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(RESEARCH ARTICLE)

Estimation of productivity yield gap contributions of climate change variability in selected horticultural crops (fresh maize and okra) in Anambra State, Nigeria

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Abstract

Most horticultural crops are susceptible to climate extremes that affect vegetative growth and yield. Climate variability poses a great threat to food security and the sustainability of the agricultural sector in Nigeria. However, the study estimated the productivity yield gap contributions of climate variability among maize and okra farmers. Data was collected from a cross-section of 160 farmers. Statistical tools such as descriptive statistics, second-order quadratic and linear regression models and Chi-square were utilized to operationalize the study objectives. The study established that high temperature was the highest climate variability (okra - 80.0%, and maize - 78.7%); whereas fug was lowest with 38.3% (okra) and 30.4% (maize). Again, flood contributed to the highest (27.5% - okra, and 36.5% - maize) yield gap. All the climate variability cumulatively explained 6.49 ton/ha (maize) and 3.47 ton/ha (okra) yield gap. However, the farmers are producing 2.26 ton/ha (maize) and 1.70 ton/ha (okra) below their optimal level. For better management, the study revealed that sex, age, education, household size, and cooperative membership are responsible for okra farmers; while age, marital status, and farming experience are responsible for maize farmers' managerial ability. The study, therefore, concludes that climate variability significantly reduced horticultural crop yield. Howbeit, the study recommends that farmers should be taught to adopt climate-smart agricultural practices.

Keywords: Yield Gap; Productivity; Climate Variability; Horticultural Crops; Anambra State

1 Introduction

Agriculture remains an important sector of Nigeria's financial system as it contributes to food, raw materials and job creation. With respect to the four subsectors of Nigerian agriculture (crop production, livestock, forestry and aquaculture), the crop production subsector has hired more rural households to reduce exploitative and destructive migration to cities [1]. Edited by Sirakumar *et al.* [2] and Oluwole *et al.* [3], about 90% of these crops produced in Nigeria depend on rainfall due to the underdeveloped irrigation system. These, however, exposed every aspect of horticultural plant growth and yield in Nigeria to the adverse effect of climate change that alters agricultural productivity.

This crop productivity was referred to as an achievable crop yield per hectare [4]. The adopted definition solved the puzzle or deciphered the challenges met in attempt to interpret agricultural productivity [4]. This is largely due to the diversity of capital being utilized in agricultural production [5, 6]. It also suggested that the use of each factor of production should not depend solely on its availability. Thus, Pandit and Shafi defined productivity as the art of securing an increase in output from the same input or getting the same output from smaller input [7, 8]. With this in-depth

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definition of agricultural productivity, this present study prioritized the need to correlate crop productivity with climate change impacts and its variability, especially regarding horticultural crops. Thus, climate change implies difference in the statistical distribution of average weather condition over a long time [9]. Nwosu attributed the cause of this deviation from normal weather conditions over a long period to both natural and human activities [10].

Kumar *et al.* [11] and Sivakumar *et al*. [2] accentuate that climate change is attributed to the largest decline in crop productivity globally and in sub-Saharan Africa precisely. West Africa recorded the largest agricultural productivity loss ranging from 36% to 44% of the entire loss in Africa, again; climate change is responsible for about 42% GDP loss in agricultural sector in Africa [12]. Climate change caused environmental threat with adverse impact on crop productivity, it also affects mankind directly through influence on food production and security [13]. This climate change and its variability resulted from the global use of fossil due to industrialization [14], again; the impact of climate change is manifested through varied Agroecology conditions. Nti submitted that, climate change needs to be addressed as a tool to arrest poverty in Africa, being that more than 50% of the continent's population depends on agriculture as a means of livelihood [15]. Corroboratively, Mesfin and Bekele allude that the livelihoods of millions of poor and susceptible people in Africa are constantly threatened by climate change which has altered the natural and physical resources they depend on [16].

The study by Data identified some climate variability that affects the productivity of horticultural crops including unpredictable high temperature, and rainfall among others [17]. Abewoy similarly confirmed climate variability challenging the productivity of horticultural crops to include drought, salinity, humidity, wind pressure, solar radiation, flooding, and temperature [18]. Afterwards; Malhotra suggested that rise in temperature affects the growth performance of horticultural crops (maize and okra), variation in temperature can alter photosynthesis rate, shorten the crop duration; days to flowering and fruiting, hastens fruit maturity, ripening and senescence [19].

With the above information, it is evident that the gap in the yield of horticultural crops in Nigeria will be wide if not properly addressed to boost food production, and jobs created by horticultural crops. To address the yield gap, it is important to understand the concept of yield gap which Zhang *et al.* [20] defined as the difference between the obtained or observed yield and expected yield. Practically, the potential yield is the maximum yield achieved by local farmers [21, 22]. Before Africa can obtain optimum yield in horticultural crop production, effort must be made to adopt climate-smart agriculture targeted at ameliorating the impact of climate variability in agriculture. Ability to mitigate the impact of climate change on horticultural plants will help to increase job contribution. Kainga and Johnson recommended that the jobs created by horticultural crops in Nigeria could not commiserate with those of the Western World [23].

In light of these, we seek to estimate the productivity yield gap contributions of climate variability in some selected horticultural crops (fresh maize and okra) in Anambra State, Nigeria, with the intent of providing an actionable policy recommendation.

