ENCOURAGING CLIMATE SMART AGRICULTURE AS PART SOLUTION TO THE NEGATIVE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SUSTAINABILITY IN SOUTHEAST NIGERIA

Onyeagocha[1], S.U.O; Nwaiwu[1], I.U.O; Obasi[1], P.C; Korie[1], O.C.; N.G. Ben-Chendo[1]; G.O. Ellah[1] and M.Y. Okpeke[2]
[1]Department of Agricultural Economics, Federal University of Technology Owerri, Imo State, Nigeria.
[2]Department of Agric. Extension and Management, School of Agric., Delta State Polytechnic, P.M.B 005, Ozoro, Delta State, Nigeria

Abstract
The devastating menace of fast changing climate system on agricultural sustainability has constituted a great concern to both the local and global communities and as part of remedial measures, this study investigated the potential and the Climate SMART agricultural practices as a prelude to abating its devastating effects on agricultural sustainability in South-east Nigeria. Multi-stage sampling technique was used to select a sample of 312 cassava based food crop farmers in the study area. Primary and secondary data were used in the study. Data were analysed using ordinary least square regression tools, descriptive statistical tools and Total Factor Productivity model as an index of sustainability. Results showed that of the four variables used, namely; rainfall, temperature, relative humidity and sunshine, two variables; rainfall and temperature hadstatistically significant effects on agricultural sustainability at α =0.05 and t = 3.18 and 5.32, respectively. For temperature, b < 0, for rainfall b > 0. The result further suggested that climate SMART Agriculture entails adopting agricultural practices that reduces the rate of emission of dangerous greenhouse gases, encourages carbon sequestration, and facilitating the buildup of the resilient capacities of farmers through the use of disease resistant and high yielding varieties of crops. In the studied area, it was also found that the following adaptation/mitigation strategies were practiced; late commencement of planting, use of fertilizers, mulching, breaking of daily work periods and planting of cover crops among others. It was concluded that climate system is actually changing and negatively affecting agricultural sustainability. Therefore, farmers should be encouraged to adopt both on-farm and off-farm mitigation/adaptation practices so as to keep the environment clean and hence making production more sustainable.

Key words: Climate, Smart, Agriculture, Sustainability, Change and Regression

1.0 Introduction

The near collapse of the oil sector, which diverted the attention of Nigerians away from agriculture is a thing of concern to policy makers and indeed all stakeholders in economic planning and development. The time to refocus development strategies towards sustainable rural development which is synonymous to agricultural development and hence economic growth and development, is now. Currently, Nigeria has 75 percent of its land suitable for agriculture,but only 40% is cultivated (Ayodele, *et.al;* 2013). Before the oil boom of 1980s, agriculture was the mainstay of Nigerian economy. Agriculture is made up of four sub-activities, namely: crop production, livestock, forestry and fishing. In nominal terms, the sector grew by 9.17% year-on-year. This was higher than growth rates recorded in the corresponding quarter of 2014 and the First Quarter of 2015 by 2.50% points and 1.73% points respectively. Growth in the sector was driven by output in crop production accounting for 83.89% of overall growth of the sector. Agriculture contributed 17.89% to nominal GDP during the quarter under review. This was marginally higher than shares recorded in the corresponding period of 2014 and Q1 of 2015 by 0.65% points and 0.12% points, respectively(NBS, 2016). Real agricultural GDP growth in the Second Quarter of 2015 stood at 3.49% (year-on-year), a decrease of 0.19% points from the corresponding period of 2014. Growth in the Second Quarter was also 1.21% points lower from the First Quarter of 2015; while positive growth in agricultural output has been relatively lower as a result of lower crop output, which in turn was as a result of a late onset of rains during the quarter. The contribution of Agriculture to overall GDP in real terms was 21.12% in the Second Quarter of 2015, marginally higher from its share in the corresponding quarter of 2014 and higher from the First Quarter of 2015 by 1.33% points (NBS,2016). Although the agricultural sector has been contributing meaningfully in the nations GDP, its contribution has been dwindling owing to so many factors prominent among which is the menace of climate change.

Climate change has been identified as one of the greatest challenges to the persistent low agricultural productivity amidst myriads of efforts by government and other stakeholders (Buckland, 1997; Matarira, *et.al.*, 1995; Adama, *et.al.*, 1998; Apata, *et.al.*, 2009). Temperature and rainfall changes induced by climate change interact with atmospheric gases, fertilizers,the activities of insects, plant pathogens, weeds, and the soil's organic matter to produce unanticipated responses. Despite these uncertainties, an average global temperature rise of slightly more than one-half degree

Centigrade would lengthen the frost-free growing season in the Corn Belt by two weeks (Malone, 1974). However, if temperatures continue to increase beyond a specific threshold, a crop's productive summer growing season could become shorter, thus reducing the yield (Monteith, 1981).When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield (Fischer *et.al*., 2002). Also, if night-time temperature minima rise more than do daytime maxima as is expected from greenhouse warming projections, heat stress during the day may be less severe than otherwise, but increased night-time respiration may reduce potential yields (Eze *et. al.*, 2008).

