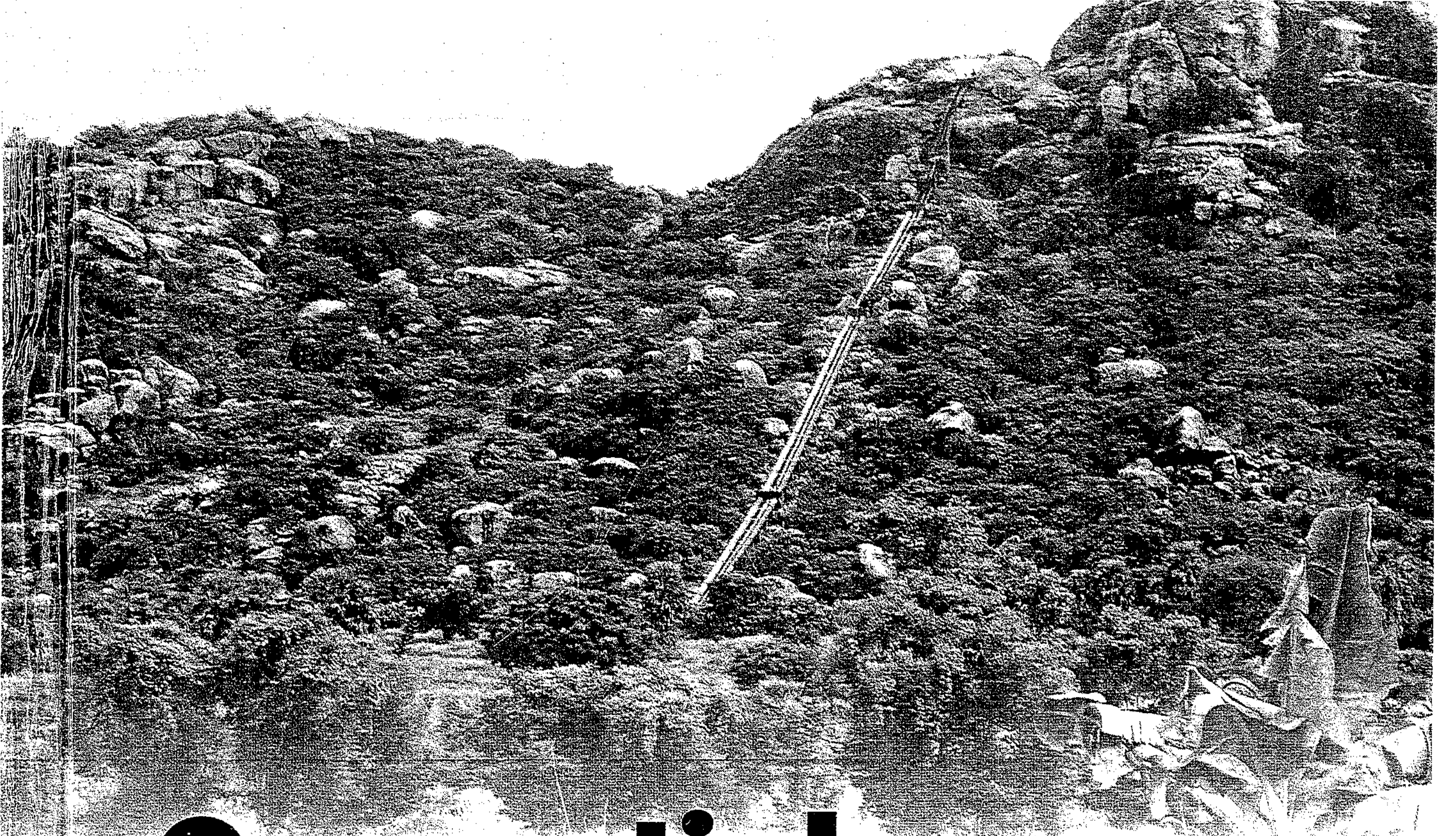

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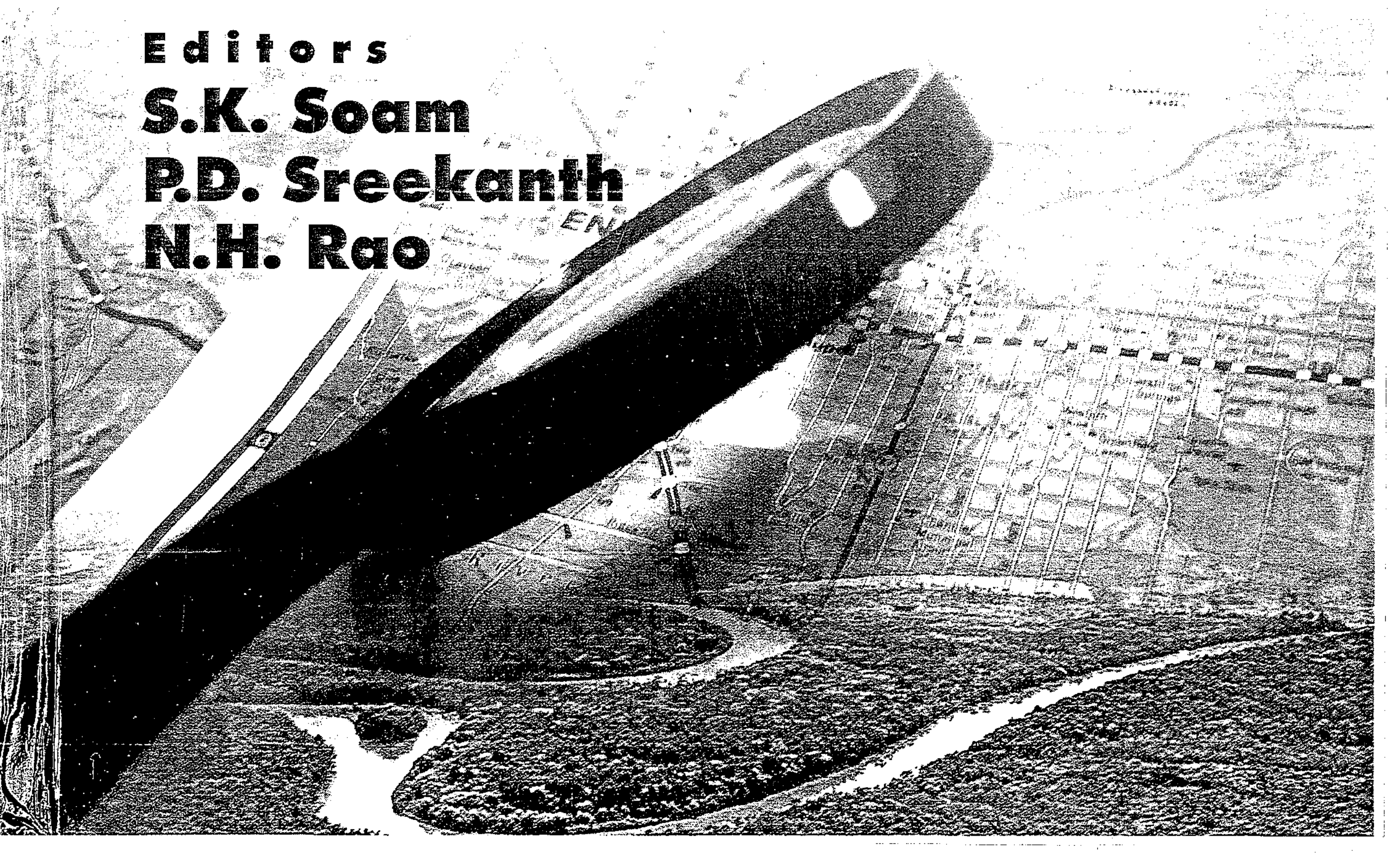

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2013

New India Publishing Agency
Pitam Pura, New Delhi-110 088

Chapter - 24

Moisture Stress Assessment through NDVI and Climate Tools for Crop Management at Anantpur District, AP

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Abstract

Anantapur is the driest district of Andhra Pradesh and hence, agriculture conditions are very often precarious. Groundnut grows where other crops fail and thus it is the predominant crop of Anantapur district. Groundnut is grown in about 7.5 lakh ha in Anantapur district; however the average yields are low at 500 kg ha^{-1}. Among various available vegetation indices, normalised difference vegetation index (NDVI) is widely used for all reasons, which is a single numerical indicator of presence and condition of green vegetation. NDVI mapping at a regional scale helps to assess the spatial changes in the vigour of green vegetation and thus occurrence of any moisture stress. Climate tools have a great role in understanding the crop performance and estimating the yields. This study was taken up by using freely available MODIS data to understand NDVI in terms of abiotic stresses over Anantapur district and linking with the actual rainfall conditions, groundnut crop acreage and production. Results indicate that low groundnut yields in general could be related to NDVI-based stress measurements and rainfall quantum and *distribution in the area however, with a few exceptions. It is hoped that by combining improved practices through IWM with climate-adapted crop varieties, rainfed farmers of Anantapur district can sustain their crop production under present climate variability and become resilient to future climate change.*

