A Paradigm Shift from Area-Led to Productivity-Led Production of Maize in Nigeria

Sadiq, M.S.[1*], Singh, I.P.[2] and Ahmad, M.M.[3]

[1]Department of Agricultural Economics and Extension, FUD, Dutse, Nigeria
[2]Department of Agricultural Economics, SKRAU, Bikaner, India
[3]Department of Agricultural Economics, BUK, Kano, Nigeria

***Corresponding author:** sadiqsanusi30@gmail.com

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Abstract: *Unlike in the past when production performance was judged from the area, in recent time's growth performance is hinged on productivity. In Nigeria, increasing maize production through area expansion is no longer feasible owing to pressure on demand for arable limited land for allied sectors, urbanization, industrialization etc. thus threatening sustainable maize production which is the precursor for self-sufficiency in maize production. It is in lieu of this that the present research empirically examined the ex-post and ex-ante production trend of maize production in Nigeria. Time series data that spanned for 58 years (1961-2018) and covered production, area, yield and crop prices were used. The data were sourced from the FAO database and the collected data were analyzed using both descriptive and inferential statistics. The empirical evidence showed that maize production is not sustainable as area growth rate predominates in increasing the production growth rate of maize in the studied area. In addition, it was observed that variability in the production of maize owes majorly to uncertainty viz. weather vagaries. Furthermore, weather vagaries viz. drought and flood; and non-remunerative price of maize affected the supply response of maize. In a decade ahead, a deficit in the supply of maize is very imminent which will be owed to poor productivity, thus affecting the food security of maize in the studied area. Thus, the onus lies on the policymakers to invest adequately on technology and infrastructure in order to achieve a sustainable production of maize that will guarantee maize food security in the country.*

Keywords: Acreage response, Area expansion, Maize, Nigeria, Sustainable production

1. Introduction

Maize is an important staple food for more than 1.2 billion people in sub-Saharan Africa (SSA) and Latin America; and is the most important cereal crop in SSA (IITA, 2020). In SSA, it is a staple food for those living in SSA (Anonymous, 2020) as it is food for approximately 50 percent of its population (Agricdemy, 2020). The worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42 percent. Africa produces 6.5 percent and imports 28 percent from countries outside the continent. In addition, the worldwide consumption of maize is more than 116 million tons, with Africa consuming 30 percent and SSA 21 percent. East and South Africa use 85 percent of its production as food, while Africa as a whole uses 95 percent, compared to other world regions that use most of its maize as animal feed (IITA, 2020; Anonymous, 2020).

In 2007, the largest producer of maize in Africa was Nigeria with nearly 8 million tons, followed by South Africa (IITA, 2020). But currently, Nigeria is the 2nd largest producer of maize in Africa after South Africa and the 11th largest maize producing nation in the world (Agricdemy, 2020). This showed that South Africa has swapped its position with Nigeria; taken the lead rank in Africa.

As a versatile crop that is not just consumed domestically, the crop is used industrially by confectionery and animal feed manufacturers, flour mills, breweries and bakeries. Despite Nigeria's high production volumes, the country's average yield of 1.8 tons/ha is one of the lowest among the top ten producers in Africa (Agricdemy, 2020; IITA, 2020). It lags behind countries such as Egypt and South Africa where the yields are 7.7 tons/ha and 5.3 tons/ha respectively, making it difficult for the country to meets its total domestic and industrial demand. Generally, the average yield of maize in Nigeria and other sub-Sahara Africa countries is low i.e. 1.68 tons/hectare, which is very low when compared to the average yield in the United States: 9.3 tons/hectare over the same period (Anonymous, 2020).

In Nigeria, an increase in maize production has been achieved greatly by area expansion rather than an increase in productivity. The cultivated area increased from 2.8 million hectares in 1986 to over 3 million hectares in 2000 and over 6 million hectares by 2011. Of the total world production (1,133,540 million tons) in 2018, Nigeria, the largest producer in sub-Sahara Africa produced 11 million tons, representing 0.009% of the world production. Anonymous (2020) reported that Nigerian's maize production increased has grown at an average annual rate of 6.89.

Nigeria's surging population is expected to reach 200 million by 2025. Thus, this growth will lead to an increasing demand for maize to serve both domestic and industrial consumption; and this represents a golden opportunity for farmers and entrepreneurs to explore. It is because of this that this research was conceptualized to devise a roadmap that will help the country to achieve a sustainable maize production which can guarantee maize food security in the country. Therefore, the broad objective of this study is to determine a sustainable maize production that can guarantee maize food security in the country. The specific objectives were to examine the production trend and growth pattern of maize production, extent and magnitude of production instability, determine factors influencing farmers' acreage allocation decision and, forecast the production trend of maize in Nigeria.

2. Materials and Methods

Time series data sourced from FAO data bank that covered production, area, yield, producers' prices of maize, rice, sorghum and millet, and spanned from 1961 to 2018 were used. For proper examination, the data were divided according to the reform periods which marked the economy of the country. The reform periods were pre-Structural Adjustment Period (SAP) (1961-1984), SAP (1985-1999) and post-SAP (2000-2018). The collected data were analyzed using both descriptive and inferential statistics. The first objective was achieved using descriptive statistics and compound growth model. The second objective was achieved using the instability index and Hazell's decomposition model while the third and last objectives were achieved using Nerlove's distributed lag model and ARIMA model, respectively.

2.1 Model specification

2.1.1 Growth rate

The compound growth rate is used to study growth. Thus, the compound annual growth rate was calculated using the exponential model indicated below:

$$\gamma = \alpha\beta^{t} \quad [1]$$

$$\ln\gamma = \ln\alpha + t\ln\beta \quad [2]$$

$$\text{CAGR} = [Antilog\beta - 1] \times 100 \quad [3]$$

Where,

CAGR = Compound growth rate;

t = Time period in a year

y= Area/Yield/Production

α = Intercept

β = Estimated parameter coefficient

2.1.2. Instability index

Coefficient of variation (CV), Cuddy-Della Valle Index (CDII) and Coppock's index were used to measure the variability in the production, area and yield (Boyal*et al*., 2015; Sandeep*et al*., 2016).

$$\text{CV}(\%) = \frac{\sigma}{\bar{X}} * 100 \quad [4]$$

Where

σ = standard deviation

$\bar{X}$ = *the mean values of area, yield or production*

$$CDII = \text{CV}*(1\text{-R}^2)^{0.5} \quad [5]$$

Where

CDII = Cuddy-Della instability index;

CV = Coefficient of variation;

R2 = Coefficient of multiple determination (Cuddy-Della Valle, 1978).

Note: The instability index classification is low instability (≤20%), moderate instability (21-40%) and high instability (>40%) (Shimla, 2014, Umar *et al*., 2019).

