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Short Communication

Wheat yield forecast models based on meteorological parameters

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Crop yield forecasting based on meteorological data is very important from several points of view. The empirical-statistical approach is mostly used in current operational crop-yield and production forecasts on national or regional basis. Using crop yield as dependent variable and weather factors as independent variables, empirical statistical models for predicting crop yield have been reported by Mall et al. (2000), Mall (1996), Shankar and Gupta (1988), Gupta and Singh (1988) and Rupa Kumar and Subbaramayya, (1986). Mainly differing weather conditions cause yield fluctuations from year to year. In a fairly long time series yields may also affected by other factors which can bring about a systematic change during the reference period is not included in this study. The present study reports an empirical-statistical-yield-weather model for wheat in the Varanasi district of Uttar Pradesh, India.

Empirical-statistical models use samples of yield and weather data from an area to estimate coefficients by regression technique. The district yield data of winter wheat for Varanasi were collected from Krishi Bhawan, Lucknow, U.P., from 1970-71 to 1998-99. The meteorological data of corresponding periods were collected from Meteorological Observatory, Agricultural Farm, Banaras Hindu University, Varanasi. Weather parameters for 23 weeks (46^{th} to 16^{th} standard week) were considered.

First of all the critical weather periods were arrived at by working out systematically the correlation coefficient (C.C.) between the yield and different meteorological parameter during different periods continuously increasing from two to ten week. Thus 22 C.Cs were found out between yield and different weather parameter in 23 weeks. Then 21 C.C. were obtained between yield and 21 periods, each period consisting of 3 weeks. In this manner, periods were increased to 10 weeks yielding 14 C.Cs. From a critical examination of these C.Cs, those sensitive weather periods that are statistically significant were selected as factors for working out the regression equation.

Numerous combinations and permutation were tried. That combination of weather parameters were selected which gave high and significant multiple correlation coefficient. The individual parameters in this combination also satisfy the statistical test on the mandatory 1,2 and 5 percent level at least but some at 10 percent levels also. A computer program had been developed, which calculates all multiple correlation's of

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all combinations, dropping gradually one or more variables one by one till the combinations in which the parameters used are all significant.

The selected periods are given in Table 1. The X_1, X_2, X_3,.....X_{10} are the weather parameters for respective periods shown against them. It is evident that for wheat yield at Varanasi, the rainfall is important for the period 51st week to 2nd week, whereas the maximum, minimum, and average temperature becomes important for the periods 4th to 6th standard week. The maximum, minimum, and average relative humidity seems to be less important for wheat yield at Varanasi, However in these cases the maximum C.Cs are found from 2nd to 4th weeks. The sunshine is significantly important from 49th to 2nd week and number

Table 1: Weather parameters during different period (week no.) having the highest correlation coefficient with yields.

Subscripts of X with parameter to maximum CCs	Corresponding weather parameter	Period in standard weeks	Highest Correl-ation	Mean	Standard deviation	Coefficient of variation (%)
X_1	Rainfall (mm)	51-2	0.47**	2.2	2.83	129
X_2	Maximum Temperature (°C)	4 - 6	0.52**	23.1	1.69	7
X_3	Minimum Temperature (°C)	4 - 6	0.61***	9.8	1.39	14
X_4	Average Temperature (°C)	4 - 6	0.53**	16.3	1.14	7
X_5	Maximum Humidity (%)	48-49	-0.35	80.0	6.60	8
X_6	Minimum Humidity (%)	48-49	-0.37*	41.0	9.01	29
X_7	Average Humidity (%)	48-49	-0.39*	60.0	8.50	14
X_8	Sunshine Duration (hours)	49-50	-0.63***	8.9	0.69	7
X_9	Evaporation (mm/day)	49-51	-0.35	2.1	0.37	17
X_{10}	No. of rainy day (days)	51-3	0.60***	0.5	0.59	119
	Yield (kg/ha)			16.7	5.24	31

*** Significant at 1 % level
** Significant at 2 % level
* Significant at 5 % level

Table 2: Models with four, six and ten weather parameters with multiple CCs and F-statistics.

Parameter	Equation	Multiple CC	F-statistics
4	$Y = 11.10 + 0.81 X_2 + 0.96 X_3 - 2.78 X_8 + 1.69 X_{10}$	0.86	12.83
6	$Y = 16.27 + 0.40 X_1 + 1.07 X_2 + 1.63 X_3 - 1.42 X_4 - 2.88 X_8 + 1.63 X_{10}$	0.89	9.58
10	$Y = 28.92 + 0.39 X_1 + 0.86 X_2 + 1.92 X_3 - 1.74 X_4 - 2.17 X_5 - 2.11 X_6 + 4.16 X_7 - 1.21 X_8 - 3.27 X_9 + 2.33 X_{10}$	0.92	6.42

