different seasons and given in Table 1. The percentage change in seasonal rainfall during the El Niño years compared to normal rainfall was also computed for the seasons in different districts. From Table 1, it can be observed that

- The average summer season rainfall during El Niño years from March to May was less than the normal rainfall in coastal Andhra Pradesh by 9 per cent and the decrease in rainfall can be seen in East Godavari, West Godavari, Krishna and Guntur districts forming central parts of the coastal area.
- The average rainfall during the southwest monsoon season during the El Niño years was less than the normal rainfall in all the districts of the state. The departure was less than normal by more than 10 per cent in all districts except Srikakulam and Visakhapatnam districts.
- El Niño effect is more pronounced in Rayalaseema region compared to Telangana followed by coastal Andhra Pradesh. Anantapur and Kurnool districts in Rayalaseema region experienced negative departure in average southwest monsoon rainfall by more than 20 per cent.
- The average rainfall during the *rabi* season from October-December is more in Coastal Andhra Pradesh during the years with El Niño compared to normal rainfall.
- S.P.S Nellore district which receives most of its rainfall during northeast monsoon season received nearly 20 per cent more rainfall during northeast monsoon season.

Therefore, it is obvious that the rainfall is likely to be less than Normal during southwest monsoon season throughout the state and more than normal during *rabi* season in Coastal Andhra Pradesh.

Table 1. Per cent change in average seasonal rainfall (mm) during El Niño years compared to normal rainfall (mm) in Andhra Pradesh (1971-2009)

Districts	Winter (JAN - FEB)			Summer (MAR - MAY)			SW Monsoon (JUN - SEPT)			Post monsoon (OCT - DEC)		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	2.9	2.3	27.1	75.9	58.3	30.1	146.3	208.1	-29.7	151.7	151.5	0.2
Chittoor	10.0	11.8	-15.7	84.9	87.2	-2.7	244.3	278.4	-12.2	380.3	367.3	3.5
YSR Kadapa	2.5	5.4	-54.4	62.2	55.5	12.1	220.7	261.1	-15.5	240.2	247.5	-2.9
Kurnool	5.7	5.1	10.6	69.8	62.0	12.6	255.9	325.1	-21.3	155.3	144.2	7.8
Rayalaseema	**5.3**	**6.2**	**-8.1**	**73.2**	**65.8**	**13.0**	**216.8**	**268.2**	**-19.7**	**231.9**	**227.6**	**2.1**
Srikakulam	16.0	20.7	-22.8	100.2	118.6	-15.6	506.5	526.5	-3.8	260.0	234.9	10.6
Viskhapatnam	14.5	19.8	-26.6	132.1	146.7	-9.9	459.9	509.9	-9.8	286.4	247.1	15.9
Vizinagaram	67.5	73.1	-7.7	222.9	167.3	33.2	385.5	430.9	-10.5	219.5	214.4	2.4
East Godavari	9.5	16.6	-43.1	67.3	101.2	-33.5	467.5	541.0	-13.6	341.4	266.6	28.0
West Godavari	8.6	14.0	-38.1	63.4	78.5	-19.2	480.2	572.2	-16.1	271.3	218.0	24.4
Krishna	12.1	11.1	8.7	59.1	65.8	-10.1	413.7	500.3	-17.3	286.3	204.3	40.1
Guntur	11.4	12.2	-6.2	59.7	64.3	-7.1	318.3	413.0	-22.9	281.5	192.5	46.3
Prakasam	13.1	16.2	-19.1	62.0	59.5	4.2	205.6	259.0	-20.6	371.5	300.5	23.6
SPS Nellore	26.9	22.6	19.0	51.1	67.0	-23.8	198.8	220.9	-10.0	716.8	599.9	19.5
Coastal AP	**19.9**	**22.9**	**-15.1**	**90.9**	**96.6**	**-9.1**	**381.8**	**441.5**	**-13.9**	**337.2**	**275.4**	**23.4**
Adilabad	11.7	16.9	-30.7	34.9	34.0	2.8	802.7	947.0	-15.2	68.7	105.5	-34.9
Nizambad	9.9	15.3	-35.1	33.8	43.6	-22.5	575.0	704.7	-18.4	104.4	103.4	0.9
Karimnagar	16.5	16.4	0.6	48.2	42.9	12.4	558.8	639.3	-12.6	101.5	105.5	-3.8
Warnagal	17.9	11.5	56.1	50.8	50.4	0.7	555.8	634.9	-12.5	123.3	118.7	3.9
Khammam	52.3	66.0	-20.7	171.7	139.0	23.5	484.6	595.2	-18.6	185.1	169.3	9.4
Medak	33.6	68.3	-50.7	112.3	106.5	5.4	345.4	435.8	-20.7	121.4	144.0	-15.7
RangaReddy	9.7	7.9	22.8	60.7	63.6	-4.6	388.9	464.1	-16.2	113.0	126.3	-10.5
Mahabubnagar	3.0	3.5	-13.7	46.0	51.8	-11.2	296.9	356.3	-16.7	136.4	107.6	26.7
Nalgonda	10.9	14.0	-22.2	49.1	51.6	-4.8	321.7	396.0	-18.8	150.9	130.7	15.5
Telangana	**18.4**	**24.4**	**-10.4**	**67.5**	**64.8**	**0.2**	**481.1**	**574.8**	**-16.6**	**122.7**	**123.4**	**-0.9**

*PC=*per cent* change

The percentage change in average annual rainfall during the El Niño years compared to normal annual rainfall in different districts of Andhra Pradesh is given in Table 2. The average annual rainfall during El Niño years is less than normal by more than 10 per cent in both Rayalaseema and Telangana regions. It was only 4 per cent in coastal Andhra Pradesh. The average annual rainfall was less than normal by more than 10 per cent in all the districts of Telangana region. The departure was less than 10 per cent in all the districts of Coastal Andhra Pradesh.

Table 2. Per cent change in District wise average annual rainfall (mm) during El Niño years compared to normal rainfall years in Andhra Pradesh (1971-2009)

Districts	Rainfall (mm)		
	El nino Years	Normal years	*Per cent* change
Anantapur	476.5	565.5	-16
Chittoor	833.3	898.8	-7
YSR Kadapa	627.4	701.2	-11
Kurnool	605.2	679.9	-11
Rayalaseema	**635.6**	**711.3**	**-11**
Srikakulam	1080.9	1106.3	-2
Vizinagaram	1032.3	1046.8	-1
Viskhapatnam	1051.8	1125.0	-7
East Godavari	1043.6	1128.3	-8
West Godavari	974.4	1065.0	-9
Krishna	900.6	954.9	-6
Guntur	805.4	848.3	-5
Prakasam	760.0	766.2	-1
SPS Nellore	1081.8	1025.8	5
Coastal Andhra	**970.1**	**1007.4**	**-4**
Adilabad	918.0	1103.3	-17
Nizambad	828.8	1036.0	-20
Karimnagar	845.8	959.2	-12
Warnagal	866.6	981.8	-12
Khammam	1000.8	1121.4	-11
Medak	705.1	880.5	-20
RangaReddy	687.2	831.7	-17
Mahabubnagar	590.4	666.3	-11
Nalgonda	640.8	748.5	-14
Telangana	**787.1**	**925.4**	**-15**

The year to year variability of rainfall during the southwest monsoon season for the state is shown in Figure 5. Red coloured points indicate the rainfall during the El Niño years. It can be seen that the rainfall was below normal in 8 out of 10 El Niño years and was more than normal in the years 1982 and 1997. Therefore, the chances of getting above normal rainfall during the El Niño years are less with a probability of 80 per cent. Six of the deficit rainfall events associated with El Niño experienced a negative departure from normal by equal to more than the half the standard deviation (SD) of seasonal rainfall, thereby indicating impending drought situations likely to occur in association with El Niño.

