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Climatic Dynamics and Food Security Implications in Sub-Sahara Africa.

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Abstract

To bring to the fore the aim of this research, effects of fluctuating temperature, was measured against food and nutrition security in the region using food production index, and undernourished population growth rate as proxies; controlled over share of arable land, irrigation, population and labour share for agriculture. Dynamic panel of generalized method of moments (GMM) was adopted, the period 2000 to 2016 were considered and 29 countries in sub-Sahara Africa were selected within the empirical framework of global water balance as mentioned by Rai and Singh (2012). Findings from the study reveals that the short run effect of temperature increase in degrees pose at least -3.1% negative and significant impact effects on the food production while the long run elasticity hits -7.5% and the controlled effect on arable land revealed a positive impact on the food production to the tune of 3.9%. Contrarily, arable land expansion reduces the under nourished population by -8.55%. Population increase on the other hand increases undernourished population in the region to the tune of 11.95%. The study therefore recommended expansion in the arable land and encourages population control policy in order to negate the undesired effects of temperature on food and nutritional security.

Keywords: Climate, Temperature change, Food security, sub-Sahara Africa

1. INTRODUCTION

Agricultural performance in the world has been tied to some climatic factors and patterns that vary across zones and regions. However, the roles of climatic factors and the disparity in climatic zones pose major challenge on the realization of food security in sub-Sahara Africa. Hence, the varying climatic indicators in the region as shown in the figure 1 below further questions the thrust for a steady and stable food production leading to food security. Food security is a multidimensional yet complex phenomena as reiterated by[1] who expanded the scope for measuring food security to include food production index, mortality rate and life expectancy at birth total while rainfall and annual temperature were the indicators for climate change.

Climate change has constantly threatened food and nutrition security in sub-Sahara Africa despite several reforms of the national agricultural policy accompanying interventions. For an instance, according to [2,3], the regular rainfall in 2011 caused a sharp drop in the year's cereal and pasture production in Africa. Likewise, in Central Africa, mixed weather conditions in Cameroon and the central Africa Republic in early 2012 posed negative impacts on early crop. Also North Africa witnessed a sharp decline in cereal production in Morocco as a result of erratic and insufficient rains during the late 2011 and 2012. These effects of climatic factors amounts to pressure on food price index and subsequently heightens food insecurity in the region. Africa is therefore confirmed to be ranked as one of the regions to be the worst hit by continued climate change with a greater impacts on the agricultural sectors based on the 2050 projection. The projected food outcomes on cereal production in the year 2050 is expected to decline by the 3.2% and wheat production is expected to share more from the negative effects of climate change. Conversely, the projected food price is expected to be 4%, 7%, and 15% higher than the historic price of food attributed to climate change and climatic dynamics whilst outcomes threaten food availability, affordability and food self-sufficiency in sub-Saharan Africa states, [4].

Furthermore, efforts to mainstream Smart Climate agriculture (SCA) in the region reiterates the emphasis on agriculture as the mainstay of African economy despite the negative impacts

of climate change on food security and the associated loss in interest by the youth population, as reported by [3]. Although, agricultural sector could have been stationed to benefit from the dense population growth in sub-Sahara Africa but reverse is the outcome now. For an instance, Africa's population is predicted to grow with a geometric progression and could lead to the projected population growth of between 1.93 and 2.27 billion people in the year 2050 compared to 1.02 billion in 2010 alongside the dehumanizing scourge of food insecurity in the region, [2]. Juxtaposing the population growth rate in Africa and food production, it could be seen that if the population growth trend sustains, the current outcome of food and nutrition insecurity would be worse. Furthermore, the estimated number of people facing chronic food deprivation in the world increased to 821 million in 2017 from 804 million in 2016. This suggest that the prevalence of food insecurity is worsening in Africa just as the region has the highest prevalence of undernourishment that affects close to 21% of the population (256 million people) compared to other regions such as South America with 5% prevalence of undernourishment in 2017 and Asia prevalence of undernourishment decreased to 11.4%, [5].

