

Climate Change, Crop Protection Products, and Cocoyam Value Chain among Rural Women Farmers in Nigeria: A Study of South-East Region

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Abstract

This paper critically examines the impact of climate change, crop protection products (CPPs) usage on cocoyam value chain among rural women farmers in Nigeria. we adopted a quasi-experimental design using survey research technique, aimed at gathering information from a representative sample of the population, between 2022 and 2023 farming season. A total of 800 rural women respondents were sampled across the five states of south-eastern Nigeria. The result from both descriptive and inferential statistics of propensity score matching indicate that climate change and usage of CPPs have made significant impact in the production of cocoyam and such impact has affect decent job creation, food security and the entire rural economy in the country. While the study noted that wrong use of CPPs in coping with climate change has caused more harm to cocoyam production than the climate change itself. Hence, policy makers and development organizations should endeavour to encourage change agents to embark on massive training of the rural farmers on how to rightly use CPPs to improve productivity and improve food security in Nigeria and sub-Saharan Africa. The study therefore suggests that, any attempt to develop sustainable agricultural production policies that will be effective especially as it concerns cocoyam must involve a sound scientific knowledge of the present challenges facing the crop from the angles of climate change and maybe CPPs.

Keywords: Climate Change, Crop Protection Products, Cocoyam, Value Chain, Rural Women, South-East Region.

Introduction

Achieving food security and improving nutrition demand of the world population by promoting sustainable agriculture remains the nucleus of goal one and goal two of the United Nations Sustainable Development Goals (SDGs) targeted toward ending both

poverty and hunger (Beyene, 2023). Unfortunately, the increase in global population continues to gallop while rate of food production appears to be decreasing alarmingly especially in Africa (Adeboyejo et al, 2021; Uduji et al 2024, Nwanmuoh et al 2024a, 2024b 2024c). To Omotesho (2020), Ridwan et al (2022), ending hunger and eradicating poverty in sub-Saharan Africa (SSA) has been on the front burner of both research and policy making for a number of years without much to show for it. Food insecurity remains more pronounced in SSA, a region which that is already bedeviled with widespread inequalities, high level of poverty as epitomized in low rural incomes (Okoye et al, 2015; David-Chukwu et al, 2021). In a report of Food and Agricultural Organisation FAO (2019), IFAD, UNICEF, WFP & WHO (2020), about 31 out of the 39 food-insecure countries are located in Sub-Saharan Africa and over 250 million people suffer severe food insecurity with over 239 million people severely malnourished. Incongruously, the farming families whose major livelihood is agriculture constitute about 90% of the severely food unsecured and malnourished people of the SSA nations (FAO, 2019; Okolo-obasi et al 2025a, 2025b).

In Nigeria, population growth rate outweighs the rate of agricultural productivity and this has continuously been the root of food shortage and continuous increase in food prices (Nwanmuoh et al 2024). Many scholars Olayide (2016), Afolami and Ogungbenro (2018) Uduji et al (2018, 2019a 2019c, 2020a, 2020d) and even policymakers FAO (2021), have attributed this Nigeria's snail speed growth in agricultural productivity to climate change (Ifeanyi-Obi et al, 2017) and irresponsible use of crop protection products (Uduji & Okolo-obasi, 2019b). These assertions may not be far from the fact that agricultural activities in Nigeria are extensively practiced on a small-scale by mainly nano or small scale farmers who use mostly crude implements (Omotesho, 2020), poor in innovative and climate change adaptability (Anabaraonye et al, 2022). To this, farming has not sufficiently assured sustainable livelihood for the populace especially the rural women, hence, the level of food insecurity in the country (Eruola et al 2021)

Climate as a general weather condition of a place for a long period is a vital factor that influences agricultural production because it affects the type of crops to be cultivated, land use type, and season of cultivation (Ani et al., 2022). To Agbola and Fayiga (2016) Osuji et al (2023) precipitation, temperature and sunlight are some influential climate factors that have direct effect on agricultural production and as well determine the spread of pests and diseases among other effects. Thus, climate change which according to Adishi and Oluka (2018) Malhi et al (2021), is a change in climate that is attributable directly or indirectly to human activities, that alters the atmospheric composition of the earth. Such changes as seen in increasingly unpredictable and erratic weather systems according to Muringai et al (2020), Ibebuchi and Abu (2023) Udemezue et al (2024) lead to global warming with other major challenges including unprecedented attacks of strange diseases, pest and weeds on agricultural produce thereby affecting food security and rural livelihoods in Nigeria and other SSA nations.

Owing to the fact that agriculture is very sensitive to climate as it depends heavily on water, land, and other natural resources affected by climate; significant damages are often caused by climate change agriculture and such damage most time led to shock and panic by farmers (Anabaraonye et al., 2022). To this, Uduji and Okolo-obasi (2019a) asserted that, most panic reactions by farmer following climate change often result in reckless use of crop protection products (CPPs). The CPPs according to Arigbo et al (2023) have enormous potential to help sub-Saharan Africa achieve food security, but in some cases, the misuse has actually led to the deterioration of soil fertility.

Such deterioration has been heavily witnessed in the production and marketing of cocoyam, a root crop commonly grown in the South-Eastern and North Central Nigeria (Ifeanyi-Obi et al 2018). In the South Eastern Nigeria, cocoyam is regarded as woman crop, a special reserve of the women to cultivate (Okeke, 2019). It is often grown in combination with other food crops mostly by smallholder rural women farmers beside their husband's yam mounds (Okereke, 2020). Though cocoyam is widely grown for the roots, almost all part of cocoyam is edible medicinal and good for the body (Onwubuya & Ajani, 2015). However, for the past few years, the productivity of rural women in cocoyam farming has continuously been dropping leading to high cost of the available ones in the market (Udemezue et al, 2024). This continuous drop in production many scholars attributed to climate (Adamaagashi et al, 2023) and irresponsible use of CPP (Uduji and Okolo-obasi 2019a, 2019b; Ifenkwe, 2019; Otekunrin et al, 2021) or both (Ridwan et al, 2022; Anyiam et al (2023).

