Journal of Agrometeorology 16 (2) : 199-202 (December 2014)

Yield forecasting of rice and wheat crops for eastern Uttar Pradesh

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ABSTRACT

Eighteen years (1991-2008) of weather data and yield data of rice and wheat for 9 districts of Eastern Uttar Pradesh was used to develop yield prediction equations. Models were validated with 2 years (2009 and 2010) data. Results indicated that models explained 51 to 79 percent variations for rice yield and 65 to 92 percent variations for wheat yield in different districts. The percent Mean Bias Error (MBE) was between -1.05 (Mau) to 6.17 (Mirzapur) for rice and from -6.56 (Mau) to 0.01 (Varanasi) for wheat crop. The percent Root Mean Square Error (RMSE) was between 6.87 (Jaunpur) to 11.60 (Sant Ravidas Nagar) for rice and from 5.52 (Mirzapur) to 11.11 (Mau) for wheat crop. This revealed that the models can be used to some extent for predicting the yield in different districts of Eastern Uttar Pradesh.

Key words: Rice, wheat, yield forecast, Eastern Uttar Pradesh, weather data and SMW

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. Regional level estimation of crop yield is the basis for planning 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). Forecasting Agricultural output using Space, Agrometeorology and Land based observations (FASAL) is an important project operational at Ministry of Agriculture, Govt. 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 (AMFU) 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 Eastern Uttar Pradesh. The Eastern Uttar Pradesh shares about 52% acreage and 51% production of rice, 34% acreage and 32% production of wheat in Uttar Pradesh. Nine districts viz., Azamgarh, Chandauli, Ghazipur, Jaunpur, Mau, Mirzapur, Sonbhadra, Sant Ravidas Nagar and Varanasi falling under jurisdiction of the AMFU, Varanasi with headquarter at Banaras Hindu University (BHU) shares about 31% of rice acreage and 30 % of rice production, 33% of wheat acreage and 30% of wheat production in Eastern 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 Eastern Uttar Pradesh.

METARIALS AND METHODS

Rice and wheat crop yield data for the period of recent 18 years (1991-2008) were used to develop yield forecasting models. The weather data was used in standard meteorological weeks (SMW) wise starting from 22nd to 41th SMW of each year i.e. the period from transplanting to harvest of rice and from 44th SMW of current year to 11th SMW of next year from sowing to harvesting of wheat. The variables used in this study were weekly of rainfall (mm), maximum and minimum temperature (^{0}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

Table 1: Yield forecast models of rice and wheat for different districts of Eastern Uttar Pradesh

Crops	District	Regression equation	R^2	Standard Error	MBE (%)	RMSE (%)
Rice	Azamgarh	1904.23+Z341×0.0216	0.73*	314	5.94	9.21
	Chandauli	1954.82+Z351×0.0916+Z30×0.364	0.76*	370	2.77	11.11
	Ghazipur	2454.50 + Z121×1.75 + Z240 × 0.03	0.60*	289	5.43	9.28
	Jaunpur	2780.98+Z121×1.270+Z21×69.08+Z140×0.011	0.79*	280	-0.03	6.87
	Mau	1873+Z351×0.18 + Z141× 0.06	0.76*	296	-1.05	11.08
	Mirzapur	5940.47+Z351×0.050+Z10×(-0.6.22)	0.73*	368	6.17	11.20
	Sonbhadra	879.10+Z121×3.091+Z40×1.040+Z131×0.0902	0.51*	516	3.57	7.32
	Sant Ravidas Nagar	4977.60+Z11×59.20	0.58*	449	-1.00	11.60
	Varanasi	165.87+Z121×3.26+Z340+0.01	0.58*	370	1.33	10.66
Wheat	Azamgarh	2096.41+Z251×0.566	0.89*	187	-6.06	10.71
	Chandauli	9871.15+Z31×97.557+Z40×-1.49	0.74*	373	0.00	6.47
	Ghazipur	202.515+18.03+Z11×36.488+Z151×0.32	0.82*	245	-3.48	9.83
	Jaunpur	2275.61+17.327+Z151×0.361+Z121×0.572	0.92*	183	-4.78	9.46
	Mau	4590.33+21.74+Z31×30.511+Z41×2.548+Z51×3.374	0.90*	171	-6.56	11.11
	Mirzapur	1814.75+Z151×0.246+Z241×0.199	0.79*	217	-0.15	5.52
	Sonbhadra	1121.59+39.82+Z11×27.47+Z351×0.47+Z250×0.035	0.65*	236	-3.82	8.92
	Sant Ravidas Nagar	5039.41+Z341×0.447+Z121×1.734	0.81*	404	-1.20	10.99
	Varanasi	2920.83+Z251×0.408+Z131×1.162+Z151×0.333	0.74*	291	0.01	5.64

