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Research Article

Effect of rainfall on productivity of cotton

P. A. Pandya, S. M. Ghosiya, V. H. Pithiya, S. P. Dudhatra

Abstract

Study of rainfall and its effect on crop yield is very useful for crop planning for rainfed cash crop like cotton for farmers and policy makers in rainfed agriculture. A study was conducted to evaluate rainfall variability and its effect on Cotton yield for Junagadh district of Gujarat for seasonal, monthly, fortnightly and weekly rainfall by correlation & regression analysis. Arithmetic mean, standard deviation and coefficient of variation for seasonal rainfall was found as 982 mm, 349 mm and 36 % respectively. July month contributes about 40% of the total seasonal rainfall. Correlation coefficient between seasonal rainfall and yield was 0.66, while it was highest as 0.46 for September and lowest as 0.15 for August. For fortnightly rainfall, the highest correlation coefficient was founded as 0.64 for Fifth Fortnight (5F) and negative -0.27 for 1F. 31st Standard Meteorological Week (SMW) recorded highest correlation 0.65. The regression analysis revealed that predictability for seasonal, monthly and fortnightly rainfall was 43%, 55% and 84 % respectively, while it was 96% for weekly rainfall. 5 FN and 31st SMW were found most substantial in all above parameters.

Keywords rainfall variability, cotton productivity, standard meteorological correlation, regression

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Introduction

India ranks first among the rainfed countries in the world in terms of area with 60% of total net sown area, but counts amongst the lowest in rainfed yields (<1 ton/ha). Rainfall is the most important climatic parameter which influences the growth characteristics of crops [1]. Singh et al. [2] reported that moisture is the most limiting factor for crop production in semi-arid region, the greatest risk to crop yields in Indian Agriculture is attributed to the variability of seasonal rainfall. Ajayi et al., [3] stated that rainfall is undoubtedly a determining agro-meteorological factor in the crop production. Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. Cotton accounts more than 70 % of the raw fiber used by the world textile industry and handlooms; hence it is also called “King of fibers” [4].

However, national average yield of cotton 415 kg/ha is way behind the top countries. Which implies that there is huge scope of exploring the cotton productivity potential in India. It is not only the total amount of rainfall but also the distribution of rainfall within the crop period is important. Sultan et al., [5] reported that for cotton, drier regions were most sensitive to climate variability. Gwimbi and Mundoga [6] revealed that significant rainfall deficits at critical stages of crop growth have frequently led to a serious shortfall in crop production. High rainfall could result in over saturation and water logging which had adverse effect on cotton growth and development [7].

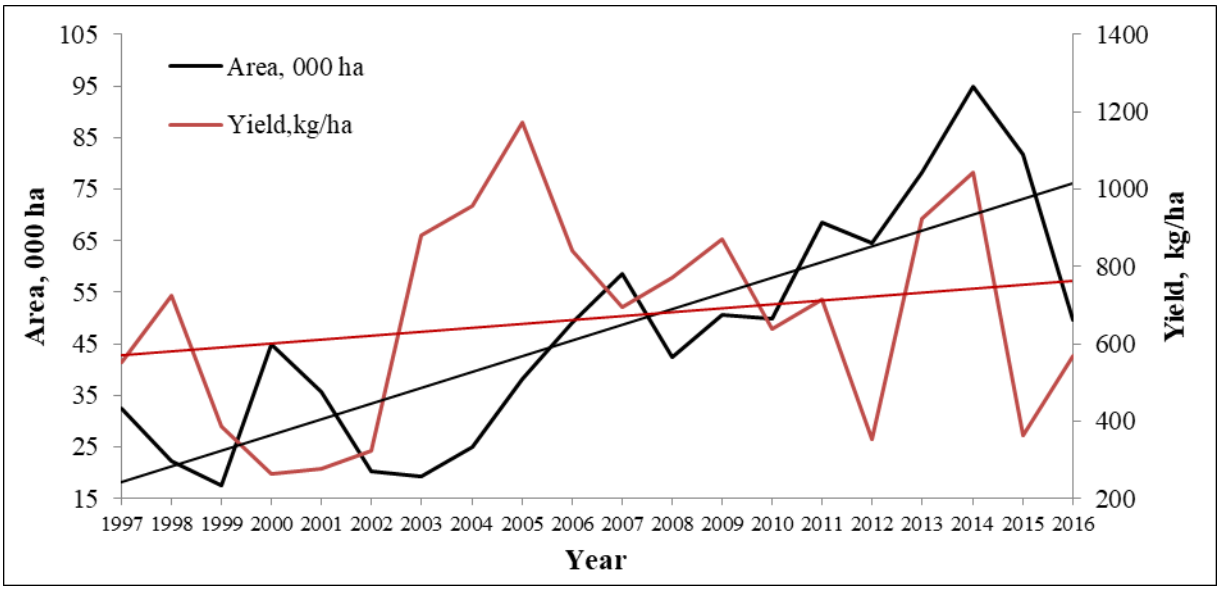

Figure 1. Cultivation Area and Yield of Cotton for Junagadh District

Large intra seasonal variability of rainfall and hence the day-to-day variation of rainfall can have significant impact on the Kharif crop production [8]. Such studies are even more important in semi-arid environments characterized by highly variable rainfall during critical crop growth stages which results in low yields [9-10].

