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Variability and Trend in Summer Monsoon Rainfall and its Correlation with Crop Yield in the Districts of Andhra Pradesh During 2011-2020

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ABSTRACT

In the context of climate change and its impact on agriculture, the paper analyses the trend of monsoon rainfall and its correlation with crop yield in Andhra Pradesh. The summer monsoon is the main rainy source of water for the state of Andhra Pradesh. The Kharif crops depend on the southwest monsoon rains to the extent that its adverse variability may lead to water stress and agrarian crisis. It has been observed from the study that in recent years the contribution of monsoon rainfall during September is increasing, and any harvest during the month is correspondingly affected, leading to a decline in the crop yield.

INTRODUCTION

Andhra Pradesh (AP) is an agrarian state where about 62% of its population still depends on agriculture. Agriculture in the state is mainly dependent on rain-fed riverine systems and irrigation. The monsoon rains feed the rivers and hence help agriculture in the state. Of all the meteorological factors that have a bearing on agriculture and crop yield, rainfall has an indubitable influence, and its variability can cause water stress leading to an agrarian crisis in certain pockets of the farming-sensitive economy of the state.

As per the National Crime Records Bureau (NCRB), Andhra Pradesh recorded the third highest number of farmer suicides in India in 2019, with a total of 1,029 farmers taking their own lives in the state, against 664 in 2018. The data showed that 438 farmers in AP who owned farmland, 306 tenant farmers, and 401 agricultural laborers had died by suicide (https://www.thenewsminute.com/article/andhra-pradesh-records-third-highest-farmer-suicides-country-132140, https://www.newindianexpress.com/states/andhra-pradesh/2020/sep/02/1029-farmers-committed-suicide-in-andhra-pradesh-last-year-up-from-664-in-2018-2191296.html).

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Andhra Pradesh is located between 12°41′ and 19.07°N latitude and 77° and 84°40′E longitude. It has a coastline of 974 km, with two major rivers (Godavari and Krishna) flowing across the state. The monsoon year is between June to September. The climate varies across the state. It is hot and humid in coastal districts, while it is mainly semi-arid in Rayalaseema districts. According to the standards of the Indian Meteorological Department (IMD), heavy rainfall is categorized into three categories- heavy, very heavy, and extremely heavy, if the rainfall is in the ranges of 64.5-115.5mm, 115.6-204.4 mm, and above 204.4 mm, respectively.

The Problem

Ray et al. (2019) observed that during the recent decade (2007-2016) annual extreme rain events increased by 18%

when compared to the past decade (1997-2006). Goswami et al. (2006) and Mukherjee et al. (2005), pinpointed that there is a significantly increasing trend in the frequency and magnitude of extreme rain events and the frequency of heavy and very heavy rain events (while the frequency of moderate events decreased significantly) over central India.

Dash et al. (2009), reported that the frequency of long spells is decreasing, and the frequency of short rainy spells, dry spells, and prolonged dry spells are increasing. Krishna Kumar et al. (2004) and Mallick et al. (2007), observed that the crop yield during the Kharif season is low when monsoon rainfall is low.

Considering the rain gauge data of 1476 stations for the period 1901-2003, Guhathakurta & Rajeevan (2006), analyzed the spatial and temporal trend in rainfall over the country, the homogeneous regions, and its 36 subdivisions. Significantly, an increasing trend was observed in coastal Andhra Pradesh and Rayalaseema during the monsoon. The increasing trend in July and August is statistically significant while in September, the trend increased which is statistically not significant. Monsoon rain registered decreasing trend in June which again is statistically not significant. Over Rayalaseema, the trend was increasing with statistical significance during June and July. It also shows an increasing trend without significance in August but registered decreasing trend in September month, which is statistically not significant. Annual rainfall has been increasing in July and August months and decreasing in September over coastal Andhra Pradesh.

Rainfall data for 102 years analyzed using MK and Sen's slope estimator test by Rajwade et al. (2018), observed an increasing trend in annual rainfall in Andhra Pradesh and Telangana states. Specifically, an increasing trend of a magnitude ranging between 7 and 9% in mean annual rainfall in coastal Andhra Pradesh and Rayalaseema regions is observed by Vijay et al. (2010). Annual precipitation time-series data from 1991 to 2019 also indicated an increasing trend during June and monsoon seasons and a decreasing trend in the July and winter seasons (Significant at A 5% level) in the Prakasam district of AP. However, the trend and pattern of precipitation in coastal Andhra analyzed using daily and monthly rainfall data for 36 years from 1983 to 2018 by Baig et al. (2021), exhibited a decreasing trend. Climatic parameters and temperature impacted rainfall trends on a seasonal and annual scale as evidenced in an investigation by Aruna Jyothy et al. (2021). They reported that relative humidity, vapor pressure, and wind speed significantly impacted rainfall at Kurnool while vapor pressure impacted rainfall at Kakinada. At Machilipatnam, vapor pressure and temperature influenced rainfall considerably.

Rao et al. (2011) analyzed trends in rainfall over the districts of erstwhile Andhra Pradesh state using 1° X 1° gridded and rain gauge data. While the gridded data showed no trend over the state as a whole, the block level and gridded data showed a mismatch of increasing/decreasing trends in the districts.

It is evident from the above studies that rainfall has been mostly exhibiting an increasing trend in Andhra Pradesh. Most of the studies focused on the variability and trends in different rainfall events considering 30 or more years of data. However, the limitation of these studies is that they have not studied district-wise rainfall trends, which could vary with the corresponding impact. Further, recent data was not considered. Such an analysis is needed for policy-related decisions like mitigation and respite measures of the government in view of the climatic variations across the districts of Andhra Pradesh.