It is estimated that agriculture is responsible for about three-quarters of tropical deforestation (Carr, 2004; Skutsch,*et al.,* 2007; Wollenberg,*et al.,* 2012) and accounts for about 10 to 12% of the total global anthropogenic emissions of greenhouse gases (GHGs) in 2005 (Smith *et al.*, 2007). Yet, the world needs more food than ever before to sustain the increasing population of people living in extreme hunger, especially in Africa where about 70% of the people are engaged in some sort of agricultural activity (African Union (AU, 2012) The need for a more sustainable approach to agriculture has led to suggestions that agriculture is the key and holds enormous potential to contribute to any strategy to adapt to climate change and reduce emissions particularly in an African context (Beddington *et. al*., 2011). Climate-Smart Agriculture (CSA) is one approach that has been championed as the "holy grail" of agricultural development (Naess, 2011) ensuring that agriculture is key to climate change adaptation and mitigation (Wollenberg *et. al*., 2011; Beddington et al., 2012). Climate-SMART Agriculture is derived from the acronym SMART, where S stands for specific, M stands for measureable, A for achievable, R for reliable and T for timely (McCarthy *et al*., 2012).

Climate-SMART Agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. It is an approach for developing agricultural strategies to secure sustainable food security under climate change. It aims at tackling three main objectives: sustainableincreasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible (FAO, 2016). The subject matter sustainability is central to any climate change abatement discourse and is integral in this article. Sustainability has been defined in several ways by several authors. According to World Commission on Environment and Development (1987) sustainable development is that which meets the needs and aspirations of the present without compromising the ability of future generations to meet their own needs. FAO,(1989) defined sustainable agriculture as one that involves the successful management of resources for agriculture to satisfy human needs, while maintaining or enhancing the quality of the environment and conserving natural resources. Keaney, (1989) defined it as agricultural systems that are environmentally sound, profitable and productive and that maintain the social fabric of the rural community. Okigbo, (1991) defined it as one which maintains an acceptable and increasing level of productivity , that satisfies prevailing needs and is continuously adapted to meet the future needs for increasing the carrying capacity of the resource base and other worthwhile human needs.

Sequel to the broad nature of sustainability, most attempts to devise a method of measuring it have concentrated on developing partial indices which estimate some aspect of the broader concept. Dumanski, (1987) reviewed a number of these indices. The physical indices of sustainability include the Soil Erosion Vulnerability Index developed by Pierce *et. al.,* (1983), the Erosion Sensitivity Index developed by Lee and Goebel (1986) and Putman (1986) and the Potential Land Flexibility Index developed by Dumanski (1987). Dumanski concluded that sustainability, in spite of its academic and emotional appeal, cannot be measured at this time. This is because sustainability is a highly dynamic concept which varies spatially and temporally with change in technology, market, policies and resource availability and quality.

At International Institute of Tropical Agriculture (IITA), a range of strategies have been adopted to construct measures that apply at the cropping system level, although the effects of this level on higher hierarchical levels are taken into consideration in some approaches. In one approach, biological, physical and economic measures were merged into a single index. Ehui and Spencer (1990) have done this by using a single economic index, Total Factor Productivity (TFP), which is defined as the value of all outputs produced by the system during one cycle divided by the total value of all inputs used by the system during one cycle of the system'(Lynam and Herdt,1989). In normal economic practice, the outputs and inputs would be confined to those attributes, such as purchased inputs, labour cost and value of the harvest. Ehui and Spencer (1990) have extended this by costing natural resources used within the system, such as soil nutrient. The costed productivity factors are aggregated to give the Total Factor Productivity(TFP) index. If the TFP shows a constant or upward trend over a period of time, then the system is sustainable. The TFP can be analysed to determine which factors contributes most to sustainability or the lack of it. This study adopted the construct as used by Ehui and Spencer(1990) and Lyman and Herdt(1989).

Following from the fact that climate change menace cannot be eradicated because both the natural and anthropogenic causes are part of the dynamic ecosupport systems, emphasis is now on building adaptation/mitigation and resilience capacities of farmers. This study is therefore geared towards exposing the devastating effects of climate change on agricultural sustainability and the adaptation/mitigation approaches practiced in the study areawith a view to emphasizing the technologies that are in tandem with climate smart agricultural practices.

2.0 Materials and methods

The study was carried in South-east (SE) Nigeria. South-east lies within Latitudes 5°N to 6° N of the Equator and Longitudes 6°E and 8°E of the Greenwich (prime) Meridian (M.S Corporation, 2009). Southeast Nigeria is made up of five States namely; Abia, Anambra, Ebonyi, Enugu and Imo. The zone occupies a total land mass of 10,952,400 hectares with a population of 16,381,729 people (NPC, 2006). Multi-stage sampling technique was used to select a sample of 312 respondents across two South-east States; purposively selected based on their positions under topographic and vegetation delineations of the five states.

Data for the study were collected with the aid of well-structured and validated questionnaire. Primary data concerning the respondents socio-economic features and adaptation/mitigation measures being taken against the changing climate were collected while secondary data on the metrological and input-output variables were collected from National Root Crop Research Institute Umudike, Imo Agricultural Development Project and National Bureau of Statistics(NBS) data bases, respectively.

Data were analysed using descriptive statistics tools like mean, frequency, percentage and frequency polygon or line graphs. Others are the use of Total factor productivity model as an index of productivity and the use of ordinary least square regression model to measure the influence of climate change on sustainability.

Here Total Factor Productivity(TFP) is given as

$$TFP = \frac{V_{T_o}}{V_{T_n}} = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} P_{qij} Q_{ij}}{\sum_{j=1}^{m}\sum_{t=1}^{n} P_{xtj} X_{tj}} \quad \text{……Eqn. 2.1}$$

Where V_{T_o} = Value of Total Output in Naira/annum

V_{T_n} = Value of Total Input in Naira/annum.

