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A Study on Impact of Climate Change on Wheat Production in Kurukshetra District of Haryana

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SUMMARY

The present paper attempts to study the effect of Wheat production in the Kurukshetra area of Haryana, India, is affected by changes in meteorological conditions.The study examined 35 years of time series data on wheat yield as well as weekly data on five weather variables for the crop season from 1985-86 to 2019-20. Using weather indices and time trend as regressor variables and wheat yield as regressand the effect of various factors was investigated using step-wise regression analysis. It has been found that weighted weather indices of each weather variable including time trend have exhibited significant effect on the wheat yield. It has also been found that rise in all five weather variables except relative humidity has been detrimental to wheat yield during harvesting phase of the crop.The overall results indicate the fact that changes in climatic variables show detrimental as well as beneficial the role depending upon the phases of crop production in getting out its final output. On the basis of root mean square error the Model-P_5 has been proven to be best among all the models the average percent standard error (PSE) value of the Model-P_5 is 0.94 which shows that these models are better for forecast.principal component techniques are best created model.

Keywords: Weather variables; Weather indices; Climate change and Regression model.

1. INTRODUCTION

Climate change and fluctuation have a huge impact on agricultural production. Indian agriculture, in particular, is extremely subject to changes in climate conditions. The south-west monsoon's performance, as well as ideal weather conditions, is critical to Indian agriculture's prosperity. Farmers and policymakers alike are concerned about unusual weather patterns. The burning of fossil fuels by automobiles, coal by power plants, industrial sector emissions of greenhouse gases, large-scale deforestation, and other factors have contributed to an increase in the earth's surface temperature and a shift in rainfall patterns in recent years. Changes in climate factors have resulted in a loss of moisture, an increase in the frequency of cyclones, thunderstorms, and floods, as well as a rise in sea level it's possible that several coastal cities and towns may be destroyed. In terms of food grain production, even a small increase in the earth's surface temperature could result in a significant drop in the country's wheat production, as well as a significant reduction in the quality of rice (especially basmati rice), fruits, vegetables, and medicinal plant products that are highly valued for export. Various research workers Jain *et al.*, (1980),Agrawal *et al.*, (1983 & 86), Saseendran *et al.*, (1999), Rathore *et al.*, (2001), Mall *et al.*, (2006),have worked in this direction to workout relationship between crop yield and weather variables. Azfar *et al.* (2014) and Sisodia *et al.* (2015) developed yield projection models depending on weather parameters for rice and wheat. Verma *et al.* (2014 &15) attempted the principal component technique for pre-harvest estimation of cotton yield based on plant biometrical characters distributed over six successive stages of cotton crop growth. Muema *et al.* (2018) used Principal Component Analysis in Measuring Performance of Public Irrigation Schemes in Kenya. Two important food crops in India are Rice and Wheat both of which relate significantly to the nation's overall production of food grains while wheat is primarily

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cultivated in the *Rabi* (Nov.-Apr.) season and *Kharif* (Jun.-Oct.) is the principal growing season for rice. The timing and method of sowing, the establishment of the crop and the climate during the growing season are the key factors impact on productivity. India be the globe second-larger producing of wheat (www.mapsofindia.com/indiaagriculture/). Haryana ranks fourth among the many Indian states in terms of wheat production (www.agricoop.nic.in/statistics). The variables are standardized when the correlation matrix is employed and the whole variance will be the same to the amount of factors utilized in similar study. The variables will keep their original metric if the covariance matrix is applied. But it's important to utilize variables with scales and variances are comparable. In contrast to FA which examines the typical variation PCA the initial matrix examines the overall variance. PCA also makes the assumption that there were no measurement errors in the original measurements. The current work attempts to investigate the impact of changes in meteorological variables on wheat yield by creating appropriate statistical models.

2. MATERIAL AND METHODOLOGY

2.1 Area and crop covered

The study was conducted in the Kurukshetra area of eastern Haryana, India, between the latitudes of 29° 52′ and 30° 12′ and the longitudes of 76° 26′ and 77° 04′ in the north eastern part of the state. It lies in the eastern plain zone of Haryana. On the surface, the soils are loamy sand to sandy loam, and in the subsurface, sandy loam to clay loam, however they are easily ploughable. Wheat farming is a natural choice for the area due to the ideal climate, soil, and lack of irrigation facilities. Wheat crops are often cultivated during the rabi season, when the weather is more conducive to their growth.