On the other hand, several programmes and policies have been put in place in the thrust for a sustainable food secured region. The most recent of these policies are tied with the Millennium and Sustainable development goals. Sadly, these efforts by organized institutions and regional governments to ensure sustainability and adaptability in climatic dynamics towards the realization of food security, have not fully delivered on its promise. Food security as reported indicators by the United Nation for Food and Agriculture Organization within a period of 2014-2016 still shows a decline valued at \$161 per person from \$163 per person for a period of 2013-2015 on the average in food production. Considering other food production components, the percentage of arable lands in sub-Sahara Africa used for agriculture also declined to 42.14% in 2011-2014 from 43.16% in 2010. Also, hectare per person declined to 0.21% in 2000 from 0.27% in 2015 yet the average carbon content in the top soil as a percentage in weight in 2008 and 1991 were 1.12% and 2.1% respectively for Africa. Another major devastating blow that hit the region's economy is that the share of

agriculture employment also declined by 4.1% within 2017-2018, yet, food insecurity still persist in the region, [5, 6].

Therefore, it is on this premise that this study is poised to ascertain the inter-linking influence of climatic dynamics on the realization of food and nutritional security in Sub-Saharan Africa. In order to achieve this, the effects of the fluctuating temperature on food security in the region would be measured over time. The correlations between the share of arable land for agricultural purpose and the food security in the region alongside the impact of the increasing population growth in the region on food security would be investigated. The remaining part of this research would be organized in headings starting from introduction, patterns of climate dynamics in sub-Sahara Africa, empirical literatures, empirical framework, result and discussion and summary and conclusion. In addition, findings from this study would to a great extent inform the regional and multinational organization responsible for food security issues in sub Saharan Africa such as the United Nations Food and Agriculture Organization on the real projectile to the path of sustainable food security in Sub-Sahara Africa.

2. Climatic Dynamics and Food Security in sub-Sahara Africa.

Increased variability in the climate change pattern continuously threatens the future and sustainability of agriculture in world but of all the hunger hotspots in the world, Sub Saharan African countries are the worst hit.. Projections have revealed that there would be an increased concentration of the poor who depend heavily on agriculture as a major means of livelihood in the developing countries of South Asia and sub-Sahara Africa. In this light, [7] suggested a Climate smart agriculture (CSA) for food security approach as a means of integrating climate change issues in both the adaptation and mitigation practices in order to enable African agriculture thrive towards a food secure region. Among other findings, CSA found building evidence, increasing local institutional effectiveness, fostering coherence between climate and agricultural policies and linking climate change and agricultural financing as the road map for inclusive climate and agricultural policy strengthening. Global

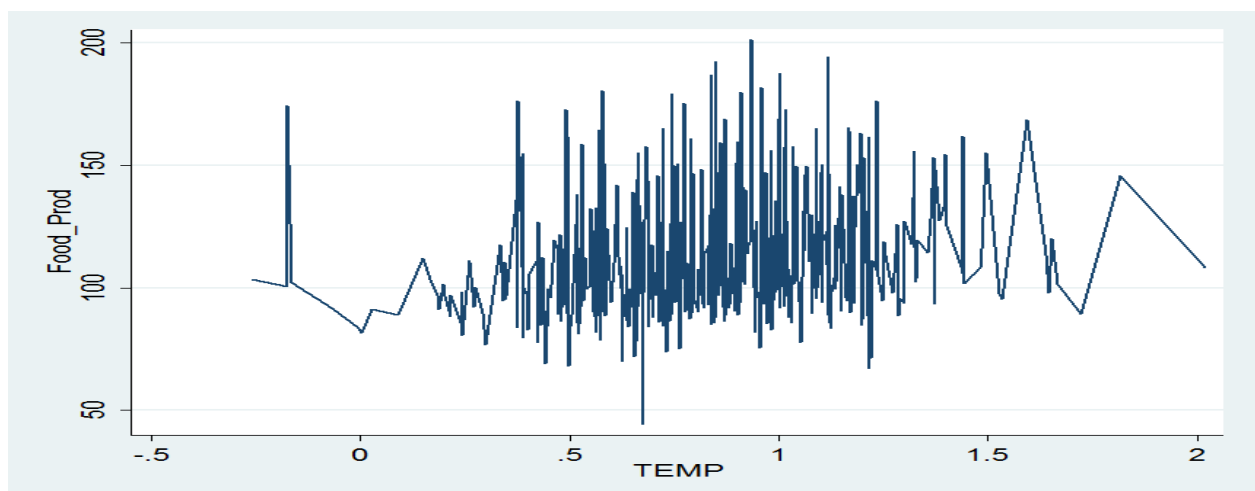
water scarcity reemerged as an aspect of climate change that threaten the food policy in addition to energy crisis and credit crisis. Therefore, it was revealed that the increasing population growth and income had put pressure and water scarcity and thereby leading to delayed attainment of food security, [8]. Furthermore, a micro perspective on the impact of climate change on the provision of food security in Ethiopia used a two-stage regression approach. Findings from the first stage show that credit, extension and information are the major drivers of adaption. Secondly, the effect of adaptation on food productivity showed that there exist a significant different in food productivity between farmers that applied adaptation practices and the farmers that do not apply adaptation practices to cope with climate change using an econometric approach on Ricardian model, [9]. Likewise, Mexico has also shown to be one of the countries whose crop production is heavily limited by climate change. For example, maize production out increases higher than the production area of cultivation due to climate factors like low, seasonal and fluctuating rainfall limits the crop area for the growing of maize,[10].