Objectives of the Study

Against this backdrop, the present study focuses on analyzing rainfall trends for the period 2011-2020 across the districts of Andhra Pradesh for the summer monsoon season. The study also considered mean seasonal rainfall distribution and anomalies for the period 1991-2020 to understand inter-decadal variation during the recent climatological time strip.

MATERIALS AND METHODS

A statistical analysis of rainfall for all the districts of Andhra Pradesh is carried out to identify the variability and trends in monthly rainfall in the monsoon season for the decade 2011-2021. The trend in the time-series rainfall data is observed using linear regression and the Mann-Kendall test. The monthly average rainfall is analyzed by computing the mean, standard deviation, and coefficient of variance. The correlation between crop yield and seasonal rainfall is carried out to understand the association between rainfall and yield at study locations for the reference period. Data collected from Indian Meteorological Department (IMD) was analyzed for this purpose.

The crop data has been garnered from the website https://aps.dac.gov.in/APY/Public_Report1.aspx. The data is extracted from "The Area and Production Statistics", Ministry of Agriculture and Farmers Welfare.

Rao et al. (2011) and some other studies observed that the gridded data has an inherent inadequacy in presenting rainfall as it is an area weighed average rainfall and hence is at variance with the point-location rainfall. In this study, the IMD 0.25 degree X 0.25 degree gridded-rainfall data is used only to analyze anomalies in the rainfall regime in

various districts during the recent climatology period and also to address the issue of the unavailability of data at various point locations. To address the issue of parity and correlation, rainfall at stations is used to reflect the district rainfall and crop yield in the district as a unit. This analysis helps in planning agricultural operations. A proper understanding of the trends in rainfall and its correlation with crop yield will help in foreseeing associated risks and thereby reduce spending on stimulus packages.

Fig. 1 depicts the study area with 13 districts of Andhra Pradesh each with its geographical extent. Anantapur is the largest district with 19.1 thousand sq.km followed by Kurnool with an area of 17.7 sq.km. Srikakulam is the smallest district with 5.8 thousand sq.km out of 13 districts in Andhra Pradesh.

RESULTS AND DISCUSSION

Inter Decadal Variations (1991-2020)

The mean seasonal rainfall distribution and anomalies: Fig. 2(i)(a) depicts the mean rainfall during the climatology 1991-2020 while 2(i)(b-d) shows the mean rainfall during the first decade (1991-2000), the middle decade (2001-2010), and the last decade (2011-2020) respectively. Similarly, 2(ii)(a-d) displays mean rainy days (days with rainfall of 2.5 mm or more); 2(iii)(a-d) moderate rainy days (days with 15.5 mm or more rainfall) and 2(iv)(a-d) heavy rainfall (days with rainfall 64.5 mm or more). There are few district-wise very heavy and extremely heavy rainfall days or episodes to perform the analysis.

Fig. 2(i) (a) shows the mean seasonal rainfall in the districts of Andhra Pradesh during the climatological period 1991-2020. A gradual decrease in rainfall as one moves from north to south/southwest is evident in the state. The north coastal districts of Andhra Pradesh, namely, Srikakulam, Vizianagaram, Visakhapatnam, East and West Godavari districts, and South Coastal district Krishna show a conspicuously higher rainfall range of 600-800 mm with mountainous regions in western parts of these districts having received even higher rainfall of 800 mm or more. Eastern stretches of Guntur recorded 500-600 mm rainfall while the western parts of Guntur, central parts of Kurnool, and a smaller southern portion of Chittoor received 400-500 mm. The rainfall received in the rest of the south coastal districts Prakasam and Nellore, the remaining parts of Rayalaseema districts ranged between 300-400 mm with the lowest rainfall of about 300-50 mm recorded in western parts of Anantapur and northern parts of Nellore. In Fig. 2(i)- the (b), (c), and (d) panels display the decadal anomalies with respect to climatological normal rainfall. The figures show distinct positive and negative anomalies of mean decadal rainfall in the first decade (1991-2000), the middle decade (2001-2010), and the last decade (2011-2020) with respect to the long-period normal mean rainfall climatology. It clearly shows that the rainfall anomalies in the first decade are quite high in the southwestern and southern parts of Andhra Pradesh comprising Prakasam and Nellore followed by large stretches of Kurnool, southern parts of Anantapur, northern pockets of Chittoor, and discrete eastern areas of Kadapa districts. Only parts of Godavari districts have positive anomalies while the rest of the state has negative anomalies in the mean decadal rainfall. In the middle decade, parts of northern coastal districts Viz., Srikakulam, Vizianagaram, Visakhapatnam, and East & West Godavari, Guntur, Prakasam, Kurnool, Anantapur, and many parts of Kadapa recorded demarcated positive mean decadal rainfall anomalies. There is a precariously large deficit in the districts of Krishna, Nellore, and Chittoor during the middle decade. During the recent decade 2011-2020, conspicuously, parts of the coastal districts-namely, West Godavari, Krishna, Guntur, and southern parts of Chittoor recorded large positive anomalies of 50-100 mm or more mean decadal rainfall. Interestingly, major areas of Anantapur, Nellore, some parts of Kadapa, Srikakulam, Vizianagaram, Visakhapatnam, and East Godavari have positive anomalies up to 50 mm mean decadal rainfall. The remaining parts of the state have no negative anomalies. Thus, the mean rainfall regimes have exhibited distinctive decadal differences.

Mean rainy days: The mean rainy days (days with 2.5 mm or more rainfall as shown in Fig. 2(ii(a)) show a gradual decrease in the mean number of rainy days from the north to the southern districts of the state. The northern coastal districts have received a greater number of mean rainy days (30 days to 38; and above in mountainous areas of the northern districts) than the southern coastal districts and Rayalaseema (18 to 24 days) with eastern fringes of Kurnool and western parts of Prakasam district receiving a shade better with 24 to 28 days of rainfall during 122 days. There is a conspicuous increase in the number of rainy days during the latest decade 2011-2020. Smaller fragments of East and West Godavari, Guntur received 6 to 10 days of positive anomalies in the mean number of rainy days while larger stretches of Prakasam, Nellore, Kurnool, East Godavari, Visakhapatnam, and parts of the remaining districts also showed positive anomaly of 2 to 4 while smaller fringes of other districts have smaller negative anomalies up to 2 days of mean rainy days during the decade 2011-2020.

