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Impact of Meteorological Parameters on the Economic Well-being in East Godavari and Vishakapatnam Districts of Andhra Pradesh, India

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Abstract:

The changing precipitation pattern and its impact on agricultural resources are important problems leading to social and economic issues. Studies have been carried out at regional and global scales to understand the changes that are taking place with reference to meteorological parameters. Agriculture is sensitive to both short and long term changes in weather, which in turn affect crop productivity and thereby the Gross Domestic Product (GDP) of the region. The present paper has examined the climate variability in East Godavari and Vishakapatnam districts of Andhra Pradesh, India. The main aim of this study is to identify the changes in annual, seasonal and monthly pattern of precipitation and their impacts on agricultural productivity. For this, land use patterns, climatic factors, agricultural productivity and GDP for the period 1980-2008 were used. Statistical methods including percent deviation of rainfall, multiple regression analysis, bio-economic and Ordinary Least Square (OLS) methods were used. The land use patterns for the region were derived and agro-climatic regions were identified for both the districts. The major findings include identification of the years in which excess rainfall has occurred in the two districts, 21% for East Godavari and 10% for Vishakapatnam. The monthly and seasonal analysis of rainfall has shown that the south west monsoon contributes maximum to the productivity of rain fed crops in the region. The bio-economic model and the OLS results have indicated that Visakhapatnam *district is more sensitive to changes to the meteorological parameters and has higher impact on economic well being when compared to East Godavari.*

Key words: land use patterns, multiple regression analysis, bio-economic modeling, ordinary least square model, agricultural productivity

Introduction

India is a tropical country and its agricultural planning and water utilization are dependent on monsoon rainfall. More than 75% of rainfall generally occurs during the monsoon season even though this rainfall is usually uneven both in time and space. In addition, there is a growing consensus that emissions of greenhouse gases due to human activity will lead to changes in both temperature and precipitation. Since temperature and precipitation are direct inputs in agricultural production, many believe that the largest effects will be in the agriculture sector (Cf. Olivier Deschenes et al. 2006). This is also expected to have an impact on the economic well being of the country. Hence a critical analysis of the rainfall patterns and any changes in the frequency and intensity is worth studying. Studies have been carried out in various regions of the country. Rainfall is a crucial agro-climatological factor and its analysis is an important perquisite for agricultural planning in India (Alak Gadgil 1986). Jagannadhasarma (2005) has analyzed the rainfall pattern of the coastal zone of Krishna-Godavari River Basin Andhra Pradesh, India. G.Vennila (2007) has also studied the rainfall variation of Vattamalaikarai sub-basin, Tamil Nadu, India. The present study aims to understand the changes in climatic conditions for the period 1980 to 2008 in the districts of East Godavari and Vishakapatnam.

Study Area

The State of Andhra Pradesh, India is divided into four regions: Telangana, Coastal Andhra, Uttarandhra, and

Rayalaseema. Coastal Andhra comprises nine districts and is rich in agricultural resources, owing to the delta of the Godavari and Krishna rivers. The districts of Vishakapatnam and East Godavari are two of the nine districts in this region (Figure 1). The districts are further subdivided into administrative blocks called 'mandals.' The district of East Godavari comprises 57 mandals, while Vishakapatnam has 44 mandals. The entire region is divided into agro-climatic zones on the basis of rainfall distribution, soil conditions and agricultural patterns.

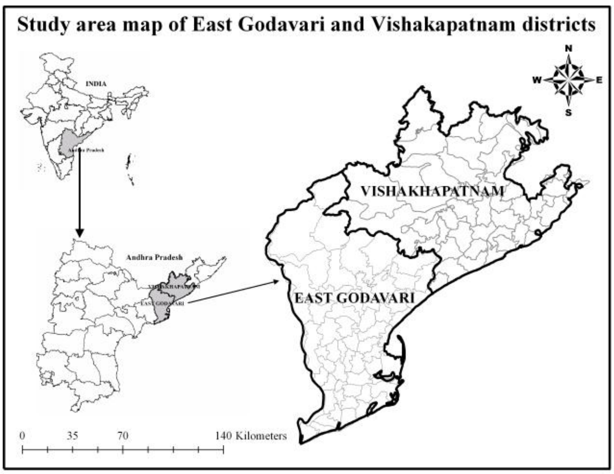

Figure 1. Study area map of East Godavari and Vishakapatnam districts

The number of mandals falling in the agro-climatic zones is given in Table 1 and shown in Figure 2. Both districts chosen for this study are predominantly in the North Coastal Zone. The district of East Godavari has 48 mandals in the North Coastal Zone and 7 mandals in the High Altitude and Tribal Zone, out of the 57 mandals in the district. Similarly, as shown in Figure 2, Vishakapatnam has 42 mandals in the North Coastal Zone and only 2 mandals in the High Altitude and Tribal Zone.