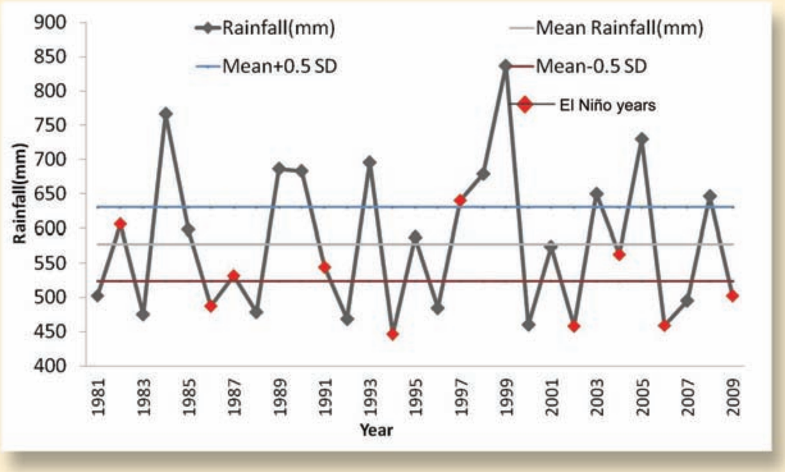


Figure 5. Year-wise average southwest monsoon rainfall (mm) in Andhra Pradesh (1981-2009)

The year wise annual rainfall for the state during the years 1981 to 2009 is shown in Figure 6. It can be seen that the annual rainfall is less than normal in 7 out of 10 years and it was more than normal during the three years 1987, 1991 and 2006. Therefore, the annual rainfall can be expected to be above average with 30 per cent probability during El Niño years. All the three of the severe deficit rainfall events in association with El Niño have occurred during the recent decade only.

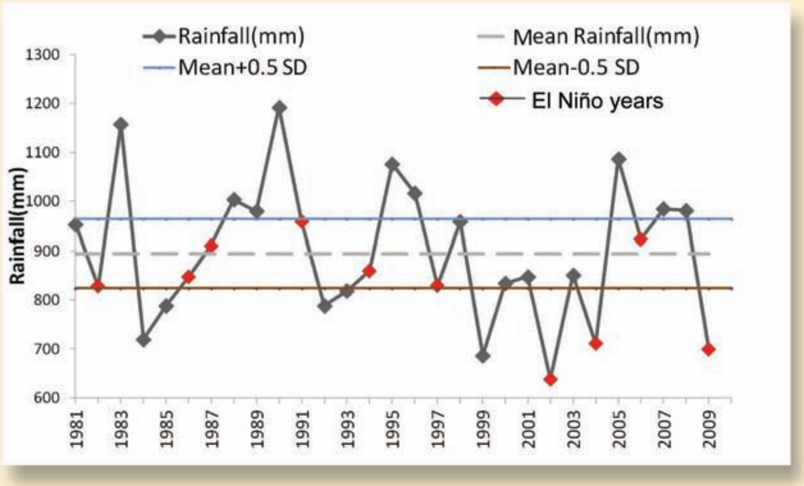


Figure 6. Year-wise annual rainfall (mm) in Andhra Pradesh (1981-2009)

By comparing figures 5 and 6, it can be observed that

- the annual rainfall was less than normal during both the years 1982 and 1997 when the southwest monsoon rainfall was above average among El Niño years, and
- the southwest monsoon rainfall was less than normal during the years 1987, 1991 and 2006 although the annual rainfall was above average among the years with El Niño.

Therefore, it may be possible that either the annual rainfall or the southwest monsoon season rainfall is likely to be less than normal during the years with El Niño. Hence, El Niño unambiguously serves as a signal of deficit rainfall for the state during the southwest monsoon season and if it does not happen, leads to deficit annual rainfall.

Thermal Regime

The location of the stations for which the temperature data considered is already shown in Figure 4. There is slight increase in annual temperatures by 0.1 to 0.3^0C during El Niño years compared to normal temperatures for some of the locations spread in the three meteorological sub-divisions of the state namely Rayalaseema, Telangana and Andhra Pradesh (Table 3). But when the diurnal range in temperatures during El Niño years is compared with normal values for 7 locations in Telangana region, it was observed that (Table 4), there were no appreciable differences in the diurnal range of temperature during different seasons. Similar observations were made for other locations also hence the values are not presented. Therefore, thermal regime seems to be unaffected by El Niño factor in the state.

Table 3. Mean annual temperature (°C) during El Niño years compared to normal temperature at some selected locations in Andhra Pradesh

Stations	El Niño	Normal	Difference
Anantapur	27.9	27.6	0.3
Tirupati	27.7	28.1	-0.4
Kurnool	26.0	26.4	-0.4
Arogyavaram	25.4	25.3	0.1
Rayalaseema	**26.8**	**26.9**	-0.1
Lam	28.7	28.5	0.2
Rajahmundry	27.7	27.9	-0.2
Maruteru	26.6	26.8	-0.2
Ongole	29.5	29.6	-0.1
Ankapalle	27.9	27.7	0.2
Machilipatnam	28.2	28.2	0
Rentichintala	29.4	29.3	0.1
Kovur	29.3	29.3	0
Gannavaram	28.5	28.6	-0.1
Coastal AP	**28.4**	**28.4**	0.0
Hayathnagar	25.7	25.8	-0.1
Rajendranagar	26.2	26.1	0.1
Jagtial	27.0	27.0	0
Palem	25.9	26.4	-0.5
Patancheru (ICRISAT)	25.9	25.7	0.2
Rudrur	26.4	26.3	0.1
Medak	26.6	26.5	0.1
Hanmakonda	28.3	28.3	0
Telangana	**26.5**	**26.5**	0.0

Table 4. Mean diurnal range in temperature (°C) during different seasons in Telangana region

Stations in Telangana	Years	Jan-Feb	Mar-May	Jun-Sep	Oct-Dec	All years
Hayatnagar	El Niño	15.2	14.1	9.3	12.5	12.8
	Normal	14.7	14.1	8.7	12.8	12.6
Jagitial	El Niño	15.6	16.1	9.2	14.0	13.7
	Normal	15.9	16.5	9.4	13.8	13.9
Palem	El Niño	15.6	14.1	9.1	12.1	12.7
	Normal	15.3	13.3	8.2	11.8	12.1
Patancheru (ICRISAT)	El Niño	15.3	14.7	8.8	12.6	12.8
	Normal	15.1	15.1	8.7	13.2	13.0
Rudrur	El Niño	15.3	14.9	9.0	13.5	13.1
	Normal	15.4	15.5	9.2	13.9	13.5
Medak	El Niño	14.9	15.4	8.6	13.9	13.2
	Normal	15.5	15.4	8.1	13.7	13.2
Ranjendranagar	El Niño	16.4	14.5	8.8	13.1	13.2
	Normal	15.7	14.6	8.4	13.3	13.0

CHAPTER-4

Total Food Grain Production and Crop Yields

The year wise total food grain production in the state for the years 1981 to 2007 is shown in Figure 7. It is generally observed that the total food grain production in the state was

- less than 12 million tons during the period up to 1987
- between 11 to about 13 million tons during the years 1988 to 1995 and
- between 10 to 19 million tons after the year 1996 onwards

Therefore, there was an increasing trend in the total food grain production in the state during the study period considered.

However, it is interesting to note that the total food grain production in the state during El Niño years fluctuated only between 9 million tons to 12 million tons up to the year 2002, although it ranged from about 9.5 to 15.0 million tons during the normal years. Therefore, there is an obvious signal that the total food grain production decreases by at least 0.5 million tons to 3 million tons during the years with El Niño , despite of the increasing trend in the total food grain production in the state up to the year 2002. It was only during the recent two El Niño years 2004 and 2006, the total food grain production was above average. However, these two years were years with weak El Niño. But the total food production during the years 2004 and 2006 declined compared to the corresponding preceding year, thereby confirming the fact that achieving increased growth rate in food grain production may be a difficult task during El Niño years.