2.2 Data Description

2.2.1. Yield Data

Time series data on yield for wheat crop of Kurukshetra district of Haryana for 35 years (1985-86 to 2019-20) have been collected from theStatistical Abstract of Haryana.

2.2.2. Weather Data

The Department of Agro Meteorology, Chaudhary Charan Singh Haryana Agriculture University of Hisar, Haryana, provided weekly weather data on weather variables in the Kurukshetra district of Haryana during the different growth phases of wheat crop from (1985-86 to 2019-20. The data was collected for the first 27 weeks of crop cultivation, from the 41st to 52nd standard meteorological week (SMW) of one year and the 1st to 15th SMW of the following year. The study included data from five weather variables: Minimum Temperature, Maximum Temperature, Relative Humidity, Rainfall and Sun-shine (hr).

2.2.3.Crop Season

Wheat is usually planted in October and harvested in April. The stages of crop development are covered in detail here.

(i) Preparation and Sowing Phase

This phase covers 3 weeks from about October 8 (41th SMW) to about October 28(43th SMW). This phase of the crop is important because in this phase the land is prepared for the sowing. If the weather condition is adverse during this phase the sowing of the crop is generally delayed.

(ii) Vegetative Phase

The Vegetative Phase covers 10 weeks from about October 29 (44th SMW) to about Dec. 31 (52nd SMW). Vegetative phase include germination, crown root initiation stage, tillering, jointing. Germination generally takes about 5-7 days depending upon temperature. The crown –root initiation (CRI) occurs in the dwarf wheat about 20-25 days after sowing (DAS).The crown roots comprise several nodes. Tiller production in wheat often starts about 15 DAS with a new tiller added every 4-5 days until 45 DAS.Jointing is the peak plant growth stage starting from 45-60 DAS. The upper and intermediate nodes expand during this period. The internodes become progressively nodes expand during this period. The internodes become progressively longer from the base to the top. The uppermost internodes are the longest.

(iii) Flowering, Milking and Dough stage

This phase covers 10 weeks from about Jan. 1 (1st SMW) to about March. 11(10th SMW). This stage is also known as physiological maturity.

(iv) Ripening and Harvesting Phase

This phase covers 5 weeks from about March 12 (11th SMW) to about April 15(15th SMW).

2.3 Individual effect of weather variables

Two new variables from each weather variable are developed in order to analyze the effect of each weather variable following the procedure developed by Ranjana *et al.* (1986). Let X_{iw} be the value of the i^{th} weather variable X_i at w^{th} weeks (w = 1, 2,…..n). In this study n is 27. Let r_{iw} be the simple correlation coefficient between weather variable X_i at w^{th} week and adjusted crop yield (Y) for trend effect over a period of K years. The generated variables are then given by

$$Z_{ij} = \sum_{w=1}^{n} r_{iw}^{j} X_{iw} / \sum_{w=1}^{n} r_{iw}^{j} \; ; j=0,\ 1 \quad (1)$$

We have unweighted generated variable

$$Z_{i0} = \sum_{w=1}^{n} X_{iw} / n \quad (2)$$

and for j = 1, we get weighted generated variables

$$Z_{i1} = \sum_{w=1}^{n} r_{iw} X_{iw} / \sum_{w=1}^{n} r_{iw} \quad (3)$$

The new variables $Z_{i0}$and Z_{i1} were generated for each weather variable i(i=1, 2….p). The following model is then fitted to study the effect of individual weather variable on crop yield

$$Y = a_0 + a_1 Z_{i0} + a_2 Z_{i1} + c\mathrm{T} + e,\ i=1,2,\ldots.p \quad (4)$$

where, Y is the actual crop yield; T is variable expressing time effect, a_0, a_1, a_2 and c are parameters of the model to be evaluated for the effect of variables and ε is error term supposed to follow normal distribution with mean zero and variance σ^2. The above model is fitted using step wise regression method for each weather variable.