Mean moderate rainfall days: The mean Moderate rainfall days (15.5 mm or more) are shown in Fig. 2(iii(a). Mean moderate rainfall days of 12 to 16 are observed over

coastal districts from Srikakulam to Krishna districts with hilly areas recording 16 to 20 days. There are three clear stratified zones with a gradual decrease from north to south in respect of mean moderate rainfall 12-16 days, 10-12 days, and 8-10 days as observed in the Guntur district. Major portions of Kurnool and Chittoor recorded 8-10 days while the remaining southern coastal districts and Rayalaseema districts recorded 6-8 days with some pockets of Nellore and Anantapur getting only 4-8 days of mean moderate rainfall days during the climatological period 1991-2020. During the decade 2011-2020, all the districts recorded positive anomalies in the number of moderate rainfall days except Kurnool, Prakasam, some parts of Kadapa and Nellore, smaller stretches of Chittoor, Visakhapatnam and East & west Godavari districts. The districts of Vizianagaram, West Godavari, Krishna, and Guntur recorded positive anomalies for up to 4 days during the decade.

Mean heavy rainfall days: The mean heavy rainfall days (64.5 mm or more) during the period 1991-2020 are shown in Fig. 2 iv(a). Only the hilly areas of east Godavari recorded mean heavy rainfall days of 1.8 to 2 days. West Godavari, major parts of Krishna, and a few parts of East Godavari, Visakhapatnam, Vizianagaram, and Srikakulam reported mean heavy rainfall days ranging from 0.8 to 1.6. Rest parts of the state outside Rayalaseema districts, Prakasam and Nellore recorded 0.6 to .08 mean heavy rainfall days. It is seen that Rayalaseema districts, Prakasam, and Nellore recorded only 0.2 to 0.4 mean heavy rainfall days during the period 1991-2020. During the decade 2011-2020, most parts of Rayalaseema districts, Prakasam, and Nellore recorded negative anomalies of -0.5 to -1.0 days of mean heavy rainfall days. Major parts of Vizianagaram, Visakhapatnam, East Godavari, and smaller portions of other districts recorded positive anomalies of 0.5 days of mean heavy rainfall days. The mountainous areas of Visakhapatnam and Vizianagaram recorded mean heavy rainfall days of 0.5 to 1.0 during 2011-2020. It is thus observed that a large inter-decadal variation is recorded with no clear areal bias, with a gradual increase in the mean rainfall distribution and anomalies, rainfall intensities, and anomalies from 1991 to 2020.

Analysing Rainfall Trends During the Recent Decade (2011-2020)

District level analysis as per the IMD criteria for the rainy days to extreme weather rainy days (2.5mm to 204.4mm) is observed to be increasing in the recent decade.

The trend in mean rainfall for the period 2011-2021 for the monsoon season: Table 1 depicts the monthly mean rainfall in mm and the coefficient of variance for the study period in Andhra Pradesh. From the analysis, it is evident that September month contributes the maximum rain (28.5%), followed closely by August (27.5%), July (26.3%), and June (17.7%).Fig. 3 shows rainfall for each month in the monsoon season. The trend lines for each month and season are also

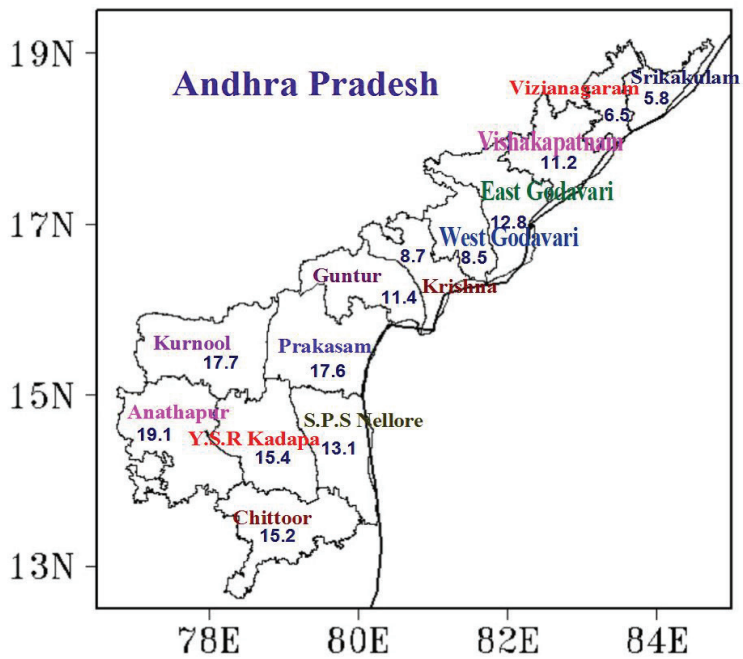

Fig. 1: The district-wise geographical area (shown in bold numbers in thousands of sq.km) of the state of Andhra Pradesh (as per the information published by the Directorate of Economics & Statistics, Vijayawada).