Table.1 Districts showing number of mandals in three agro-climatic zones

Agro-climatic zones	Temperature	Rainfall	Soil	Crops	Districts chosen for this study	
					East Godavari	Vishaka patnam
North Coastal Zone	Max: 33-36^{0}c Min: 26-27^{0}c	South west monsoon 1000-1100mm	Red soils with clay base, pockets of acidic soils	Paddy, ground nut, Jowar, bajra, Sugarcane, Mestas, jute, sun hemp, sesamum, black gram and horticultural crop.	48	42
Krishna-Godavari Zone	Max: 32-36^{0}c Min: 23-24^{0}c	South west monsoon 800-1100mm	Deltaic alluvium, Red soil with clay, Black clay soils, Red loams, coastal sands and saline soils.	Paddy, groundnut, Jowar, bajra, tobacco, cotton, chilies, sugarcane and horticulture crops.	2	0
High Altitude and Tribal Zone	-	South west monsoon >1400mmm	Hill slopes, Undulating transported soil.	Horticultural crops, millets, pulses, chilies, turmeric and paper.	7 Total 57	2 Total 44

Figure 2. Agro-climatic zones in the districts of East Godavari and Vishakapatnam

The weather in East Godavari is moderate throughout the year, except during the months of April and May when the temperature may reach a maximum of 48°C. The normal rainfall for the district is 1219mm. Visakhapatnam is also the hottest during the month of May, with an average maximum temperature of about 36 °C, and coolest in the month of January with an average maximum temperature up to 29 °C. The normal rainfall received by the district is 1202mm.

Methodology

The data for this study is obtained from Directorate of Economics and Statistics (DES), Government of Andhra Pradesh for the period 1980 – 2008. Meteorological, agricultural and related data are collected on a monthly basis. The land use / land cover map for the districts of East Godavari and Vishakapatnam was derived from IRS - LISS III satellite imagery (National Remote Sensing Centre, Hyderabad). Arc GIS 9.1 software was used for mapping and carrying out the spatial data analysis at district and mandal level to understand the spatial distribution of the various meteorological parameters and its impact on agricultural productivity. Statistical analysis was carried on the data for the two districts using SYSTAT version 7.0.1 software. Percent deviation of rainfall, coefficient of variance, and multiple regression models are analyzed to correlate the relationship between rainfall, temperature and crop yield. The multiple linear regression analysis (bio-economic modeling) is done using equation (1) to find out the overall impact of rainfall, temperature, human labour and fertilizer input on the crop yield.

$$Y=f\ (F, HL, AR, DFNR, MAXTEMP, MINTEMP) \qquad (1)$$

Where, Y= Yield in kg/hectare; F= fertilizers in kg/hectare; HL=Human Labor hour per hectare; AR= Mean Annual Rainfall (mm); DFNR=%Deviation from normal Rainfall; Max tem=Maximum Temperature in ^{0}C; Min tem=Minimum Temperature in ^{0}C.

The results of the cropping pattern and productivity were used to identify the impact on agricultural productivity while the Ordinary Least Square model (OLS) was used for the correlation between the agricultural GDP and prices.

Results and Discussions

The analysis for the meteorological parameters and its impact on economic well being of the region was studied over a period of 28 years. During this period the rainfall, temperature, crop productivity and land use data were collected and analyzed for the two districts of East Godavari and Vishakapatnam. The land use pattern for the region was derived from the satellite imagery and is presented in Figure 3 (a & b). As we understand that human alteration of the patterns of land use is one of the most profound impacts on the functioning of natural ecosystems (Steffen et al. 2004), its impacts are felt on water quality and ecosystem function. This could be of particular concern in high-elevation ecosystems owing to the combined effects of increased precipitation, steep slopes, limited vegetation, large areas of exposed bedrock, and shallow soils, often resulting in rapid hydrological flushing during snowmelt and rainfall (Cf. Williams et al. 1993). After mapping the land use / land cover patterns for the two districts, the agro-climatic regions were demarcated to identify the types of agricultural land and also understand the cropping patterns in the study areas.

