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Yield Estimation and S[illegible] Analysis [illegible]ize (*Zea Mays L.*) C[illegible]s Using DSSAT Soft[illegible]sosa, Weste[illegible]iopia

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An experiment was conducted in the Assosa university f[illegible]019 and 2020 on maize cultivars with the objective of calibrating and validating maize cultivar coefficie[illegible]SSAT software version 4.7.5. Five-cultivar coefficient was calibrated and evaluated using 2019 and valid[illegible]he 2020 crop data. The Genetic coefficient among cultivar showed, SHONE is highest in grain filling rate, [illegible]E, BH545 and MH138 are highest in delay [illegible]velopment due to photo-period sensitivity, and highest i[illegible]r of kernels. Normalized difference RMSE [illegible]was Zero for days to anthesis, days to maturity and g[illegible]hile it was between 0-20% for leaf number [illegible]yield as calculated by DSSAT during calibrati[illegible]ious crop growth showed higher R2 (>90) [illegible]st measured crop parameters during va[illegible]e calibration results of 2019 showed tha[illegible] the ob[illegible]lues of maize cultivars are similar[illegible] near 1, for at least five measured values days to an[illegible]rity, dry biomass yield, grai[illegible]nit grain weight. The sensitivity analys[illegible] also showed that [illegible] different cultivars can [illegible]ing on the climatic condition that co[illegible] occur in study site. The d[illegible]ged, starting fro[illegible]gh to May 10 and May 20 continuou[illegible] increased the grain and dry bi[illegible]ield on May 1 wa[illegible]pared to actual time of planting ([illegible]

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Keywords: Maize cultivars; Calibration; Validation; Sensitivity; Plant density; Date of planting

Introduction

DSSAT is one best crop simulation software, which is showing best promises in yield estimation and yield prediction over long time enabling decision support to different parties (Abera et al., 2018; Hoogenboom, et al.2012). DSSAT Software package has gone through different progress since its development with only few crops and four crop models (CERES maize, CERES-wheat, SOYGROW, NUTGROW) (Jone et al., 2003; Kaleita et al., 2020) to more than 42 crops and addition of new modules (Kaleita et al., 2008; Sachin et al., 2019; Abayechaw, 2021). Its advancement for use in many operating systems (Thorp et al., 2011), data interchange system and its ability to be integrated with different software (Dzotzi et al., 2013; Thorp et al., 2008) inclusion of new modules (Kaleita et al., 2020) used in precision agriculture (Paz et al., 2001a, 2003; Thorp et al., 2008) and with its betterment in the challenges in formatting input and output files (Kaleita et al., 2008) it has become more user friendly, and is well validated for a number of regions and crops (Thorp et al., 2008) [1].

In the same line as the progress in DSSAT developers the progress that demand in the users of DSSAT in the agricultural sector should also be in line by evaluating and validating the different new interfaces of DSSAT added from time to time and covering most areas of the agricultural ecosystem while, adjusting crop coefficients of cultivars is needed for its efficient utilization (Hoogmboom et al., 2020) [2]. The demand continues in evaluation and validation of crop parameters for various crop genes by environment interactions so that we can address the different combination of effects from changes occurring on the environment (Abera et al., 2018) and changes occurring by varying different technologies (Thorp et al., 2008) and at the end it will be possible to find ways to modify or optimize the models within DSSAT for our local condition and specific crop (Jing-yi et al., 2012) [3].

Environmental changes that arise due to climate change and variability across agro-ecosystems (Abera et al., 2018) as well as the differential potent[illegible]rent agroecologies, technologies used in the [illegible]ices are the major causes (Jone et al., 2003) for fluctuations and yield gap problems that are widely seen in most cropping systems and have predicted future impact on the crops productivity (Abera et al., 2018; Mulune et al., 2015) [4]. For example in Ethiopia climate change perdition across time between 2010-2099 showed a decrease in maize yield by more than 24 % at the end of the century. The use of adaptation strategies, such as, the best cultivar of maize and change in the date of planting will have a salvaging effect up to 12% yield reduction during predicted years of 2012 -2040 (Eulenstein et al., 2017). Being at the start of long term climate change predictions this study is done with the objective of Evaluating and validating different cultivars using DSSAT-CSM, while testing the maize cultivar sensitivity based on some anticipated climate change scenarios [5].

