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Short Communication

Utility of gridded data for yield prediction of wheat using DSSAT model

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Crop productivity depends on many factors like weather, agronomic management practices, soil type and other major inputs. Weather variables like maximum temperature, minimum temperature, rainfall, wind speed and sunshine hours plays a key role in wheat production in India (Bharadiya *et al.,* 2015). Uttar Pradesh is one of the major wheat producing state in India with an area of 9.64 million hectare, production 30 million metric tons, with a productivity of 31.13 quintals per hectare in 2017. Wheat production can be adapted to climate change situations through shifts in sowing dates, cultivars and agronomic management practices (Pramod *et al.,*). Therefore, wheat yield forecast using weather based models are very important (Bal *et al.,* 2007; Vashisth *et al.,* 2020). The variation in the meteorological parameters, in combination with other parameters such as soil characteristics, cultivar, pest and diseases, etc. has paramount influence on agricultural productivity (Pathak and Wassmann, 2009). The impact of climatic variability on yield of crops is generally studied by simulation approach, which is relatively less expensive, time saving and easy than actual experimentation. This approach has been employed by a number of researchers in different parts of the world for different crops (Pearl *et al.,* 1989; Abraha and Savage, 2006; Mall *et al.,* 2004; Tubiello and Ewert, 2002; Peng *et al.,* 2004). In order to take various policy based decisions, early prediction of crop yield plays a vital role (Dakhore *et al.,* 2011). Meteorological or weather data is one of the most important input in yield prediction models. Gridded weather data has an inevitable approachas weather source, as the model outputs are generated at fixed spatial grid points. However, depending on the application, requirement of spatial and temporal resolution can be different (Pai *et al.,* 2014). Predictions of climate change suggest modification of developmental calendars for temperate crops, particularly those grown over winter (Butterfield *et al.,* 1992).

CERES-wheat 4.0.6.0 embedded in the DSSAT package, is a comprehensive model that simulates the phasic development of wheat crop, the growth of its leaves, stems, roots and spikes and their response to weather. It is important to know how climatic change will affect growth, development, water use and productivity of the wheat (*Triticum aestivum L.*) crop. Several mechanistic models have been used to estimate potential yield and assess the effect of climate change (Hundal and Kaur, 1997). DSSAT model describe the phenological development of crops through the crop life cycle using the degree day accumulation. Realizing the importance of modeling techniques under climatic variability scenarios for micro-level/farm- level planning and the contribution for sustainable wheat productivity in Allahabad, the proposed study was undertaken to analyze the utility of gridded weather data to predict wheat yield at Allahabad and inter-comparison of predicted yield using gridded and station data as weather source incorporating different statistical indices.

Allahabad has a humid subtropical climate. Annual mean temperature of Allahabad is 26.1ÚC and monthly mean temperature varies between 18 to 29ÚC. The net sown area of all the *rabi* crops grown in Allahabad are 259.29 (000' hectare). Wheat is grown in 211378 hectares with total production of 469115 metric tons and 22.19 quintals ha^{-1} productivity in Allahabad district of Uttar Pradesh. Weather variables like Tmax, Tmin (1° x 1° resolution) and Rainfall (0.25° x 0.25° resolution) of gridded weather data was sourced from India Meteorological department, New Delhi from year 2004-2005 to 2014-2015. Station weather data of the same period was sourced from weather observatory of Sam Higginbottom University of Agriculture Technology and Sciences (Allahabad). Crop simulation model DSSAT-CERES Wheat model was employed in this study to predict wheat yield using two different weather sources (gridded and station data) by calibration and validation process. Wheat variety PBW 343 were selected for this study. The crop was sown on 15 November and harvested during the last week of March. This variety (PBW 343) is suitable for timely sown and irrigated condition. The variety normally takes early (126-134 days) to mature.

In this study, crop management data includes detail inputs like plot information, field input, management data which includes planting date, irrigation scheduling, fertilizer application, harvest particulars and simulation details of wheat (Variety PBW 343). Genetic coefficient provide information regarding selected wheat variety on wider spectrum like: P1V Days optimum vernalization (20), P1D Photoperiod response (70), P5 Grain filling phase (800), G1 Kernel no./ unit canopy weight during anthesis (20), G2 Standard Kernel size under optimum condition (mg), G3 Standard non stressed mature tiller weight (1.5g) and PHINT interval between successive leaf tip appearances.