Unlike a CV, Coppock's instability index gives a close approximation of the average year-to-year percentage variation adjusted for trend (Coppock, 1962; Ahmed and Joshi, 2013, Kumar *et al*., 2017,; Umar *et al*., 2019).

$$CII = \left(Antilog\sqrt{\log V} - 1\right) * 100 \quad [6]$$

$$\log V = \frac{\Sigma\left[log\frac{X_{t+1}}{X_t} - m\right]^2}{N-1} \quad [7]$$

Where

$X_t = Area\ or\ Yield\ or\ Production\ in\ year'{t}'$

$N = number of year(s)$,

CII = *Coppock's* instability index

$m = mean difference between$ $the \log of\ X_{t+1} and X_t$;

$logV = Logarithm Variance of$ $the series$

2.1.3 Source of change in production

Instantaneous change: It measures the relative contribution of the area and yield to the total output change of a crop and it has been used to study the growth performances of crops by several kinds of research. The instantaneous decomposition model as used by Sandeep*et al*. (2016) is given below:

$P_0 = A_0 \times Y_0$ [8]

$P_n = A_n \times \mathrm{Y_n}$ [9]

Where,

P, A and Y = production, area and yield, respectively. The subscript 0 and n = base and the n^{th} years, *respectively*.

$P_n - P_0 = \Delta P$ [10]

$A_n - A_0 = \Delta A$ [11]

$Y_n - Y_0 = \Delta Y$ [12]

From equation (5) and (9) we can write

$P_0 + \Delta P = (A_0 + \Delta A)(Y_0 + \Delta Y)$ [13]

Therefore,

$$P = \frac{Y_0 \Delta A}{\Delta P} \times 100 + \frac{A_0 \Delta Y}{\Delta P} \times 100 + \frac{\Delta A \Delta Y}{\Delta P} \times 100 \quad [14]$$

$$Production = Area effect + Yield\ effect + Interaction effect \quad [15]$$

Hazell's decomposition model

Hazell's (1982) decomposition model was used to estimate the change in average production and change in the variance of production with respect to between regimes and the overall period. Hazell decomposed the sources of change in the average of production and change in production variance into four (4) and ten (10) components. Decomposition analysis of change in production assesses the quantum of increase or otherwise of production in year 'n' over the base year that results from the change in the area, productivity or their interaction. Following Hazell's (1982) as adopted by Umar *et al*. (2017; 2019), the model is presented below:

I. Changes in average production are affected by changes in area-to-yield covariance and also changes in the mean area and mean yield.

$$E(P) = \bar{A}\bar{Y} + COV(A, Y) \quad [16]$$

$$\Delta E(P) = E(P_2) - E(P_1) = \bar{A}_1 \Delta \bar{Y} + \bar{Y}_1 \Delta \bar{A} + \Delta \bar{A} \Delta \bar{Y} + \Delta COV(A, Y) \quad [17]$$

Table 1: Components of change in the average production

Sources of change	Symbols	Components of change
Change in mean area	$\Delta \bar{A}$	$\bar{A}_1 \Delta \bar{Y}$
Change in mean yield	$\Delta \bar{Y}$	$\bar{Y}_1 \Delta \bar{A}$
Interaction effect	$\Delta \bar{A} \Delta \bar{Y}$	$\Delta \bar{A} \Delta \bar{Y}$
Changes in area-yield covariance	$\Delta COV(A, Y)$	$\Delta COV(A, Y)$

II. Change in variance decomposition: In this, the production variance was decomposed into its sources, i.e., area variance, yield variance, area-yield covariance, and interaction of higher-order between area and yield. A change in each of these components can result in a shift in output variance.

$$V(P) = \bar{A}^2 . V(Y) + \bar{Y}^2 . V(A) + 2\bar{A}\bar{Y}COV(A, Y) - COV(A, Y)^2 + R \quad [18]$$

Table 2: Components of Change in Variance production

Sources of change	Symbols	Components of change
Change in mean area	$\Delta\bar{A}$	$2\bar{Y}\Delta\bar{A}COV(A,Y)+\{2\bar{A}\Delta\bar{A}+(\Delta\bar{A})^2\}V(Y)$
Change in mean yield	$\Delta\bar{Y}$	$2\bar{A}\Delta\bar{Y}COV(A,Y)+\{2\bar{Y}\Delta\bar{Y}+(\Delta\bar{Y})^2\}V(A)$
Change in area variance	$\Delta V(A)$	$\bar{Y}^2V(A)$
Change in yield variance	$\Delta V(Y)$	$\bar{A}^2V(Y)$
Interaction effect I (changes in the mean area and mean yield)	$\Delta\bar{A}\Delta\bar{Y}$	$2\Delta\bar{A}\Delta\bar{Y}COV(A,Y)$
Changes in area-yield covariance	$\Delta COV(A,Y)$	$\{2\bar{A}\bar{Y}-2COV(A,Y)\}COV(A,Y)-\{\Delta COV(A,Y)\}^2$
Interaction effect II (changes in the mean area and yield variance)	$\Delta\bar{A}\Delta V(Y)$	$\{2\bar{A}\Delta\bar{A}+(\Delta\bar{A})^2\}\Delta V(Y)$
Interaction effect II (changes in mean yield and area variance)	$\Delta\bar{Y}\Delta V(A)$	$\{2\bar{Y}\Delta\bar{Y}+(\Delta\bar{Y})^2\}\Delta V(A)$
Interaction effect IV (changes in the mean area and mean yield and changes in area-yield covariance)	$\Delta\bar{A}\Delta\bar{Y}COV(A,Y)$	$(2\bar{A}\Delta\bar{Y}+2\bar{Y}\Delta\bar{A}+2\Delta\bar{A}\Delta\bar{Y})\Delta COV(A,Y)$
Residual	ΔR	$\Delta V(AY)$

2.1.4. Nerlovian's model

Directly, the supply response was calculated by including partial adjustment and minimal adaptive expectations (Nerlove, 1958). The Nerlovian model describes the supply dynamics by incorporating price expectations and partial adjustment of the area. Since the desired output is a function of price expectation in this model, the supply function as the Nerlove's response model as adopted is presented below (Sadiq *et al.*, 2017).

$$A_t^* = \beta_0 + \beta_1 MP_{t-1} + \beta_2 RP_{t-1} + \beta_3 SP_{t-1} + \beta_4 MLP_{t-1} + \beta_5 MPR_{t-1} + \beta_6 RPR_{t-1} + \beta_7 SPR_{t-1} + \beta_8 MLPR_{t-1} + \beta_9 Y_{t-1} + \beta_{10} YR_{t-1} + \beta_{11} WI_t + \beta_{12} T_t + \beta_{13} A_{t-1} + \varepsilon_t \quad [19]$$

The first equation is behavioural, stating that desired acreage (A_t^*) depend upon the following independent variables.