Materials and Methods

Description of the Study Site

The experiment was conducted for two seasons in a warm sub-humid lowlands agro-ecology possessing one altitude feature in the region. The major agroecology covering vast area of the region are the warm moist lowlands and warm sub-humid lowlands having distribution in all the Zones and most districts. Assosa district is selected to represent warm moist lowlands agroecology. The study site is geographically located at 34o 31’E longitude and 10o04’N latitude with an altitude 1580 meters and it is approximately 660 km west of the capital, Addis Ababa [6].

Description of the study materials

Five maize varieties adapted to the agroecology, which are high yielding; resistant to disease and recently released varieties, were selected for the study. Based on the selection criteria the five varieties were, Shone (Pioneer), Melkasa6, MH138, BH545 and local variety. Blended NPS and KCl (60% K) fertilizer was used to supply the three major nutrients, nitrogen, phosphorus and potassium and one micro-nutrient which is deficient in the soil of the study site (Table 1) [7].

Soil Sample and sampling methods

Soil samples were taken from the whole field at 10 points and from 4 depths (0-20, 20-40, 40-60 and 60-80 cm) before treatment application and from each plot at 3 points diagonally after crop harvest from 30 cm depth of and samples from the similar experimental unit were composited [8].

Soil physical properties like soil texture and soil dry bulk density, accompanied by chemical properties were tested following standard methods, in the Assosa University Soil Lab. Soil texture were determined using density method proposed by Bouyoucos (2003); the dry bulk density were measured by core sampling method of Black (2003); the soil pH (1:2.5) by pH meter (potentiometric analysis) (Jackson, 2003); the percent organic carbon content using wet potassium dichromate oxidation method (Walkley and Black, 2003); while the exchangeable K was measured by flame photometer; total N by kjeldahl digestion method (Jackson, 2003); and available P by Bray No 1 method (Bray et al., 1945) [9].

Treatments and design of the experiments

The five cultivars of maize SHONE (Pioneer), MELKASA6, MH138, BH545; and one local cultivar that was planted under two nutrient condition one with (NPS and KCl) and the second one without (NPS and KCl) fertilizers. The four cultivars and the local cultivar with two nutrient situations were planted for two seasons as single factor experiment. The six (6) treatments was, planted on plot size of 4.5 m x 4.5 m with plant spacing of 75 cm and 30 cm between rows and between plants on a row, respectively, for all the cultivars. The experiment was laid in RCBD design, with three replications.

Data collected

Crop data

Data on days to emergence, days to anthesis and silking and days to physiological maturity; and crop data on four important stages was measured to calculate the genetic parameter, like P1, P2, P5, G2, G3 and PHINT at each leaf appearance. P1 is the thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days, oC day, above a base temperature of 8 oC) during which the plant is not responsive to changes in photoperiod. P2 is the extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 h). P5 is the thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8 oC). G2 is Maximum possible number of kernels per plant. G3 kernel filling rate during the linear grain filling stage and under optimum conditions (mg day−1). And PHINT is the Phyllochron interval; the interval in thermal time (degree days) between successive leaf tip appearances, to record the phyllochron the plants were observed every day starting from emergence until flowering [10].

Growths of maize such as the leaf area index and plant height were recorded at each full appearance of new leaves until the end of leaf growth and start of flowering. Plant samples were selected from the central plant rows for measuring the LAI and the plant height. Yield component data were also measured at physiological maturity, while the grain yield and final dry biomass yield were taken at time of full maturity. All plant parts (leaves, stalk and the husk) were separated dried and summed up for dry biomass yield [11].

Climate and soil data

A 40 year data between (1980-2020) on five climate variables, solar radiation, maximum temperature, minimum temperature, relative humidity and rainfall was collected from Ethiopian meteorology agency of Benishangul Gomez region, however because of high numbers of missing data between (1980-2000) only 20 year data between (2000-2020) was used for the calibration and validation purpose as completeness of climate data is more important than the numbers of years (Hognboom, et al., 2012).

During the period of the experiment in the 2019 the amount of rainfall in the growing period was 967 mm which is slightly lower than the rain fall amount in the growing period of 2020 experiment year 987 mm. The min and max temperature during 2019 was slightly higher than 2020 in the growing period the different climatic variable in the two growing period (Figure 1,2).

Soil analysis was made by taking soil samples from four depths of 0–20, 20–40, 40–60, and 60–80 and 80-100 cm and soil physical properties like: texture, dry bulk density, and some soil chemical properties, such as pH, Organic carbon, Total N, available P, available K were taken before and after the experiment [12].