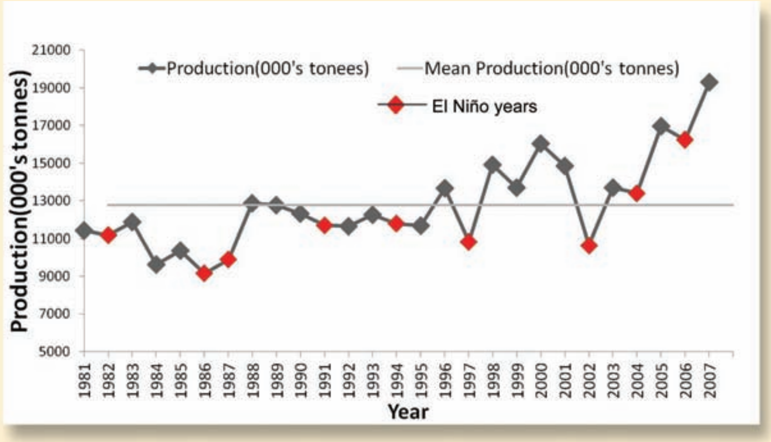


Figure 7. Year-wise total food grain production ('000 tones) in Andhra Pradesh

The year wise yields of total food grains in the state for the study period are shown in Figure 8. It can be noticed that the yields

- were 1100 to 1300 kg/ha up to 1987,
- increased to 1500 kg/ha up to 1992 from the year 1988, and
- varied from 1600 kg/ha 2400 kg/ha during the years 1993 to 2007.

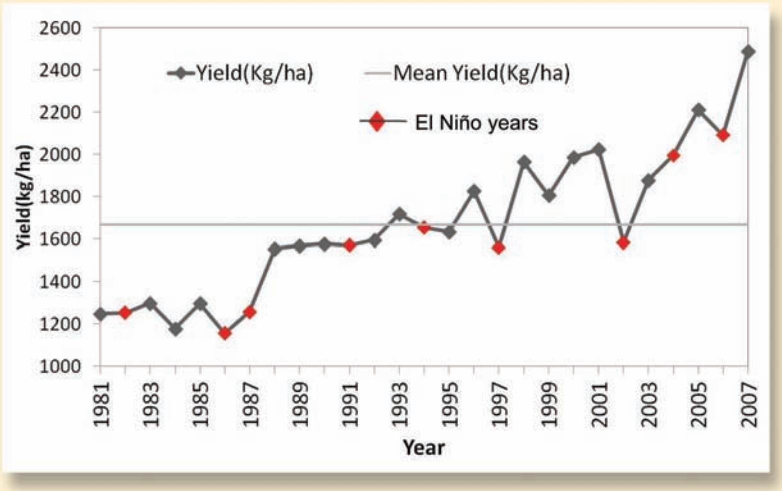


Figure 8. Average yield (kg/ha) of food grains in Andhra Pradesh (1981-2009)

It is interesting to note that above average yield of total food grains were achieved during the two El Niño years 2004 and 2006 which were weak El Niño years.

However, it is interesting to note that yields during El Niño years were less than the preceding higher values thereby indicating the possibility of decline in productivity during the years with El Niño compared to previous year. Therefore, moderate and strong El Niño is a signal for declining trend in the yield, in general and weak El Niño events have exerted lesser influence on food grain productivity so far.

District-wise production and yield of total food grains

As El Niño suggests the possibility of decline in production and productivity of total food grains in the state, the district wise data were also analyzed to identify the districts which are more vulnerable to El Niño effect. The per cent change in average production during the El Niño years compared to the average production in the remaining years was calculated for all the districts and is shown in Figure 9. It can be inferred that

- the production was not affected only in S.P.S Nellore district which receives predominantly more northeast monsoon rainfall,
- the production decreased by 10 to 20 per cent in most of districts barring West Godavari and S.P.S Nellore districts, and
- the production declined by more than 15 per cent in Adilabad, Nizamabad, Karimnagar, Medak, Nalgonda, Mahabubnagar, Prakasam, Anantapur, Y.S.R Kadapa, Chittoor, Srikakulam, Vizianagaram and Visakhapatnam districts.

Therefore, the effect of decreasing tendency of the southwest monsoon rainfall on food grain production during El Niño years appears to be more in larger part of the state barring West Godavari, Guntur, Ranga Reddy and S.P.S Nellore districts.

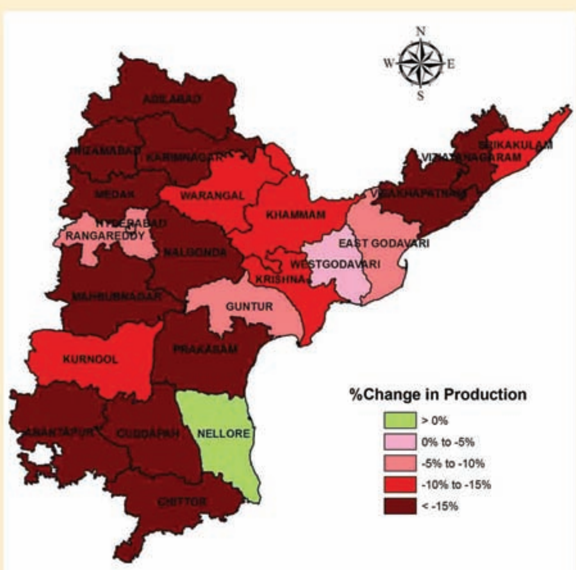


Figure 9. Per cent change in average total food grain production during El Niño years compared to normal years in Andhra Pradesh (1981 – 2007)

The per cent decline in yield during the years with El Niño compared to the remaining years in different districts of Andhra Pradesh is shown in Figure 10. In general, the tendency is that the regions better served by northeast monsoon rainfall are comparatively less vulnerable to decline in productivity during El Niño years as the southwest monsoon rainfall has a tendency to decline in the state. The yields declined by more than 10 per cent in western parts of the state and as well as in Vizianagaram and Visakhapatnam districts which have lesser irrigated area.

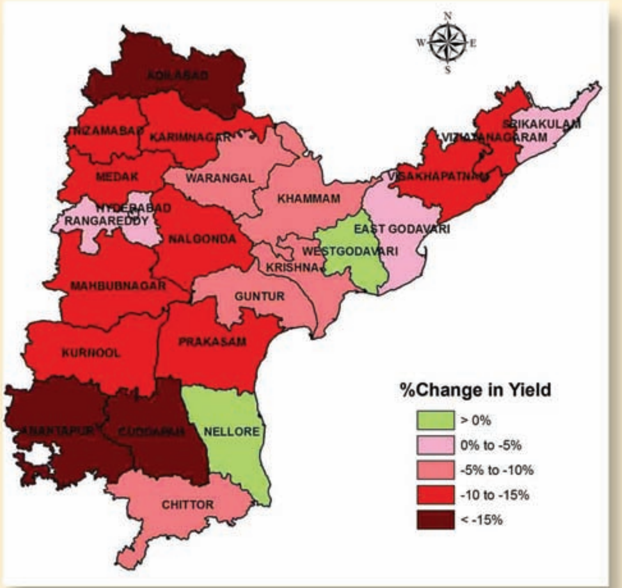


Figure 10. Per cent change in average total food grain yield during El Niño years compared to normal years in Andhra Pradesh (1981 – 2007)

Therefore, it is obvious that El Niño is not a desirable signal from the point of view of total food grain production and productivity as well in larger part of the state, although the magnitudes vary geographically.

In view of the above, detailed analysis was also carried out to find the changes due to El Niño effect in area, production and productivity of some crops rice, groundnut and pearl millet in different districts of the state for making an assessment of the El Niño factor on the performance of predominately irrigated and rainfed crops. The results were presented and discussed as follows.

Groundnut

Rayalaseema region and Mahabubnagar district in Telangana region account for 75 per cent of the area under groundnut with 81 per cent production for the state. The district-wise average of area, production and yield of groundnut during the years with El Niño compared to the remaining years is given in Table 5. It is observed that

- the production of the crop for the state was not affected by El Niño,
- among the five major districts covering Rayalaseema and Mahabubnagar district in Telangana under groundnut in the state, the average yield declined by about 16 per cent in Anantapur district only during El Niño years,
- the average area under groundnut decreased by 4.5 per cent in Telangana region during El Niño years. But the production and productivity have shown positive change.

