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Predicting yield for wheat crop in eastern region of Uttar Pradesh using DSSAT model

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Abstract
The crop simulation models can predict crop yield as a function of soil, climate and genetic coefficients. Forecasting yield of crops is important for planners in taking tactical decisions for ensuring food availability. The aim of this study was the calibration and validation of CERES –wheat model (v4.7) for High yielding variety of wheat in Prayagraj and Varanasi district of Uttar Pradesh. Crop simulation models are useful tool to forecast the crop yield. Based on the areas under different dates of sowing and crop cultivars, a correction factor was applied on simulated yield to predict the district wise and regional wheat yield. The simulated yield were higher than the actual yield in the both district, while the forecasted yields were very close to actual. The Relative deviation of the forecasted yield from the actual was ±4% and ±9%. The results clearly indicated that the CERES-Wheat model can be used to regional production estimates of wheat in Uttar Pradesh.

Keywords: DSSAT v 4.7 model, weather data, simulated yield, forecasted & actual yields

Introduction
Uttar Pradesh with the total area of 24.09 million hectare, wheat is Cultivated as a rabi crop. Wheat is main agriculture produce and the state contributes around 32% of the country's total wheat production, Forecasting of wheat yield, well in advance, is important for policy makers in the government for further course of action and planning. Increasing the accuracy of agricultural forecasting is an important application of earth observation. The study on review to aware about the ability to reliably forecast crop production, yield and quality is valuable for economic planning and commodities forecasting as well ensuring global food security. Study, regarding the overview of the current crop yield forecasting methods, which includes ways to use crop yield forecasting method to improve agriculture and rural statistics across the globe.
Directorate of Economics and Statistics releases estimates of area, production and yield in respect of 51 principal crops of food grains, oilseeds, sugarcane, fibers and important commercial and horticulture crops (Anonymous, 2010) [2]. These crops together accounts for nearly 87% of agriculture output and contribute significantly in the GDP for Uttar Pradesh. Change in intensity in solar radiation, temperature and distribution of rainfall provoke physiological reactions that affect crop growth and grain yield in rice (Yoshida and Parao, 1979). Therefore, a proper planning is needed to predict yield in advance as it will help in implementing and formulating of policies related to food procurement, distribution and import-export decisions.
In the present study efforts are made to estimate the wheat yield on operational basis using DSSAT crop growth simulation model CERES-Wheat v4.7.The methodology is already in use for generation of operational yield forecast for wheat and all the major crops in different states in the country

Material and Methods
Yield Forecasting using DSSAT v 4.7
Forecasting of wheat productivity was performed by running model step wise for calibration and validation process which include simulated yield, observed yield, plotting observed trend graph, calculating correction factor. DSSAT v4.7 model were run using actual weather data during the cropping season for the districts of Uttar Pradesh. CERES-wheat is useful tool to describe continuous crop growth and to estimate crop yield during the crop growing season and indicates crop stage and state.

Forecasting of regional wheat yield

As simulated yield is higher than actual district yield, suitable correction factor has been computed for each state using results from recent past years. A correction factor is mathematical adjustment made to calculate to account for deviations in observed yield. This is mainly to reduce the difference between simulated and observed yield. Average of previous year yield difference (simulated minus actual) considered as correction factor for yield forecast. The simulated yield is a point application and has limitation of capturing variations in soil, weather, inputs and other biotic/abiotic stresses, which are generally higher on regional/district scale. The point run from the model needs to be compared with the actual regional productivity (by use of historic data) and subsequently generating a correction factor for toning the simulation result down to realistically match with the actual value. A correction factor is applied to reduce the difference between simulated and observed yield. On the basis of historic datasets, correction factor for each district was computed.

As simulated yield is higher than actual district yield, suitable correction factor has been computed for each district using results from recent past years. Average of previous year yield difference (simulated minus actual) considered as correction factor for yield forecast.