Before forecasting wheat yield using models, it is important to study about the intercomparison of weather data (gridded and station) using statistical indices. Thus, in Table 1, statistical indices like Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) were employed to compare gridded and station weather data of Allahabad from year 2004 to 2015. Maximum temperature shows 0.79 to 0.93°C error, Minimum temperature depicts 0.73 to 1.13°C error and Rainfall accounts for 8.36 to 12.38 mm error difference between gridded and station weather data by using statistical indices like RMSE and MAE (Table 1). This shows that the error difference between both the weather sources were very less. Unavailibility of high quality and accurate station data especially in remote locations of India is a major problem. As a result, many studies regarding agro based decision making, food security, land use and global climate change have to rely on gridded data. Mourtzinis *et al.* (2017) also conducted similar study which emphasized on simulating maize growth and development using gridded weather data. Also, it aims to examine how gridded weather data compared relatively to the existing station weather data in the corn belt of United States.

Yield prediction

Wheat yield were predicted by running DSSAT 4.6 model. Wheat productivity from year 2004-2005 to 2011-2012 was used for calibration whereas wheat yield obtained in year 2012-2013 to 2014-2015 were taken for validation. In order to analyze the importance of gridded weather data for predicting wheat productivity and its intercomparison with actual or observed weather data, different statistical indices like Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Normalized Root Mean Square Error (NRMSE), Coefficient of Determination (R^2) and D Index are utilized in this study. Similar study were analysed by Yang *et al.,* (2014), where group of deviation statistics indices like RMSE, NRMSE, MAE and modeling efficiency (ME) are employed for crop model calibration and evaluation. These statistical indices also play a significant role to calculate error obtained in yield prediction through modeling and minimizing the error difference between actual and simulated yield. Inter-comparison between two weather sources (actual and gridded data) and also analyzing the accuracy of simulated wheat yield obtained using gridded and station/observed weather data were compared in current study using following indices.

1. $\text{RMSE} = \sqrt{\sum \frac{(Ys-Yo)^2}{n}}$

Where Y_s is simulated Yield, Y_o is observed or actual yield and n is the number of observation

2. $NRMSE = \left(\frac{RMSE}{Average\ of\ Yo}\right) * 100$

Where Y_0 is observed or actual Yield

3. $D\ Index = 1 - \frac{\sum_{i=1}^{n}(S_i - Ob_i)^2}{\sum_{i=1}^{n}(|S_i - Ob_{avg}| + |Ob_i - Ob_{avg}|)^2}$

Where S_i is simulated yield, Ob_i is observed or actual yield. Ob_{avg} is Observed average yield

4. Coefficient of Determination (R Square)

5. Mean Absolute Error (MAE) =

$$\text{MAE} = \frac{\sum_{i=1}^{n}|\text{Wg} - \text{Ws}|}{\text{n}}$$

Where W_g is gridded weather data, W_s is station or actual weather data and n is the number of observations.

The simulated yield obtained from DSSAT model and observed yield of wheat from year 2004-2005 to 2014-2015 is given in Table 2. Correction factor of each year were calculated by subtracting the observed yield from average of simulated yield. Correction factor also plays a significant role in reducing the difference between the simulated yield predicted from model and observed yield. Decline in wheat yield in year 2009-2010 to 2188 kg ha^{-1} from 2809 kg ha^{-1} in 2008-2009 was due to severe drought across the country in 2009 (Table 2).