Problem

While there is a need to increase food sources to meet the growing food demand in the world and Nigeria in particular, it appears that either the efforts being made are not enough or are not well channeled. Hence, food crisis continues on the upward trend and according to Mba et al. (2020), Okolo-obasi et al (2024a, 2024c, 2025a), the combined effect of the food crisis and the global financial downturn has forestalled progress in rural development as a result, leading to high hunger and malnutrition trends. To enhance the quick reversal of the food crisis in Nigeria, increasing the output of important staples like cocoyam becomes a standing option. Hence, in order to increase food availability, food production and household consumption, massive production of cocoyam has always been encouraged considering its high-income generation, profitability, and medicinal values.

However, several studies have noted the efforts to improve the cocoyam value chain in Nigeria but asserted that the productivity continues to decline due to recurring climate and environmental disasters experienced in various parts of the country (Ayinde et al. 2011; Ikem, 2018; Ughaelu, 2017; Ani et al., 2022; Gbenga et al., 2020; Akukwe et al, 2023). In order to combat the climate disaster, smallholder farmer have adapted massive use of crop protection products which some studies are in turn refereeing to as a major bane to cocoyam production especially in the eastern part of Nigeria. The realization of these effects, therefore, calls for an in-depth study of the relationship between climate change,

usage of crop protection product and agricultural productivity in Eastern region of Nigeria. It is on the basis of the arguments concerning the deployment of CPPs to make up for the loss to climate change that this study was conceived to make contribution in the debate in four distinct areas that have received enough mention in the literature. The quest to explore those areas necessitated the four research questions as follows:

- What is the impact of climate change on productivity of rural women cocoyam farmers in Nigeria?
- To what level have rural women cocoyam farmer resulted to usage of CPPs to cope with climate change in Nigeria?
- What is the impact of using crop protection products on productivity of rural women cocoyam farmers in Nigeria?
- What other coping method can be adapted to combat effect of climate change on rural women cocoyam farmer in Nigeria?

Study hypothesis

According to Tajudeen et al (2022), Umar and Gray (2023), the changes in environmental conditions resulting from climate change has differently impacted on the six vegetative zones of Nigeria, thus, the impacts vary across regions. Because there is a high level of demand for food justifies, there is an urgent need to increase the farm yield of all crops at the grassroots level, but climate change and use of CPPs seems to have shorten productivity. While some scholars like Adishi and Oluka (2018), Tajudeen et al (2022), Enize and Agala (2023), have argued that climate change has been the major cause of low productivity of cocoyam in Nigeria, others, like Obasi et al (2014), Ume et al (2018) and Ogunlade et al (2020), have argued that if cocoyam is a tuber crop and other tuber crops like yam, cassava and potatoes are doing well in the same environment and climate, something more than climate change must be responsible for decrease in cocoyam production. On this note we hypothesis therefore, that:

Ho1: Climate change has not made any significant impact on the productivity of rural women cocoyam farmers in Nigeria.

On the other hand, crop protection products (pesticides, herbicides, insecticides, and fungicides) studies Uduji et al (2022, 2023), Arigbo et al (2023) averred to be endowed with enormous potential to help sub-Saharan Africa achieve food security because it has the capacity to control weed species, harmful insects, and plant diseases that afflict crops. But, the misplaced use of by smallholder farmers in Africa may have led to deterioration of soil fertility which seems to be very harmful to cocoyam production in the rural areas of the country. Thus, we hypothesize that:

Ho2: The level of usage of CPPs have no significant relationship with the productivity rural women cocoyam farmers in Nigeria

Other parts of the paper include: section 2, which provides a brief background, literature and theoretical underpinnings; section 3, which describes methods and provides working

material; section 4, which presents the empirical results and corresponding discussion as well as Section 5 which contains the concluding remarks, limitations and future research directions.

Background, Literature and Theoretical Underpinning Climate Change

Climate is a term used for the general weather conditions of a location for some period of time. It is a pivotal factor in determining productivity in agriculture as it influences type of crops to be cultivated, type land to be used as well as season for cultivation of each type of crop (Ani et al., 2022). To Agbola and Fayiga (2016) Osuji et al (2023), precipitation, temperature and sunlight are some influential climate factors that have direct effect on agricultural production and as well determine the spread of pests and diseases among other effects. Thus, climate change which according to Ifeanyi-Obi and Togun (2017), Adishi and Oluka (2018), Malhi et al (2021), Udemezue, et al (2023) is a change in climate that is attributable directly or indirectly to human activities, that alters the atmospheric composition of the earth leading to global warming and other challenges. The recent increasingly unpredictable and erratic weather systems (climate change) has consistently affected food security and rural livelihoods negatively (Muringai et al., 2020). According to research, Ifeanyi-Obi and Togun (2017), Udemezue, et al (2023), climate change is one of the most serious environmental threats facing mankind worldwide; it affects agriculture in several ways leading to lowering agricultural productivity.

Climate Change and Agricultural Productivity

Agriculture is very sensitive to weather and climate and depends heavily on water, land, and other natural resources affected by climate (Anabaraonye et al., 2022). Thus, a significant cost of the damage caused by climate change impacts is mostly felt in the areas of agriculture. Sub Saharan African nations have been termed to have been at disadvantage as the tropical areas stand to experience some of the most severe effects of climate changes in the years ahead (Okringbo et al, 2017). This in part is owing to the fact that, agricultural production in SSA nations are heavily rainfall dependent, hence variation in system, frequency and volume of rainfall due to climate change will easily lead to much agricultural land lost, with shorter growing seasons and lower yields (Ifeanyi-Obi & Togun, 2017).

In Nigeria, scholars like Ifeanyi-Obi and Togun (2017), Eneji et al (2021), Ibebuchi and Abu (2023), noted that climate change has been taking its toll on agricultural system especially among the rural poor farmers as it affects crops at every stage from planting activities to post harvest activities. Irregularity in rainfall, reduced rainfall, increased temperature, increased intensity and prolonged drought are all being experienced in the country (Enete, et al, 2010; Ifeanyi-Obi & Togun, 2017; Gbenga et al, 2020). The impacts of these climate irregularities include increased environmental damage, increased infestation of crop by pests and diseases (Adishi and Oluka, 2018), depletion of household assets (Aminu & David, 2021), increased rural urban migration (Uduji et al 2021), increased biodiversity loss,

depletion of wildlife and other natural resource base (Oyewole et al, 2022), changes in the vegetation type (Nwanmuoh et al 2023), decline in forest resources (Eneji et al., 2020), decline in soil conditions - soil moisture and nutrients (Onyeneke et al., 2020), increased health risks and the spread of infectious diseases (Enize and Agala, 2023), changing livelihood systems, etc. (Reilly, 1999; Abaje and Giwa, 2007).

