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Sorghum Food Security in Nigeria

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Abstract: The study examined the food security of sorghum in Nigeria using annual time series data that ranged from 1961 to 2018. The data were sourced from the FAO database and the collected data were analyzed using both descriptive and inferential statistics. The empirical findings showed sorghum to be an orphan crop as the production growth performance throughout the regime shift was poor given that area expansion rather than productivity was the major factor that influenced an increase in the production of sorghum. In addition, an increase in area was the major factor responsible for the change in average production within and between the regime shifts. It was observed that fluctuation in the average production between the regime shifts was caused by area risk and uncertainty *viz*. weather vagaries. It was established that the acreage allocation decision of the farmers was governed by both institutional and non-institutional factors. Furthermore, the future food security of sorghum production is not promising as the production will be marked by a gentle rise owing to the gentle rise in area as productivity will be marked by a marginal increase in trend. Therefore, the food insecurity of sorghum is another timing-bomb which the country will contain with given its versatile purposes. Thus, the policymakers need to take urgent steps to avert impending importation which will affect the country's economy.

Anahtar Kelimeler: Forecast, growth, nigeria, production, sorghum, trend

Nijerya'da Sorgum Gıda Güvenliği

Özet: Çalışma, Nijerya'da sorgumun gıda güvenliğini 1961 ile 2018 yılları arasında değişen yıllık zaman serisi verilerini kullanarak incelemiştir. Veriler FAO veri tabanından elde edilmiş ve toplanan veriler hem tanımlayıcı hem de çıkarımsal istatistikler kullanılarak analiz edilmiştir. Ampirik bulgular, sorgum üretimindeki artışı etkileyen ana faktörün üretkenlikten ziyade alan genişlemesi olduğu göz önüne alındığında rejim değişikliği boyunca üretim büyüme performansı zayıf olduğundan sorgumun yetim bir ürün olduğunu gösterdi. Buna ek olarak, rejim değişiklikleri içinde ve arasında ortalama üretimdeki değişiklikten sorumlu ana faktör, alandaki artıştı. Rejim kaymaları arasındaki ortalama üretimdeki dalgalanmanın alan riski ve belirsizlikten, yani hava durumu değişkenlerindeki belirsizlikten kaynaklandığı gözlendi. Çiftçilerin arazi tahsis kararının hem kurumsal hem de kurumsal olmayan faktörler tarafından yönetildiği tespit edilmiştir. Ayrıca, sorgum üretiminin gelecekteki gıda güvenliği ümit verici değildir, çünkü üretim, alandaki hafif artış nedeniyle hafif bir artışla işaretlenecektir, çünkü üretkenlik eğilimde marjinal bir artışla işaretlenecektir. Bu nedenle sorgumun gıda güvensizliği, ülkenin çok yönlü amaçları nedeniyle içereceği bir başka zamanlama bombasıdır. Bu nedenle, politika yapıcıların ülke ekonomisini etkileyecek olan ithalatı önlemek için acil adımlar atması gerekiyor.

Keywords: Tahmin, büyüme, nijerya, üretim, sorgum, akım

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1. Introduction

Other than in Africa, per capita, food production has increased globally over the last few decades (FAO, 2018).

Global demand for crops is rising, and further demand is expected to increase by 59-98 percent by 2050 (Elferink and Schierhorn, 2016). The USDA (2014) and FAO (2016) estimated that Nigeria accounts for up to 40 percent of total sorghum production in Africa and the largest in West Africa, contributing approximately 71 percent of total regional sorghum production. After the United States and India, the country is the third-largest producer in the world. Nevertheless, 90 percent of American and Indian sorghum is intended for animal feed, making Nigeria the world's leading producer of food grain sorghum (Anonymous, 2020). The crop is grown on around 6.1 million ha in Nigeria, with total annual production projected at about 6.8 million tonnes (FAO, 2020). It has several uses including, among others, malt, beer, beer powder, sorghum meal, sorghum rice, and animal feed.

A regional study of the production and consumption of sorghum in Nigeria provides a general overview of the prospects inherent in its value chain. It was observed that the main producers are in the northern region leaving a large deficit in the southern regions. The crop is the most important cereal food in the northern region, contributing about 73 percent of total calorie and 52 percent of protein intake per capita (Aduba et al., 2013; Odozi et al., 2015; Mundia et al., 2019).

Production of sorghum in Nigeria exceeds all other crops (Baiyegunhi and Fraser, 2009; Mundia et al., 2019;) and has the ability to be sustainable and competitive (Aduba et al., 2013; Mundia et al., 2019). However, they reported that the climate challenges and institutionally induced price volatility negatively affect production. Lake Chad's shrinking in the past few decades has put a strain on the livelihood of 40 million people whose food and income rely on subsistence farming (FAO, 2017). Colman and Young (1989) and Odozi (2015), as cited by Mundia et al. (2019), argued that sorghum farmers are faced with trade regulations that increase fees and limit access to agricultural inputs, high transport costs, and export prohibitions. Besides, weak farmer-to-market linkages and the self-consumer nature of production have led to a poorly defined value chain for sorghum (Gourichon, 2013). This is further compounded by periodic militant insurrections in the dominant cultivation area of northeastern Nigeria that continue to affect sorghum production (FAO, 2017).

The commercial production of sorghum has been driven by industries like beverages (malt and beer) and biofuels (Gourichon, 2013; Edom, 2018). Sorghum and corn were used exclusively in the production of beer, even after the lifting of the ban on barley imports in 1999. Yet the popularity of corn and soybeans has resulted in decreasing the production of sorghum in all output regions (USDA, 2014). During the past, Nigeria was self-sufficient, but recently, due to violence, sorghum imports from the US were required to meet local demand in the northeastern areas (Scott et al., 2017). They stated, however, that the farmers are still optimistic because of increasing prices, growing demand from regional markets in Niger, Chad, Mali, and Burkina Faso and from the beverage industry, and committed input support from private sector industrial consumers.

