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Modeling Maize Production towards Site Specific Fertilizer Recommendation in Ghana

Williams Kwame Atakora.[α], Mathias Fosu.[σ] & Francis Marthey [ρ]

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Validation results showed good agreement between predicted and measured yields with a NRMSE value of 0.181. Highest observed mean harvest maturity yield of 3831and 3795 kg/ha were obtained from plots which received 120-90-60 and 120-60-60 kg/ha N-P_2O_5-K_2O respectively. However, the model under predicted weight per unit grain. The mean difference between observed and simulated by-product produced at maturity and top weight at maturity was significant ($P \leq 0.001$).In general, maize yield simulation by DSSAT under Guinea savanna agro-ecological conditions was good. Average predicted harvest maturity yields were very close to measured values with MD of 336.0, RMSE of 498.77, NRSME of 0.181 and simulated and observed mean yields of 3096 and 2750 kg/ha for the entire treatments respectively. The mean difference between predicted and observed was not significant. The highest harvest maturity yield predicted and observed was achieved with 120-90-60 kg/ha N-P_2O_5-K_2O. The predicted and observed average mean yield were 3831 and 3999 kg/ha, respectively. Based on the simulation results from this study the DSSAT model appeared to be suitable for the Guinea savanna agro-ecological conditions in Ghana.

Sensitivity analysis results showed that the DSSAT model is highly sensitive to changes in weather variables such as daily maximum and minimum temperatures as well as solar radiation. However, the model was found to be least sensitive to rainfall. Similarly, the model was found to be sensitive to soil and genetic parameter of the cultivar.

I. Introduction

Maize is the most important cereal crop produced in Ghana and it is also the most widely consumed staple food in Ghana with increasing production since 1965 (FAO, 2008., Morris et al 1999). In Ghana, maize is produced predominantly by smallholder resource poor farmers under rain-fed conditions (SARI, 1996). Low soil fertility and low application of external inputs are the two major reasons that account for low productivity in maize. The soils of the major maize growing areas in Ghana are low in organic carbon (<1.5 %), total nitrogen (< 0.2 %), exchangeable potassium (<100 mg/kg) and available phosphorus (< 10 mg/kg) (Adu, 1995, Benneh et al 1990).

From 1969 to 1972, UNDP/FAO carried out series of fertilizer trials with Ministry of Food and Agriculture (MoFA) under UNDP/FAO Ghana Project "Increased Farm Production through fertilizer use." Fertilizer recommendations were made for maize and other crops.

Soil conditions have changed over the years and the old recommendations are not the most efficient today hence the need to update fertilizer recommendations for maize (and other crops) in Ghana. It is therefore necessary to quickly update fertilizer recommendation for maize using modern tools which will not only evaluate the profitability of crop productions but also the quality of the environment within which crop production is carried out, and combine crop, soil and genetic components of crop production. Decision Support System for Agro-technology transfer (DSSAT) model is one of such tools.

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Table 1 : Soil chemical attribute used for running the DSSAT model

	Mean	Min.	Max.	Std. deviatin	Std. Error of Mean	Variance	CV
pH (1:2.5 Water)	5.053	4.700	5.300	0.203	0.052	0.041	4.019
mg (cmol./kg soil)	1.435	0.400	2.540	0.565	0.146	0.319	39.352
K (cmol./kg soil)	0.197	0.110	0.270	0.047	0.012	0.002	23.978
ECEC (cmol./kg soil)	4.027	2.510	5.310	0.747	0.193	0.588	18.545
Organic Carbon (%)	0.237	0.060	0.480	0.158	0.041	0.025	66.611
Calcium (cmol./kg soil)	1.613	0.670	2.540	0.464	0.120	0.216	28.788
Total Nitrogen (%)	0.028	0.110	0.060	0.015	0.004	0.001	52.956

Table 2 : Soil physical attribute used for running the DSSAT model

	Mean	Min.	Max.	Std. deviation	Std. Error of Mean	Variance	CV
Bulk Density (g/cm^3)	1.613	0.670	2.540	0.464	0.120	0.216	28.788
Clay (%)	21.31	17.000	36.100	4.510	1.170	20.360	21.180
DULL (mm/mm^3)	0.167	0.124	0.294	0.046	0.012	0.002	27.516
Silt (%)	14.45	0.020	32.100	6.260	1.620	39.200	43.340
SLL (mm/mm^3)	0.106	0.078	0.180	0.028	0.007	0.001	26.722
Stones (%)	26.1	4.000	37.000	9.610	2.480	92.440	36.840

The Maize model included into DSSAT is CERES-Maize, and has been tested and used by many researchers around the world for various applications. CERES is a family crop-soil-climate computer model at the core of computer software (DSSAT) (IBSNAT, 1994). DSSAT integrates these crop models to asses yield, resource use and risk associated with different crop production practices.