On the other hand, African region has been classified to be one of the poorest regions in the world with slow growth in agricultural sector and low per capita income in 2010 to the value of \$688 (in constant 2000 USD) compared to \$1,717 in the rest of the developing world, [11]. The geographical location of African region is a unifying factor that classifies the region as a unit with a homogenous climatic experiences characterized by a common vegetation and originated from the Atlantic coast on the west of the red sea. Africa as a large continent is usually referred to as dry region with biggest dry land in the World. For instance, about 1,274 million hectares out of the total area of more than 3, 052 million hectares are deserts in the region. But, the rainfall and temperature dynamics and its effect on food production remain unpredictable overtime, [12].

Hence, the performance in the agricultural sector may not have reflected in the climatic change with the region. For example, despite the common characteristics in climate component in Africa, temperature fluctuation still vary from countries in the region with the period of 2000-2016 as in figure 2 below but a cross response of food production to

temperature change reveals that during the period 2000 to 2016, food production performed well between 0.5°C and 1.2°C for the regional agricultural performance, [6]. Likewise from table 1 below, climatic factors such as precipitation and evaporation vary greatly from regions. For example, the level of precipitation in Africa seem the same with Asia at 696mm/year but Africa has higher evaporation of 582 relative to Asia with 420. The other regions like Europe also vary in level of precipitation and evaporation. In this way, the respective performance in the agriculture in these regions tied to climatic factor would also grossly vary across the continents. For example, the response of food production to temperature varies from country to country between regions and within countries in the Africa shown in figure 2 below and appendix figure 3.

Figure 2: Response of Food Production to Temperature change



Computed by the author using WDI data and across the countries.

Table 1: Estimate of Average Annual Precipitation (P), Evaporation€, Runoff Rate (P-E) and Runoff Ratio [(P-E)/P]

Region	Surface Area(10 Km ²)	P(mm/year)	E(mm/year)	P-E(mm/year)	(P-E)/P
Europe	10.0	657	375	282	0.43
Asia	44.1	696	420	276	0.40
Africa	29.8	696	420	276	0.40
Australia	8.9	803	534	269	0.33
North America	24.1	645	403	242	0.38
South America	17.9	1564	946	618	0.40
Antarctica	14.1	169	28	141	0.83
All land areas	148.9	746	480	266	0.36
Arctic Ocean	8.5	97	53	44	0.45
Atlantic Ocean	98.0	761	1133	-372	-0.49
Indian Ocean	77.7	1043	1294	90	-0.24
Pacific Ocean	176.9	1292	1202	90	0.07
All Oceans	361.1	1066	1176	-110	-0.10
Globe	510.0	973	973	0	0

Source: Pagano, T.C. and Sorooshian, S., *Encyclopedia of Hydrological Sciences*, John Wiley and Sons, New York 2005 and cited from Rai and Singh, (2012).

In a similar report, [13] used annual rainfall, forest depletion and carbon emission as proxy for climate change. Among the variables, carbon emission showed to be consistent with its impact on the Nigeria economy both in the short run and in the long run. [14] also revealed the dimensions of impact on food security by climate change to include food availability, food accessibility, food utilization and food system stability. Another regional studies by [1]

expanded the scope for measuring food security to include food production index, mortality rate and life expectancy at birth total while rainfall and annual temperature were used in the study the indicators for climate change. Evidence from the study revealed that a decreased rainfall coupled with an increased temperature reduces food production and increase the total undernourished population as well as increase the mortality rate. Following the [1] approach, this study analyses the effects of climatic dynamics on the food security in sub-Sahara Africa, the study used food production index and undernourishment population rate as proxy to measure food security while, the climate dynamics were measured using annual temperature, rainfall and carbon emission spread across its lag.

