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Precipitation distribution and impact of weather parameters on area, production and productivity of pigeonpea in Jalgaon district

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Abstract
The secondary data on area, production and productivity of pigeonpea in Jalgaon district from the year 1991 to 2018 (28 years) were collected from Epitome of Maharashtra. The data on weather parameters considering the crop period were collected from Oil Seeds Research Station, Jalgaon. Looking to the adverse climatic situation and persistent changes in area, production and productivity of pigeonpea in Jalgaon district, the present investigation was undertaken in order to study the impact of weather parameters on area, production and productivity of pigeonpea.
The study revealed that the maximum number of years had recorded low and strong irregular precipitation distribution in Jalgaon district during the study period. The area under pigeonpea has been mainly influenced by wind velocity and number of rainy days in Jalgaon district. The production of pigeonpea has been influenced by number of rainy days and the productivity of pigeonpea has been influenced by rainfall and number of rainy days and indirectly influenced by relative humidity at evening in the Jalgaon district during the study period.

Keywords: Rainfall, weather parameters, pigeonpea, area, production and productivity

Introduction
The variability of rainfall and the pattern of extreme high and low precipitation are very important for agriculture as well as the economy of the Maharashtra state. Climate changes and variability will directly and significantly affect the current and future agriculture (Greg *et al*. 2010). It is well established that rainfall is changing on both global and regional scales due to global warming. The general behavior of different crops in the different regions is very fluctuating due to climatic conditions as a result the growth rates varies from crop to crop and region to region depending upon situations. Many estimates, predictions and forecasting are being made by the different research workers every year to alarm the people, government and policy makers about the productivity of each crop and agriculture as a whole. Crop growth and development are affected by solar radiation, relative humidity, rainfall, temperature and cloud cover which combine to produce the observed impacts of climate on crop yield (Daubenmire 1974) [4]. Ayinde *et al*. (2011) [3], observed the effect of climate change on agricultural productivity in Nigeria. Ajay Kumar *et al*. (2014) [1, 2] carried out the study for the understanding of relationship between climatic factors and sugarcane productivity. Mali *et al*. (2014) [10] analyzed the impact of weather changes on sugarcane production and to quantified the interrelationship between different weather parameters and yield of sugarcane. Due to the large variability in rainfall and weather parameters, farmers are facing problems in getting remunerative production of crops in all regions of Maharashtra state. Looking to the adverse climatic situation and persistent changes in the area, production and productivity of pigeonpea in Jalgaon district, the present investigation was undertaken in order to study the variability in precipitation distribution and impact of weather parameters on area, production and productivity of pigeonpea crop.

Materials and Methods
The secondary data on area, production and productivity of pigeonpea in Jalgaon district from 1991 to 2018 (28 years) were collected from Epitome of Maharashtra and data on rainfall and weather parameters were collected from Oil Seeds Research Station, Jalgaon.

Precipitation Concentration Index

The annual and seasonal rainfall variability will be measured by PCI

$$PCI_{annual} = 100 * \left[\sum pi^2 / (\sum pi)^2 \right]$$

$$PCI_{seasonal} = 33.33 * \left[\sum pi^2 / (\sum pi)^2 \right]$$

where, pi denotes rainfall amount of the i[th] month

Correlation

The mean of one of the random variable is linearly dependent upon the random component of the other. A correlation coefficient (-1) to (+1) indicates a pair of variables that vary together precisely, one variable being related to the other by means of a positive (negative) scaling factor. x_i is the weather parameter (T_{max},T_{min}, RHI,RHII, wind velocity, Evaporation, BSS, rainfall, no. of rainy days etc.) and y_i is the area, production and productivity of crop.

$$r = \frac{\sum X_i Y_i - \frac{(\sum X_i)(\sum Y_i)}{n}}{\sqrt{\left(\sum X_i^2 - \frac{(\sum X_i)^2}{n}\right)} \cdot \sqrt{\left(\sum Y_i^2 - \frac{(\sum Y_i)^2}{n}\right)}}$$

Path analysis

Path analysis extends the idea of regression modeling and gives flexibility of quantifying indirect and total causal effects in addition to the direct effect. The relationship can be expressed in the form of a partial regression equation and is given by

$$Y = \mu + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots\cdots + \beta_9 X_9 + R$$

Where,

$\beta_1, \beta_2 \cdots\cdots, \beta_9$ are the regression coefficients.