Thus, climate affects agriculture, and what distinguishes between the annual bountiful harvest and economic ruin of farmers are variations in precipitation and temperature (Akukwe et al, 2024).

In the eastern Nigeria region dominated as a rain forest zone, the impacts of climate change are seen in the areas of delays in the onset of rainfall, longer dry season, heat waves and intense flooding along the coastal lines while in the mangrove swamp witness heavy flooding in usually dry plains and persistent sea level rise with associated risk to farming activities (Berhanu and Wolde, 2019). Therefore, any attempt to develop sustainable agricultural production policies that will be effective especially as it concerns cocoyam must involve a sound scientific knowledge of the present challenges facing the crop from the angles of climate change and maybe CPPs usage as adaptation strategies used by the farming households.

Crop Protection Products (CPPs)

Crop protection products (CPPs) are products used by farmers to control pests, weeds, and diseases in agriculture. Such products are insecticides, fungicides, herbicides, and plant growth regulators. According to African Development Report (2015, 2020,2023), Uduji et al (2022, 2023), Uduji and Okolo-obasi (2022, 2024), because farming remains an important economic sector in SSA and a vital driver to her rural development, job creation and poverty alleviation, improving farming production in the area must ensure profitable yields, the well-being of farmers and also protect the long-term productivity of the land alike. This is where CPPs plays a major role as studies Liverpool-Tasie (2015), Olayide (2016), Ume et al (2018) and Arigbo et al (2023), suggested that crop protection products (pesticides, herbicides, insecticides and fungicides) have enormous potential to help sub-Saharan Africa achieve food security.

In Nigeria, CPPs are used to control weed species, harmful insects, pest and plant diseases that afflict crops and agricultural produce. In 2013, the IFC (International Finance Corporation) invested \$6 million in Saro Agro-sciences Ltd, a major distributor of herbicides and insecticides, in an effort to increase access to agrochemicals for over 500,000 smallholder farmers by 2016, via the GESS programme in Nigeria. In 2021, Nigeria spent about \$244 million annually on pesticides, many agricultural households in Nigeria rely on pesticides and inorganic fertilizers. The federal government's growth enhancement support scheme (GESS) has increased farmers' access to CPPs. Farmers also source CPPs from the open market, farmer's co-operative societies, and state ADPs. The potential of CPP has been fully demonstrated by scholars like Otekunrin et al (2021), Amusan et al (2022), Osiji

et al (2023), however, cases of CPP misuse by the smallholder farmers have actually led to the deterioration of soil fertility in the rural areas of the country. While some farmers overuse CPPs, others underuse them yet many agricultural households in Nigeria have little access to safety controls, such as PPE.

Cocoyam Production

Cocoyam is an essential root and tuber crop commonly grown in the middle belt and southern part of Nigeria (Adeyanju et al, 2019; Adiele, 2023). According to Amadi et al (2015), Otekunrin et al (2021), cocoyam which originated in South East Asia came into West Africa especially Nigeria around 1840 and easily became a staple food in Nigeria. Cocoyam ranks third in importance after cassava and yam among the root and tuber crops cultivated and consumed in Nigeria (Baruwa and Oke, 2015; Okereke, 2020; Aminu & David, 2021). It is crop rich in carbohydrates with two major types *Colocasia esculentum* and *Xanthosoma sagittifolium* grown in Nigeria (Abdulrahman et.al., 2015). It can grow in combination with other food and tree crops which are mostly practiced in Nigeria by smallholder farmers. According to FAOSTAT (2021), global cocoyam production stood at 9.76 million tons in 2000 and reached 10.54 million tons in 2019 with Nigeria, Cameroon, China (mainland) and Ghana ranked 1st, 2nd, 3rd and 4th respectively (Otekunrin, et al,2021). Nigeria is the largest cocoyam producer in the world with annual output of about 5.49 million metric tonnes equivalent to 45.9% of the world's production and 72.2% of West Africa's total output (Aminu & David, 2021; Udemezue et al.,2024).

A very popular carbohydrate food crop that can be processed into many recipes like cocoyam cake (achicha) cocoyam flour (ede ofee) and many more (Amadi, et al, 2015; Enibe et al, 2019). Almost all part of cocoyam is edible and among the south-easterners, cocoyam leaves are processed into vegetable (mpoto) that can serve to feed both human and farm animals. This leaves according to Udemezue (2024) which are soft textured are also rich source of vitamin A (β -carotene), C, calcium and micronutrients of nutritional importance due to their antioxidant properties.

Cocoyam according to Boakye et al (2018), Nkeme et al (2021) contains low starch making it preferable to diabetics as close substitutes other root crops like cassava and yam. To Igbozulike (2015), Otekunrin et al, (2021), cocoyam is endowed with high therapeutic value and are used to treat tuberculosis, ulcers, pulmonary congestion, fungal infections (Enibe et al, 2019), and also used to lower body temperature in a feverish patient (Sharma et al, 2020), and other ailments. Phytochemicals are responsible for the healing effects of many plant species. Because of its nutritional content, cocoyam in Nigeria has become a preferable raw material in industries for production of products like, bread, biscuit, pasta, salad cream and sausage binder (Ibeawuchi, et al, 2015; Enibe et al, 2019). It provides income for unemployed youths and returns that could otherwise be seen as unproductive by the society (Ume et al, 2016). Despite the economic and nutritional values associated with the crop, the production of cocoyam had stagnated for few years now due to several production constraints, including, climatic factor, low input, scarcity of planting materials,

and various pre- and post-harvest biotic challenges like taro leaf blight and cocoyam root rot blight complex among others (Amadi, et al, 2015; Okoye et al, 2015; Anyiam et al, 2023).