Therefore to use DSSAT as a tool for management decisions in sustaining economically and environmentally safe agriculture, the CERES-Maize needs to be evaluated and calibrated in the Guinea savanna agro ecological conditions where this experiment was carried out.

The general objective of this study was to update and refine fertilizer recommendations for maize in the Guinea savanna agro-ecological zone of Ghana, using short term field experiments and DSSAT V 4.5. Although the DSSAT model can synthesize information quickly and inexpensively, the reliability of the model is based on the degree to which the model accurately reflects the natural process.

In sub-Saharan Africa, maize is a staple food for an estimated 50 % of the population and provides 50 % of the basic calories. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season. Maize grains have great nutritional value as they contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983). Zea mays is the most important cereal fodder and grain crop under both irrigated and rainfed agricultural systems in the semi-arid and arid tropics (Hussan et al., 2003). The per capital consumption of maize in Ghana in 2000 was estimated at 42.5 kg (MoFA, 2000) and an estimated national consumption of 943000 Mt in 2006 (SRID, 2007).

Over the last 30 years, fertilizer consumption in sub-Saharan Africa has increased. In recent years, growth in fertilizer on cereals, particularly maize has contributed substantially to this increase. Nonetheless, current application rates remain low. Fertilization in tropical agriculture has the potential to dramatically increase production due to the highly weathered soils and the limited reserves of nutrients (Stewart et al., 2005), yet increased nutrient application is rarely managed by recommendations derived from soil testing and consequently this leads to misuse and associated economic (Chase et al., 1991) and environmental risks (Bundy et al., 2001; Cox and Lins, 1984). In Ghana currently the importers of fertilizers to the various sectors of food production and other uses are numerous with a growing interest in the fertilizer import business.

The end users of fertilizers in the food production sector of Ghana, consists of a large number of small scale farmers in units of large households especially in the Northern, Brong Ahafo and parts of the Ashanti region. With proper education, affordable price, timely availability and accessibility, demand for fertilizers in Ghana is enormous.

Farmers make decisions that are surrounded by natural and economic uncertainties, mainly weather and prices. Agricultural research is designed to provide information that will help the farmer in making such decisions. The weakness of this approach and the need for greater in-depth analysis has long been recognized (Hamilton et al., 1991).

Recently, application of a knowledge-based systems approach to agricultural management has been gaining popularity due to the growing knowledge of processes involved in plant growth, and the availability of inexpensive powerful computers (Jones, 1983). The system approach makes use of dynamic simulation models of crop growth and cropping systems. Simulation models that can predict crop yield, plant growth and development, and nutrient dynamics offer good opportunities for assisting, not only farm managers, but also regional decision makers in several aspects of decision making. Regional policy decision related to agriculture involves maintenance of an adequate supply and quality of water for domestic and industrial consumption (Lecler, 1998). Agriculture is usually the major user of water of a region and a large quantity of chemicals are applied to the land. Thus making rational decisions regarding the impact of agricultural practices on the non-agricultural segment of the society is important.

Computerized decision support systems are now available for both field-level crop management and regional level productions. The Decision Support System for Agro-technology Transfer (DSSAT) is an excellent example of such a management tool. It enables users to match the biological requirement of a crop to physical characteristics of the land to achieve specific objective(s).

II. Materials and Methods

a) *Study area*

The study was carried out in the Northern region of Ghana. The field experiment was done at Kpalesawgu, a suburb of Nyankpala near the Savanna Agricultural Research Institute's experimental field. The site is located about 16 km west of Tamale and lies on latitudes N 090 24' 15.9''and longitude W 0010 00' 12.1''of the interior Guinea Savanna agro-ecological zone of Ghana, which has a mean daily temperature of 26 ^{0}C (SARI, 1996). The area has a uni-modal rainfall pattern averaging about 1100 mm annually (Dankyi *et al*., 2005). The Guinea Savanna zone was strategically selected for a number of reasons: (i) it is an important breadbasket area (ii) it is an important growing area for maize, (iii) the highest concentration of past soil fertility management research is located within this area, (iv) the nearness to large local and regional markets for inputs and outputs. The study covered a period from June to December 2010.

b) *Experimental Design*

A randomized complete block design with four replications was used. The plot size was 5.0m × 15.0 m with plant spacing of 80 cm × 40 cm. Treatments applied were N-P_2O_5-K_2O 0-0-0, 40-60-60, 80-60-60, 120-60-60, 150-60-60, 120-0-60, 120-45-60, 120-90-60, 120-60-0, 120-60-45 and 120-60-90 kg/ha.

