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Prediction of wheat yield for different districts of Chhattisgarh plain through statistical model

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Abstract
The performance of regression of model was validated with actual yield of the year 2015 & 2016. At F1 (Initial stage) stage the error % of model varied from -0.2 to -19.4% for 2015 and 2.5 to 14.7% for 2016. Highest error was noticed for Rajnandgaon district -19.4% followed by Raipur -18.6% during 2015, while Korba district showed lower error percentage (0.2%) followed by Kanker (-1.6%). In 2016, Rajnandgaon district showed highest % of error -25.4% whereas Bilaspur showed lowest -1.7% of error with 90% accuracy. The percentage of error ranged from -2.4 to -20.6% during 2015 & -6% to -22.2% during 2016 at F2 (Mead season stage) stage. Korba district showed lowest -2.4% of error. While highest -20.6% of error was noticed for Kawardha district in 2015. During 2016, highest -26.5% of error was observed for Rajnandgaon and lower -6% error was for Raigarh district.

Keywords: Validation, SPSS, weather indices

Introduction
Pre-harvest forecast of the crop production at suitable stages of crop period before the harvest is vital for advance policy formulation in regards to crop procurement and distribution. For deciding future prospects and possible course of action in advance these models are useful for farmers. Thus, reliable and timely pre-harvest forecasting of crop yield is very important (Yadav *et al.* 2014) [4]. It is very important for national food security, early determination of import / export plan and price. It is also important in providing timely information for optimum management of growing crops (Horie *et al.* 1992) [2]. Multiple correlation and regression techniques are basis of statistical model. Predictor's linear combination (both technological parameter and meteorological parameters) is required for Correlation and regression. It considers that the impact of weather and technological advance on yield based on parameters were taken from historical data, and find out the most probable outcomes for current year. Statistical models are comparatively simple and cost effective. Several authors have claimed to achieve over 75% of variation. The main drawback of statistical model is the smallest prediction interval, whereas sectors of the food system are mostly interested in abnormal years.

Materials and Methods
Crop yield data of wheat crop
Last 26 years (1990-2016) crop yield data of wheat crop for 11 districts of C.G. were collected from Directorate of Agriculture & Biotechnology, Raipur (C.G.).

Weather Data
Weekly weather data of different district were collected from Department of Agrometeorology COA IGKV, Raipur during crop growth period (Nov. 2017 to Apr. 2018). Different weather parameters *i.e.* max. & min. Temperature (°C), rainfall (mm), humidity, solar radiation (per meter square) of weekly weather data SPSS model.
Yield forecast models have been worked out through step-wise regression method using SPSS (Statistical Package for the Social Sciences) statistical software on window 7 operating system. Yield forecast models at F1 (initial stage) and F2 (mead season stages) have been worked out through step-wise regression method using SPSS statistical software. Yield was regressed with 42 variables (weighted and un-weighted) to get best regression model. Two indices were worked out.

Un-weighted weather index = Sum (each weekly weather variable)

Weighted weather index = Sum (each weekly variable x correlation coefficient between yield and particular week weather variable)
Weather indices denoted as Z; un-weighted indices are 0 and weighted indices are 1. For instance, maximum temperature taken as 1st variable, hence weather index of un-weighted maximum temperature is Z10 and for weighted Z11. In the same way, other indices were worked out for other weather variables. To study the combined effect of weather variables, un-weighted and weighted indices were also computed. After getting best regression model, significant variables entered in the model and wheat yield for the subsequent year were predicted.

Regression equation
$Y = a + (b1)(x1) + (b2)(x2) + (b3)(x3) + (b4)(x4)$

Where,
Y = Predicted population
A = Intercept
b1, b2, b3, b4 = Regression coefficient
X1, x2, x3, x4 = Dependent variables

Linear regression estimates the coefficients of the linear equation, involving one or more independent variables, which best predicts the value of the dependent variable. The model's output has shown here in which the following abbreviations are used:

Tmax = Mean maximum temperature
Tmin = Mean minimum temperature
Rain = Rainfall in millimeters
SSH = Total sunshine hours

The value for R^2 (correlation coefficient) shows how strong is the correlation held between a predictor or independent variable and the dependent variable. The sign of "r" indicates the slope of the regression line.

