

Original Research Article

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Estimated Yield Forecasting of Rice and Wheat for Central Uttar Pradesh using Statistical Modal

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ABSTRACT

Twenty three years (1992-2015) weather data of rainfall (mm), Maximum and Minimum temperature ($^{\circ}$ C), maximum and minimum relative humidity (%) and yield data of rice and wheat crop for 12 districts were used for yield prediction using statistical method under FASAL Project, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur Uttar Pradesh. The regression equation was generated for statistical method using SPSS package. The models were validated using 2 year (2016 and 2017) data. The result indicated that model explained 45 to 73 percent variation in rice crop yield and 49 to 74 percent variation in wheat crop in different districts. The F value 13.53 (Mathura) to 57.20 (Auraiya) variation for rice crop and 11.42 (Agra) to 54.51 (Mainpuri) variation for wheat crop was observed in different districts. The percent standard error was between 90.67 (Farrukhabad) to 217.73 (Auraiya) for rice crop and 153 (Mathura) to 252 (Kanpur Dehat) for wheat crop. This revealed that the models can be used to some extent for yield prediction in different districts of Central Uttar Pradesh.

Keywords

Rice, Yield
forecast, Central
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Introduction

Crop acreage estimation and crop yield forecasting are two components, which are crucial for proper planning and policy making in the agriculture sector of the country. Estimation of crop yield in regional level is the basis for planning of crop production prospects at national level. Models based on weather parameters can provide reliable

forecast of crop yield in advance of harvest and also forewarning of pests and diseases attack, so that suitable plant protection measures could be taken up timely to protect the crops (Agrawal and Mehta, 2007). Agrometeorology and Land based observations (FASAL) is an important project operational at Ministry of Agriculture, Government of India in collaboration with Space Application Centre (SAC), Institute of

Economic Growth (IEG) and India Meteorological Department (IMD). Under this FASAL project, IMD in collaboration with 46 Agromet Field Units (AM FU) located at different parts of the country develops intra-seasonal operational yield forecast at district and state level for 13 major crops of India during *Kharif* and *Rabi* seasons using statistical model (Ghosh *et al.*, 2014).

Rice and wheat are the major food grain crops of Central Uttar Pradesh. The Central Uttar Pradesh shares about 36% acreage and 35% production of rice. 43% acreage and 44% production of wheat in twelve districts of Uttar Pradesh viz. Agra, Auraiya, Etawah, Etah Farrukhabad, Hardoi, Kannauj, Kanpur dehat, Kanpur Nagar, Mainpuri, Mathura and Unnao falling under jurisdiction of the AMFU, Kanpur under Chandra Shekhar Azad University of Agriculture & Technology, Kanpur which shares about 32% of rice acreage and 30 % of rice production, 41% of wheat acreage and 42% of wheat production in Central Uttar Pradesh (Anonymous, 2010). The present study was undertaken to investigate the feasibility of estimating the productivity of rice and wheat crops based on weather variables using past weather and yield records of different districts of Central Uttar Pradesh.

Materials and Methods

Crop yield data of Rice and wheat for the period of recent 23 years (1992-2015) were used to develop yield forecasting models. The weather data was used in standard meteorological weeks (SMW) wise starting from 27th to 38th SMW of each year i.e. the period from transplanting to harvest of rice and from 40th SMW of current year to 11th SMW of next year from sowing to harvesting of wheat. The variables used in this study were weekly rainfall (mm), maximum and minimum temperature (°C), RH- I i.e.

morning relative humidity (%) and RH- II i.e. afternoon relative humidity (%) for rice crop. All the weather parameters together with solar radiation data were used for wheat yield prediction. Rainfall was not used as a parameter for wheat forecasting. For selecting the best regression equation among number of independent variables, stepwise regression procedure was adopted. Statistical Package for Social Science (SPSS) computer software was used for the analysis of data with probability level of 0.05 to enter and 0.1 to remove the variables. A regression model was fitted considering the entered variables obtained from individual stepwise regression analysis to predict the yield of rice and wheat for subsequent years. The multiple linear stepwise regression analysis has been developed on the basis of examination of coefficients of determination (R²), Standard Error (SE) of estimates values resulted from different weather variables. The F values are used for the degree of accuracy of each considered correlation to fit the measured data. F value provides information on the long term performance of the models. The best agro meteorological indices were selected to develop agro meteorological yield model for the each district as per methodology given by Ghosh *et al.*, (2014). Yield forecast models for all twenty three districts which produce rice and wheat have been developed and their performance s have been validated against the observed year in 2015-16 and 2016-17.