Data analysis

Crop data in the first season, was used to calibrate the CERES maize model of DSSAT software version 4.7.5, while in the second season the

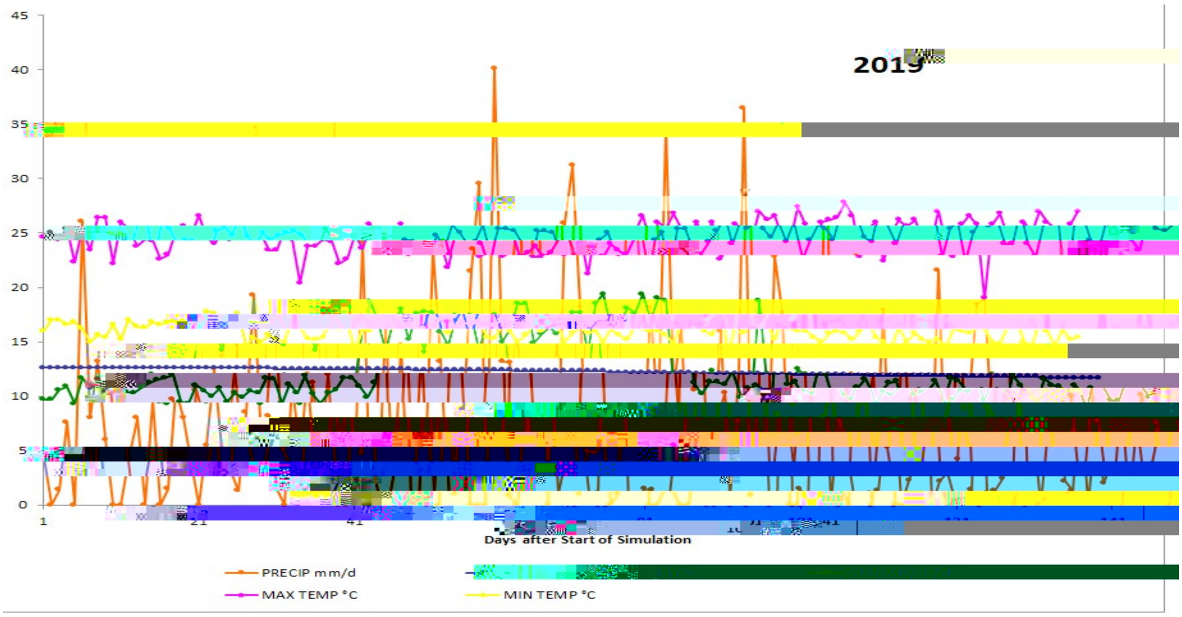

Figure 1: The weather condition in the growing period of 2019.

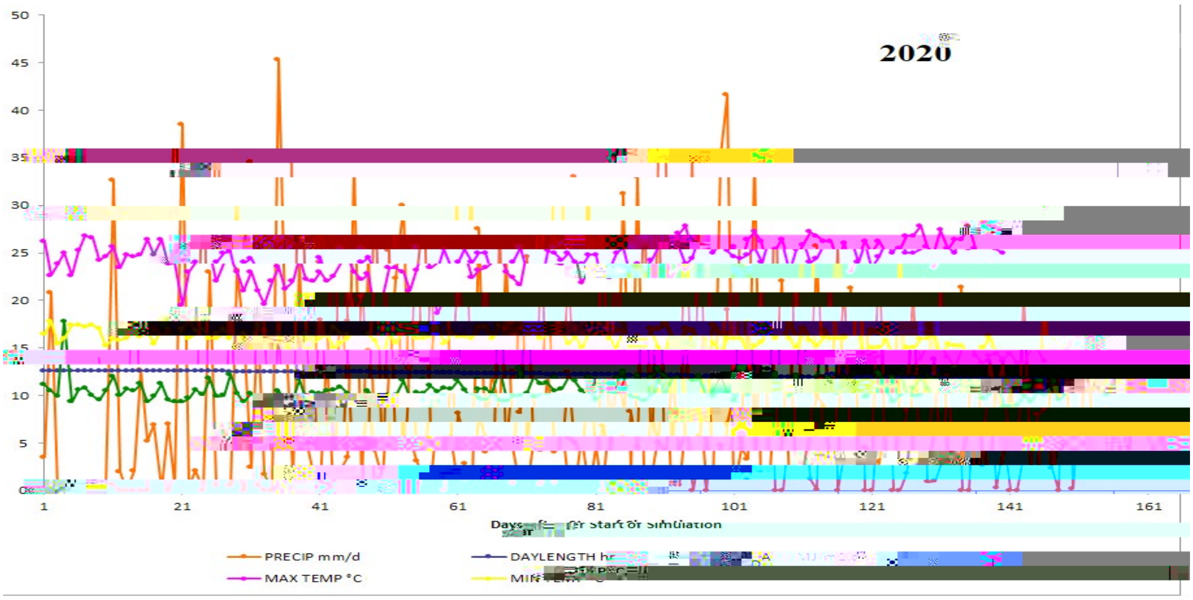

Figure 2: The weather condition in the growing period during 2020.

