Rainfall Pattern and Agricultural Performance in YSR Kadapa District of Andhra Pradesh, India

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ABSTRACT

YSR Kadapa district which falls under semi-arid drought prone area of Rayalaseema region of Andhra Pradesh state has got very little net crop area irrigated (30-35%) as the region totally depends on the south west (SW) and north east (NE) monsoon with an annual rainfall of 680-750 mm. In this context an attempt is made to study empirical relationship between rainfall variations and performance of agriculture (crop area, production, productivity, usage of irrigation and fertilizer) during the years 2018-24. Secondary data on rainfall were obtained from India Meteorological Department (IMD), secondary data on crop area, production, yield etc., on irrigation, on fertilizer use from the Directorate of Economics and Statistics (DES), Govt of A P and from the Ministry of Agriculture & Farmers Welfare were analysed through the description, trend analysis and Karl Pearson Correlation. The study results reflect higher fluctuation in crop area and production due to greater variability in rainfall. The Kharif crops especially ground nut and cotton are much susceptible for deviation from trend, when the rainfall is less in the SW monsoon, but Rabi crops are less affected to changes in rainfall variability due to existence of residual soil moisture and canal irrigation. Correlation analysis revealed non-significant negative correlation between rainfall and agricultural productivity for both Kharif ($r=0.580$; $p>0.05$) and Rabi ($r=0.051$; $p>0.05$) seasons, however correlation coefficient of rainfall with fertilizer use was perfect in both the season ($r=1.000$; $p<0.01$). In both seasons rainfall shows perfect relation with fertilizer use and plays a mediate role between farmers' decision of using input in agricultural production. This study strongly recommends the increased coverage under micro and major irrigation projects and watershed development, climate smart agriculture, diversified crop growing for overcoming the problems of rainfall induced agriculture in the region.

Keywords: ***Agricultural Performance, Kharif, Pearson Correlation, Rainfall Variation, Rabi Season.***

INTRODUCTION

Indian agriculture is largest employment sector that engages about 55% of total work force of country. The livelihood base in rural India remains heavily dominated by agriculture. In terms of agro-climatic zones of India, Rayalaseema, a semi-arid region of Andhra Pradesh, is vulnerable structurally to the variability in rainfall. The YSR Kadapa district in Rayalaseema is one of the five chronologically drought-prone districts of Rayalaseema having an average annual rainfall from 680 to 750 mm. South west monsoon (June to September) dominates in kharif agriculture, while north east monsoon (October to December) dominates in rabi agriculture. About 5.2 lakh ha of net cropped area is under command, out of which only 30-35 percent are under irrigation, while ground water (tube well, dug well) dominates (83-87 percent) in Net irrigated area, meaning agriculture has to cope up with chronic water scarcity (Government of Andhra Pradesh, 2023; IMD, 2024). In semi-arid arid regions rainfall and agricultural output are intrinsically linked, not only statistically but also existentially, wherein any deviation from the normal patterns would trigger a cascade of consequences such as crop failure, income shocks, indebtedness, and food insecurity among the smallholder farmers. Changing climate exacerbates the inter-seasonal rainfall variability and increase the incidence of extreme events (Singh et al., 2014; Ministry of Earth Sciences, 2022). Still empirical district level studies correlating crop specific productivity, irrigation and input-use dynamics and multi-seasonal rainfall dynamics are quite less. The present study attempts to bridge this research gap by empirically examining the impacts of rainfall variability on agricultural performance, in terms of crop area, output, yield, irrigation coverage and fertilizer consumption for YSR Kadapa district for the years 2018-24.