Results and Discussion

Rice yield forecast

The yield variations explained by model together with standard error are shown in Table 1. Coefficient determination (R²) has been significant at 5% probability level for rice in all the twelve districts of Central Plain Zone of Uttar Pradesh. The R² was ranged between 45% (Hardoi) to 73% (Farrukhabad).

The percent F value was ranged between 13.53 (Mathura) and 57.20 (Auraiya), However, the percent standard error was ranged between 90.67 (Farrukhabad) and 217.73 (Auraiya). The best agro meteorological indices to incorporate in the agro meteorological yield model for rice was selected as, RH-I (Z41) for Agra district, TIME for Auraya, Etawah, Farrukhabad, Kanpur Dehat, Mainpuri district, TIME, RH-1 (Z41) for Etah, Tmax. x Tmin (Z121) for Hardoi, Kannauj district, TIME, Rain (Z31) for Kanpur district, Rain (Z31) for Mathura district and TIME x RH I (Z141) for Unnao district.

The validation of model for rice during the year 2016 and 2017 are shown in Table 2. Result revealed that in 2016, the models for Agra (10.15%), Auraya (-5.26%), Etawah (-5.15%), Etah (18.40%), Farrukhabad (7.24%), Hardoi (11.02%), Kannauj (10.70%), Mainpuri (-1.68%) and Unnao (-16.70%) districts have underestimated the yield while over estimation was observed in Kanpur Dehat (5.72%), Kanpur (6.30%), and

Mathura (1.56%) in 2016. Whereas, during 2017 Rice yield under estimated in all the twelfth districts, models Auraya (-2.44%), Etah (21.93%), Hardoi (21.78%), Kannauj (19.80%), Mathura (28.23%) and Unnao (-2.70%) and over estimated in Agra (9.54%), Etawah (2.21%), Farrukhabad (8.69%), Kanpur Dehat (8.37%), Kanpur (5.40%) and Mainpuri (2.57%) districts. Models had less than ± 10% error in rice yield prediction for all districts during both the years. This has indicated that the model can be used for prediction of rice yield in above districts. The result revealed that agrometeorological yield model explained the yield variability due to variations in temperatures, rainfall and relative humidity during the different stages (tillering, panicle initiation, booting and physiological maturity). Maximum and minimum temperatures were found common agrometeorological indices for most of the districts of this region. However, rainfall with relative humidity is also proved important agrometeorological indices for some of the districts of Central Uttar Pradesh.

Table.1 Yield forecast models of rice for different districts of Central Uttar Pradesh

SN	District	Equation	R ²	Forecast yield (Kg/ha)	F	Std Error	ERROR (%)	
							2016	2017
1	AGRA	Y= 601+ 30.50*Z41	0.59	2367	32.71	146.52	10.15	9.54
2	AURAIYA	Y= 1927+45.67*TIME	0.71	3206	57.20	217.73	-5.26	-2.44
3	ETAWAH	Y=2035+ 31.97*TME	0.63	2930	40.76	180.55	-5.15	2.21
4	ETHA	Y=2348 +27.03*TIME+30.09*Z41	0.67	2431	20.42	153.07	18.40	21.93
5	FARRUKHABAD	Y=1887+ 24.28*TIME	0.73	2519	56.31	90.67	7.24	8.69
6	HARDOI	Y= -1237+ 2.3*Z121	0.45	1659	17.78	184.73	11.02	21.78
7	KANNAUJ	Y=-2102+3.90*Z121	0.52	1941	24.91	185.20	10.70	19.80
8	KANPUR DEHAT	Y= 17.98+32.20*TIME	0.57	2700	29.82	212.63	5.72	8.37
9	KANPUR	Y=1529+25.20*TIME+2.37*Z31	0.62	2255	14.83	186.80	6.30	5.40
10	MAINPURI	Y=1816+33.32*TIME	0.64	2716	38.80	181.42	-1.68	2.57
11	MATHURA	Y=2187+5.82*Z31	0.55	2813	13.53	166.49	1.56	28.23
12	UNNAO	Y=4063+0.73*Z141	0.56	1979	29.70	166.54	-16.70	-2.70