3.0 Empirical review

In the views of Gliessman (1992) as cited in [15], agro-ecology applies the concepts of ecology and principles to the design and management of agricultural system. Classifying the ecology of the world into nine zones as it is peculiar to several regions and countries in the world, Sub-Sahara Africa ecological composition include: warm arid and semi-arid tropics, warm, sub-humid tropics, warm humid tropics and warm humid tropics. Majorly, the food crops grown in the region include but not limited to: sorghum, millet, cowpea, pigeon pea, groundnut, sweet potato, rice, maize, cotton, cassava, yam, bananas, plantain, tea, coffee and others. Furthermore, [15] considered rainfall as the major proxy for ecology measurement and stressed on the essence for the knowledge of the ecology of a region which mainly help in the (i) quantitative assessment of the biophysical resources upon which agriculture and forestry depend and (ii) identification of location-specific changes necessary to increase food production through a comparison of farming system. Upon these, relies the hope for an increased potential for crop productivity in many agro-ecological zones in the world, the burgeoning population of the world in time, exerts much pressure on the cultivation expansion as well as on other land resources. Conversely, [16], revealed that the primary aim of agro- ecology is the assessment of the land suitability and its potentials for productivity. In addition, the identified elements of the agro ecological zoning are: land resources, inventory and land utilization types, and land suitability evaluation. Prior to the modern

methods and tools for agro-ecological zoning (remote sensing and geographic information system), there were several attempts to classify the land area into climatic regions. For example, the manual overlay of isolines representing either potential evapotranspiration or temperature or their combination. In a case of ecological zoning in a Mountain ecosystem in Kumaon Himalayas in India with spatial variability (latitudes 28°45' to 30°00'N, longitude 78°45' to 80°15') using Global Digital elevation model observed a close similitude between the spot height observation and Global Digital Elevation Model based elevation data ($R^2 = 0.98$). Regressing the long-term monthly and annual averages of mean temperatures from six meteorological stations using a microsta statistical software showed that a good agreement between annual mean temperature and elevation (annual mean temperature = $24.443 - 0.0045 * \text{elevation}$, $R^2 = 0.97$). Similarly, long term average annual rainfall recorded at different rain gauge were also regressed against elevation for developing rainfall- elevation relationship (annual rainfall = $515.1 + 0.3843 * \text{elevation}$, $R^2 = 0.75$). The conclusion drawn from the study suggested that a strong negative correlation between temperature and elevation would be a basis for estimating spatial variation in temperature with bias in the mountain ecosystem.

The role of agro-ecology in the planning and development of agricultural systems simultaneously targets the thrust for increase crop productivity vis a vis food and nutritional security in the face of growing population in the world. [17], study on the “use of agro-climatic zones to upscale simulated crop yield potential” in United States found that there exist difference in the crop yield potential from water limited yield potential as some crops are of climatic zone specific. With the sample frame of the study drawn from six global climate zonation scheme and evaluated for climatic homogeneity within delineated climate zones and coverage of crop area, it was revealed that of the four schemes, the Global yield Gap atlas Extrapolation dominates in approach. Based on a matrix of three categorical variables it delineate climatic zoning covers and 80% of global crop area and there were climate homogeneity with zones. Similarly, climatic zoning scheme derived from two climate-related categorical variables require a comparable number of zones to cover 80% of

crop area within the zone, heterogeneity was greater than the Global yield Gap Atlas Extrapolation Domain for most weather variables that are sensitive elements of crop production. In a similar study by [18], yield gap as the difference in the crop (soybean) potential yield from water or rain-fed production, crop yield is found to vary from regional climate as in North America. United States known as the major producer of soya beans showed by the observation that across the 10 technology extrapolation domain, soybeans average yield potential ranged from 33 to 5.3Mg ha⁻¹ for rain fed field and from 5.3 to 5.6 Mg ha⁻¹ for irrigated fields. These also support the possibility of the climatic zoning affecting the yield of a crop. Several academics and practitioners reports from empirical studies identified the understanding of agro ecological zoning as the bases for a better agricultural planning. African region being characterized with varied ecological zoning suggested that agricultural planning starts with the agro-ecology zoning of the region, [19,20,21]. In the same way, findings from Indonesia study supports that agro-ecology influences the variation in productivity with the yard stick for agro ecology to include: rainfall, air temperature, soil texture, slope, drainage and slope as the biophysical land variables. The Fuzzy logic model was adopted in contrast to other model in the literature, [22].