1.1 Statement of the Problem

Just like in other developing countries, Horticultural crop production in Nigeria has being controlled by smallholder farmers [25]. As obtained in the Western world, efforts should be directed towards commercialization of horticultural crop production for a sustainable and secure food systems [26, 27]. It is important to declare the issue of climate change and its variability a national emergency because of its heavy impact on food productivity. Many horticultural crops such as the vegetable types are susceptible to climate variability [18, 28-30]. Environmental extremes like high temperature, reduced irrigation water availability, flooding, drought, erratic rainfall pattern, and salinity which are further magnified by climate change are the chief cause of low yields in horticultural crop productivity. Abewoy thinks that disruptive rise in temperature, inconsistent rainfall patterns, low humidity, drought, flood, and salinity causes upsurge in the incidence of diseases that adversely affects the growth of plants [18].

Over the years, studies in Africa concentrate their effort to understand farmers' perception of climate variability which have often clarified that African farmers are now very much aware of the rise in temperature and erratic rainfall patterns, consistency of flooding, and drought among other disasters in several parts of Africa that slows down the performance of crops [12, 14, 31-34]. Recently; studies have emerged to attempt the yield gap contribution by the identified climate variability which farmers in the region demonstrates sound awareness of its adverse impact on crop production. De-Graft and Kweku recorded some strides in their study on the effects of climatic variables and crop area on maize yield and variability in Ghana, they adopted linear regression to ascertain the effect of temperature and crop area on vegetable yield [35]. They failed to establish individual variability contribution to the yield gap. Their study interestingly established that temperature and annual rainfall increase yearly by 0.03°C and 0.25mm respectively. Baffour-Ata *et al.* came up with the result that temperature, rainfall, and length of dry days explained 43%, 32%, and

30% of the yield gap in crop maize production [36]. Joshi *et al.* also found that temperature increases by 0.7°C annually which magnifies climate impact on crop productivity [37]. Joshi *et al*. also found that climate change contributed 50% to the variation in food crop yield [37]. The study by Chemura *et al*. on the impacts of climate change on the agro-climatic suitability of major food crops in Ghana also found that climate change contributed 66% yield reduction to food production [38].

Not much work has been done on yield gap analysis in the study area which this present study was designed to address especially among the selected horticultural crop which has enjoyed limited attention in the study area. Thus; this work addressed the issues with climate variability contribution to the yield gap of okra and maize in Anambra State.

Maize is one of the main staple crops in Nigeria whose production is to be promoted for the attainment of food self-sufficiency In Nigeria, maize production ranks third after sorghum and millet among the cereal crops [39]. A survey conducted in Nigeria reveals that maize accounts for about 43 per cent of calorie intake, with income elasticity of demand of 0.74, 0.65, and 0.71 for low income earners. Apart from being horticultural food crops, maize and okra have equally become commercial crops on which many agro-based industries depend for raw materials [40].

Yogendra and Harender summarized that okra plays a significant role in human nutrition by providing carbohydrates, protein, fat, minerals, and vitamins that are generally deficient in basic foods in the diet of developing countries [41]. Okra requires a longer, warmer, and better humid climate to improve yield. It is sensitive to frost and extremely low temperature. The temperature range for okra is from 18°C to 35°C. Several scholars submitted that low precipitation, high light intensity with hot and dry conditions, low relative humidity, and optimum solar radiation are needed by living organisms and all physiological processes to aid okra growth and yield [41-43]. Howbeit; these factors are often altered by climate change which has threatened the sustainability of horticultural plants. With the above information, its necessary to provide answers to the following research question:

- What is the climate change variability peculiar to the study area?
- Are this climate change variability contributing to the horticultural yield gap?
- What are the explained and unexplained yields contributed by climate change variability?
- Are there some climate change variability yield gap management profiles existing in the study area?