Table 1. Monthly rainfall variability

Month/ Fortnight	Arithmetic Mean, mm	Standard Deviation, mm	CV (%)	Month/ Fortnight	Arithmetic Mean, mm	Standard Deviation, mm	CV (%)
June	189	126	67	4F	124	108	87
July	387	195	50	5F	200	134	67
August	187	134	72	6F	104	103	99
September	193	155	80	7F	74	67	90
1F	15	23	153	8F	112	132	119
2F	125	111	89	9F	80	76	96
3F	123	96	78	10F	25	38	152

Regression analysis is used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. Many researchers have evaluated the effect of rainfall and its distribution on crop yield for Kharif season using correlation and regression analysis for cotton and other crops [11-14]. Abdoulaye et al., [15] used a crop simulation model and showed that rainfall variations of the last growing stages have a significant and negative impact on yield for cotton. Based on the facts mentioned above, a study was planned to evaluate the rainfall variability for Junagadh district (Gujarat, India) and to find the effect of rainfall on Kharif Cotton yield for Junagadh district by correlation and regression analysis.

Methodology

Junagadh is located at southwest of Gujarat State, India (21.520 N latitude and 70.450 E Longitude). The district receives precipitation through the south west monsoon which usually commences by the beginning of June and withdraws by the middle of September with average annual rainfall 900 mm. Cotton is the major crop of the district grown in Kharif season. The rainfall variability and cotton yield was

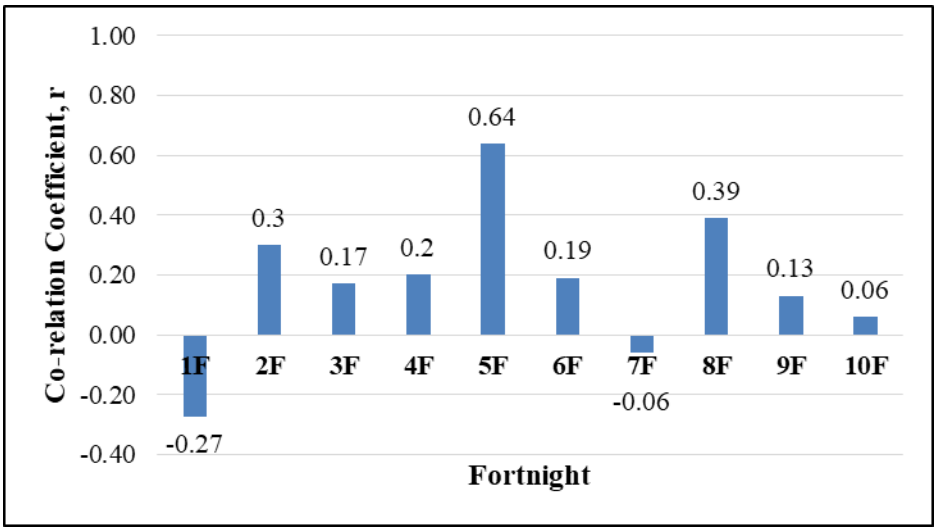

Figure 2. Correlation between fortnightly rainfall and yield

analyzed by considering rainfall data of 20 years from 1997 to 2016 for four splitted durations of seasonal (June -September), monthly, fortnightly (combining two SMWs) and weekly rainfall (SMW 22 to 41) by Arithmetic Mean, Standard Deviation and Coefficient of Variation (CV %). The correlation of yield with seasonal rainfall, each of 5 Months, 10 Fortnights and 20 SMWs was carried out along. The multiple liner regression analysis was worked out with rainfall as independent variable and yield as dependent variable to derive information on rainfall-yield relationship and develop yield prediction models for Cotton.

