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Short communication

Wheat yield forecast models using temperature based simple and weighted indices for Punjab and western Uttar Pradesh

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Weather plays an important role in determining crop growth, development and hence yield. Weather variables like rainfall, temperature, sunshine hours, relative humidity, etc., therefore, are used as indicators in modelling crop yield. One of the approaches to crop yield modelling is development of empirical-statistical models using multiple linear regression techniques (Saha, 1999, Vyas *et. al.*, 1999). The empirical approach identifies a set of variables and also the specific period which affect the yield. Since in any year this approach chooses only statistically significant periods for these weather variables, the physiologically significant periods of these variables may get excluded in the model. The effect of weather variables within the growing season varies at different periods which is not taken into account by these regression based models. Year-to-year choice of some variables is not maintained, limiting their utility for long term predictions. To overcome these limitations an approach based on weighted indices which uses full season data has been recommended (Agrawal *et. al.*, 2001, Jain *et. al.*, 1999). In this paper, wheat yield models for two meteorological subdivisions such as Punjab and Western Uttar Pradesh are developed using weighted temperature based indices and compare the model stability, goodness of fit and forecast errors for 1999-2002 with those of simple temperature based yield models.

Weekly average maximum and minimum temperature data from November to April for 26 year (1977-2002) were collected from India Meteorological Department (IMD) weekly weather reports and used in the study. District wise area and production statistics for the corresponding years (1977-1978 to 2000-2001) were collected from various sources like Agricultural Situation in India, State Department of Agriculture and Bureau of Economics and Statistics. Group of districts within the study state were assigned to meteorological subdivision for computing average wheat yield.

The wheat growing season from November to March was divided into

fortnightly intervals with 1st to 15th and 6th to end of the month as first and 16th second fortnight, respectively. Weekly maximum and minimum temperatures were converted to fortnightly average temperatures. Yield data was subjected to linear regression with year to remove the effect of technological trend. Yield deviation, the difference between trend predicted yield and actual yield was taken as dependent variable to study the effect of temperatures on yield in isolation. Correlation coefficients were computed between yield deviations and fortnightly maximum and minimum temperatures. Weighted temperature indices were computed as follows:

$$Z_i = \sum_{W=1}^{n} r_{iw} T_{iw} / \sum_{W=1}^{n} r_{iw} \quad \text{.....(i)}$$

w = fortnight number, T_{iw} is the fortnightly maximum or minimum temperature, r_{iw} = correlation coefficient of yield deviations with maximum or minimum fortnightly temperature in w^{th} fortnight, n is the number of fortnights.

The mathematical expression for the deviation yield model and yield prediction models are given as:

$$Ylddev = a_0 + \sum_{i=1}^{p} a_i Z_{i_i} \quad \text{.....(ii)}$$

where, Ylddev is yield deviation, p is number of variables and a_0, a_i are regression coefficients. Z_i is the weighted temperature index as given above.

$$YPRED = \hat{Y}_t + \hat{Ylddev} \quad \text{.....(iii)}$$

where, YPRED is predicted wheat yield for meteorological subdivision, $Y_t = k+lt$, k and l are regression coefficients, t is year and Y_t is the trend predicted yield.

The yield models were tested for their statistical significance using R^2, t test and F test. The stability of coefficients and the performance of the models from year to year was checked. The model coefficients were computed for each season using weighted temperatures and yield deviations upto previous season and forecasts were made for 1998-1999 through 2001-2002. Results of multiple regression analysis are given in Table-1. The present approach was compared with stepwise regression approach using simple temperature indices in terms of model stability and its performance.