The blocks were arranged from east to west with eleven plots each and a surface area of 75 m^2 (15 m long and 5 m wide) separated by 1m alley and has eight rows per plot. The plants were monitored and phenological data as well as management information were collected. These include sowing date, date of fertilizer application, date of flag leaf stage, date of flowering, date for grain filling and date of maturity. The phonological stages were noted when 50% of plant population attained that stage. Final total biomass and grain yield were also measured from a plot size of 9m2 by harvesting above-ground biomass and separating them into the various components according to the procedure described in Hoogenboom *et al*. (1999). Grain yield and total biomass were expressed in t ha–1. Soil samples (both disturbed and undisturbed) were taken at different horizons (0–10, 10–20, 20–30, 30–40, 40–50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120, 120-130, 130-140, and 140-150 cm). Soil organic carbon, pH, soil particle distribution, wilting point, field capacity, bulk density and saturation were all determined as described in Hoogenboom *et al*. (1999), (Table 1and Table 2).

Table 3 : Monthly total rainfall, monthly means,solar radiation, sunshine hours, maximum and minimum temperature between 1971-2010 at Tamale, Ghana used for running the model.

Month	SRad($MJm^{-2}\,d^{-1}$)	Tmax(^{0}C)	Tmin(^{0}C)	Rain	Nwet	SunH
Jan	11.0	35.1	18.8	2.3	0.2	7.4
Feb	11.8	37.2	21.8	8.1	0.6	7.5
Mar	12.4	37.7	24.9	38.4	3.1	7.3
Apr	12.5	36.2	25.2	70.3	5.3	7.3
May	12.2	34.1	24.2	117.9	8.1	7.3
Jun	11.9	31.9	23.0	133.0	9.5	7.1
Jul	11.9	30.2	22.8	161.7	10.6	6.8
Aug	12.1	29.6	22.6	185.7	12.6	6.6
Sep	12.2	30.2	22.4	214.1	14.4	6.9
Oct	11.9	32.2	22.6	85.5	7.6	7.4
Nov	11.3	34.9	21.5	11.6	0.9	7.8
Dec	10.7	34.6	19.2	3.0	0.3	7.4

The experimental field had been under fallow since 2008. Before then sorghum was planted. The land was ploughed, harrowed and ridged. Maize variety *Obaatanpa* was planted on 18th June, 2010 with a spacing of 80 cm x 40 cm.

Three seeds were planted and later thinned to two plants/ hill. Thinning was done before fertilizer was applied.50% of the nitrogen and all the phosphorus and potassium were applied two weeks after planting. The remaining nitrogen was applied five weeks after planting. The fertilizer was banded on both sides of the plant and buried.

c) Model Calibration

A calibration of a model can generally be defined as an adjustment of some parameters and functions of a model so that predictions are the same or at least very close to data obtained from field experiments (Penning de Vries, 1989). For crop growth models the calibration involves determining genetic coefficients for the cultivar (Table 4) to be grown in a location. For the current study various crop growth development parameters were used to calibrate DSSAT. These values include silking date, physiological maturity date (black layer formation), grain weight, number of grains per plant and number of grains per square meter.

The calibration procedure of the CERES-Maize model consisted of making initial estimates of the genetic coefficient and running the model interactively, so that simulated values match as closely as possible the measured data. The values of the thermal time from seed emergence to the end of the juvenile stage (P1), the photoperiod sensitivity coefficient (P2), and the thermal time from silking to maturity (P5), were computed using observed silking and physiological maturity dates. Potential kernel number plant-1 (G2) and grain growth rate (G3) are input parameters to determine the potential grain yield. The DSSAT model acts to reduce this potential as a result of suboptimal environmental conditions. As suggested by Kiniry (1991), when these values are not obtained in these conditions, an alternative is to calibrate these parameters by running the model on existing data sets. The calibration procedure was performed using the GENCALC in DSSAT (Hunt et al., 1994).

Table 4 : The genetic coefficients of used for modeling the *obaatanpa* maize variety in CERES-maize model at Kpalesawgu, Ghana

Codes	Definitions	Values
P1	Thermal time from seedling emergence to the end of the juvenile phase during which the plant is not responsive to changes in photoperiod (expressed in degree days).	320.00
P2	photoperiod sensitivity coefficient	0.100
P5	Thermal time from beginning of grain filling to physiological maturity (expressed in degree days).	945
G2	maximum kernel number plant-1	350
G3	potential kernel growth rate	8

d) Statistical Evaluation and Model Validation

Despite the fact that a considerable amount of information on agricultural modeling has been published in the last decades, there is no standard methodology to evaluate the predictive ability of a model. In fact, it has been subject to a considerable debate (15). As attempts to evaluate these models have increased, various ways of evaluation has been suggested (16, 17, 18; 19). For the present study the methods of Addiscott and Whitmore (1987) and Willmott (1982) were followed to analyze simulation accuracy.

An analysis of the degree of coincidence between simulated and observed values were carried out by using Root Mean Square Error (RMSE)(18), and the ratio of RMSE over the average (Stockel*et al*., 1997), Loague and Green 1991), Mean Difference (MD). The RMSE has been widely used as a criterion for model evaluation (Ma *et al* 1998, Retta*et al* 1996, Kiniry*et al* 1997, Jemison *et al* 1994, Legnick*et al* 1994). RMSE is calculated by:

$$\text{RMSE} = \sqrt{1/N\sum(Oi - Pi)2}$$

Where P and O are the predicted and observed values for the observation, and N is the number of observation within each treatment. RMSE is measure of the deviation of the simulated from the measured values, and is always positive. A zero value is ideal. The lower the Value of RMSE the higher the accuracy of the model prediction.