The effects were obtained by differentiating the fitted model (4) with respect to X_{iw} variable X as follows:

$$\frac{\partial Y}{\partial X_{iw}} = a_1 / n + a_2 r_{iw} / \sum_{w=1}^{n} r_{iw} \quad (5)$$

Let Y_0 be the yield of the crop estimated from fitted model (4) by replacing X_{iw} by $\bar{X}_{iw}$ where $\bar{X}_{iw}$ is the average of X_i (i^{th} weather variable) at w^{th} week over k years. Y_0 is then given by

$$Y_0 = \hat{a}_0 + \hat{a}_1 \sum_{w=1}^{n} \hat{X}_{iw} / n + \hat{a}_2 \sum_{w=1}^{n} r_{iw} \hat{X}_{iw} / \sum_{w=1}^{n} r_{1w};$$

ignoring trend effect n

where $\hat{a}_i^{'s}$ (i= 0, 1, 2) are estimated value of $\hat{a}_i^{'s}$

Assume that the PCA identified the first k principal components as the most significant ones as loading has explained more than roughly 75% of the total variance. As a result, the yield was used as the regressed in the multiple linear regression model along with the trend variable (T) and these first k principal components as regressors. The type of model taken into account is as follows:

$$Y = \beta_0 + \beta_1 PC_1 + \beta_2 PC_2 + \ldots\ldots\ldots. + \beta_k PC_k + \delta T + \varepsilon$$

Where Y is the crop yield, $\beta_i^{'s}\,(i = 0,1,2,\ldots..k)$ and δ are model parameter, PC_1, PC_2,......PC_k are principal components, T is the trend variable and ε is error term assumed to follow normal distribution with mean 0 and variance σ^2.

2.4 Comparison and post-sample validity checking of fitted models

Comparison and validation of fitted models were made using adjusted R^2, percent relative deviations, root mean square error (RMSE) and PSE of post sample forecast yields.

R^2 (Coefficient of Determination):

It is generally used to test the model fit. The formula for R^2 is as follows:

$$R^2 = 1 - \frac{ss_{res}}{ss_t}$$

where SS_{res} and SS_t are the residual sum of square and the total sum of square respectively.

Adjusted R^2 is given by the following formula:

$$R_{adj}^2 = 1 - \frac{ss_{res} / (n-p)}{ss_t / (n-1)}$$

Percent Relative Deviation (RD %)

RD (%) = {(observed yield – forecast yield)/ observed yield} *100.

Root Mean Square Error (RMSE)

It is used as a measure of comparing two models and its formula is given as

$$RMSE = \left[\left\{\frac{1}{n}\sum_{i=1}^{n}(O_i - E_i)^2\right\}\right]^{\frac{1}{2}}$$

where, n is the number of years for which prediction has been made, O_i and E_i are the observed and predicted values, respectively.

Percent Standard Error of the Forecast (CV):

Let $\hat{y}_f$ be forecast value of crop yield. The percent standard error (PSE) of forecast yield $\hat{y}_f$ is given by

$$PSE = \frac{\sqrt{V\left(\hat{y}_f\right)}}{Forecastyield} \times 100$$

3. RESULTS AND DISCUSSION

New weather variables have been created (unweighted and weighted means of weekly weather data). Stepwise regression analysis is used to investigate the impact of individual meteorological variables on agricultural productivity. At various weeks of crop growth, fitted models are used to determine the effects of one unit rise above average in climatic variables. Reversing the vertical scale results in the impact of one unit decreasing below the average. Fig. 1 indicates the yield of kurukshetra district of haryana incerease as well as decrease path follow. Table 1 and 2 summarizes these consequences the results are presented and discussed in the following section.

Table 1. Coefficient of determination (R^2) for Kurukshetra district under several models

Weather Variables	Model							
	I	II	III	IV	V	VI	VII	VIII
Maximum Temperature	0.72	0.72	0.71	0.71	0.72	0.72	0.72	0.72
Minimum Temperature	0.70	0.70	0.71	0.71	0.71	0.71	0.75	0.75
Relative humidity	0.68	0.68	0.69	0.69	0.71	0.71	0.70	0.70
Rainfall	0.71	0.71	0.75	0.75	0.71	0.71	0.70	0.70
Sunshine hours	0.69	0.69	0.70	0.70	0.68	0.68	0.69	0.69

3.1 Effect of Maximum Temperature

The following is the Multiple Regression equation (Model-I) for Maximum temperature is given below.

$$Y = -30.933 + 0.954Z_0 + 4.414Z_1 + 0.986T$$

(R^2=0.72**)

The results were derived from

$$\frac{\partial Y}{\partial X_{xy(w)}} = -0.954 + 4.414r_{xy(w)}$$

The effect of 1^0C above the average during preparation, sowing and Crown root initation stage has been demonstrated to be positive. The effect of 1^0C above the average during germination, Jointing stage, Flowering stage and Milking stage has been demonstrated to be negative. However, during the impacts varied between the tillering and dough stages. During the ripening and harvesting stages, the impacts have been found to be favorable. The 7^{th}, 8^{th}, 20^{th}, 21^{st}, 24^{th}, 25^{th} and 26^{th} weeks all showed significant benefits.