Input data

a) Weather data

The weather data (daily basis) on maximum and minimum temperatures, rainfall and solar radiation of ten years (2009 – 2019) for centre Prayagraj was obtained from Department of Environmental science and NRM, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences and the data of district of Varanasi from the Meteorological Centre of BHU Varanasi. The complete weather data sets without any discrepancies are needed for crop simulation models to calculate dry matter accumulation and to determine the physiological development of the crop. Solar radiation was calculated by the model based on Hargreaves method, which is reported to be best suited for Indian conditions.

b) Soil data

Layer wise (0 – 120 cm) data of soil physical and chemical properties which includes Bulk density, Hydraulic conductivity, as organic carbon, clay contents, silt contents, soil pH organic carbon content, clay and silt content etc. of Prayagraj district was collected from India Meteorological Department, New Delhi.

c) Crop data/cultivar file

Dominant crop cultivar Malviya 234 considered for the forecast. These coefficients are crucial because they strongly influence the simulation of growth and development of the crop. The CERES-wheat model uses seven genetic coefficients are collected from IMD, New Delhi then again they are calibrated for Prayagraj and Varanasi condition via trial and error method. The genetic coefficients for the three varieties are shown in Table 1 below and description of genetic coefficients are as follows:

Table 1: Genetic co-efficient for test cultivars of wheat by using GLUE module of DSSATv4.6

Description	Abbreviations	Malviya-234
Days at optimum vernalizing temperture required to complete vernalization.	PIV	20
Percentage reduction in development rate in a photoperiod 10 hours shorter than the optimum relative to that at the optimum.	PID	90
Grain filling (excluding lag) period duration (degree days).	P5	770
Kernel number per unit canopy weight at anthesis (1/g).	G1	23
Standard kernel size under optimum conditions.	G2	34
Standard, non- stressed dry weight (total including grain) of a tiller at maturity (g).	G3	1.3
Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.	PHINT	95

Crop management and experimental data

The experimental data of Project FASAL of SHUATS and BHU was used for the calibration and validation of model. Experiment includes cultivars which the experiments were conducted based on split plot design. Planting dates were 1st week of December for every cultivar. Grain yield was provided for the model as observed data for the calibration and validation of model. The yield data was collected from DACNAT (Directorate of Economics and Statistics) for both the district.

Results and Discussion

The CERES-Wheat v4.7 crop growth simulation model was calibrated and evaluated for the different district of wheat growing area of Uttar Pradesh. In the present study efforts are made to estimate the wheat yield for the year 2018-19 using CERES-Wheat crop growth simulation model embedded in DSSAT v4.7 software.

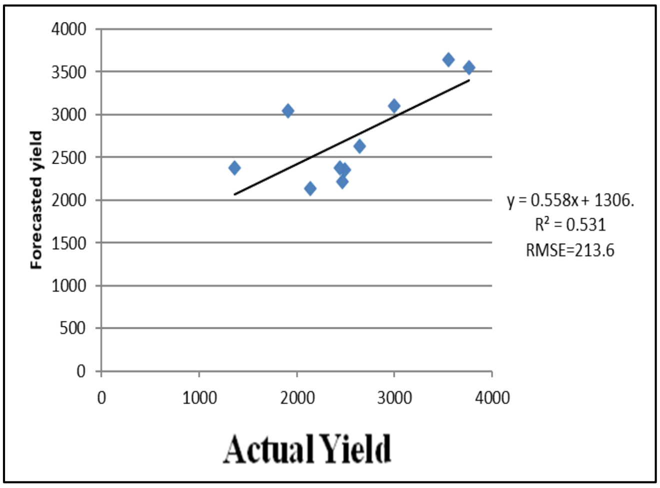

Fig 1: Observed and forecast yields (kg ha^{-1}) of wheat in Prayagraj district (2009-19)

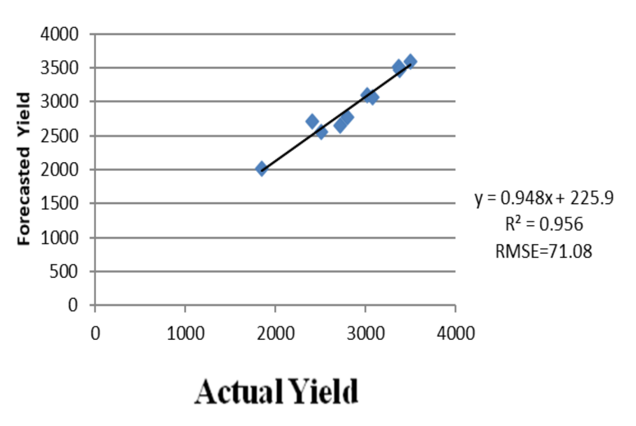

Fig 2: Observed and forecast yields (kg ha^{-1}) of wheat in Varanasi district (2009-19)