The MD is a measure of the average deviation of the predicted and observed values and is calculated by:

$$\text{MD} = 1/N \sum (Oi - Pi)$$

The positive and negative signs of the MD reflect that, on average, the model is overestimating or under estimating the observed values, respectively. A t-test was used to determine whether MD is significantly different from zero (Addiscott and Whitmore 1987).

e) Weather

Weather data used by the model in running simulations were daily rainfall amount, daily solar radiation, minimum and maximum daily temperature. A summary of weather parameters for the growing season is presented in Table 3. These were collected from a weather station located in the study area. Forty years historical weather data for the study area were used as input data for the DSSAT Weatherman to simulate 40 years weather data for the study area. This was used to evaluate the impact of weather on crop, nutrient and water productivity.

Table 5 : Observed yield of maize, total biomass, stover and unit grain weight in response to mineral fertilizer application in Kpalesawgu, Ghana

Treatment Kg/ha N-P_2O_5- K_2O	Unit grain wt. (g)	Tot Biomass (kg/ha)	Stover (kg/ha)	Yield (kg/ha)
0-0-0	0.338	764	533	231
40-60-60	0.465	7301	6092	1208
80-60-60	0.513	9627	7124	2503
120-60-60	0.475	10181	6392	3789
150-60-60	0.513	10431	6909	3522
120-0-60	0.435	2313	1055	1258
120-45-60	0.510	9940	6701	3239
120-90-60	0.478	11392	7562	3831
120-60-0	0.483	9537	6223	3314
120-60-45	0.515	9975	6203	3772
120-60-90	0.480	10374	6796	3578

III. Results and Discussions

a) Grain yields

Grain yield measured ranged from 231 kg/ ha^{-1} when no mineral N fertilizer was applied, to 3831 kg/ ha^{-1} at 120-90-60 kgN-P_2O_5-K_2O ha^{-1} application in the field. (Table5). Significant (p=0.05) grain yield increases in maize cultivation were observed between the all levels of mineral fertilizer application. The low yields in the control which is a normal practice of farmers explain their reluctance to cultivate mineral fertilizer. The yield gaps between the no application plots and the mineral fertilizer were not compensated for by the application of as much as 120 $kgNha^{-1}$ an indication that mineral N is not the only yield limiting factor. This means that mineral fertilizer alone cannot solve crop production problems on poor soils. Yield differences are more likely to be attributed to the differences in their soil fertility (Table 1). Thus, for improved crop production, mineral fertilizer must be complemented with measures to increase soil organic carbon as it is highly associated with fertility.

b) Validation of the Model

i. *Data available for model validation*

Data for model validation include silking and maturity dates, grain yield, grain weight, and above ground biomass.

ii. *Simulation of the field experiment*

Comparison between measured and predicted maize yield showed good agreement. The NRMSE was 0.181 (Loague and Green, 1991). Comparison between predicted and simulated yield at harvest maturity for all treatments is presented in Figure 1.

Simulated and observed grain yield for 120-60-60, 150-60-60 and 120-90-60kg/ha N-P-K were 3795.0 and 3789 kg/ha, 3646and 3522.0 kg/ha, 3990 and 3831 kg/ha, respectively.

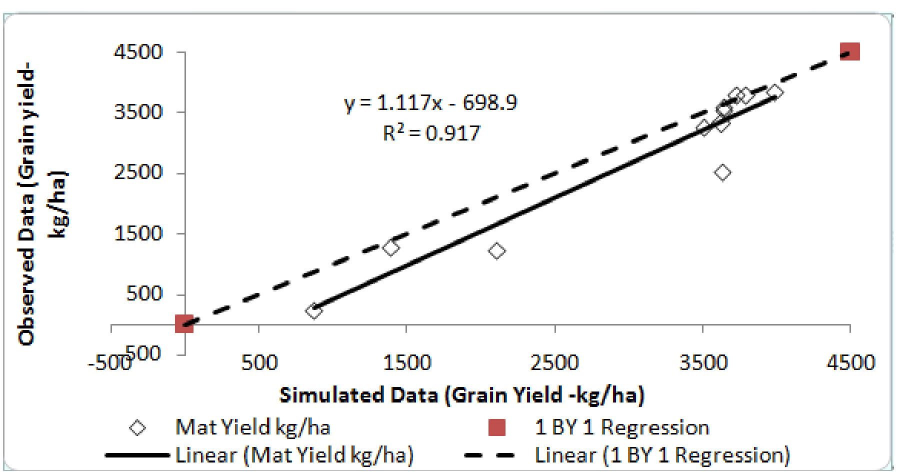

Figure 1 : Comparison of grain yield predicted by the DSSAT model with measured values.

