Journal of Agrometeorology 19 (2) : 167-169 (June 2017)

Short Communication

Forecasting the maize yield in Himachal Pradesh using climatic variables

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Maize is a major cereal crop of Himachal Pradesh grown during *kharif* season mainly under rain fed conditions. Kangra, Mandi, Sirmaur and Chamba districts are major producers of maize. Climatic parameters determine the agricultural productivity of any region and therefore, the direct effects of the climatic factors on crop growth and development have always been a subject of detailed investigation. A number of statistical techniques such as multiple regression, principal component analysis and agro-meteorological models (Baweja, 2002, Bazgeer*et al*. 2008 and Ravi and Bains, 2007) have been used to quantify the response of crops to weather. By coupling technology trend with weather variables, models were developed by Mallick et al. (2007). Under FASAL project, India Meteorological Department has adopted the model, using composite weather indices in predicting yields at district level for major crops in different states of the country (Ghosh *et al.* 2014). In this paper, an attempt has been made to develop suitable pre-harvest forecasting model for maize yield in different districts of Himachal Pradesh.

The yield data of maize for the period of 1985-2015 were collected from Directorate of Agriculture, Government of Himachal Pradesh. The daily data on weather parameters such as temperature (max. & min.), relative humidity (morn. &even.), amount of rainfall for last 30years period was collected from Met Centre, Shimla. Weekly weather data on morning relative humidity evening relative humidity namely, X_1-maximum temperature(°C), X_2- minimum temperature(°C), X_3- relative humidity morning(%), X_4- relative humidity evening (%), X_5- rainfall (mm) were used. The data for the period of 1985-2012was used in developing the forecast models and the remaining three years data (2013-2015) was used for the validation of the models.

The yield forecast models were developed based on modified Hendricks and Scholl Model (Agrawal *et al*. 1986) using composite weather indices (Ghosh *et al.* 2014). The model finally recommended was of the form;

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij}Z_{ij} + \sum_{i\neq i'=1}^{p}\sum_{j=0}^{1} a_{ii'j}Z_{ii'j} + cT + e$$

Where,

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \quad and \quad Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{i'w}$$

Here Y is the maize yield (t ha^{-1})

r_{iw} is is correlation coefficient of yield with i-th weather variable in w-th period. Others have their usual meanings.

For each weather variable, two variables were generated- one as simple accumulation of weather variable and the other one as weighted accumulation of weekly data on weather variable, weights being the correlation coefficients of weather variables, in respective weeks with yield. Similarly, for joint effect of weather variables, weekly interaction variables were generated using weekly products of weather variables taking two at a time. Stepwise regression was used to select significant generated variables Z_{ij} and $Z_{ii'j}$(Table 1). Model performance was evaluated by calculating the different statistical parameters viz. standard error (SE), correlation coefficient and root mean square error (RMSE).

The regression equation developed for different districts using weather parameters at mid-season stage is shown in Table 2. R^2 value which is measure of goodness of fit indicates that the generated weather variables are able to explain 32 to 88 per cent variation in the maize yield in different districts, the highest being in Shimla district and lowest being in Bilaspur district. These models were further used to forecast the yield in different districts of the state for 2013 and 2014 (Table 2) and compared with observed yields. The percentage deviation of observed value ranged between -7.5 and 7.1 for the year 2013 and for 2014 the deviation ranged between 0.7 and 15.1. The predicted maize yields for most of the districts were within acceptable error limit (±10%) in both the years of validation except for Kangra which is slightly above the acceptable error limit. Thus these models can be used to forecast the maize yield in different districts of Himachal Pradesh.

Table1: Weather indices used in models using composite weather variables.

	Simple weather variables					Weighted weather variables				
	T_{max}	T_{min}	RF	RH_I	RH_{II}	T_{max}	T_{min}	RF	RH_I	RH_{II}
T_{max}	Z10					Z11				
T_{min}	Z120	Z20				Z121	Z21			
RF	Z130	Z230	Z30			Z131	Z231	Z31		
RH_I	Z140	Z240	Z340	Z40		Z141	Z241	Z341	Z41	
RH_{II}	Z150	Z250	Z350	Z450	Z50	Z151	Z251	Z351	Z451	Z51

Table 2: District wise maize yield forecast models of Himachal Pradesh

District	Equation	Weather elements	RMSE	R^2	S.E	% deviation (±)	
						2013	2014
Kangra	Y=4972.96+0.336*Z120+110.33 *Z21+ 8.98*Z51	Tx*Tn,Tn,RHII	196.8	0.55	232.1	6.3	15.1
Chamba	Y=6116.88+32.45*Z11+0.546 *Z131-0.631*Z231	Tx, Tx*RF, Tn*RF	477.9	0.58	329.5	-2.5	1.1
Bilaspur	Y=1861.43+0.058*Z351	RF*RHII	307.0	0.32	273.1	1.0	9.8
Sirmaur	Y=2221.75+40.02*Time-0.074 *Z150 +1.11*Z241+4.019*Z31	Time, Tx*RHII, Tn*RHI, RF	339.5	0.80	195.7	6.0	9.6
Solan	Y=3572.30+16.339*Time+0.029 *Z341+13.884*Z41	Time, RF*RHI, RHI	294.8	0.69	216.5	7.1	0.7
Shimla	Y= 342.18+46.92*Time+69.91 *Z11+0.707*Z241-0.012*Z450	Time, Tx, Tn*RHI, RHI*RHII	89.6	0.88	150.6	1.6	-2.8
Hamirpur	Y=140.324+47.15*Z11+0.058 *Z451	Tx, RHI* RHII	281.0	0.57	178.4	-4.6	5.1
Una	Y=3623.32+25.77*Time+10.620 *Z10+84.128* Z11+0.038*Z341	Time, Tx, RF *RHI	214.5	0.78	148.8	5.8	4.1
Mandi	Y=1178.46+3.81*Z121+0.078 *Z351	Tx*Tn, RF *RHII	309.3	0.59	216.2	-7.5	-0.3
Kullu	Y= -611.86+58.98*Time+0.236 *Z131+0.079*Z140	Time, Tx*RF, Tx*RHI	356.7	0.81	269.2	1.0	8.9

ACKNOWLEDGEMENTS

The paper is based on the findings of ongoing researchproject on "Forecasting Agricultural Output using Space, Agrometeorology and Land based observations (FASAL)" funded byIMD, Pune. Authors are thankful to Director General of Meteorology for encouragement.

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Received : April 2016; Accepted: April 2017