Keywords: *Climate, MODIS, NDVI, Anantapur, Groundnut, Integrated Watershed Management*

1.0 Introduction

Anantapur is the driest district of Andhra Pradesh and hence, agriculture conditions are very often precarious. Both the monsoons evade the district as it is under rain-shadow region for southwest monsoon and being far from the east coast, rains from the northeast monsoon are little in many years. The district receives about 570 mm of average annual rainfall. About 340 mm is received in southwest monsoon period and about 155 mm in the northeast monsoon period. Evapotranspiration demands are high and the annual potential evapotranspiration is about 2000-2200 mm, thus making the district to have a typical arid climate. Net area sown varies with rainfall from about 9 to 11 lakh ha, which is about 46 to 58 per cent of the total geographical area. Soils in the district are predominantly light textured, gravelly, shallow Red soils with depths varying between 30 cm and 60 cm. These soils hold plant-available water ranging from 40 mm to 70 mm in the soil profile and are low in nutrients.

Groundnut is the predominant crop of Anantapur district. Groundnut grows where other crops fail. Groundnut is grown on nearly 23.95 million ha worldwide with the total production of 36.45 million tons and an average yield of 1520 kg/ha in 2009. Groundnut is grown in about 7.5 lakh ha in Anantapur district however; the groundnut productivity of Anantapur district is very low due to highly variable rainfall, poor soil conditions and resource poor farmers. Abiotic stresses could lead to groundnut yield losses of more than 50 per cent in the arid Anantapur district. Moisture stress at critical stages has an adverse impact on growth and productivity of groundnut crop in Anantapur district. Thus, there is a need to understand the naturally occurring and essentially unavoidable abiotic stresses, particularly the moisture stress. Among various available vegetation indices, normalised difference vegetation index (NDVI) is widely used for all reasons, which is a single numerical indicator of presence and condition of green vegetation. NDVI mapping at a regional scale helps to assess the spatial changes in the vigour of green vegetation and thus occurrence of any moisture stress. Monitoring of such regional scale maps in near real-time has applications not only in research but also for management. With this objective a study was taken up by using freely available MODIS data to understand the concept of NDVI in terms of abiotic stresses over Anantapur district and linking with the actual rainfall conditions, groundnut crop acreage and production.

2.0 Description of Study Area

Anantapur is one of the four districts of Rayalaseema region in Andhra Pradesh. It is bounded by Kurnool District in the north, Kadapa district in the northeast, Chittoor district in the southeast and Karnataka State on the West. The district has a total geographical area of 19.13 lakh hectare. For administrative purposes, the district is divided into three revenue divisions, namely, Anantapur, Dharmavaram, and Penukonda; there are sixty-three revenue mandals. Anantapur district has nine towns and 959 revenue villages and a total population of 4.08 million as per the 2011 census. Sex Ratio in Anantapur is at 977 per 1000 male compared to 2001 census figure of 958. The initial provisional data released by census India 2011, shows that density of Anantapur district for 2011 is 213 people per sq. km. In 2001, Anantapur district density was at 190 people per sq. km. Almost 75 per cent of the population in the district lives in rural areas. Agriculture remains the predominant activity in the villages, with 80 per cent of total workers engaged in agriculture, either as cultivators or agricultural labourers. Mining is also an important activity.

Forest area in the district is low at 1.97 lakh ha which is about 10 per cent of the total geographical area (Anonymous 2007). Pennar is the important river in the district; Jayamangala, Chitravathi, Vedavathi and Hagari rivers also important water sources to several large and medium irrigation tanks in Anantapur district. However, irrigation potential is low and is about 10 per cent of the net sown area.

Soils in Anantapur district are predominantly Red (about 65 per cent) except in Kanekal, Bommanahal, Vidapanakal, Uravakonda, Vajra Karur, Guntakal, Gooti, Pamidi, Peddavadugur, Yadaki, Tadipatri, Yellanur, Peddapappur and Putlur mandals. In these mandals, red and black soils occur almost in equal proportion. In the district, Red clayey soils occur extensively followed by Red loamy soils. Alluvial soils, Black soils and Rock lands occupy about 35 per cent of the total geographical area.