Where,

$A_t = current\ area\ under\ maize$;
$MP_{t-1} = one\ year\ lagged\ price\ of\ maize$
$RP_{t-1} = one\ year\ lagged\ price\ of\ Rice$
$SP_{t-1} = one\ year\ lagged\ price\ of\ sorghum$
$MLP_{t-1} = one\ year\ lagged\ price\ of\ millet$
$MPR_{t-1} = one\ year\ lagged\ price\ risk\ of maize;$
$RPR_{t-1} = one\ year\ lagged\ price\ risk\ of\ rice$
$SPR_{t-1} = one\ year\ lagged\ price\ risk\ of sorghum;$
$MLPR_{t-1} = one\ year\ lagged\ price\ risk\ of millet;$
$Y_{t-1} = one\ year\ lagged\ yield\ of\ maize;$
$YR_{t-1} = one\ year\ lagged\ yield\ risk\ of\ maize;$
$WI_t = weather\ index\ for\ rice;$
$T_t = time\ trend\ at\ period\ 't';$
$A_{t-1} = one\ year\ lagged\ area\ under\ maize;$
$\beta_0 = intercept;$
$\beta_{1-n} = parameter\ estimates;\ and,$
$\varepsilon_t = Disturbance\ term.$

Price and yield risks were measured by the standard deviation of the three preceding years. For the weather index, the impact of weather on yield variability was measured with a Stalling's index (Stalling, 1960; Ayalew, 2015). To get the predicted yield the actual yield was regressed on time. The actual yield ratio to the predicted yield is defined as the weather variable. In the acreage response model, the weather effects such as rainfall, temperature etc. can be captured by this index (Ayalew, 2015).

The number of years required for 95 percent of the effect of the price to materialize is given below (Sadiq*et al*. 2017).

$$(1-r)^n = 0.05 \quad [20]$$

Where;

r = coefficient of adjustment (1-coefficient of lagged area)

n = number of year

Marginal effect and price elasticities for semi-logarithm functional form are given below

$$ME = \frac{Pricecoefficient}{Meanofpredictor(s)} \quad [21]$$

$$SRE = \frac{Pricecoefficient}{Meanofcurrentarea} \quad [22]$$

$$LRE = \frac{SRE}{Coefficientofadjustment} \quad [23]$$

2.1.5. ARIMA

Box and Jenkins (1976) submitted that ARIMA (p, d, q), which is a combination of Auto-regressive (AR) and Moving Average (MA) with an integration or differentiation order (d), denotes a non-seasonal ARIMA model. The p and q are respectively the order of autocorrelation and the moving average (Gujarati et al., 2012). ARIMA in its general form is as follows:

$$\Delta^d Z_t = \alpha + \left(\delta_1 \Delta^d Z_{t-1} + \cdots .. + \delta_p \Delta^d Z_{t-p}\right) - (\varphi_1 \varepsilon_{t-1} + \cdots .. + \varphi_q \varepsilon_{t-q}) + \varepsilon_t \quad [24]$$

Where

Δ *denotes difference operator like*:

$$\Delta Z_t = Z_t - Z_{t-1} \quad [25]$$

$$\Delta^2 Z_{t-1} = \Delta Z_t - \Delta Z_{t-1} \quad [26]$$

Here, $Z_{t-1} \ldots \ldots \ldots, Z_{t-p}$ are values of past series with lag 1… p, respectively.

Forecasting accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE), relative mean absolute prediction error (RMAPE) (Paul, 2014), Theil's U statistic and R^2 were computed using the following formula:

$$MAPE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1}) \quad [27]$$

$$RMPSE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1})^2 / A_{t-1} \quad [28]$$

$$RMAPE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1})/A_{t-1} \times 100 \quad [29]$$

$$U = \sqrt{\frac{\sum_{t=1}^{n-1} \frac{(\hat{Y}_{t+1} - Y_{t+1})^2}{Y_t}}{\sum_{t=1}^{n-1} \frac{(Y_{t+1} - Y_t)^2}{Y_t}}} \quad [30]$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (A_{ti} - F_{ti})}{\sum_{i=1}^{n} (A_{ti})} \quad [31]$$

Where,

R^2 = *coefficient of multiple determination*

A_t = *Actual value*

F_t = *Future value*

T = *time period*

3. Results and Discussion

3.1 Trend and growth pattern of maize production

The production trend of maize exhibited fluctuating trend during the pre-SAP era with the output being characterized by slight rise and decrease. Thereafter, the production trend was marked by a steep rise which persisted and peaked in the year 1995 and afterwards, the production trend declined steeply till the end of the SAP period i.e. 1999. Furthermore, during the post-SAP period, a cyclical trend marked the production of maize: a steep increase in the production that exhibited a cyclical trend *viz.* ebb-recovery-prosperity and peaked in the year 2016. Afterwards, a declined cyclical trend set in during the end of the post-SAP transition (Figure 1-4). It was observed that the production trend was majorly driven by area expansion from the pre-SAP era through to the SAP era with yield effect been marginal. The yield was marked by a marginal cyclical trend that persisted through pre-SAP and SAP transitional periods. However, during the post-SAP period, both area expansion and yield simultaneously were the driving force which caused steeped increase in the production trend of maize till the end of the transitional era. Therefore, it can be inferred that the area effect predominates in the supply expansion of maize production in the studied area.

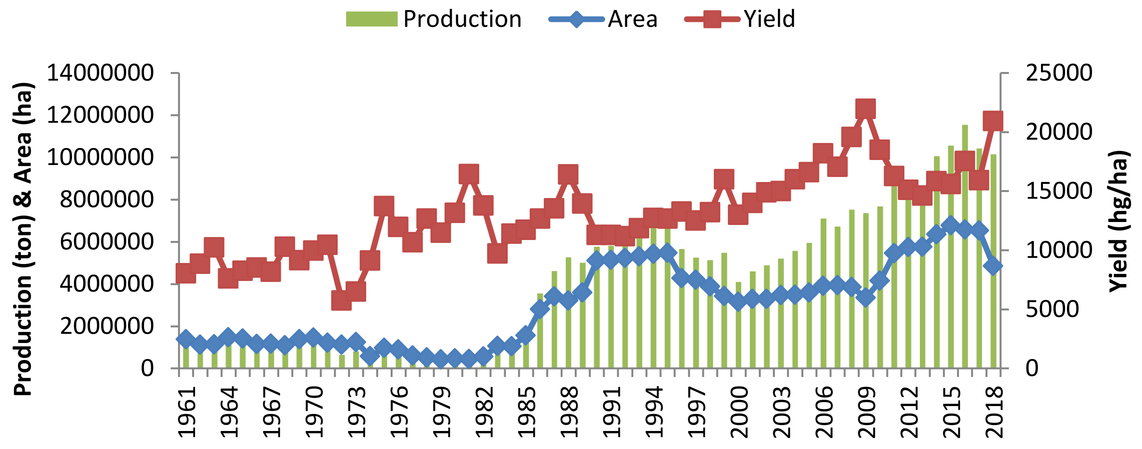

Figure 1: Production trend of Maize (1961-2018)