*Significant at 5% probability

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 the subsequent years. The multiple linear stepwise regression analysis has been developed on the basis of examination of coefficients of determination (R^2), Standard Error (SE) of estimates values resulted from different weather variables. Two statistical tests, percent Mean Bias Error (MBE) and percent Root Mean Square Error (RMSE) are used to the degree of accuracy of each considered correlation to fit the measured data. MBE provide information on the long term performance and RMSE short 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 nine districts which produce rice and wheat have been developed and their performances have been validated against the observed yields in 2009-10 and 2010-11.

RESULTS AND DISCUSSION

Rice yield forecast

The yield variations explained by model together with standard error are shown in Table 1. Coefficient of determination (R^2) has been significant at 5% probability level for rice in all the nine districts of Vindhyan Agro-climatic Zone of Eastern Uttar Pradesh. The R^2 was ranged between 51 (Sonbhadra) and 79% (Jaunpur). The percent MBE was ranged between -1.05 (Mau) and 6.17 (Mirzapur). However, the percent RMSE was ranged between 6.87 (Jaunpur) and 11.60 (Sant Ravidas Nagar). The best agrometeorological indices to incorporate in the agrometeorological yield model for rice was selected as Rain×RH I (Z341) for Azamgarh district, Rain×RH II (Z351) and Rain (Z30) for Chandauli district, Tmax×Tmin (Z121)

Table 2: Validation of model for forecast of rice and wheat yield for different districts of Eastern Uttar Pradesh

District	Rice yield (kg ha^{-1})						Wheat yield (kg ha^{-1})					
	2009			2010			2009-10			2010-11		
	Forecasted	Observed	Error (%)	Forecasted	Observed	Error (%)	Forecasted	Observed	Error (%)	Forecasted	Observed	Error (%)
Azamgarh	1904	1979	-4.0	1899	1751	7.8	2356	2584	-8.8	2540	2800	-9.3
Chandauli	2424	2632	-8.6	2193	2028	7.5	1939	2068	-6.2	2631	2542	3.5
Ghazipur	2346	2235	4.7	2036	1855	8.9	2793	2762	1.1	2628	2701	-2.7
Jaunpur	2017	2154	-6.7	2056	1976	3.9	2531	2720	-7.0	2630	2857	-7.9
Mau	1836	2002	-9.0	1591	1461	8.2	2186	2400	-8.9	2593	2814	-7.9
Mirzpur	2149	2068	3.8	1696	1550	8.6	2032	1984	2.4	2371	2315	2.4
Sonbhadra	1323	1349	-1.9	1306	1183	9.4	1727	1882	-8.2	1615	1728	-6.6
Sant Ravidas Nagar	1976	1997	-1.0	1985	1973	0.6	2182	2249	-3.0	2930	2875	1.9
Varanasi	2044	2152	-5.3	1623	1489	8.3	2456	2511	-2.2	2896	2781	4.1

and Tmin×RH I (Z240) for Ghazipur district, Tmax×Tmin (Z121), Tmin (Z21) and Tmax×RH I (Z140) for Jaunpur district, Rain×RH II (Z351) and Tmax×RH I (Z141) for Mau district, Tmax×RH II (Z351) and Tmax (Z10) for Mirzapur district, Tmax×Tmin (Z121), RH I (Z40) and Tmax×Rain (Z131) for Sonbhadra district, Tmax (Z11) Sant Ravidas Nagar district and Tmax×Tmin (Z121) and Rain×RH I (Z340) for Varanasi district.