Groundnut is grown mostly as a rainfed crop during *kharif* season in little over 1.5 million ha and irrigated crop during summer season in about 0.3 to 0.4 million ha. The district wise average area, production and productivity of *kharif* groundnut during El Niño years compared to remaining years are given in Table-6. By critically going through the contents of Table 6, it can be observed that

- there was decline in average area under groundnut by 18 per cent in Rayalaseema region and 13 per cent increase in area in Telangana region during the years with El Niño,
- the average yields declined by little over 18 per cent during El Niño years in Rayalaseema region where groundnut is a predominant crop,
- the average yields also declined by 9 to 13 per cent in Coastal Andhra Pradesh and Telangana region respectively,
- the average area under groundnut in the state declined by 8.5 per cent and production by 25 per cent during El Niño years.

Table 5. Per cent change in average area sown (1000ha), production (1000 tons) and yield (kg/ha) of groundnut during El Niño years compared to normal years in Andhra Pradesh (1981-2008)

District	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	657.2	668.7	-1.7	424.6	517.3	-17.9	646.2	773.5	-16.5
Chittoor	235.5	234.3	0.5	267.5	245.8	8.8	1135.8	1049.2	8.3
Y.S.R Kadapa	176.4	168.8	4.5	134.5	138.0	-2.5	762.5	817.4	-6.7
Kurnool	236.5	243.8	-3.0	221.2	211.3	4.7	935.3	866.9	7.9
Rayalaseema	**1305.6**	**1315.6**	**0.1**	**1047.8**	**1112.4**	**-1.7**	802.6	845.6	-5.1
Srikakulam	42.1	43.1	-2.3	41.9	41.7	0.4	995.5	968.3	2.8
Vizianagaram	63.8	66.3	-3.8	57.8	62.6	-7.7	905.2	943.9	-4.1
Visakhapatnam	23.1	23.0	0.2	24.0	24.5	-1.9	1040.6	1062.9	-2.1
East Godavari	6.0	6.1	-1.8	6.3	6.6	-4.0	1050.3	1074.2	-2.2
West Godavari	6.4	6.6	-2.9	10.0	9.5	5.2	1564.7	1444.2	8.3
Krishna	21.8	20.4	7.1	24.8	26.9	-7.9	1135.6	1320.4	-14.0
Guntur	13.4	14.4	-7.2	19.2	21.0	-8.4	1437.5	1455.7	-1.2
Prakasam	30.0	34.8	-13.9	33.8	38.3	-11.8	1129.5	1102.4	2.5
S.P.S Nellore	25.0	23.7	5.7	46.5	43.1	7.8	1857.1	1820.0	2.0
Coastal AP	**231.5**	**238.4**	**-2.1**	**264.3**	**274.2**	**-3.1**	1141.4	1150.2	-0.8
Adilabad	2.7	2.8	-3.4	3.2	3.2	0.4	1159.5	1114.9	4.0
Nizamabad	7.0	8.5	-18.2	10.8	12.3	-11.5	1556.5	1438.0	8.2
Karimnagar	32.1	35.3	-9.2	38.7	38.3	0.9	1206.0	1085.2	11.1
Warangal	62.5	64.1	-2.5	59.0	61.6	-4.2	944.8	961.7	-1.8
Khammam	21.4	21.5	-0.4	24.4	24.4	0.1	1139.3	1133.9	0.5
Medak	5.5	5.5	0.1	6.1	5.6	8.6	1104.3	1018.3	8.4
Rangareddi	6.8	6.8	0.9	7.4	7.2	2.4	1083.5	1068.1	1.4
Mahaboobnagar	132.3	138.8	-4.6	108.4	97.7	10.9	819.3	704.3	16.3
Nalgonda	47.6	49.4	-3.6	41.3	41.3	0.1	868.4	836.4	3.8
Telangana	**318.0**	**332.7**	**-4.5**	**299.4**	**291.6**	**0.9**	941.6	876.6	7.4
AP State	**1854.6**	**1886.6**	**-1.7**	**1612.8**	**1678.0**	**-3.9**	869.63	889.4	-2.2

***PC=*per cent* change**

Table 6. Per cent change in average area sown (1000 ha), production (1000 tons) and yield (kg/ha) of *kharif* groundnut during El Niño years compared to normal years from 1981-2006 in Andhra Pradesh

Districts	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	620.3	673.4	-7.9	354.8	474.2	-25.2	585.6	638.1	-8.2
Chittoor	192.6	216.5	-11.1	150.5	206.5	-27.1	736.8	818.1	-9.9
Y.S.R Kadapa	137.9	156.8	-12.1	68.0	104.4	-34.8	458.6	505.3	-9.2
Kurnool	199.1	215.2	-7.5	127.4	157.7	-19.2	643.0	809.7	-20.6
Rayalaseema	**1149.8**	**1262.0**	**-8.9**	**700.8**	**942.8**	**-25.7**	**609.5**	**747.0**	**-18.4**
Srikakulam	36.0	36.7	-1.9	30.8	33.9	-9.3	852.9	895.0	-4.7
Vizianagaram	60.9	64.0	-4.8	50.0	59.8	-16.4	819.8	940.3	-12.8
Visakhapatnam	19.4	22.2	-12.7	17.5	23.3	-25.0	934.6	1167.9	-20.0
East Godavari	4.0	3.8	5.8	3.5	3.6	-3.0	802.2	1019.0	-21.3
West Godavari	2.6	2.2	15.5	1.9	2.4	-20.4	801.6	1414.6	-43.3
Krishna	8.5	9.0	-5.5	7.8	6.5	20.6	1191.0	963.4	23.6
Guntur	2.7	2.6	5.1	2.3	2.5	-7.7	957.4	1065.0	-10.1
Prakasam	13.8	15.7	-11.9	10.9	13.4	-18.7	743.3	923.7	-19.5
S.P.S Nellore	6.2	5.6	11.2	8.0	7.8	3.3	1402.8	1655.7	-15.3
Coastal AP	**154.2**	**161.8**	**-4.7**	**132.7**	**153.2**	**-13.4**	**860.6**	**947.0**	**-9.1**
Adilabad	1.0	0.7	43.4	0.4	0.4	15.3	511.6	628.5	-18.6
Nizamabad	1.9	2.0	-4.6	1.0	1.2	-18.1	540.6	971.5	-44.4
Karimnagar	13.3	14.8	-10.2	8.3	9.9	-16.9	664.6	583.0	14.0
Warangal	28.6	31.5	-9.2	20.0	24.4	-18.1	794.7	942.3	-15.7
Khammam	7.4	7.3	1.6	5.0	4.5	10.8	705.9	664.5	6.2
Medak	2.3	2.7	-14.9	1.3	1.9	-33.7	604.9	853.8	-29.2
Rangareddy	2.2	2.5	-13.6	1.3	1.7	-24.7	557.3	867.4	-35.7
Mahaboobnagar	92.6	105.2	-11.9	42.6	58.4	-27.1	476.9	631.4	-24.5
Nalgonda	31.8	35.3	-9.8	20.6	26.4	-22.0	647.9	742.4	-12.7
Telangana	**181.1**	**201.9**	**-10.3**	**100.4**	**128.8**	**-22.1**	**554.5**	**638.1**	**-13.1**
AP State	**1481.7**	**1619.3**	**-8.5**	**931.8**	**1320.4**	**-29.4**	**613.2**	**817.4**	**-25.0**

*PC=per cent change

The averages of area, production and productivity of groundnut grown during *rabi* season for the years with El Niño compared to the remaining years are given in Table 7. It is observed in general, that

- there is slight decline in average productivity by 2.5 per cent for the state although the area under groundnut decreased by 7.7 per cent during El Niño years, and
- there is decrease in productivity by 7 to 11 per cent in Kurnool, Mahaboobnagar and Warangal districts where the crop is grown in more than 30,000 ha in each district

Thus, it can be generally said that the average production and productivity of groundnut for the entire state were not significantly affected by El Niño. But there are some areas of concern like Anantapur district both during *kharif* and summer seasons as highlighted in the preceding paragraphs.