Anantapur being a drought-prone district, land holdings are small and the farmers are resource poor. Almost 90 per cent of the cropped area is rainfed and groundnut is the most predominant crop. About 70 per cent of the cultivated area is under groundnut, which is due to its commercial value and also as a source of fodder for livestock in drought years. Groundnut yields are low and year-to-year variation in productivity is observed which is linked to the highly variable rainfall.

3.0 Data and Methods

Daily rainfall data of all the 63 mandals in Anantapur district for the period 2000 to 2009 was procured from the Directorate of Economics and Statistics, Government of AP. Analysis of the rainfall data indicated that the year 2003 has received very low rainfall with a deviation of about -36 per cent from the normal and the year 2005 received good rainfall with a deviation of +30 per cent. Mandal-wise groundnut area and production statistics were collected from the Department of Agriculture, Anantapur district.

Moderate resolution Imaging Spectroradiometer (MODIS) is a coarse resolution instrument on-board TERRA and AQUA satellites covering the whole globe every 1 to 2 days, acquiring data with high radiometric sensitivity in 36 spectral bands ranging from 0.4 μm to 14.4 μm. Two bands are imaged at a resolution of 250m, and 5 bands at a resolution of 500m and the rest 29 bands at 1km spatial resolution. The TERRA system provides land-based products and the AQUA satellite provides products for ocean and aerosol based products. Apart from these, the MODIS also provides some useful products such as 8-day composites and 16-day composites of reflectance, NDVI and other indices suitable for many global change study projects. These datasets will also provide an understanding of the dynamic processes and change dynamics occurring on land, in the oceans and in the lower atmosphere.

In the present study MOD09Q1 surface reflectance bands 1, 2 with a temporal granularity of 8 days are downloaded for the study area from the MRTWEB. NDVI was computed based on these bands for September during the period 2000 to 2009. Groundnut is generally sown in middle of July to first week of August and by the end of September, the crop is generally in its best vegetative stage. End of September represents the transition from green vegetative to reproductive phase during *Kharif* season for groundnut in Anantapur district. Monitoring of crop vigour at this stage can indicate the stress or no stress due to available moisture status. Thus MODIS 8-day composites as on 29 Sep every year were made and analysed. NDVI distribution over Anantapur district clearly indicated high contrasting scenes for the two years 2003 and 2005, which were indicated by earlier rainfall analysis. Hence, rainfall and MODIS 8-day composite NDVI images for the years 2003 (drought year) and 2005 (wet year) were used for assessing the stress in relation to groundnut acreage and productivity in Anantapur district. Using ArcGIS 10.0 software, NDVI images were classified in to three classes and number of pixels falling in the stressed vegetation class was identified, counted and area under stress in ha was estimated for each mandal for both the years.

4.0 Results and Discussion

Kudair and Bathalapalli mandals received lowest annual rainfall between 100 to 150 mm during the drought year 2003 and about 600 mm in the wet year 2005. Twenty four mandals received less than 300 mm of annual rainfall in 2003. Only eleven mandals received more than 300 mm of annual rainfall; Gandlapenta and Tadipatri received about 600 mm in the drought year 2003. In the wet year 2005, only five mandals received less than 500 mm of annual rainfall and Peddapappur received the lowest rainfall of about 340 mm. Twenty-two mandals received more than 800 mm of annual rainfall; Amadaguru, Gandlapenta and Mudigubba received rainfall between 1000 to 1100 mm in 2005. Weekly cumulative rainfall from 10-Jun to 23-Sep during the two years 2003 and 2005 presented in the figure 1 shows not only the difference the total rainfall but also clearly brings out the contrasting differences in the rainfall distribution.

