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EXPLORING NICHES OF MEDIUM-SEASON GRAIN SORGHUMS IN DRYLAND AREAS OF NIGERIA- COPING STRATEGIES WITH IMPACTS OF CLIMATE VARIABILITY

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Background

Climate variability constitutes a major risk to agricultural production in West Africa drylands posing challenges to the livelihood of smallholder farmers. Sorghum crop, which displays a great diversity in growth, development and resource use efficiency has the potential to improve productivity of resilient farming system. However, to better understand plant growth and development in response to the environment there is need for applicable models for Agricultural Production Systems sIMulator (APSIM) framework (Keating *et al.,* 2003; Holzworth *et al.,* 2014). The application of well-calibrated crop growth models, could help to estimate their production potential in different sites and soil conditions, as well as the impact of different management interventions (Akinseye *et al.,*2017). This would further allow us to better assess the interaction of phenology with patterns of water use and WUE, a great interest to develop crop adaptation strategies in terms of combating climate variability.

Objectives

1. To calibrate and evaluate APSIM to simulate growth and development of medium-season grain
2. Stimulate for water use and water use efficiency (WUE) as well as the grain productivity across different sites and soil types along rainfall gradient of dryland areas in Nigeria

Methodology

The sorghum crop module was calibrated and evaluated within the APSIM (APSIM7.9) framework for early maturing (Samsorg-40) and medium-maturing(Samsorg-45) cultivars grown under semi-arid environment in Nigeria. Crop management and cultivar information were derived from the three seasons (2014-2016) field experiments conducted at the ICRISAT research station in Minjibir (Latitude 12.17^{0}N and Longitude 8.65^{0}E) and Bayero University, Kano(BUK) (Latitude 12.98^{0}N and Longitude 9.75^{0}E). The trials was conducted under optimum condition with appropriate plant density (30 x 75 cm) and fertilizer application(NPK 60:30:30). Generally, input data required for the model are crop management information, cultivar specific parameters (genetic coefficient), soil properties and daily weather records. Cultivar-specific parameters, important for the calibration procedure, which quantify growth and development include days to 50% flowering and maturity, total biomass at harvest and yield. Thereafter, the model was evaluated using different statistical skills such as mean bias error (MBE),root mean square error(RMSE) and % of mean observed(RMSEn) respectively.

Simulation Activities

- The temporal rainfall variability for the three selected sites (Sokoto, Kano and Samaru) within the dryland areas of Nigeria (**Fig.1**) was determined by calculating the start of growing season, end of growing season and length of growing season based on the methods reported by **Akinseye et al. (2016).**
- The cultivar-specific parameters were calibrated well to account for the high-yielding of Samsorg-40 (94-96days) and Samsorg-45 (107-111days) sorghum cultivar characteristics.
- The calibrated cultivar-specific parameters for Samsorg-40 and 45 performed a 30-year period (1981-2010) simulation with historical weather data to analyse the agricultural potential, including grain yield as well as water use and use efficiency. The simulations were carried in three sites stated above which represents the gradient of dryland areas of Nigeria.
- The model was set to considered the following sowing windows; 45days (Jun-15 –Jul-30) for SHZ and SSZ at cumulative of 25mm in 3 rainy events and 60days (Jun-01 –Jul-30) for NGS at cumulative of 30mm in 3 rainy events.