Cocoyam production and climate change

Climate change according to intergovernmental panel on climate change (IPCC) is an alteration in the frequency and magnitude of intermittent weather events as well as the slow continuous rise in global mean temperature leading to global warming (IPCC, 2007). To Oyewole et al (2022) Tajudeen et al (2022), it involves natural climate cycle and human activities which resulted in the accumulation of heat-trapping “greenhouse” gases in the atmosphere and has become a threat to economic development and sustainability of mankind worldwide. This change in climate variability has negative influence on agricultural production including cocoyam which is a root crop highly dependent on rainfall and other weather conditions. Because of poor climate in the recent time, production of cocoyam has witnessed increase in pest and diseases attacks leading to low productivity especially among the rural women farmers. Hence, drought, increase in pest and diseases infestation has been a threat to cocoyam production for almost ten years now resulting in low yield which affected the rate of demand and supply.

However, studies show that cocoyam farmers have devised diverse adaptation and coping strategies aimed at alleviating the negative consequences of climate change on their produce. Such strategies include diversification of crops, hybrid or high yielding variety use, change of planting date, use of crop protection products among others (Adebayo and Onu, 2012; Nkeme et al, 2021), unfortunately some of the coping strategies adopted eventually lead to scourging of cocoyam leaves due to incessant attack of pest and diseases like (*colocasia esculenta*) leaf blight disease caused by *phytophthora colocasiae* among others on cocoyam.

Method and Materials

We adopted a quasi-experimental research design in this study employing a quantitative method as a result of dearth of quantitative technique in most of the reviewed. According to (Uduji and Okolo-Obasi, 2017, 2018a, 2018b, 2018c; Uduji *et al*, 2019a, 2019b, 2019c, 2019d, 2019e, 2020b), the quantitative approach best suit comparing two sets of population based on a treatment or perceived treatment. Here two sets of respondents experiencing same climate conditions but responding in different ways are compared.

Sample Size

The sample size used in the study was calculated using the Cochran formula for sample size determination mathematically represented as follows:

$$n = \frac{Z^2 p(1-p)}{e^2} \quad \text{Equation (1)}$$

Where, n = the sample size;

z = the standard normal deviation for a given level of confidence, (95% confidence =1.96)

d = margin of error at 0.05 for CI at 95%;

p = proportion to be estimated. If the value of p is not known with certainty, p is always assumed to be 0.5. Therefore, we calculated the sample size thus:

$n = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = n = \frac{0.9604}{0.0025} = 384$; this, we approximated to 400, this was multiplied by two because we have two separate groups of people (the farmers who used CPP and those who do not). To this, our total sample size used was 800 respondents.

Sampling Procedure

We ensured that relevant population was represented by using used multi-stage sampling technique (involving both cluster, quota and simple random sampling) in selecting the final respondents used for the study. In the stage one of the sampling, we listed the five states in south eastern Nigeria as our first cluster. In stage two out of each cluster, we selected two local government areas LGAs per making a total of 10 LGAs for the study. In stage three, from each of the selected LGA, we selected two rural communities each to give us a total of 20 communities used in the study. In the next stage, we engaged the services of community gate keepers to select 400 respondent cocoyam farmer who use CPP in the two years under review and another 400 farmers who did not use CPP in their cocoyam farming in the last two years 2022 and 2023. Hence, the sample size is distributed in line with the Table 1 below.

Table 2. Sample size determination table

States	Total Population	Population of women farmers	% Total Population	Sample per state	CPP users	Non-CPP users
Abia	3,727,347	1,192,751	0.18	142	71	71
Anambra	5,527,809	1,437,230	0.21	172	86	86
Ebonyi	2,880,383	1,296,172	0.19	155	77	77
Enugu	4,411,119	1,588,003	0.24	189	95	95
Imo	5,408,756	1,189,926	0.18	142	71	71
Total	21,955,414	6,704,083	1.00	800	400	400

Source: NPC, 2017/Authors' computation

Data collection

We engaged participatory rural appraisal techniques involving the use written semi-structured questionnaire (SSQ), key informant interview (KII) and observations to primarily generate data used for the study. The use of this technique was informed by the fact that, the views and activates of the people being studied are paramount. The SSQ and KII guide were the major tool used for the survey to garner data from the respondents selected for the study. The questionnaire was directly administered by the researchers with the help of research assistants and helpful community gate keepers. The use of local research assistants was to ensure that the rural women participants were attended to in the

languages best suitable for them. Data was generated from the women in 2022 and repeated in 2023 to ensure that adequate information were collected for pre-planting, planting/ harvesting and post-planting and harvesting period.

Analytical framework

The study employed both descriptive and inferential statistics to analyse the data collected. While objectives 2 and 4 of the study were achieved using descriptive statistics, objectives 1 and 3 were achieved using inferential statistics which combined both propensity score matching (PSM) and logit model in the analysis.

Econometric model specifications.

This study examines the impact of climate change and the usage of crop protection products on productivity of rural women cocoyam farmers in Nigeria. Towards achieving this goal, we estimated a standard logit with marginal effect to help us in estimating what the determinants of usage or non-usage of CPPs are. The model of this decision is specified as follow:

$$Y_i = \beta X_i + \mu_i \quad \text{equation (2)}$$

This model shows that, $Y_i = 1$ if a rural woman i gets to use CPPs and 0 otherwise ($Y_i = 0$ if she uses not). The above model has a binary outcome of the probability of a rural cocoyam farming woman uses CPPs (Y_i) as explained by certain set of factors (X_i) which are considered exogenous to the Rural woman as expressed in this form:

$$P(Y_i = 1) = f(X_i \beta_i) \quad (3)$$

$$P(Y_i = 0) = 1 - f(X_i \beta_i) \quad (4)$$

In equation 3 and 4, Y_i = the response of rural woman i that uses CPPs or not and, X_i = the set of characteristics associated with the rural woman i .

Hence, the probability is estimated in the logit model as follow:

$$P(Y = 1) = \frac{e^u}{1+e^u} \quad (5)$$

$$P(Y = 0) = \frac{e^u}{1+e^u} \quad (6)$$

Where $u = \beta_i X$ = the probability model, i.e the regression of the conditional expectations of Y on X . In this study, we repeated the same treatment for all the dependent variables while estimating binary treatment and binary outcome model using the propensity score matching. We did such to model the rural woman cocoyam farmer's involvement or not in using CPPs as a joint decision, the issue of endogeneity was addressed based on previous studies (Okolo-Obasi & Uduji, 2021; Okolo-Obasi *et al*, 2021; Uduji *et al*, 2019a, 2019b). In the propensity score matching, we created value of the probability of using CPPs from the logit regression assigning each rural woman a propensity score.