Even though 120-90-60 kg/ha N-P-K gave the highest mean yield, there was no significant (Lsd=0.05) difference between predicted and observed mean yields when 120-60-60 kg/ha N-P_2O_5-K_2O was applied. Both simulated and observed mean harvest maturity yields increased with increased N and P. However, the effect of K on mean yield was minimal. This suggests that K is not limiting in soils in the Guinea savanna agro-ecological zone of Ghana.

Results of simulated and measured top weight at maturity and by-product produced at maturity for all treatments are presented in Figures 2 and 3 respectively. Similarly the model prediction for top weight at maturity and by-product produced at maturity was considered excellent with NRSME of 0.097 and 0.090 (Loague and Green, 1991) respectively. Thus the model prediction was in close agreement with measured values.

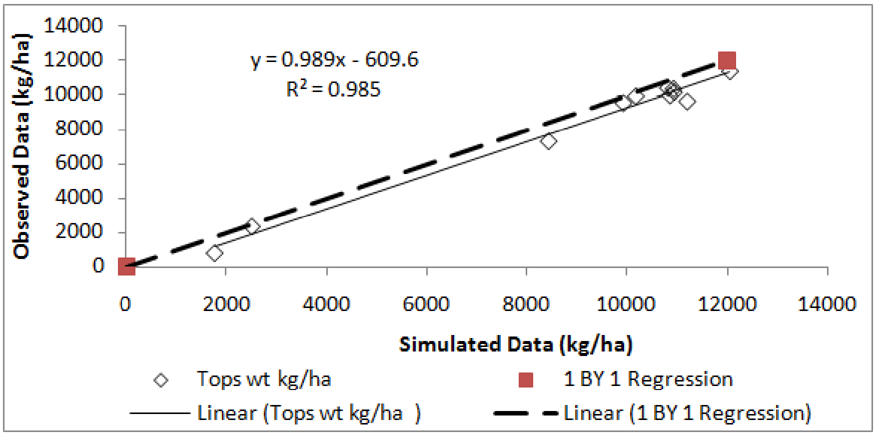

Figure 2 : Comparison of top weight at maturity predicted by the DSSAT model with measured values.

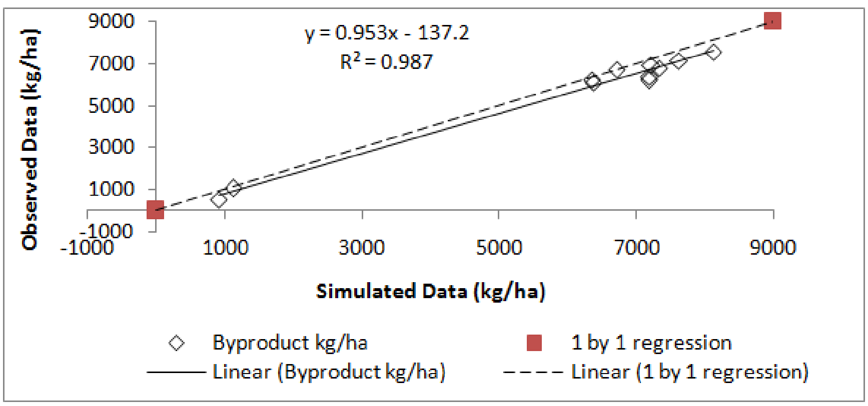

Figure 3 : Comparison of by-product produced at maturity predicted by the DSSAT model with measured values.

The DSSAT model under predicted days to physiological maturity (Figure 4). Predicted values were 1-2 days earlier for all treatments except when there was no application of inorganic fertilizer. The model estimated the maturity date to be 9th October 2010. However, the observed maturity dates were between 8th - 12 October 2010. The DSSAT model failed to account for the rapid growth optimized by the N and thus assumed one maturity date for all the treatment. Model performance was mixed in predicting the harvest index. It under predicted for plots with high levels of fertilizer and over predicted for plots with low fertilizer rates.

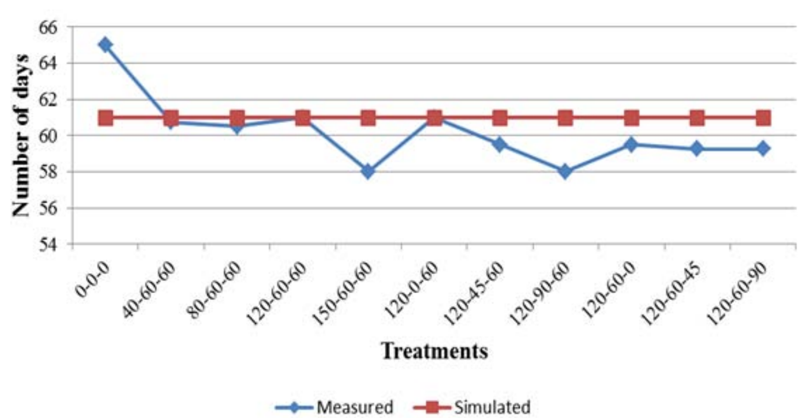

Figure 4 : Comparison of Anthesis (DAP) predicted by the DSSAT model with measured values

c) Statistical evaluation and model validation

Although yield at harvest maturity, top weight at maturity and by-product produced at maturity were calibrated with data measured in the experimental field, simulated values were slightly over predicted by the model. A summary of statistical analysis of the results of these variables is presented in Table 6.