Key Results

- The phenological development was captured with a very high accuracy and provided excellent agreement between simulated and observed values for crop phenology with RMSE values being equal or less than 3 days for time of 50% flowering and 4 or less days for time to physiological maturity (**Table 1**).
- Time to maturity was simulated with less accuracy than flowering for both cultivars possibly reflecting the additive effects of errors simulating the intermediate flowering and grain fill stages.
- Analyses for the seasonal rainfall of the selected sites (Kano, Samaria, and Sokoto), indicated that rainfall during the growing seasons exhibited a high inter-seasonal variability. Start of growing season (SGS) showed a high inter-annual variability **(Fig.1)** and the latter the season start, the shorter is their expected length of growing season (LGS). The 25 and 75% percent quartile—a measure of the long-term variability was particularly wide (about 30 days difference for SGS) at all sites and LGS varied from 122-153 days in Samaru, 101-133 days in Kano; 84-115 days in Sokoto respectively.
- There was a little response to in-crop rainfall ranging from 421 to 770mm indicating less inter-annual variability in simulated grain yield **(Fig.2).** The mean simulated grain yield for both cultivars was relatively stable at about 2000kg ha^{-1} at all sites.
- Water use efficiency (WUE) was significantly higher for samsorg-40 compared to Samsorg-45 (result not shown), independent of the in-crop rainfall simulated during the growing season due to its fast phenological development. However, **Fig.3** shows the boxplot of simulated WUE (total biomass and grain yield) slightly increased from low (Sokoto) - to the high rainfall site (Samaru) ranging from a simulated mean of 55.5 – 60.2 (kg ha^{-1} mm^{-1}) for total biomass and 15.9 -17.2 (kg ha^{-1} mm^{-1}) for grain yield.

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Table 1: Evaluation of the model performance in simulating phenological development, total biomass and grain yield for the sorghum cultivars calibrated under optimum condition

Cultivar parameters	Unit	N	MBE	RMSE		Observed range	Observed mean
				Absolute value	% of mean observed		
SamSorg-40(SS-40)							
50% Flowering	DAP	5	-2.8	3.3	6.7	67 - 71	68
Maturity	DAP	5	-0.5	4.4	4.7	92 - 96	94
Total Biomass	kg ha^{-1}	5	-296	1167	20.3	4105 - 7195	5740
Grain yield	kg ha^{-1}	5	28	364	23.7	1090 - 2088	1537
SamSorg-45 (SS-45)							
50% Flowering	DAP	5	-1.2	2.6	3.3	74 - 84	78
Maturity	DAP	5	1.6	3.3	3.1	100 - 111	107
Total Biomass	kg ha^{-1}	5	-1203	1362	11.2	10184 - 14656	12296
Grain yield	kg ha^{-1}	5	232	353	13.9	1655 - 3060	2526

DAP- Days after planting; N-number of observations; MBE-mean bias error; RMSE-root mean square error