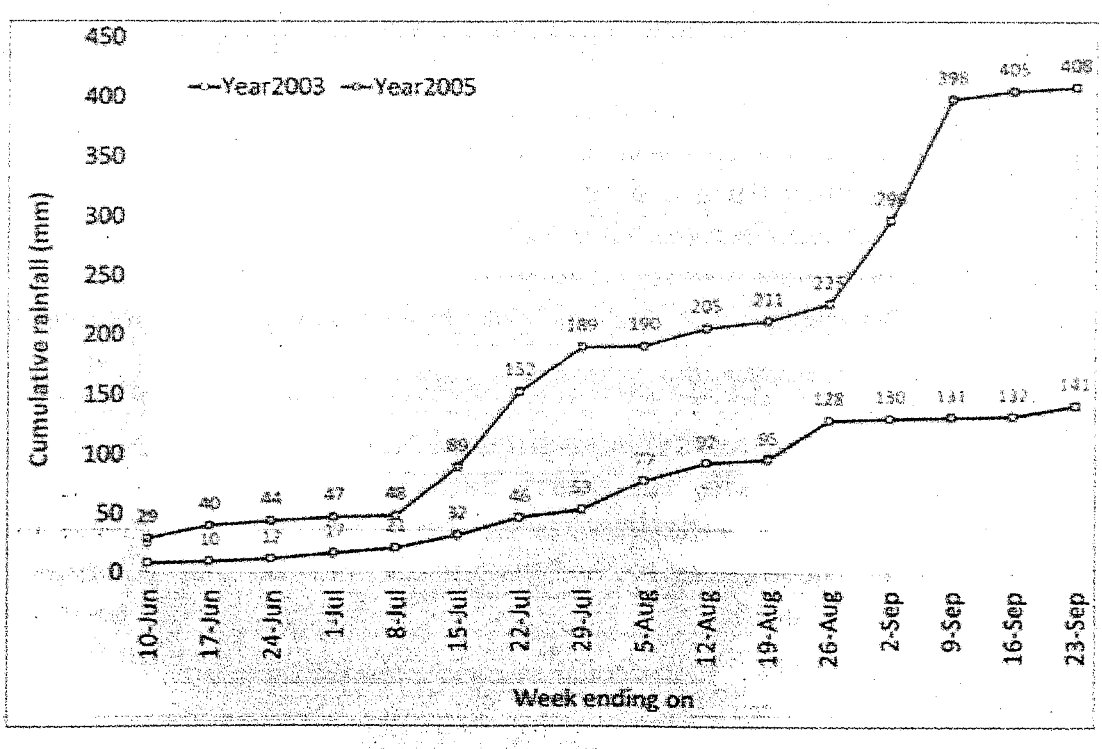
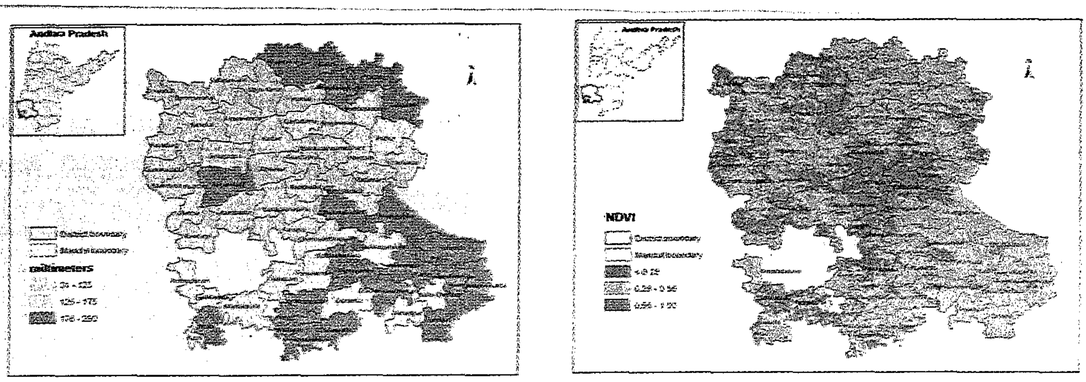


Fig. 1 : Weekly rainfall distribution in Anantapur district

NDVI data from MODIS has been widely used for different purposes ranging from large area crop land mapping (Wardlow et al, 2008), land cover change mapping (Lunetta et. al. 2006), linking species composition and MODIS based NDVI (Kate et. al., 2008). Stress identification studies have been carried out using the MODIS NDVI over heterogeneous crops for identification of individual crops. Using the MODIS 8-day composite NDVI data for Anantapur district, three classes of vegetation stress namely high (<0.28), moderate (0.28-0.56) and low (>0.56) degree of stress are created for the two years 2003 and 2005 as done by Nageswara Rao et al. (2012). Maps of rainfall for the southwest monsoon season and the spatial distribution of NDVI in Anantapur district are presented in the figures 2 and 3.