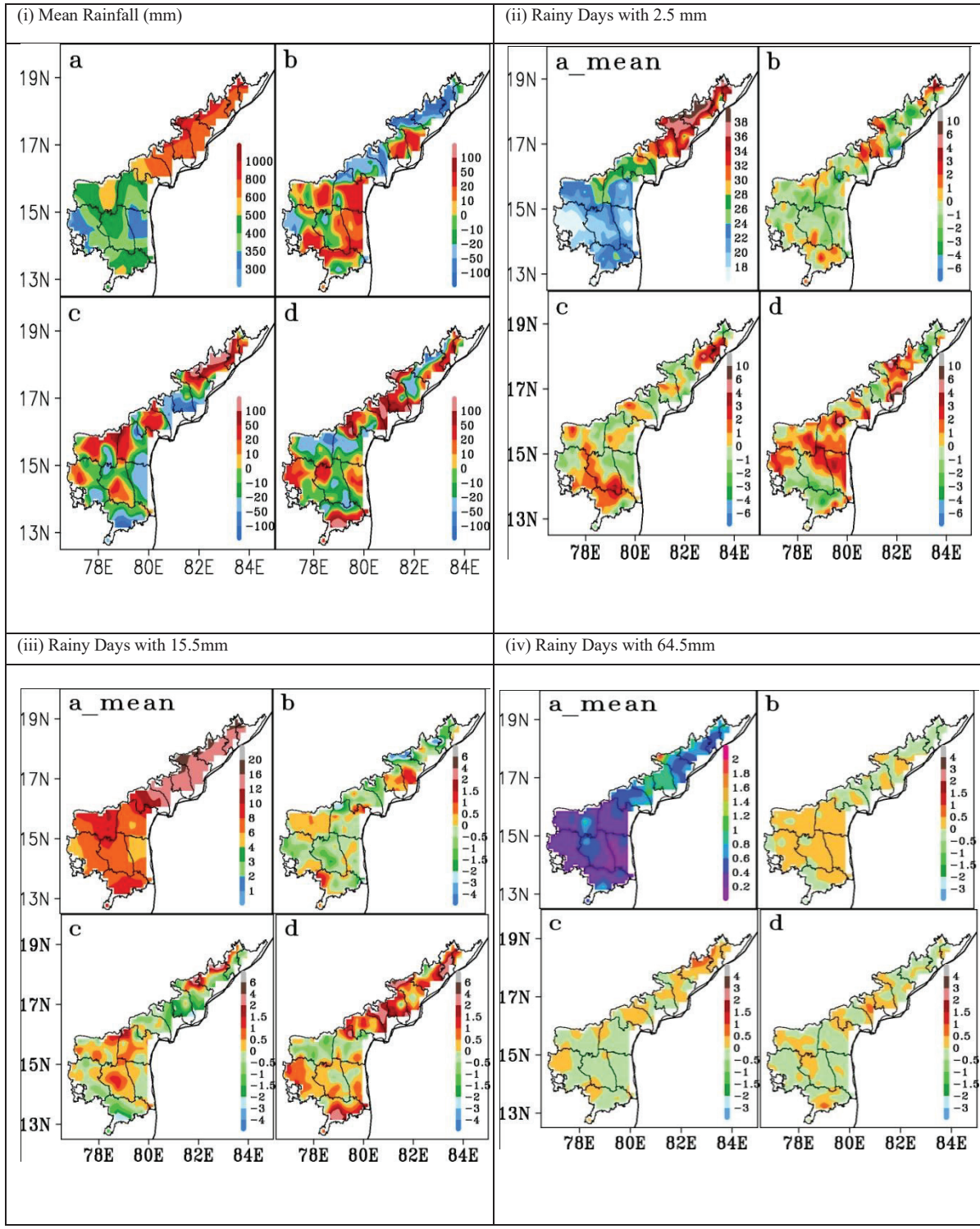

Fig. 2: The Rainfall(mm) distribution (i) (a) climatology [1991-2020],(b) first decade (1991-2000), (c) Middle decade (2001-2010) and (d) last decade (2011-2020), and the rainfall intensities with (ii) rainy days (above 2.5mm), (iii) rainy days (above 15.5mm) and (iv) rainy days (above 64.5mm) (a) mean rainy days 1991-2020 (b) differences (first decade) (1991-2000), (c) differences middle decade (2001-2010) and (d) differences last decade(2011-2020).

Table 1: Mean rainfall in mm and coefficient of variance in % (month-wise) for the study period.

	June	July	August	September
Mean	100.8196	149.6492	156.9372	162.6249
CV	57.35074	49.35901	48.93465	49.16178

displayed. Monthly and seasonal rainfall exhibited an upward trend; however, they are statistically not significant for June, July, and August.

The trend is upward and moderately significant during September and the entire monsoon season. During the last decade, the highest rainfall by month varied. It is June 2015 (594.4 mm). For July, it was in the year 2018(644.6 mm) while august received the maximum in the year 2020(885.4 mm) and 768.8 mm of rainfall was received in September 2013. The highest rainfall recorded for June, July, and August was in East Godavari and it was in September for Anantapur.

The trend in district-wise rainfall: Table 2 represents the mean rainfall and coefficient of variance (district/month-wise) for the study period. Coastal districts viz. East Godavari, West Godavari, Srikakulam, Visakhapatnam, Vizianagaram, and Krishna received mean rainfall in the range of 124-136 mm in June,148-260 mm in July, 180-244 mm in August, and 145-238 mm in September, while the districts of Rayalaseema region viz. Anantapur, Chittoor, Kadapa, and Kurnool received mean rainfall of around 67-80 mm in June, 69-122 mm in July, 73-125mm in August, and 125-143 mm in September. West Godavari received the highest mean rainfall, 207.8 mm, during the monsoon season, while Anantapur received the lowest (83.5mm).

Fig. 4 depicts mean rainfall trends for June to September. During June, Anantapur, Chittoor, and Kurnool districts registered an increasing trend in mean rainfall days at a 5% significant level, while the rest of the districts show no significant trends. There is no significant trend in Andhra Pradesh during July except in East Godavari, which exhibited an increasing trend (at a 5% significance level). Only East Godavari and Guntur showed an increasing trend at a 5 % significant level in August. However, in September, the districts of West Godavari, Chittoor, Kadapa, and Kurnool showed an increasing trend at a 5% significant level.