Table 2. Weekly rainfall variability

SMW	Arithmetic Mean, mm	Standard Deviation, mm	CV (%)	SMW	Arithmetic Mean, mm	Standard Deviation, mm	CV (%)
22	26	21	64	32	78	99	127
23	14	15	104	33	33	33	102
24	95	121	127	34	31	31	102
25	61	65	106	35	55	66	120
26	55	80	145	36	58	58	99
27	191	74	81	37	87	124	143
28	74	79	106	38	68	66	97
29	54	62	116	39	36	61	169
30	96	86	90	40	19	37	197
31	121	113	93	41	07	13	197

Results and Discussion

Rainfall variability

The arithmetic mean (AM), standard deviation (SD) and coefficient of variation (CV) for seasonal rainfall of Junagadh for the duration under study was found as 982 mm, 349 mm and 36% respectively. The monthly and fortnightly rainfall variability given in Table 1 shows that as the rainfall increases the CV% decreases. Highest rainfall was observed in July as 987 mm with lowest 50 % as compare to rest of months and contributes about 40% of the total seasonal rainfall. Whereas other three months each contributes about 19-20% of the total seasonal rainfall. The past records shows that the contribution of 1F (28 May-10 June)

and 10F (1 October- 14 October) is least (2-3%) in total seasonal rainfall with highest CV% 152-153. This suggests the onset and withdrawal of monsoon in those respective fortnights with very high variations in rainfall. The highest average rainfall was 200 mm in fifth fortnight (23 July-05 August) which contributes about 20% of the seasonal rainfall with lowest CV 67%. Whereas 2F, 3F and 4F contributed equal rainfall i.e. 13% in total seasonal rainfall, it covers the duration 11 June to 22 July. Rainfall of 2F to 8F has high standard deviation and varied highly as coefficient of variation was found to be 89% to 119% respectively. If cotton crop critical stage falls under 5F, then it may result in high production as compare to other fortnights.

Table 3. Regression analysis of seasonal rainfall and yield

	Coefficients	Standard Error	P-value
Intercept	156.01	144.74	0.295
X Variable 1	0.52	0.14	0.001*

*P<0.05

Table 4. Regression analysis of monthly rainfall and yield

	Coefficients	Standard Error	P-value
Intercept	135.22	142.86	0.358
X_1 (June)	0.43	0.41	0.312
X_2 (July)	0.83	0.26	0.006*
X_3 (August)	-0.12	0.39	0.758
X_4 (September)	0.76	0.33	0.037*

*P<0.05

In case of weekly rainfall, Table 2 reveals that highest average rainfall was observed in SMW 27 which contributed about 20% of the total seasonal rainfall with CV% less than 100. Table 1 and Table 2 reveals that when 5FN having highest avg. rainfall and lowest CV among all fortnights, splitted in to two weeks the contribution of 30SMW is high between two weeks and both weeks are among the six weeks out of twenty having CV less than 100% including SMW 22, 27, 36 and 38. The above observations reveals that SMW 27, 30 and 31 are most reliable and if sowing is done in such a way that critical crop stage for irrigation fall in these weeks, the higher yield may be obtained. SMW 41 observed with lowest average rainfall and highest CV% which suggests the withdrawal of monsoon. The area under cultivation and yield of Kharif cotton for Junagadh district is given in Figure 1.

Table 5. Regression analysis of fortnightly rainfall and yield

	Coefficients	Standard Error	P-value
Intercept	107.69	122.10	0.401
X1(1F)	-4.73	2.03	0.045*
X2(2F)	1.34	0.67	0.077
X3(3F)	1.41	0.81	0.115
X4(4F)	0.58	0.69	0.424
X5(5F)	1.24	0.39	0.011*
X6(6F)	-0.19	0.50	0.712
X7(7F)	-0.29	0.78	0.717
X8(8F)	0.42	0.43	0.355
X9(9F)	-1.09	1.62	0.517
X10(10F)	1.93	2.55	0.468

Highest yield for the duration 1997 to 2016 was 1171 kg/ha in the year 2005 while lowest yield was recorded as 263 kg/ha in the year 2000, the average yield of these twenty years was 666 kg/ha. The liner trend shows that both cultivation area and yield have shown increasing trend, however the rate of increase in cultivation area was higher as compare to productivity.