Apart from the influence of agro-ecology on the yield gap of crop and agricultural system, the technical efficiency of the crops are seemed affected by the agro ecology. A major crop case- on wheat production also showed that even the technical efficiency of crop yield is also influenced by the agro-ecology. For example, the mean technical efficiency estimates for lowland, midland and highland agro ecologies were 57%, 82% and 78% respectively. Also, the technical efficiency ranges from 24.4 to 88.6% in the lowland, 51.6% to 94.4% in the midland and 34.5% to 94.3% in the highland agro-ecologies all in Ethiopia. The result from the study points to the fact that agro-ecology design is key for the assessment of the agro productivity since the study adopted an appropriate function (Cobb Douglas) and adequate model (Stochastic Frontier) for analysis as reported by [23]. In a similar way, rainfall and other components of agro-ecology were identified as the determinants of the technical efficiency differentials among maize farmers in Nigeria using Oyo and Kebbi farmers as a

case study. The author applied descriptive statistics and stochastic frontier model and result indicated that the sample farmers were not technically efficient, with mean technical efficient of only 0.5588 and 0.5758 in Oyo and Kebbi state respectively[24]. In Kogi state for example, other socio-economic characteristics that still affect the technical efficiency of maize include sex, education, household size, age, [25]. Climate variability as an agro-ecological factor also affects the production of maize. [26] revealed a significant differences in average annual rainfall, temperature, maize hectare and output in the seven identified ecological zone at 5% level. While all these still suggest the role of agro-ecology on the production of crop. Considering the technical efficiency of rice production in North central Nigeria, the average technical efficiency was revealed to be 81.6% for upland rice and of 76.9 for lowland [27]. The upland and low land composition makes up the agro-ecology factors as reviewed. This indirectly suggests the effects of the agro-ecological zoning on the technical efficiency of the rice production in Nigeria. A departure from the conventional survey data analysis to panel data analysis study by [28], using panel data econometric model for the period of 1995 and 2006 suggests that another agro ecological factor like land expansion influence the crop productivity in Nigeria. The dry savannah showed an inverse relationship (-0.353) with crop production while the moist savannah show a direct relationship with crop production (0.008). Although not significant, the signs of the coefficients suggest a varied relationship of various ecological zones with the crop productivity in the country.

4.0 Analytical Framework: Agronomic Crop yield Model

Plethora of literature has revealed several models for the study of climate change interaction with agriculture. Agronomic model for example is primarily built on the ground to stimulate the dynamic response of crops to their environment [29]. Crop model as a branch of agronomic model is built to stimulate the dynamic response of crops to their environment. Most authors adopted the representation of environmental elements by climatic factor as an indicator capable of influencing the cropping systems. Therefore, agronomic model makes it possible for a speedy measure of evaluation capable of reducing environmental problems. Furthermore, the application of the agronomic models breaks down the phenotypic effect into

genotype, environment and genotype-environment interaction. The driving aims of agronomic model include; (i) a better characterization of the environment for a possible change in the configuration network. (ii) Enrichment of the genotype environment interaction by reducing the components into factors in order to limit the factors for probe genotype, (iii) experiment and findings.

In order to measure the impacts of climatic dynamics on the realization of food security in the region, the study of [1] was adopted with the framework of agronomic crop yield model and food security measured by food production index and undernourishment rate in sub-Saharan Africa. Therefore, building the food security on the global water balance as mentioned by [30]:

$$FS_{it} = F \left[GWB = \frac{dS_{atm}}{d_t} = E - P \right], \dots, (1)$$

Where FS is the vector of food security indicators (food production and undernourishment population growth), GWB is the Global water balance, S_{atm} is the total amount of water stored in the entire atmosphere in form of vapor, liquid and solid; P and E are the corresponding global fluxes of precipitation and evapotranspiration respectively. Using the Cobb Douglas production function in its stochastic to expresses equation 2 in order to satisfy the nonlinear characteristic of the climatic factor in relation to Food security indicators we state as mentioned by [31] in general expression:

$$Y_i = \beta_1 X_{2i}^{\beta_2} X_{3i}^{\beta_3} e^{u_i} \dots (2)$$

Where Y is the output, X_2 is the climatic inputs, X_3 is the non-climatic inputs (labour and capital), u is the stochastic disturbance term and e is the base of natural logarithm.

