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Effect of rainfall and temperature on rice yield in Puri district of Odisha in India

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Abstract
This study aims to analyze the effect of monthly rainfall and monthly temperature on kharif rice yield of Puri district, Odisha. Block wise rainfall data were analyzed to find the variability of rainfall over the district. The block wise rainfall data were collected from Special Relief Commissioner of Odisha. Temperature data were collected from India Meteorological Department, Pune, for the district and yield data of kharif rice were collected from Directorate of Economics and Statistics, Government of Odisha. Block wise rainfall analysis was done using SAS and Weather Cock. Linear regression analysis was performed through SAS to find out the effect of seasonal rainfall and temperature on kharif rice yield. The study showed that mean annual rainfall and rainy days were 1491mm and 57 days respectively. The variability of annual rainfall in the district is about 33% CV and the variability of annual rainy days is 19% CV. Variations on both rainfall and temperature were found not to directly relate to the variations noticed in the yield of kharif rice of Puri district.

Keywords: Rainfall, variation, linear regression

Introduction
Rainfall and temperature are the two dominant weather elements influencing the crop yield (Chi-chung and McCarl 2004) [4]. It also determines the potential of any region in terms of crops to be produced, farming system to be adopted, the nature and sequence of farming operations to be followed and to achieve higher agricultural productivity as well. Around 60 percent of the Indian agriculture is rain dependent, distress prone and vulnerable to climate (Parthasarathy and Dhar, 2014) [5]. Climatic variability, particularly rainfall is the major factor influencing the agricultural productivity and sustainability in the tropics (Rao P. G., 1993) [6]. Studies indicate that increase in temperature with rainfall uncertainties may lead to loss of 10 to 40 percent crop production in India due to its large population and limited resources. Rainwater management and its optimum utilization is a prime issue of present day research for sustainability of rainfed agriculture (Enete I.C., 2014) [7]. In order to address the issue a detailed knowledge of rainfall distribution can help in deciding the time of different agricultural operations and crop planning. However, in rainfed areas, it is mainly depends upon the magnitude and distribution of rainfall both in space and time. The rainfall pattern decides the cultivation of crops, their varieties, adoption of cultural operations. The information on annual and seasonal rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, seeding, irrigation, fertilizer application and crop planning.

Puri district is a coastal district on the eastern part of Odisha, India, covering an area of 348 thousand hectare and situated in East and South Eastern Coastal plain Zone of Odisha (Agronica 2005) [1]. It is located at 19’ 28 N Latitude 26’ 35 N, 84’ 29 E. Longitude 86’ 25 E blessed with sandy-clay-loam, silty-loam, Loam, clay-loam and clayey soil in varied agro-eco system. Its altitude is at sea level. The population of the District is 15, 02, 682 (as per 2001 Census) and the density of population is 431 people per sq. km. The district has 11 blocks namely Astarang, Brahmagiri, Delang, Gop, kakatpur, Kanas, Krushnaprasad, Nimapada, Pipili, Puri and Satyabadi. The rural population is 12, 98, 654 and the urban, 2, 04, 028. This District has warm and humid climate. The summers are from March to June, monsoons from June to September and winters are from October to February. The minimum temperature of the District is approximately 7.5^0 C and the maximum 34.1^0 C. the broad soil groups are mixed red & black and mixed red & yellow. The mean annual rainfall and rainy days are 1491mm 57 days respectively. Paddy, green gram, black gram, horse gram and groundnut are grown in the District. Paddy comprises the major crops.

The district has189 thousand hectare cultivated area spread over 22, 58 and 109 thousand hectares in upland, medium land and low land respectively out of which paddy is cultivated in 103 thousand hectares during kharif as rainfed (Odisha Agriculture Statistics 2013-14) [2]. So the production of rice depends up on the distribution of rainfall. So an attempt has been made to analyze the effect of monthly rainfall on rice yield.

Materials and Methods

Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Government of Odisha for the period from 1993 to 2014 and processed by using Statistical Analysis System (SAS 9.3). long term weather parameters like daily maximum temperature (Tmax), minimum temperature (Tmin) and rainfall of Puri district were collected from India Meteorological Department, Pune, for the period over 34 yrs (1981 - 2014). District yield data of Kharif rice were collected from Directorate of Economics and Statistics, Government of Odisha.

