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Short Communication

Calibration and validation of APSIM maize simulation model for different date of sowing

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Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops in globe. In India maize ranking third (9.2 m. acres) only behind wheat and rice, produced 27.8 million MT and the average productivity of 2965 kg ha^{-1} attained in 2018-2019 (Indiastat, 2021). Maize is cultivating in wide range of agroclimatic conditions from humid subtropical to warmer temperate regions. Process-based crop simulation models are tools for assessing the impact of climate change. Many of these models consider the interaction of the plant-soil-atmosphere continuum and crop management versus their effects on crop productivity. APSIM (Agricultural Production Systems Simulator) model is one of the best crop simulation models and used for simulating maize growth and development under wider agroclimatic conditions and management practices. (Archontoulis *et al.,* 2014; Yamusa, and Akinseye, 2018; Akinseye *et al*., 2019) In India, several researches were conducted in the past by using APSIM model *viz*. yield gap analysis of maize, climate change impact studies on wheat and soybean (Mohanty *et al.,* 2017; Patidar *et al*., 2020; Sinha *et al*., 2021) study was conducted to calibrate, validate and evaluate the APSIM-Maize model at Coimbatore, Tamil Nadu.

The field experiment was conducted at eastern block farm of Tamil Nadu Agricultural University (TNAU) of the Coimbatore situated at 11°N, 76°E and 426.7 msl. Maize COM (H) 8 cultivar was used for conducting the experiments. Two experiments were conducted *viz*., experiment I (*winter*) and experiment II (*Rabi*). Sowing windows of experiment I *viz*., D_1- II FN of Feb (17.02.2022), D_2- I FN of March (04.03.2022), D_3 - II FN of March (19.03.2022) and experiment II D_1- II FN of Aug (24.08.2022), D_2- I FN of Sep (12.09.2022), D_3 -II FN of Sep (26.09.2022) were taken as main plot and two levels of spacing *viz*., S_1 – 60x25 cm, S_2 – 45x25 cm were taken as sub plot which was layout using split plot design and replicated three times. Planting was done at 5 × 5 m^2 plots. All the agronomic practices were followed as per the TNAU crop production guide (TNAU, 2020). The average weather prevailed 2022-2023 during the cropping period maximum temperature 31.8°C, minimum temperature 22.1°C and solar radiation 13.6 MJ m^{-2} day^{-1}. The soil of the experimental site classifies as a sandy loam soil in different layers *viz*.,0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm and 60-100 cm with sand 41.2- 38.31 per cent, silt 32.51-28.52 per cent and clay 26.29 - 33.17 per cent. Air dry(mm/mm), Lower limit, drain upper limit(mm/mm) and saturated water content(mm/mm) range in different layers (0.08-0.18,0.16-0.20,0.29,0.32 and 0.41-0.42 respectively). The soil bulk density (g/cm$^{3)}$ and pH range in different layers (1.28 -1.20 and 9.9 -7.1).

APSIM model description

The Agricultural Production Systems sIMulator (APSIM) is a farming systems model developed by Agricultural Production Systems Research Unit (APS-RU), Commonwealth Scientific and Industrial Research Organization (CSIRO) and Queensland government, Australia. APSIM simulates yield in response to inputs of daily weather, crop genetic information, soil properties and crop management practices. Phenological phases (seedling stage, flowering stage and maturity stage) and yield of crops are the key output of the APSIM-maize model. APSIM–maize calibration and

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Table 1: Cultivar parameters of COM (H) 8 calibrated for the APSIM-Maize model

Parameters	Unit	COH (M) 8	Remarks
Duration from emergence to end of juvenile	◦C day	100	Calibrated
Duration - end of juvenile to flowering initiation	day	200	Calibrated
Duration - flag leaf to flowering stage	◦C day	34	Calibrated
Hour - Photoperiod critical 1	Hour	12.5	Default
Hour - Photoperiod critical 2	Hour	24	Default
Duration - flowering to start of grain filling	◦C day	120	Calibrated
Duration - flowering to maturity	◦C day	576	Calibrated
Duration - maturity to seed ripening	◦C day	1	Yamusa, and Akinseye, (2018)
Grain maximum no per head		460	Calibrated
Base temperature	◦C day	10	Default

Table 2: Observed and Simulated values on phenophases duration during calibration

Sowing window	Flowering DAS			Maturity DAS			LAI			Yield		
	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev (%)
D_1	62	58	-6.9	95	89	-6.7	3.9	3.5	-11.4	4942	4622	-6.9
D_2	56	51	-9.8	86	79	-8.9	3.8	3.5	-8.6	2497	2011	-24.1
D_3	56	51	-9.8	84	80	-5.0	3.7	3.4	-8.8	2708	2384	-13.6
	RMSE= 4.69, MAE= 4.67, d = 0.629, χ^2 = 0.42 R^2= 0.98			RMSE= 5.80, MAE= 5.67, d = 0.712, χ^2 = 0.41 R^2= 0.93			RMSE= 0.34, MAE= 0.33, d = 0.71, χ^2 = 0.03 R^2= 0.85			RMSE= 384.4, MAE= 376.6, d = 0.97, χ^2 = 61.21 R^2= 0.99		

*Obs – Observed, Sim – Simulated, Dev - Deviation (%)

validation was done using data collected from the field Experiment I (winter, 2022) and Experiment II (*Rabi,* 2022), respectively.