2 Literature Review

2.1 Conceptual Framework

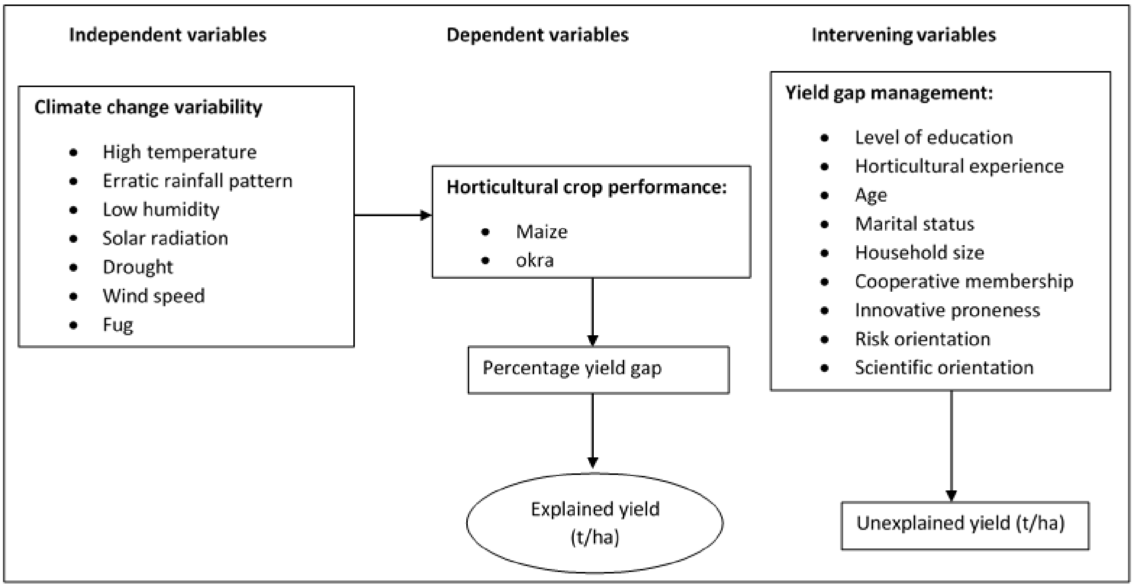

Figure 1 Obianefo concept of productivity yield gap contributions by climate change variability, 2022

The need to discuss the interaction of the productivity yield gap contribution by climate variability (figure 1) is sacrosanct towards an understanding of the study concept; independently; the yield of selected horticultural crops is dependent on the existence of climate variability in the study area. Thornton *et al.* defined climate variability as a variation in climatic parameters (temperature, rainfall, etc.) from its long-term mean [44]. It is the occurrence of extreme temporal and spatial scales of weather events. Horticultural farmers need to identify the existence of particular climate variability that threatens the growth, yield, and survival of horticultural crops in their area. With this identification of variability existence; the need to understand the quantity of harvested produce is very important. The observed quantity of maize and okra harvested is further subjected to a second-order polynomial plot of trend-line analysis. This will help the researcher(s) to predict the boundary line system of each climate variability impact.

The magnitude of the yield gap depends solely on the farmers' management's ability to incorporate alternative measures to reduce the effect on crop productivity. Reduction in the impact of climate is possible with the adoption of climate-smart agricultural technologies which heavily depends on the farmers' innovative proneness. Farmers with high innovative inclination or proneness are better adopters of agricultural technologies to improve production [45]. Equally, the farmers' ability to manage the yield gap contributed by climate variability determines the size of explained yield which Andulem *et al.* defined as the difference in technical efficient yield or maximum obtainable yield for a given input level and actual yield, which is explained by sub-optimal crop management with time, inputs and challenges (climate variability) it encounters [46].

3 Material and methods

3.1 Research Design

A survey research design was used for the study, Shaughnessy *et al.* submitted that survey methodology samples individual units of a population [47]. The goal is to gain an understanding of the detailed nature and inter-relationships and internal operations of the study units without the need to generalize for the population. To this effect, a questionnaire was used to gather dependable data from selected horticultural farmers in Anambra state.

3.2 Area of the Study

Anambra State played host to the study, the State comprised 21 Local Government Areas which include Aguata, Awka North, Awka South, Anambra East, Anambra West, Anaocha, Ayamelum, Dunukofia, Ekwusigo, Idemili North, Idemili South, Ihiala, Njikoka, Nnewi North, Nnewi South, Ogbaru, Onitsha North, Onitsha South, Orumba North, Orumba South, and Oyi. The state is organized into four agricultural zones (Onitsha, Aguata, Awka, and Anambra) to aid planning for easy community or rural development [48]. The state is bounded by Delta State to the West, Imo State and Rivers State to the South, Enugu State to the East, and Kogi State to the North. Geographically; Anambra State is situated between latitudes 5° 32' and 6°45' N and longitude 6°43' and 7° 22 'E respectively with an estimated land area of 4,865sqkm^{2}. The annual temperature and rainfall are 25.9°C and 138 mm respectively [49].

3.3 Sampling Technique and Sample Size

Multi-stage sampling technique was adopted to select the study representatives. In the first stage, one local government area (LGA) was purposively selected from each agricultural zone in the State and was classified as upland and riverine areas (Aguata and Awka zone – upland & Onitsha and Anambra zone – riverine). One LGA was further selected from each zone (Aguata – Orumba North; Awka – Awka North; Onitsha – Ogbaru; and Anambra – Anambra west).

Table 1 Selected agricultural zones and local government areas and communities for the study

Selected crop	Zone	LGAs	Community	Sample size
Okra	Anambra	Anambra west	Umueze-anam,	20
			Umudiora	20
	Onitsha	Ogbaru	Ossomala	20
			Umunankwo	20
Fresh maize	Awka	Awka North	Achalla	20
			Amanuke	20
	Aguata	Orumba North	Ufuma	20
			Omorgho	20
Total			160	

Source: Field Survey: 2022.

In stage two, two communities were purposively selected from each LGA from which four villages were randomly selected to make it thirty-two (32) villages.

In the last stage, five horticultural crop farmers were randomly sampled from each village to bring the sample size to one hundred and sixty (160) selected horticultural crop farmers.

3.4 Data Collection and Administration

Three research assistants were recruited, trained and mobilized on the use of the Kobocollect tool, each enumerator covered one LGA, while the researcher covered one LGA to complete the four LGAs. The choice of recruiting research assistants was to expedite the data collection process, in the end; each enumerator spent three weeks in the field.