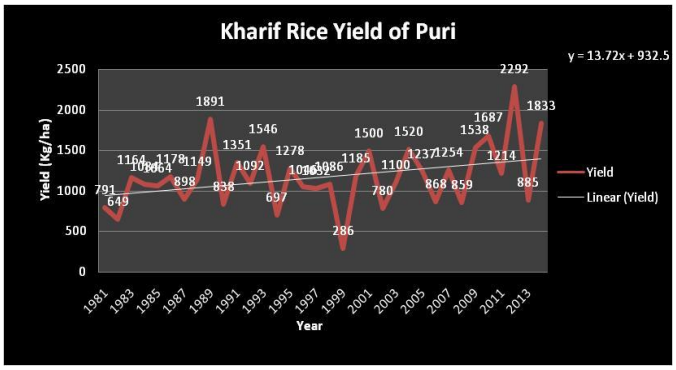

Fig 1

Data Analysis

Spatial and temporal variability of rainfall were calculated by using block wise daily rainfall data. Twenty years rainfall data of Puri district in Odisha were used to find out the mean annual, seasonal and monthly variability of rainfall and rainy days with respect to each block using the "Rainy Day.exe" module of "weather cock" software developed by CRIDA, Hyderabad (WC) (Rao *et al*. 2015). Standard deviation (SD) and Co-efficient of variance (CV) was calculated by using statistical equation. Rainy day analysis was done considering that a day with a minimum rainfall of 2.5mm is a rainy day.

Seasonal rainy days and rainfall analysis for each block was also done by the same module which was used for annual rainfall analysis. The whole year was categorised into four major seasons namely Monsoon, Post-monsoon, summer and winter according to the Odisha condition. Monsoon season consist of four months namely June, July, August and September. Post-monsoon consist of two months namely October and November. Likewise December, January and February are under winter season and March, April and May are under summer season. SD and CV were also derived for four seasons.

Daily weather data of Puri station were taken as the secondary data source for Puri district. It is due to unavailability of daily weather data in block level. Both seasonal and monthly normal t_{max} and t_{min} of Puri district were calculated by using the "SAS 9.3" software. The input data file was comprised of daily Tmax and Tmin for the period of 1981 to 2014 (34years). To derive normal seasonal and monthly temperature "Proc means" and "proc tabulate" procedure were used. Descriptive statistics and multiple linear regression model were fitted to analyze the findings using "Proc reg" procedure of SAS 9.3 software (SAS Institute Inc.). The multiple linear regression analysis is specified thus,

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots.. + \beta_n X_n + €$$

Where

- Y is the dependent variable which is predicted to lie on the best-fit regression plane'
- $\beta 0$, is the intercept,
- β_1 is the partial regression coefficient which quantifies the sensitivity of Y to change in X_1, adjusting for the effect of X_2 on Y.
- β_2 is the partial regression coefficient which quantifies the sensitivity of Y to change in X_2, adjusting for the effect of X_1 on Y.
- And € is the error.

Results and Discussion

Rainfall

Distribution of rainfall and rainy days

Rainfall analyses were done on daily data at block level for all the 11 blocks of the district for the period from 1993 to 2014 (Source: Special Relief Commissioner, Government of Odisha, Bhubaneswar). Rainy day analysis was done considering a day with minimum rainfall of 2.5mm is a rainy day.

Annual rainfall and rainy days

The average annual rainfall of the district is 1491mm. Most of the blocks receive moderate rainfall (1300 to 1600 mm). Blocks with very high rainfall (>1600 mm) are Astarang, Nimapada and Puri (Table 1). Two blocks Gop and Krushnaprasad receive very low rainfall (<1300 mm). Except four blocks namely Astarang, Kakatpur, Nimapada and Puri, rest all seven blocks receives less rainfall than the district's average rainfall. Puri block receives highest rainfall among the all blocks of Puri district.

The variability of annual rainfall in the district is about 33% CV (Tab 1). Three blocks have high variability (>35%), while 3 blocks have low variability (<30%). Variability is maximum (44%) in Brahmagiri and Delang block and minimum (25%) in Astarang and Pipili block. Variability of four blocks namely Gop, Kanas, Puri, Kakatpur and Nimapada is close to district's average variability.

The average number of rainy days in a year in the district is 57 days (table. 2). Out of total blocks 3 blocks have few rainy days (<55 days) while 4 blocks have high rainy days (55-60 days) and 2 block have very high rainy days (>60 days).

Nimapada has the highest variability (26%) of rainy days while the average variability of rainy days of the district is 19% (Fig. 2). All of the blocks are close to district's average variability of rainy days except Pipili, Puri and Nimapada block. Pipili and Puri block have the lowest figure of variability of rainy days (15 days).

Temperature

Temperature analysis on IMD data was carried out. For each block IMD data were not available. Therefore the data available for only Puri was used to analyse the temperature of entire Puri district. The average annual maximum temperature of Puri district is 29° C. In the month of April and May

maximum temperature exceeds 30ºC and May is the hottest month of the year (Table 3). During monsoon and post-monsoon season mean maximum temperature of the district varies from 28º-29ºC. The mean maximum temperature remains below 27ºC in winter season.