Formula of Deviation (%)

$$\text{Deviation \%} = \frac{\text{Predicted yield} - \text{Actual yield}}{\text{Actual yield}} \times 100$$

Result and Discussions

Table 1: Notations for un-weighted and weighted indices

S. No	Weather variable	Un-weighted index	Weighted index
1	Tmax	Z10	Z11
2	Tmin	Z20	Z21
3	Rainfall	Z30	Z31
4	RH-I	Z40	Z41
5	RH-II	Z50	Z51
6	SSH	Z60	Z61
7	Tmax &Tmin	Z120	Z121
8	Tmax & Rainfall	Z130	Z131
9	Tmax & RH-I	Z140	Z141
10	Tmax & RH-II	Z150	Z151
11	Tmax & SSH	Z160	Z161
12	Tmin & Rainfall	Z230	Z231
13	Tmin & RH-I	Z240	Z241
14	Tmin & RH-II	Z250	Z251
15	Tmin & SSH	Z260	Z261
16	Rainfall & RH-I	Z340	Z341
17	Rainfall & RH-II	Z350	Z351
18	Rainfall & SSH	Z360	Z361
19	RH-I & RH-II	Z450	Z451
20	RH-I & SSH	Z460	Z461
21	RH-II & SSH	Z560	Z561

Table 2: Yield forecast equations at F1 stage of wheat for 11 districts of Chhattisgarh plain

SSN	District	Equation	Weather Parameters in the equation	F1 Forecast yield - 2017	Actual yield		Forecast yield (F1)		% of error		R^2	Std. Error	F
					2015	2016	2015	2016	2015	2016			
1	Raipur	Y=4201.0912+51.807894*Z21+0.786013* Z141+19.426698*Time	Time, Tmin, Tmax*RHI,	1601	1924	1770	1564	1654	-18.6	-6.5	0.75	133.9	16.6
2	Durg	Y= 639.45+28.79265*Time	Time	1215	1320	1272	1157	1186	-12.2	-6.7	0.84	59.6	79.2
3	Mahasamund	Y=6752.1844+1.1293651*Z141	Tmax*RH-I	1671	1718	1781	1495	1677	-13	-6	0.52	200.8	13.1
4	Rajnandgaon	Y=2178.7856+30.350874*Z21+21.036256*Time+Z10(-6.1978319)	Tmin., Time, Tmax.	1004	1144	1404	921	1044	-19.4	-25.4	0.88	63.9	33.2
5	Kawardha	Y=452.24841+0.268616*Z251+16.930127*Time	Tmin*RH-II, Time	986	1333	1435	1449	1241	8.7	-13.4	0.87	74.4	34.1
6	Dhamtari	Y=352.79547+32.941476*Time+4.4531089*Z51	Time, RH-II	1423	1534	1475	1462	1436	-4.6	-2.6	0.82	105.1	29.8
7	Kanker	Y=124.50041+466.13881*Z21+0.5554428*Z141	Tmin, Tmax*RHI	1562	1864	1714	1833	1758	-1.6	2.5	0.74	103.0	16.1
8	Janjgir Champa	Y=3679.9001+Z40(-2.9941072)+2.3616214+Z121	Tmax*Tmin,RH-I	1438	1834	1506	1641	1418	-10.5	-5.7	0.70	135.5	15.3
9	Korba	Y=2654.6949+0.2113844*Z141	Tmax*RH-I	939	897	1070	894	938	-0.2	-12.3	0.51	87.3	12.4
10	Raigarh	Y=1920.9485+19.971363*Time+0.603303*Z141+0.1435178*Z140+0.2442826*Z241	Time, Tmax*RH-I, Tmin	1715	1891	1628	1683	1868	-10.9	14.7	0.88	61.1	29.4
11	Bilaspur	Y=1861.0223+18.533741*Time+0.454694+0.454691*Z141+0.117478*Z140+0.617061*Z121	Time, Tmax*RH-I, Tmin	1350	1486	1414	1382	1388	-6.9	-1.7	0.90	62.9	35.2

Table 3: Yield forecast equations at F2 stage of wheat for 11 district of Chhattisgarh plain