A concurrence was found on comparison of Figure 2 and Figure 3 (a & b) and it was found that most of the agricultural land in both districts is covered under North Coastal Zone. The High Altitude and Tribal Zone are covered with agricultural plantation / barren rocky/ uncultivable land / deciduous forest / scrub land in Vishakapatnam while in East Godavari most of the zone is covered with agriculture land/ swamp / mangrooves / rivers. The Krishna-Godavari zone of East Godavari district is primarily identified as agricultural land. These land use patterns are also reflected in the types of crops grown in the regions. In the North Coastal and Krishna-Godavari zones the crops grown are predominantly paddy, groundnut and sugarcane. Chillies are widely grown in the High Altitude and Tribal Zone of both the districts.

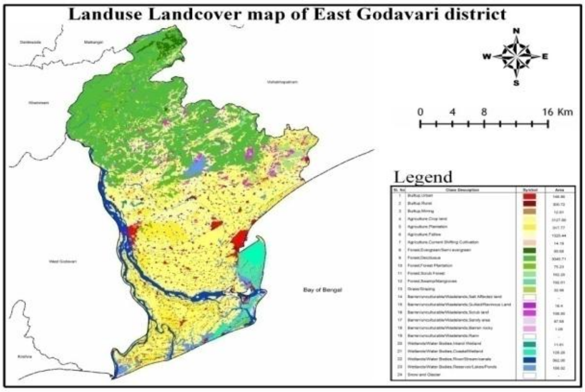

Figure 3(a). Land use/ Land cover map of East Godavari district

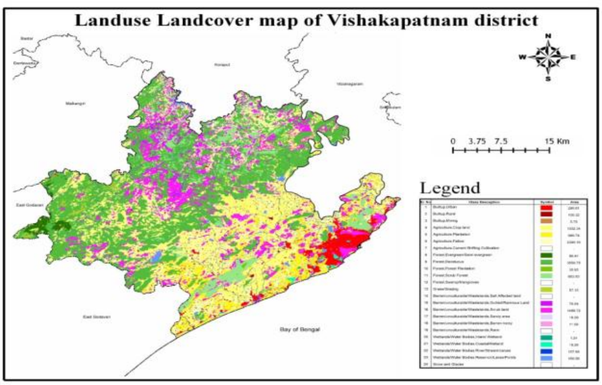

Figure 3(b). Land use/ Land cover map of Vishakapatnam district

An analysis of the rainfall received and its deviation from normal was done at district level for the two districts. The percent deviation of annual rainfall from normal rainfall as calculated for the period 1980-2008 is shown in Figure 4. The percent deviation from normal is classified as per the IMD standards for excess, normal, deficit and scanty. It can be observed that the maximum excess rainfall is received in the year 1989-1990 for both districts while the deficit rainfall for the districts is seen in the year 2002-2003. The number of years in each of these categories for the districts is shown in Table 2.

Kandiannan et al. (2008) analyzed high rainfall tract of northern agro-climatic zone of Kerala for 26 years, between 1980-2005. The results also showed deficit rainfall for the same year of 2002 – 2003, as observed in the present study. Anup

Das et al. (2008) studied the annual rainfall distribution pattern of Umiam, Meghalaya, India for the period of 27 years and the deficit rainfall was observed in the year of 1998. However, an interesting observation in this study was the more erratic nature of the annual rainfall observed during the period 2006-09.

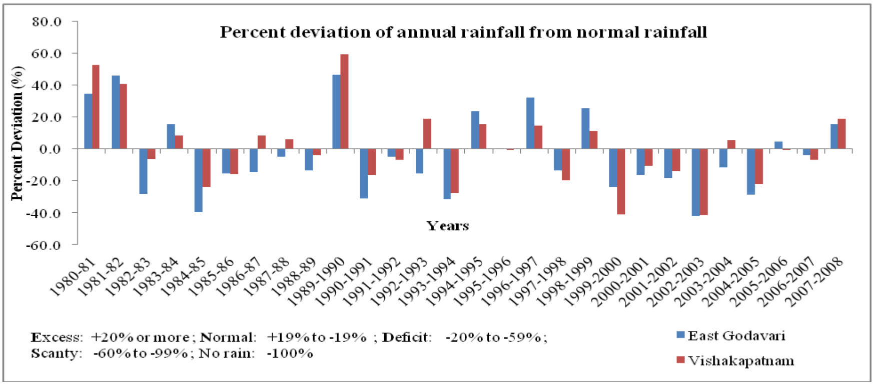

Figure 4. Graph showing percent deviation of annual rainfall from normal in East Godavari and Vishakapatnam districts.