Table 6 : Comparison of mean values of selected field observations and their simulations for the growing season

Variable Name	*Mean*		*SD*		*r-Square*	*MD*	*RMSE*	*NRMSE*	*d-Stat.*
	O[d]	S[d]	O[d]	S[d]					
Byproduct (kg/ha)	5599	6017	2305.74	2402.81	0.987	418.0	505.450	0.090	0.989
Tops weight (kg/ha)	8349	9052	3362.02	3373.20	0.986	704.0	810.352	0.097	0.986
Harvest index	0.340	0.37	0.09	0.08	0.529	0.0	0.067	0.197	0.833
Mat Yield (kg/ha)	2750	3086	1211.37	1038.41	0.918	336.0	498.771	0.181	0.952
Weight (g/unit)	0.4745	0.31	0.005	0.030	0.870	-0.2	0.169	0.356	0.358

Significant at P ≤0.005 Significant at P≤0.001Od- Observed dataSd- Simulated data MD-Mean difference SD- Standard deviationRMSE- Root Mean Square Error*

Model prediction for by-product produced at maturity, top weight at maturity and maize grain yield at maturity were considered excellent withRMSE value of 505.45, 810.35 and 498.77, respectively (Wallach and Goffinet, 1987). Predicted and observed mean harvest maturity yield were 3086 and 2750 kg/ha with a standard deviation of 1211.37 and 1038.41 respectively (Table 6).

d) Water resource productivity

Results of the effect of different levels of N, P and K on water productivity are presented in Figure 5a-5c.Results of simulated and observed water productivity showed that water productivity increases when N levels are increased. Water productivity was however inefficient when 150 kg/ha N was applied (Figure 5a).

The effect of K on predicted and observed Water productivity was minimal (Figure 5b). This is to be expected since according to the experimental results, the mean differences in yield was not significant (lsd=0.05) when 45 and 60 kg/ha K were applied. The order magnitude of P effect is similar to that of N (Figure 5b).Higher values of water productivity are obtained when evapotranspiration (ET) is used rather than rainfall (Figures. 5a-c). This is because not all the rain water is used by the crop as some may be lost through direct evaporation, run off and deep percolation. In general the data showed that rainwater productivity can be greatly improved when soil fertility is increased. Other ways of increasing water productivity is by insitu rainwater harvesting through tied-ridges (Fosuet *al*., 2008).

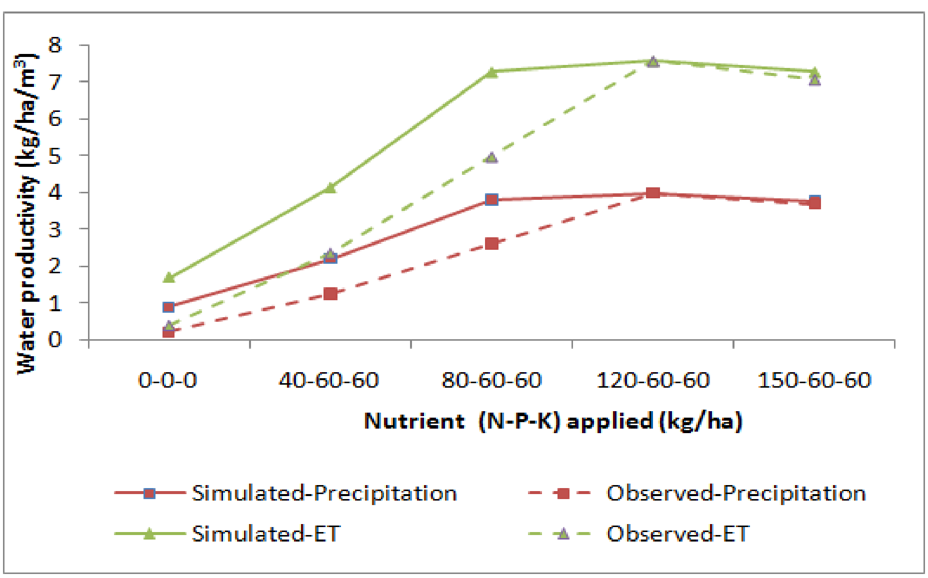

Figure 5a : Relationship between predicted and observed water productivity at different levels of nitrogen application.