SN	District	Equation	Weather Parameters in the equation	F2 Forecast yield - 2017	Actual yield		Forecast yield (F2)		% of error		R^2	Std. Error	F
					2015	2016	2015	2016	2015	2016			
1	Raipur	Y=3832.5621+52.459644*1+ 20.146909*Time+0.5391554*Z141	Tmin, Time, Tmax*RH-I	1578	1924	1770	1574	1623	-18.1	-8.2	0.80	125.7	21.6
2	Durg	Y=621.908497+25.4540764*Time	Time	1181	1320	1272	1130	1156	-14.3	-9	0.80	69.8	64.3
3	Mahasamund	Y=1401.147+1.7700225*Z11	Tmax*Tmin	1410	1717	1781	1507	1411	-12.2	-20.7	0.55	192.1	14.7
4	Rajnandgaon	Y=1991.1988+22.679955*Time+31.716939*Z21+Z10(-3.5590096)	Time, Tmin,Tmax	1028	1144	1404	942	1031	-17.5	-26.5	0.91	54.9	50.4
5	Kawardha	Y=2850.5416+0.1749344*Z251+28.6122*Time+Z140(-0.0604994)	Tmin*RH-II,Tmin*RH-I,Time	1166	1332	1435	1057	1115	-20.6	-22.2	0.95	43.2	52.7
6	Dhamtari	Y=151.93244+33.912515*Time+4.9242471*Z51	Time,RH-II	1436	1534	1475	1425	1372	-7.0	-6.9	0.85	85.2	33.2
7	Kanker	Y=1668.9915+885.7353*Z21	Tmin	1642	1863	1714	1803	1524	-3.2	-11	0.55	185.4	17.3
8	Janjgir Champa	Y=3429.4605+4.2507407*z41+0.1918657*z251	Tmin*RH-II	1399	1834	1506	1548	1414	-15.5	-6.1	0.81	90.4	23.9
9	Korba	Y=2543.9534+0.1315666*Z141	Tmax*RH-I	888	897	1070	875	920	-2.4	-14	0.6	78.7	22.2
10	Raigarh	Y=923.6844+42.16808*z11+1.360*Z121+ Z140(-0.04138)	Tmax,Tmin,RH-I	1452	1890	1628	1732	1530	-8.3	-6	0.67	111.0	13.2
11	Bilaspur	Y=2460.4832+1.1761523*Z121+Z140(0.0558164) +13.345023*Time+Z120(-0.2874594)	Tmax*Tmin,RH-I,Time	1245	1486	1414	1416	1285	-4.6	-9.1	0.87	76.6	29.6

Yield forecast model for wheat crop were developed for 11 districts of Chhattisgarh state through stepwise regression method. Maximum temperature, minimum temperature along with relative humidity were the major factors affecting the wheat yield in most of the district during both the stages F1 & F2 of forecast and played crucial role to decide the wheat yield.

The predicted yield and error based on regression modes during the stages F1 & F2 of forecast are given in the Table 2 and 3, respectively. The performance of regression model was validated with actual yield of the years 2015 & 2016. At F1 (Initial stage) stage, the error % of model varied from -0.2 to -19.4% for 2015 and 2.5 to 14.7% for 2016. Highest error was noticed for Rajnandgaon district -19.4% followed by Raipur -18.6% during 2015. While Korba district showed lower 0.2% of error followed by Kanker -1.6%. In 2016, Rajnandgaon district showed highest % of error -25.4% whereas Bilaspur showed lowest -1.7% of error with 90% accuracy. The percentage of error ranged from -2.4 to -20.6% during 2015 & -6% to -22.2% during 2016 at F2 (Mid season stage) stage. Korba district showed lowest -2.4% of error. While highest -20.6% of error was noticed for Kawardha district in 2015. During 2016, highest -26.5% of error was observed for Rajnandgaon and lower -6% error was for Raigarh district. The developed models have reasonably good R^2 i.e. 0.51 to 0.90% & 0.55 to 0.95% in F1 (Initial stage) and F2 (Mid season stage) respectively. At F1 stage highest R^2 value was found in Bilaspur while lowest in Korba district and highest R^2 value was found in Kawardha& lowest was in Kanker and Mahasamund at F2 stage. Giri *et al.* (2017) [1] reported that rice crop at pre-harvest stage had R^2 values in a range of 0.4 to 0.78. It was less for Balaghat, Mandla, Narsinghpur and Sidhi districts as compared to Jabalpur, Seoni and Shahdol districts. Similar findings was also observed by Rajegowda *et al.* (2014) [3]

Conclusion

The model can be used to some extent for predicting the yield in these districts of Chhattisgarh state. Further improvement is required in statistical model.

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