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Evaluation of APSIM – Maize model under different sowing dates at Samaru, Nigeria

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ABSTRACT

APSIM – maize model was validated with the experimental data on three maize cultivars (Sammaz 33, Sammaz 37 and Sammaz 27) sown on three different dates during 2015 wet season at the Institute for Agricultural Research Samaru Zaria Nigeria (Lat. 7R" 38'N, Long. 11R" 11'E Lat. 686m). For the testing efficiency of the model performance, R^2, RMSE and RMSEn was computed. RMSEn between observed and simulated values by APSIM for grain yield was lowest (5.4%) for Sammaz 33 cultivar as compared to Sammaz 37 (10.5%) and Sammaz 26 (27.6%). Similar results were obtained for the other parameters, with Sammaz 33 out yielding the other two cultivars. The observed values under second sowing date showed better performance of days to flowering, physiological maturity and leaf area index for all the varieties. The grain yield performance were higher under first sowing date. The results led to the conclusion that APSIM model is efficient in simulating maize growth and development in arid environment of Samaru.

Keywords: Agricultural productivity, APSIM, crop simulation, maize, rainfall.

Samaru belongs to the Nigerian Northern Guinea Savannah of the West African semi-arid region with a mean annual precipitation of about 1011mm with coefficient of variation of 16 per cent (Oluwasemire and Alabi, 2004). The area has a uni-modal pattern of rainfall that starts in May, peaks in July/August when frequent heavy rainfall is experienced before finally terminating in October. The area is characterized by high evapotranspiration, always higher than the rainfall from October to May thus determining the growing period of crops.

Agriculture which is the mainstay of the rural livelihoods and National Gross Domestic Product (GDP) of most African countries including Nigeria is the most vulnerable to climate variability and change. In Nigeria, maize which is one of the most widely grown cereals is equally the most vulnerable to climate variability. Until recently, the bulk of maize grain produced in Nigeria was from the southwest zone of the country but there has been a dramatic shift of the grain production to the savannah which can be regarded as the maize belt of Nigeria (Ikem and Amusa, 2004). Maize is most productive in this area because sun shine is adequate and rainfall is moderate (Obi, 1991).

Crop modelling is an effective tool in understanding and analysing the consequences of management options under variable climatic conditions. A model like APSIM (Agricultural Production Systems Simulator) has been in used in simulating maize growth and development for a wide range of climatic conditions (Archontoulis *et al.,* 2014) and management practices (Fosu-Mensah *et al.,* 2012). APSIM model has been used for various applications in India, viz. yield gap analysis of maize (Mohanty *et al.* 2017), climate change impact studies on wheat and soybean (Mohanty *et al.,* 2015; 2017). APSIM has had limited use in Sub-Saharan Africa due to the scarcity of suitable input data for model parameterization, testing, and application (Whitbread *et al.,*2010).

This work aimed at investigating the reliability of rainfall onset predictions and their effects on three maize varieties and validating APSIM-Maize model so as to develop intervention packages for maize production in the semi-arid zone of Samaru, Nigeria.

MATERIALS AND METHODS

Experimental details

The experiment was conducted during the 2015 wet season at the Institute for Agricultural Research (IAR) field in Samaru (Latitude 11^0 11'N and Longitude 7^0 38'E) and laid out as a split – plot arrangement in a randomized complete block design (RCBD) with three replications.