Table.2 Validation of model for forecast of rice yield under different districts of Central Uttar Pradesh

SN	District	2016			2017		
		Observed	Forecasted	Error%	Observed	Forecasted	Error%
1	AGRA	2542	2284	10.15	2680	2424	9.54
2	AURAIYA	2959	3115	-5.26	3085	3160	-2.44
3	ETAWAH	2726	2866	-5.15	2964	2898	2.21
4	ETHA	2887	2355	18.40	3025	2361	21.93
5	FARRUKHABAD	2663	2470	7.24	2732	2495	8.69
6	HARDOI	2314	2059	11.02	1297	1718	21.78
7	KANNAUJ	2684	2396	10.70	2987	2397	19.80
8	KANPUR DEHAT	2796	2636	5.72	2912	2668	8.37
9	KANPUR	2493	2337	6.30	2504	2369	5.40
10	MAINPURI	2606	2650	-1.68	2754	2683	2.57
11	MATHURA	2346	2309	1.56	2451	1759	28.23
12	UNNAO	1858	2169	-16.70	2098	2155	-2.70

Table.3 Yield forecast models of wheat for different districts of Central Uttar Pradesh

S.N.	District	Equation	R ²	Forecast yield (Kg/ha)	F	Std Error	ERROR	
							2016	2017
1.	AGRA	Y= 2834+0.38*Z241+0.5*Z351	0.52	3034	11.42	161.6	22.39	8.06
2.	AURIYA	Y=3113+0.83*Z131	0.49	3105	21.33	184	22.31	12.08
3.	ETAWAH	Y=3136+17.26*Z51	0.52	2991	23.62	171	25.93	19.22
4.	ETHA	Y=2067+33154*TIME+8.50*Z51	0.74	2901	30.16	164	12.56	5.59
5.	FARRUKHABAD	Y=2804+37.01*TIME	0.54	3804	26.5	243	4.87	- 10.11
6.	HARDOI	Y=2391+34.43*TIME	0.68	3321	47.63	169	10.55	-0.39
7.	KANNAUJ	Y=2835+36.58*TIME	0.59	3833	32.23	201.8	4.47	0.31
8.	KANPUR DEHAT	Y=1528+0.44*Z141	0.53	3461	24.71	252	26.79	15.09
9.	KANPUR	Y=1479+0.54*Z241	0.60	2549	31.79	184	35.10	29.67
10.	MAINPURI	Y=2665+35.62*TIME	0.71	3627	54.51	163	11.43	3.32
11.	MATHURA	Y=1755+1.55*Z121+18.46*TIME	0.68	3565	21.79	153	15.54	4.78
12.	UNNAO	Y=2001+37.42*TIME	0.62	3012	35.44	209	7.96	7.54

Table.4 Validation of model for forecast of wheat yield for different districts of Central Uttar Pradesh

SN	District	2016			2017		
		Observed	Forecasted	Error%	Observed	Forecasted	Error%
1.	AGRA	4080	3167	22.39	3528	3244	8.06
2.	AURIYA	4017	3121	22.31	3511	3087	12.08
3.	ETAWAH	4140	3067	25.93	3598	2906	19.22
4.	ETHA	3881	3394	12.56	3374	3185	5.59
5.	FARRUKHABAD	3921	3730	4.87	3421	3767	-10.11
6.	HARDOI	3636	3252	10.6	3274	3287	-0.4
7.	KANNAUJ	3925	3750	4.47	3798	3786	0.31
8.	KANPUR DEHAT	4588	3359	26.79	3985	3384	15.09
9.	KANPUR	4065	2638	35.1	3714	2612	29.67
10.	MAINPURI	4015	3556	11.43	3715	3292	3.32
11.	MATHURA	4104	3466	15.54	3687	3511	4.78
12.	UNNAO	3191	2937	7.96	3217	2975	7.54