β_1 is partial regression coefficient of Y on X_1 means the amount of change that can be brought about in Y due to one unit change in X_1 and $X_2 \cdots\cdots, X_9$ are held constant. $\beta_2 \cdots\cdots, \beta_9$ have similar meanings. R is the residual component.

For estimating the contribution of each weather parameter on area, production and productivity of pigeonpea, a set of nine simultaneous equations is then formulated from path diagram as

$$rY_{X_1} = a + br_{X_1X_2} + cr_{X_1X_3} + \cdots\cdots\cdots + ir_{X_1X_9}$$
$$rY_{X_2} = ar_{X_2X_1} + b + cr_{X_2X_3} + \cdots\cdots\cdots + ir_{X_2X_9}$$
$$\vdots$$
$$\vdots$$
$$rY_{X_9} = ar_{X_9X_1} + br_{X_9X_2} + cr_{X_9X_3} + \cdots\cdots\cdots + i$$

Where,

$Y_{X_1} \ldots\ldots Y_{X_9}$ represent the estimated values of correlation coefficients between dependent

variable Y, and the component variables, i.e., X1, X2 ……X9.

$r_{X_1X_2}$ – Estimates of simple correlation coefficient between x1 and x2 variables.

$r_{X_1X_3}$ – Estimates of simple correlation coefficient between x1 and x3 variables.

Similarly, for $r_{X_2X_1}, r_{X_2X_3} \ldots\ldots\ldots r_{X_9X_8}$

a, b, c, d, e, f, g, h, i - Direct effects of variables X1, X2 ,……. X9.

Results and Discussion

The Precipitation Concentration Index (PCI) of Oliver as an indicator of rainfall concentration for annual and seasonal scales. The PCI is an index of rainfall concentration and variability. It is valuable for water resource planning, management and provides information on water variability for the relevant government agencies and should be taken into account.

Table 1: Year wise Annual and Seasonal Precipitation Concentration Index (PCI)

Year	Annual PCI	Pre monsoon	Seasonal PCI			Post monsoon	Winter
			Kharif	Rabi	Summer		
1991	40.11	12.76	13.58	25.00	12.76	16.67	--
1992	20.67	25.00	8.73	25.00	25.00	16.67	--
1993	28.02	--	11.60	8.89	--	9.00	25
1994	25.56	25.00	9.67	11.29	25.00	9.78	25
1995	15.91	12.53	9.78	14.84	12.53	16.67	25
1996	23.93	25.00	10.21	23.22	25.00	16.67	25
1997	26.43	25.00	11.74	11.54	25.00	14.44	23.45
1998	25.00	25.00	10.37	15.43	25.00	10.29	--
1999	18.52	25.00	8.73	25.00	12.64	16.67	25
2000	30.19	25.00	13.33	--	25.00	--	--
2001	27.10	--	13.11	20.78	--	16.67	25
2002	26.87	12.56	10.73	25.00	22.80	16.67	25
2003	25.28	19.53	8.75	25.00	10.98	--	22.13
2004	32.50	25.00	12.14	25.00	25.00	16.67	--
2005	25.54	12.71	9.82	12.98	12.71	16.67	25
2006	32.61	15.65	12.77	25.00	15.65	16.67	--
2007	28.33	16.65	10.19	25.00	16.65	16.67	--
2008	26.32	--	8.84	25.00	--	16.67	--
2009	21.15	--	11.85	10.40	--	8.38	12.62
2010	24.04	--	10.93	19.25	25.00	13.19	12.65
2011	33.13	25.00	11.17		25.00	--	--
2012	37.81	--	12.89	25.00	--	16.67	--