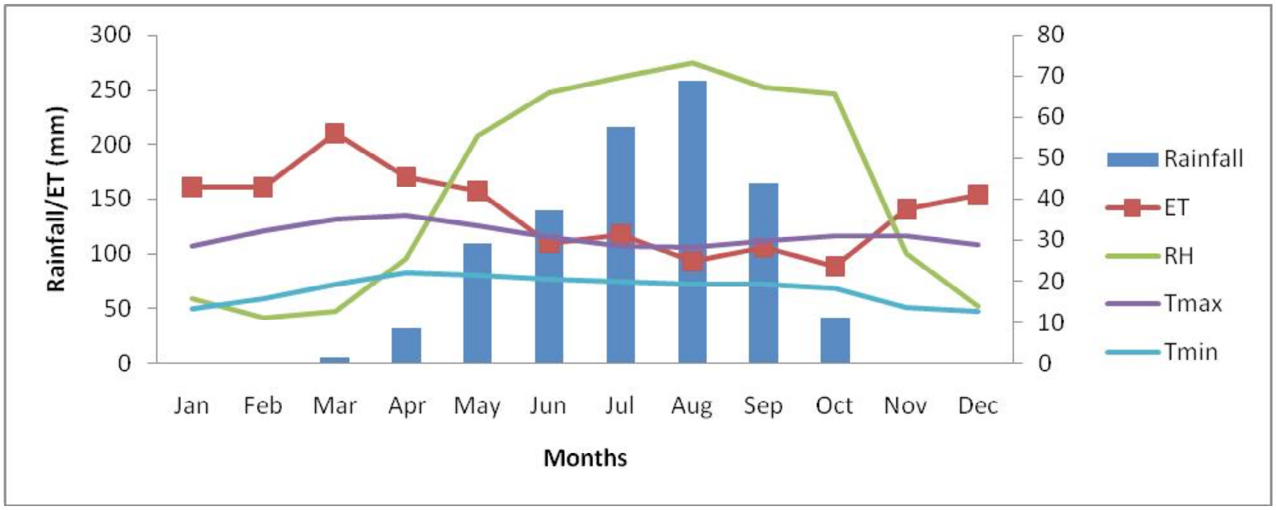

Fig. 1: Long term climatic data over Samaru

Main plot treatments: sowing date (SD1, SD2 and SD3):

SD1: 29/5/2015, was based on the rainfall onset prediction by the Nigerian Meteorological Agency (NIMET, 2015) which predicted its first planting window to be from 19^{th} – 26^{th} May of 2015,

SD2: 10/6/2015, based on Omotosho *et al.*(2000); "The beginning of the first two rains totaling 20 mm or more, within 7 days, followed by 2 to 3 weeks each with at least 50 per cent of the weekly crop water requirement"

SD3: 27/6/2015, based on farmers sowing dates which normally begins from the 2^{nd} week of June.

Sub plot treatment (Variety – 3):

V1: Sammaz 33 (Extra early maturing variety)

V2: Sammaz 37 (Early maturing variety)

V3: Sammaz 26 (Medium maturing variety)

Land preparation, farm management and data collection

The field was divided into three equal blocks according to planting dates. Each block was divided into three equal replications with nine plots in each replication.

Establishment records (date of sowing, emergence (>50%), thinning, plant population and successive tip appearance) of the crops on main stem were taken. Within each plot, a net plot was marked out and plant stands in each net plot was selected and marked for observation. Days to 50 per cent emergence and tasselling, number of leaves per plant, number of cobs per plot at harvest, cobs weight per plot at harvest, 100 grain weight and date of harvest were recorded. The growth measurements were carried out at two weeks intervals commencing from 4 weeks after emergence. This was determined using the method adopted by (Stickler *et al.,* 1961). One plant was taken from each plot outside the designated final harvest area and the length and breadth of leaves of each plant was recorded. The average of these length and breadth was multiplied by a factor of 0.80 to obtain the leaf area of each plot.

APSIM Maize simulation model

The data collected from the field experiments was used for APSIM model evaluation. Specific cultivar coefficients for the genotypes used in this experiment was not in the list of genotypes available with the model, therefore, evaluation was done using basic information for the cultivar coefficients provided with the model. The cultivar coefficients were adjusted, until main growth and development stages were simulated within 10 per cent of the measured values.

To evaluate the performance of the APSIM model, R^2, absolute and normalized root mean squared error (RMSE and RMSEn) (Wilmot *et al.,* 1985) were calculated as follow.

Absolute RMSE = $(\Sigma\,(Pi - Oi)^2/n)^{0.5}$

RMSEn = $100\,(\Sigma\,(Pi - Oi)^2/n)^{0.5}/O_{mean}$

Where Pi is the simulated value, Oi is the observed value and n is the number of measurements. RMSEn is stated in percentage of simulated amounts than observed amounts. According to the above descriptions RMSEn < 10 per cent is excellent, 10 per cent < RMSEn < 20 per cent is well, 20 per cent < RMSEn < 30 per cent is moderate, RMSEn > 30 per cent is weak (Rinaldy *et al*., 2003).

RESULTS AND DISCUSSION

Climatic condition of the study area

The mean monthly climatic data of fifty years (1963

Table 1: Final settings of APSIM-Maize module after calibration and evaluation for three varieties

Parameter	Source	Units	Sammaz 33	Sammaz 37	Sammaz 26
Thermal time accumulation					
Duration-emergence to end of Juvenile	Calibrated	°C day	218	280	400
Duration-flag leaf to flowering stage	Calibrated	°C day	170	170	170
Duration-flowering to start of grain filling	Calibrated	°C day	600	580	540
Duration-flowering to seed ripening	Literature	°C day	1	1	1
Photoperiod					
Daylength photoperiod to inhibit flowering	Default	H	12.5	12.5	12.5
Daylength photoperiod for insensitivity	Default	H	12.5	24	24
Base temperature	Literature	°C day	6	6	6
Optimum temperature	Default	°C day	35	35	35

Table 2: Simulated and observed phenological, morphological and yield data of different varieties under three dates of sowing