Simulated yields, in general, were slightly overestimated, but the deviation was not much and the regression line more or less matched with the 1:1 line. The values of RMSE, percent error and correlation coefficient were 213.6 kg ha^{-1}, ±9% and .531 for Prayagraj district. The values of RMSE, percent error and correlation coefficient were 71.08 kg ha^{-1}, ±4% and .956 for Varanasi district.

The year wise simulated, forecasted and actual yield averaged over all the locations are also presented in Table 1 and 2. It is also seen that the forecasted yield was very close to observed yield during 2009-2019 with per cent error of only ±9 and ±4. The observed and forecasted yield in both the districts (Fig. 2 and 3) was very close with coefficient of determination of 0.956 and RMSE of 71.08 in Varanasi district as compare Prayagraj district

Thus the model can be used in predicting the district wise as well as regional yield of wheat in different districts of Uttar Pradesh. The results clearly revealed the capability of the simulation model to forecast the wheat yield by incorporating the variability in other unaddressed factors with the simulation results. Thus the result show the performance of the methodology of yield forecast over different district, and the averaged results over seasons and the results clearly revealed satisfactory performance of the approach in yield estimates on district as well as regional scales. The findings were in agreement with the results reported by Singh *et al*., (2015 a & b).

Table 1: Mean simulated and derived forecasted yields (kg ha^{-1}) using DSSAT v4.7 model in the test locations

Model Performance (averaged over Prayagraj locations)			
Year	**Simulated (kg ha^{-1})**	**Forecasted (kg ha^{-1})**	**Observed (kg ha^{-1})**
2009-10	3284	2141.9	2140
2010-11	3250	2212.6	2470
2011-12	3560	2627.3	2640
2012-13	3189	2361	2490
2013-14	3107	2376.7	2440
2014-15	3001	2382.4	1360
2015-16	3558	3044.1	1910
2016-17	3510	3100.8	3000
2017-18	3553	3548.5	3760
2018-19	3843	3643.2	3550
Mean	3384.8	2743.85	2576
SD (kg ha^{-1})	246.91	523.83	684.38
CV (%)	7.2	17.8	26.5
Percent error	±9		

Table 2: Mean simulated and derived forecasted yields (kg ha^{-1}) using DSSAT v4.7 model in the test locations

Model Performance (averaged over Varanasi locations)			
Year	**Simulated (kg ha^{-1})**	**Forecasted (kg ha^{-1})**	**Observed (kg ha^{-1})**
2009-10	3100	2553.15	2510
2010-11	3541	2765.9	2800
2011-12	3320	3089.65	3020
2012-13	3698	3066.4	3080
2013-14	3210	2650.15	2720
2014-15	2500	2011.9	1850
2015-16	3125	2708.65	2410
2016-17	3852	3507.4	3370
2017-18	3741	3468.15	3380
2018-19	3789	3587.9	3500
Mean	3387.6	2940.92	2864
SD (kg ha^{-1})	421.26	523.83	684.38
CV (%)	12.4	16.9	17.04
Percent error	±4		

The simulated wheat yield predication along with observed yield in 2009-19 for the both district, validation results indicate that the hind cast wheat yields for most of the districts are within the acceptable error limit (±10%) in all the years of validation; however, prediction was marginally higher in the Varanasi district as compare to Prayagraj district.

Conclusion

The study indicated that DSSAT v 4.7 is a strong tool for prediction of yield in advance, with the introduction of the correction factor to transform the point based results to regional/districts scales. There is a need to create databases for relational layers of bio-physical and socio-economic aspects for the growing regions to be subsequently integrated with the crop simulation results for regional estimates

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