3.5 Data Analysis

A combination of analytical tools of simple descriptive statistics, second-order polynomial plot & quadratic regression, linear regression, and inferential statistics such as chi-square were used. Objectives one, some parts of two, and three utilized simple descriptive statistics such as charts and percentages. Objective two was achieved with a second-order quadratic or polynomial regression plot, and objectives three and four were achieved with ordinary least square regression. The null hypothesis one was tested with chi-square.

3.6 Model Specification

The descriptive statistics are mathematically stated as;

$$p = \sum \frac{F}{n} * 100$$

Where:

- p = percentage
- F = frequency
- n = sample size

The yield gap contribution was defined as:

$$\%YG = \frac{Y_{att} - Y_p}{Y_{att}} * 100$$

Where:

- %YG = percentage yield gap
- Y_{att} = maximum observed yield
- Y_p = maximum predicted yield

The quadratic model from where the actual yield was predicted was defined as:

$$Y^* = \alpha_1 x^2 + \alpha_2 x + \alpha_0$$

- Y* = predicted yield
- x = vector of climate variability
- α = parameter of estimation

The ordinary least square regression used to predict explained yield was defined as:

$$E_Y = \beta_0 + \beta_1 X_1 + \cdots \beta_7 X_7 + \varepsilon_i$$

Where

- E_Y = predicted explained yield

- X_i = vector of climate variability
- βi = parameter to be estimated. The explained yield was later estimated as the difference of maximum observed yield to minimum predicted yield, while the unexplained yield was estimated as the difference of average observed yield to minimum predicted yield.

The ordinary least square regression for the determinants was defined as:

$$YG = \delta_o + \delta_{1j}Z_{1i} + \delta_{2j}Z_{2i} + \cdots \delta_{pj}Z_{pi}$$

Where:

- δi = parameter to be estimated
- Zi = vectors of farmers' characteristics.

Chi-square model whose contingency value was used to judge the significance of hypothesis one was defined as:

$$x^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where:

O_i is the observed climate variability across crops, E_i is the expected value of climate variability across crops, x^2 is the chi-square value whose decision value is set at a probability value of 0.05 alpha level for 1.96.

4 Results and discussion

4.1 Identification of the Climate Variables Peculiar to the Study Area

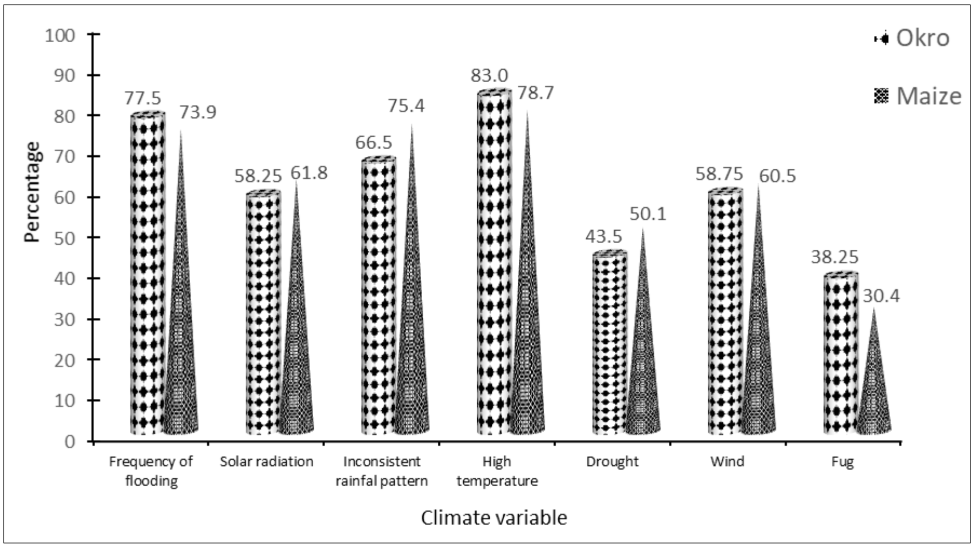

Figure 2 Climate Variables peculiar to the study area

The climate variables reported by the horticultural crop farmers in the study are presented in figure 2; the cylindrical shape represents information about okra while the conical shape represents maize respectively. The study reported that horticultural farmers have witnessed more frequent flooding events in the study area. It was observed that flooding is more peculiar to okra farmers (77.5%) than their maize (73.9%) counterparts. The study by Obianefo *et al.* suggested that flooding became an annual event in the riverine communities of Anambra State starting in 2012 [50]. Abewoy alludes that increasing temperature, reduced irrigation water availability, flooding, and salinity are the major limiting factors in sustaining and increasing vegetable and horticultural productivity [18]. The study of Okonkwo summarized that the Federal and State Government spends a huge amount of money to relieve flood victims (crowding out) of the shock felt on their farms [51]. The fug variable has the least percentage of occurrence in both okra (38.3%) and maize (30.4%). This fug is the stuffy atmosphere of a poorly ventilated space, especially where farm inputs are stored before they are used. Poorly ventilated space may encourage the growth of mods that may reduce the productivity of crops.

Also, solar radiation was more peculiar to maize farmers (61.8%) than okra farmers (58.3%) in the study; sunlight is necessary for photosynthesis to occur but Baffour-Ata *et al.* editorialized that excessiveness of sunlight may increase the heat radiation that hampers crop growth [36]. The study also found that inconsistent rainfall has become a pattern among okra (66.5%) and maize (75.4%) farmers. The incidence of climate change has brought about inconsistency in the onset of rainfall to support the assertion of Temesgen *et al.* who opined that climate change causes the spatial distribution of rainfall [52]. Traore, *et al.* allude that crops need water to thrive well, especially during hot weather [53].