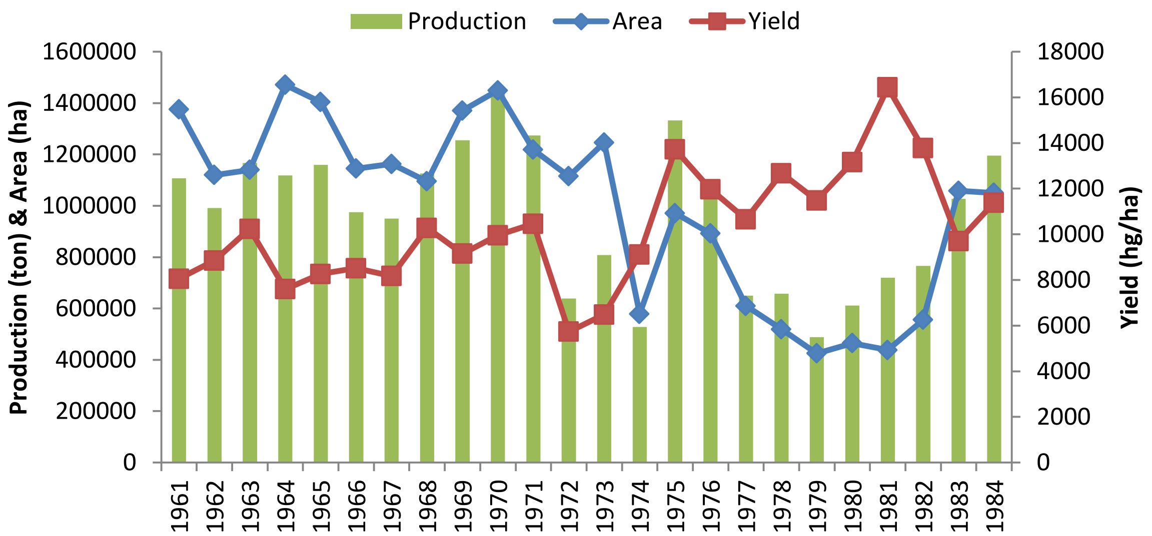

Figure 2: Pre-SAP production trend of Maize (1961-1984)

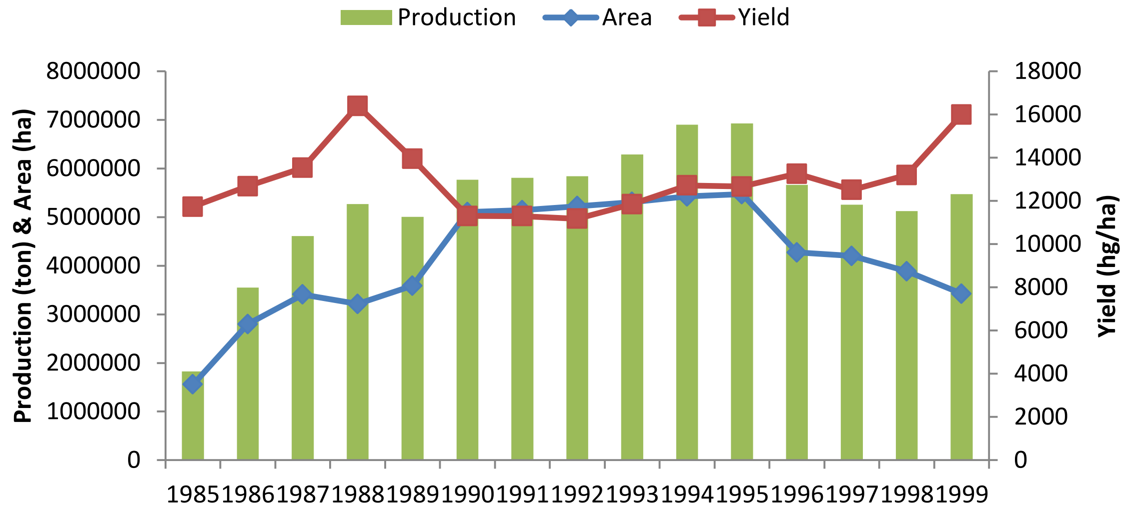

Figure 3: SAP production trend of Maize (1985-1999)

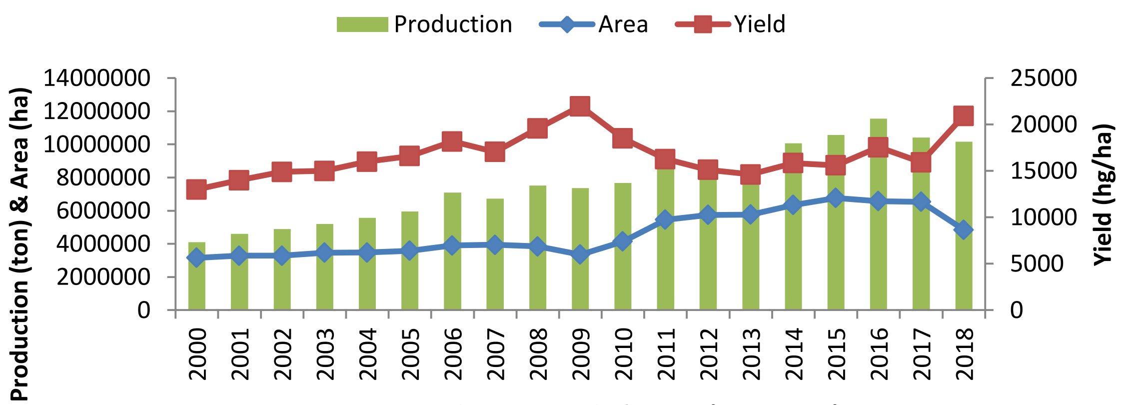

Figure 4: Post-SAP production trend of Maize (2000-2018)

Furthermore, it was observed that both the average annual production and area increased hyperbolically from the pre-SAP transition to SAP transition: both increased by five-folds and thereafter inclined gently from SAP era to post-SAP era (Table 3). However, the average annual yield increased in an arithmetic pattern from the pre-SAP period to SAP period and in turn from SAP regime to post-SAP regime. Thus, this reinforced the evidence of area expansion which was concluded to be the major factor that determined the increasing trend that marked maize production in the studied area. Generally, it can be inferred that this production trend is not favourable for maize food security in the country.

The results of the growth rate showed that during the pre-SAP era, the maize production witnessed a declined growth rate annually i.e. negative growth rate (-1.9%) and thereafter, during the SAP transition, the production of maize was marked by an inclined growth rate annually i.e. positive growth rate (4.5%). The inclined growth rate persisted through to the post-SAP period with the annual growth rate being 5.5% (Table 3). The annual area growth rate during the pre-SAP period exhibited similar growth pattern with that of the production i.e. negative growth rate; and thereafter, from SAP to post-SAP transitions, the growth rate increased steeply. For the yield, it recorded a positive annual growth rate during the pre-SAP (2.1%) and subsequently became stagnant during the SAP regime; and thereafter, witnessed a gentle increase during the post-SAP regime (1.0%). During the SAP period, there was no growth in the yield. Generally, for the overall period, the growth rate of maize production inclined owing to the pronounced growth rate in the area in spite of the marginal increased growth rate in yield, thus implying food insecurity in the supply of maize.