In the year 2009-2010, with the decline in observed wheat yield under field condition, there is an increase in simulated or predicted yield. Severe drought in the year 2009, where 47% of area across India was affected can be a major reason of decline in actual wheat yield in the district. In the year 2004-2007, with the increasing trend in observed yield, simulated yield also shows an increase in trend of wheat yield. The statistical analysis carried out using various indices like Root Mean Square Error (RMSE), Normalized Root Mean Square Error (NRMSE), D Index and Coefficient

Table 1: Inter-comparison of gridded and station weather data using statistical indices

Indices	Max. temperature (°C)	Min. temperature (°C)	Rainfall (mm)
Root Mean Square Error (RMSE)	0.93	1.13	12.38
Mean Absolute Error (MAE)	0.79	0.73	8.36

Table 2: Simulated and observed yield with correction factor

Year	Simulated yield (kg ha^{-1})	Correction factor (Average of Sim. yield – Obs. yield)	Observed yield (kg ha^{-1})	Sim. Value-CF
2004-2005	3918	869	2578	3049
2005-2006	4040	863	3451	3177
2006-2007	4369	856	3835	3513
2007-2008	4955	850	3200	4105
2008-2009	3652	843	3000	2809
2009-2010	4979	837	2791	2188
2010-2011	3537	831	3254	2706
2011-2012	4811	824	3791	3987
2012-2013	3997	818	3325	3179
2013-2014	2939	811	2971	2128
2014-2015	3314	805	3122	2509

Table 3: Statistical indices value using gridded and observed weather source after simulation of wheat yield from DSSAT model.

Weather Source	RMSE (Kg ha^{-1})	NRMSE (%)	D Index	R^2
Gridded Data	428.6	13.5	0.77	0.54
Observed Data	382.5	12.09	0.71	

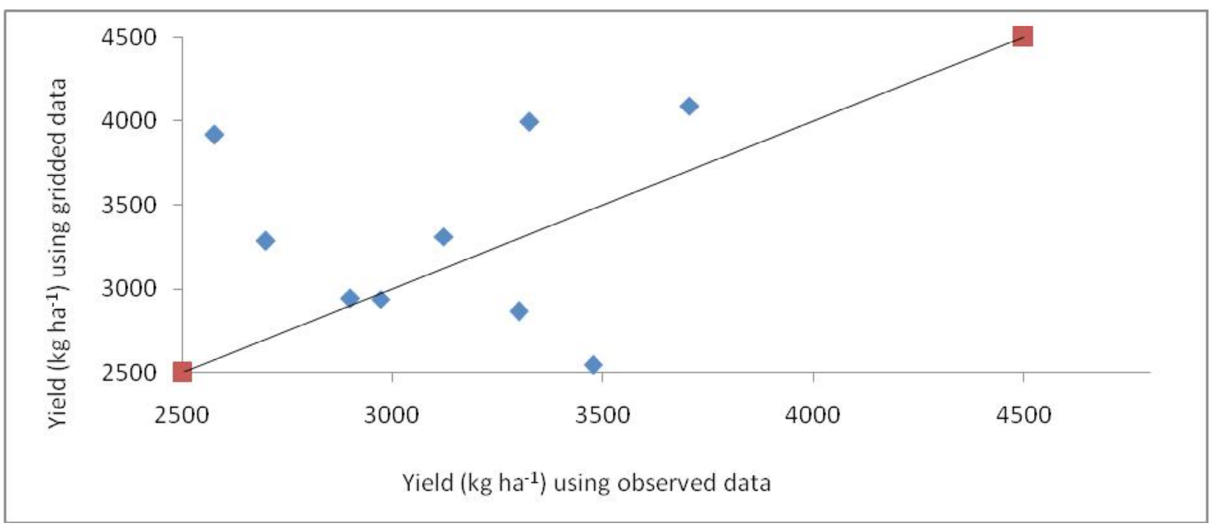

Fig. 1: Inter-relationship using scatter plot graph showing simulated yield (kgha^{-1}) using gridded and station weather data

of Determination (R^2) for inter-comparing the difference between wheat yield obtained by using gridded and observed weather data are presented in Table 3. It was observed that NRMSE and D Index value using gridded and station data show very least difference (Table 3). The scatter plot describing interrelationship between wheat yield (kg ha^{-1}) using gridded and observed weather data from year 2004-2005 to 2014-2015 is given in Fig. 1. Three observations of wheat yield were under predicted (wheat yield prediction using observed data) and remaining observations of yield was over predicted (wheat yield prediction using gridded data). Thus, statistically, wheat yield prediction using two different weather sources (gridded and observed) have not shown any significant difference. Therefore, in the absence of observed data, gridded data can be used as an alternative to predict wheat yields in Allahabad district of Uttar Pradesh. The same may be applicable for places having similar agro-climatic conditions as that of Allahabad.