The study interestingly found that okra farmers (83.0%) reported more high temperatures than maize farmers (78.7%) in the study. The high temperature will affect the vegetative growth of a plant which will inversely reduce yield or productivity. In a similar study by De-Graft and Kweku, they noted that in the last decades; the average temperature has increased by 0.21°C per annum [35], and Joshi *et al*. submitted that high temperature adversely affected maize and millet production in Ghana [37]. This finding corroborates with Chemura *et al.* who suggested that high-temperature impact the sustainability of agriculture [38]. The study equally found that 50.1% of maize farmers reported more drought peculiarity than 43.5% of okra farmers. Drought is simply defined as a prolonged period of abnormally low rainfall that leads to a shortage of water. A prolonged shortage of water will affect all-year-round farming as many farmers may not afford the cost of irrigation. Furthermore, the study revealed that 60.5% of the maize farmers recorded more wind peculiarity than okra (58.8%) farmers. The wind is simply the perceptible natural movement of air in the form of a current of air blowing from a particular direction. In areas of high intensity; it may lead to the falling of some growing crops, this reduction in the population of crops planted will equally reduce the expected yield from the field.

4.2 Yield-Related Factors and their Contributions to Yield Gap

Several analytical procedures were employed to investigate the yield gap contribution of the climate variables suspected to affect horticultural productivity in the study. Zhang *et al.* approached the yield gap contributions through a boundary line system developed by Webb in 1972 which was used to quantify yield constraints [20]. Webb noted that the first step to achieving a good yield gap analysis is to remove outliers through a boxplot analysis [54]. Wairegi *et al.* defined outliers as those data that isolate themselves from other data which can give a misleading result if not treated [55]. Figure 3 shows a clean boxplot result whose outliers have been successfully removed in readiness for the quadratic line plot analysis. Chart A to G of figure 3 to 4 represents the line plots of quadratic estimation for the climate variables contributing to the horticultural yield gap. The derived quadratic equation was used to predict the percentage yield gap as a function of the ratio of the difference between maximum obtained and predicted yield to maximum observed yield.

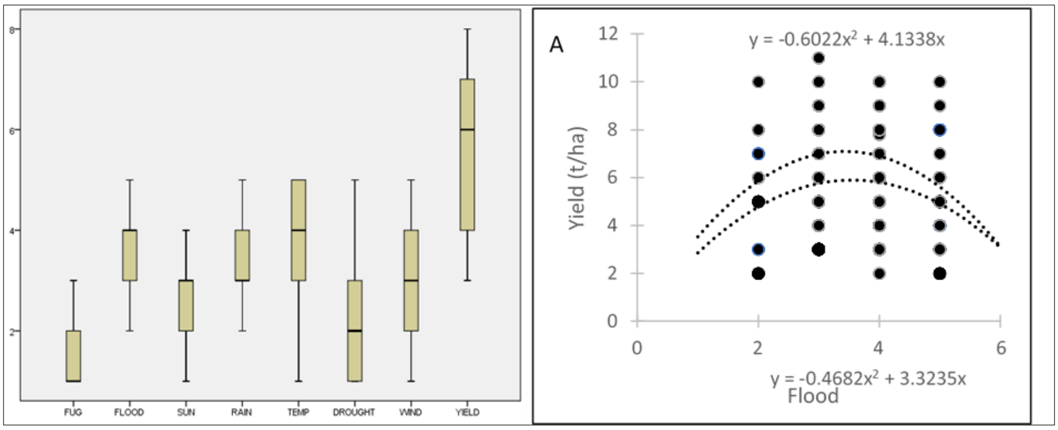

Figure 3 Identification and removal of outlier

The study revealed that the frequency of flooding events (figure 5) contributed to more yield gap reduction in maize (36.5%) than in okra (27.5%). This result indicates that a selected horticultural crop's productivity is affected by a flood. Flood has a more adverse effect on food security and sustainability in the study area. This result is far below the 66% climate contribution to maize production reported in Chemura *et al.* on the impacts of climate change on agro-climatic suitability of major food crops in Ghana, they allude that climate hurts crop yield [38]. Again, solar radiation contributed more yield gap reduction in maize (36.0%) than in okra (25.9%). High sun intensity increases stress on crops, especially among those without thermophile quality. This yield reduction contributed by solar radiation agrees with the 29.6% predicted by Adu-Boahen *et al.* in Climatic variability and food crop production in the Bawku West District of the Upper East Region of Ghana [14]. Their study thinks that climate change would contribute to about 68% yield gap by 2080 if not handled with caution [14]. Equally, inconsistency of rainfall contributed 34.2% and 23.7% in maize and okra respectively. Maize once again witnessed more yield reduction than okra, horticultural crops need rain to thrive well.

Temesgen *et al.* contend that prolonged onset of rainfall during the farm season will affect growth and performance [52]. Baffour-Ata *et al.* found in their study that delay in onset of rainfall reduced maize yield by 30% [36].