3.2 Effect of Minimum Temperature

The following is the Multiple Regression equation (Model-VII) for Minimum temperature is given below:

$$Y = 32.143 - 2.148Z_0 + 0.362Z_{00} - +0.060Z_{11} + 0.768T$$

(R^2=0.75**)

The results were derived from

$$\frac{\partial X}{\partial X_{xy(w)}} = -2.148 + 0.362 \times 2X_w + 0.060 \times 2X_w r_{x^2y(w)}$$

Table 2 shows that during the preparation, seeding, germination, tilling stage, jointing stage, flowering and milking stages, it was discovered that a 10^c increase above the average has a beneficial effect. During the Crown root initiation stage, however, the benefits were inconsistent. During the dough stage, the impacts have been found to be favorable. The 20^{th} week revealed considerable positive benefits. The effect of 10 degrees

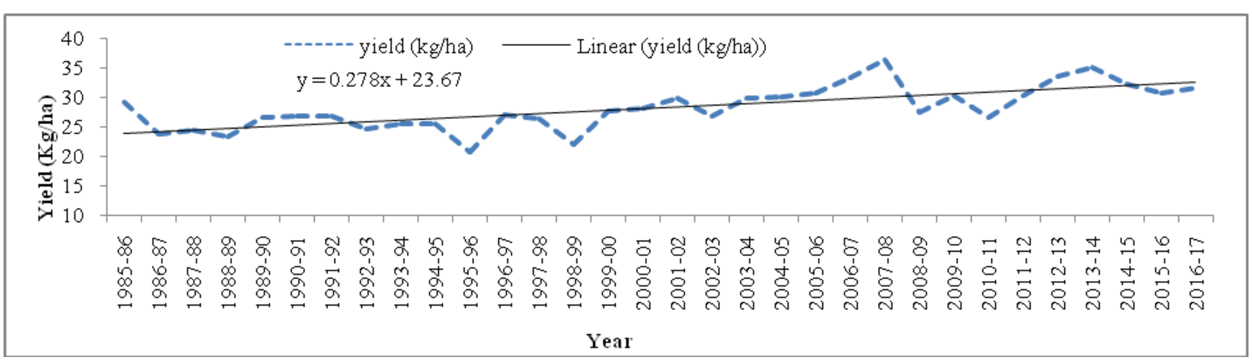

Fig. 1. Annual wheat yield (q/ha) of Kurukshetra district

Celsius over the average during the ripening and harvesting stages has been shown to be negative.

3.3 Effect of Relative Humidity

The following is the Multiple Regression equation (Model-V) for Relative Humidity is given as:

$$Y = -61.905 - 0.198Z_0 + 8.174Z_1 + 0.001Z_{00} + 0.903T$$

(R^2=0.71**)

The effects were derived from

$$\frac{\partial Y}{\partial X_{xy(w)}} = 0.198 + 0.001 \times 2X_w + 8.174 \times 2X_w r_{x^2 y(w)}$$

With the exception of the harvesting stage, the effects were generally positive to wheat yields throughout the crop growing period. However, the seventh week had no effect.

3.4 Effect of Rainfall

The following is the Multiple Regression equation (Model-III) for Rainfall is given below:

$$Y = -7.006 - 0.202Z_0 + 0.040Z_{11} + 1.194T$$

(R^2=0.71**)

The results were derived from

$$\frac{\partial Y}{\partial X_{xy(w)}} = 0.202 + 0.040 \times 2X_w r_{x^2 y(w)}$$

In general, a one-mm increase in rainfall over the normal weekly rainfall has had a positive effect on the germination, dough, ripening and harvesting stage. However, during preparation, sowing, crown root initiation stages, tillering, jointing, flowering and milking stage the effects were changeable. During the milking process, the effects have been found to be useful. In the 19th week, the results were noticeable.