The validation of model for rice for year 2009 and 2010 are shown in Table 2. Results revealed that in 2009 the models for Azamgarh (-4.0%), Chandauli (-8.6%), Jaunpur (-6.7%), Mau (-9.0%), Sonbhadra (-1.9%) Sant Ravidas Nagar (-1.0%) and Varanasi (-5.3%) districts have underestimated the yield while over estimation was observed in Ghazipur (4.7%) and Mirzapur (3.8%) in 2009. Whereas, during 2010 in all the nine districts models overestimated Azamgarh (7.8%), Chandauli (7.5%), Ghazipur (8.9%), Jaunpur (3.9%), Mau (8.2%), Mirzapur (8.6%) , Sonbhadra (9.4%) Sant Ravidas Nagar (0.6%) and Varanasi (8.3%) the rice yield. 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 the above districts. The result revealed that agro meteorological 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 common agrometeorologial indices for most of the districts of this region. However, rainfall with relative humidity is also important agrometeorological indices for some of the districts of Eastern Uttar Pradesh.

Wheat yield forecast

The yield variations explained by model for wheat crop together with standard error are shown in Table 1. Coefficient of determination (R^2) has been significant at 5% probability level for wheat in all the nine districts of eastern Uttar Pradesh. The R^2 was ranged between 65 (Sonbhadra) and 92% (Jaunpur). The percent MBE was ranged between -6.56 (Mau) and 0.01 (Varanasi). However, the percent RMSE was ranged between 5.52 (Mirzapur) and 11.11 (Mau). The best agrometeorological indices to incorporate in the agrometeorological yield forecast model was selected as Tmin×RH II (Z251) for Azamgarh district, solar radiation (Z31), and RH I (Z40) for Chandauli district, Tmax (Z11), Tmax×RH II (Z151) for Ghazipur district, Tmax× RH II (Z151) and Tmax×Tmin (Z121) for Jaunpur district, solar radiation (Z31), RH I (Z41) and RH II (Z51) for Mau district, Tmax×RH

II (Z151) Tmin×RH I (Z241) for Mirzapur district, Tmax (Z11), solar radiation×RH II (Z351) and Tmin×RH II (Z250) for Sonbhadra district, solar radiation×RH I (Z341), and Tmax×Tmin (Z121) for Sant Ravidas Nagar district and Tmin×RH II (Z251), Tmax×solar radiation (Z131) and Tmax×RH II (Z151) for Varanasi district.

The validation of model for wheat for 2009-10 and 2010-11 are shown in Table 2. Results revealed that the models underestimated in Azamgarh (-8.8%), Chandauli (-6.2%), Jaunpur (-7.0%), Mau (-8.9%), Sonbhadra (-8.2%), Sant Ravidas Nagar (-3.0%) and Varanasi (-2.2%) while over estimation was observed for Ghazipur (1.1%) and Mirzapur (2.4%) in 2009-10. During 2010-11 models underestimated in Azamgarh (-9.3%), Ghazipur (-2.7%), Jaunpur (-7.9%), Mau (-7.9%), Sonbhadra (-6.6%) and overestimated in Chandauli (3.5%), Mirzapur (2.4%), Sant Ravidas Nagar (1.9%) and Varanasi (4.1%) districts. Results also indicated that the model has predicted the wheat yield within ±10% error in all the nine districts of Eastern 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 Azamgarh, Ghazipur, Jaunpur, Sonbhadra, and Varanasi. Whereas variations in solar radiation 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, a rise by 0.5°C 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 temperatures prevailed during the cropping season. We, therefore infer that maximum and minimum temperatures together with RH were significant weather parameters for deciding wheat productivity in the region.

CONCLUSIONS

Yield forecast has been done for rice and wheat crops for nine districts of Eastern Uttar Pradesh. The developed models have less MBE (below ±7%) and RMSE (below ±12%) and reasonably good R^2 (between 51 and 92%). The models are validated with ±10% error in all the nine districts of Eastern Uttar Pradesh. Therefore, it could be used for yield forecasting satisfactorily for both crops and for all the nine districts of East Vindhyan Agro-climatic Zone of Eastern Uttar Pradesh. Further, by and large, the maximum and minimum temperatures in combination with relative humidity have formed most important agrometeorological indices, which can be useful in forecasting of yield of rice and wheat crop in the region.

ACKNOWLEDGMENTS

We acknowledge the India Meteorological Department, Ministry of Earth Science for the financial support through FASAL project.

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Received : September, 2013 ; Accepted : June, 2014