Therefore, it can be inferred that there is a deficit in the supply of maize in the studied area.

Table 3: Growth pattern of maize production

Variables		Pre-SAP	SAP	Post-SAP	Overall
Area (ha)	CGAR %	96.1***	104.0**	104.5***	103.9***
	AGR %	-4.0***	4.0**	4.5***	3.9***
	AA	994791.7	4134827	4606115	2989890
	Status	277.29***(A)	-55525.47***(D)	2345.97***(A)	759.49***(A)
Yield (hg/ha)	CGAR %	102.1***	100.4^{NS}	101.0*	101.4***
	AGR%	2.1***	0.4^{NS}	1.0*	1.4***
	AA	10243.88	12952.13	16664.47	13047.59
	Status	6.813***(A)	35.97^{NS}(S)	-27.78^{NS} (S)	0.100***(A)
Production (ton)	CGAR %	98.1**	104.5***	105.5***	105.4***
	AGR%	-1.9**	4.5**	5.5***	5.4***
	AA	960750	5288600	7654956	4272951
	Status	587.23**(A)	-53037.41**(D)	-2475.61***(D)	2539.23***(A)

Source: Authors' computation, 2020

Note: CGR- Compound growth rate; AGR- Annual growth rate; AA- Annual Average; A- Acceleration; D- Deceleration; S- Stagnation; ton = tone; hg = hectogram; and, ha = hectare

*** ** * $^{\& NS}$ means significant at 1, 5, 10% and Non-significant respectively

3.2 Magnitude and extent of instability

The coefficient of variation (CV) results showed that production of maize was marked by moderate instability throughout the transitional phases *viz.* pre-SAP, SAP and post-SAP; and it owed to moderate instability in the area given that yield variability was low (Table 4). Though, the moderate instability which marked production during the pre-SAP regime owed both to area and yield who exhibited moderate instability simultaneously. However, the precipitated high instability which marked the production of maize for the overall period owed majorly to the high shock in the area cultivated under maize production in the studied area.

Furthermore, in determining the exact direction of the production instability (CDII), it was observed that fluctuation in the production of maize was marked by moderate instability during the overall and pre-SAP periods; and it owed to high fluctuation in the area alongside low yield instability for the former and moderate instability in the area during the latter period. However, production of maize witnessed moderate instability during the SAP and it owed to moderate instability which marked area as yield instability was low (Table 4). Surprisingly, the fluctuation in the production of maize during the post-SAP transition was low and it might be due to the policy effect as both area and yield witnessed moderate instability.

It was observed that the effect of price volatility (CII) on production across the transitional periods was high and it owed to the simultaneous effect of both area and yield which were high across the reform phases (Table 4). Therefore, it can be inferred that the deficit of maize supply affected the price of maize given that the commodity has multiple demand purposes.

The empirical evidence showed that variability in the production of maize between pre-SAP and SAP periods was majorly due to "interaction between changes in mean area" alongside "change in area variance" and "change in the mean area". Furthermore, between SAP and post-SAP periods, the production variability was due to "change in area variance" (Table 5). However, examining production variability vis-à-vis the entire transitional periods, evidence showed "residual effect" *viz.* uncertainty which owed to weather vagaries to be the prime factor which caused variability in the level of maize production. Thus, it can be inferred that weather vagaries *viz.* erratic rainfall: flood and dry-spell are the majors affecting maize production in the studied area.

Table 4: Magnitude of area, yield and production instability in maize production (%)

Regimes	Variables	CV	CDII	CII
Pre-SAP	Area (ha)	34.98	25.5378	58.54538
	Yield (hg/ha)	24.569	19.7624	46.81379
	Production (ton)	28.518	25.61863	71.86593
SAP	Area (ha)	27.931	23.78239	55.07161
	Yield (hg/ha)	12.096	11.93772	42.66285
	Production (ton)	24.164	19.3463	49.97626
Post-SAP	Area (ha)	28.617	13.14514	44.40454
	Yield (hg/ha)	13.944	12.78749	43.68011
	Production (ton)	29.304	6.68234	50.43801
Overall	Area (ha)	65.342	40.80607	105.8339
	Yield (hg/ha)	27.137	15.20641	45.38572
	Production (ton)	76.638	36.67431	116.6881

Source: Authors' computation, 2020

Table 5: Sources of instability in maize production

Source of variance	Pre-SAP to SAP	SAP to Post-SAP	Overall
Change in mean yield	-6.22	14.74	-4.44
Change in mean area	26.63	0.55	0.70
Change in yield variance	-3.97	-0.31	-0.85
Change in area variance	38.64	56.90	33.56
Interaction between changes in mean yield and mean area	-10.40	0.14	-0.86
Change in area yield covariance	16.50	-4.16	1.82
Interaction between changes in the mean area and yield variance	-64.55	-0.07	0.66
Interaction between changes in mean yield and area variance	23.13	37.29	-29.16
Interaction between changes in the mean area and yield and change in area-yield covariance	69.42	-1.80	-1.47
Change in residual	10.81	-3.28	100.04
Total change in variance of production	100.00	100.00	100.00

Source: Authors' computation, 2020

Table 6: Instantaneous source(s) of change in maize production (Intra-wise %)

Source of change	Pre-SAP	SAP	Post-SAP	Overall
Area effect	100.6434	68.65467	53.38427	66.07131
Yield effect	335.822	47.30645	71.24788	59.07376
Interaction effect	-336.536	-15.957	-24.6304	-25.1439
Total change	100	100	100	100

Source: Authors' own computation, 2020

Table 7: Sources of change in maize production (Inter-regime wise %)

Source of change	Pre-SAP to SAP	SAP to Post-SAP
Area effect	6.15	66.45
Yield effect	73.42	26.43
Interaction effect	19.41	7.57
Covariance effect	1.02	-0.46
Total change	100	100

Source: Authors' computation, 2020

3.3 Source(s) of change in the production level

For the instantaneous sources of change in the average annual production status of maize, the empirical evidence showed "yield effect" to be the major source of growth in maize production during the post-SAP period. However, both "yield effect" and "interaction effect" affected the production growth of maize during the pre-SAP transition with the former increasing the production growth while the latter plummeting the production growth of maize in the studied area. For the SAP and overall periods, the average annual production growth was majorly due to "yield effect" (Table 6). Therefore, it can be concluded that area expansion predominates in driving growth in the average annual production level of maize in Nigeria.

Furthermore, it was observed that "change in the mean area" was responsible for the production growth of maize during the SAP period to be higher than that of the preceding period while production growth of SAP been lower than that of the post-SAP owed majorly to "change in mean yield" (Table 7). This showed that the effect of innovation *viz.* improved varieties in the production of maize during the post-SAP period.