P_q = Price of output in Naira

Q = Quantity of Output

i = Type of output (i ranges from 1- nth output type)

j = Farmers (j ranges from 1 - mth farmer)

P_x = Price of input

X = Quantity of input

t = Type of input (t ranges from 1 – nth input type)

Adopted from Lynam and Herdt,(1989); Ehui and Spencer (1990); Ali and Byerlee, (2000), Sidhu and Byerlee, (1992); Spencer and Swift, (1992) and Cassman and Pingali, (1995); Nwaiwu, *et.al*; (2014a).

The multiple regression model for this is stated implicitly as:

Ss = f(Ts, Rf, Rh, Sh,T, e) ……Eqn. 2.2

Where Ss = Agricultural Sustainability (measured as Total factor productivity for 30 years).

- Ts = Mean annual temperature of the system for 30 years period in ^{0}C
- Rf = Mean annual rainfall for 30 years period in mm
- Rh = Mean annual relative humidity for 30 years period in %
- Sh = Mean annual number of hours of sunshine also for 30 years period in (in hours)
- T = Time trend variable measuring the number of years involved (1, 2, 3, 4, …30)
- e = error term (Nwaiwu *et al*., (2014a)

The *a priori* theoretical expectations of the coefficients are as follow;

Ts = temperature is hypothesised to be negatively and significantly related to sustainability. The basis of this is that if temperatures continue to increase beyond a specific threshold, a crop's productive summer growing season could become shorter, thus reducing the yield and productivity (Monteith, (1981); Rosenzweig and Hillel (2000)).

Rf = precipitation is theorized to affect sustainability positively. The basis for this theoretical expectation is justified with the fact that precipitation increase affects crop yield positively (IPCC, 2001a; IPCC, 2001b; Rosenzweig and Hillel, 1995) by readily dissolving the nutrients for easy soil absorption by plants.

Rh = relative humidity should be positively related TFP. The basis for this assumption is that crops tend to absorb soil nutrients for optimum yield when there is sufficient humid air (Adejuwon, 2004).

Sh = sunshine duration is expected to be positively related to TFP. The basis for this *a priori* expectation lies in the fact that tropical crops require higher photoperiods (day lengths) for their vegetative and reproductive growth and development (Adejuwon, 2004).

*Apriori Expectation:*bTs<0, while bRf, bRh, bRh, and bSh >0.

3.0 Results and Discussion

3.1 Trend Climate variable

3.1.1 Trend of Temperature

Table 3.1 shows the analysis of temperature records in South-east Nigeria between the periods of 1972 through 2011

Table 3.1 Analysis of Temperature Records from 1972-2011.

Temperature	Values
Mean (^oC)	26.77
Standard deviation (^oC)	0.441
Maximum temp. (^oC)	27.65
Minimum temperature (^oC)	25.95
Trend (^oC/year)	1.192*
Correlation coefficient (r)	0.425*

*Significant at 1%
Source: NRCRI, Umudike, 2011

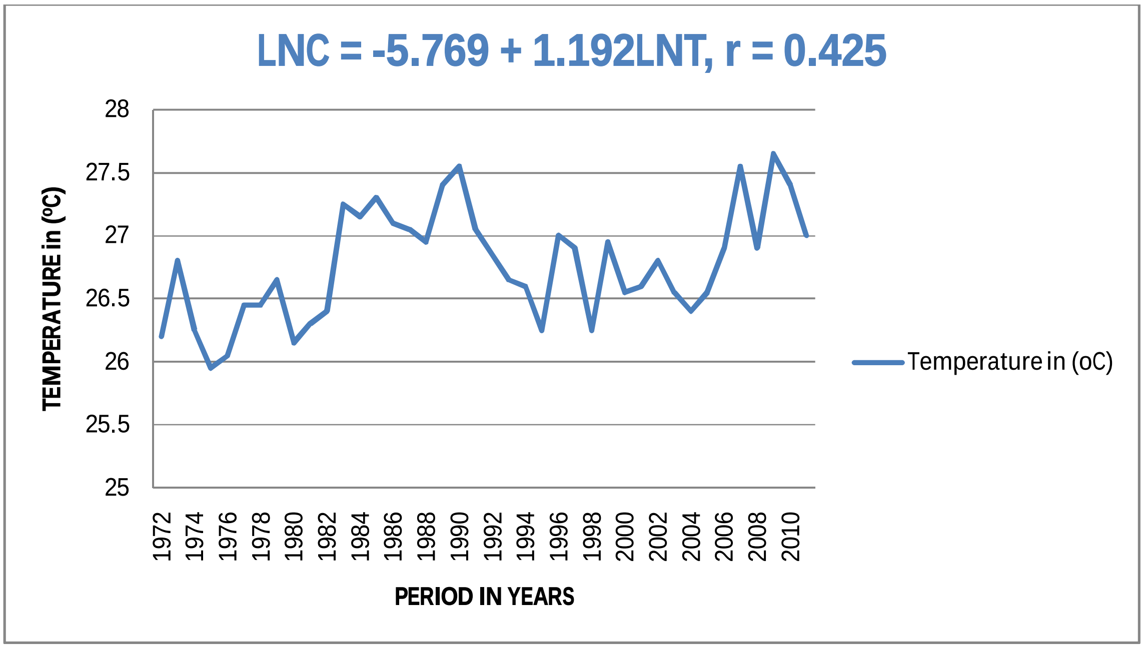

Figure 3.1 Trend of temperature of Southeast Nigeria between 1972-2011.
Source: NRCRI, Umudike, 2012.