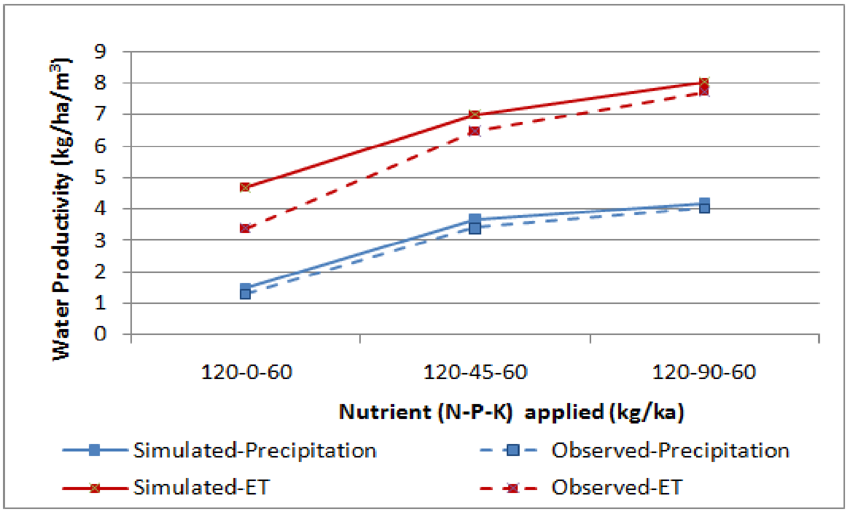

Figure 5b : Relationship between predicted and observed water productivity at different levels of P application.

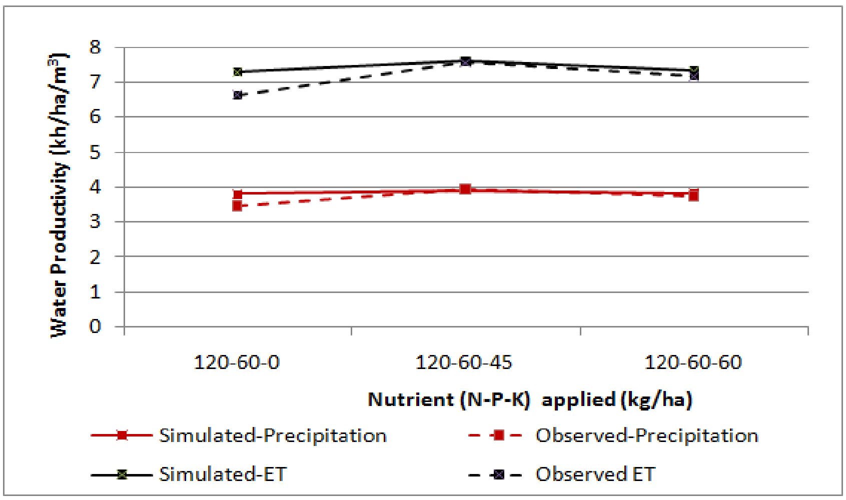

Figure 5c : Relationship between predicted and observed water productivity at different levels of K application.

e) *Seasonal analysis*

i. *Biophysical analysis*

Results of biophysical simulation of yield conducted by the DSSAT model over a 40 year period is presented in Table 7. The results indicate minimum and maximum yield within the 40 year period of simulation with their mean yields and standard deviations. 120-90-60 kg/ha N-P_2O_5-K_2O recorded the highest yield of 4182 kg/hawith a mean yield and standard deviation of 2860 kg/ha and 713, respectively.

Table 7 : Simulation of maize yield by DSSAT over a 40 year period

Treatment N-P_2O_5-K_2O (kg/ha)	Mean	St Dev.	Yield (kg/ha)	
			Minimum	Maximum
0-0-0	502.22	129.2	169	890
40-60-60	1654.7	323.9	1184	2316
80-60-60	2552.9	480.3	1271	3427
120-60-60	2799.1	662.6	1408	4136
150-50-60	2708.1	666.6	1321	4028
120-0-60	596.1	116.3	395	954
120-45-60	2510.6	623.7	1286	3987
20-90-60	2860.1	713.5	1269	4182
120-60-0	2589.1	633.1	1264	3622
120-60-45	2672	652.5	1204	3920
120-60-90	2714.1	688.6	1204	4155

Meanwhile, the minimum yield obtainable when the above treatment was applied is 1269 kg/ha. However 4136 kg/ha maximum yield was also obtained when 120-60-60 kg/ha N-P2O5-K2O was applied with mean yield and standard deviation of 2799 kg/ha and 662, respectively (Table 7).