According to ICRISAT (2019), the country's industrial demand for sorghum is growing; with industries taking up about 20 percent of the total sorghum produced. This increased demand is attributed to a growing understanding of the health benefits of sorghum and the high import price policy of the government. Therefore, it is in view of these enormous potentials that this research aimed at examining the trend and growth patterns of sorghum production for the purpose of achieving self-sufficiency in sorghum production in the country. The specific objectives were to: examine the trend and growth pattern of sorghum production; determined the extent and magnitude of production instability; determined the sources of change in production; determined the factors influencing farmers' acreage allocation decision; and, forecast the production trend of sorghum production in Nigeria.

2. Material and Method

The study used annual time series data that ranged from 1961 to 2018 and the data were sourced from the FAO databank. The collected data covered production, area, yield, and producers' prices of maize, sorghum and millet. The data were examined vis-à-vis three regime shifts *viz*. pre-Structural Adjustment Period (SAP) (1961-1984), SAP (1985-1999), and post-SAP (2000-2018). For data analysis, both descriptive and inferential statistics were used. The objectives in descending order were achieved using descriptive statistics and compound growth model; instability index and Hazell's decomposition model; instantaneous and Hazell's decomposition models; Nerlove's distributed lag model and ARIMA model.

2.1. Empirical model

Growth rate: The compound annual growth rate calculated using the exponential model is given below:

$$\gamma = \alpha\beta^{t} \quad (1)$$

$$ln\gamma = ln\alpha + tln\beta \quad (2)$$

$$CAGR = [Antilog\beta - 1] \times 100 \quad (3)$$

Where, CAGR is compound growth rate; t is time period in the year; γ is area/yield/production; α is intercept; and, β is the estimated parameter coefficient.

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).

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

Where, σ is standard deviation and $\bar{X}$ is the mean value of area ,yield or production

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

Where CDII is the Cuddy-Della instability index; CV is the coefficient of variation; and, R^2 is the coefficient of multiple determination (Cuddy-Della Valle, 1978). The instability index classification is low instability (≤20%), moderate instability (21-40%) and high instability (>40%) (Shimla, 2014; Umar et al., 2019).

Unlike CV, Coppock's instability index give 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).

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

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

Where,

X_t=Area or Yield or Production in year 't',
N=Number of years(s),
CII=Coppock's instability index,
m=Mean difference between the log of X_{t+1} and X_t, and
$logV$=Logarithm variance of the series

2.2. Source of change in production

Instantaneous change: The instantaneous decomposition model as used by Sandeep et al. (2016) is given below:

$$P_0 = A_0 \times Y_0 \quad (8)$$

$$P_n = A_n \times Y_n \quad (9)$$

Where, *P*, *A* and *Y* represent the production, area and yield respectively. The sub-script *0* and *n* represent the base and the n^{th} years respectively.

$$P_n - P_0 = \Delta P \quad (10)$$

$$A_n - A_0 = \Delta A \quad (11)$$

$$Y_n - Y_0 = \Delta Y \quad (12)$$

From equation (8) and (12) we can write

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

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: Following Hazell's (1982) as adopted by Umar et al. (2017; 2019); Sadiq et al. (2019), the model is presented below:

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	$\Delta COV(A,Y)$	$\Delta COV(A,Y)$

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 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 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 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	$\Delta V(AY)$

Changes in average production (Table 1),

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

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

Change in variance decomposition (Table 2),

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

Nerlovian model: The Nerlove's response model as used by Sadiq et al. (2017) is presented below:

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

The first equation is a behavioral equation, stating that desired acreage (A_t^*) depends upon the following independent variables:

Where,

A_t= current area under sorghum,
MP_{t-1}= one year lagged price of maize,
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,
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 sorghum,
YR_{t-1}= one year lagged yield risk of sorghum,
WI_t= weather index for rice,
T_t= time trend at period t,
A_{t-1}= one year lagged area under sorghum,
β_0= intercept,
β_{1-n}= parameter estimates, and,
ε_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 (Sadiq et al., 2019; Ayalew, 2015; Stalling, 1960).

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:

$$ME = \frac{Price\ coefficient}{Mean\ of\ predictor(s)} \quad (21)$$

$$SRE = \frac{Price\ coefficient}{Mean\ of\ current\ area} \quad (22)$$

$$LRE = \frac{SRE}{Coefficient\ of\ adjustment} \quad (23)$$

2.3. ARIMA

ARIMA in general form is as follows (Gujarati et al., 2012):

$$\Delta^d Z_t = \alpha + \left(\delta_1 \Delta^d Z_{t-1} + \cdots .. + \delta_p \Delta^d Z_{t-p}\right) - \left(\varphi_1 \varepsilon_{t-1} + \cdots .. + \varphi_q \varepsilon_{t-q}\right) + \varepsilon_t \quad (21)$$

Where, Δ denotes difference operatör like:

$$\Delta Z_t = Z_t - Z_{t-1} \quad (22)$$

$$\Delta^2 Z_{t-1} = \Delta Z_t - \Delta Z_{t-1} \quad (23)$$

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

2.4. 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 formulae:

$$MAPE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1}) \quad (24)$$

$$RMPSE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1})^2 / A_{t-1} \quad (25)$$

$$RMAPE = 1/T \sum_{i=1}^{5} (A_{t-1} - F_{t-1}) / A_{t-1} \times 100 \quad (26)$$

$$U = \sqrt{\frac{\sum_{t=1}^{n-1} \frac{(\hat{Y}_{t+1} - Y_{t+1})^2}{Y_t}}{\sum_{t=1}^{n-1} \frac{(Y_{t+1} - Y_t)^2}{Y_t}}} \quad (27)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (A_{ti} - F_{ti})}{\sum_{i=1}^{n} (A_{ti})} \quad (28)$$

Where, R^2= coefficient of multiple determination, A_t = Actual value; F_t = Future value, and T = time period.