Fig. 5 depicts the trend in the average frequency of rainy days during the study period. In June, the average frequency of rainy days is high (3-14 days) in Krishna, Guntur, West Godavari, Visakhapatnam, Vizianagaram, and Kadapa. Anantapur, Chittoor, Nellore, and Srikakulam districts recorded rainy days of around 2-8 days. In July and August, the average frequency of rainy days in the range of 6-20 was recorded in East Godavari, West Godavari, Krishna, Srikakulam, Visakhapatnam, and Vizianagaram. The lowest frequency range is observed in Anantapur in June, July and August. On September 7-17, rainy days were recorded in East Godavari, Srikakulam, West Godavari, Vizianagaram, and Visakhapatnam. However, in Guntur, Nellore, and Prakasam, the range is between 1-14 days. For the entire

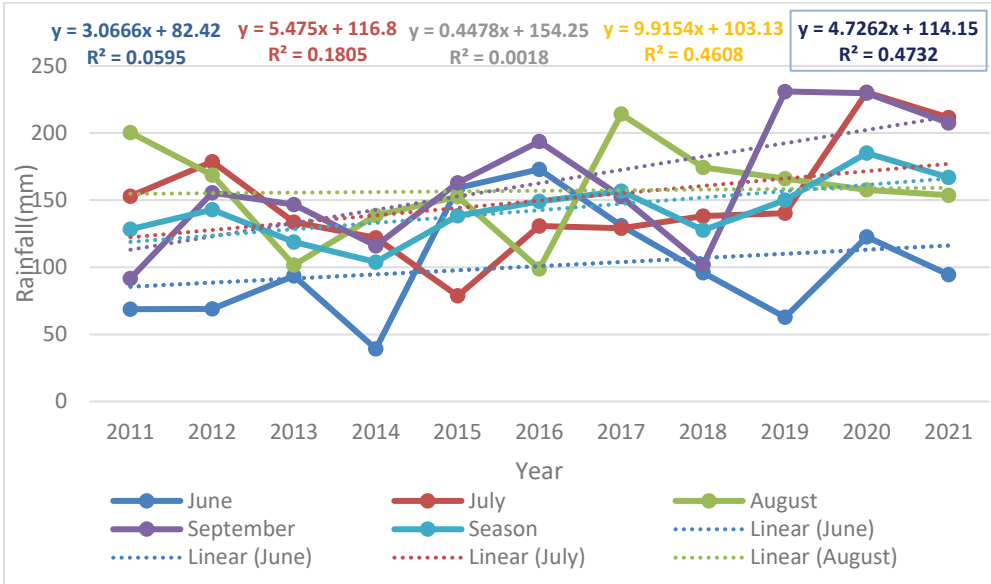

Fig. 3: Trends in rainfall for the monsoon season.

Table 2: Mean rainfall and coefficient of variance (district/month-wise) for the study period.

	June		July		August		September	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
East Godavari	127.9	58	226.4	54	204.9	58	185.9	45
Guntur	112.0	51	154.3	40	171.0	44	163.7	50
Krishna	130.6	68	203.9	60	188.7	55	145.0	59
Nellore	55.0	76	87.6	48	103.3	45	97.0	53
Prakasam	58.9	69	97.9	45	101.2	56	115.1	54
Srikakulam	123.6	47	196.7	40	202.4	41	222.5	40
Visakhapatnam	133.6	52	148.2	54	180.4	45	213.9	48
Vizianagaram	135.7	50	170.2	36	212.1	30	237.8	35
West Godavari	134.0	47	259.9	37	243.8	42	193.4	44
Anantapur	67.4	60	69.3	62	72.5	59	124.8	54
Chittoor	80.4	57	122.2	59	125.2	55	135.9	53
Kadapa	71.4	49	94.2	55	119.4	50	136.3	50
Kurnool	80.2	63	114.5	54	115.3	56	142.8	55