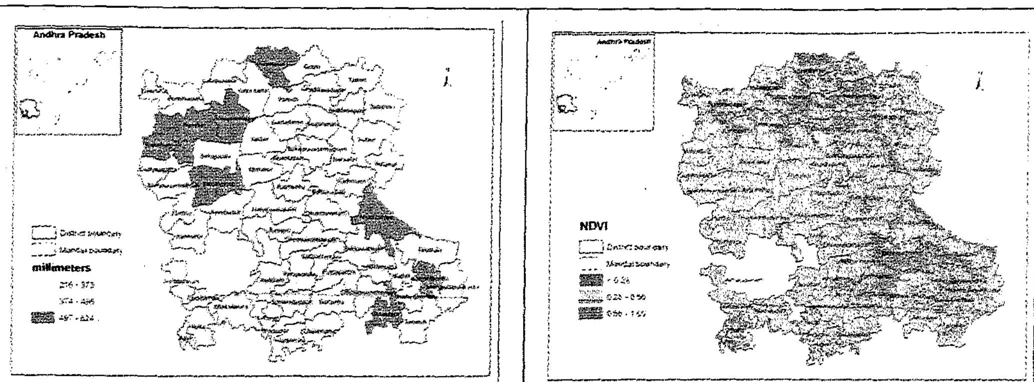


Rainfall during Jun-Sep 2003 MODIS 8-day composite NDVI in 2003

Fig. 2 : Rainfall and NDVI distribution in Anantapur district during 2003

NDVI computed for Anantapur district for a low rainfall year and a high rainfall year was used to understand the stress during these selected years indicating a direct relationship between rainfall and NDVI. A comparison between the NDVI during the dry year (2003) and rainfall clearly shows a match between the low rainfall mandals and NDVI class showing stress (Figure 2). Except Kalyandurg mandal, where the rainfall is showing high up to 290 mm and showing a stressed condition in NDVI, almost all the central and north-western mandals show a direct relationship between stressed NDVI and low rainfall, such as Anantapur, Rapthadu, Tadimarri, Bathalapalli, Kanaganapalli and Kudair, Vajra Karur, Vidapanakal in the northwest. North-eastern mandals show a low stress as is shown in the rainfall map (Guntakal, Gooti, Tadipatri, Yadaki and Peddavadagur). It can be clearly seen that the southern mandals with higher rainfall show higher NDVI indicating better vegetation condition.

The high rainfall year (2005) also shows a relatively very good relationship between good rainfall and higher NDVI values indicating agriculturally good year. The cluster of mandals from Kanekal in the east to Putlur in the west shows a direct relationship between rainfall and NDVI (figure 3). The southern tail of the district has almost similar trend in both the selected years where the rainfall is higher to avoid stress. Mandals like Bukkapatnam, Puttaparthi, Nallamada, Talupula, Mudigubba were well endowed in both the contrasting years.



Rainfall during Jun-Sep 2005 | MODIS 8-day composite NDVI in 2005

Fig. 3 : Rainfall and NDVI distribution in Anantapur district during 2005

Percentage of areas under high stress to the total mandal geographical areas were examined with the rainfall from 04 Jun to 23 Sep to understand their relationship and shown in figure 4. It is seen that as the rainfall increases, the stressed areas have decreased and above 300 mm of rainfall, there is a significant reduction in the highly stressed areas.