Table 2. Distribution of percent deviation values in the two districts of Andhra Pradesh for the period 1980 – 2008 in various seasons.

	No. of years of rainfall distribution				
Seasons	Excess	Normal	Deficient	Scanty	No rain
East Godavari district Normal rainfall- 1219mm					
Annual rainfall	6	15	7	-	-
SWM	9	10	9	-	-
NEM	4	11	10	3	-
WINTER	7	4	5	9	2
HOT	3	4	13	7	1
Vishakapatnam district Normal rainfall- 1202mm					
Annual rainfall	3	20	5	-	-
SWM	9	14	5	-	-
NEM	10	7	8	3	-
WINTER	5	8	5	4	6
HOT	3	7	14	2	2
Excess- +20% or more; Normal- +19% to -19%; Deficit- -20% to -59%; Scanty- -60% to -99%; No rain- -100%					

The spatial analysis and distribution of rainfall for the region is important. Figure 5 shows the contour of the rainfall patterns in the region, with reference to the mean annual rainfall.

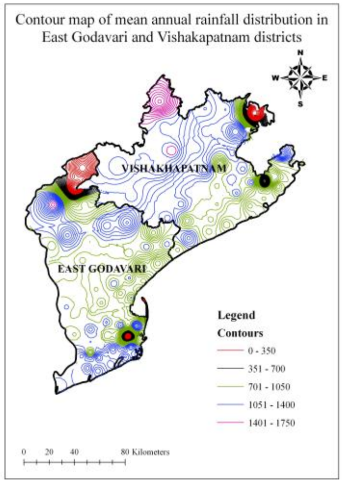

Figure 5. Distribution of mean annual rainfall in East Godavari and Vishakapatnam districts

Seasonal analysis is done for the districts East Godavari and Vishakapatnam to find out the rainfall patterns in the monsoon seasons i.e., South West Monsoon (SWM), North East Monsoon (NEM), Winter Period and Hot Period. The major amount of rainfall in the districts is received during SWM, while a significant amount is received in the NEM period. From the results (Table 2), it is found that during SWM 32% of the years received excess rainfall in the districts East Godavari and Vishakapatnam. However, when compared to Vishakapatnam, East Godavari district has recorded higher (32%) number of years with deficit rainfall during the same period for the south west monsoon. Similarly for the NEM, also East Godavari district showed more deficit years (35%) of rainfall when compared to Vishakapatnam (28%). In respect of excess rainfall, East Godavari districts showed 35% of years, while 14% was recorded for Vishakapatnam. Studies undertaken in similar parts of the country indicate that the trend is fairly consistent showing irregular monsoon patterns (G Malla 2008). The excess, normal, deficit and scanty years of rainfall using monthly rainfall data during the period 1980-2008 was calculated and the results were given in Table 3. It is observed that during the months June to October, which is also part of the SWM period, 25 to 35% of the years have received excess in both districts. Rao et al. (2009) in a similar analysis observed the shifts in monthly peak rainfall pattern in southern peninsular region. The study also registered that the probabilities of occurrence of deficit rainfall conditions have increased between 1991 and 2003.

Table 3. Monthly distribution of percent deviation values in the two districts of Andhra Pradesh for the period 1980 – 2008

Month	No. of years of rainfall distribution											
	East Godavari						Vishakapatnam					
	Normal rainfall (mm)	E	N	D	S	No rain	Normal rainfall (mm)	E	N	D	S	No rain
June	129	8	10	8	2	-	129	10	10	8	-	-
July	197	7	8	12	1	-	197	8	8	12	-	-
August	196	7	11	9	1	-	196	9	11	8	-	-
September	190	9	4	14	1	-	190	7	13	8	-	-
October	205	8	11	7	2	-	205	10	6	10	2	-
November	87	6	2	7	13	-	87	5	1	9	13	-
December	5	6	4	1	10	7	5	7	2	2	10	7
January	10	9	0	3	7	9	10	9	2	4	5	8
February	12	7	1	3	10	7	12	6	2	3	8	9
March	21	7	2	1	12	6	21	7	2	5	10	4
April	35	10	4	5	7	2	35	14	5	3	4	2
May	115	2	1	12	12	1	115	3	2	11	9	3
E= Excess- +20% or more; N= Normal- +19% to -19%; D= Deficit- -20% to -59%; S= Scanty- -60% to -99%; No rain- -100%												