According to the statistical records of temperature in South-east Nigeria as recorded by the Agromet unit of the NRCRI, Umudike from 1972-2011, temperature showed an increasing trend with the highest temperature occurring in 2009 at 27.65^{o}C and the lowest occurring in 1975 at 25.95 ^{o}C (Table 3.1 and Fig.3.1). Also the mean and standard deviation of the temperature record were 26.77 ^{o}C and 0.441 ^{o}C respectively (Table 3.1). This shows that there was a very small variability in temperature from year to year. The trend coefficient is 1.192 and is statistically significant at 1% level (Table 3.1). The correlation coefficient is 0.425 and is statistically significant at 1% level implying that temperature has a significant positive relationship with time. This therefore indicates that climate with respect to temperature is really changing and increasing; hence there is indeed global warming. This finding is consistent with the report of Nwajiuba and Onyeneke, (2010) that temperature is positively and significantly increasing with time, hence the global warming is real. This is also in tandem with New *et. al.*, (2006) who found that extreme cold days and nights have decreased and hot days and nights have increased. According to Monteith, (1981), if temperatures continue to increase beyond a specific threshold, a crop's productive summer growing season could become shorter, thus reducing the yield.

3.1.2 Trend of Rainfall

Table 3.2 shows the analysis of rainfall records in southeast Nigeria between the periods of 1972 through 2011.

Table 3.2 Analysis of Rainfall Records from 1972-2011.

Rainfall	Value
Mean(mm)	2158.89
Standard deviation (mm)	288
Maximum (mm)	2751.9
Minimum (mm)	1511.4
Trend (mm/year)	2.09
Correlation coefficient (r)	0.091

Source:NRCRI, Umudike, 2012

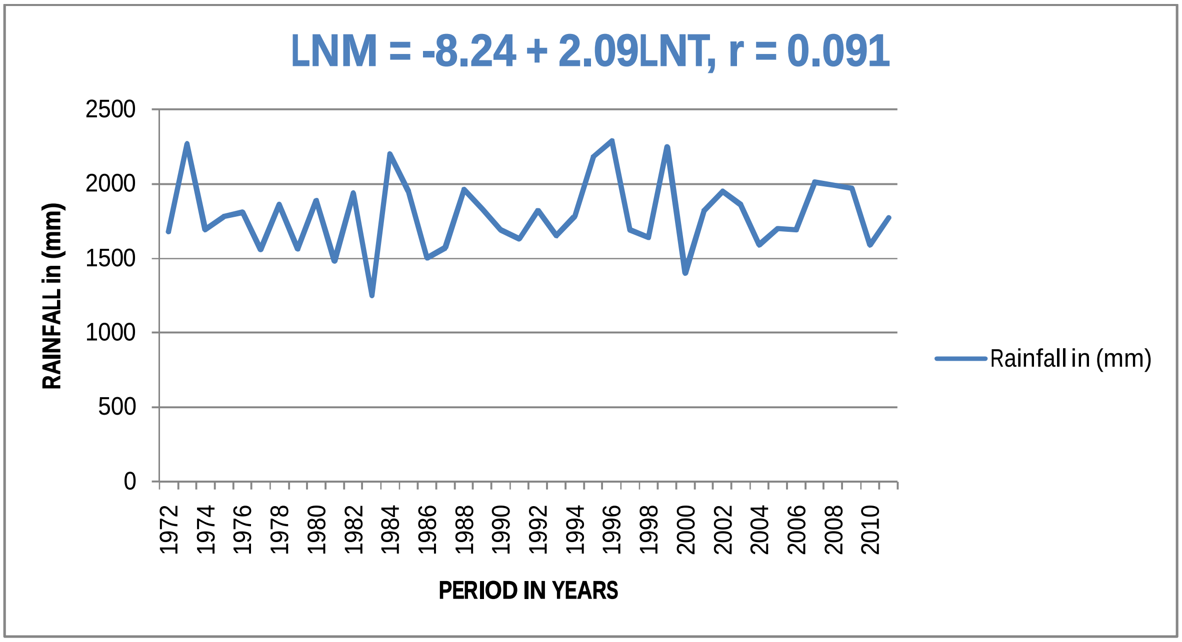

Figure 3.2 Trend in Volume of Rainfall of Southeast Nigeria between 1972-2011.
Source: NRCRI, Umudike, 2012.

Statistics of rainfall volume in southeast Nigeria between the periods of 1972-2011 showed an increasing trend with the highest occurring in 1996 and lowest occurring in 1983 with values of 2751.9mm and 1511.4mm respectively (Table 3.2 and Fig.3.2). The mean and standard deviation are 2158.89mm and 288mm respectively (Table 3.2). This implies that there is a high variability in rainfall within this period hence the observed positive trend though not statistically significant. The coefficient of correlation is 0.091, but not statistically significant. This indicates that there is a weak positive relationship between rainfall and time. This finding slightly disagrees with the observation of Nwajiuba and Onyeneke (2010) who reported a decreasing trend in rainfall. The deviation could be as a result of the fact that they used rainfall records from 1978-2007 which did not account for the changes that may have occurred before 1978 and after 2007, which is captured in this study. However, the result is consistent with the findings of New *et.al.*,(2006) that average dry spell length, average rainfall intensity, and annual 1-day maximum rainfall all show statistically significant increasing trends. This indicates an increased trend in the likelihood of the occurrence of weather hazards, such as heavy storms leading to floods, high temperatures, and both seasonal and mid-rainy season droughts that agriculture and other sectors have to contend with. According to Falkenmark, (1989) rainfall is the major limiting factor in the growth and production of crops worldwide and adequate moisture is critical for plants, especially during germination and fruit development. Obviously, food crops grown in Southeast Nigeria which is dominantly a rainforest zone require high amount of rainfall. Cassava particularly requires about 1000-1500mm of rainfall for optimum production (Wheatley *et al;* 1995). This favourable rainfall volume may account for the good performance of Nigeria as the world's largest producer of cassava (FAOSTAT, 2012).