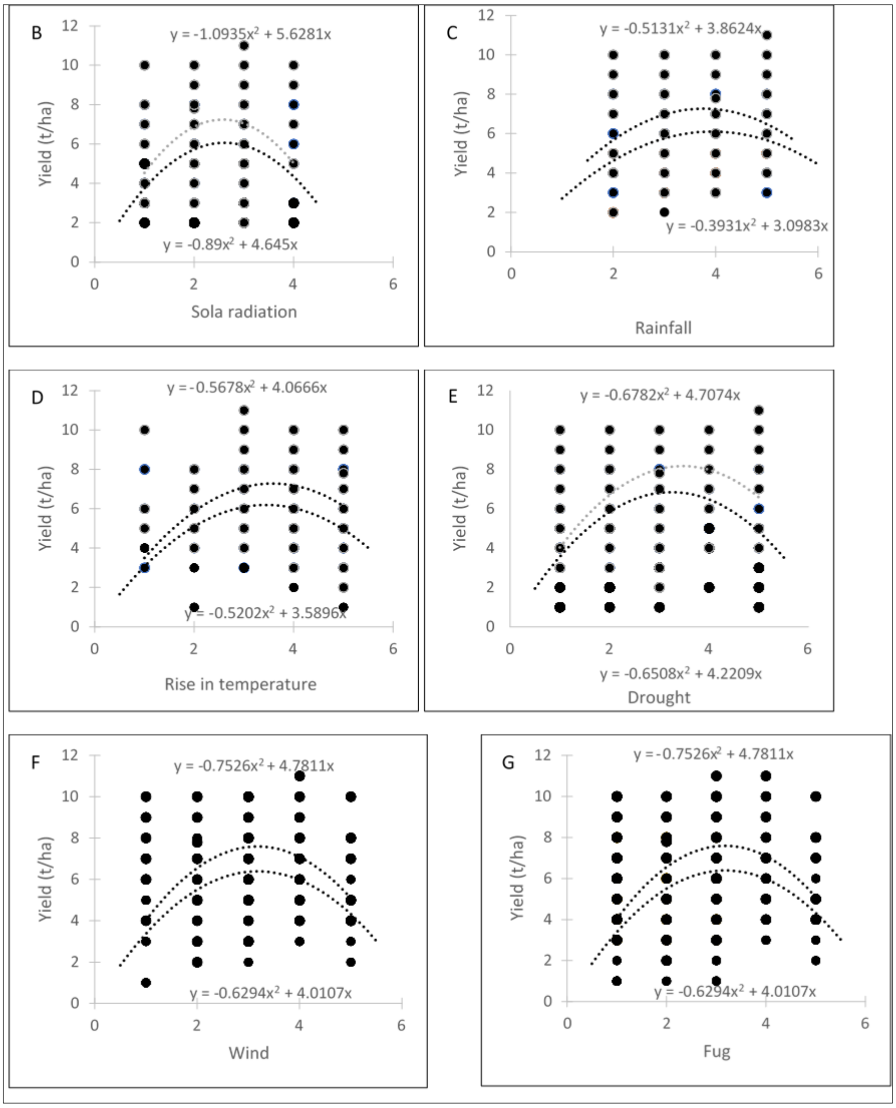

Figure 4 Chart A to G shows the boundary line plot of actual yield and climate variables

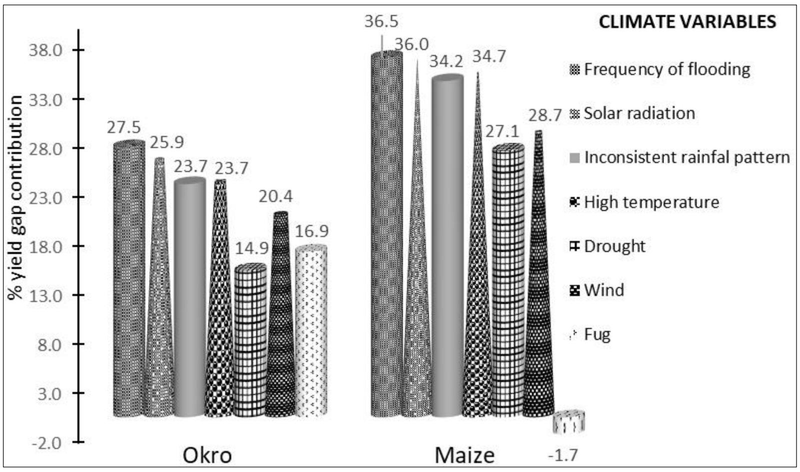

Figure 5 Yield gap contribution of climate variables

The study further found that a temperature rise caused 34.7% yield reduction in maize and 23.7% in okra. Maize demonstrated more impact on temperature rise than okra, confirming the assertion of Yogendra and Harender who opined that okra is more sensitive to a low temperature below 18°C and above 35°C, within this temperature range; the yield gap in maize will be kept to minimal [41]. The study by De-Graft and Kweku noted that temperature significantly affects the yield of horticultural crops at 1% level of probability [35]. A temperature rise will increase the stress level of plants and in return reduce yield which threatens food availability. The study also found that drought which is the shortage of water due to prolonged abnormal low rainfall recorded the least contribution to the yield gap in okra (14.9%) and 27.1% in maize. This result has just confirmed that maize is more drought tolerant than okra in the study area. Furthermore, wind contributed more yield reduction in maize (28.7%) than in okra (20.4%). The study finally revealed that fug which is caused by low ventilation contributed 16.0% to okra. The variable was found not to have any effect on maize. From the discussed results, it's evident that maize was more responsive to the negative impact of climate change than the okra plant. These findings are necessary to form a sound policy recommendation for the stakeholders of the agricultural sector.