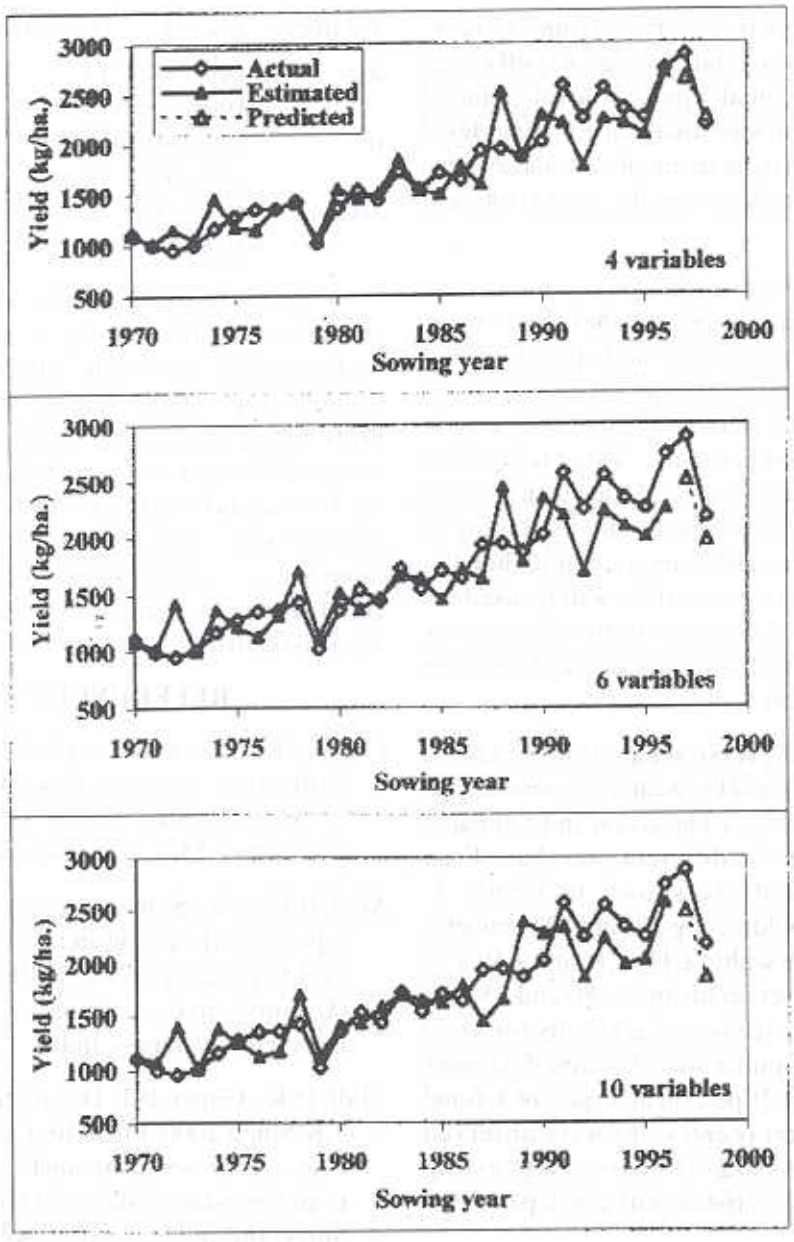

Fig. 1 Actual, estimated and forecasted wheat yield for different years with four, six, and ten weather parameters in Varanasi district.

of rainy days is important from 51st to 3rd week. All the partial correlation coefficients are significant at 5 percent level, some of them are also significant at 1 percent level except for maximum, minimum, and average humidity which are significant at 10 percent level.

Although regression equations were obtained from a single weather parameter as well as with two, three and upto all the ten weather parameters and for each of them multiple C.Cs were obtained for the purpose of discussion here only. Three regression equations were finally selected with four, six and ten weather parameters for forecasting. If only four variables are available then the model with four variables will be used for forecasting. Like wise the models with six and ten variables are included here for similar reason.

The regression equations obtained with four, six and ten weather parameters are shown in Table 2. The actual and estimated wheat yields for different years have been obtained and are shown in Figure 1. Predicted yields using 4,6 and 10 parameter models were within + 15, + 15 and + 10% of actual district yields in 75, 80 and 85% of cases under study and accounts for yield variation of similar order. Extreme deviations of 45, 49 and 21 percent in respect of 4, 6 and 10 parameter regressions were observed during the 1972-73 season suggesting smoothed out variation with the 10 parameter model.

Prediction with independent data sets for two year was as follows:

Parameter	Seasons	Percent deviation
4	1997-98	13
	1998-99	14
6	1997-98	13
	1998-99	9
10	1997-98	8
	1998-99	3

It may be concluded that the empirical statistical model developed above with weather parameters for the sensitive periods accounts for 75 to 85 percent of the wheat yield variations at Varanasi and has a reasonable forecasting potential. Depending on the actual number of the weather parameter data available, respective model from four, six or ten weather parameters could be utilize to estimate wheat yield in the Varanasi district.

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