Wheat yield forecast

The yield variations explained by model for wheat crop together with standard error are shown in Table 3. Coefficient of determination (R^2) has been significant at 5% probability level for wheat in all the twelve districts of central Uttar Pradesh. The (R^2) was ranged between 49 (Auriya) and 74% (Etawah). The percent F value was ranged between 11.42 (Agra) and 54.51 (Mainpuri), However, the percent standard error was ranged between 133.0 (Hathrus) and 252.0 (Kanpur dehat). The best agrometeorological indices to incorporate in the agrometeorological yield forecast model was selected as Tmin x RH-I (Z241), Rain x RH-II (Z351) for Agra, district, Tmax. x Rain (Z131) for Auriya district, RH-II (Z51) for the Etawah, Time, RH-II (Z51) for Etah district, TIME for Farrukhabad, Firozabad, Hardoi, Kannauj, Mainpuri and Unnao district, Tmin x RH-I (Z241), Tmin. x RH-II (Z251) for Hathrus, Tmax. x RH-I (Z141) for Kanpur dehat, Tmin. x RH-II (Z241) for Kanpur and Tmax x Tmin (Z121), TIME for Mathura district.

The validation of model for wheat during the year 2016-17 and 2017-18 has been shown in

Table 4. Results revealed that the models estimated error in Agra (22.39%), Auriya (22.31%), Etawah (25.93%), Etah (12.56%), Farrukhabad (4.87%), Hardoi (10.55%), Kannauj (4.47%), Kanpur Dehat (26.79%), Kanpur (35.10%), Mainpuri (11.43%), Mathura (15.54%) and while over estimation was observed for Kannauj (4.47%), Farrukhabad (4.87%) and Unnao (7.96%) in 2016-17. During 2017-18 models underestimated in Auriya (12.08%), Etawah (19.22%), Farrukhabad (-10.10%), Hardoi (-0.39%), Kanpur Dehat (15.09%), Kanpur (29.67%) and over estimated in Agra (8.06%), Etah (5.59%), Kannauj (0.31%), Mainpuri (3.39%), Mathura (4.75%) and Unnao (7.54%) districts. Results also indicated that the model has predicted that the wheat yield with in±10% error in all the twelve districts of Central Uttar Pradesh. Maximum & minimum temperatures, RH-I and RH-II are important agrometeorological indices for wheat yield forecast. Predicted yield was closed to observed yield, therefore, it can be used for yield forecasting and planning purpose.

The results showed that agro-meteorological yield model explained the yield variability due to variations in minimum, maximum

temperatures together with relative humidity with respect to major wheat growing districts of Agra, Etah, Kannauj, Mainpuri, Mathura and Unnao. Whereas, variations in rain also influenced in other districts where wheat cultivation is comparatively less intensive. According to Singh *et al.*, (2010) and Singh *et al.*, (2011). Over the past few years, the per hectare yield of wheat in India has fallen due to the temperature rising steadily in January, February and March (a period most crucial for the wheat crop). Maximum and minimum temperatures are very sensitive weather parameters for wheat crop, arise by 0.5⁰C in winter temperature is projected to reduce wheat yield by 0.45 t ha⁻¹ in India (Lal *et al.*, 1998). Wheat growing belts of this region are also largely influenced by maximum and minimum temperature prevailed during the cropping season. Therefore, it can be infer that maximum and minimum temperatures together with RH found were significant weather parameters for deciding wheat productivity in the region.

In conclusion, yield forecast has been done for rice and wheat crops for twelve districts of Central Uttar Pradesh. The developed models have reasonably good R² between 45 to 73% variation in rice crop yield and between 49 to 74% variation in wheat crop yield in different districts. The F value between 13.53 to 57.20% variation for rice crop and between 11.42 to 54.51% variation for wheat crop in different districts. The percent standard error was between 90.67 to 217.73 % for rice crop and between 153 to 252 % for wheat crop. The models were validated with ± 10% error in all the twelve districts of *Central Uttar Pradesh*. Therefore, it could be used for yield forecasting satisfactorily for both crops and for all the

twelve districts of central plan zone of Uttar Pradesh. Further, by and large, the maximum and minimum temperatures in combination with relative humidity have formed most important agrometeorological indices which can useful in forecasting of yield of rice and wheat crop in the region.

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