Pearl millet

Pearl millet may not be a very important crop for the state as it occupies about 0.2 million ha with average productivity just around 700 kg/ha. It is predominantly grown as rainfed crop of 80 to 90 days duration and is sown with the onset of monsoon in typical shallow soils and *alfisols* and provides an opportunity to examine the effect of El Niño on short duration crops grown under rainfed conditions in typical marginal lands. The district wise averages of area, production and productivity of pearl millet during the years with El Niño compared to the remaining years are given in Table 8. It is observed that there was decrease in the area under the crop by little over 7 per cent and average production of the crop as well as the average yield decreased by more than 20 per cent during the El Niño years. This may be due to decrease in rainfall during the southwest monsoon season. Therefore, short and medium duration rainfed crops which are grown under rainfed conditions are likely to be affected during the years with El Niño. However, there is opportunity to increase the overall productivity in some of these areas by intercropping with long duration crops like pigeon pea and castor wherever decrease in southwest monsoon rainfall is likely to be compensated by increasing northeast monsoon rainfall during such years.

Table 7. Per cent change in average area sown ('000ha), production ('000 tons) and yield (kg/ha) of *rabi* groundnut during El Niño years compared to normal years in Andhra Pradesh (1981-2006)

District	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	18.1	20.3	-10.7	23.1	25.5	-9.4	1270.3	1251.8	1.5
Chittoor	25.8	27.5	-6.3	61.0	61.5	-0.9	2363.6	2234.7	5.8
Y.S.R Kadapa	21.7	23.4	-7.4	38.7	38.7	-0.1	1783.6	1653.2	7.9
Kurnool	31.6	35.6	-11.4	51.9	65.9	-21.3	1643.8	1849.8	-11.1
Rayalaseema	**97.2**	**106.9**	**-9.1**	**174.6**	**191.6**	**-8.9**	**1796.4**	**1792.1**	**0.2**
Srikakulam	7.4	7.0	6.6	9.9	9.4	4.9	1332.5	1354.6	-1.6
Vizianagaram	4.5	4.6	-2.3	6.0	5.6	7.6	1343.1	1219.9	10.1
Visakhapatnam	2.1	2.3	-9.3	3.5	3.7	-7.4	1651.3	1617.6	2.1
East Godavari	2.2	2.0	11.3	3.0	3.3	-9.2	1332.3	1633.1	-18.4
West Godavari	4.1	4.3	-5.0	7.2	7.6	-5.4	1746.9	1754.4	-0.4
Krishna	12.1	12.1	0.7	18.5	20.5	-9.6	1527.3	1701.0	-10.2
Guntur	9.2	13.9	-34.2	14.4	21.0	-31.1	1578.7	1507.9	4.7
Prakasam	19.2	19.6	-2.3	25.9	25.8	0.2	1349.3	1315.7	2.6
S.P.S Nellore	18.9	19.1	-0.8	37.7	37.6	0.3	1996.6	1975.1	1.1
Coastal AP	**79.7**	**84.8**	**-6.1**	**126.1**	**134.6**	**-6.3**	**1582.3**	**1586.2**	**-0.2**
Adilabad	2.1	2.4	-15.1	2.6	3.1	-18.2	1235.2	1282.0	-3.6
Nizamabad	4.4	8.1	-45.2	6.2	14.1	-55.9	1402.5	1739.9	-19.4
Karimnagar	19.7	22.1	-10.7	27.2	32.1	-15.1	1381.4	1452.9	-4.9
Warangal	35.5	33.4	6.2	38.6	39.1	-1.2	1088.0	1169.7	-7.0
Khammam	16.3	14.5	12.9	21.7	20.1	7.6	1328.4	1393.2	-4.7
Medak	2.5	3.8	-32.5	3.5	4.8	-27.1	1370.7	1268.6	8.1
Rangareddy	3.6	5.0	-28.5	4.7	6.2	-25.0	1307.5	1247.1	4.8
Mahaboobnagar	34.6	37.7	-8.3	39.1	46.4	-15.7	1132.0	1231.0	-8.0
Nalgonda	14.4	17.3	-16.8	15.4	19.2	-19.6	1070.8	1108.6	-3.4
Telangana	**133.1**	**144.2**	**-7.7**	**159.0**	**185.1**	**-14.1**	**1194.6**	**1283.2**	**-6.9**
AP State	**310.0**	**336.0**	**-7.7**	**459.7**	**511.2**	**-10.1**	**1482.9**	**1521.7**	**-2.5**

PC=per cent change*Pearl millet

Table 8. Per cent change in average area ('000 ha), production ('000 tons) and yield of pearlmillet during El Niño years compared to normal years in Andhra Pradesh (1981 to 2007)

District	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	18.1	20.3	-10.7	23.1	25.5	-9.4	1270.3	1251.8	1.5
Anantapur	11.8	12.2	-3.2	4.8	7.9	-39.7	404.7	649.5	-37.7
Chittoor	6.1	7.0	-13.3	5.3	8.4	-37.1	861.0	1187.0	-27.5
Y.S.R Kadapa	7.1	8.5	-16.2	8.4	11.3	-25.4	1177.7	1322.9	-11.0
Kurnool	18.7	21.1	-11.5	10.3	15.1	-31.5	552.4	713.3	-22.6
Rayalaseema	**43.7**	**48.9**	**-10.5**	**28.8**	**42.6**	**-32.5**	**657.8**	**872.0**	**-24.6**
Srikakulam	5.3	5.1	4.0	6.1	6.1	0.5	1161.8	1201.8	-3.3
Vizianagaram	5.7	6.0	-5.9	5.1	6.4	-19.2	907.4	1057.5	-14.2
Visakhapatnam	30.1	32.1	-6.3	22.9	27.9	-18.2	760.7	871.5	-12.7
East Godavari	7.6	7.3	3.8	5.9	4.9	19.7	769.6	667.6	15.3
West Godavari	0.0	0.2	-81.3	0.0	0.1	-68.2	888.9	523.4	69.8
Krishna	0.1	0.2	-25.3	0.1	0.2	-43.8	724.8	963.5	-24.8
Guntur	3.3	4.1	-19.4	1.1	2.8	-62.2	319.5	680.2	-53.0
Prakasam	25.0	29.7	-15.7	21.1	35.0	-39.8	843.4	1180.3	-28.5
S.P.S Nellore	4.1	5.0	-18.4	4.2	8.0	-48.1	1024.5	1611.6	-36.4
Coastal AP	**81.1**	**89.5**	**-9.4**	**66.4**	**91.3**	**-27.3**	**818.6**	**1020.3**	**-19.8**
Adilabad	0.5	0.6	-14.7	0.1	0.2	-72.3	120.6	371.1	-67.5
Nizamabad	3.6	4.2	-14.2	1.3	2.2	-38.9	372.9	523.7	-28.8
Karimnagar	0.3	0.3	-22.4	0.1	0.2	-72.3	224.6	629.0	-64.3
Warangal	4.8	5.0	-2.5	3.0	2.7	11.0	617.8	542.9	13.8
Khammam	1.7	1.9	-12.4	1.1	1.0	6.8	660.9	542.0	21.9
Medak	2.3	2.2	4.1	0.7	0.9	-13.1	319.6	382.6	-16.5
Rangareddi	2.4	2.7	-11.0	0.8	1.2	-39.6	311.1	458.4	-32.1
Mahaboobnagar	18.9	21.1	-10.1	7.0	8.5	-17.8	367.8	402.0	-8.5
Nalgonda	41.8	41.8	-0.1	13.2	16.7	-20.9	317.2	400.7	-20.8
Telangana	**76.3**	**79.8**	**-4.4**	**27.3**	**33.7**	**-19.0**	**357.3**	**421.9**	**-15.3**
AP State	**200.8**	**217.0**	**-7.4**	**122.8**	**167.3**	**-26.6**	**611.6**	**771.0**	**-20.7**

***PC=per cent change**

Rice

Rice is a dominant irrigated crop grown both during *kharif*, *rabi* and summer seasons as well occupying an area of over 3.8 million ha with production of nearly 10 million tons. The average annual yields of rice during El Niño years compared to remaining years are given in Table 9.