2013	24.58	--	9.18	25.00	25.00	16.67	25
2014	24.41	22.32	11.41	15.66	14.88	16.67	11.69
2015	22.39	10.05	9.31	12.04	7.60	14.46	13.66
2016	26.42	25.00	9.45	25.00	25.00	16.67	--
2017	26.26	--	9.65	25.00	--	16.67	--
2018	31.02	--	10.61	25.00	--	16.67	--

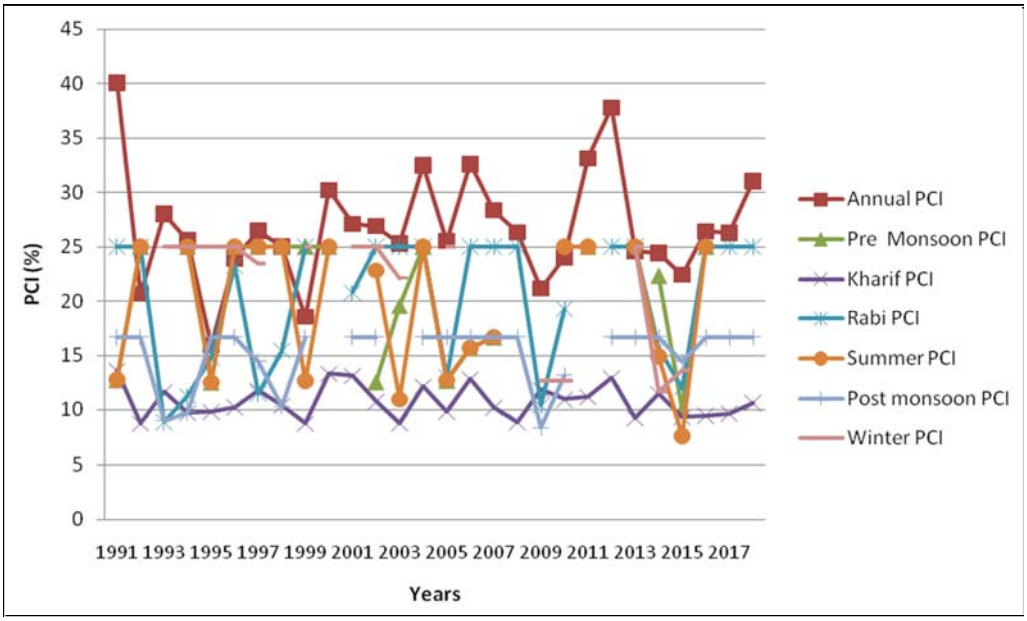

Fig 1: Annual and Seasonal PCI

We are using technique to examine 28 years rainfall data of Jalgaon district. On annual basis, the results of PCI calculated for Jalgaon district (Table 1 and Fig. 1), showed the PCI value ranges from the lowest value of 15.91 in 1995 to the highest of 40.11 recorded in 1991. The most of all annual values of PCI falls in the range of strong irregular precipitation distribution with PCI value greater than 20. The moderate precipitation distribution was observed in the year 1995 with PCI value 15.91. While, irregular precipitation distribution was recorded in the year 1999 under the study period. The uniform or low precipitation distribution observed in the year 2015 (10.05) during the pre-monsoon season. The moderate precipitation distribution observed during the years 1991, 1995, 2002, 2005 and 2006. The irregular precipitation distribution was observed in the year 2007(16.65). However, most of the years fall in strongly irregular precipitation distribution during 1992, 1994, 1996 to 2000, 2004, 2011, 2014 and 2016 with PCI value 25.

For the 28 years period, only 39 per cent of the years in *kharif* season yielded the PCI value less than 10, indexing uniform or low precipitation distribution during 1992, 1994, 1995, 1999, 2003, 2005, 2008, 2013, 2015, 2016 and 2017. The 61 per cent of the years showed PCI value within the moderate precipitation distribution of the years 1991, 1993, 1996 to 1998, 2000 to 2002, 2004, 2006, 2007, 2009 to 2012, 2014 and 2018. The similar result was reported by Ezenwaji *et al*. (2017) [5].