3.4 Farmers' acreage response

The OLS estimation showed the semi-logarithm functional form to be the best fit for the specified equation among all the estimated functional forms given that it satisfied the economic theory, statistical criterion and econometric criterion. The diagnostic tests showed the residual to be devoid of heteroscedasticity, serial correlation, and Arch effect and are normally distributed as indicated by their respective test statistics which were different from zero at the plausible margin of 10% probability level. In addition, the specified equation is adequate, the data has no structural break and there is no change in the parameter(s) estimates as indicated by their respective test statistics which were not different from zero at 10% degree of freedom. Thus, the parameter estimates of the best fit functional form are reliable for future prediction (Table 8).

The coefficient of multiple determination been 0.9394, means that 93.94% of the variation in the current acreage under maize production is been determined by explanatory variables included in the model while disturbed economic reality accounted for 6.06%. The parameter estimates that influenced the current acreage under maize production are weather index, lagged maize producer price, lagged yield risk of maize, lagged price risk of maize, time index and lagged area of maize as indicated by their respective t-statistics which were different from zero at the acceptable margin of 10% degree of freedom.

The negative significant of the weather index implied that poor weather condition i.e. weather vagaries *viz.* flood and drought decreased the current acreage allocated to maize production. In addition, non-remunerative of the producer price of the studied crop discouraged maize producers as indicated by the negative significant of the estimated parameter, thus, this made the farmers shift to the production of the alternative crop(s) that fetched remunerative price. This price disincentive is due to the importation of maize into the country, thus dampening the price of the locally produced maize. This price disincentive made the farmers decrease the current acreage cultivated under maize production. Thus, government price support measures were not in the right direction to attain the desired goal of higher maize production in the studied area. The short-run elasticity showed the acreage responsiveness of the current area to price change to be -0.66. A negative acreage response is not an uncommon feature as previous studies viz. Sadiq*et al*. (2017) observed negative price coefficients for maize and *bajra* in Rajasthan, India. In addition, in a related study, Sadiq*et al*. (2019) reported a negative price coefficient for cowpea in Nigeria. Furthermore, if given a sufficient time for adjustment, the acreage responsiveness of maize to a price change in the long-run will be -1.18, as indicated by the long-run elasticity (LRE) index. Thus, it can be inferred the impact of price policy on this crop would be high in the long-run given that the crop showed a high elasticity. It was observed that maize required a moderate time *viz.* 3.65 years for the price effect to materialize. The moderate is the time for an adjustment; the less effective would be the price policy instrument in bringing desired change in the supply of maize in the studied area.

It was observed that the farmers were risk-averse to yield fluctuation while they had risk preference for variability in maize price as indicated by negative and positive significances of the former and latter respectively. Thus, risk aversive attitude of the farmers towards yield variability affected farmers' current acreage allocation decision while farmers' risk preference for price fluctuation encouraged them to increase the current acreage cultivated under maize in the studied area. The downward fluctuation in the price of maize led to an increase in the production of maize.

Furthermore, the empirical evidence revealed that economic policies in the country *viz.* innovations, subsidies, credit policies etc. had a positive impact on the farmers' current acreage allocation decision, thus encouraged them to increase the current area cultivated under maize production as evidenced by the significance of the time index parameter estimate. It was observed that the rate of adjustment of the area under maize cultivation was moderate as indicated by the estimated adjustment coefficient of 0.44. In addition, it can be inferred that there is less rigidity in the adjustment of area cultivated under maize as indicated by the positive significant of the lagged acreage parameter estimate.

Table 8a: Farmers' acreage response

Items	Linear	t-stat	Exponential	t-stat	Semi-log (+)	t-stat	Double-log	t-stat
Intercept	293697(530606)	0.553^{NS}	13.711(0.42285)	32.43***	−2.65e+7(8.65e+6)	3.070***	−1.6237(3.4182)	0.475^{NS}
MP_{t-1}	11.900(48.348)	0.246^{NS}	7.283e-6(2.43e-5)	0.299^{NS}	−2.09e+6(1.07e+6)	1.956*	−0.6887(0.4215)	1.634^{NS}
RP_{t-1}	−38.017(33.718)	1.127^{NS}	−3.06e-5(1.89e-5)	1.614^{NS}	1.11e+6(702400)	1.580^{NS}	0.04918(0.2777)	0.177^{NS}
SP_{t-1}	−50.761(49.27)	1.030^{NS}	−4.68e-5(2.69e-5)	1.739*	499560(851103)	0.587^{NS}	0.2635(0.3365)	0.783^{NS}
MLP_{t-1}	69.618(78.91)	0.882^{NS}	6.47e-5(4.21e-5)	1.536^{NS}	312584(1.05e+6)	0.298^{NS}	0.28005(0.4139)	0.676^{NS}
MPR_{t-1}	−40.580(54.487)	0.744^{NS}	−4.85e-5(2.95e-5)	1.647^{NS}	517862(210834)	2.456**	0.2057(0.0833)	2.469**
RPR_{t-1}	82.889(47.254)	1.754*	3.06e-5(2.02e-5)	1.519^{NS}	18862.4(187954)	0.100^{NS}	0.01638(0.0743)	0.220^{NS}
SPR_{t-1}	−8.599(53.914)	0.159^{NS}	2.21e-5(3.13e-5)	0.705^{NS}	−315233(266883)	1.181^{NS}	−0.1267(0.1055)	1.201^{NS}
$MLPR_{t-1}$	−15.453(70.521)	0.219^{NS}	2.19e-5(4.46e-5)	0.493^{NS}	−340934(217434)	1.568^{NS}	−0.0535(0.0859)	0.622^{NS}
Y_{t-1}	71.061(36.031)	1.972*	1.889e-5(2.36e-5)	0.801^{NS}	951775(793005)	1.200^{NS}	0.3627(0.3135)	1.157^{NS}
YR_{t-1}	18.250(86.94)	0.209^{NS}	2.46e-5(5.97e-5)	0.412^{NS}	−149964(84660.3)	1.771*	−0.00668(0.0334)	0.199^{NS}
T_t	7954.74(16022.2)	0.496^{NS}	0.0031(0.0145)	0.210^{NS}	104752(33323.4)	3.143**	0.0129(0.0132)	0.980^{NS}
WI_t	−1.01e+6(604636)	1.668^{NS}	−0.60292(0.30384)	1.984*	−1.16e+6(663972)	1.740*	−0.0628(0.2625)	0.239^{NS}
A_{t-1}	0.9375(0.0739)	12.67***	4.30e-7(8.35e-8)	5.151***	1.39e+6(295203)	4.697**	0.8937(0.1167)	7.658**
R^2	0.9546		0.8852		0.9394		0.9434	
F-stat	234.69***		71.73***		34.59***		37.24***	
Autocorrelation					$1.44\{0.245\}^{NS}$			
Arch effect					$4.66\{0.19\}^{NS}$			
Heteroscedasticity					$12.69\{0.47)^{NS}$			
Normality					$2.71\{0.25\}^{NS}$			
RESET test					$2.51\{0.12\}^{NS}$			
Chow test					$3.71\{0.827\}^{NS}$			
CUSUM test					$-0.136\{0.892\}^{NS}$			

Source: Authors' own computation, 2020

Note: *** ** * ^{NS} means significant at 1%, 5%, 10% probabilities and Non-significant respectively.