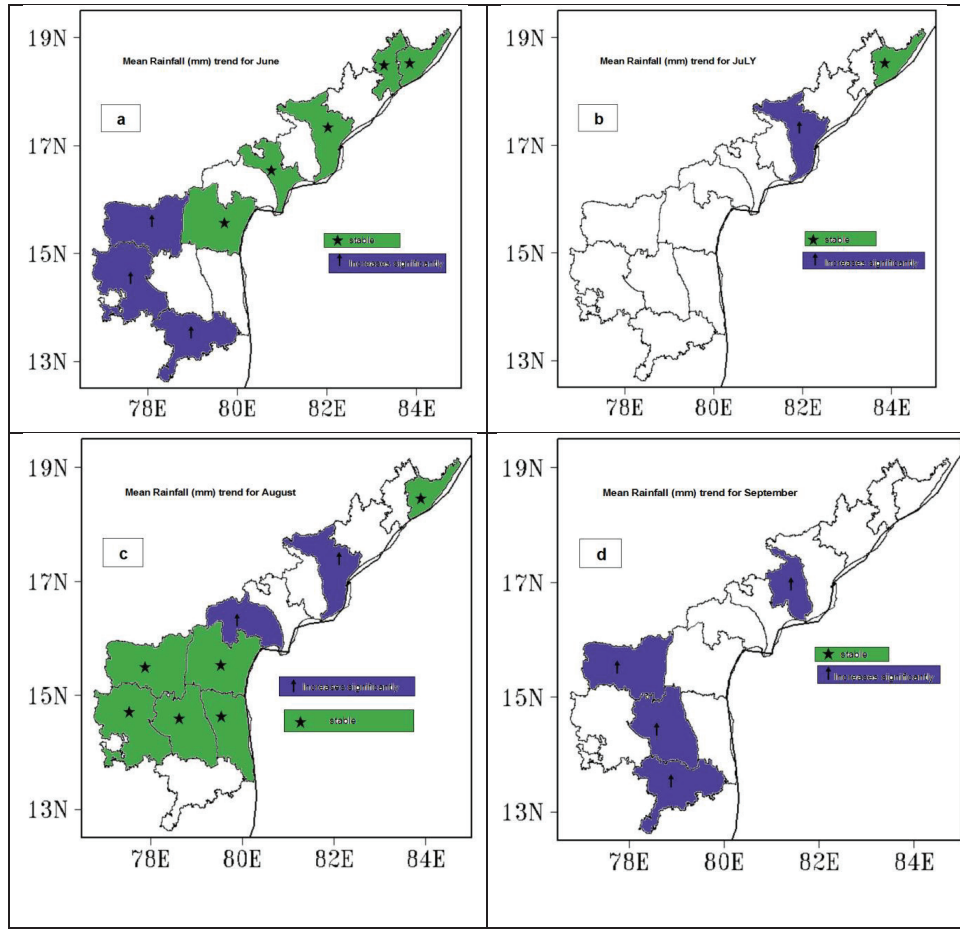

Fig. 4: Mean rainfall trend during the monsoon season.

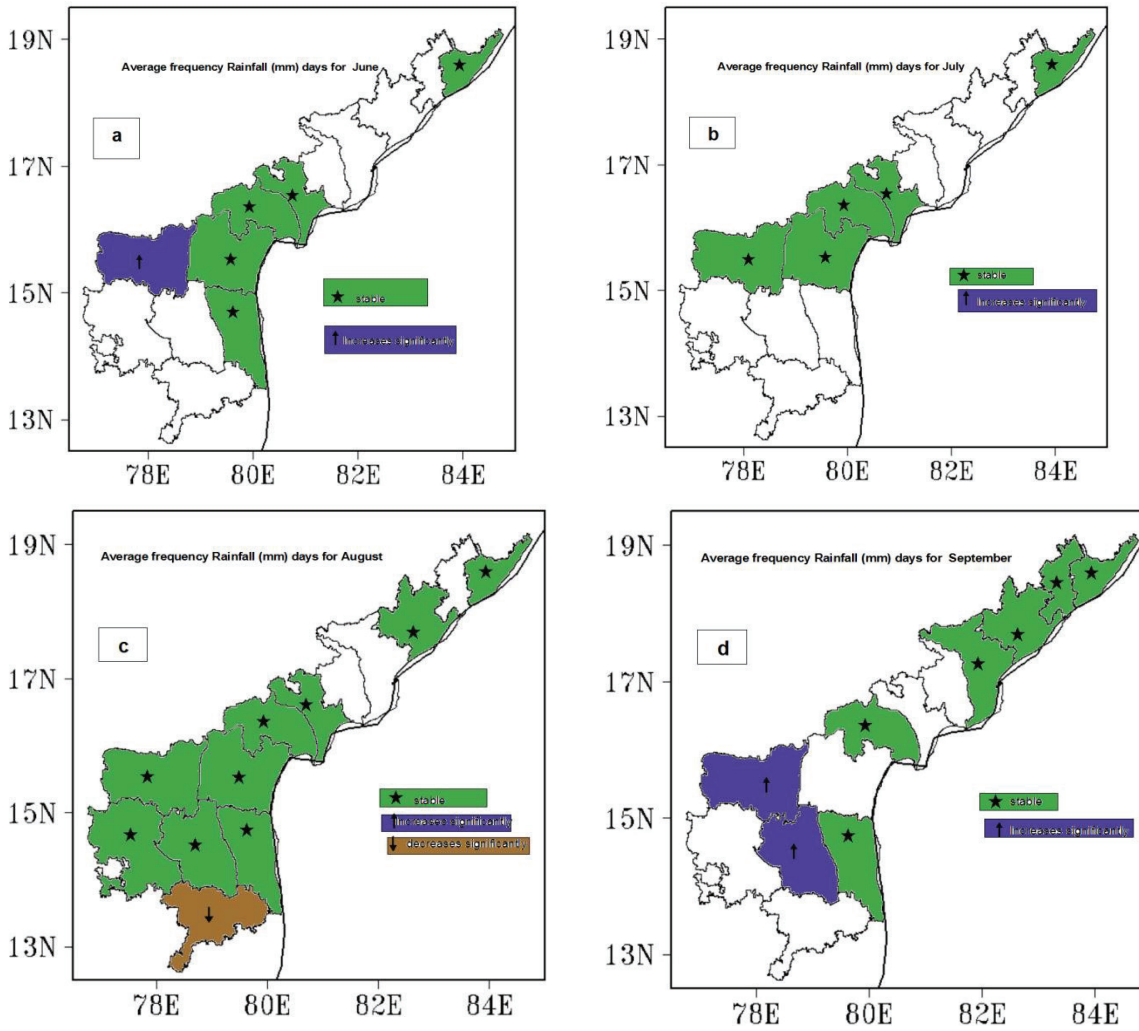

Fig. 5: Trend in an average frequency of rainfall days for the study period.

monsoon season, Guntur and Srikakulam indicated a stable trend in the average frequency of rainy days. There is a decreasing trend in Chittoor for August. Kadapa showed a significantly increasing trend for September while Kurnool witnessed the same in June and September-all significant at a 5% level.

The State's northern districts, West Godavari, Vizianagaram, Srikakulam, Krishna, and Districts of Rayalaseema region Anantapur, Kadapa, and Kurnool recorded average heavy rainfall days (2.27-6.90) for the entire monsoon season. While the central districts of Nellore and Prakasam received in the range of 0.63 to 2.81 days. Except in June, Guntur and Chittoor also recorded a more significant number of heavy rainfall days in the range of 2.36 to 5.27 days.