Table 9. Per cent change in average area ('000 ha), production ('000 tons) and yield of rice during El Niño years compared to normal years in Andhra Pradesh (1981 to 2007)

Districts	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	51.4	52.6	-2.3	119.3	120.9	-1.3	2306	2315	-0.4
Chittoor	94.0	86.0	9.3	216.5	189.6	14.2	2260	2251	0.4
Y.S.R Kadapa	59.9	58.4	2.5	148.0	147.7	0.2	2454	2512	-2.3
Kurnool	76.6	83.5	-8.3	197.2	210.3	-6.2	2551	2490	2.5
Rayalaseema	**281.9**	**280.6**	**0.5**	**681.0**	**668.5**	**1.9**	**2416**	**2383**	**1.4**
Srikakulam	194.0	193.8	0.1	360.2	380.0	-5.2	1865	1933	-3.5
Vizianagaram	120.1	124.4	-3.4	219.0	237.3	-7.7	1814	1859	-2.4
Visakhapatnam	95.9	99.1	-3.2	134.8	144.9	-7.0	1379	1427	-3.4
East Godavari	392.6	391.1	0.4	1065.7	1087.3	-2.0	2714	2783	-2.5
West Godavari	441.2	444.1	-0.7	1242.3	1329.2	-6.5	2846	3005	-5.3
Krishna	358.2	377.1	-5.0	957.5	1016.4	-5.8	2666	2718	-1.9
Guntur	291.0	298.7	-2.6	874.8	860.5	1.7	2997	2886	3.8
Prakasam	122.9	120.1	2.4	345.7	310.4	11.4	2758	2559	7.8
S.P.S Nellore	208.0	212.9	-2.3	564.7	557.6	1.3	2711	2601	4.2
Coastal AP	**2223.8**	**2261.2**	**-1.7**	**5764.6**	**5923.6**	**-2.7**	**2592**	**2620**	**-1.1**
Adilabad	70.9	65.6	8.1	137.0	109.9	24.7	1910	1645	16.1
Nizamabad	137.2	136.7	0.4	333.2	325.3	2.4	2424	2343	3.5
Karimnagar	196.4	204.1	-3.8	557.3	566.2	-1.6	2745	2692	2.0
Khammam	151.7	147.4	2.9	388.1	371.5	4.5	2362	2316	2.0
Warangal	158.1	156.8	0.8	360.4	340.0	6.0	2343	2222	5.4
Medak	99.0	103.2	-4.1	201.9	211.6	-4.6	2026	2050	-1.2
Rangareddi	42.4	44.1	-3.8	93.9	94.5	-0.6	2179	2157	1.1
Mahaboobnagar	106.7	120.3	-11.3	217.1	240.9	-9.9	1927	1967	-2.1
Nalgonda	221.7	235.1	-5.7	601.0	621.4	-3.3	2697	2604	3.6
Telangana	**1184.0**	**1213.1**	**-2.4**	**2889.9**	**2881.2**	**0.3**	**2441**	**2375**	**2.8**
AP State	**3689.8**	**3755.1**	**-1.7**	**9335.7**	**9472.8**	**-1.4**	**2530**	**2523**	**0.3**

***PC=per cent change**

The productivity of the crop was not affected by El Niño in the state, although few districts got slightly lesser yields during El Niño years.

The changes in average area, production and productivity of *kharif* rice during El Niño years compared to remaining years are given in Table 10. There was decrease in average area in the state by 9 per cent during the El Niño years and average production declined by 12 per cent. The decrease in production and productivity are 18.0 and 7.0 per cent respectively in Telangana region. The average productivity of rice during *kharif* season decreased by more the 10 per cent in Adilabad and Nizamabad districts of Telangana region and Visakhapatnam district in coastal Andhra Pradesh. The short fall in production of rice during *kharif* season appear to have been compensated during *rabi* season.

Table 10. Per cent change in average area (‘000 ha), production (‘000 tons) and yield of *kharif* rice during El Niño years compared to normal years in Andhra Pradesh (1981 to 2007)

Districts	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	28.0	34.1	-17.9	63.7	80.0	-20.4	2277.6	2348.4	-3.0
Chittoor	28.3	39.4	-28.2	55.9	85.6	-34.7	1978.0	2174.0	-9.0
Y.S.R Kadapa	41.4	48.7	-15.0	101.3	125.8	-19.4	2449.0	2583.6	-5.2
Kurnool	62.6	68.9	-9.1	159.7	173.6	-8.0	2551.3	2519.9	1.2
Rayalaseema	**160.2**	**191.0**	**-16.1**	**380.7**	**464.9**	**-18.1**	**2376.0**	**2434.3**	**-2.4**
Srikakulam	178.1	198.5	-10.3	343.0	373.9	-8.3	1926.6	1883.7	2.3
Vizianagaram	112.7	125.0	-9.9	197.5	237.7	-16.9	1752.6	1901.3	-7.8
Visakhapatnam	86.8	100.0	-13.1	109.1	147.0	-25.8	1256.4	1470.1	-14.5
East Godavari	233.9	251.0	-6.8	514.1	556.2	-7.6	2197.6	2216.2	-0.8
West Godavari	258.2	268.1	-3.7	638.4	621.8	2.7	2473.0	2319.1	6.6
Krishna	276.4	284.5	-2.9	679.3	734.1	-7.5	2457.8	2579.8	-4.7
Guntur	275.6	287.3	-4.1	768.1	854.4	-10.1	2787.2	2974.2	-6.3
Prakasam	60.5	77.2	-21.6	149.6	200.8	-25.5	2471.4	2600.7	-5.0
S.P.S Nellore	48.2	56.2	-14.2	125.5	144.6	-13.3	2602.1	2574.2	1.1
Coastal AP	**1530.4**	**1647.9**	**-7.1**	**3524.7**	**3870.6**	**-8.9**	**2303.1**	**2348.9**	**-2.0**
Adilabad	56.3	64.4	-12.6	80.4	117.2	-31.4	1428.3	1821.1	-21.6
Nizamabad	100.8	115.5	-12.7	215.4	278.0	-22.5	2136.7	2405.7	-11.2
Karimnagar	113.8	128.2	-11.3	291.6	348.7	-16.4	2562.8	2719.7	-5.8
Warangal	109.4	122.8	-10.9	246.4	298.9	-17.6	2252.8	2434.4	-7.5
Khammam	130.6	139.1	-6.1	283.5	325.6	-12.9	2170.5	2341.2	-7.3
Medak	65.0	77.9	-16.6	119.9	155.9	-23.1	1845.2	2000.1	-7.7
Rangareddi	24.4	29.5	-17.3	49.3	61.4	-19.7	2020.9	2081.8	-2.9
Mahaboobnagar	65.2	79.8	-18.4	128.3	155.5	-17.4	1969.3	1947.3	1.1
Nalgonda	136.8	153.0	-10.5	360.3	425.1	-15.2	2633.3	2778.7	-5.2
Telangana	**802.3**	**910.2**	**-11.9**	**1775.3**	**2166.3**	**-18.0**	**2212.7**	**2379.9**	**-7.0**
AP State	**2493.0**	**2749.4**	**-9.3**	**5680.7**	**6501.9**	**-12.6**	**2278.6**	**2364.9**	**-3.6**

***PC=per cent change**

Food Grain Crops other than Rice

By revisiting the Figure 9' it can be seen that the average total food grain production decreased by more than 15 per cent in 12 districts of the state during El Niño years. The decline in production of rice in these districts is more than 10 per cent during *kharif* season. Therefore, the higher variability in total food grain production in these districts can be attributed to shortfall in production of rainfed crops as well. It is also of interest to note from Figure 10, that the average yields also declined by more than 15 per cent in Adilabad, Y.S.R Kadapa and Anantapur districts indicating the chances of obtaining lower yield of rainfed crops as well during El Niño years.

The average of area, production and productivity of total food grain crops other than rice during the years 1981 to 2006 are given in Table 11. It can be seen clearly that the area under food grains other than rice decreased by 9.8 per cent. But the average production during El Niño years decreased by 42.7 per cent and the productivity decreased by 36.4 per cent. Therefore, it is obvious that El Niño is exerting greater influence on productivity of rainfed crops as a result of decreasing tendency of southwest monsoon rainfall. Barring West Godavari district in coastal Andhra Pradesh, all other districts showed decline in average production and productivity by more than 25 per cent.