The uniform or low precipitation distribution in *Rabi* season was observed in the year 1993 (8.89). The irregular precipitation distribution was observed in the year 2010. Out of 26 years, 23 per cent of the year recorded moderate precipitation distribution in *Rabi* season. However, 62 percent of the year falls in the range of strong irregular precipitation distribution of Jalgaon district. Out of 21 years, the uniform or low precipitation was observed in 2015(7.60) during summer season. About 29 per cent of the years recorded moderate precipitation while only 10 per cent of years recorded irregular precipitation distribution. However, 57 per cent of the year strongly irregular precipitation was recorded during summer season in Jalgaon district. The similar result was reported by Luis *et al*. (2011) [9].

In post monsoon season of Jalgaon district, three years recorded low precipitation distribution viz. 1993 (9.00), 1994 (9.78), 2009 (8.38).While 15 per cent of the years recorded moderate rainfall distribution of Jalgaon district. However, 69 per cent of the years recorded irregular precipitation distribution under the study period. Out of 15 years, four years moderate precipitation distribution was recorded during winter season of Jalgaon district. While maximum number of years strong irregular precipitation distribution was recorded in Jalgaon district.

The correlation coefficients for different pairs of variables are assessed and shown in Table 2. The area under pigeonpea crop in Jalgaon district was positively correlated with production (0.65) and it was followed by wind velocity (0.55) and number of rainy days (0.39). However, it was significant and negatively correlated with bright sunshine hours (0.38). The production of pigeonpea was highly and positively correlated with productivity of pigeonpea (0.75) and it was followed by number of rainy days (0.53) and rainfall (0.42). The productivity of pigeonpea in Jalgaon district was positive and significantly correlated with rainfall (0.39) and it was followed by number of rainy days (0.38). However, the productivity of pigeonpea was found negative and significantly correlated with wind velocity (0.38). Rainfall and number of rainy days are important weather parameters influencing the production and productivity of pigeonpea in Jalgaon district and wind velocity was adversely affecting the productivity of pigeonpea. The similar result was reported by Laxmi (2014) [8].

Table 2: Inter relationship between area, production and productivity of pigeonpea and weather parameters (1991-2018).

	A	P	Y	T_{max}	T_{min}	RHI	RHII	BSS	Evap.	Wind Vel.	Rainfall	No. of rainy days
A	1.00											
P	0.65**	1.00										
Y	-0.08	0.75**	1.00									
T_{max}	-0.10	-0.21	-0.23	1.00								
T_{min}	0.09	-0.03	-0.12	0.41*	1.00							
RHI	0.18	0.07	-0.08	-0.28	-0.41*	1.00						
RHII	-0.07	0.05	0.12	-0.69**	-0.39*	0.59**	1.00					
BSS	-0.38*	-0.25	0.08	0.17	0.08	-0.30	0.06	1.00				
Evap.	0.04	-0.16	-0.22	0.27	0.23	-0.32	-0.22	0.52**	1.00			
Wind Velocity	0.55**	0.04	-0.38*	0.09	0.03	0.24	-0.28	-0.40*	0.39*	1.00		
Rainfall	0.25	0.42*	0.39*	-0.57**	-0.46*	0.28	0.40*	-0.16	-0.17	0.07	1.00	
No. of rainy days	0.39*	0.53**	0.38*	-0.56**	-0.20	0.14	0.25	-0.28	-0.14	0.12	0.64**	1.00

**Significant at 1% level, * Significant at 5% level

The results of path analysis between area under pigeonpea and weather parameters are depicted in Table 3. The diagonal elements represent direct effects and off diagonal elements represent indirect effects. The wind velocity had highly positive direct effect of 0.745 on area under pigeonpea and it was followed by number of rainy days (0.272), relative humidity at evening (0.207), minimum temperature (0.179) and bright sunshine hours (0.121). The highest total indirect contribution of evaporation and relative humidity at morning were found positive (0.297) and it was followed by rainfall (0.200) and number of rainy days (0.125). However, the highest total indirect contribution of bright sunshine hours was negative (0.501) followed by relative humidity at evening (0.277). The total highest direct and indirect contribution on area under pigeonpea was found positive in case of wind velocity (0.551) and it was followed by number of rainy days (0.397), rainfall (0.218) and relative humidity at morning (0.183). Therefore, the area under pigeonpea was directly influenced by wind velocity, number of rainy days. The residual value was 0.56, it indicates that 56 per cent of variation in area under pigeonpea was accounted by other factors; and 44 per cent variation in area of pigeonpea was accounted by nine selected weather parameters.