Values in ( ) and { } are standard error and probability level respectively

Table 8b: Short and long-run elasticity estimates

Variables	Mean	Marginal Effect	SRE	LRE
MP_{t-1}	20809.2	-100.213	-0.6622	-1.18307
RP_{t-1}	22954.42	48.35845	0.352492	0.629755
SP_{t-1}	18356.96	27.21366	0.158635	0.283413
MLP_{t-1}	18331.15	17.05207	0.099261	0.177337
MPR_{t-1}	3156.401	164.0673	0.164446	0.293797
RPR_{t-1}	3283.017	5.745447	0.00599	0.010701
SPR_{t-1}	3547.603	-88.858	-0.1001	-0.17884
$MLPR_{t-1}$	3141.25	-108.535	-0.10826	-0.19342
Y_{t-1}	13467.21	70.67352	0.302235	0.539967
YR_{t-1}	1144.526	-131.027	-0.04762	-0.08508
T_t	27	3879.704	0.033264	0.059429
WI_t	0.997916	-1157702	-0.36686	-0.65543
A_{t-1}	3057552	0.453458	0.440272	0.786581

Source: Authors' own computation, 2020

Table 9: ARIMA model

Items		Production (ton)	Area (ha)	Yield (hg/ha)
ADF	Level	-2.005^{nst}	-2.171^{nst}	-1.890^{nst}
	1st Diff	-6.846^{st}	-4.775^{st}	-6.913^{st}
KPSS	Level	2.581^{nst}	2.176^{nst}	2.276^{nst}
	1st Diff	0.1712^{st}	0.0916^{st}	0.0293^{st}
ADF-GLS	Level	-1.651^{nst}	-1.696^{nst}	$-1.241(0.197)^{nst}$
	1st Diff	-4.411^{st}	-4.646^{st}	$-1.026(2.57e-5)^{st}$
ARIMA (1,1,1)(AIC)		1684.31	1660.15	1022.75^{+}
ARIMA (1,1,0)(AIC)		1682.64^{+}	1659.20	1033.49
ARIMA (0,1,1)(AIC)		1682.68	1658.61^{+}	1031.52
Autocorrelation test		$0.462(0.793)^{NS}$	$1.219(0.543)^{NS}$	$1.298(0.254)^{NS}$
Arch LM test		$1.838(0.606)^{NS}$	$0.893(0.826)^{NS}$	$1.983(0.575)^{NS}$
Normality test		6.037(0.048)*	22.19(1.51e-5)***	$2.303(0.316)^{NS}$

Source: Authors' computation, 2020

Note: ADF-GLS and KPSS tau critical levels at 5% probability are -3.03 and 0.462 respectively.

*** ** * $^{NS,\ nst\&st}$means significant at 1, 5, 10%, Non-significant, non-stationary and stationary respectively

Table 10: One step ahead forecast of maize production

Period	Production (ton)		Area (ha)		Yield (hg/ha)	
	Actual	Forecast	Actual	Forecast	Actual	Forecast
2014	10058968	8549160	6346551	5806963	15850	16150.48
2015	10562050	10324339	6771189	6571066	15599	16848.14
2016	11547980	10744958	6579692	6885711	17551	16792.65
2017	10420000	11766024	6540000	6530214	15933	17864.9
2018	10155027	10484217	4853349	6592849	20924	17120.53

Source: Authors' computation, 2020

Table 11: Validation of models

Variable	R^2	RMSE	RMSPE	MAPE	RMAPE (%)	Theil's U
Production(ton)	0.987971	724085.5	49147.4	-126896	-1.39099	0.999683
Area (ha)	0.94096	794940.6	128724.1	-367122	-7.47741	1.014577
Yield (hg/ha)	0.983918	2016.634	211.6839	276.156	0.473083	0.800314

Source: Authors' computation, 2020

3.5 Production forecast of maize (2019-2030)

The conventional unit root tests *viz.* ADF and KPSS showed that at a level all the variables were non-stationary as indicated by their respective tau-statistics which were not different from zero at 5% t-critical level. But after the first difference, they became stationary as their respective tau-statistics were different from zero at 5% t-critical level. In addition, in order to validate the results of the classical unit root tests, the neo-classical unit root test *viz.* ADF-GLS was applied to the variables and it showed a similar result, thus indicating the reliability of the variables for future prediction. Furthermore, for the forecasts, results of ARIMAs at different levels showed ARIMA (1, 1, 0), ARIMA (0, 1, 1) and ARIMA (1, 1, 1) to be the best fit to forecast production, area and yield. In addition, residuals of the chosen ARIMAs had no problem of serial correlation and Arch effect; and, were normally distributed as indicated by their respective t-statistics which were not different from zero at the plausible margin of 10% (Table 9).

Furthermore, through the one-step-ahead forecast, the validity of the predictive power of the chosen ARIMAs and how closely they could track the path of the actual observations were verified (Table 10).

In addition, it was observed that the chosen ARIMAs were reliable for prediction as indicated by their respective Theil's inequality coefficient (U) and the relative mean absolute prediction error (RMAPE) which were less than 1 and 5% respectively (Table 11). Thus, the selected ARIMAs can be used for *ex-ante* projection with high projection validity and consistency as the predictive error associated with the estimated equations in tracking the actual data (*ex-post* prediction) are insignificant and low.

The results of the one-step-ahead-out of the sample forecast for the period 2019 to 2030 showed that gentle increase i.e. arithmetic rate increase would permeate the future production trend of maize (Table 12 and Figure 5). Also, area and yield forecasts would be marked by the same trend that marked production, thus, the simultaneous effect of area and yield would drive the production trend of maize in the country (Table 12 and Figure 6 & 7). Furthermore, even the optimistic production level is not good enough to balance the supply and demand for maize in the country given that it serves both domestic and industrial purposes. Therefore, it can be inferred that a deficit in the supply of maize looms ahead and will owed to poor productivity, thereby affecting the food security of maize in the studied area. Thus, onus lies on the policymakers to invest adequately in the area of technology and infrastructure so as to contain the supply deficit affecting domestic maize consumption in the country.