Table 11. District-wise average area ('000 ha), production ('000 tons) and yield (kg/ha) of other foodgrains (excluding Rice) in Andhra Pradesh (1981 - 2007)

Districts	Area			Production			Yield		
	El Niño	Normal	PC	El Niño	Normal	PC	El Niño	Normal	PC
Anantapur	161.9	164.6	-1.7	85.7	134.5	-36.2	529.7	816.7	-35.1
Chittoor	31.9	63.4	-49.7	-19.4	69.1	-128.1	-607.7	1088.9	-155.8
Y.S.R Kadapa	80.1	85.0	-5.7	44.0	90.2	-51.2	549.2	1062.3	-48.3
Kurnool	341.3	332.5	2.6	269.0	332.5	-19.1	788.2	1000.1	-21.2
Rayalaseema	**615.1**	**645.5**	**-4.7**	**379.4**	**626.2**	**-39.4**	**616.7**	**970.2**	**-36.4**
Srikakulam	76.1	99.9	-23.9	40.6	80.7	-49.7	534.2	807.8	-33.9
Vizianagaram	72.5	83.5	-13.2	33.4	76.6	-56.4	460.5	916.7	-49.8
Visakhapatnam	119.6	133.2	-10.2	71.7	118.5	-39.5	599.5	890.0	-32.6
East Godavari	94.1	129.1	-27.2	16.1	125.6	-87.2	171.6	973.0	-82.4
West Godavari	21.2	36.6	-42.1	49.0	77.8	-37.1	2313.4	2127.4	8.7
Krishna	171.8	166.1	3.4	107.8	188.2	-42.7	627.7	1132.7	-44.6
Guntur	201.0	209.8	-4.2	130.7	261.4	-50.0	650.2	1245.7	-47.8
Prakasam	201.8	228.7	-11.8	108.1	241.0	-55.1	535.9	1053.6	-49.1
S.P.S Nellore	46.8	43.5	7.7	39.2	53.9	-27.2	838.1	1239.5	-32.4
Coastal AP	**1004.9**	**1130.5**	**-11.1**	**596.8**	**1223.7**	**-51.2**	**593.9**	**1082.4**	**-45.1**
Adilabad	275.0	290.1	-5.2	131.0	225.4	-41.9	476.5	776.9	-38.7
Nizamabad	115.3	140.7	-18.0	134.6	264.3	-49.1	1167.2	1878.8	-37.9
Karimnagar	177.3	210.9	-15.9	262.6	471.5	-44.3	1481.1	2235.4	-33.7
Warangal	162.0	186.9	-13.3	120.4	229.6	-47.5	743.5	1228.1	-39.5
Khammam	147.4	174.0	-15.3	80.5	173.5	-53.6	546.1	997.1	-45.2
Medak	279.1	296.7	-5.9	219.2	303.7	-27.8	785.3	1023.6	-23.3
Rangareddi	165.2	178.8	-7.6	123.2	140.2	-12.1	745.6	783.8	-4.9
Mahaboobnagar	376.9	401.7	-6.2	200.6	295.4	-32.1	532.1	735.4	-27.6
Nalgonda	181.3	203.9	-11.1	13.5	139.0	-90.3	74.3	681.9	-89.1
Telangana	**1879.6**	**2083.8**	**-9.8**	**1285.6**	**2242.6**	**-42.7**	**684.0**	**1076.2**	**-36.4**

***PC=per cent change**

Castor

Year-wise yield of castor in Andhra Pradesh is shown in Figure 11. Castor is an indeterminate crop of 130 to 140 days grown mostly under rainfed conditions. The seed yield of castor depends more on the rainfall during post monsoon season as the crop will be in reproductive stage during that period. The yield of castor varied from about 200 to 350 kg/ha upto the year 2001 and thereafter there is an increasing trend in yield. The years 2002, 2004 and 2006 which were El Niño years recorded seed yield of more than 350 kg/ha. Even during the years 1991 and 2006 which were also El Niño years the Southwest monsoon rainfall was less than normal but the annual rainfall was more than normal. The yield of Castor is more during these two years compared to their respective preceding years. It's an obvious indication that a long duration crop like Castor is unaffected by El Niño factor. As the Southwest monsoon rainfall is likely to be less and the north east monsoon rainfall compensates for the annual rainfall long duration crops are expected to perform better during El Nino years.

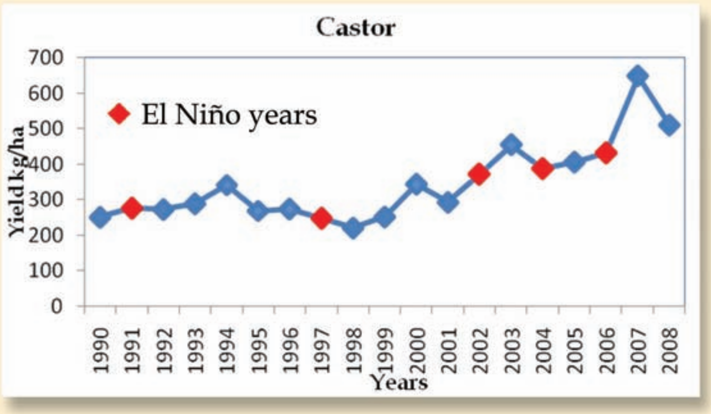


Figure 11. Year-wise yield of castor in Andhra Pradesh

Pigeonpea

Year-wise yield of pigeonpea in Andhra Pradesh is shown in figure.12. Pigeonpea is also an indeterminate crop of more 150 days duration and is grown mostly under rainfed conditions. The yield of pigeonpea mostly depends upon the post monsoon rainfall as the crop will be under reproductive stage during the period. There is an increasing trend in the yield of Pigeonpea after the year 2002. During the El Niño year 1997 the Southwest monsoon rainfall was above average but the annual rainfall was less than normal. Consequently the yield of Pigeonpea decreased considerably. During the other El Niño years the yields were better than the lower values recorded during the preceding years without El Niño. Particular attention is drawn to the years 1991 and 2006 when the southwest monsoon rainfall was less than normal and the annual rainfall was above normal. During these two years the yield of pigeonpea was more than 350 kg/ha which was above average. Therefore long duration crops like pigeonpea were comparatively less affected during the El Niño years.

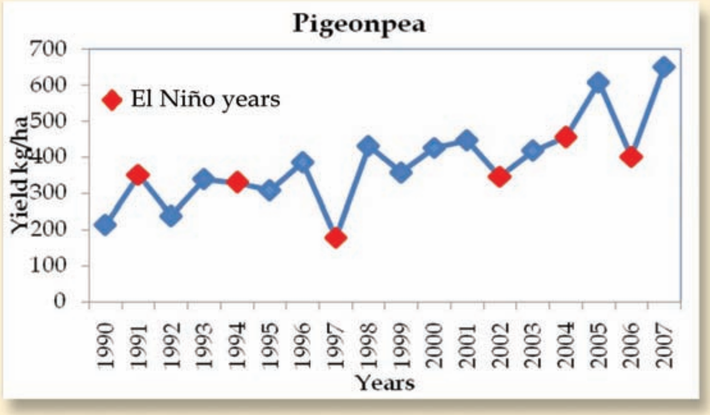


Figure 12. Year-wise yield of pigeonpea in Andhra Pradesh

Chickpea

Chickpea is a pulse crop of about 100 to 110 days duration grown under conserved moisture conditions during *rabi* season. It was only during the year 1997 when the Southwest monsoon rainfall was above average and the annual rainfall was below average the crop yield was lowest of about 400 kg/ha. During other El Niño years the yield of Chickpea was more than 700 kg/ha. It can also be seen that the yield of chickpea during the El Niño years 2002, 2004 and 2006 was more than even 900 kg/ha which is higher than the best yields obtained upto the year 2000. Therefore there is a general indication that *rabi* crops are likely to perform better during El Niño years. The yield of *rabi* crops can also be further improved by adapting appropriate moisture conservation practices, judicious use of fertilizers and timely pest and disease control measures.