Therefore, in estimating the impact of usage of CPPs to combat climate change on cocoyam productivity, we identified two groups, the control (those who do not use CPPs) and treatment (those who used CPP) groups. In this study we denoted the treatment group as $R_i = 1$ for Rural woman i , and the control group as $R_i = 0$. Based on the propensity score as determined by the logit above, we matched the treatment groups to the control group. So:

$$P(X_1) = Prob\left(R_2 = \frac{1}{X_2}\right) (0 < P(X_2) < 1) \quad (7)$$

Where X_1 is a vector of control variables that were there before the CPPs were introduced. This is if R_1 's is independent over all 1 and the outcomes are independent of CPPs given X_1 , then outcomes are also independent of CPPs given $P(X_1)$, just as they will do if CPPs are used randomly. In the study, we noted our obligations to circumvent the observable selection bias by matching on the probability of the treatment (covariates X) so as to draw a more acceptable conclusion about the CPPs impact on productivity of rural women cocoyam farmers. With this in mind, we defined the propensity scores PS of the vector X as:

$$P(X) = Prob\left(Z = \frac{1}{X}\right) \quad (8)$$

Where Z = the treatment indicator = 1, if the chosen rural woman uses CPPs, and 0 if not. For the fact that propensity score is a balancing score, both the treatment and control will receive the same observable covariate X so that the variances between the two is seen as a result of the treatment. This difference between treatment and control groups is estimated by the average treatment effect on the treated (ATE). Based on this, the true ATE, on the basis of the propensity score matching is expressed as:

$$ATT_{PSM} = E_{P(X)} \left\{ E\left(\frac{Y_1}{Z} = 1, P(X)\right) - E\left(\frac{Y_0}{Z} = 0, P(X)\right) \right\} \quad (9)$$

$EP(X)$ stands for expectation with respect to the distribution of propensity scores in the population. The true ATE shows the mean difference in either increasing or reducing productivity of the rural women cocoyam farmers. In this, we achieve a suitable match of every user with her counterfactual in as much as their observable characteristics are identical.

Results and Discussion

Analysis of the data generated from the field started a description of the social, economic and demography of the respondent rural women selected for the study.

Descriptive analysis

The socio-economic and demographic characteristics are common among both the rural women using CPP (the treatment) and those not using CPPs (the control). The characteristics helps in understanding the similarities and differences in the rural women status in both groups. The analysis indicates that while about 40% of the treatment group are full time farmers, only about 20% of the control are into full farming. On the other hand,

while about 27% of the rural women in treatment group cultivate mostly cocoyam, about 31% in the control are in the same category. Also, an average of 32.5% of women in both treatment and control cultivate mostly cassava while 15% are involved in Vegetables. Only an average of 3% are fully involved in yam cultivation. This buttresses the assertion of scholars like Onwubuya and Ajani (2015), David-Chukwu et al (2021), that while yam is regarded as the king of crops and exclusive for men to cultivate other tuber crops like cassava and cocoyam are seen as women crop.

Table 2. Socio-economic characteristics of the respondents

Treatment			Control		
Variables	Freq	%	Freq	%	Cum
Primary Occupation					
Fishing	38	10	10	44	11
Trading	115	29	38	134	34
Farming	161	40	79	80	20
Paid Employment	49	12	91	56	14
Handicraft	25	6	97	65	16
Unemployed	12	3	100	21	5
	400	100		400	100
Level of Education					
None	16	4	4	127	32
FSLC	91	23	27	219	55
WAEC	248	62	89	38	10
Degree and above	45	11	100	16	4
	400	100		400	100
Annual Income					
1000 - 50,000	18	5	5	97	24
51,000 - 100,000	33	8	13	73	18
101,000 - 150,000	42	11	23	54	14
151,000 - 200,000	51	13	36	64	16
201,000 - 250,000	118	30	66	59	15
251,000 - 300,000	89	22	88	46	12
Above 300,000	49	12	100	7	2
	400	100		400	100
Major crop cultivated					
Yam	10	3	3	13	3
Cassava	127	32	34	132	33
Cocoyam	109	27	62	123	31
Rice	44	11	73	31	8
Maize	39	10	82	24	6
Vegetable	62	16	98	57	14
Others	9	2	100	20	5
	400	100		400	100

Treatment			Control		
Variables	Freq	%	Freq	%	Cum
Age of Respondents					
> 20 years	15	4	4	11	3
21-30 years	47	12	16	28	7
31-40 years	155	39	54	52	13
41 - 50 years	90	23	77	160	40
51 - 60 years	51	13	90	87	22
> 60 Years	42	11	100	62	16
	400	100		400	100
Household Size					
1-4 Person	95	24	24	181	45
5-9 Person	105	26	50	122	31
10-14 Person	111	28	78	61	15
>14 Person	89	22	100	36	9
	400	100		400	100
Farming experience					
< 5 Years	45	11	11	32	8
5 -15 Years	67	17	28	53	13
16-25 Years	146	37	65	86	22
26 - 35Years	75	19	83	126	32
36-45 Years	45	11	95	64	16
> 45 Years	22	6	100	39	10
	400	100		400	100
Major cropping pattern					
Mixed	145	36	36	204	51
Sole	36	9	45	42	11
Both	219	55	100	154	39
	400	100		400	100
Farm size (Ha)					
< 1	162	41	41	188	47
1 – 2	214	54	94	201	50
Above 2 40	24	6	100	11	3
	400	100		400	100

Source: Authors' compilation based on household survey.

The analysis also shows that while the average age of the treatment group is 34 years, with an average farming experience of 16.5 years, that of the control group is 44 years and 25 years respectively. This may explain why usage of CPPs is reduced in the control group because they have seen many years in the farming and must have experience both sides. This is in line with Azeez and Madukwe (2015), in that, the more experience one gets in a business the more pitfall he/she avoids. On the side of educational qualification, the treatment group are more educated than the control, have larger farm size, while the control has larger household size. This agrees with Obidike et al (2021) that while larger household can provide more family labour to control weed and pest, the smaller and educated household tend to pay for any easy labour. Osahon & Ifenkwe (2019), Ogunlade et al (2020) on their own observed that the higher the level of education is not the higher the level of knowledge in CPPs usage, but farming experience teaches better.