From the analysis it is found that the SWM and NEM seasons are receiving uneven pattern of rainfall and this effect is due to changes in the climatic conditions and impact of human activities on the environment. These results also impact the agricultural productivity of the study area. Rainfall and temperature directly affect the agriculture and food supply through their effects on crop productivity. The agricultural productivity of rain fed crops varies largely depending on the monsoon pattern in any given year. A study by Pramod K Agarwaal et al. (2010) in upper river Ganga basin carried out showed that the impact of overall deficit of 23% in rainfall during the south-west monsoon in 2009-10 had adversely affected *Kharif* production. Studies have also shown that climate change also causes disruption in normal weather pattern, changing intensity and duration of monsoon (G.Malla 2008). In the current study a large part of the net sown area is rain-fed, thereby making the productivity in this area very sensitive to any changes in the pattern of rainfall.

To assess the impact of agricultural productivity in these agro-climatic regions in both the districts, bio-economic modeling and Ordinary Least Square models have been used. The inputs of the bio-economic model include climate variables (rainfall and temperature), fertilizers, human labor hour to study the impact on agricultural productivity. The output is based on multiple regression equations to determine the agricultural productivity in different conditions. A total of 5 different case conditions are analyzed (Table 4).

Table.4 Cases considered for regression analysis for assessing agricultural productivity

case 1	case 2	case 3	case 4	case 5
Mean annual rainfall	Percent Deviation from normal	Mean annual rainfall	Mean annual rainfall	Mean annual rainfall
Max Temp	Max Temp	MaxTemp	Max Temp	Max Temp
Min Temp	Min Temp	Min Temp	Min Temp	Min Temp
Fertilizers	Fertilizers	Fertilizers	-	-
Human labour hour	Human labour hour	-	Human labour hour	-

The data for three crops: paddy, groundnut, sugarcane in the North Coastal Zone and chillies for the High Altitude and Tribal Zone was gathered using this model to understand the impact of parameters in the last 2 decades. The multiple correlations, obtained in the analysis, which is the percent of variance in the dependent variable, helped explain collectively by all of the independent variables. Table 5 shows the regression values obtained in all the 5 cases for the three crops in the different zones.

Table 5. Results of Regression analysis for crops grown in different agro-climatic zones of East Godavari and Vishakapatnam district

Agro-climatic zone	**Crops**	**R^2 values**				
East Godavari		Case 1	Case 2	Case 3	Case 4	Case 5
NCZ & KGZ	Paddy	0.68	0.68	0.55	0.43	0.25
	Groundnut	0.65	0.65	0.64	0.65	0.56
	Sugarcane	0.62	0.62	0.34	0.4	0.33
HATZ	Chillies	0.61	0.61	0.44	0.47	0.43
Vishakapatnam						
NCZ	Paddy	0.89	0.89	0.82	0.81	0.79
	Groundnut	0.79	0.79	0.77	0.77	0.75

	Sugarcane	0.91	0.91	0.53	0.91	0.18
HATZ	Chillies	0.90	0.9	0.75	0.76	0.75
NCZ – North Coastal Zone; KGZ- Krishna-Godavari Zone; HATZ-High Altitude and Tribal Zone						

Results indicate that when the variables of actual average rainfall, maximum temperature, minimum temperature, fertilizers and human labour hour (case 1) are used with regression analysis, the variability observed is approximately 68% and 89% in productivity for paddy in East Godavari and Vishakapatnam districts respectively. Under similar conditions the productivity of groundnut in East Godavari showed 65% of variation and 79% in Vishakapatnam district while sugarcane productivity varied by 62% in East Godavari and 91% in Vishakapatnam. In the overall analyses, Vishakapatnam has high variation and is more sensitive to changes with reference to the meteorological parameters (Case 1) when compared to East Godavari. This would lead to an inference that Vishakapatnam is showing more climatic variations than the district of East Godavari. The High Altitude and Tribal Zone area which covers about 16% has chillies as its principle crop. East Godavari showed 61% variation while in Vishakapatnam 90% variation was observed for Case 1 (Table 5). However, chillies showed 75% variation in productivity in Vishakapatnam while 43% variation in East Godavari for Case 5 of the analyses.