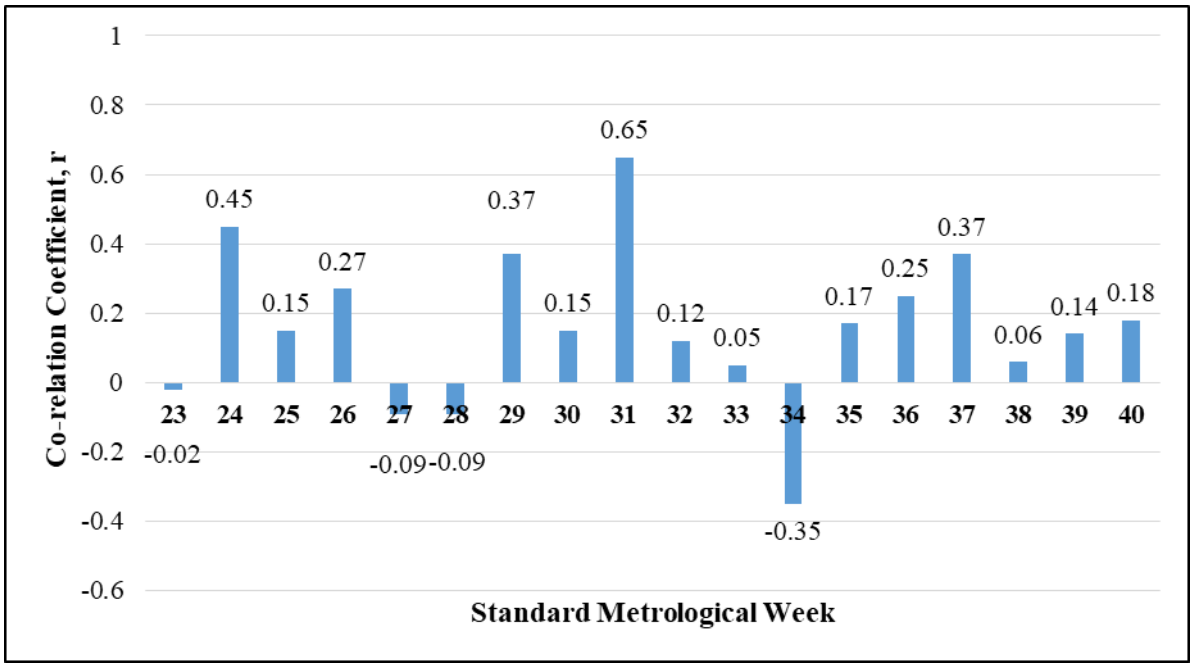

Figure 3. Correlation between weekly rainfall and yield

Correlation and regression analysis

The correlation coefficient between seasonal rainfall and average yield of cotton for Junagadh district was found as 0.66. Adhikari et al., [16] conducted a study in Zimbabwe, reported an 80% decrease in precipitation resulted in a 38% decline in cotton yield. While it was found as 0.31, 0.50, 0.15 and 0.46 for month of June, July, August and September respectively. Thakare [17] studied the impact of weather parameters on cotton productivity at Surat (Gujarat), India and observed that during main sowing period of cotton i.e. June-July which affected the sowing time of crop (delayed in sowing period) which ultimately affected growth, as well as enhanced irrigation needs ultimately affected the crop physiology of cotton. Correlation between fortnightly rainfall and yield shown in Figure 2, indicates that the highest correlation coefficient has been founded as 0.64 for 5F (23 July-05 August). It is evident from Table 1 that 5F has highest rainfall contribution of 200mm with lowest CV 67% than rest of the fortnights which reflects that it is most crucial for cotton cultivation in the district. 7F (20 August-2 September) and 10F (1 October- 14 October) rainfall have almost no correlation with cotton yield. 1F (28 May-10 Jun) rainfall and has the negative co-relation coefficient i.e. -0.27. Out of 20 weeks, rainfall of 31SMW has highest positive correlation with cotton yield with correlation coefficient 0.65 followed by SMW 24, 29 and 37 (Figure 3). Rainfall of SMW34 and 41 showed negative correlation with yield. SMW 34 (20 August-26 August) has reported to have highest negative correlation coefficient as-0.35% which indicates that high amount of rainfall during this SMW has detrimental effect on cotton production in Junagadh District. SWMs 23, 27, 28, 33 and 38 were found to have almost no correlation with yield of cotton which implies that higher or lower rainfall in these weeks have negligible effect in cotton yield. From the Figure 2, it can be observed that correlation coefficient, r was highest in 5F i.e. 0.64,but from Figure 3, it can be stated that that in 5F SMW 31 has higher correlation coefficient while SMW 32 has low value of 0.12. SMW 34 has highest negative correlation coefficient, i.e. rainfall in this week has proven to be detrimental to cotton crop production. Singh et al., [18] also stated that marginal effect of rainfall on cotton was negligible, however, excessive rainfall is detrimental to cotton yield.