We represent equation 1 in panel data regression model as:

$$y_{it} = \delta y_{i,t-1} + x_{it}^1 \beta + \mu_i + u_{it}, \dots (3)$$

For $I = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$. δ is a scalar x_{it} is $k \times 1$, μ_i denotes the i -th individuals effect and u_{it} is the disturbance.[32]. We are therefore allowed to specified in specific terms of this study where the output is measured food security indicators and inputs are combined with the control variables like climatic dynamics indicators in as in equation (3)

$$\begin{aligned} \text{LogFP}_{it} = & \tau_0 + \tau_1 / \text{LogFP}_{it-1} + \tau_2 / \text{Loglabour}_{it} + \tau_3 / \log \text{Arable_land}_{it} + \tau_4 / \text{Logtemp_change}_{it} \\ & + \tau_5 \text{rainfall}_{it} + \tau_6 \text{Logagro_value_output} + \tau_7 \log \text{land_use_irrigation} + \alpha_i + \mu_{it}, \dots (4) \end{aligned}$$

Where LogFP_{it} is denote the log of food production across countries in Africa.

Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value and the calculated index is given as (2004-2006 = 100). LogLabour denotes the labour of the countries in Africa measured share of agricultural employment. Employment is defined as persons of working age who were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period or not at work due to temporary absence from a job, or to working-time arrangement and is measured in ratio of total employment.

logland denotes the ratio of land used for agriculture across Africa countries. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded and is measured as Arable land (% of land area). Temperature change denotes the log of ecology temperature obtained in the countries and is measured in $^{\circ}\text{C}$ for the respective countries. Logland use denotes the Land area equipped for irrigation. All data for this study were collected from United Nation Food and Agriculture Organization and World Bank development indicators for a period of 2000-2016.

The other indicator for food security in this study is undernourishment and population growth rate would be examined against some climatic indicators as below:

$$\text{LogUP}_{it} = \tau_0 + \tau_1 / \text{LogUP}_{it-1} + \tau_2 / \text{Loglabour}_{it} + \tau_3 / \log \text{Arable_land}_{it} + \tau_4 / \text{Logtemp_change}_{it} + \tau_5 \text{rainfall}_{it} + \tau_6 \text{Logagro_value_output} + \tau_7 \log \text{land_use_irrigation} + \alpha_i + \mu_{it}, \dots (5)$$

Where UP denotes the undernourishment population growth rate in the region. Other variables remain as defined earlier above.

5.0. Result and Discussion

Dynamic panel outcome has always proven to be an improvement of the static panel result. The challenge insight lies in the determination of and the validity of the instrumental variable. The judgment on the validity of the instruments as well as the model precision determination is based on several tests like Sargan, Hansen, AR(1) and AR(2). According to Kiviet,(1995) and Arellano and Bond(1991) as mention by [32]; dynamic panel is preferred over other long panel especially in a large cross sections and short time, (T). Results from a static panel data model, one step and two step system of GMM were compared and the discussion of this study mostly focused on the model with consistent estimate and less spurious output based on the Sargan, Hansen, first difference autoregressive term AR(1) and second difference of the autoregressive term AR(2). The finite sample bias of the static and first difference for the AR(1) model is improved by the system GMM, Blundell and Bond(2000) as mentioned by [33], The null hypothesis of the Sargan and Hansen test states that the instruments are efficient against the alternative that the instruments are not efficient. The null hypothesis is to be accepted over the alternative hypothesis according to *a priori* expectation.

It is against this background that this study's discussion would be based on the estimates of the two-step difference of the GMM from the first scenario on food security while the one-step system of GMM would be discussed for the nutritional security from the second scenario. From the first scenario, the dynamic effect of the log of food production revealed to be 0.59% and with an incremental impact on food production. Temperature effect in turn showed an inverse or decreasing impact of -3.1% on log of food production for every degree increase in the temperature in the short run but the long run elasticity effects of the

temperature reveals to have 7.5% decrease on food production for every degree increase in the temperature. Similarly, the expansion of arable land for agriculture as a control to temperature correspondingly showed increases in the log of food production. This implies that as the arable in sub-Sahara Africa expands, food production would increase to the tune of 3.9% in the short run. Observing from the impact of increase in temperature and impact of the expansion of arable land for agriculture on log of food production, it could suggest that expansion of arable land for agriculture could be a measure of shrinkage indicating an adverse effects of rising temperature on food production. Evidence above supports the [1] to show that temperature change and climatic dynamics have a negative effect on the log of food production but this study further improved on [1] by the evidence of the expansion of arable land for agriculture showing an increasing or positive impact on food production.