LITERATURE REVIEW

Gadgil & Gadgil (2006) proved there to be a statistically significant relationship between Indian seasonal monsoon rainfall and Agricultural GDP and indicated that up to 50% of the fluctuations in Agricultural GDP can be explained by performance of the monsoon. Pant & Rupa Kumar (1997) report extremely high coefficients of variation of rainfall in rain shadow regions of the Deccan Plateau, indicating inherent vulnerability in such regions as Rayalaseema. Raji Reddy et al (2007) highlight the crucial role of evenly distributed rainfall in rain-fed farming in Andhra Pradesh, and that absence of rain for even a short duration at key crop growth stages causes yield reduction rapidly in the flowering and grain filling stage. At the district level Suvarna et al (nd) shows for Yerraguntla mandal in YSR district that even the distribution of rainfall within a season between the SW Monsoon (66.8 mm) and the NE Monsoon (108.7 mm) plays as much, if not more important role than the totals, with localized crop failure even in seasons where totals might appear sufficient, being linked to insufficient rainfall distribution. Anitha and Swarn Pragathi (2017) find that lack of sufficient and irregular rainfall can decrease crop production in drought prone Kadapa up to 50% in rain-fed farming, and suggests crop insurance and micro-irrigation as necessary institutional responses. Khedikar et al (2023) shows how rainfall variability greatly affects production of pigeon pea (turf) and cotton in similar semi-arid districts of Maharashtra, and stresses the importance of climate resilient crop varieties. Kandula et al (2024) characterized persistent drought in Rayalaseema and suggested watershed development and sustainable water use practices.

Objectives

1. To examine the variations and trends in seasonal rainfall in YSR Kadapa district.
2. To study the factors influencing agricultural productivity in YSR Kadapa district.
3. To study the impact of rainfall pattern status on agricultural area, production and productivity of major crops in YSR Kadapa district of Andhra Pradesh.

The YSR Kadapa district (formerly, Kadapa), is situated in southern part of the Deccan Plateau in Andhra Pradesh, India (13 32' – 15 09' N and 77 55' – 79 35' E). It extends to a vast area of 15, 179 km2 and comprising of 51 mandals; with the livelihood primarily depending upon agriculture, and the total population being 2.88 million. Soils types are predominantly Red Ferralitic soils (42.15 – 53.48 %) and have low moisture retention, while black cotton soils which are preferred for dryland crops are prevalent in other parts. Average rainfall is 680-750mm, well below national average and falls during SW monsoon (June to September), NE monsoon (October to December), winter (January to February), and pre-monsoon (March to May) seasons. Major irrigation sources include K. C. Canal, Tungabhadra Project High level canal – I (TBPHLC – I), future Veli Gonda project, and Handri-Niva Sujala Sravanthi (HNSS) Lift irrigation scheme, along with several tanks and large number of sub-wells and bore wells.

Data sources

Data collected for the present study is secondary data for the period 2018-24 or shorter whenever data are available. Annual and season wise rainfall data taken from Indian Meteorological Department (IMD), Pune. Crop area, production and yield data taken from Directorate of Economics and Statistics (DES), Govt of Andhra Pradesh and Ministry of Agriculture and Farmers welfare (MoA & FW) UPA portal. Irrigated area data from district agriculture office records and water resources department, Government of Andhra Pradesh reports. Fertilizer application (N, P, K) data from DES Andhra Pradesh season and crop reports.

ANALYTICAL METHODS

Three statistical techniques were applied, (i) descriptive statistics and coefficient of variation (CV) are used to describe the level and variation in rainfall, area, production and yield data; (ii) Trend analysis and graphically for determining the direction of change over the study period; (iii) Pearson correlation co-efficient(r) was calculated to measure the linear association between rainfall and a) Total agricultural productivity, b) Fertilizer consumption, c) Irrigated area. Crop level correlation matrix was constructed for Kharif and Rabi season to assess inter relationship between the productivity of various crops. The significance was tested at $p < 0.05$. The data was analysed using SPSS and Microsoft Excel computer software packages. The Kharif season crops are ground nut, cotton, rice and red gram. The crops in the Rabi season include Bengal gram, rice, red gram, groundnut and cotton. These 5 major crops have occupied over 90 per cent of the gross cropped area in the district.

Rainfall trend in YSR Kadapa district (2018-23)

The total rainfall recorded in YSR Kadapa district from 2018 to 2023 recorded variation over the years with high range of year-to-year variation (Table 1). The total SW monsoon deficit was 198.7 mm (-10.0%) over the period during which four years out of five years showed deficit. Most deficit was in the year 2018 that recorded 202.2 mm lower rainfall (-48.6% deficit). Mean SW monsoon was 393.5 mm. Only one year of SW monsoon that gained rainfall more than normal was 2021 (477.1 mm against normal 393.5 mm). The NE monsoon had overall surplus of 256.2 mm

