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Short Communication

Yield prediction of sugarcane and paddy for districts of Uttar Pradesh

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Reliable and well-timed forecasts are essential for appropriate agriculture planning which is full of uncertainties. Well-timed and accurate crop yield forecasting is essential for crop production, marketing, storage, and transportation decisions and also helps managing the risk associated with these activities (Bannayan and Crout, 1999, Potgieter *et al.*, 2005).Weather plays an important role in crop growth as well as crop development. Therefore, models based on weather parameters can provide reliable forecast of crop yield in advance of harvest. A number of yield forecasting models have been developed for various crops. Yield forecasting regression models utilise data on yield and weather variables for past several years pertaining to locations under consideration. By studying the relationship of yield with different weather elements, predictors are identified. Generally, rainfall, temperature, humidity, rainy days, dry days and cloud amount etc. during critical phases of crop growth fulfill the criteria to be predictors (Jayanta Sarkar, 2003). Crop yield in different years is affected by technological change and weather variability. The technological factors will increase yield smoothly through time and therefore, year-number can be used to study the overall effect of technology on yield. The weather variability both within and between seasons is unmanageable source of variability in yield. The weather variables affect the crop differently during various stages of development. Thus, extent of weather influence on crop yield depends not only on the magnitude but also on the distribution pattern of weather variables over the crop season.

Thus, there is a need of dividing the crop season into different intervals. Thus, a technique based on relatively smaller number of manageable variables and at the same time taking care of entire weather distribution may solve the problem. The regression model which was used for yield forecasting is weather indices based model which is modified Hendricks and Scholl method at IASRI (Agrawal and Mehta, 2007).

The model is given below:

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

Where,

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

Where,

r_{iw} is correlation coefficient of yield with i-th weather variable in w-th week

$r_{ii'w}$ is correlation coefficient of yield with product of i-th and i'-th weather variables in w-th week

m is week of forecast

p is number of weather variables used

e is random error distributed as N $(0,s^2)$.

In this model, for each weather variable, two types of indices were developed, one as simple total of values of weather variable in different periods (un-weighted index - Z_{i0}) and the other one is weighted accumulation of weekly weather variable, weights being correlation coefficients of weather variable in respective weeks with yield (weighted index - Z_{i1}). Similarly, for interaction of weather variables, indices were generated using weekly products of weather variables taking two at a time. Stepwise regression technique was used to select the important weather indices (Agrawal *et al.* 2001; Mehta *et al.* 2000).

Sugarcane yield prediction

Yield forecasting models of sugarcane are presented for 8 districts *viz.* Meerut, Bareilly, Allahabad, Kaushambi, Fatehpur, Bahraich, Varanasi and Gorakhpur districts in the Table 1. The weather data for maximum temperature (Tmax), minimum temperature (Tmin), relative humidity at 8:30 IST (RH I), relative humidity at 17:30 IST (RH II) and daily rainfall values were collected for the period of

Table 1: Yield forecasting models for Sugarcane

S/No.	District	Regression Equations	R^2	Yield (qha^{-1})
1.	Meerut	$Y=58425.48+602.0\ Z_{21}$	0.52*	668.7
2.	Bareilly	$Y=43820.21+9.22\ Z_{121}$	0.85*	577.9
3.	Allahabad	$Y=13734.08+35.67\ Z_{141}-19.72\ Z_{241}$	0.81*	409.0
4.	Kaushambi	$Y=36346.03+3.25\ Z_{131}$	0.62*	775.1
5.	Fatehpur	$Y=31223.02-34.66\ Z_{50}+34.7\ Z_{121}+2.29\ Z_{131}$	0.84*	452.7
6.	Bahraich	$Y=42863.81+6.67\ Z_{30}+1.58\ Z_{231}$	0.63*	510.1
7.	Varanasi	$Y=44256.65+223.74\ Z_{41}+7.04\ Z_{121}$	0.72*	434.2
8.	Gorakhpur	$Y=62143.19+561.96\ Z_{21}+3.8\ Z_{251}$	0.81*	578.9

*Significant at 5 per cent level of significance.

Table 2: Yield forecasting models for Paddy

S/No.	District	Regression Equations	R^2	Yield (qha^{-1})
1.	Allahabad	$Y=2601.7 + 0.08Z_{451}$	0.51*	18.5
2.	Kaushambi	$Y=1186.4 + 60.11Z_{11}$	0.70*	17.9
3.	Fatehpur	$Y=1657.3 + 0.06Z_{131}$	0.64*	16.8
4.	Bahraich	$Y=722.1 + 11.06Z_{51}$	0.61*	17.7
5.	Varanasi	$Y=2182.2 + 0.07Z_{351}$	0.50*	27.6

*Significant at 5 per cent level of significance.