3.5 Effect of Sunshine Hours

The following is the Multiple Regression equation (Model-III) for Sunshine Hours is given below:

$$Y = -16.883 - 7.153Z_0 + 7.833Z_1 + 1.321T$$

(R^2=0.71**)

The effects were obtained from

$$\frac{\partial Y}{\partial X_{xy(w)}} = -7.153 + 7.833 r_{xy(w)}$$

Increases in sunshine hours of one unit over the normal weekly sunshine hours have been observed to have a negative impact on crop yield throughout the wheat production cycle, except for the milking, dough and ripening stages. As a result, an increase in sunlight hours from milking through harvesting phases may be favorable to wheat productivity. The effects were most noticeable between the 19th and 27th weeks. However, the fourth week had no effect.

Table 2. Percent change in yield per unit increase in weather variable over its average value

Growth phase	Week no	SMW	Weather variable				
			Max. temp	**Min. temp**	**Relative humidity**	**Rainfall**	**Sunshine hours**
Preparation, Sowing	1	41	0.483	0.003	6.814	0.001	-61.35
	2	42	1.745	0.008	3.889	0.000	-4.294
	3	43	0.776	0.017	4.001	0.004	-4.685
Germination	4	44	-0.452	0.009	4.421	0.002	0.000
Crown root initiation stage	5	45	0.169	0.008	1.605	0.001	-4.813
	6	46	0.036	-0.010	0.402	0.001	-4.144
	7	47	1.610	-0.000	0.000	0.004	-4.281
Tillering stage	8	48	1.311	0.003	0.825	0.000	-3.299
	9	49	0.318	0.002	1.144	0.003	-3.777
	10	50	-1.088	0.008	2.980	0.003	-3.451
Jointing stage	11	51	-0.114	0.014	2.506	0.012	-2.674
	12	52	-0.156	0.031	2.751	0.010	-2.850
	13	1	-1.253	0.009	3.758	0.006	-3.806
Flowering stage	14	2	-1.010	0.024	1.972	0.003	-2.800
	15	3	-0.369	0.006	2.700	0.000	-4.098
	16	4	-1.509	0.009	3.268	0.010	-3.679
Milking stage	17	5	-0.747	0.008	3.780	0.005	3.543
	18	6	-1.657	0.019	3.536	0.001	2.610
	19	7	-0.762	0.022	4.038	1.840	2.424
Dough stage	20	8	1.356	3.100	4.403	0.011	1.748
	21	9	1.589	0.002	4.137	0.001	1.839
	22	10	-0.299	-0.012	2.257	0.004	3.253
Ripening stage	23	11	0.533	-0.031	2.180	-0.002	1.950
	24	12	1.452	-0.006	1.993	-0.009	2.744
	25	13	1.308	-0.003	4.503	-0.004	2.184
Harvesting stage	26	14	1.138	-0.012	-3.210	-0.004	1.937
	27	15	0.732	-0.010	-3.114	-0.002	2.666

Table 3. Models fitted for Kurukshetra district at m=18, 19, 20, 21 and 22

m	MODEL	R^2	Adj. R^2
18	$Y = 14.220 - 1.085Z_{40} - 0.048Z_{451} + 0.023Z_{241} + 0.811T$ (7.784) (0.407) (0.018) (0.004) (0.145)	81.0	79.6
19	$Y = 14.420 - 1.082Z_{40} - 0.041Z_{451} + 0.020Z_{241} + 0.815T$ (7.782) (0.403) (0.016) (0.006) (0.148)	82.1	81.0
20	$Y = 14.420 - 1.080Z_{40} - 0.041Z_{451} + 0.020Z_{241} + 0.815T$ (7.783) (0.402) (0.012) (0.008) (0.147)	83.9	79.7
21	$Y = 13.420 - 1.088Z_{40} - 0.045Z_{451} + 0.019Z_{241} + 0.810T$ (7.780) (0.406) (0.013) (0.001) (0.141)	79.9	78.2
22	$Y = 14.423 - 1.080Z_{40} - 0.042Z_{451} + 0.021Z_{241} + 0.810T$ (7.779) (0.402) (0.012) (0.004) (0.144)	79.7	78.1

It is the best time to predict wheat output in the Kurukshetra district according to a perusal of Table 3 in 20th week (3rd week of February) as the value of R^2 does not significantly increase when data from later periods are included. Finally, the model generated for m=20 is

$$Y = 14.420 - 1.080Z_{40} - 0.041Z_{451} + 0.020Z_{241} + 0.815T$$

(R^2=0.83)