3. Results and Discussion

3.1. Trend and growth pattern of sorghum production

A cyclical trend *viz*. marginal increase and decrease marked the production of sorghum during the pre-SAP period with area expansion dominating in driving the trend as yield effect was marginal (Figure 2). However, the driving effect of yield during the mid 70s and late 70s predominate area in the production trend of sorghum. Thereafter, an increase owing solely to area expansion marked the production trend of sorghum during the SAP regime (Figure 1, 3). It was observed that the production trend steeped downward during the late 80s and sharply inclined during the year 1991 which was due to steep area decline and increase for the former and later respectively. During the post-SAP regime, the gentle rise which marked the production trend between the year 2000 and 2006 was driven majorly by productivity as area expansion was marginal; the production trend steeps downward in the year 2007 and thereafter revived upward during the year 2008 owing majorly to fluctuation in yield (Figure 4). Afterward, the production trend exhibited a cyclical trend between the year 2009 and 2011, with a steep decline in the production during the year 2009 owing to a steep decline in area and rapid recovery in production that was majorly driven by a galloped rise in yield. Thereafter, a gentle rise marked the production trend of sorghum till the year 2016 where it peaked and area expansion was the major driving force as yield steeped downward. However, at the end of the transition period (2017 to 2018), the gentle decline in the production trend of sorghum owes to both gentle decreases in area and yield.

Furthermore, it was observed that between the pre-SAP and SAP period; and likewise between the SAP era and post-SAP era, the average annual production exhibited an arithmetic increase (Table 3). Besides, both the average annual area and yield through the three regimes increased by arithmetic rate, thus the reason for the gentle increase in the average annual production of sorghum. The increase between the pre-SAP and SAP regimes were higher than the increase between the SAP and post-SAP regimes. In summary, the average annual area cultivated under sorghum has increased from 4.3 million hectares during the pre-SAP era to 5.5 million hectares during the SAP period; and thereafter increased to 6.2 million hectares during post-SAP regime. Also, both production and yield of sorghum exhibited a similar trend in the studied area. However, the average annual increase in production, area and yield from pre-SAP to SAP periods was steeper than that from SAP to post-SAP periods. Generally, it can be suggested that the increases in area, production and yield of sorghum have been comfortably sustained in the studied area.

The intra-year variation in the production and area of sorghum is considerably large across the transition periods as evident from the compound annual growth rates. However, in the case of yield, the variation was observed to be large during the pre-SAP period while during the SAP period and the post-SAP periods it was marginal and insignificant respectively. The annual production of sorghum during the pre-SAP period was marked by a negative insignificant growth rate and thereafter witnessed a positive significant growth during the SAP era; and afterward, a negative significant annual

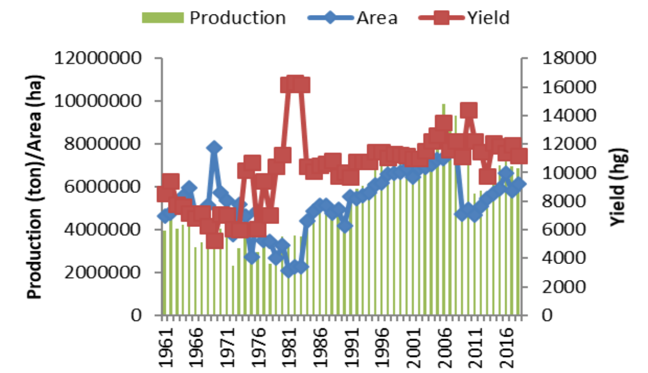

Figure 1: Production trend of sorghum (1961-2018)

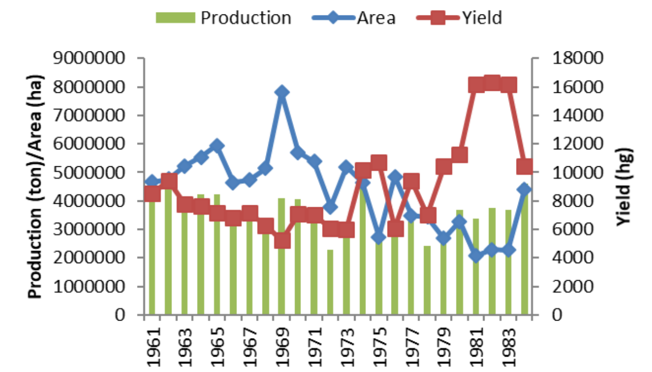

Figure 2: Pre-SAP production trend of sorghum (1961-1984)

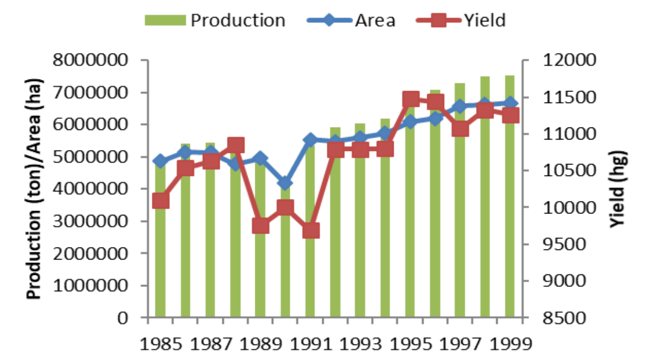

Figure 3: SAP production trend of sorghum (1985-1999)