Analysis (Table 2) still show the sorry nature of the average annual income of both the treatment groups. the indication is that poverty among the rural women is still very high even as the price of cocoyam in the market kept increasing. If the country and other SSA nations must pursue a commitment to lowering poverty by 2030, effort must be geared towards improving the farming livelihood of rural women farmer. This finding give consent to African Development Report (2015, 2022; Nwanmuoh et al 2024a,2024b; Okolo-obasi et al 2025a, 2025b) in that eliminating extreme poverty over the next 10-15 years, would require Africa to at least double average per capita consumption from what it is today. At the same time, most countries would require less than 5% of their national income to lift poor people out of poverty.

Cocoyam farmers rate of awareness and sources of information on climate change

Analysis Figure 1 shows that almost all the rural women farmers, about 92% are aware of climate change affecting their production for the past 5 to 10 years. Only about 3% are not aware while about 5% are not interested in providing answers to the question. This is a serious sign that awareness of climate change may not be a challenge anymore in the region as opined by earlier studies like Nzeadibe, et.al (2011) that majority of the rural farmers are unaware of climate change. The implication of this increased awareness is that farmers are bound to be more prepared for effective actions to combat the challenges posed by the changes. This is because according to Ifeanyi-Obi et al (2018), awareness of the challenge is pivotal to adopting suitable agricultural measures and technologies.

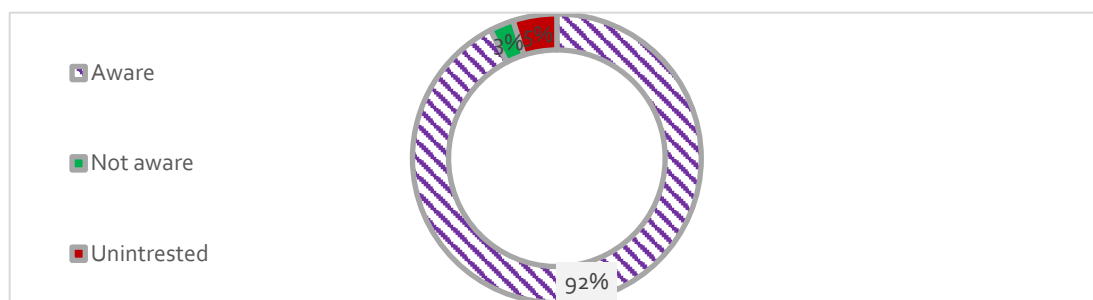


Figure 1: Cocoyam farmers rate of awareness of climate change

Source: Authors computation

Analysis Figure 2 shows that while about 35% of the rural women farmers get their climate information from personal experience, about 18% gets from fellow farmers, 21% from community gatekeeper, 12% from extension agents and 14% from media (6% traditional and 8% social). This is an indication that, the change agents may have not done well in the region in getting the people to be adequately informed of climate change and its implications on their productivity and health. To this, while many are aware of the change, the impact of the change is still sketchy to them, hence those issue which may not be climate issues are attributed to climate.

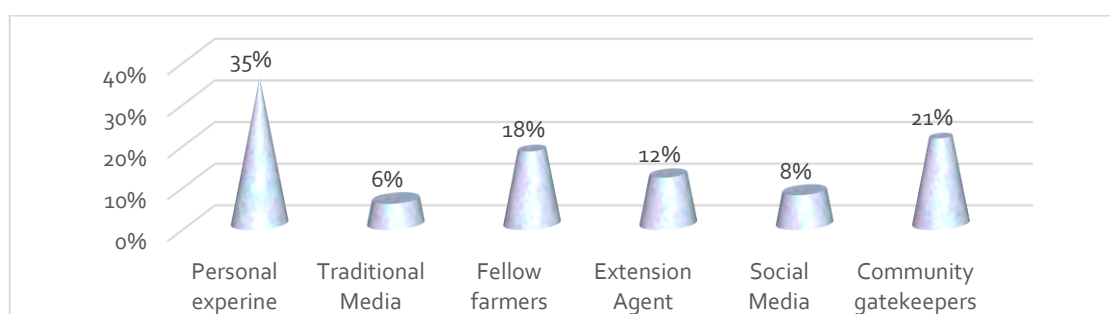


Figure 2: Cocoyam farmers' sources of information on climate change

Source: Authors computation

The impact of climate change on productivity of rural women cocoyam farmers in Nigeria

Based on key informant report, various variable of climate change affecting production of cocoyam ranges from changes in rainfall pattern, humidity, atmospheric temperature, drought, and solar radiation. With this, climate change effects gain more intensely severe and requires that farmers increase their knowledge of the impacts.

Analysis Table 3 shows the impact these variations are making on production of cocoyam as observed by the farmers. Most of the rural farmers about 58.4% on average from around the states with highest in Anambra (72%) agreed that climate change reduces soil fertility as a result of increased erosion and flooding incidence. This implies that climate change has

made significant impact on soil fertility. Also, climate change is making significant impact on reduction of available land for planting cocoyam as the places covered by flooding are most times washed away. To this about 60% rated it high and significant. In the area of increased insects/pests/rodents attack of cocoyam in the farms as a result of change in climate, about 61.8% of the respondents rated it high and significant, increase in disease incidence as a result of the change in climate was also rated 64%, and significant while about 57.2% rated increased growth of weed in the farms due to change in climate as also high and significant. In all these impacts, while stunted growth in cocoyam may not have been rated too high (48%) the rating is significant but painfully, reduced yield in cocoyam as a result of the changes in climate was rated as high as 64% indicating that all around the region, cocoyam farmers are losing as their output is consistently decreasing for many years.