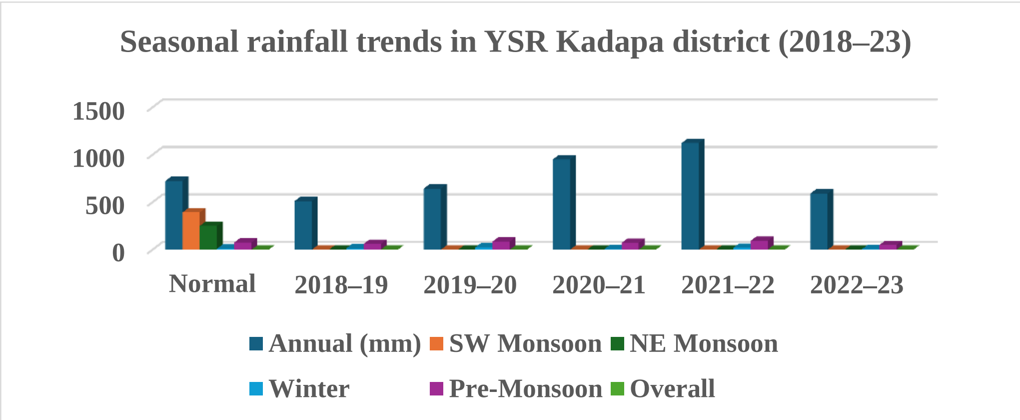
(+20.8%). Major surplus obtained was from NE monsoon year 2020 (+157.1 mm), 2021 (+305.2 mm) and 2022 (+36.7 mm). Whereas, NE monsoon year 2018 had deficit of 65.2 mm against 251 mm normal (-74% deficit), adversely affecting the Rabi cultivation. Rainfall received during pre- monsoon (hot season) and winter season recorded surplus of 120.9 mm (+58.8%) and 45.8 mm, respectively.

Table 1. Seasonal rainfall trends in YSR Kadapa district (2018–23): normal vs actual (mm)

Year	Annual (mm)	SW Monsoon	NE Monsoon	Winter	Pre-Monsoon	Overall
Normal	724.8	393.5	251.0	10.3	76.3	—
2018–19	512.0	191.3 (−51.4%)	65.2 (−74.0%)	14.1	59.6	Deficit
2019–20	644.0	322.7 (−18.0%)	209.6 (−16.5%)	25.4	86.3	Deficit
2020–21	951.0	349.2 (−11.3%)	408.1 (+62.6%)	6.4	71.0	Surplus
2021–22	1124.0	477.1 (+21.2%)	556.2 (+121.6%)	18.7	91.7	Surplus
2022–23	593.0	251.3 (−36.1%)	287.7 (+14.6%)	5.9	48.1	Deficit

Source: *IMD District Rainfall Data, Pune (2024).*

Fig.1 Seasonal rainfall trends in YSR Kadapa district (2018–23)



Source: *IMD District Rainfall Data, Pune (2024)*

Area, production and productivity of agriculture:

There was a striking sensitivity in performance of agriculture to the variability in monsoon. Kharif groundnut area reduced from 29,827 hectares in 2020-21 to 3,651 hectares in 2022-23-fall by 88 percent in single season after the deficit SW monsoon-demonstrating the risk aversion nature of farmers. Nevertheless, the area under cotton more than quadrupled from 10,940 ha to 46,263 ha in the study period because of enhanced MSP and perceived profitability. The cotton yield, dropped by more than 50 percent, from 1.84 t/ha under monsoon surplus year (2021-22) to 0.75 t/ha under deficit year (2022-23), which confirmed the crop to be very sensitive to moisture deficit. Kharif rice area varied in a highly irregular manner from 27,616 ha in 2022-23 to 52,146 ha in 2021-22 generally reflecting monsoon behaviour. The area of Bengal gram the main Rabi crop ranges between 70,350 ha and 106,078 ha. Yield fell to 0.25 t/ha in 2018-19 but went up to 1.28 t/ha in 2019-20 after the deficit year of northeast monsoon. Rabi rice yield showed stable growth from 3.08 t/ha in 2018-19 to 3.59 t/ha in 2022-23 reflecting smoothing down effect of canal and tank irrigation.

Trends in irrigation.