To assess the adequacy of the chosen models, the residual histograms are reasonably symmetric; additionally, the normal-probability plot provided a graphical means of comparing the residual distribution to the normal. The residuals have an approximate normal distribution, as shown in Fig. 2. Except for a few outliers, the normality assumption appears to be reasonable. Except for a few influential observations, the residual plot against fitted values for the model recommended in this empirical study produces a distribution of points scattered randomly about 0 in an un-patterned fashion

The above model makes it clear that the significant explanatory variables are the weighted weather indices interactions of rainfall and sunshine hour as well as unweighted weather indices of rainfall and weighted weather indices interactions of minimum temperature and rainfall including time trend variable (T). The yield predictions for the year 2017-18, 2018-19 and 2019-20 have been calculated using the forecast model that has been fitted as mentioned above and is shown in table 4. The table 4 results shows that the forecast yield and the observed yield were quite closely matched. The forecast percent deviation ranged 1.32 to 8.93.

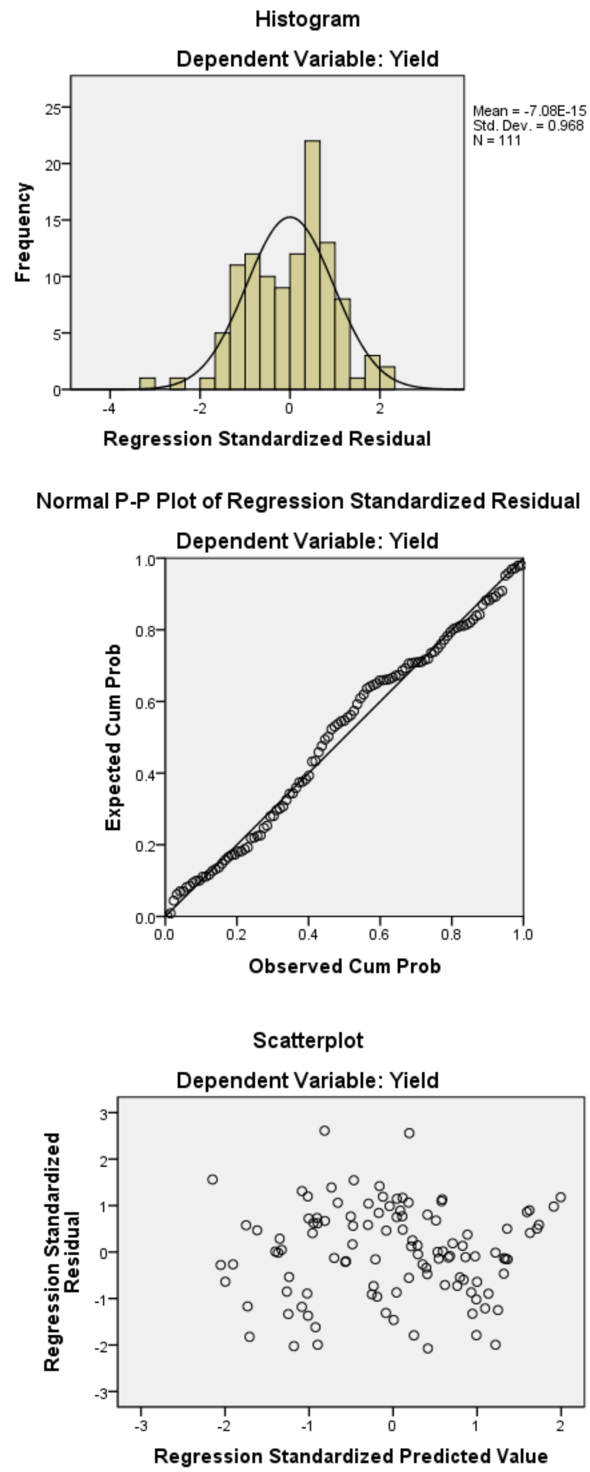

Fig. 2. Regression diagnostics of the selected zonal model

The forecast percent standard error ranged from 3.47 to 3.75. Therefore, it can be inferred that the afore mentioned model can accurately predict wheat yield one and a half month before the harvest.