Table 3. Impact of Climate change on Productivity of cocoyam farmers in the rural communities¹

	Abia			Anambra			Ebonyi			Enugu			Imo			Av	Remark
Climate effect	H %	M %	L %	H %	M %	L %	H %	M %	L %	H %	M %	L %	H %	M %	L %	%	
Reduced soil fertility due to increased erosion and flooding incidence	53	32	15	72	19	9	55	29	16	58	33	9	54	34	12	58.4	S
Reduction in the available land for planting cocoyam due low lying land being flooded.	52	36	12	63	23	14	63	28	9	61	25	14	61	28	11	60	S
Increased insects/pests/rodents attack of cocoyam in the farms as a result of change in climate	65	28	7	58	34	8	65	27	8	72	19	9	49	39	12	61.8	S
There is increased disease incidence as a result of the change in climate	61	35	4	64	29	7	71	18	11	66	21	13	58	33	9	64	S
There is increased growth of weed in our farm due to change in climate change	56	27	17	55	36	9	61	33	6	49	39	12	65	34	1	57.2	S
There is reduced yield in cocoyam as a result of the changes in climate	66	31	3	62	26	12	59	32	9	62	26	12	71	21	8	64	S
Increased loss during storage as a result of increased intensity of heat	72	22	6	65	32	3	65	24	11	69	30	1	69	28	3	68	S
There is stunted growth of cocoyam planted due to change in climate variables.	45	32	23	48	41	11	52	38	10	51	32	17	44	45	11	48	S

Source: Authors computation

¹ H = high, M = moderate, L = low, S = significance, N = not significant

To further compound the problem of low yield, the farmers disclosed that there is increase in loss during storage as a result of increased intensity of heat which often lead to the decay of corms and cormels. This impact rated as high as 68% shows that the shelf life of the most cocoyam produced has been seriously reduced. This confirms the assertion of, Ridwan et al (2022, Udemezue et al (2024), in that it has become a serious challenge as cocoyam which are used to be stored in the barn to be used during the off season are rushed out to avoid post-harvest loss thereby reducing the income power of producers.

In the opinion of most key informants interviewed, the reduction of shelf life of cocoyam is majorly attributed to the use of CPPs which many farmers have adopted as a coping strategy to boost production of cocoyam.

Rate of rural women cocoyam farmers' usage of CPP

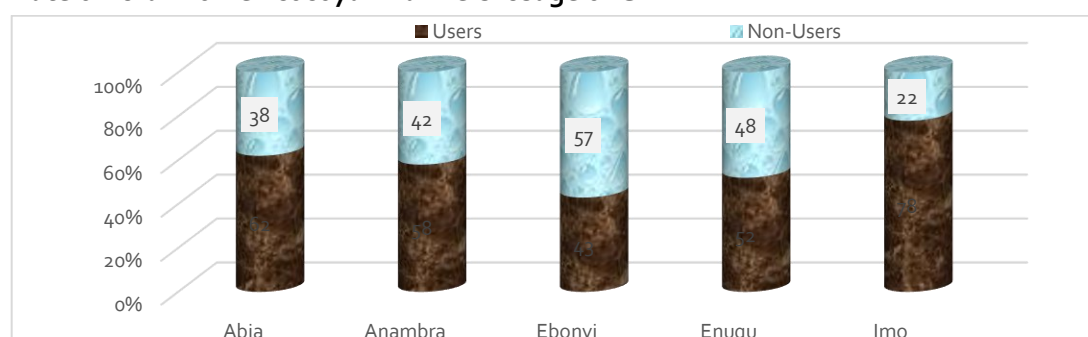


Figure 3: Percentage distribution of rural women adoption and usage of CPPs as coping strategy.

Source: Author's compilation based on field survey

Analysis (Figure 3) shows that in Abia state, while 62% of the rural farmers have adopted CPPs as coping strategies to battle climate change and enhance cocoyam productivity, about 38% are not using it. Anambra has 58% users and 42% non-users, Ebonyi 43% user and 57% non-users, Enugu has 52% user and 48% non-user and Imo has 78% user and 22% non-users. This simply means that on average, while about 58.6% of the rural farmer in the state have adopted and used CPPs about 41.4% are currently not using CPPs.

Table 4. Distribution of respondent according to reasons for not Using CPPs.

Reasons	Abia	Anambra	Ebonyi	Enugu	Imo	Average
Can't afford it	25	37	31	31	27	30.2
Does not know how to use it	33	23	38	21	32	29.4
Afraid of its bad effect on crops	13	14	5	12	15	11.8
Just don't like it	15	16	11	21	18	16.2
Had bad experience with it	14	10	15	15	8	12.4
	100	100	100	100	100	100

Source: Author's compilation based on field survey

Analysis Table 4 and Figure 3 described the reasons adduced by non-user on why they are not using CPPs. While about 25% are not using CPPs in Abia because they cannot afford it, Anambra recorded 37% Ebonyi 31%, Enugu 31% and Imo 27%. This agrees with Eruola et al (2021), in that the cost of arm input has discouraged many from adopting innovate technologies in farming. While about 38% of non-user in Ebonyi is because of lack of experience in usage, Enugu recorded on 21% in that category and others are Abia (33%), Imo (32%), Anambra (23%). This may mean that more work is expected from the change agent especially in Ebonyi state on the usage of CPPs. This agrees with Uduji and Okolo-obasi (2019) in that most damages caused by CPPs are not because CPPs are bad but irresponsible usage is what is scaring many would be user away.

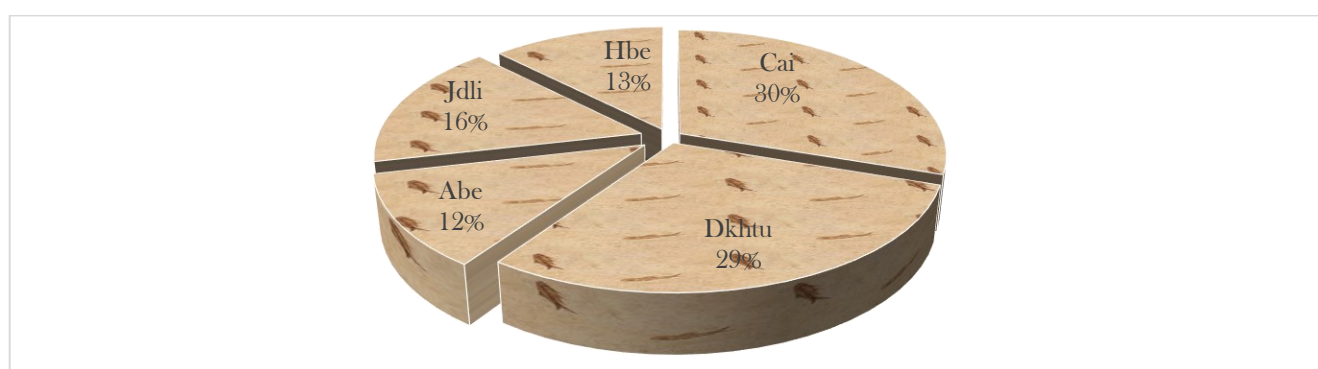


Figure 4. Reason for not adopting CPPs as coping strategy²

Source: Authors computation

On average in the zone, while about 30% of the non-user are not using because they cannot afford it, about 29% do not know how to use it, about 12% are afraid of its harmful effect on human and crops, about 13% had had harmful experience in the past, and 16% just don't like it for undisclosed reasons.