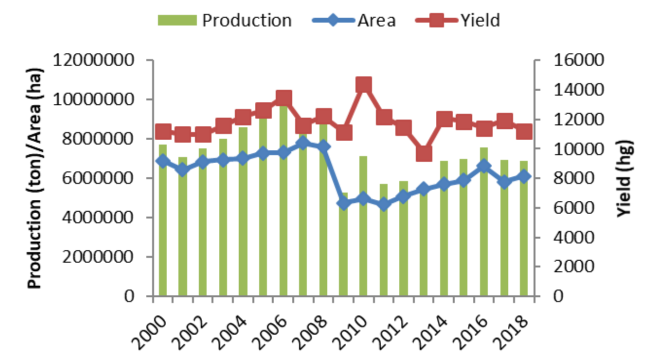

Figure 4: Post-SAP production trend of sorghum (2000-2018)

Table 3. Growth pattern of sorghum production

Variables		Pre-SAP	SAP	Post-SAP	Overall
Area (ha)	CGAR %	96.6***	102.6***	98.6**	100.7***
	AGR %	-3.4***	2.6***	-1.4**	0.7***
	AA	4363354	5573180	6275958	5302783
	Status	-7515.53*** (D)	11603.15***(A)	5876.07*(A)	917.89***(A)
Yield (hg)	CGAR %	102.8***	100.8***	100.0^{NS}	101.0***
	AGR%	2.8***	0.8***	0.0^{NS}	1.0***
	AA	9017.46	10702.80	11803.95	10366.14
	Status	37.79***(A)	7.587**(A)	-14.38^{NS}(S)	-2.568(D)
Production (ton)	CGAR %	99.3^{NS}	103.5***	98.6*	101.7***
	AGR%	-0.7^{NS}	3.5***	-1.4*	1.7***
	AA	3596875	5995133	7412284	5466990
	Status	7016.45^{NS}(S)	17165.07***(A)	-2369.62^{NS}(S)	-136.32***(D)

CGR- Compound growth rate; AGR- Annual growth rate; AA- Annual Average; A- Acceleration; D- Deceleration; S- Stagnation.
*** , ** , * , ^{NS} means significant at 1, 5, 10% and non-significant respectively.

growth rate marked the production of sorghum in the studied area (Table 3). Thus, the annual growth of sorghum production has steeply increased from -0.7% during the pre-SAP period to 3.5% during the SAP period, and thereafter the plummeted to -1.4% during the post-SAP period. Besides, the area exhibited a similar growth trend with annual production. However, the yield of sorghum witnessed a positive significant annual growth rate across the two preceding periods and a negative insignificant annual growth rate during the post-SAP era. The annual growth in area cultivated under sorghum plummeted during the pre-SAP era (-3.4%) and it sharply increased to 2.6% during the SAP period; and afterward, steeply declined to -1.4% during the post-SAP era. The annual growth in sorghum productivity has marginally increased from 2.7% during the pre-SAP period to 0.8% during the SAP period, and thereafter, stagnant (0.0%) during the post-SAP era. For the overall period, it was observed that production, area and yield witnessed a positive significant growth rate. Therefore, it can be inferred that the performance of sorghum production growth was poor because the growth trend of production was majorly governed by the trend growth behavior of the area as the growth effect of yield across the transitional periods was marginal.

If the production of sorghum is doubled during the pre-SAP and SAP periods, the production level will accelerate while it will stagnant during the post-SAP period. Doubling of the area would results in a deceleration during the pre-SAP period and acceleration during both succeeding periods. Besides, doubling the productivity of sorghum will make the yield to accelerate during the pre-SAP and SAP periods, and will become stagnant during the post-SAP regime (Table 3).

3.2. Sources of instability in sorghum production

A perusal of the CV index showed the production of sorghum throughout the transitional periods to be marked by a low instability while area and yield witnessed a moderate fluctuation during the pre-SAP period and a low fluctuation during the succeeding periods (Table 4). However, for the overall period, sorghum production was marked by a moderate fluctuation which owed to intermittent moderate instability in both area and yield.

Table 4. Magnitude of instability in sorghum production (%)

Regimes	Variables	CV	CDII	CII
Pre-SAP	Area	31.663	22.32185	51.88723
	Yield	36.222	29.09057	50.921
	Production	18.471	17.84149	44.6565
SAP	Area	13.481	7.056631	42.18385
	Yield	5.5023	4.050829	38.90052
	Production	17.862	9.349866	44.09199
Post-SAP	Area	15.742	13.85833	43.28751
	Yield	8.4699	8.465664	39.98575
	Production	18.25	16.48572	44.30577
Overall	Area	26.155	23.85703	49.94479
	Yield	24.002	18.24784	47.56477
	Production	35.867	22.31262	53.41218

Furthermore, a careful examination of the exact direction of the instability showed the production of sorghum to be marked by a high instability across all the transition periods and the overall period (Table 4). The high instability in the production of sorghum was triggered by a high instability that marred both area and yield. Therefore, it can be inferred that the production of sorghum has not been stable in the country owing to the surging demand of the crop for human and industrial purposes. It is very obvious that the crop is an orphan crop; year-in-year-out, the food security of sorghum is threatened by low supply, thus prompting fluctuation in area expansion and introduction of varieties of technologies especially improved seed varieties.

A cursory review of the effect of price shock on the production of sorghum showed the production to be marred by a low instability across all the transitional periods while both area and yield witnessed a moderate instability during the pre-SAP period and thereafter transit to a moderate instability during the succeeding periods. However, for the overall period, price shock caused moderate instability in the production, area and yield of sorghum (Table 4). Therefore, it can be inferred that price volatility has little effect on sorghum production in the country as evidenced by the CDII index which is below 20%.