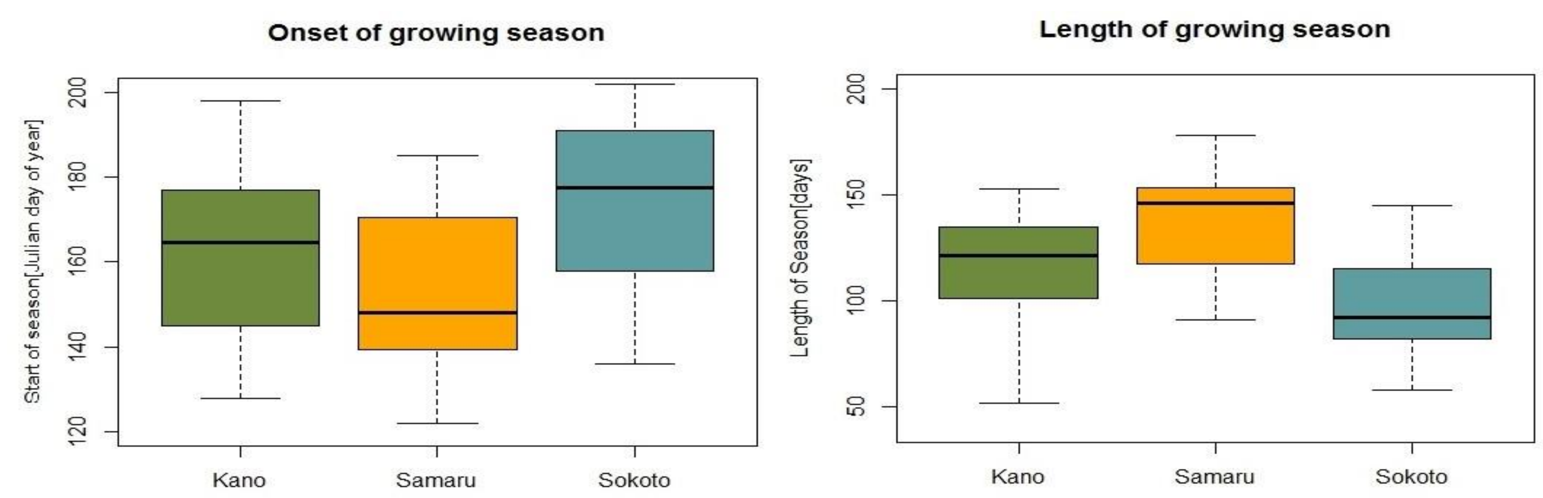

Fig 1: Boxplots representing characteristics of growing season length in Kano, Samaru and Sokoto,, dryland areas of Nigeria, including start of growing season (day of the year and growing season length (days)

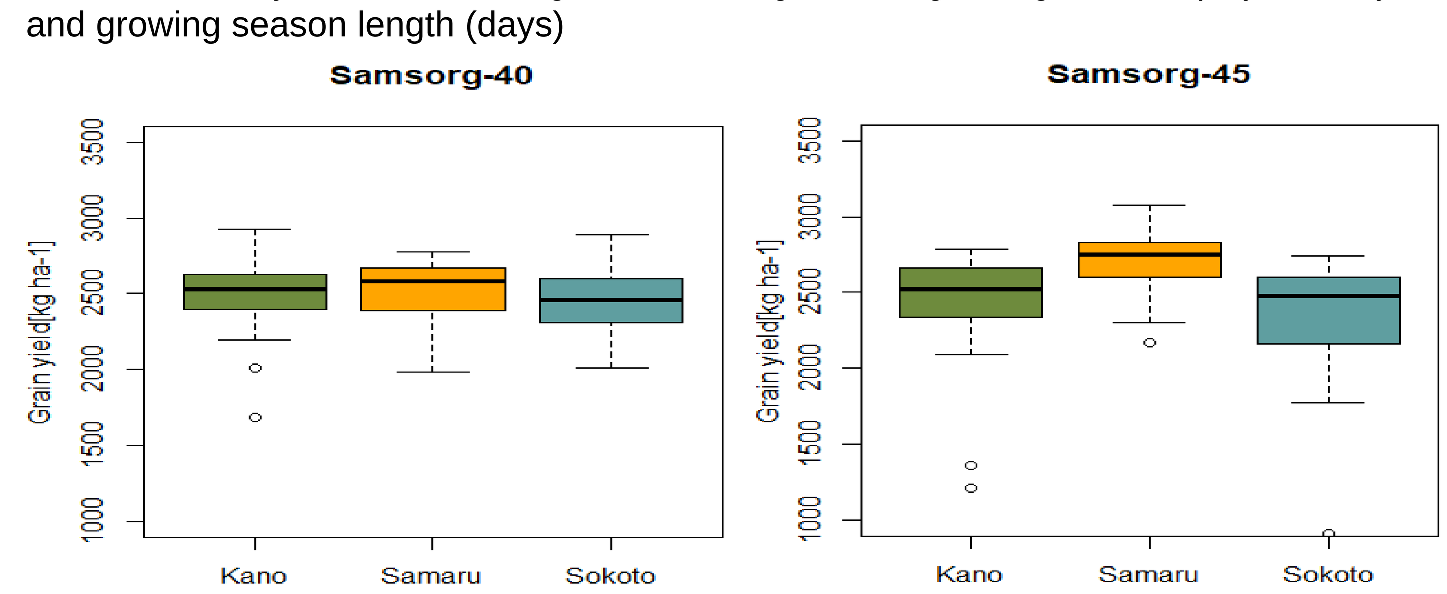

Fig.2: Box plot of 30-year simulated grain yield for Samsorg-40 and Samsorg-45 at different rainfall gradient(Kano-749mm,Samaru-1013mm and Sokoto-582mm) and soil with different plant available water capacity.