The impact of using crop protection products on productivity of cocoyam farmers in Nigeria

Analysis (Table 5) summarized the average differences in the basic scores and independent observable characteristics between the user and non-users of CPPs.

In matching the treatment and control as proposed in equation 9 to determine the average treatment effect (ATE), we noted the difference in means which shows that the score on soil fertility improvement due usage, scores on available land for planting cocoyam, scores on sustainable control of insects/pests/rodents attack of cocoyam, scores on sustainable of crop disease incidence, scores on sustainable control of growth of weed, scores on improve yield in cocoyam produced, scores on increased shelf-life and storage ability, and scores on improve rapid growth of cocoyam, significantly varies showing the difference between user

² Cai = Can't afford it, Dkhtu = Does not know how to use it, Abe = Afraid of its bad effect on crops, Jdli = Just don't like it, Hbe = Had bad experience with it

and non-users of CPPs as a result of the usage. In all the categories measured, this shows that the treatment actually has reduced soil fertility by (11.05%), availability of land for planting cocoyam by (13.07%), control of crop disease incidence by (8.6%), as well as shelf-life and storage ability of cocoyam by (8.95%).

Table 5. Comparison of mean score and observable characteristics across user and non-user of CPPs (N =800)

Score in Percentage of maximum score	Treatment	Control	Difference
Scores on soil fertility improvement	31.29	42.34	-11.05**
Scores on available land for planting cocoyam	21.32	34.39	-13.07**
Scores on sustainable control of insects/pests/rodents attack of cocoyam	37.41	33.42	3.99*
Scores on sustainable of crop disease incidence	22.73	31.33	-8.6**
Scores on sustainable control of growth of weed	28.32	26.78	1.54**
Scores on improve yield in cocoyam produced	32.43	28.34	4.09**
Scores on increased shelf-life and storage ability	19.37	28.32	-8.95***
Scores on improve rapid growth of cocoyam	37.52	24.34	13.18**
Socio-economic characteristic of rural farmers.			
Age	25.44	29.35	-3.91
Education	22.43	23.17	-0.74
Marital Status	19.19	18.81	0.38
Household Size	11.18	15.71	-4.53
Primary Occupation	25.12	22.81	2.31
Annual Income	32.16	33.63	-1.47
Observation	400	400	

***= significant at 1% level, **= significant at 5% level, *= significant at 10% level

Source: Authors' compilation based on household survey

Also, from the treatment we noted that control of insects/pests/rodents attack of cocoyam improved by 3.99%, control of growth of weed improved by 1.54%, rapid growth of cocoyam improved by 13.18% and yield of cocoyam produced improved by 4.09%

Generally, our findings agreed with Adiele (2023), in that the use of CPPs destroys the soil flora and fauna even as the target was to destroy diseases and pest. Hence this destruction of soil microbe reduces fertility of the soil thereby rendering many hectare un productive and uncultivable. On the other hand, while we noted that control pest and weeds improved because of usage of CPPs, the study also showed that the ability to control diseases was reduced and shelf life reduced. This is in line with Afolami and Ogungbenro (2018), Mukaila et al (2022), and Enize and Agala (2023) in that wrong use of CPPs have ended up introducing disease including post-harvest diseases that destroy harvested cocoyam. It is therefore our contention in this study that wrong use of CPPs in coping with climate change

has caused more harm to cocoyam production than the climate change itself. Hence, policy makers and development organizations should endeavour to encourage change agents to embark on massive training of the rural farmers on how to rightly use CPPs to improve productivity and improve food security in Nigeria and sub-Saharan Africa.

Concluding Remarks and Recommendations

Climate have shown to have significantly affected agriculture, as what differentiates between the annual bountiful harvest and economic ruin of farmers are the changes in climate as it concerns rainfall pattern, humidity, atmospheric temperature, drought, and solar radiation. However, recent arguments started showing that in attempt to cope with the changes in climate farmers who are now fully aware adopt many strategies which include the use of crop protection products. This crop protection product appears to have the potential to lift up the produce of the farmers but irresponsible and wrong usage of such appears to be detrimental. Thus, we set out this study to investigate the impact of climate change and crop protection products on the productivity of women cocoyam farmers in the rural communities of southeastern Nigeria. The study builds on scholarly evidence on the relevance of climate change and use of CPPs in Nigeria.

In modeling this impacts on both sides, this study adopted both descriptive and inferential statistics of propensity score matching (PSM) to test the hypotheses that: *Climate change has not made any significant impact on the productivity of rural women cocoyam farmers in Nigeria and the level of usage of CPPs have no significant relationship with the productivity rural women cocoyam farmers in Nigeria.* we sampled eight hundred rural women cocoyam farmers across the five states of south-eastern Nigeria selecting those who use CPPs and those who do not but experience the same climate change situations with the users. The results of the study's data analysis show that both climate change and usage of CPPs have made significant impact on productivity of the rural women cocoyam farmers. The average treatment effect of either using or not using CPPs indicate that, while CPPs may have aided in weed, pest, diseases and rodent control, its wrong usage has done more harm to production of cocoyam than good. This implies that in adopting usage of CPPs as coping strategies for climate change, a well-designed and integrated programme of training of rural farmers on the usage can make significant contributions to productivity and in improving food security, spurring decent job creation and boosting agricultural markets. The findings therefore suggest that, any attempt to develop sustainable agricultural production policies that will be effective especially as it concerns cocoyam must involve a sound scientific knowledge of the present challenges facing the crop from the angles of climate change and maybe CPPs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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