A statistically significant trend in heavy rainfall days at a 5% significant level is found in Anantapur and Kurnool in June, Vizianagaram in July, East Godavari in July, and August and September in Kadapa (Fig. 6). An increasing trend in the average frequency of heavy rainy days is observed in Kadapa in June, West Godavari and Chittoor in July, Guntur in August, and Nellore, Prakasam, and Kurnool in September month with varied significant levels. Only one district (Kurnool) in the state exhibited a decreasing trend in August. One northern district of the state, East Godavari, and districts of Rayalaseema region Kurnool, Kadapa, and Chittoor showed an increasing trend compared to other districts of the state. There is no trend in the central districts except Guntur in August and Prakasam in September.

The average frequency of very heavy rainfall days (Fig. 7) for the monsoon season indicates that the northern districts, West Godavari, East Godavari, and Krishna, recorded a greater number of 0.27 to1.27 heavy rainfall days than the

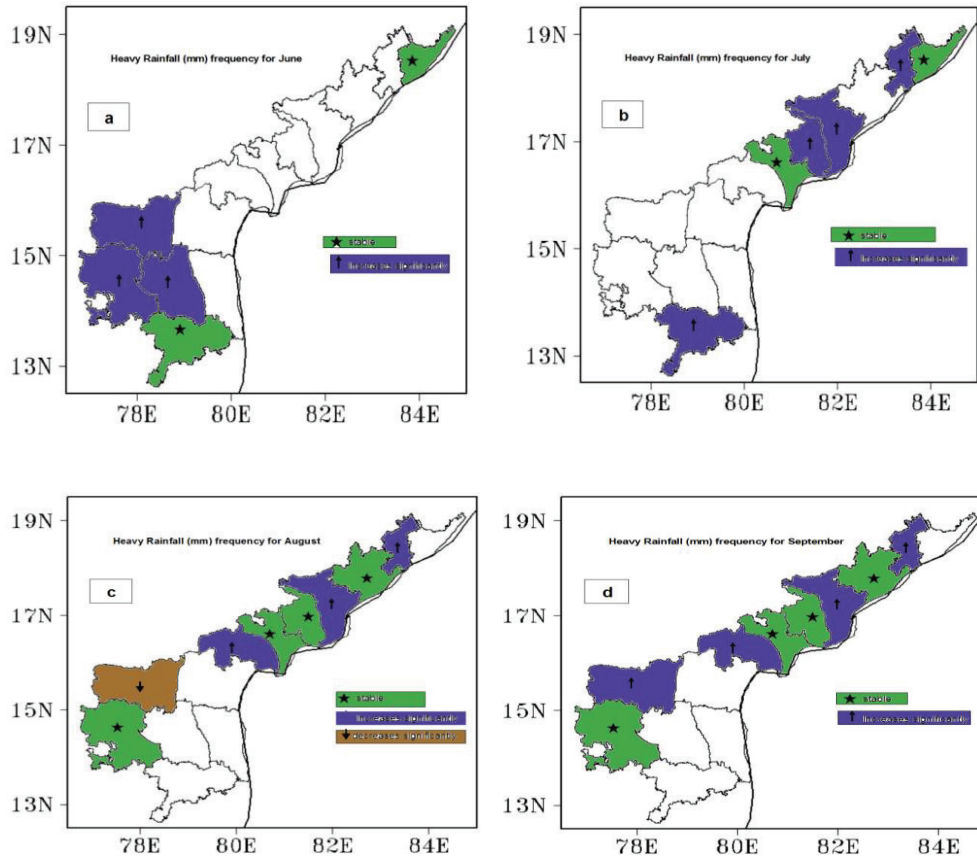

Fig. 6: Trend in an average frequency of heavy rainfall days.

central and southern parts of the state. However, Kurnool recorded the highest average number of very high rainfall days (1.72) in September for the entire study period.

There is no significant trend in very high rainfall days in the entire state most of the time. In August, Guntur recorded a decreasing trend. In September, an increasing trend in northern districts such as Krishna, Srikakulam, and West Godavari was observed at a 5% significant level.

The state's northern districts recorded extremely heavy rainfall days in the study period. West Godavari recorded extremely heavy rainfall events in June (1), July (1), and August (3). East Godavari (1 day) and Kadapa (1 day) were recorded in August, while Vizianagaram (4), Visakhapatnam (3), and Guntur (2) recorded the same in September.

Pearson Correlation Between Crop Yield and Rainfall

Table 3 presents Pearson's correlation coefficients between crop yields and rainfall during the season in the districts of Andhra Pradesh. It can be easily noticed that rainfall is strongly and positively correlated with three major crop

Table 3: Pearson correlation matrix for mean rainfall and crop yield (district/crop-wise).

District	Crop			
	Rice	Groundnut	Maize	Bajra
East Godavari	0.27	0.77	0.29	-0.09
Guntur	0.33	0.6	0.66	-0.18
Krishna	0.26	0.09	0.25	ND
Nellore	0.21	0.03	-0.02	0.1
Prakasam	0.068	0.17	0.33	0.62
Srikakulam	0.42	-0.67	0.67	0.2
Visakhapatnam	0.57	0.55	0.19	0.55
Vizianagaram	0.69	-0.11	0.61	0.72
West Godavari	0.3	0.62	0.46	ND
Anantapur	0.16	0.78	0.34	0.64
Chittoor	0.17	0.67	0.58	0.12
Kadapa	-0.56	0.62	0.6	0.13
Kurnool	0.3	-0.02	0.68	0.8