Table 3: Decomposition of correlation coefficients between area of pigeonpea and weather parameters

	T_{max} (^{0}C)	T_{min} (^{0}C)	RHI (%)	RHII (%)	BSS (Hrs.)	Evap. (mm)	Wind Velocity (kmph)	Rainfall (mm)	No. of rainy days
Tmax	0.065 [6]	0.073	0.032	-0.142	0.020	-0.088	0.069	-0.008	-0.123
Tmin	0.026	0.179[4]	0.047	-0.081	0.010	-0.073	0.025	-0.008	-0.037
RH-I	-0.018	-0.073	-0.114 [8]	0.122	-0.036	0.103	0.177	0.004	0.018
RH-II	-0.045	-0.070	-0.067	0.207 [3]	0.007	0.070	-0.206	0.005	0.029
BSS	0.011	0.014	0.034	0.011	0.121[5]	-0.167	-0.301	-0.003	-0.100
Evap.	0.018	0.040	0.037	-0.045	0.063	-0.323 [9]	0.292	-0.002	-0.043
Wind Velocity	0.006	0.006	-0.027	-0.057	-0.049	-0.127	0.745 [1]	0.002	0.052
Rainfall	-0.031	-0.078	-0.026	0.061	-0.021	0.039	0.092	0.018 [7]	0.164
No. of rainy days	-0.029	-0.024	-0.008	0.022	-0.04	0.051	0.141	0.012	0.272 [2]

Diagonal (Direct) and off-diagonal (indirect effects), Residual effect = 56%, R^2 = 44%

The number of rainy days had high positive direct effect (0.348) on production of pigeonpea followed by relative humidity at morning (0.287), rainfall (0.248) and minimum temperature (0.163). The highest total indirect contribution was exhibited by wind velocity (0.429) and it was followed by relative humidity at evening (0.319), rainfall (0.157) and number of rainy days (0.144). The highest direct and indirect contribution of number of rainy days was found to be positive (0.492). The similar result was reported by Ajay Kumar *et al*. (2014) [1, 2].

The production of pigeonpea was directly influenced by number of rainy days. The residual value was 0.70 and it indicated that 70 per cent of variation in production of pigeonpea was accounted by other factors; and 30 per cent of variation in production of pigeonpea was accounted by nine selected weather parameters.

The results of path analysis between productivity of pigeonpea and weather parameters are depicted in Table 5. The results indicated that the evaporation had high positive direct effect (0.495) on productivity of pigeonpea and it was followed by relative humidity at morning (0.409), rainfall (0.367) and number of rainy days (0.197). The highest total indirect contribution of relative humidity at evening on productivity of pigeonpea was found positive (0.644) and it was followed by wind velocity (0.640) and bright sunshine hours (0.344).

Table 4: Decomposition of correlation coefficients between production of pigeonpea and weather parameters

	T_{max} (^{0}C)	T_{min} (^{0}C)	RHI (%)	RHII (%)	BSS (Hrs.)	Evap. (mm)	Wind Velocity (kmph)	Rainfall (mm)	No. of rainy days
T_{max}	-0.098 [6]	0.066	-0.081	0.189	-0.042	0.063	-0.036	-0.118	-0.157
T_{min}	-0.040	0.163 [5]	-0.118	0.108	-0.024	0.052	-0.0129	-0.109	-0.048
RHI	0.028	-0.067	0.287[2]	-0.162	0.075	-0.074	-0.093	0.055	0.023
RHII	0.068	-0.064	0.169	-0.276 [7]	-0.014	-0.050	0.108	0.073	0.037
BSS	-0.016	0.013	-0.086	-0.015	-0.251 [8]	0.120	0.157	-0.044	-0.128
Evap.	-0.027	0.037	-0.091	0.060	-0.130	0.231 [4]	-0.153	-0.030	-0.055
Wind Velocity	-0.009	0.005	0.068	0.076	0.101	0.091	-0.389 [9]	0.031	0.066
Rainfall	0.047	-0.071	0.064	-0.082	0.044	-0.028	-0.048	0.248 [3]	0.210
No. of rainy days	0.044	-0.022	0.019	-0.029	0.092	-0.036	-0.074	0.150	0.348 [1]