An examination of the risk source showed "change in area yield covariance" and "change in residual" to be the major sources of risk for both between the pre-SAP and SAP periods; and, SAP and post-SAP periods. However, for the overall period, "change in mean yield" was the major source of risk in sorghum production (Table 5). Therefore, it can be inferred that fluctuation in the production of sorghum was determined by uncertainty, area risk and technological risk. Climate change *viz*. erratic weather vagaries has been an impediment to sorghum production, thus prompting incessant area expansion and re-introduction of drought resistant sorghum varieties and adaptation strategies year-in-year-out. It is worth to note that the variance indices of the overall period indicate that the series of sorghum innovative technologies vis-à-vis improved seed varieties and practices have triggered fluctuation in the production of sorghum in the country.

3.3. Sources of change in sorghum production

A cursory review of the instantaneous sources of change in production showed "yield effect" to be the major source of incremental change in the average annual production during the pre-SAP period while "area effect" dominates in determining an incremental change in the production level during the SAP, post-SAP and overall periods. However, it was observed that the 'interaction effect" has an overwhelming influence in decreasing the average annual production level during the pre-SAP and the overall periods (Table 6). Thus, it can be inferred that increase in the production of sorghum was majorly driven by area expansion in the studied area.

Furthermore, the results of inter-regime changes in the average annual production level showed "change in the mean area" to be the dominant factor that makes the

Table 5. Sources of instability in sorghum production

Source of variance	Pre-SAP to SAP	SAP to Post-SAP	Overall
Change in mean yield	-144.86	-76.52	404.35
Change in mean area	12.94	-9.67	-81.97
Change in yield variance	-96.43	9.64	155.84
Change in area variance	-47.32	41.45	162.07
Interaction between changes in mean yield and mean area	-9.40	-0.73	200.44
Change in area yield covariance	208.63	56.08	-242.75
Interaction between changes in mean area and yield variance	-60.89	2.58	-151.80
Interaction between changes in mean yield and area variance	-19.34	8.97	-159.65
Interaction between changes in mean area and yield and change in area-yield covariance	105.69	13.59	232.39
Change in residual	150.98	54.60	-418.91
Total change in variance of production	100.00	100.00	100.00

Table 6. Instantaneous source(s) of change in sorghum production (Intra-wise %)

Source of change	Pre-SAP	SAP	Post-SAP	Overall
Area effect	339.9654	75.26164	120.9713	132.633
Yield effect	433.2388	27.52104	6.984965	112.9548
Interaction effect	-673.188	-2.78308	-27.9627	-145.576
Total change	100	100	100	100

average annual production of sorghum during the SAP period to be greater than that of the pre-SAP. Likewise, the same factor was responsible for a change in the average annual production during the post-SAP period to be higher than that of the SAP period (Table 7). However, it was observed that "change in mean yield" also contributed in making the sorghum production level of the succeeding regimes to be higher than that of the preceding regimes. Therefore, it can be inferred that area expansion was the major driving force that creates incremental change in the sorghum production level between the regimes that characterized the economy of the studied area.

Table 7. Sources of change in sorghum production (Inter-regime wise %)

Source of change	Pre-SAP to SAP	SAP to Post-SAP
Area effect	33.13	43.17
Yield effect	49.15	52.91
Interaction effect	9.19	5.44
Covariance effect	8.53	-1.52
Total change	100	100

3.4. Farmers' acreage response

The results of the OLS estimation showed the semi-logarithm functional form to be the best fit for the specified equation among all the tested functional forms as it satisfied the economic, statistical and econometric criteria. The diagnostic tests showed that the Langrage multiplier (LM) and Chi^2 test statistics were not different from zero at 10% degree of freedom, thus indicating homoscedasticity of the residual and normality in the distribution of the residual. Besides, the residual is devoid of serial correlation and Arch effect as indicated by their respective test statistics which were beyond the plausible margin of 10% probability level. The non-significant of the CUSUM and RESET test statistics showed stability in the parameter estimates with no change and the model specification is adequate, respectively. Also, the data has no problem of structural break i.e. the sample is treated as one population and not a sub-population despite different regimes as indicated by the insignificant of the Chi^2 test statistic at 10% degree of freedom. The problem of spurious regression and spurious correlation were absent as evident from the R^2 value which is lower than the Durbin-Watson statistics and the non-outrageous of the R^2 value, respectively (Table 8). Thus, the chosen functional form is reliable for future prediction with certainty, efficiency and consistency.

The value of the coefficient of multiple determination being 0.9891 implies that the predictor variables included in the model were responsible for the 98.91% variation in the current acreage under sorghum production while disturbed economic accounts for 1.09% variation in the current acreage cultivated for sorghum production. The explanatory variables found to have a significant impact on the farmers' acreage allocation decision were yield of sorghum, weather (WI), price of sorghum, price of maize, price risk of maize, time and the lagged acreage cultivated under sorghum as indicated by their respective parameter estimates which were within the plausible margin of 10% probability level.

The positive sign of the lagged yield of sorghum on the current acreage cultivated under sorghum implies that the adoption of improved seed varieties coupled with innovative sorghum practices increased the yield of the farmers, thus encouraged them to increase the current area allocated to sorghum production. The positive sign of the weather index (WI) revealed that the use of drought resistant varieties of sorghum made the farmers overcome the problem of weather vagaries. Thus, weather vagaries *viz*. drought is not a disincentive to the farmers' acreage allocation decision on sorghum production in the studied area.