Statistical evaluations

The model was run between the observed and simulated outputs and compared statistically for each parameter evaluated. The model goodness of fit between simulated and observed values was evaluated by using statistical indices *viz*., root mean square error (RMSE), MAE, d-index, coefficient of determination (R^2) and chi-square following Willmott (1981).

Calibration of the APSIM-maize model was done by using the observed values from the field experiment I (Winter, 2022) as model input for the Maize COM (H) 8. Table 1 shows the lists of key variables used to calibrate the model along with the default values found in the APSIM maize files.

Phenophases duration, LAI and yield under calibration and validation

Data on phenophases duration LAI and yield during calibration revealed that the average phenological duration of flowering and maturity was observed longer during early sowing window (D_1) in both the observed and simulated values (deviation of -6.9 and -6.7%, respectively) whereas it was reduced in the delayed sowing dates. LAI and grain yield were observed higher yield at early date of sowing (D_1) in both observed and simulated values (deviation of -11.4 and -6.9 respectively), whereas the LAI and grain yield decreased under mid and late date of sowing (D_2 and D_3).

Overall, the prediction of model was good, confirmed by overall lowest RMSE≤4.69, RMSE≤5.80 lowest MAE≤4.67, MAE≤5.67 good d≥0.629, d≥0.71 and highest R^2≥0.98, R^2≥0.93, values during flowering stage maturity stage respectively. Overall, the prediction of model good which confirmed by lowest RMSE≤0.34, RMSE≤384.4 lowest MAE≤0.33, MAE≤376.6 good d≥0.71, d≥0.97 and highest R^2≥0.85, R^2≥0.99 values for LAI and grain yield respectively. The result was corroborated by Zhou *et al*., (2022) that the whole phenological phase of winter sowing maize was longer than that of summer sowing maize. From the comparison of NRMSE of the whole growth period was less than 5%, which was accurate simulation (Table 2).

The observed and simulated data on phenophases duration, LAI and grain yield during validation dataset are presented in the Table 3.

The average phenological duration of flowering and maturity was observed longer during early sowing window (D_1) in both the observed and simulated values (deviation of -10.3% and -4.3 %, respectively). LAI and grain yield were observed higher at early date of sowing (D_1) (deviation of 10.0 and 7.1 respectively). The result was supported by Yamusa, and Akinseye, (2018) who observed the closely matched values by the simulated days to flowering, days to physiological maturity, leaf area index, and grain yield of three kinds sown on three different dates.

Table 3: Observed and simulated values on phenophases duration during validation

Sowing window	Flowering DAS			Maturity DAS			LAI			Yield		
	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev. (%)	Obs.	Sim.	Dev (%)
D_1	64	58	-10.3	96	92	-4.3	3.6	4.0	10.0	4878	5253	7.1
D_2	62	57	-8.8	95	91	-4.4	3.4	3.7	8.1	4514	4819	6.3
D_3	62	57	-8.8	92	90	-2.2	3.2	3.6	11.1	4310	4726	8.8
	RMSE= 4.69, MAE= 4.66, d = 0.629, χ^2 = 0.49, R^2= 0.99			RMSE= 5.80, MAE= 5.66, d = 0.712, χ^2 =0.12, R^2= 0.93			RMSE= 0.37, MAE= 0.37, d = 0.64, χ^2 = 0.03, R^2= 0.92			RMSE= 368.3, MAE= 365.4, d = 0.61, χ^2 =27.07, R^2= 0.96		

*Obs – Observed, Sim – Simulated, Dev - Deviation (%)

It is concluded that APSIM-maize model had an excellent performance for determining maize phenology, LAI and grain yield. According to our results, yield was maximum under early sowing window whereas the values reduced with a delay in the sowing date. Overall, the APSIM model simulated the values more accurately which was confirmed by lowest deviation percentage and also by lowest RMSE, lowest MAE, good d and highest statistical values. The results also provided a theoretical basis and technical support for further research on the yield potential of APSIM-maize simulation and to find out the key limiting factors related to the yield gap in this region.

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