3.2 Sustainability of Agricultural Production Systems in Southeast Nigeria

Table 3.3 shows the sustainability of cassava production in SE Nigeria between 1982-2011.

Table 3.3 Analysis of Sustainability/TFP of Cassava Production in SE Nig. (1982-2011).

Sustainability/TFP	Value
Mean	1.17
Maximum	1.94
Minimum	0.16
Standard deviation	0.44
Trend	0.033*
Correlation coefficient (r)	0.534*

*significant at 1%
Source: Field Survey Data, 2012

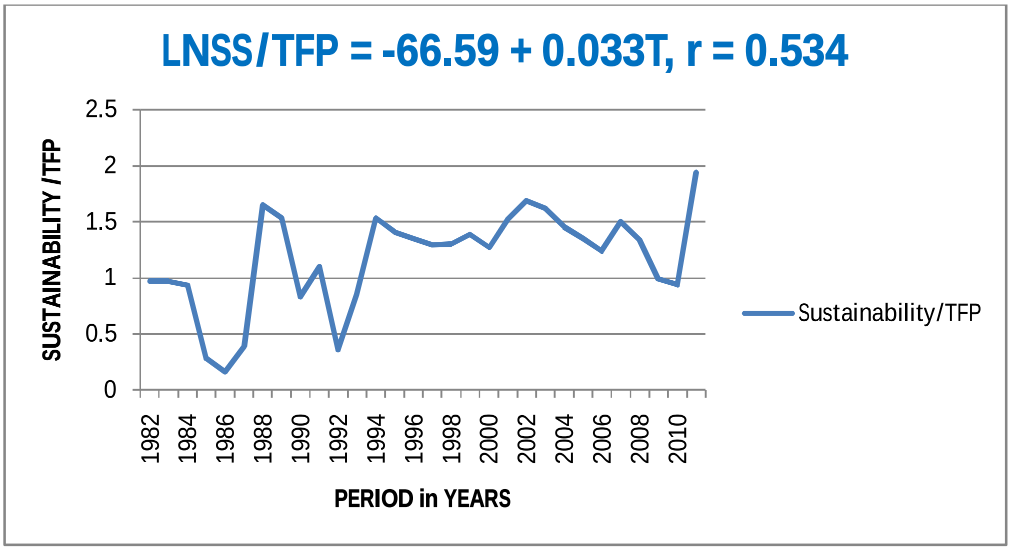

Figure 3.3 Trend of Sustainability/TFP of Cassava Production in Southeast Nigeria from 1982-2011
Source: IMADP 1982-2011/NBS, 2008.

According to Tables 3.3, and Figure 3.3, the mean sustainability of cassava production in Southeast Nigeria was 1.17, with a standard deviation of 0.44. This shows that there was a relatively low variability in sustainability of cassava production over the period studied. The maximum and minimum values were 1.94 and 0.16 occurring in the years 2011 and 1986 respectively. The trend coefficient was 0.033 and was statistically significant at 1% level and positively related to sustainability. This implies that sustainability is showing a statistically significant increasing trend over the time studied. Therefore, according to Spencer and Swift, (1992) cassava production in Southeast Nigeria is sustainable since it shows an increasing trend over time although there is observed fluctuations over the period which may be caused by such factors like annual climate challenges, pest and diseases, labour availability and efficiency, and market prices. Table 3.3 also shows that the coefficient of correlation was 0.534 and was statistically significant at 1% level. This also implies that sustainability/TFP strongly changes with time and that the time trend effect should not be ignored.

3.3 The Effect of Climate Change on Agricultural Sustainability.

Table 3.4 Shows the Effect of Climate Change on Agricultural Sustainability.

Table 3.4 Result Showing the Effects of Climate Change on Agricultural Sustainability

Predictor Variables	Linear	Semi-log	Cobb- Douglas	Exponential
Constant	12.27	23.14	13.89	11.25
	(2.829)*	(1.3187)	(0.5248)	(1.64)
Temp. (X_1)	-0.4741	-11.3572	-10.264	-0.4918
	(-3.73341)*	(-3.118)*	(-1.8704)***	(-2.452)**
Rainfall (X_2)	0.0011	2.004	2.4942	0.0013
	(5.3693)*	(5.321)*	(4.3940)*	(4.0234)*
Rel. Hum.(X_3)	0.0048	0.2924	0.5132	0.0045
	(0.1389)	(0.1161)	(0.1352)	(0.0835)
Sun. dur (X_4)	-0.2173	-0.7991	-1.0389	-0.2443

.	(-1.3378)	(-1.0971)	(-0.9467)	(-0.9519)
Time (X_5)	0.0150	0.1367	0.2440	0.0239
	(2.5748)**	(2.170)**	(2.572)**	(2.5906)**
R^2	0.73	0.72	0.63	0.61
F-Value	(13.10)*	(12.69)*	(8.50)*	(7.58)*
Standard error	0.2504	0.253	0.381	0.395
TSS	5.62	5.62	9.69	9.69
N	30	30	30	30

*Significant at 1%; **Significant at 5%; ***Significant at 10%
Source: Field Survey Data, 2012.