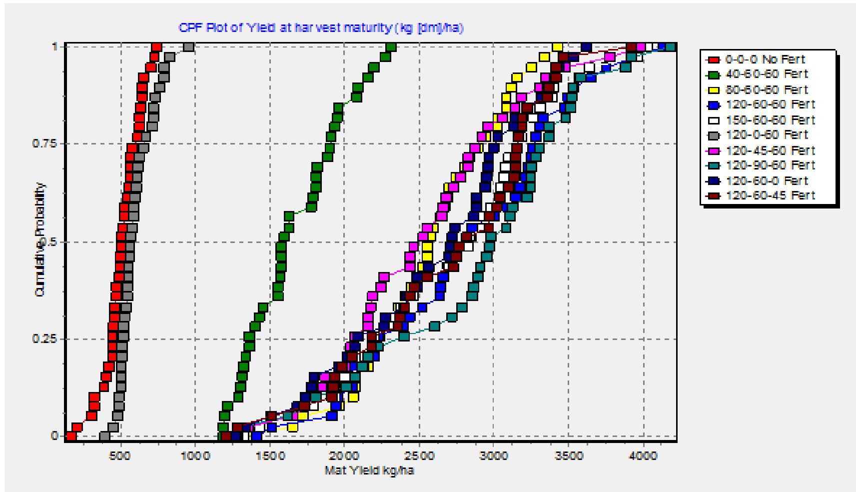

Figure 6 : Cumulative probability function plot of yield at harvest maturity for a 40 year period.

Result of cumulative probability of attaining harvest grain yield by specific treatment is presented in Figure 3.8.2. For instance at 75% cumulative probability, the maximum average maize grain yield of 600, 1800 and 3200 kg/ha were obtained when 0-0-0, 40-60-60 and 120-90-60 kg/ha N-P_2O_5-K_2Owere applied. This implies that at 75% of the 40 year simulation, no matter the management and or agronomic practices that is employed, maize grain yield cannot exceed 600, 1800 and 3200 kg/ha on application of 0-0-0, 40-60-60 and 120-90-60 kg/ha N-P_2O_5-K_2O.

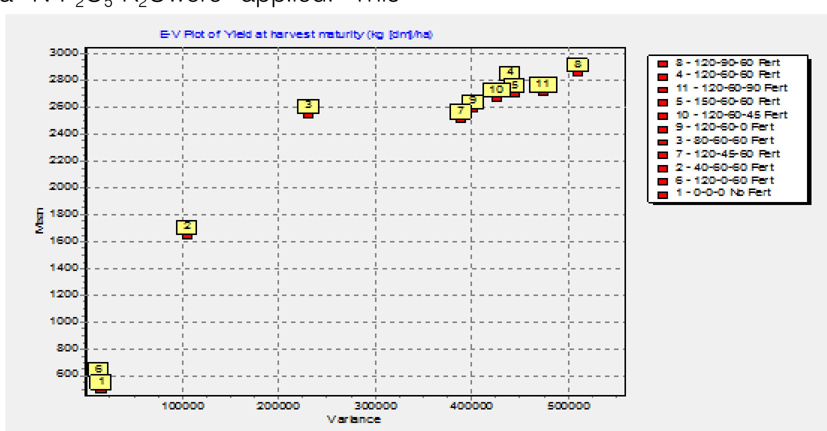

Figure 7 : Mean-Variation of yield at harvest maturity (kg [dm]/ha)

Results of variability in attaining predicted average harvest yield is presented in Figure 7. Treatments 1 and 6 present the least variability in obtaining their corresponding average harvest maturity yield. The results showed that when no fertilizer was applied (0-0-0 kg/ha N-P_2O_5-K_20), obtainable yield range is limited but increases when fertilizer is applied (Figure 7). Treatment 6 (120-0-60 kg/ha N-P_2O_5-K_20) showed that P is very limiting in the soil and even with high levels of N, yield cannot be increased significantly in the absence of P. Therefore treatments with higher average harvest maturity yield with less variability in obtaining them are considered the best. Treatment 8 recorded the highest mean yield and variation of 2900 kg/ha and 500000, respectively.

IV. Conclusion

In general, maize yield simulation by DSSAT under Guinea savanna agro-ecological conditions was good. Average predicted harvest maturity yields were very close to measured values with MD of 336.0, RMSE of 498.77, NRSME of 0.181 and simulated and observed mean yields of 3096 and 2750 kg/ha for the entire treatments respectively. The mean difference between predicted and observed was not significant.

The highest harvest maturity yield predicted and observed was achieved with 120-90-60 kg/ha N-P_2O_5-K_2O. The predicted and observed average mean yield were 3831 and 3999 kg/ha, respectively. Based on the simulation results from this study the DSSAT model appeared to be suitable for the Guinea savanna agro-ecological conditions in Ghana. However, the model performance in simulation for a long term basis needs to be evaluated.

There was scarcity of detailed field data e.g. leaf area index, tops N at anthesis, grain N at anthesis etc. for adequately evaluating the model. Therefore, a field experiment should be setup in other areas of the GSAZ for calibrating and validating major subroutines of the model including soil water balance components.This study recommends120-90-60 kg/ha N-P_2O_5-K_2O as the most economically and strategically efficient fertilizer rate that gives maximum yield and maximum returns at Kpelsawgu in the Guinea savanna agro-ecological zone of Ghana. However, 80-60-60 and 120-60-60 kg/ha N-P_2O_5-K_2O are also recommended by this study.

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