crop data were used to validate using the statistic root means squared error (RMSE), Normalized difference RMSE (nRMSE), mean absolute error (MAE), index of agreement (d) of DSSAT (Yang et al., 2014). Then crop growth and yield of maize scenarios were estimated by changing climatic variables that approximate the El-nino periods of historic El nino years, and different adaptation strategies were tested based on changes in the length of growing period and maize varieties using the DSSAT software.

Result and Discussion

Soil Test Results

The soil analysis across five depth showed that the dry bulk density increased downward in the range between 2.00 - 2.20, while the soil pH; organic carbon, total nitrogen and available phosphorus decreased across depth within range between, 5.50-5.30, 2.84-0.62, 0.49-0.12, and 27.0-25.2 respectively, while the available potassium increased downward from 0.5-0.8 (Table 2).

Evaluation of calibrated result

Calibration of five maize varieties using the DSSAT Software: the days to anthesis, the days to physiological maturity, grain yield, harvest index, unit grain weight, and kernels number are simulated with acceptable RSME and d-stat values, higher R2 values and within the ranges of crop coefficient limits.

The minimum and maximum DSSAT-CSM crop coefficients and the new calibrated coefficients of the five cultivars of maize are shown. Comparison of the cultivars from the genetic coefficient may show that variety SHONE is the highest in grain filling rate, while it was the second in number of kernels compared to BH545 and MH138, calibration year. In both calibration and validation year all parameter showed less than 10% different except for harvest index in the first year and LAI and harvest index in the second year.

The nRMSE comparison between Calibrated vs. Validated show that values for validated year are higher in six measured parameters among nine. This can be an indication that better estimation was done during the calibration than validation year hence. Improving high values seen in the harvest index during the calibration year by improving the genetic coefficient could improve the simulation during validation. The R2 and d-stat values are greater than 0.70 for at least four parameter in the calibration year (2019) compared to the validation year (2020) which showed less values for most parameters, exhibiting variability in yield estimation.

Sensitivity analysis on the planting date and plant spacing

Date of Planting

Changing time of planting known in the area from June 1-15 to a different date of planting between May 1 to June 30 showed a change both in phenology and yield of maize. When the planting date is shifted 1 month before the known time sowing in the site June 1-15 the phenology as well as the yield of maize decreased. Increasing the panting date between May 10 to May 20 the phenology and the yield increased compared to May 1 planting, but without difference between the two days of planting (May 10 and May 20), however, planting date when shifted to June 24 the phenology are approximately similar to the known planting date of the site, but the grain yield and dry biomass decreased for both calibrated and validated simulations in 2019 and 2020, data presented here is only validation year. Therefore, the time of planting of the area could still be as appropriate using the DSSAT model, but with changes in the climate changes or fluctuation the panting date between May 10 to end of May could be beneficial during the occurrence of short rains due to El Nion (Table 8,9).

Plant population (plant spacing)

The plant spacing was made for the corresponding plant population without changing on row spacing, but making change only on plant spacing (Table 10).

Changing the plant spacing (plant desity), from 4.4 plants m-2 to 5.3 and up to 12 plants m-2 consciously increased the grain yield and biomass yield without change on the phenology of maize (days to anthesis, days to physiological maturity). However, increasing the plant density to 14 plants m-2 decreased the grain, but kept increasing the dry biomass yield of maize cultivars, during both evaluation years (2019) and validation year (2020) data presented here is only validation year (Table 11,12) [14].

Conclutions

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Table 10: Plant population per meter square and its corresponding plant spacing.

Plant population in 1 m^2	**Area in m^2 used per plant**	**Pant spacing (m x m)**
5.3	0.188	0.75 x 0.25
6.2	0.161	0.75 x 0.21
7.4	0.135	0.75 x 0.18
8	0.125	0.75 x 0.16
9	0.111	0.75 x 0.15
12	0.083	0.75 x 0.11
14	0.071	0.75 x 0.095

	Population Density (5.3, 6.2, 7.2, 8, 9, 12, 14 plant m^{-2}) maize cultivars							
Cultivar	5.3	9	12	14	5.3	9	12	14