According to Table 3.4 showing the effects of climate change (Temperature, Rainfall, Relative humidity, Sunshine duration) and Time trend variable on agricultural sustainability, the lead equation chosen was the semi-log functional form. This choice emanated from the fact that the outcome from the semi-log function best captured the *a priori* expectation. Besides, it has the second highest value of the coefficient of multiple determinations R^2 with a value of 0.72. This implies that 72% of the variations in the dependent variable, agricultural sustainability is explained by the variations in the independent variables (climate elements), plus time trend variable. This is confirmed by the F-value of (12.69) which is statistically significant at 1% level with F-tab of 3.90. The coefficient of temperature and rainfall are statistically significant at 1% level with absolute t-cal of 3.18 and 5.32 respectively and t-tabulated of 2.76. Temperature was inversely proportional to agricultural sustainability which means that the higher the temperature, the lower the agricultural sustainability. It is obvious that higher temperatures reduce the yield of most crops. According to Monteith, (1981) higher temperatures beyond a specific threshold reduces a crops productive summer growing season and thus reduces the yield. Besides, higher temperatures reduce labour use efficiency, hence lower total factor productivity and agricultural sustainability. This result is in line with *a priori* theoretical expectation that temperature is negatively related to sustainability.

Furthermore, the table showed that coefficient of rainfall was directly proportional to agricultural sustainability. This implies that the higher the volume or amount of rainfall, the more sustainable the agricultural production system or sustainability. This is also in line with the *a priori* theoretical expectation that the coefficient of rainfall (Rf) >0. This finding agrees with Falkemark, (1989) who opined that availability of rainfall is the major limiting factor in the growth and production of crops worldwide.

3.4 The Measures Employed by Farmers to Mitigate the Effects of Climate Change.

Table 3.5 shows the distribution of respondents according to measures/ strategies being adopted by food crop farmers to mitigate/adapt to the effects of climate change on their food production activities.

Table 3.5 Mitigation/Adaptation Strategies to Climate Change.

Strategy Adopted	Imo		Ebonyi		Pooled	
	Freq*	%*	Freq*	%*	Freq*	%*
Late com.. of planting	124	68.50	125	95.40	249	79.80
Digging of ditches	70	38.70	07	20.60	97	31.10
Use of fertilizer	126	69.60	122	93.10	248	79.50
Use of pesticide	49	27.10	121	92.40	170	54.50
Const. of farm shed	85	47.00	117	89.30	202	64.70
Use of irrigation	61	33.70	13	9.90	74	23.80
Choice of crop. syst	163	90.10	131	100.00	294	94.20
Breaking of daily wk	150	82.90	131	100.00	281	90.10
Mulching strategy	144	79.60	99	75.60	243	77.90
Planting of cov. crops	127	70.20	131	100.00	258	82.70
Making of structures	50	27.62	85	64.80	135	43.27
Contour ploughing	56	3.30	04	3.10	06	1.90
Crop rotation	139	76.80	131	100.00	270	86.50
Shifting cultivation	103	56.90	126	96.20	229	73.40
Continuous cropping	90	49.70	04	3.10	94	30.10
Mixed farming	175	96.70	128	97.70	303	97.10
Mono cropping	14	7.73	40	30.50	54	17.30
Mixed cropping	181	100.00	131	100.00	312	100.00

*Multiple responses recorded, hence frequency and percentage not additive
Source: Field Survey Data, 2012; (Nwaiwu, *et. al*., 2014c)

According to Table 3.5, the farmers in the study area adopted the following strategies to adapt to the menace of climate change; (i) late commencement of planting, (ii) use of fertilizers, (iii) use of pesticides, (iv) construction of farm sheds, (v) selection of cropping pattern/system, (vi) breaking of daily work schedules or periods, (vii) mulching, (viii) planting of cover crops, (ix) crop rotation, (x) shifting cultivation, (xi) mixed farming, (xii) mixed cropping. According to the Table, 79.8%, 79.5%, 54.5%, 64.7%, 94.2%, 90.1%, 77.9%, 82.7%, 86.5%, 73.4%, 97.1%, and 100% respectively responded positively to the use of these strategies. The adoption of the above strategies agrees with the principles of climate-smart agriculture. This follows from the fact that they are individually and/or collectively specific, measureable, achievable, reliable and timely (McCarthy et al., 2012).

It is obvious from the Table that while the farmers in the two States of focus reacted similarly in the use of most of the outlined strategies, their reaction in the use of pesticides differs. Also in Table 3.5, only 23.8% of the studied population used irrigation facilities in their production process. This fact goes a long way in explaining the rudimentary level of farm production in the study area where farming is wholly dependent on rain-fed water source. The 23.8% that used irrigation may have been using non-automated irrigation facilities but manual operation using borehole water, and pumping from streams and rivers.

4.0 Conclusion

The study has explicitly shown that the climate system is drastically changing and negatively affecting agricultural sustainability. While temperature increases reduces the yield potential of crops, rainfall showed a seemingly positive relationship to sustainability but the incidence of flooding and erosion that are exacerbated by excessive rainfall invariably cancels the positive effects on sustainability. The study finally identified the climate smart strategies adopted to include late commencement of planting, planting of cover crops, use of fertilizers, crop rotation, mixed farming/cropping among others as being appropriate in the area. These suggest that with little government incentive inform of subsidies and improved technologies the resilience capacities of farmers would be enhanced.