Mean annual minimum temperature of Puri district is 22.0ºC. December is the coolest month (16.5ºC) followed by January (17.0ºC). During summer and monsoon season mean minimum temperature remains above 24.5ºC except March (Table 3). Minimum temperature remains below 20ºC during winter season including November.

Table 1: Block wise normal annual rainfall (1993-2014) with standard deviation and CV (%)

Block	RF (mm)	SD	CV
Astarang	1605.3	403.9	25
Brahmagiri	1449.7	645.7	45
Delang	1449.7	645.7	45
Gop	1268.2	406.7	32
Kakatpur	1596.8	493.2	31
Kanas	1386.5	441.2	32
Krushnaprasad	1290.0	490.3	38
Nimapada	1662.4	568.2	34
Pipili	1475.0	374.2	25
Puri	1815.1	560.5	31
Satyabadi	1402.7	364.7	26
Mean	1491.0	490.4	33

Table 2: Block wise normal annual rainy days with standard deviation and CV (%)

Block	No of Rainy Days	SD	CV
Astarang	54	10	19
Brahmagiri	59	12	21
Delang	59	12	21
Gop	54	9	17
Kakatpur	61	10	16
Kanas	58	9	16
Krushnaprasad	56	13	23
Nimapada	58	15	26
Pipili	61	9	15
Puri	55	8	15
Satyabadi	54	9	17
Mean	57	11	19

Table 3: Seasonal mean maximum and minimum temperature

Season	T_{max} (^{0} C)	T_{min} (^{0} C)
Winter (Jan-Feb)	26.6	18.5
Summer (Mar-May)	30.1	24.7
Southwest (Jun-Sep)	29.8	24.8
Northeast (Oct-Dec)	28.3	19.9
Average	29	22

Result of regression analysis

Table 4 shows the regression results for the effect of seasonal mean rainfall and mean temperature for kharif season on rice yield in the study area. After some econometric considerations, the result from the linear regression model was chosen as the lead equation. The result of the regression analysis showed that the regression coefficient of determination (R^2) was 0.24, it connotes that about 24% of variation in rice yield could be explained by monthly mean rainfall and monthly mean temperature in kharif season. The remaining 76% were largely due to other variables outside the regression model that also affects rice yield. The regression result also reveals low R-values which indicated that there is no casual relationship between the variables. Both the mean monthly rainfall and mean monthly temperature had a positive but not significant relationship with rice yield. The result reveals that the amount of monthly rainfall and the monthly mean temperature may not necessarily determine the output of rice in the area of study.

Table 4: Regression result on the effect of rainfall and temperature on rice yield

Analysis of Variance					
Source	**DF**	**SS**	**MS**	**F Value**	**Pr > F**
Model	2	1192411	596206	4.52	0.0196
Error	29	3829236	132043		
Corrected Total	31	5021648			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-9080.86659	3627.4907	827477	6.27	0.0182

Octrf	-0.83421	0.48057	397872	3.01	0.0932
Augtx	328.14706	115.23207	1070790	8.11	0.008

Summary of Stepwise Selection

Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	Augtx	NA	Augtx	1	0.1582	0.1582	-4.844	5.64	0.024
2	Octrf	NA	Octrf	2	0.0792	0.2375	-5.0236	3.01	0.093

Sum of Residuals	0
Sum of Squared Residuals	3829236
Predicted Residual SS (PRESS)	4571131