It was observed that in Case 1 actual rainfall data is used, while in case 2 the percent deviation data is used for the modeling and calculation of the r^2 values. As both are derived from the same source, as expected, both values are similar. Hence, any one case can be used for further productivity impact calculations. In case 5 when only the weather parameters are used, it can be seen that the correlation values are not significant in the case of East Godavari. However, case 5 is fairly well correlated for Vishakapatnam and therefore this may not be the appropriate method to indicate the variations occurring in the crop productivity. A similar study by A.M.Tunde et al (2011), used regression and correlation analyses to examine the impacts of temperature, relative humidity, rainfall and number of rainy days on food production, where the results revealed that, while maize production is correlated highly with rainfall amount, relative humidity, number of rainy days, maximum and minimum temperature correlated with the crops but very weak. This also clearly indicates that the climatic variables examined have an impact to a certain limited extent and is dependent not only on the crop type but also the terrain. Based on the impacts on productivity, the effect on Gross Domestic Productivity was carried out by using Ordinary Least Square model (OLS). The OLS model was used to estimate the R^2 values. The analysis uses weather, agricultural GDP, productivity and prices data. The index number used in the analysis of the datasets is obtained based on productivity of the crops to be analyzed. Two data sets are generated in the present study and the results for the R-square, Multiple-R, T-stat are presented in Table.6. A similar study analyzed the impact of weather on commodity prices and measured the degree of weather risk inherent on commodity prices and consequent linkages to inflation, exchange rates and GDP by using ordinary least square and co-integration models (Laddha 2007).

Table 6. Results of Ordinary Least Square model for East Godavari and Vishakapatnam districts.

Agro-climatic zones	Districts	Commodities	Observations	Prices, Index number, Annual rainfall			Prices, Index number, Annual rainfall , GDP		
				Multiple R	R Square	T - stat intercept	Multiple R	R Square	T - stat intercept
NCZ & KGZ	East Godavari	Paddy	11	0.66	0.44	0.17	0.77	0.59	3.75
		Ground nut	11	0.60	0.36	2.16	0.88	0.78	5.06
		Sugarcane	9	0.76	0.58	-0.51	0.81	0.65	3.49
HATZ		Chillies	11	0.64	0.41	1.21	0.47	0.22	2.56
NCZ	Vishakapatnam	Paddy	11	0.20	0.04	3.50	0.82	0.68	5.08
		Ground nut	11	0.38	0.15	4.89	0.72	0.52	2.90
		Sugarcane	9	0.25	0.06	2.49	0.35	0.13	1.50
HATZ		Chillies	11	0.69	0.47	3.12	0.63	0.40	0.98
NCZ – North Coastal Zone; KGZ – Krishna – Godavari Zone; HATZ – High Altitude and Tribal Zone									

From the results it can be seen that the correlation values for the data incorporating the GDP have shown a good correlation for groundnut (r^2 0.78) and sugarcane (r^2 0.65) in the North coastal and the Krishna-Godavari Zones of East Godavari district, while paddy has shown a reasonably good correlation (r^2 0.68) in the North Coastal Zone of Vishakapatnam. Chillies in the high altitude zone have shown poor correlation (r^2 0.22 and 0.40), which is indicative of the fact that the contribution of chilies to the agricultural GDP is not very significant.

Conclusions

Meteorological parameters contribute significantly towards the economic growth of the region. The study was carried out in the two districts of Andhra Pradesh viz. East Godavari and Vishakapatnam, with an aim to understand the relation between meteorological parameters and the agricultural productivity of the rain-fed crops in the North Coastal Zone and the High Altitude and Tribal Zones of the two districts. The results from seasonal rainfall analysis show that during SWM, 32% of the years received excess rainfall in the districts East Godavari and Vishakapatnam. However, when compared to Vishakapatnam, East Godavari district has recorded higher (32%) number of years with deficit rainfall. Similarly for the NEM, East Godavari district showed more deficit years (35%) of rainfall when compared to Vishakapatnam (28%). Monthly analysis showed that 25 to 35% of the years have received excess rainfall for the months June to October, which is also part of the SWM period. Results from multiple regression analysis indicate that the variables of actual average rainfall, maximum temperature, minimum temperature, fertilizers and human labour hour (case 1) is around 68 and 89% of variation in the productivity of paddy in East Godavari and Vishakapatnam districts, as observed for case 1. From the overall analysis it is found that Vishakapatnam district is affected with a high percent of variation in productivity of crops in both North Coastal Zone and High Altitude and Tribal Zones. The study concludes that the impact of climate variability on crop productivity and further on agricultural GDP is significant for ground nut, sugarcane and paddy in the north coastal agro climatic region for both the districts while it is not significant in case of chilies grown in the high altitude areas.

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