1991-2010 and crop yield data were collected for the period of 1991-2010. Weekly weather data from 8 to 41 standard meteorological weeks as well as yield data for the period of 1991-2008 were utilized for model development and crop as well as weather data for the period of 2009-2010 were used for model validation purpose. The current season weather data of 41 standard meteorological week were used for forecast of sugarcane yield in 2011. The yield forecasts were obtained by this methodology at 41 standard meteorological week *i.e.* 2 and ½ months before harvest. The weighted weather indices Z_{21}, Z_{121} and Z_{131} has been found significant for Meerut, Bareilly and Kaushambi districts, respectively. However, weighted weather indices Z_{141}, Z_{241} were found significant for Allahabad. The un-weighted weather index Z_{30} and weighted weather index Z_{231} were found significant for Bahraich. The weighted weather indices Z_{41}, Z_{121} were found significant for Varanasi. The weighted weather indices Z_{21}, Z_{251} were found significant for Gorakhpur. In case of Fatehpur, un-weighted weather index Z_{50} and weighted weather indices Z_{121} and Z_{131} were found significant. Z_{30} is un-weighted weather index of rainfall. Z_{21} and Z_{41} are weighted weather index of Tmin and RH I, respectively. Z_{121} is weighted weather index of product of Tmax and Tmin. Z_{131} is weighted weather index of product of Tmax and rainfall. Z_{141} is weighted weather index of product of Tmax and RH I. Z_{231} is the weighted weather index of product of Tmin and rainfall. Z_{241} is the weighted weather index of product of Tmin and RH I. Most of the cases, weighted weather indices have been found significant than un-weighted weather indices. Models have been validated using data for period of 2009-2010 years. In most of the cases, there was good conformity between forecasts and observed values. The errors were calculated 2.6-5.0 per cent, 4.9–17.1 per cent, 8.3-15.0 per cent, 7.3-13.7 per cent, 11.7-15.1 per cent, 1.2- 2.9 per cent, 5.9-12.9 per cent, 13.8-15.4 per cent for Meerut, Bareilly, Allahabad, Kaushambi, Fatehpur, Bahraich, Varanasi, Gorakhpur, respectively. The yield forecasts were 668.7 qha^{-1}, 577.9 qha^{-1}, 409.0 qha^{-1}, 775.1 qha^{-1}, 452.7 qha^{-1}, 510.1 qha^{-1}, 434.2 qha^{-1} and 578.9 qha^{-1} for Meerut, Bareilly, Allahabad, Kaushambi, Fatehpur, Bahraich, Varanasi and Gorakhpur, respectively.

Paddy yield prediction

The weather indices based yield forecasting models of paddy have been developed and presented for 5 districts *viz.* Allahabad, Kaushambi, Fatehpur, Bahraich and Varanasi districts in Table 2. Similar to prediction of sugarcane yield, weather parameters *viz.* maximum temperature (Tmax), minimum temperature (Tmin), relative humidity values at 8:30 IST (RH I), relative humidity values at 17:30 IST (RH II) and daily rainfall values were utilized for the period of 1991-2010 and crop yield data were utilized for the period of 1991-2010. Weekly weather data from 22 to 37 standard meteorological weeks as well as yield data from the period of 1991-2008 were utilized for model development and further weather and crop data for the period of 2009-2010 were used for model validation. The current season weather data were utilized for forecast of paddy yield for the *kharif* season 2011. The yield forecasts were obtained by this methodology at 37th Standard meteorological week i.e. 1 to 1 and ½ months before harvest. The weather indices Z_{451}, Z_{11}, Z_{131}, Z_{51} and Z_{351} and have been found significant for Allahabad, Kaushambi, Fatehpur, Bahraich and Varanasi districts, respectively. Z_{451} is weighted weather index of product of RH I and RH II. Z_{11} is weighted weather index of T max. Z_{131} is weighted weather index of product of Tmax and rainfall and Z_{51} is the weighted weather index of RH II. Z_{351} is the weighted weather index of product of rainfall and RH II.

In most of the cases, there was good agreement between forecasts and observed values. The error was around 15.8 per cent for Allahabad. However, an error was calculated 0-0.5 per cent for Kaushambi district. The error was calculated 2.9-17.8 per cent for Varanasi district. For Fatehpur and Bahraich districts, models were under estimating crop yields as compared to actual yields in years 2009 and 2010. The errors were calculated as 23.7-33.9 per cent and 22.9-23.7 per cent, respectively for Fatehpur and Bahraich districts. The paddy crop might have received sufficient and well distributed rainfall during grain filling period and which contributed to soil moisture which resulted in higher production than predicted values in Fatehpur and Bahraich districts. The paddy yield forecasts for the *Kharif season* 2011 were 18.5 qha^{-1}, 17.9 qha^{-1}, 16.8 qha^{-1}, 17.7 qha^{-1} and 27.6 qha^{-1} for Allahabad, Kaushambi, Fatehpur and Bahraich and Varanasi, respectively.

It was observed that in most of the cases, weighted indices were found to be significant and satisfactory recommended for yield forecasting. With this approach, reliable yield forecasts for sugarcane and paddy could be obtained at pre harvest stage before maturity.

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