The positive sign of the price of maize implied that the farmers were conscious of the effect of the divergent cobweb effect given that a shift to the cultivation of the competing crop (maize) will lead to price dampening in the subsequent season due to a glut in the supply of the competing crop (maize). Thus, instead of shifting to the competing crop, they tend to increase the area allocated to sorghum in order to avert the divergent cobweb effect which will affect their business going concerned. In addition, it revealed the subsistence characteristics of the farmers; having a poor capital base and shifting to the cultivation of maize would require extra capital which will be difficult for the farmers to meet-up with. The negative significant of the sorghum price implies that the dampening of sorghum price affected farmers' turnover ratio, thus affected the current acreage allocated to sorghum production. In addition, it revealed that the imperfection of the market price is not in the right direction to support the higher production of sorghum in the country. Furthermore, the supply response was marked by negative price elasticity in the short-run (-0.11). A negative supply response is not an uncommon feature on acreage response as evident by some studies *viz*. Sadiq et al. (2017), Jain et al. (2005). This result is contrary to the findings of Sadiq et al. (2017) who discovered a positive short-run price elasticity for Jowar (sorghum) crop acreage response in Rajasthan state of India. However, government policy impact may be the reason for the contrary results. In the long-run, the impact of pricing policy instruments on this crop will be inconsequential as evident from the intensity of the long-run elasticity (-1.22) which is low. It was observed that the time required for the price effect to materialize in the long-run is very high (30.79 years), thus indicating higher technological and institutional constraints affecting sorghum production in the studied area. The higher the constraints, the more is the time required for price adjustment.

The non-significant of the price of millet showed that the millet production is capital intensive, and the poor resource nature of the farmers made them not to be favourably disposed to the production of the crop. The negative significance of the maize price risk coefficient indicated that the price trend of maize and sorghum moved together, as a downward shock in the price of maize plummet the price of sorghum, thus affected the farmers' acreage allocation decision on sorghum production. Thus, a downward fluctuation in the price of maize forced the farmers to decrease the current acreage cultivated under sorghum in the studied area.

Furthermore, the negative significance of the time trend revealed that the economic policies in the country did not favoured sorghum production in the country. This did not come as a surprise as the crop is not a major mandate crop with adequate government attention despite being a versatile crop of importance to humans, animals and brewing industries. Given that sorghum is produced at the subsistence level, the farmers are insensitive to upward volatility in the price of sorghum as indicated by the positive non-significant of the sorghum price risk coefficient. Likewise, the positive non-significant of the millet price risk coefficient showed that upward volatility in the price of millet did not encourage the farmers as capital paucity has affected their capacity to produce this alternative crop which requires extra cost. The low level

Table 8a. Farmers' acreage response

Items	Linear	t-stat	Exponential	t-stat	Semi-log (+)	t-stat	Double-log	t-stat
Intercept	3.508e+6 (1.039e+6)	3.374***	15.275 (0.2082)	73.36***	−7.420e+7 (3.36e+6)	22.06***	8.3558 (3.9901)	2.094*
MP_{t-1}	−61.911 (43.707)	1.416^{NS}	−1.749e-5 (9.484e-6)	1.844*	1.059e+6 (322606)	3.284**	−0.020183 (0.30906)	0.065^{NS}
SP_{t-1}	−132.10 (91.722)	1.440^{NS}	−2.341e-5 (1.519e-5)	1.542^{NS}	−598637 (249453)	2.400**	−0.038131 (0.23589)	0.161^{NS}
MLP_{t-1}	185.45 (130.29)	1.423^{NS}	3.818e-5 (2.313e-5)	1.651^{NS}	−313125 (281376)	1.113^{NS}	0.15751 (0.26746)	0.588^{NS}
MPR_{t-1}	−78.720 (36.603)	2.151**	−9.992e-6 (6.191e-6)	1.614^{NS}	−147064 (67706.0)	2.172**	−0.100728 (0.06143)	1.640^{NS}
SPR_{t-1}	108.355 (72.997)	1.484^{NS}	2.299e-5 (1.139e-5)	2.020*	41723.4 (67506.1)	0.618^{NS}	0.065486 (0.063511)	1.031^{NS}
$MLPR_{t-1}$	−47.473 (100.63)	0.471^{NS}	−1.672e-5 (1.668e-5)	1.003^{NS}	45294.5 (54508.2)	0.831^{NS}	0.025161 (0.052516)	0.479^{NS}
Y_{t-1}	135.71 (47.446)	2.860***	2.639e-5 (1.214e-5)	2.175**	531290 (180428)	2.945***	0.094188 (0.21849)	0.431^{NS}
YR_{t-1}	−279.34 (165.52)	1.688*	−5.976e-5 (3.958e-5)	1.510^{NS}	−10669.3 (26778.4)	0.398^{NS}	−0.033879 (0.02473)	1.370^{NS}
T_t	28866.0 (20553.6)	1.404^{NS}	0.008745 (0.003922)	2.229**	−22950.5 (8850.33)	2.593**	−0.009403 (0.008323)	1.130^{NS}
WI_t	−2.695e+6 (536122)	5.027***	−0.78029 (0.12240)	6.375***	968985 (216015)	4.486***	−0.45440 (0.18931)	2.400**
A_{t-1}	0.54349 (0.10565)	5.144***	1.097e-7 (2.294e-8)	4.783***	4.818e+6 (174837)	27.56***	0.38629 (0.16349)	2.363**
R^2	0.7875		0.8299		0.9891		0.7729	
F-stat	73.60 [5.6e-23]***		134.5 [5.4e-28]***		256.20 [3.1e-27]***		9.59 [3.2e-7]***	
D-W stat					2.080 $[0.376]^{NS}$			
Autocorrelation					0.515 $[0.724]^{NS}$			
Arch effect					11.40 $[0.179]^{NS}$			
Heteroscedasticity					24.70 $[0.311]^{NS}$			
Normality					2.385 $[0.303]^{NS}$			
RESET test					0.523 $[0.473]^{NS}$			
Chow test					0.615 $[0.324]^{NS}$			
CUSUM test					-0.531 $[0.598]^{NS}$			