Table 4. Comparison between observed and forecast yield along with statistical measures at m=20 for Kurukshetra district of Haryana using step wise regression

Year	Observed Yield	Forecast Yield	Percent Deviation	PSE	RMSE
2017-18	48.20	47.56	1.32	3.75	2.68
2018-19	49.51	51.37	3.76	3.47	
2019-20	47.12	51.32	8.93	3.48	

Table 5. Detail of fitted model P_5 for Kurukshetra district of Haryana

S.no.	Variables	Regression Coefficient	Adjusted R^2
1	Constant	8.48^{**}	84.00
2	PC_1	1.10	
3	PC_2	0.39	
4	PC_3	2.23**	
5	Trend	0.79^{**}	

'*' significant at 5% level of significance (P<0.05)
'**' significant at 1% level of significance (P<0.01)

In table 5 the model P_5 includes a constant term, three principal components (PC_1, PC_2, and PC_3), and a trend term. The adjusted R^2 is 84.00%, indicating that the model fits the data well. The regression coefficients for the variables are also shown, with PC_3 having the highest coefficient of 2.23 (significant at p<0.01). The trend term also has a significant coefficient of 0.79 (significant at p<0.01).

Table 6. Statistical Performance of models for Kurukshetra district of Haryana using for principal component analysis

Model	Year	Observed Yield	Predicted Yield	Percent Deviation	PSE	RMSE
P_1	2017-18	48.20	49.46	2.62	1.35	0.99
	2018-19	49.51	49.80	0.59	1.33	
	2019-20	47.12	48.25	2.40	1.38	
P_2	2017-18	48.20	49.38	2.44	1.24	2.22
	2018-19	49.51	50.77	2.54	1.20	
	2019-20	47.12	50.55	7.29	1.21	
P_3	2017-18	48.20	48.17	0.05	1.23	0.86
	2018-19	49.51	49.58	0.15	1.19	
	2019-20	47.12	48.61	3.17	1.22	
P_4	2017-18	48.20	49.40	1.30	0.84	1.28
	2018-19	49.51	49.95	1.44	0.83	
	2019-20	47.12	48.93	1.57	0.85	
P_5	2017-18	48.20	48.53	0.69	0.95	0.69
	2018-19	49.51	49.35	0.31	0.93	
	2019-20	47.12	48.26	2.42	0.96	
P_6	2017-18	48.20	48.08	1.41	1.89	1.79
	2018-19	49.51	49.73	0.98	1.83	
	2019-20	47.12	50.21	1.00	1.81	

Table 6 presents the observed and forecast wheat yield based using different forecast models for different periods 2017-18 to 2019-20. The Percent deviation, Percent standard error and RMSE are also presented in this table. On the basis of root mean square error the Model-P_5 has been proven to be best among all the models. The average percent standard error (PSE) value of the Model-P_5 is 0.94 which shows that these models are better for forecast. This indicates that forecast of Model-P_5 have been most satisfactory among all the models for Kurukshetra district of Haryana as a result the models P_5 can be used to accurately predict wheat production roughly 1.5 months before to harvest.

4. SUMMARY AND CONCLUSION

As for as the effect of individual weather variable on wheat yield is concerned, it can be concluded that the per unit increase in the magnitude of most of the weather variables have made adverse effect on the yield during the entire crop season except during certain phases & crop growth. For example, the beneficial effect on the yield has been generally obtained during tillering and ripening phase due to unit increase in maximum temperature. Per unit increase in minimum temperature has made beneficial effect during dough phase of the crop. Similarly, beneficial effect has been observed due to unit increase in relative humidity at almost during sowing, germination, milking and dough phase of crop growth. Increase in sun-shine hours have been found to be beneficial during the phase of flowering and reproduction etc. The rainfall has very important role in all the phases of the crop production except during harvesting stage. It also indicates the fact that changes in climatic variables exhibit detrimental as well as beneficial role depending upon the phases of crop production in getting out its final output. A perusal of the results indicates the preference of using prediction equations based on higher loading displaying weather variables obtained through PC analysis. Model P_5 is the most reliable for predicting wheat yield in Kurukshetra district as it performed well with low deviation and PSE values in all models. Trend yield (Tr) has been observed an important parameter appearing in all the models, indicating that most of the variability in yield is explained by Tr, which is an indication of technological advancement, improvement in fertilizer/insecticide/pesticide/weedicide used and increased use of high yielding varieties. The percent deviations of post-sample period forecasts falling between 0.69-2.42 percent favour the use of developed model. It can also be concluded that a reliable pre-harvest forecast of wheat yield can be made one &half months before the harvest from the proposed forecast model. In the end, it is concluded that the district-level yield prediction gives good agreement with DOA yield. Moreover, the developed models provide reliable forecasts of wheat yield at least one month in advance of the crop harvest, while DOA yield estimates are obtained quite late after the actual harvest of the crop.

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