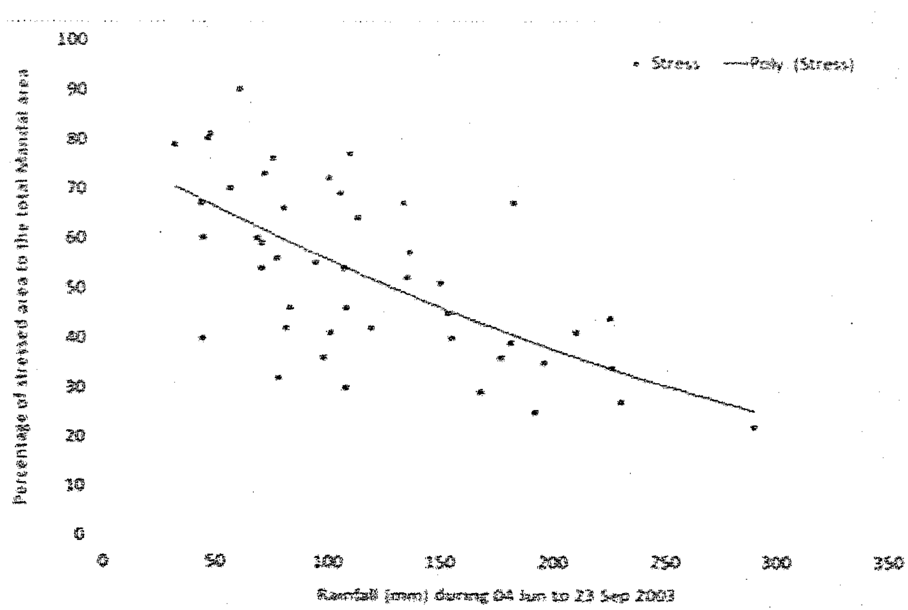


Fig. 4 : Rainfall and NDVI based moisture stress relation in 2003

To assess the impacts of seasonal rainfall and stress on the groundnut acreage and productivity, data on these for selected mandals of Anantapur district and for total Anantapur are presented in the table 1. Long-term average area under groundnut for the mandal is considered as normal area.

Table 1 : Changes in groundnut acreage, yield, rainfall and stressed area in Anantapur

Selected Mandal	Groundnut area (ha)			Rainfall(04 Jun to 23 Sep) (mm)		Stressedarea (ha)		Groundnut yield (kg ha^{-1})	
	Normal	Year 2003	Year 2005	Year 2003	Year 2005	Year 2003	Year 2005	Year 2003	Year 2005
Anantapur	11,800	7,302	11,922	46	360	17,821	445	143	172
Guntakal	18,500	17,462	20,722	210	524	16,584	779	402	1,004
Kalyandurg	29,500	22,752	34,209	182	624	30,836	861	154	322
Mudigubba	26,500	25,585	29,398	192	622	5,532	486	205	698
Narpala	11,500	9,545	12,050	136	391	18,079	76	30	216
Pamidi	10,000	8,706	10,650	108	453	13,830	393	171	921
Peddavadagur	11,600	11,518	16,942	226	373	10,402	105	436	1,040
Rapthadu	16,000	13,218	16,290	60	335	23,962	158	33	363
Rayadurgam	19,500	18,450	18,960	75	530	25,761	955	195	707
Roddam	18,100	16,719	19,540	83	351	14,709	1,113	127	263
Tadimarri	11,300	11,007	12,350	80	343	17,217	410	35	131
Tadipatri	4,650	1,904	7,052	225	398	15,776	193	443	713
Uravakonda	15,500	9,972	22,276	105	568	29,137	756	183	753
Vajra Karur	15,800	14,091	21,770	109	476	31,879	82	477	774
Yadaki	7,500	4,892	8,986	290	353	8,169	586	285	870
Bukkapatnam	11,000	9,030	10,665	94	467	13,461	258	375	273
Kundurpi	16,750	18,892	18,693	113	351	22,005	785	322	265
Setturu	18,700	18,692	18,884	135	426	13,361	815	286	145
Chilamattur	11,000	9,132	12,132	271	496	152	2,496	319	589
Talupula	12,300	8,122	13,480	217	306	270	1,278	335	474
OD Cheruvu	12,500	10,664	14,890	182	387	0	1,096	505	107
Total for Anantapur district	**7,50,000**	**6,70,935**	**8,77,029**	**140**	**404**	**7,79,733**	**51,114**	**270**	**409**

Due to the very low rainfall in 2003, from the 6.7 lakh ha of area only 167.2 m t of groundnut production was recorded and the average yield was just 270 kg ha^{-1}. Good rainfall both in quantity and distribution has helped in increase in the area up to 8.77 lakh ha with a good production of about 355.8 m t. Groundnut yield was also high at 409 kg ha^{-1} in the year 2005. Except for Kundurpi mandal, groundnut area in 2003 was always lower than the normal area as well as in the wet year 2005. Rainfall was always higher in 2005 compared to 2003 for all the mandals; the difference varied from 63 mm at Yadaki to 543 mm at Kanekal.

Area under moisture stress was very high in 2003 compared to the year 2005. When the total district is taken, the stressed area (7.8 lakh ha) is more than the groundnut sown area (6.7 lakh ha) because the MODIS 8-day composite NDVI indicates not only stress for groundnut but also includes all vegetation types. Mandals like Kalyandurg and Vajra Karur have shown a difference of about 30,000 ha under moisture stress between the two years. It is seen that two mandals Guntakal and Peddavadagur have recorded very high groundnut productivity of more than 1000 kg ha^{-1} in the wet year 2005, which is more than double of the district average for that year. Bukkapatnam, Kundurpi and Setturu recorded low yields in 2005 compared to 2003, even though they experienced very low moisture stress. In spite of the low rainfall in the year 2003, OD Cheruvu mandal did not experience any moisture stress and recorded better yield compared to 2005. These findings indicate that low groundnut yields are in general be related to NDVI based stress measurements and rainfall quantum and distribution in the area however, with a few exceptions.