Ground water (tube wells and dug wells) contribute 83-87% of the total net irrigated area (NIA). The NIA has peaked at 1,67,544 ha in the year 2021-22 (excess normal SW and NE monsoon) and came down to 1,23,907 ha in 2022-23, which again confirms the dependence of ground water irrigation process on monsoon recharge. The cropping intensity was only 1.07 to 1.13, much below 1.7 to 1.9 as seen for the deltaic regions of coastal Andhra Pradesh although water scarcity led to double cropping. Paddy (rice) irrigation area dominates; The groundwater sources (tube wells and dug wells) comprise of 83 -87% of total net irrigated area (NIA). The net irrigated area reached the maximum of 1,67,544 hectares in the year 2021-22(DBT year, an above normal SW and NE monsoon year), and dropped to 1,23,907 in 2022-23 confirms the dependence of groundwater irrigated areas on monsoon recharge. The cropping intensity varies from

1.07 to 1.13, much lower compared to 1.7-1.9 of the deltaic regions of the coastal Andhra Pradesh, hence the water constraints also weaken the dominance of double cropping. Paddy (rice) irrigated area dominant.

Fertilizer consumption and rainfall

Fertilizer consumption (N, P & K) closely followed rainfall pattern for both Kharif and Rabi season. The expenditure on fertilizer inputs increased as rainfall intensity in high rainfall year, in deficit year the consumption showed rapid fall. It is similar to the almost complete correlation that occurred between rainfall and fertilizer use for both the seasons ($r = 1.000$, $p < 0.01$), and it is discussed under section 4.5. Therefore, rainfall confidence seems to be an important determinant for the decision of investing inputs.

Relationship between rainfall, productivity and inputs

Pearson correlation coefficient (Table 2) was calculated between the seasonal rainfall and (i) total agricultural productivity, (ii) fertilizer use (NPK) and (iii) net irrigated area.

Table 2. Pearson correlation between rainfall and selected agricultural variables in YSR Kadapa district (Kharif and Rabi, 2018-23)

Variable Pair	Season	r value	p value	Significance
Rainfall – Agricultural Productivity	Kharif	−0.580	> 0.05	NS
Rainfall – Agricultural Productivity	Rabi	−0.051	> 0.05	NS
Rainfall – Fertilizer Use (NPK)	Kharif	1.000	< 0.01	ST
Rainfall – Fertilizer Use (NPK)	Rabi	1.000	< 0.01	ST
Rainfall – Net Irrigated Area	Kharif	0.714	> 0.05	NS

NS = Not Significant ($p > 0.05$); ST = Significant at $p < 0.01$.

The non-significant negative correlation between rainfall and productivity can be attributed to three structural factors: (i) non-linearity in the rainfall-yield relationship in semi-arid agriculture, where both deficit and excess rainfall lead to yield losses (the U-shaped or threshold pattern is not captured by the linear correlation); (ii) mediation of rainfall–yield relationship through input inputs – perfect correlation between rainfall and fertilizer use implies that rainfall affects yields primarily by stimulating or depressing input use, thereby generating a weak direct rainfall–yield signal; and (iii) small sample size ($n = 5–6$ years), which reduces statistical power so that even a moderate correlation of $r = 0.580$ fails to achieve significance at the 5% level. Despite this statistical result, the vast body of evidence from field responses, production crashes and fertilizer trends attests to the real importance of rainfall for agricultural performance in the district.

Inter-crop Productivity Relationship

Analysis of correlation crop-wise in kharif (Table 3a) reveals a strong negative correlation between cotton and red gram ($r= 0.789$) and cotton and groundnut ($r= 0.918$). It reveals a clear indication of resource competition and acreage substitution as cotton is increasing in the district. Positive correlation between rice and red gram ($r = 0.525$) and between rice and groundnut ($r=0.366$) reveals co-production at similar moisture status. In rabi (Table 3b), Bengal gram and groundnut are positively correlated with very high r (0.911). Similarly positive correlation exists between Bengal gram and rice ($r =0.725$). Both the events clearly depict the impact of northeast monsoon and irrigation in jointly affecting the fate of the dominant rabi crops. Strong positive correlation also exists between red gram and peanut ($r = 0.802$).

Table 3a. Crop-wise Pearson correlation for Kharif season productivity, YSR Kadapa (2018–23)

Crop	Rice	Red Gram	Cotton	Groundnut
Rice	1.000	—	—	—
Red Gram	0.525	1.000	—	—
Cotton	−0.230	−0.789	1.000	—
Groundnut	0.366	0.738	−0.918	1.000

Source: *Authors' computation based on DES, GoAP data.*

Table 3b. Crop-wise Pearson correlation for Rabi season productivity, YSR Kadapa (2018–23)

Crop	Bengal Gram	Rice	Groundnut	Cotton	Red Gram
Bengal Gram	1.000	—	—	—	—
Rice	0.725	1.000	—	—	—
Groundnut	0.911	0.665	1.000	—	—
Cotton	0.188	−0.231	0.499	1.000	—
Red Gram	0.526	0.413	0.802	0.644	1.000

Source: Authors' computation based on DES, GoAP. Data.