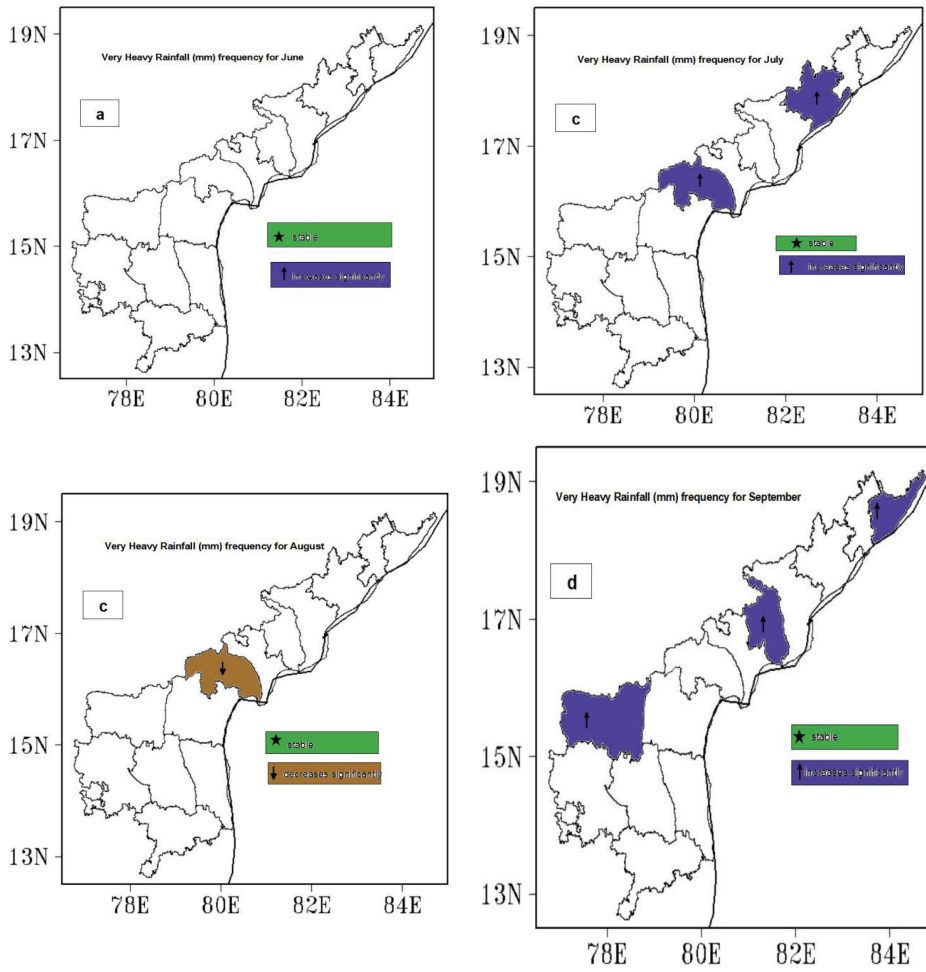

Fig. 7: Trend in the average frequency of very heavy rainfall days.

yields: rice, maize, bajra (R > 0.61), and rice, groundnut, and bajra (R > 0.55) in the districts of Vizianagaram and Visakhapatnam respectively. R > 0.58 is also found between groundnut, maize, and rainfall in Chittoor and Kadapa and with groundnut and bajra in Anantapur. A strong positive correlation of rainfall with groundnut and bajra yields is observed for Anantapur (R = 0.78), Guntur (R = 0.78), and Kurnool (0.8). Negative correlations also exist between crop yields and rainfall. Among the districts, the rainfall has less impact on the four crop yields in Krishna and Nellore while a strong impact is observed with three crop yields in Visakhapatnam and Vizianagaram.

CONCLUSIONS

The study brought significant features of rainfall patterns during the present decade for the state of Andhra Pradesh. The study helps in regional planning and management of water resources and farming operations.

i) September month contributes to the highest monsoon rainfall (28.5%), followed closely by August (27.5%), July (26.3%), and June (17.7%). Monthly and seasonal rainfall exhibited an upward trend. The trend is upward and moderately significant during September and the entire monsoon season. East Godavari received the highest rainfall in June, July, and August and Anantapur received the same in September.

ii) Increasing propensity of rainfall in September is quite apparent during the recent decade 2011-2020. The contribution of September rainfall is more than any other month (June to August) of Southwest Monsoon. The excess rainfall and longer wet period of September will adversely affect the standing crops. Hence, it needs to be examined whether there is an imminent need to change crop calendars for certain important crops. However, other factors such as temperature and precipitation may

also influence crop yields, and these factors are not considered in this study.

iii) West Godavari received the highest mean rainfall, 207.8mm, during the monsoon season, and exhibited an increasing trend in September. Kurnool and Chittoor districts registered an increasing trend in mean rainfall days at a 5% significance level in June and September.

iv) The average frequency of rainy days varied between 6 and 20 in the entire monsoon season except in June. Guntur and Srikakulam indicated a stable trend in the average frequency of rainy days for the monsoon season.

v) The state's northern districts, West Godavari, Vizianagaram, Srikakulam, Krishna, and Districts of Rayalaseema region Anantapur, Kadapa, and Kurnool recorded average heavy rainfall days (2.27-6.90) for the entire monsoon season. East Godavari, Kurnool, Kadapa, and Chittoor showed an increasing trend in average heavy rainfall days compared to other districts of the state. There is no trend in the central districts except Guntur in August and Prakasam in September.

vi) The average frequency of very heavy rainfall days for the monsoon season indicates that the northern districts received higher heavy rainfall days than the central and southern parts of the state. However, Kurnool recorded the highest average number of very high rainfall days (1.72) in September for the entire study period. There is no significant trend in very high rainfall days in the entire state for most of the time

vii) Among the districts, the rainfall has less impact on the crop yields in Krishna and Nellore while a strong impact is observed with three crop yields in Visakhapatnam and Vizianagaram districts.

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