The Multiple liner regression was carried out by considering yield as dependent variable and rainfall as independent variable. The level of significance taken with P-value 0.05. The results of regression analysis of cotton yield with seasonal rainfall is depicted in Table 1. The regression analysis of seasonal rainfall and yield shows that 43 % of variability in cotton yield was described by developed model. Gwimbi

and Mundoga [6] studied impact of climate change on cotton production under rainfed conditions in Gokwe and showed that the coefficient of determination (r^2) was 0.64 for cotton production and annual rainfall. Annual rainfall had significantly positive influence on the production and productivity of cotton in the Guntur district of Andhra Pradesh [19].

The results of regression analysis of yield and monthly rainfall is given in Table 4. Out of 4 months, July rainfall has highest positive effect on yield with coefficient as 0.83. August month rainfall has shown negative coefficient. The fitted model obtained is given by equation 2. The predictability of yield was found as 55%. When monthly rainfall is splitted in four months, predictability increased 13% as compare to seasonal rainfall. The regression analysis of yield and fortnightly rainfall is (Table 5) suggest that 10F showed highest positive effect with coefficient as 1.93 followed by 3F with 1.24. The values for 1F and 5F were found significant, and for rest of the fortnights, it was non-significant. 84% variability in yield could be expressed by fortnightly rainfall which was increased by 41% and 29% as compare to seasonal and monthly rainfall respectively. The results of regression analysis of cotton yield and weekly rainfall is shown in Table 6. The rainfall of all the SMW except SMW 31, 33 and 35 showed non - significant effect on yield of cotton due to high variability in weekly rainfall for Junagadh. Rainfall of SMW 32, 33, 34, 35 and 38 showed negative effect on cotton yield. Highest positive effect of rainfall was found for 31SMW with coefficient as 2.83 followed by 27SMW with 1.97. Very high value predictability was observed while splitting the seasonal yield into weeks with R2 as 0.96. The predictability was increased 53 %, 41% and 13 % as compare to seasonal rainfall, monthly rainfall and 13 % as compare to fortnightly rainfall.

Table 6. Regression analysis of weekly rainfall and yield

	Coefficients	Standard Error	P-value
Intercept	181.83	118.59	0.199
X1 (24 SMW)	1.06	0.43	0.058
X2 (25 SMW)	0.11	0.55	0.845
X3(26 SMW)	1.34	0.52	0.062
X4(27 SMW)	1.97	0.90	0.095
X5(28 SMW)	1.36	0.53	0.061
X6(29 SMW)	1.19	0.80	0.214
X7(30 SMW)	0.76	0.55	0.237
X8(31 SMW)	2.83	0.47	0.004*
X9(32 SMW)	-1.32	0.64	0.107
X10(33 SMW)	-4.85	1.67	0.044*
X11(34 SMW)	-1.46	1.05	0.239
X12(35 SMW)	-2.80	0.65	0.012*
X13(36 SMW)	1.48	0.72	0.109
X14(37 SMW)	0.11	0.43	0.803
X15(38 SMW)	-0.18	0.67	0.794

Rankja et al., [20] also recommended weekly rainfall model for pre harvest forecast due to higher R2 value and lower simulated forecast deviation. Parmar [21] and Pandya et al., [22] also evaluated the Influence of Rainfall Distribution on the Productivity of Groundnut and stated that among the regression equations fitted, the equations that incorporated weekly rainfall as independent variables, in general, exhibited the highest value of coefficient of determination. Abdoulaye et al., [15] reported that rainfall variations of the last growing stages have a significant and negative impact on yield. Shikha et al., [10] studied the cotton crop in changing climate. In stage 4 (101-135) days, i.e. ball formation to ball maturity, maximum water stress was seen for non-irrigated condition during drought years. It can be concluded that for fortnightly rainfall, 5F showed highest average rainfall with lowest CV%, highest correlation and highest significant positive regression coefficient, and same is true for 31SMW in case of weekly rainfall. The sowing should be planned in such a way that if most critical crop stage like peak flowering falls during these duration. The cotton yield forecast can be performed according to suggested results of fortnightly or weekly rainfall.

Conclusion

It can be concluded that correlation coefficient seasonal between rainfall and yield was 0.66, in case of monthly rainfall, highest correlation coefficient was found as 0.5 for July and lowest in the month of August as 0.15. For fortnightly rainfall, the highest correlation coefficient was found as 0.64 for 5F and negative -0.27 for 1F. 31SMW has highest positive correlation 0.65 followed by SMW 24, 29 and 37. SMW 34 had highest negative correlation coefficient as -0.35%. The regression analysis revealed that predictability by simple linear regression for seasonal, monthly and fortnightly rainfall were 43%, 55%, 84 % and 96% respectively. The total seasonal rainfall splitted into 15 weeks, the predictability was increased 53 %, 41 and 13 % as compare to seasonal monthly and fortnightly rainfall.

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