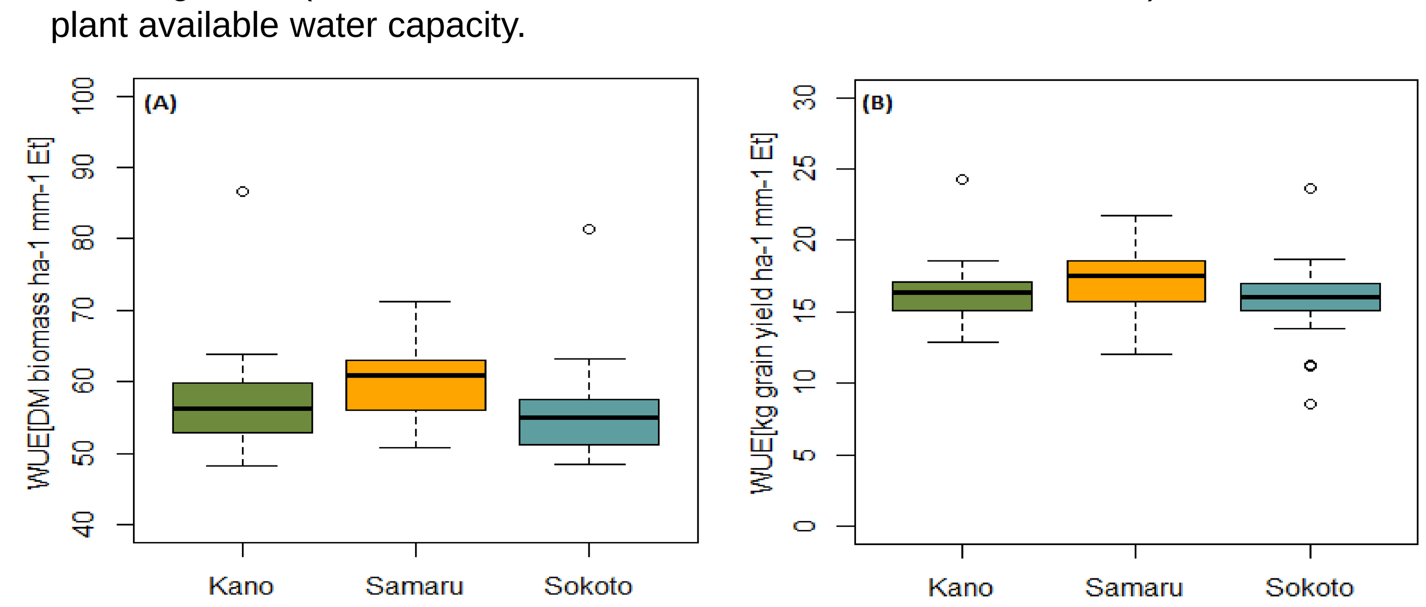

Fig.3: Boxplots of simulated long-term average water-use efficiency(WUE) for **(A)** total biomass and **(B)** grain yield along the dryland rainfall gradient (Kano-749mm,Samaru-1013mm and Sokoto-582mm) and soil with different plant available water capacity(PAWC).

Conclusions

Based on the simulation outputs, both cultivars had shown less responsiveness to increased water availability, even at low rainfall potential site (Sokoto), which implies grain yield may not significantly reduced provided the recommended fertilizer rate of NPK 60:30:30 is applied. It is however, expected that the temperature increase might have a more severe impact on yield productivity as it would accelerates crop development and maturity processes. Also, it was observed that both cultivars are suitable for higher grain yield and biomass and its follow the physiological strategy of drought escape as they flower and mature comparatively earlier than traditional grown sorghums in the region. This is a rather conservative strategy, but might be advantageous in challenging environments with shortened growing season length and high rainfall variability observed in dryland areas such as the low-rainfall potential site.

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