4.3 The Explained and Unexplained Yield Gap Contribution

This study adopted the definition of yield gap by Zhang *et al*. who defined the term as the difference between the actual yield and potential yield of farmers [20]. Practically; Van-Ittersum *et al*. and Asten *et al.* suggested potential yield as the maximum yield achieved by local farmers given the available constraints [21-22]. The analysis of yield gaps can aid the identification of production constraints for immediate policy recommendations [20, 56]. The study, therefore, observed that the explained yield gap contributed by the selected seven climate variables was highest in maize (6.49 t/ha) and 3.47 t/ha in okra indicating that the evaluated factors were major influencing factors of horticultural productivity. These findings revealed that maize is 2.26 t/ha far from the optimal yield, while okra is only 1.70 t/ha different from the optimal yield (Table 2). This difference in production output resulting from climate change impact further validates the aspersion of Allison *et al.* who thought that reclaiming the climate through green alternatives is important in achieving many sustainable development goals (SDGs) of reduction of poverty (SDG1), averting hunger (SDG2), enhancing good health and well-being (SDG3), responsible consumption and production (SDG12), reducing impacts of climate change (SDG13) and sustenance of life on land (SDG15) [57]. The unexplained yield gap average of 2.20 t/ha (maize) and 1.08 t/ha (okra) indicates that other unconsidered factors had little effect on horticultural yield than the considered factors (climate variables).

Table 2 Explained and unexplained yield gap for horticultural crops

Variable	Okra		Maize	
	Attained	Predicted	Attained	Predicted
Min	3.00	4.53	2.00	4.51
Max	8.00	6.91	11.00	8.28
Mean	5.61	-	6.71	-
Standard deviation	1.70	0.47	2.26	0.77
Explained (t/ha)	3.47	-	6.49	-
Unexplained (t/ha)	1.08	-	2.20	-

Source: Field Survey Data, 2022.

4.4 The Determinants of Yield Gap Management

The result of the ordinary least square regression approach used to investigate yield gap management variables of the selected horticultural crop farmers is presented in Table 3. The study revealed a coefficient of multiple determinants (R^2) value of 0.457 (okra) and 0.397 (maize), this implies that 45.7% and 39.7% variations in yield gap management are explained by the farmer's ability to effectively manage climate change variables for efficient agricultural production. The remaining unexplained 54.3% (okra) and 60.3% (maize) were a result of errors beyond the farmers' direct management potential. These R^2 values are within those classified as weak effect sizes by Hair *et al.* [58] as cited in Uchemba *et al.* [59] who allude that R^2 values between 0.25 – 0.49 are acceptable for non-experimental studies. The F-statistics values of 8.65 (okra) and 6.77 (maize) are significant at 1% level of probability which attests to the normality and model fitness test of the analysis.

The coefficient of sex was positive and significant at 5% level of probability for only okra, this implies that an increase in the number of male okra farmers will increase yield gap contribution by 44.9%. This indicates that male farmers are not better managers of climate variables, they may not be patient to implement the climate-smart agricultural practices recommended for improved agriculture and food sustainability.

The coefficient of age was positive and significant at 5% level of probability for okra and negatively significant at 1% level of probability for maize. These imply that a unit increase in the age of okra farmers will increase climate yield gap contribution by 2.4% (okra), and inversely reduce climate yield gap contribution by 4.8% for maize farmers. The implication is that older maize farmers are better climate managers than their okra counterparts in the study.

The coefficient of marital status was positive and significant at 1% level of probability for maize farmers alone, this implies that an increase in the number of married maize farmers will increase climate yield gap contribution by 22.4%. Uchemba *et al.* suggested that marriage comes with more responsibilities which may affect the farmer's concentration to adopt climate-smart agricultural practices targeted at improving production yield [59].

The coefficient of education was negative and significant at 1% level of probability for okra alone, this implies that a unit increase in the number of year's okra farmers spend in school will reduce climate yield gap contribution by 9.2%. The implication is that educated okra farmers are better managers of climate variables that affect horticultural yield. Obianefo *et al.* noted that educated farmers are more adaptive to climate-smart practices [50], which means that educated farmers can control the effect of the yield gap contributed through better management of horticultural crops.

The coefficient of farming experience was negative and significant at 10% level of probability for maize alone, this implies that a unit increase in horticultural farming experience will reduce climate yield gap contribution by 4.3% for maize. How long the farmers have been involved in horticultural crop production will help them to understand issues surrounding climate impacts on yield as well as strategize measures to solve them.

The coefficient of household size was negative and significant at 1% level of probability for okra alone, this implies that a unit increase in the number of household members will reduce climate yield gap contribution by 13.9%. The implication is that available family units will supply more labour to effectively manage climate change challenges in horticultural.