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REFERENCES

Abraha, M.G. and Savage, M.J. (2006). Potential impacts of climate change on the grain yield of Maize for midlands of Kwazulu-Natal, South Africa. *Agric. Ecosys. Environ.,* 115: 150-160.

Bal, S.K., Mukherjee, J., Mallick, K. and Hundal, S.S. (2004). Wheat yield forecasting models for Ludhiana district of Punjab state. *J. Agrometeorol.,* 6 (spl.issue): 161-165.

Butterfield, R.E. and Morison, I.L.J. (1992). Modeling the impact of climatic warming on wintercereal development. *Agric. Forest Meteorol.,* 62(3-4): 241-261.

Dakhore, K.K., Shekh, A.M., Bhattacharya, B.K., Mallick, K., Pandey, V. and Nigam, R. (2011). Comparison of satellite derived water and radiation use efficiency based wheat yield models over semi-arid regions. *J. Agrometeorol.,* 13 (2): 110-115.

Hundal, S.S. and Kaur, P. (1997). Application of the CERES-Wheat model to yield prediction in the irrigated plains of the Indian Punjab. *J. Agric. Sci.,* 129: 13-18.

Mourtzinis, S., Edreira, J.I.R., Conley, P. and Grassini, P. (2017). From grid to field: Assessing quality of gridded weather data for agricultural applications. *Eur. J. Agron.,* 82: 163-172.

Mall, R.K., Lal, M., Bhatia, B.S., Rathore, L.S. and Singh, R. (2004). Mitigating climate change impact on soybean productivity in India: A simulation study. *Agric. Forest Meteorol.,* 121: 113-125.

Nitin, Bharadiya. and Manekar, V (2015). Development of agro-climatic wheat yield model for Surat district, India using dimensional analysis. *J. Agrometeorol.,* 17 (2): 223-226.

Pai, D.D., Sridhar, L., Rajeevan, M. and Sreejith, O.P. (2014). Development of a new high spatial resolution (0.25° x 0.25°) long period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region. *Mausam.,* 65(1): 1-18.

Pathak, S. and Wassmann, R. (2009). Quantitative evaluation of climatic variability and risks forwheat yield in India. *Clim. Change*., 93(1):157-175.

Pearl, R.M., Jones, J.W., Curry, R.B., Boote, K. and Allen, L.H. (1989). Impact of Climate change on crop yield in southern USA: a simulation study. In: Smith, J.B. Tirpak, D.A. (Eds.) *The potential effects of global climate change on the United States.* Washington, DC.

Peng, S., Huang, J., Sheehy, J., Laza, R., Visperas, R., Zhong, X., Centeno, G., Khush, G.S. and Cassman, K.G. (2004). Wheat yields decline with higher night temperature fromglobal warmings. *PNAS.* 101(27): 9971-9975. doi.org/10.1073/pnas.1701762114.

Pramod, V. P., Bapuji Rao, B., Ramakrishna, S. S. V. S., Muneshwar Singh, M., Patel, N. R., Sandeep, V. M., Rao, V. U. M., Santhibhushan Chowdary, P., Narsimha Rao, V. and Vijayakumar, P. (2017). Impact of projected climate on wheat yields in India and its adaptation strategies. *J. Agrometeorol.,* 19 (3): 207-216.

Tubiello, F.N. and Ewert, F. (2002). Simulating the effects of elevated CO_2 on crops: approaches and application for climate change. *Eur. J. Agron.* 18: pp. 57-74.

Vashisth, A., Goyal, A. and Krishanan, P. (2020). Effect of weather variability on growth and yield of wheat crop under semi-arid region of India. *J. Agrometeorol.,* 22 (2): 124-131.

Yang, J.M., Yang, J.Y., Liu, S. and Hoogenboom, G. (2014). An evaluation of the statistical methods for testing the performance of crop models with observed data. *Agric. Syst.,* 127: 81-89.

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