	Flowering(DAS)		Maturity (DAS)		Leaf No.		LAI		Grain yield (kg ha^{-1})		Biomass yield (kg ha^{-1})	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
Sammaz 33 (Extra early maturing maize variety)												
SD1	56	55	89	84	16.3	16.8	1.68	1.69	3433	3307	3616	3468
SD2	58	53	98	84	15.8	16.9	1.97	2.17	2866	3042	4162	5043
SD3	56	58	90	87	15.3	13.7	1.93	2.36	2600	2777	3992	2665
RMSE		0.05		0.06		1.2		0.27		161		923
RMSEn		5.7%		6.3%		7.3%		4.9%		5.4%		23.5%
Sammaz 37 (Early maturing maize variety)												
SD1	63	64	95	96	16.9	17.6	1.74	1.94	3017	3191	4376	3201
SD2	65	62	98	95	16.3	17.	1.77	1.88	3006	2848	3878	2598
SD3	65	67	98	98	16.5	16.9	1.64	1.75	2333	2506	3872	2259
RMSE		2.1		1.8		1.03		0.46		291		1368
RMSEn		3.4%		2.0%		6.2%		2.8%		10.5%		33.8%
Sammaz 26 (Medium maturing maize variety)												
SD1	84	82	110	112	17.2	17.9	1.83	1.59	2644	2689	4922	3486
SD2	82	81	111	110	14.8	13.7	1.74	1.54	3179	2592	4652	3564
SD3	84	85	113	112	15.7	12.3	1.81	1.43	2066	1643	5423	2283
RMSE		0.02		0.03		2.1		0.28		724		2089
RMSEn		1.7%		1.3%		14.4%		5.3%		27.6%		41.3%

– 2012) collected from Samaru Meteorological Unit of the Institute for Agricultural Research are presented in Fig. 1. Rainfall pattern in the area is uni-modal starting in May, peaking in July/August when frequent heavy rainfall is experienced before finally terminating in October. The highest monthly rainfall of 250mm is in August. The maximum temperature (32°C), minimum temperature (18°C), sun shine hours (6.5hrs/day) are highest in April.

APSIM – Maize model performance

Genotype specific parameters were generated from the experiment for three cultivars of maize Sammaz 33 (V1), Sammaz 37 (V2) and Sammaz 26 (V3) (Table 1). Some of the parameters were taken from literature and other as default values. The observed and simulated phenological, morphological and yield data of three varieties under 3 dates of sowing are presented in Table 2. The results revealed that the simulated days to flowering, days to physiological maturity, leaf area index and grain yield of three varieties sown on three dates closely matched with the observed values. In case of variety Sammaz 33 the observed values under second sowing date (SD2) were higher day to flowering, days to physiological maturity, leaf area index and biomass yield in comparison to other sowing dates. The grain yield was however higher under the first sowing date (3433 kg ha^{-1}). Variety Sammaz 37 produced highest grain yield (3017 kg ha^{-1}) and biomass yield (4376 kg ha^{-1}) under the first sowing date (SD1). While growth parameter (LAI) was higher (1.77) under second sowing date (SD2). The medium maturing maize variety Sammaz 26 took highest number of days (113) for maturity under late sown condition (SD3). The biomass was also highest (5423 kg ha^{-1}) under SD3, however the grain yield was highest (3179 kg ha^{-1}) under second sowing date (SD2). Among the three cultivars the maximum grain yield was observed in extra early maturing variety Sammaz 33, while the maximum biomass was observed in medium maturing variety Sammaz 26.

The results on simulated values of different phenological, morphological and yield parameters (Table 2) under different dates of sowing for 3 varieties of maize show very close relationship with the observed values, as indicated by statistical parameters RMSE and RMSEn. In most of the cases, the RMSEn (%) values were less than 10, except in case of biomass yield. APSIM model under estimated the biomass under all the dates of sowing as well as for all the varieties with RMSEn (%) ranging between 23.5 and 41.3. Even the grain yield of variety Sammaz 26 was under estimated by the model (Table 2).

CONCLUSIONS

The results indicated that the simulation achieved poor results with late sowing dates (farmers sowing dates) and therefore the model should be used with caution within the limit of experimental error to simulate growth and yield over wide range of planting dates, cultivars and climatic scenarios for adaptation strategies.

To ensure minimization of the effect of rainfall variability on crop yield in general and maize in particular, at the study area, sensitization visits and other awareness programs on the seasonal forecasts of onset dates and cessation of rainy season by The Nigerian Meteorological Agency (NIMET) is recommended.

The results also led to the conclusion that APSIM model is efficient in simulating maize growth and development in semi - arid environment of Samaru. It can be used in decision making to mitigate the effect of climatic risk, selection of suitable varieties and management options for sustainable agriculture.

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