Trend analysis of yield values showed positive linear trend with very high R^2 (>0.90) for both meteorological subdivisions of Punjab and Western Uttar Pradesh (U.P.). Slope coefficient

Table 1: Wheat yield model parameters using simple and weighted indices

Met Div & Method	Forecast season	a_0	a_1	a_2	m	R^2	SE
Punjab							
Weighted	2001-2002	-0.900	0.0659	-0.0757	24	0.65	0.101
	2000-2001	-0.999	0.0697	-0.0737	23	0.67	0.099
	1999-2000	-1.005	0.0692	-0.0689	22	0.61	0.104
	1998-1999	-1.025	0.0710	-0.0700	21	0.62	0.106
Simple	2001-2002	(-1.435), $D1T_X$(0.079), $F2T_N$(-0.042)			24	0.59	0.109
	2000-2001	(-1.405), $D1T_X$(0.078), $F2T_N$(-0.043)			23	0.59	0.111
	1999-2000	(-0.739), $N2T_N$(-0.055), $D1T_X$(0.090), $M2T_X$(-0.029)			22	0.70	0.094
	1998-1999	(-0.026),$N1T_X$(0.046),$N2T_N$(0.05),$D1T_X$(0.112), $M2T_N$(-0.058)			21	0.79	0.083
West U.P							
Weighted	2001-2002	2.237	-0.0725	-0.0396	24	0.63	0.096
	2000-2001	2.184	-0.0685	-0.0446	23	0.63	0.098
	1999-2000	2.354	-0.0739	-0.0461	22	0.65	0.098
	1998-1999	2.438	-0.0843	-0.0402	21	0.71	0.090
Simple	2001-2002	(2.043), $N2T_N$(-0.068),$J1T_X$(-0.057)			24	0.41	0.120
	2000-2001	(2.079), $N2T_N$(-0.071), $J1T_X$(-0.057)			23	0.41	0.123
	1999-2000	(1.724),$N2T_N$(-0.058),$D2T_N$(0.055),$J2T_X$(0.066)			22	0.54	0.115
	1998-1999	(3.421),$N2T_N$(-0.067),$J1T_X$(-0.078),$J2T_X$(0.042)			21	0.72	0.090

METDIV. Is meteorological subdivision, a_0, a_1 a_2 are regression coefficients corresponding to intercept, weighted maximum and weighted minimum temperatures respectively, R^2 is coefficient of determination by regression of ylddev vs weighted or simple temperatures, SE is standard error of estimate, N,D,J,F,M stands for months from November to March, 1 and 2 are first and second fortnights respectively, T_X and T_N are maximum and minimum temperatures, m is the number of observations.

showed stability for the years 1998-1999 to 2001-2002 for Western U.P. whereas there is a marginal increase in slope in Punjab indicating rise in yield due to technology.

Wheat yield models using temperature data are statistically significant at 5% level. The regression coefficients are also significant at 5%. The models are stable in terms of variables and magnitude of regression coefficients indicating their use for long term predictions. The forecasts made by these models are within 5% of actual

Table 2: Comparison of wheat yield forecasts using simple and weighted indices based regression

Met. Div	Forecast seasons	Actual yield (t ha_{-1})	Weighted		Simple	
			Y Pred. (t ha_{-1})	RD (%)	Y Pred. (t ha_{-1})	RD (%)
Punjab	2001-2002	4.532	4.610	1.71	4.640	2.38
	2000-2001	4.563	4.663	2.19	4.541	-0.49
	1999-2000	4.678	4.577	-2.16	4.505	-3.69
	1998-1999	4.332	4.357	0.59	4.548	4.98
	MAE			1.37		2.88
West U.P	2001-2002	3.16	3.228	2.15	3.241	2.57
	2000-2001	3.18	3.142	-1.19	3.114	-2.06
	1999-2000	1.189	3.074	-3.60	3.078	-3.49
	1998-1999	2.955	3.242	9.72	3.361	13.73
	MAE			4.17		5.52

YPRED is predicted yield, RD(%) is relative deviation of predicted yield from actual yields (Y) and is computed as 100*(YPRED-Y)/Y. MAE is mean absolute error.

yields except for Western U.P. for the season 1998-1999.

Comparing the approach adopted in the current study with the simple temperature based method it is observed that the weighted indices based approach showed more stability in regression coefficients in both the subdivisions. The simple temperature based approach showed inconsisting in choice of variables from year to year. The models developed in the current study have higher R^2 and lower standard error of estimate in Western Uttar Pradesh and for Punjab for the seasons of 2000-2001 and 2001-2002. Mean absolute error was comparatively less than those obtained using simple temperature based models. (Table 2).

This study indicates that weighted indices based approach compared to simple temperature based approach had better stability, higher R^2 and lower forecast errors.

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