*** , ** , * , 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-run and long-run elasticity estimates

Variables	Mean	Marginal Effect	SRE	LRE
MP_{t-1}	20809.2	50.91547	0.199533	2.152422
SP_{t-1}	18356.96	-32.6109	-0.11274	-1.21615
MLP_{t-1}	18331.15	-17.0816	-0.05897	-0.63612
MPR_{t-1}	3156.401	-46.5923	-0.0277	-0.29876
SPR_{t-1}	3547.603	11.76101	0.007858	0.084762
$MLPR_{t-1}$	3141.25	14.41926	0.00853	0.092017
Y_{t-1}	10580.7	50.21313	0.100056	1.079329
YR_{t-1}	994.4506	-10.7288	-0.00201	-0.02167
T_t	27	-850.019	-0.00432	-0.04662
WI_t	0.997517	971396.5	0.182485	1.968518
A_{t-1}	5194382	0.927485	0.907298	9.787303

Average Area =5309951

of technology used in the production of sorghum discouraged farmers from increasing the current acreage allocated to sorghum production as evidenced by the negative significance of the managerial efficiency parameter. The coefficient of adjustment was very low (0.09), implying low adjustment in the area cultivated under sorghum by the farmers in the study area. In addition, it indicated that the lagged area in the current acreage under sorghum cultivation is 90.73%.

3.5. Production forecast of sorghum production

The results of the unit root tests *viz*. ADF, KPSS and ADF-GLS confirm the non-stationary of all the production parameters at the level as evident from their respective tau-statistics which were not different from zero at 5% probability level. But after the first difference, all the production parameters became stationary as indicated by their respective tau-statistics which were different from zero at 5% probability level. In order words, it implies that the residuals of the production parameters exhibit random walk at level but after the first difference they became Gaussian white noise (Table 9). Thus, this indicates that the variables have no trend and can be used for the future forecast with precision and certainty. Furthermore, the results of the ARIMAs at different levels showed ARIMA (0,1,1) to be the best fit model to forecast all the production parameters (Table 9). In addition, the residuals of the chosen ARIMAs were free from serial correlation and Arch effect as indicated by their respect t-statistics which were not different from zero at 10% degree of freedom. However, their residuals were not

Table 9. ARIMA model

Items		Production	Area	Yield
ADF	Level	$-1.1838(0.68)^{ns}$	$-1.973(0.298)^{ns}$	$-2.821(0.06)^{ns}$
	1st Diff	$-10.49(1.4e-11)^{st}$	$-10.00(3.3e-11)^{st}$	$-9.394(1.2e-10)^{st}$
KPSS	Level	2.198^{ns}	1.004^{ns}	1.343^{ns}
	1st Diff	0.073^{st}	0.045^{st}	0.0357^{st}
ADF-GLS	Level	-2.058^{ns}	2.289^{ns}	-3.004^{ns}
	1st Diff	-5.383^{st}	-10.084^{st}	-5.404^{st}
ARIMA (1,1,1)(AIC)		1724.82	1731.41	1015.13
ARIMA (1,1,0)(AIC)		1723.21	1729.78	1014.98
ARIMA (0,1,1)(AIC)		1724.11^{+}	1729.56^{+}	1014.86^{+}
Autocorrelation test		$1.830[0.608]^{NS}$	$2.24[0.326]^{NS}$	$7.997[0.156]^{NS}$
Arch LM test		$0.342[0.951]^{NS}$	$1.813[0.612]^{NS}$	$0.086[0.768]^{NS}$
Normality test		23.33[8.59e-6]***	16.57[2.5e-4]***	22.98[1.02e-5]***

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 sorghum production

Period	Production		Area		Yield	
	Actual	Forecast	Actual	Forecast	Actual	Forecast
2014	6883294	5559978	5702160	5343070	12071	10335.73
2015	7005025	6528499	5899134	5609436	11875	11652.07
2016	7556076	6909633	6630766	5828924	11395	11862.57
2017	6939000	7408632	5820000	6394389	11923	11568.17
2018	6862343	7133449	6125132	6030147	11204	11875.12

Table 11. Validation of models

Variable	R^2	RMSE	RMSPE	MAPE	RMAPE (%)	Theil's U
Production	0.989155	433363.2	26043.28	76446.27	0.927854	1.0016
Area	0.979715	461697	33870.43	122427.1	1.737023	0.907148
Yield	0.990406	411.0051	14.82615	-112.186	-1.048	0.888382

Table 12. Out of sample forecast of the variables

Year	Production			Area			Yield		
	Forecast	Pessimistic	Optimistic	Forecast	Pessimistic	Optimistic	Forecast	Pessimistic	Optimistic
2019	6995976.77	5332673.88	8659279.67	6118097.67	4373486.74	7862708.59	11431.88	8127.41	14736.35
2020	7046561.06	5022265.92	9070856.20	6141881.64	4036487.72	8247275.57	11479.37	7385.74	15573.00
2021	7097145.34	4767131.38	9427159.31	6165665.62	3752845.72	8578485.52	11526.86	6773.33	16280.40
2022	7147729.63	4547698.99	9747760.28	6189449.60	3504171.93	8874727.26	11574.36	6241.96	16906.75
2023	7198313.92	4353783.44	10042844.39	6213233.57	3280703.53	9145763.61	11621.85	5767.55	17476.14
2024	7248898.20	4179281.30	10318515.10	6237017.55	3076519.37	9397515.72	11669.34	5336.01	18002.67
2025	7299482.49	4020192.60	10578772.38	6260801.52	2887707.24	9633895.80	11716.83	4938.23	18495.43
2026	7350066.77	3873727.25	10826406.29	6284585.50	2711522.20	9857648.79	11764.32	4567.95	18960.69
2027	7400651.06	3737847.39	11063454.73	6308369.48	2545950.36	10070788.59	11811.82	4220.63	19403.00
2028	7451235.34	3611010.74	11291459.95	6332153.45	2389462.25	10274844.65	11859.31	3892.85	19825.76

normally distributed as revealed by their respective t-statistics which were within the acceptable margin of 10% degree of freedom. Non-normality of the residual is not considered a serious problem as most data in their natural form are not normally distributed. Thus, the chosen ARIMAs are reliable for the sorghum production forecast with certainty and accuracy.