Table 12: Out of sample forecast of the variables

Year	Production (ton)			Area (ha)		
	Forecast	Pessimistic	Optimistic	Forecast	Pessimistic	Optimistic
2019	10282044.58	9125030.68	11439058.48	4339397.05	3403175.74	5275618.36
2020	10437586.91	8740742.80	12134431.02	4389075.22	2835674.17	5942476.27
2021	10595204.95	8489231.21	12701178.70	4438753.39	2451393.50	6426113.27
2022	10752974.04	8305100.82	13200847.26	4488431.56	2146179.69	6830683.43
2023	10910754.12	8163187.53	13658320.72	4538109.73	1888074.20	7188145.26
2024	11068535.01	8050892.39	14086177.62	4587787.90	1662171.25	7513404.55
2025	11226315.95	7960858.53	14491773.36	4637466.07	1460080.78	7814851.36
2026	11384096.89	7888348.42	14879845.36	4687144.24	1276525.27	8097763.21
2027	11541877.84	7830098.94	15253656.73	4736822.41	1107929.16	8365715.66
2028	11699658.78	7783749.21	15615568.36	4786500.58	951737.13	8621264.03
2029	11857439.73	7747525.74	15967353.72	4836178.75	806047.83	8866309.67
2030	12015220.67	7720056.15	16310385.19	4885856.92	669401.10	9102312.75
Year	Yield (hg/ha)					
	Forecast	Pessimistic	Optimistic			
2019	19687.08	16295.60	23078.55			
2020	19164.49	15378.73	22950.25			
2021	18996.22	15119.59	22872.84			
2022	19003.69	15105.04	22902.35			
2023	19098.34	15194.29	23002.40			
2024	19236.23	15330.85	23141.61			
2025	19395.57	15489.86	23301.28			
2026	19565.54	15659.75	23471.33			
2027	19740.79	15834.98	23646.60			
2028	19918.66	16012.85	23824.48			
2029	20097.83	16192.01	24003.65			
2030	20277.64	16371.83	24183.46			

Source: Authors' computation, 2020

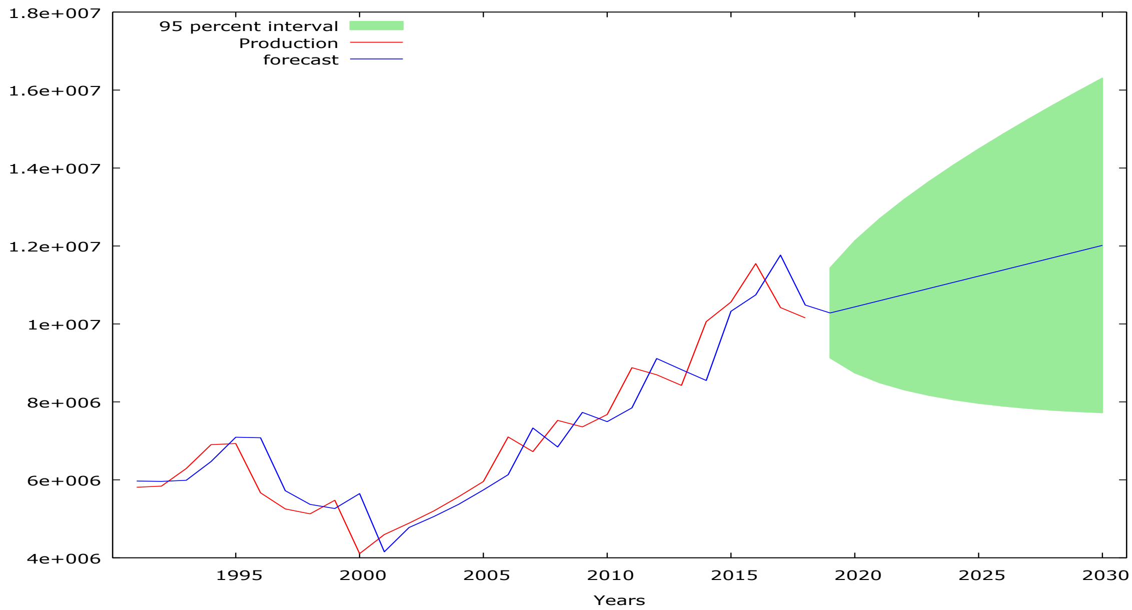

Figure 5: Production forecast of maize (2019-2030)

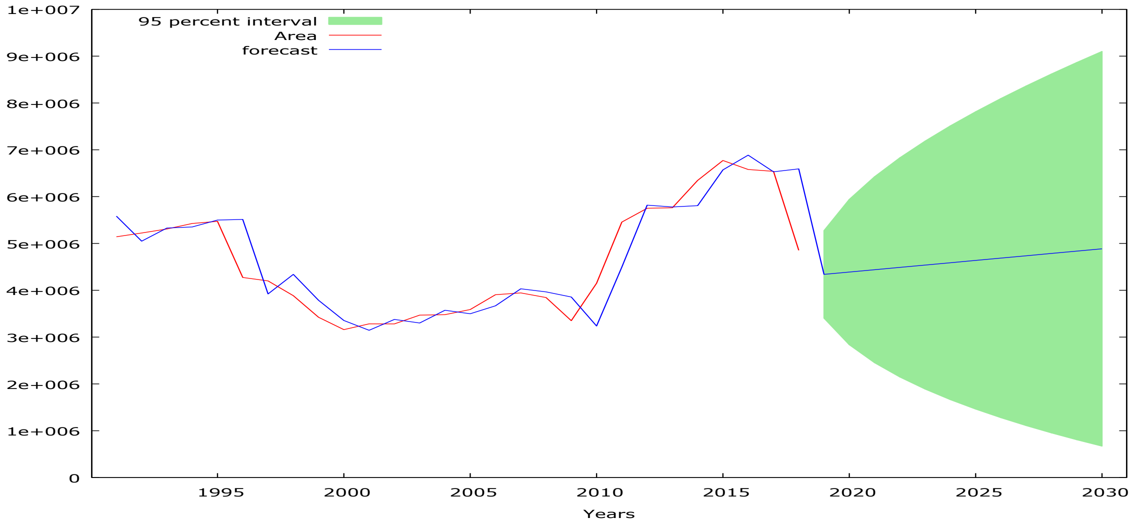

Figure 6: Area forecast of maize (2019-2030)

Figure 7: Yield forecast of maize (2019-2030)

4. Conclusions and Recommendation

The empirical evidence showed area expansion to be the major factor which drives the increasing trend exhibited by maize production. Generally, the growth rate of maize production was not sustainable as the growth rate of area expansion, which was more pronounced and the yield growth rate was marginal. It was observed that "area effect" was the major factor which made production growth of SAP to exceed that of the pre-SAP period, while "yield effect" was the prime factor which made the production growth of maize during the post-SAP period to be higher than the production level of SAP transition. Furthermore, uncertainty *viz.* weather vagaries were the major factors which caused fluctuation in the production of maize in the study area. In addition, the allocation decision of the farmers was affected by weather vagaries and poor remunerative producer price of maize. The future supply of maize cannot guarantee maize food security in the country as production growth will be premised on area expansion at the expense of productivity. Therefore, this study calls on policymakers to adopt area-risk and uncertainty- smart agriculture minimizing policies to boost maize production in order to achieve sustainable production in the studied area.

Conflict of interest

The authors declared that there is no conflict of interest for publication of the manuscript in this journal.

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