On the other hand, the scenario II showed that the dynamic effect of the undernourished population growth rate is strong and positively correlated with the first lag of undernourished population growth rate to the tune of 0.80. The effect of temperature was not significant on the determination of undernourished population growth rate although positive as opposed by [1]. In contrast, log arable land after first lag revealed a -8.55% inverse effect on undernourished population. This also suggests that the expansion of arable land for agriculture further reduced malnutrition and thus the rate of growth of undernourished population in the region. The control for population of undernourished population growth rate revealed that regional population growth, led to a corresponding increase in the rate of growth of undernourished population in the region by 11.95%, which is high and matter of concern.

6.0. Conclusion

The efforts to ascertain the regional inter-linking influence of climatic dynamics on the realization of food security and nutritional for sub-Sahara Africa has shown that climatic dynamics proxy by temperature change is consistent with a negative impact on food production both in the long run and in the short run using a cross section of 29 countries over a short time period of 2000-2016. The method of system GMM revealed an improved output

from static panel data model. In contrast to this major impact of temperature change on food production in the region, its corresponding effect on the nutrition aspect of food security remains insignificant. The interesting revelation of the control variables like arable land and population show that the expansion of arable land for agriculture counter-influence the food and nutritional security positively as opposed by the temperature change. Population increases also influenced an increase in the growth rate of under nourished population. Therefore, these evidences opined that since the negative impact of the temperature change is significant on food production, the expansion of arable land has shown to be an efficient adaptation measure for the adverse effect of temperature change on food production in the region. The negative impact of population growth on under nourished population growth also reaffirmed the essence of population control as an effective policy measure. The study therefore recommended expansion in the arable land in order to negate the inverse effects of temperature on food and nutritional security. In addition, population control policy measures is encouraged in order to reduce the impact of high population of the under nourished population growth rate.

AUTHORS' CONTRIBUTIONS

Conceptualization, and methodology, ¹IS.; software, IS.; validation, IS., and ²LA.; formal analysis, IS.; investigation, IS.; resources, LA.; data collection, LA.; writing—original draft preparation, IS and LA.; writing—review and editing, IS and LA .; visualization, IS. All authors have read and agreed to the published version of the manuscript.

DECLARATION

We declare that this research work is the original thought of the authors and has not been submitted elsewhere for consideration.

COMPETING INTEREST

The authors declare that they have no competing interest

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Appendix

Scenario I

Table 2

VARIABLES	(1) DGMM1	(2) DGMM1-CL- a	(3) DGMM2-CL- a
L.logfood	0.603*** (0.0787)	0.390* (0.220)	0.590** (0.290)
temp	-0.0362*** (0.0124)	-0.0304** (0.0154)	-0.0311* (0.0178)
L.temp	0.00202 (0.0113)	0.00865 (0.0165)	0.0179 (0.0165)
arable	0.0318*** (0.00753)	0.0367*** (0.0101)	0.0396*** (0.00839)
L.arable	-0.0240*** (0.00640)	-0.0152 (0.0181)	-0.0207 (0.0182)
logagrovalue	0.203** (0.0800)	0.257** (0.116)	0.151 (0.126)
L.logagrovalue	-0.103 (0.0733)	-0.238 (0.449)	-0.454 (0.523)
Labour	0.000596 (0.000934)	0.00241 (0.00209)	0.000188 (0.00242)

logpopulation	0.281*** (0.0920)	0.574 (0.670)	0.958 (0.709)
Observations	412	412	412
Number of crossid	29	29	29
country effect	YES	YES	YES
year effect	NO	NO	NO
Hansen_test	22.19	9.244	9.244
Hansen Prob	1	0.599	0.599
Sargan_test	298.6	8.870	8.870
Sargan Prob	0.592	0.634	0.634
AR(1)_test	-3.332	-2.910	-2.264
AR(1)_P-value	0.000862	0.00361	0.0236
AR(2)_test	1.694	1.831	1.425
AR(2)_P-value	0.0902	0.0670	0.154
No. of Instruments	314	20	20

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

DGMM1 & DGMM2 denote One-Step & Two-Step GMM respectively. Also regressions with suffix ‘‘END’’ Regressions with suffix ‘‘CL’’ follow Roodman (2009b) and collapse the instrument matrix. a & b denote lag (1 5) & lag(2 4) respectively.