Table 3 Determinants of yield gap management

	Okro		**Maize**	
Independent variable	**Coefficient**	**t-statistics**	**Coefficient**	**t-statistics**
Intercept	1.589	3.82	2.471	5.57
Sex	0.449	2.20**	-0.043	-0.28
Age	0.024	2.25**	-0.048	-2.87***
Marital Status	0.121	1.33	0.224	2.98***
Years of formal education	-0.092	-4.53***	0.071	1.60
Horticultural farm experience	-0.041	-1.57	-0.043	-1.89*
Household size	-0.139	-2.91***	0.051	0.89
Cooperative membership	0.730	3.25**	0.440	0.99
R^2	0.457	-	0.397	-
F-statistics	8.65***	-	6.77***	-
Observation	80	-	80	-

Source: Field Survey Data, 2022. (*, **, ***) Significant @ 10%, 5% and 1% respectively.

Furthermore, the coefficient of cooperative membership was positive and significant at 1% level of probability for okra alone, this implies that a unit increase in the number of horticultural farmers that are members of the cooperative association will increase yield gap contribution by 73.0%. This result is against the a priori expectation because cooperative members are supposed to be taught better ways to manage climate change's impact on crop yield.

The study, however, revealed that the determinants of yield gap management in okra are sex, age, level of education, household size, and cooperative membership; while that of maize farmers are age, marital status, and farming experience.

4.5 The Climate Variables Contributing to Yield Gap is Statistically Different across selected Horticultural Crops

Chi-square was used to test the significant difference in climate variables' contribution to the horticultural yield gap, Chi-square was identified as the best technique for frequency variables. Table 4 revealed that the calculated Chi-square value of 29.97 was greater than the tabulated 18.81 which is highly significant at 1% level of probability and 6 degrees of freedom (DF). These findings imply that climate variables affect okra and maize yield differently in the study area.

Table 4 Significant difference in yield gap contribution

Observed	Frequency of flooding	Solar radiation	Inconsistent rainfall pattern	High temperature	Drought	Wind/ humidity	Fug	Total
Okro	27.5	25.9	23.7	23.7	14.9	20.4	16.9	153.0
Maize	36.5	36.0	34.2	34.7	27.1	28.7	-1.7	195.5
Total	64.0	61.9	57.9	58.4	42.0	49.1	15.1	348.5
Expected								
Okro	28.1	27.2	25.4	25.6	18.5	21.6	6.6	-
Maize	35.9	34.7	32.5	32.8	23.6	27.6	8.5	-
DF	6	-	-	-	-	-	-	-
Chi-square tabulated @ 0.01 probability			18.81***					
Chi-square calculated			29.97***					

Source: Field Survey, 2022. (*, **, ***) Significant @ 10%, 5% and 1% respectively

5 Conclusion

The horticultural crop business has not been adequately tapped in Nigeria in terms of job creation, since the study of Kainga and Johnson submitted that job created by horticultural crop production in Nigeria has not commiserated with that of the Western World [24]. These horticultural crops are easily affected by climate change and its variables. De-Graft and Kweku used maize as a sampled crop, they editorialize that climate change tends to have negative effects on horticultural crop yield through its influence on production [35]. This means that an in-depth understanding of the relationship between climatic variables, and crop yield will facilitate the development of appropriate policies to cope with the rapidity of climate change. This necessitated the novel choice of the present study that estimated the productivity yield gap contributions of climate variability/factors in selected horticultural crops (maize and okra) in Anambra State, Nigeria.

The study gloriously established that climate variability sensitively reduced the optimal yield of okra by 3.47 tons/ha and 6.49 tons/ha for maize. With the knowledge that De-Graft and Kweku suggested an average temperature rise of 0.21°C every ten years [35], it becomes important for the farmers to develop a good sense of management through the adoption of green alternatives and climate-smart agriculture. Though, the study found that sex, age, level of education, household size, and cooperative membership are responsible to manage climate yield reduction by okra farmers; while age, marital status, and horticultural farming experience are responsible for maize farmers' managerial ability. The study however makes the following policy recommendation:

- Horticultural farmers should be taught to adopt climate-smart agricultural practices in their area
- Research stations should come up with high yield and climate-resistant horticultural crop varieties
- Farmers should be encouraged to organize themselves into a formidable group to improve their chances of accessing extension services.

Compliance with ethical standards

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Author Contributions

Conceptualization, C.A.O. and I.C.E, Data curation, C.A.O. I.K.C. and Z.A.S.; Formal analysis, C.A.O., I.A.C. and Z.A.S.; Funding acquisition, C.A.O., I.C.E., I.A.C. and Z.A.S. Investigation, C.A.O., I.C.E., I.A.C. and Z.A.S.; Methodology, C.A.O. and I.C.E.; Project administration, C.A.O. and I.A.C.; Resources, C.A.O., I.C.E., I.A.C. and Z.A.S.; Software, C.A.O. and Z.A.S.; Supervision, C.A.O., I.C.E. and I.C.A.; Validation, C.A.O., I.C.E., I.A.C. and Z.A.S.; Visualization, C.A.O., I.C.E., I.A.C. and Z.A.S.; Original draft, C.A.O., I.C.E. and I.A.C.; Writing—review & editing, C.A.O., I.C.E., I.A.C. and Z.A.S. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

Data Availability Statement

Data are available upon reasonable request from the corresponding author.

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