5.0 Resilience to Climate Change

Climate scenarios for Anantapur district as projected by National Communication (NATCOM, 2009) under A1B scenario suggest that compared to baseline (1961-1990), the rainfall is likely to decrease by about 14.4 per cent by 2021-2050 and by 8.7 per cent by 2071-2098 (Bapuji Rao et al., 2011). Southwest monsoon (Jun-Sep) rainfall is projected to decrease by 17 per cent by 2021-2050 and by 29 per cent by 2071-2098. Severity of drought during July and September months will be of great concern. In the southwest monsoon season, mean maximum temperature is likely to increase by 2.3°C during 2021-2050 and by 4.8°C during 2071-2098. Mean minimum temperature is also likely to increase by 2.2°C during 2021-2050 and by 4.2°C during 2071-2098. Temperatures are also projected to increase during the *rabi* season. Rainfed agriculture supports nearly 40% of India's estimated population of 1.21 billion in

2011 (Sharma 2011). Majority of people still live in villages, and most of them are poor and depend on rainfed agriculture for their livelihoods in Anantapur district. Drought increases the hardship for rural poor women as they need to spend more time to fetch drinking water, fodder for animals and fuel for cooking. Poor young girls will mostly be affected through their exclusion from education. Groundnut is still a preferred crop for Anantapur farmers, since it survives the rough terrain and the uncertainty of rainfall. ICRISAT's findings show that even under a climate change regime, crop yield gaps can still be significantly narrowed down with improved management practices and using Germplasm adapted for warmer temperatures (Wani et al., 2003a, Wani et al., 2012 and Cooper et al. 2009).

A drought tolerant groundnut variety, ICGV 91114, introduced by ICRISAT through farmer-participatory varietal selection has covered to 25,000 ha of the 0.8 million ha groundnut area in the Anantapur district. It has been released for cultivation in three states of India - Andhra Pradesh, Orissa and Karnataka. The choosy farmers of the district are multiplying ICGV 91114 seeds with alacrity, helped by an ICRISAT-initiated public-private seed partnership. Another drought tolerant variety, ICGV 00350, is gaining popularity in the states of Karnataka and Andhra Pradesh.

Integrated Watershed Management comprises improvement of land and water management, integrated nutrient management including application of micronutrients, improved varieties and integrated pest and disease management; and substantial productivity gains and economic returns by farmers (Wani et al. 2003b). The goal of watershed management is to improve livelihood security by mitigating the negative effects of climatic variability while protecting or enhancing the sustainability of the environment and the agricultural resource base. Greater resilience of crop income in Kothapally, Ranga Reddy district of Andhra Pradesh in the drought year 2002 was indeed due to watershed interventions. While the share of crops in household income declined from 44% to 12% in the non-watershed project villages, crop income remained largely unchanged from 36% to 37% in the watershed village (Wani et al. 2009). Agroclimatic analysis coupled with crop-simulation models, and better seasonal and medium duration weather forecasts, help build resilience to climate variability/change in watersheds (Kesava Rao et al. 2008).

This means that high yields are still possible under variable climate if farmers combine improved practices with climate-adapted crop varieties. Hence, the challenge today is to encourage rainfed farmers to adopt these improved options to increase productivity and profitability of their crops, and to become more resilient under climate variability. Several suggestions (Anonymous 2012) were made on strengthening the research and development in animal husbandry particularly in sheep farming as it is the lifeline for small and marginal farmers in Anantapur. An improved agromet advisory service at the local level along with associated weather insurance packages is a sure way to enhance the resilience of poor farmers.

6.0 Conclusions

This study to use climate data and MODIS NDVI imageries to understand the abiotic stress on crops at district level and link it with the crop acreage and productivity, with particular reference to groundnut in Anantapur district of Andhra Pradesh could produce some interesting results. These results indicate the need to further continue and strengthen such studies coupled with more frequent space-based monitoring and specific ground truth survey. Ultimate aim is to help the poor farmers of Anantapur district to sustain their agricultural production even under the threat of climate change. Developing protocols for mapping of abiotic stresses at regional level are helps to monitor the crops in near real-time. The time to act for addressing the impacts of present climate variability and future climate change through better weather based agro advisories and crop monitoring using new science tools like satellite based imageries and GIS is now, and we cannot wait any more.

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