In investigating the predictive strength of the estimated ARIMAs, the one-step-ahead forecast of the variables along with their corresponding standard errors using naïve approach for the period 2014 to 2018 for each of the chosen ARIMA models against each variable was computed (Table 10). The essence is to determine how closely the estimated models could track the path of the actual observation by validating the sample periods.

Furthermore, the empirical evidence showed the reliability of the best fit ARIMAs for prediction as evident by their respective Theil's inequality coefficient (U) and the relative mean absolute prediction error (RMAPE) which were within the acceptable margin of 1 and 5% respectively (Table 11). Thus, with high projection validity and consistency, the selected ARIMAs can be used for *ex-ante* projection as the predictive error associated with the estimated equations in tracking the actual data (*ex-post* prediction) are insignificant and low.

A cursory review of the one-step-ahead-out of sample forecast results for the period 2019 to 2028 revealed that the production trend of sorghum will witnessed a gentle rise which will be governed by a moderate expansion in area cultivated under the crop as the future incremental change in yield will be marginal (Table 12 and Figure 5 to 7). Thus, it can be inferred that the food security of sorghum in the country would continue to be threatened and if urgent steps are not taking by the policymakers, the country will resort to importation from neighboring countries in order to shore-up the deficit created due to inadequate domestic supply. This will be another food security challenge to the economy just like rice, given that the country has the wherewithal to produce the quantum of sorghum needed for domestic use and even for export, thus a threat to the country's GDP and foreign exchange earnings.

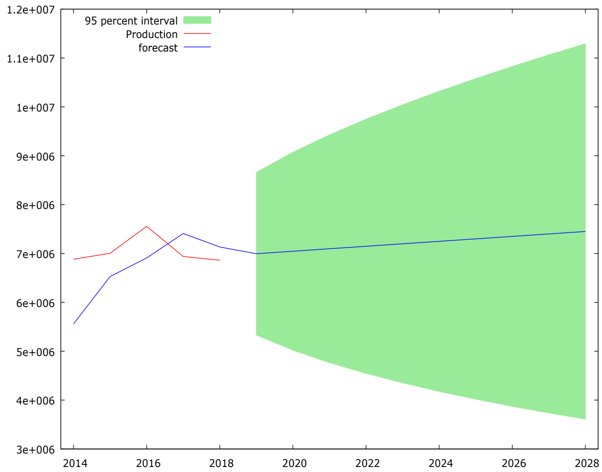

Figure 5. Production forecast of sorghum

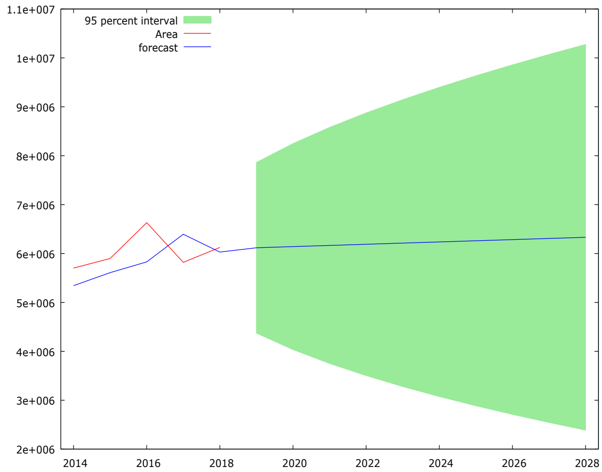

Figure 6. Area forecast of sorghum

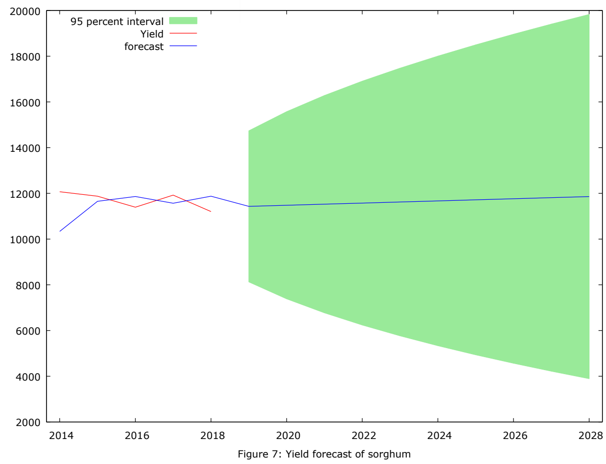

Figure 7. Yield forecast of sorghum

4. Conclusion

The empirical evidence showed the growth performance of sorghum production vis-à-vis the regime shifts that marked the economy to be poor owing to the fact that production was majorly driven by area expansion as productivity influence was marginal. In addition, area expansion was observed to be the major factor responsible for a change in average production between the regime periods. Furthermore, area risk and uncertainty *viz*. weather vagaries were the major factors responsible for production fluctuation between the periods. The acreage allocation decision of the farmers was influenced by both institutional and non-institutional factors. The future production trend of sorghum will be permeated by a gentle increase which majorly owes to a gentle increase in area expansion as the future yield will be marked by a marginal increase. Thus, the study recommends the need for urgent policy intervention in order to contain economic pilfering *viz*. importation of sorghum that will have an adverse effect on the food security of sorghum and economic growth of the country.

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