Regression analysis, crop wise:

Crop-wise regression analysis indicates that rainfall has no significant relation with productivity of any crop both in Kharif and Rabi seasons (all the p values are more than 0.05). Kharif rice has moderate negative relationship ($R = 0.668$) and Rabi Bengal gram has moderate positive relationship ($R = 0.5333$), but both have no significance. Many of the crops showed weak correlation with rainfall, the R-values being too low which cannot adequately explain variance in crop productivity through rainfall only. Due to small sample size ($n = 5$) the inferences are subject to limitation and must be interpreted cautiously.

Table 4. Rainfall and Crop Productivity (T/Ha), YSR Kadapa District (2018–23)

Crop	Season	b_0	b_1 (Slope)	R	R^2	Adj. R^2	F	p	Sig.
Rice	**Kharif**	4.4691	-0.005192	-0.6680	0.4463	0.2617	2.4179	0.2178	NS
Red Gram	**Kharif**	0.2311	-0.000110	-0.1073	0.0115	-0.3180	0.0349	0.8637	NS
Cotton	**Kharif**	1.8719	-0.001679	-0.2649	0.0702	-0.2398	0.2264	0.6667	NS
Groundnut	**Kharif**	0.4866	0.001767	0.3437	0.1181	-0.1758	0.4019	0.5711	NS
Bengal Gram	**Rabi**	0.6459	0.001198	0.5333	0.2844	0.0459	1.1923	0.3547	NS
Rice	**Rabi**	3.2022	0.000369	0.3827	0.1464	-0.1381	0.5146	0.5250	NS
Groundnut	**Rabi**	1.8942	0.000733	0.1806	0.0326	-0.2898	0.1011	0.7713	NS
Cotton	**Rabi**	2.9656	-0.002616	-0.4188	0.1754	-0.0995	0.6381	0.4828	NS
Red Gram	**Rabi**	0.2882	-0.000256	-0.4345	0.1888	-0.0816	0.6984	0.4647	NS

Notes: $p<0.001$ & $p<0.01$ & $p<0.05$ NS = Not Significant. (2) Kharif productivity in ₹ lakh/ha (aggregate); crop-level in T/Ha. (3) n=5 for all regressions. (4) Small sample size (n=5) reduces statistical power; borderline p-values should be interpreted cautiously

Source: *Authors' computation based on DES, GoAP data*

CONCLUSION

The present study, based on the analysis of rainfall, inputs and yield of major kharif and Rabi crops, found convincing empirical support that rainfall variability acts as a primary driver of the district's agriculture, though the linear correlation of rainfall with total production doesn't reach normal statistical significance levels (Kharif: $r=0.580$, $p>0.05$;Rabi: $r=0.051$, $p>0.05$) because the sample size (n=5) is small and non-linear relation exists. The powerful mediation of rainfall impacts via rainfall yield function and various inputs in semi-arid dryland conditions is strongly proved. The near-perfect positive correlation between rainfall and fertilizer use ($r=1.000$, $p<0.01$) in both kharif and Rabi periods revealed that it is the faith on adequate rainfall that decides the input (fertilizer) investment. 198.7 mm of cumulative south-west monsoon deficit across four of the five years has direct led to drastic contraction in kharif groundnut acreage (88% single season decline in 2022-23), fluctuating cotton yield (from 1.84 to 0.75 t/ha, year on year) and 1,67,544-hectare reduction in net irrigated area (explained through sharp compression by 1,23,907 hectare) and indirectly confirming the dependence on rainfall recharge for irrigation development in the district. The Rabi crop in comparison, showed relative greater stability in terms of yield due to influence of residual soil moisture, canal irrigation and excessive north-east monsoon rains (across 3 of the 5 years), where the rabi rice yield increased from 3.08 t/ha to 3.59 t/ha, confirming the importance of assured irrigation in yield stabilization. There are no statistically significant direct rainfall responses of any of the Kharif or Rabi crops, confirmed by crop specific regression

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