Table 3: **Scenario II**

VARIABLES	(1) DGMM1	(2) DGMM1-CL- a	(3) DGMM2-CL- a
L.unr	0.808*** (0.0421)	0.803*** (0.105)	0.915*** (0.0819)
Temp	0.236* (0.140)	0.0459 (0.116)	0.0775 (0.0728)
logarable	-1.967*** (0.732)	-1.492 (1.377)	-1.215 (1.194)
L.logarable	-2.943 (2.050)	-8.554** (3.984)	-7.770* (4.031)
logagrovalue	-4.399*** (1.668)	-2.164 (1.426)	-1.127 (1.124)
loglanduse	-0.417 (1.491)	-3.297 (2.104)	-0.0408 (2.430)
loglabour	-1.699 (1.169)	-0.0318 (0.801)	-0.195 (0.820)
logpopulation	10.34** (4.281)	11.95*** (4.314)	8.598* (4.495)

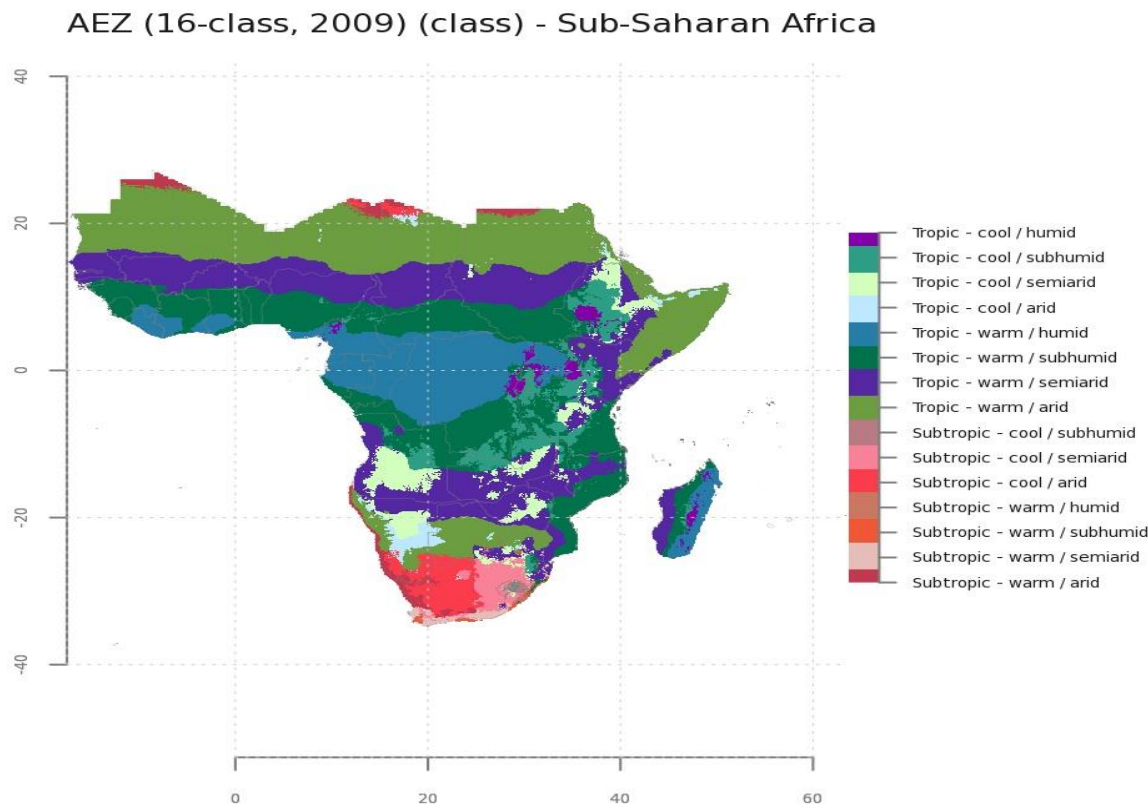
Observations	416	416	416
Number of crossid	29	29	29
country effect	YES	YES	YES
year effect	NO	NO	NO
Hansen_test	21.78	7.467	9.193
Hansen Prob	1	0.877	0.758
Sargan_test	874.7	19.53	29.43
Sargan Prob	0	0.108	0.00568
AR(1)_test	3.175	2.529	2.296
AR(1)_P-value	0.00150	0.0114	0.0217
AR(2)_test	1.524	0.649	0.0892
AR(2)_P-value	0.127	0.516	0.929
No. of Instruments	126	21	21

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

DGMM1 & DGMM2 denote One-Step & Two-Step GMM respectively. Also regressions with suffix ‘‘END’ Regressions with suffix ‘‘CL’’ follow Roodman(2009b) and collapse the instrument matrix. a & b denote lag(1 5) & lag(2 4) respectively.

Figure 2



Source: HarvestChoice/International Food Policy Research Center (IFPRI), 2009.
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Fig. 3: Food and Climatic Trend in sub-Sahara Africa