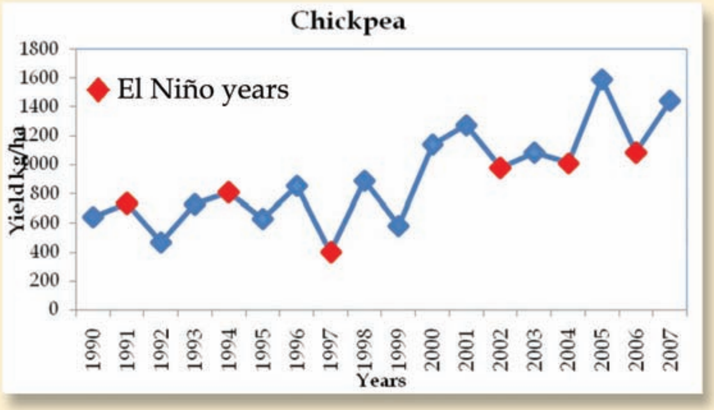


Figure 13. Year-wise yield of chickpea in Andhra Pradesh

CHAPTER-5

Possible Options for Enhancing Agricultural Production

Reliable climate predictions may not be available immediately and it might take some more time and until then, the necessity arises to identify some of the global parameters like El Niño, which can be used as a signal to climate variability at least during some of the years, even if not for all the years.

By knowing that either the southwest monsoon rainfall or annual rainfall is likely to decrease and with a possibility of increased northeast monsoon rainfall in some of the districts the following strategies may be useful for improving agricultural production of the state during the years with El Niño. These districts cover Nalgonda and Mahabubnagar in Telangana and entire coastal Andhra Pradesh excluding Vizianagaram.

- As southwest monsoon rainfall has a tendency to decrease and northeast monsoon rainfall has a tendency to increase in these districts it is important to advocate intercropping systems with long duration base crop and medium to short duration companion crop in mono cropped areas.
- In double cropping areas under rainfed conditions better yields can be expected during *rabi* season by adopting *in situ* moisture conservation practices and judicious use of fertilizers with regard to timing and quantum.
- In those districts wherever the rice yields are likely to decline, rice may be cultivated under system of rice intensification (SRI) method during *kharif* season.
- Due to increased rainfall during *rabi* season in some of the districts pests and diseases may be of threat during early stages of crop. Agromet advisory services have to be fine-tuned through reliable pest and disease warning and control mechanisms.
- Plantation crops like mango, cashew, coconut *etc.,* are likely to yield less during El Niño years wherever the pre-monsoon rainfall has a tendency to decrease and appropriate moisture conservation practices have to be followed.

- Vegetable production during summer season is likely to get affected and production can be sustained by promoting peri-urban olericulture and use of shade nets. Sprinkler irrigation needs to be advocated to improve water use efficiency.

As the data considered uptill now indicates greater vulnerability of crop production during years with strong and moderate El Niño events, farmers have to be cautioned on judicious use of irrigation water so that the available water can be spared for use in larger areas.

References

Das, A., Banga, R and Kumar, D. 2011. Global economic crisis. Impact and restructuring of the service sector in India. Working paper No.311, ADBI. http:// www.adbi.org/workingpaper/2011/09/30/4727.

Gadgil, S. and Gadgil, S. 2006. The Indian Monsoon, GDP and Agriculture. Economic and Political Weekly, November,2006 : 4887-4895.

Hansen, J.W. and Jones, J.W. 2000. Scaling up crop models for climate prediction applications. (In) Climate Predictions and Agriculture. (Ed: M.V.K. Sivakumar). International START Secretariat, Washington, D.C. p: 77-118.

Jan Null. 2011. El Niño and La Niña Intensities. http://ggweather.com/enso/oni.htm.

Kesava Murthy. R.N. 1982. Response of atmosphere to seas surface temperature anamolies over the Equatorial Pacific and the Teleconnections of the Southern Oscillation. J. Atmospheric Sciences, 39: 1241-1259.

Leglan, D.M; Bryant, K.J. and Obrian, J.J. 1999. Impact of ENSO related climate anamolies and crop yields in the U.S. Climate Change, 42: 371-375.

Mc Carl, Bruce A. Adams, Richard, M. and Chi Chang Chen. 2000. Economic effects of shifts in ENSO event's frequency and Strength. (In) Climate Prediction and Agriculture. International START Secretariat, Washington. D.C. p: 143-156.

Nicholls, N. 1986. Use of southern oscillation to predict Australian Sorghum yield. Agric. For. Meteorol., 38: 9-15.

Pidwiry, M. 2010. El Niño, La Niña and the southern oscillation. Fundamentals of Physical Geography, 2nd Edition. geo@physicalgeography.net.

Quinn, W.H. and Niell, V.T. 1987. El Niño occurrence over the past four and half centuries. J. Geophysical Research C. Oceans, 92: 14449-14461.

Rajeevan, M. and Pai, D.S. 2006. On El Niño- Indian Summer Monsoon Predictive Relationships. Res. Rep. No 4/2006. National Climate Centre, India Meteorological Department, Pune – 411 005. Pp-20.

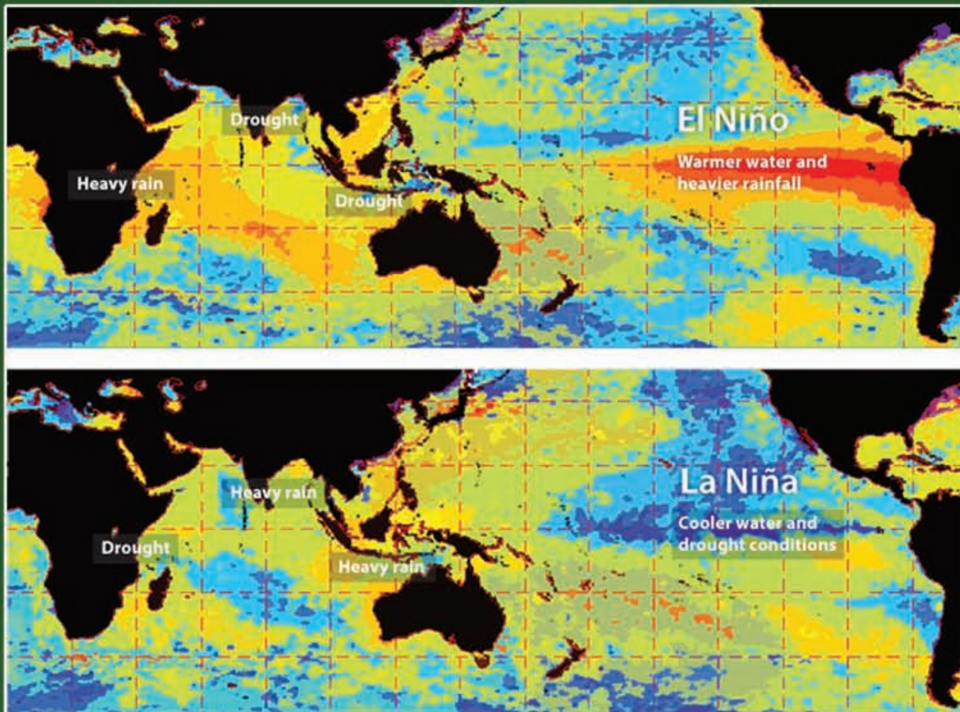
Singh, R.P. and Ramana Rao, B.V. 1988. Agricultural drought management in India- Problems and Priorities. Tech.Bull.1/1988. Central Research Institute for Dryland Agriculture, Hyderabad.

Sikka, D.R. 1980. Some aspects of large scale fluctuations of summer monsoon rainfall over India in relation to planetary and regional scale circulation parameters. Proceedings of Indian Academy of Sciences (Earth and Planet Sciences), 89: 179-195.

Stephen Zebaik. 1999. El Niño and Science of Climate Prediction. CONSEQUENCES. 5(2): 3-15.

Victor, U.S. Srivastava, N.N. Subba Rao, AVM. And Ramana Rao, B.V. 1995. El Niño 's effect on southwest monsoon rainfall in Andhra Pradesh, India. Drought Network News. University of Nebraska, Linclon. USA.

Wilby, R.L. and Wigley, T.M.L. 2000. Downscaling general circulation issues in climatic prediction. In climate Prediction and Agriculture (Ed: M.V.K. Sivakumar). International START Secretariat, Washington, D.C.: p-39-68.



National Initiative on Climate Resilient Agriculture (NICRA)
All India Coordinated Research Project on Agrometeorology
Central Research Institute for Dryland Agriculture
Santoshnagar, Saidabad, Hyderabad – 500 059, A.P., India