References

Adams, R.M., McCarl, B.A., Segerson, K., Rosenzweig, C., Bryant, K. J., Dixon, B.L., Conner, R. Everson, R.E and Ojima, D., (1998b). The economic impacts of climate change on US. Agriculture. The economic Impact of climate change, R. Mendelsohn and J. Neumann (eds), Cambridge University press, Cambidge.

Adejuwon S.A. (2004). "Impact of climate variability and climate change on crop yield in Nigeria" Paper presented at the stakeholders workshop on Assessment of Impacts and Adaptations to climate change Conference

Ali, M. and D. Byerlee. (2000). "A Decomposition Analysis of Productivity Growth and Resource Degradation in Pakistan's Punjab", Policy Research Working Paper, Rural Development Dept, World Bank, Washington, DC.

Apata T.G.; K.D. Samuel and A.O. Adeola (2009). Analysis of Climate Change Perception and Adaptation among Arable Food Crop

Farmers in South Western Nigeria. Contributed Paper presented at the International Association of Agricultural Economists' 2009 Conference, Beijing, China, August 16-22,209.

Ayodele, O. S., Obafemi, F. N., & Ebong, F. S. (2013). Challenges facingthe achievement of the Nigeria vision. Global Advanced Research Journal of

Social Sciences, 27, 143-157.

Beddington J, Asaduzzaman M, Fernandez A, Clark M, Guillou M., Jahn M, Erda L, Mamo T, van Bo, N, Nobre CA, Scholes R, Sharma R, Wakhungu J (2011). Achieving Food Security in the Face of Climate Change: summary for policy makers from the Commission on Sustainable Agriculture and Climate Change. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Beddington J, Asaduzzaman M, Clark M, Bremauntz AF, Guillou M, Howlett D, Jahn M, Lin E, Mamo T, Negra C (2012). What Next for Agriculture after Durban. Science 335:289-290. Available online at: http://dx.doi.org/10.1126/science.1217941. PMid:22267797http://dx.doi.org/10.1126/science.1217941

Buckland, R. W. (1997). "Implications of Climatic Variability for Food Security in the Southern African Development Community." Internet Journal of African Studies, Issue No. 2 – March;

Cassman, K.G. and P.L. Pingali. (1995). "Extrapolating Trends from Long-Term Experiments to Farmers' Fields: The Case of Irrigated Rice Systems in Asia." In V. Barnett., R. Payne and R. Steiner (eds), Agricultural Sustainability: Economic, Environmental, and Statistical Considerations. London: John Wiley and Sons, Ltd.

Dumanski J. (1987) Evaluating the Sustainability of Agricultural Systems. In Africaland : Land Development and Management of Acid Soils in Africa. IBSRAM proceedings No 7. Bangkok, Thailand IBSRAM.

Ehui S.K. and Spencer D.S.C (1990) Indices for Measuring the Sustainability and economic viability of farming systems. RCMP Research Monograph No.3. IITA Ibadan, Nigeria.

Eze, C., Eze, V., Korie, O., Orebiyi, J., Onyemuwa, S., Mathews- Njoku, E., Onoh, P. and Asiabaka, C. C.(2008) "Climate Change, Crop Production and Adaptation Strategies in Nigeria" In Farming and Rural Systems Economics; edited by Werner Doppler and Siegfried Bauer-Climate Change and Adaptations in Nigeria, Chinedu Nwajiuba(Ed) Vol.95 Pp 27-34

Falkenmark, M (1989) "Water Scarcity and Food Production in Africa," in D. Pimentel and C. W. Hall, eds., Food and Natural Resources (San Diego: Academic Press), p. 163.

Fischer G.; M. Shah and H. Van Velthuizen (2002) " Climate Change and Agricultural Vulnerability" International Institute for Tropical Applied Systems Analysis. Report prepared under UN Institutional Contract Agreement 1113 for World Summit on Sustainable Development. Luxemburg, Austria.

Food and Agriculture Organization (FAO)(2012) Accessed on the 30/04/2013 FAOSTAT 2012 @ www.faostat.org.

Food and Agriculture Organization FAO, (2016) Climate Smart Agriculture Internet paper accessed 27/06/2016 http://www.fao.org/climate-smart-agriculture/en/

Food and Agriculture Organization (FAO) (1989) Sustainable Agricultural Production: Implications for International Agricultural Researh. Technical Advisory Committee, CGIAR. FAO Research and Technical Paper No.4.Rome, Italy: FAO.

Keaney, D.R. (1989) Towards a Sustainable Agriculture: Need for Clarification of Concept and Technology. AMER J. Alt. Agric.4: 101-05.

Lee, L.K. and Goebel J.J (1986). Defining Erosion Potential in Crop Land : A Comparison of Land Capability Class- Subclass system with RKLS/T Categories. J Soils and Water Conservation. 41: 41-44.

Lynam J.K. and Herdt R.W.(1989). Sense and Sustainability: Sustainability as an objective in International Agricultural Research. Agric. Econs. 3: 381-98.

Malone, T (1974) "Meeting Transcript," National Academy of Sciences, May 28.

Matarira, C. H.; Makadho, J. M.; Mwamuka, F. C. (1995). "Zimbabwe: Climate Change Impacts onMaize Production and Adaptive Measures for the Agricultural Sector" in Ramos-Mane, C. andBenioff, R. (Editors) Interim Report on Climate Change Country Studies, US Country Studies Program, Washington, DC. Internet paper accessed on 19/02/2010.