Diagonal (Direct) and off-diagonal (indirect effects), Residual effect = 70%, R^2 = 30%

The highest total direct and indirect contribution of wind velocity on the productivity of pigeonpea was 0.617 and it was followed by rainfall (0.372), number of rainy days (0.340) and relative humidity at evening (0.121). The productivity of pigeonpea was directly influenced by rainfall and number of rainy days. The residual value was 0.57 and it indicated that 57 per cent of variation in respect to the pigeonpea productivity was accounted by other factors; and 43 per cent of variation in productivity of pigeonpea was accounted by nine selected weather parameters. Ajay Kumar *et al*. (2014) [1, 2] reported that climatic factors have a statistically significant impact on productivity of most of food grain crops but this effect varies across crops.

The results presented for per cent contribution of each selected weather parameter on area under pigeonpea is given in Table 6. It was observed that wind velocity was recorded higher contribution (55.50%) and it was followed by evaporation (10.43%), number of rainy days (7.40%). The per cent contribution of wind velocity was higher (15.13%) and it was followed by number of rainy days (12.11%), relative humidity at morning (8.24%), relative humidity at evening (7.62%) and bright sunshine hours (6.30%) in the production of pigeonpea. The per cent contribution of relative humidity at evening was higher (29.48%) for productivity of pigeonpea and it was followed by evaporation (24.50%), relative humidity at morning (16.73%), rainfall (13.47) and bright sunshine hours (11.22%).

Table 5: Decomposition of correlation coefficients between productivity of pigeonpea and weather parameters

	T_{max} (^{0}C)	T_{min} (^{0}C)	RHI (%)	RHII (%)	BSS (Hrs.)	Evap. (mm)	Wind Velocity (kmph)	Rainfall (mm)	No. of rainy days
Tmax	-0.242 [7]	0.031	-0.115	0.373	-0.056	0.135	-0.094	-0.174	-0.089
Tmin	-0.099	0.076 [5]	-0.168	0.213	-0.027	0.112	-0.034	-0.161	-0.027
RHI	0.068	-0.031	0.409 [2]	-0.320	0.100	-0.158	-0.242	0.082	0.013
RHII	0.166	-0.029	0.240	-0.543 [9]	-0.018	-0.107	0.282	0.109	0.021
BSS	-0.040	0.006	-0.122	-0.030	-0.335 [8]	0.256	0.411	-0.065	-0.072
Evap.	-0.066	0.017	-0.130	0.117	-0.173	0.495 [1]	-0.399	-0.044	-0.031
Wind Velocity	-0.022	0.003	0.097	0.151	0.135	0.194	-0.023 [6]	0.045	0.037
Rainfall	0.114	-0.033	0.091	-0.161	0.059	-0.059	-0.125	0.367 [3]	0.119
No. of rainy days	0.109	-0.010	0.027	-0.057	0.123	-0.078	-0.192	0.221	0.197 [4]

Diagonal (Direct) and off-diagonal (indirect effects), Residual effect = 57%, R^2 = 43%

Table 6: Per cent contribution of weather parameters for area, production and productivity of pigeonpea

Sr. No.	Particulars	Area (%)	Production (%)	Productivity (%)
1	Tmax (^{0}C)	0.42	0.96	5.86
2	Tmin (^{0}C)	3.20	2.66	0.58
3	RH-I (%)	1.30	8.24	16.73
4	RH-II (%)	4.28	7.62	29.48
5	BSS (hrs.)	1.46	6.30	11.22
6	Evap. (mm)	10.43	5.34	24.50
7	Wind Velocity (kmph)	55.50	15.13	0.05
8	Rainfall (mm)	0.03	6.15	13.47
9	No. of rainy days	7.40	12.11	3.88

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