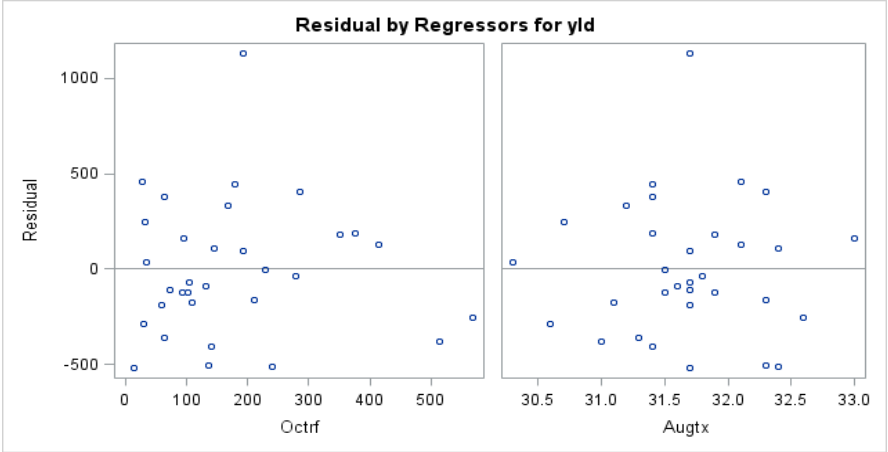

Fig 2

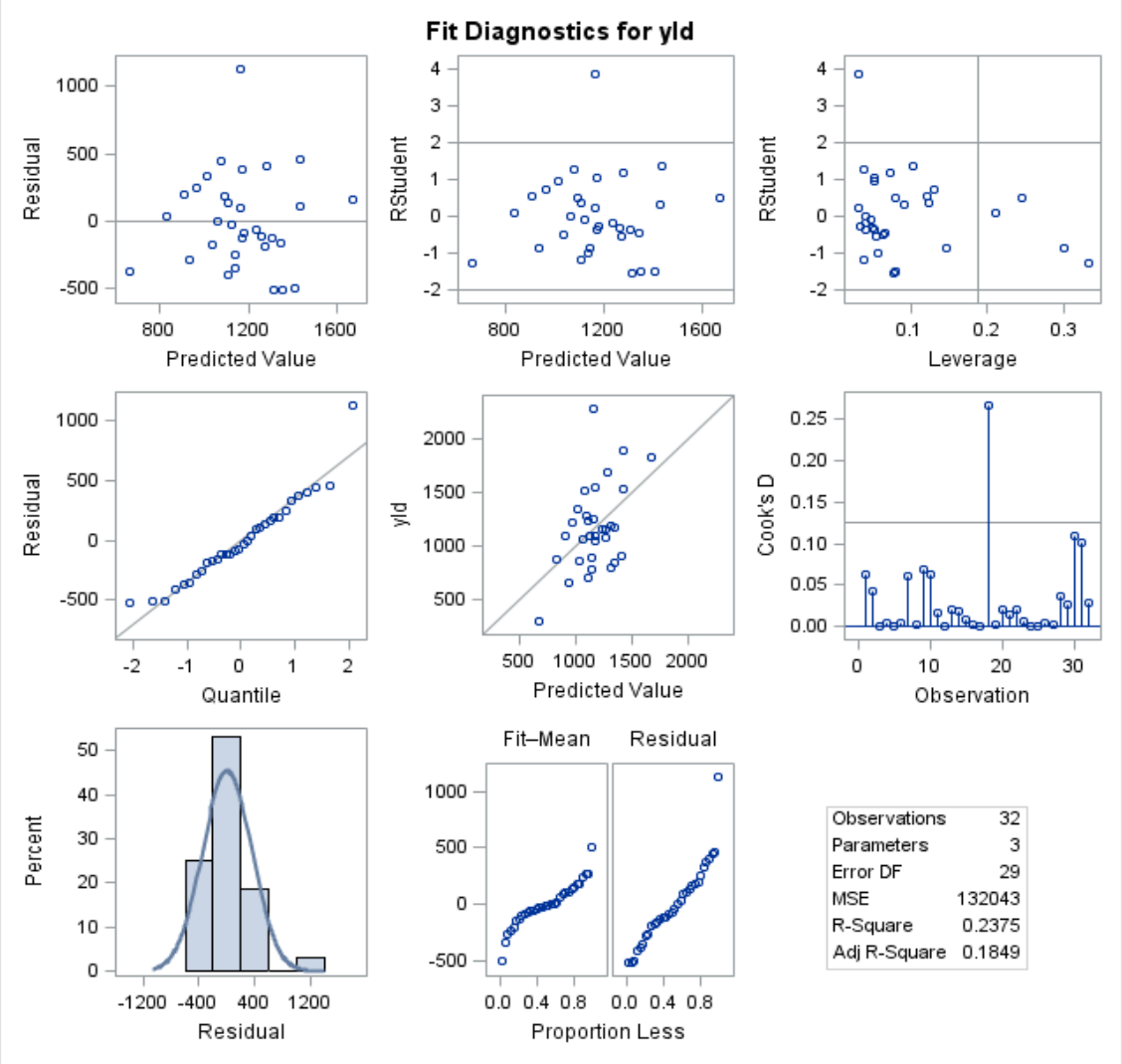

Fig 3

Conclusion

The study showed that, there were variations in the amount of rainfall over the twenty two years period (1993-2014) for all the blocks. There were also variations in the district rainfall and yield of rice during the thirty four years period (1981-2014). However, temperature remains fairly steady during the period. The type of variations recorded in the annual mean rainfall for the thirty four years period were not related to the variation noticed in the output and yield of rice for the same period. Weather variations between 1981 and 2014 in Puri district of Odisha does not influence rice yield.

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