McCarthy N, Winters P, Linares AM, Essam T (2012). Indicators to Assess the Effectiveness of Climate Change Projects. Inter-American Development Bank. Impact-Evaluation Guidelines: Technical. Notes, No. IDB-TN-398:1-37.

Monteith, J (1981) "Climate Variation and the Growth of Crops," Journal of Royal Meteorological Society 107, p. 749

National Population Commission(NPC) (2006) *Nigerian Agricultural Magazine* Vol. 4 No.3 Pp. 22 August/September, 2010.

Naess LO (2011). Climate-Smart Agriculture: the new holy grail of agricultural development? Future Agricultures. Available online at: http://www.future-agricultures.org/component/content/article/38-blog/7643-climate-smart-agriculture-the-new-holy-grail-of-agricultural-development.

New, M.; Hewitson, B.; Stephenson, D. B.; Tsiga, A.; Kruger, A.; Manhique, A.; Gomez, B.; Coelho, C.A. S.; Masisi, D. N.; Kululanga, J.; Adosi, J.; Mbambalala, E.; Adesina, F.; and Saleh, H.(2006) "Evidence of Trends in Daily Climate Extremes over Southern and West Africa" Journal of Geophysical Research – Atmospheres 111(D14). Reprint.

Nwaiwu, I.U.O; J.S.Orebiyi; D.O. Ohajianya; U.C. Ibekwe; S.U.O. Onyeagocha; A. Henri-Ukoha; M.N. Osuji and C.M. Tasie (2014a) The Effects of Climate Change on Agricultural Sustainability in Southeast Nigeria- Implications for Food Security. Asian Journal of Agricultural Extension, Economics and Sociology Vol. 3(1): Pp 23-36. 2014 Article No AJAEES.2014.003 SCIENCEDOMAIN International www.sciencedomain.org

Nwaiwu, I.U.O; D.O. Ohajianya; J.S. Orebiyi; U.C. Ibekwe; J.I. Lemchi; S.U.O. Onyeagocha; B.Odoemena; C.O. Utasi; C.O. Osuagwu and C.M. Tasie (2014c) Cliamte Change Trend and Appropriate Mitigation and Adaptation Strategies in Southeast Nigeria. Global Journal of Biology, Agriculture and Health Sciences Vol. 3(1) Pp 120-125. Global Institute for Research and Education.

Nwajiuba, C.U. and R. Onyeneke (2010) Effects of climate change on the agriculture of sub-Saharan Africa: Lessons from Southeast Rainforest Zone of Nigeria. Oxford Business & Economics Conference Program, June 28-29, 2010
St. Hugh's College, Oxford University, Oxford, UK. Internet paper accessed 24/10/11.

Okigbo, B.N. (1991) Development of Sustainable Agricultural Production Systems in Africa: Roles of International Agricultural Research Centres and National Agricultural Research Sytems. Ibadan, Nigeria: IITA.

Pierce, F.J; Larson, W.E, Doudy R.H and Graham, WA. (1983). Productivity of Soils: Assessing Long Term Change due to Erosion.J.Soil and Walter Conservation 38: 39-44.

Putman J.W.(1986). A Conservation Policy Monograph. J. Soil and Water Conservation . 41: 406-09

Rosenzweig, C. and D., Hillel (1995). Potential Impact of Climate Change on Agriculture and Food Supply. Consequences: The Nature and Implications of Environmental Change, Vol. 1, No. 2, Summer, 1995.

Rosenzweig C, Hillel D. (2000) Soils and global climate change: Challenges and opportunities. Soil Sci., 165, 47-56.Soil Sci 165:47–56.

Sidhu, D.S. and D. Byerlee. (1992). "Technical Change and Wheat Productivity in the Indian Punjab in the Post-Green Revolution Period." CIMMYT Economics Working Paper 92-02. Mexico, D.F.

Skutsch M, Bird N, Trines E, Dutschke M, Frumhoff P, De Jong, B, Van Laake P, Masera O

Murdiyarso D (2007). Clearing the Way for Reducing Emissions from Tropical Deforestation. Environ. Sci. Policy, 10:322-334. Available onlineat:http://dx.doi.org/10.1016/j.envsci.2006.08.009.

Smith P, Martino D, Cai Z, Gwary, D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O (2007). Agriculture. In: Metz B, Davidson, OR, Bosch PR, Dave R, Meyer LA (eds) Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge and New York.

Spencer D.S.C and Swift M.J.(1992). Sustainable Agriculture. Definition and Measurement. In Biological Nitrogen Fixation and Sustainability of Tropical Agriculture. Proceedings of Fourth International Conference of the African Association for Biological Nitrogen Fixation (AABNF) Held at the International Institute of Tropical Agriculture (IITA), Ibadan Nigeria 24-28 September 1990. Edited by Mulongoy K., Gueye M. and Spencer D.S.C. IITA, A Willey Sayce Co-publication.

Wollenberg E, Campbell BM, Holmgren P, Seymour F, Sibanda L, von Braun J (2011). Actions Needed to Halt Deforestation and Promote Climate-Smart Agriculture. CCAFS Policy Brief 4. CGIAR Research Program on Climate Change, Agriculture and Food

Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org.

Wollenberg E, Higman S, Seeberg-Elverfeldt, C, Neely C, Tapio-Biström ML, Neufeldt H (2012). Helping Smallholder Farmers Mitigate Climate Change. CCAFS Policy Brief 5: 1-6. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: ccafs.cgiar.org/resources/reports-and-policy-briefs.

World Commission on Environment and Development (1987) Our Common Future. London Oxford University Press