

---

## **Issues in Climate Smart Agriculture in Southeastern Nigeria**

**E. O. Okoro<sup>1\*</sup>, V. U. Okwu-Delunzu<sup>2</sup> and C. S. Ofordu<sup>2</sup>**

<sup>1</sup>*Department of Science Laboratory Technology, Abia State Polytechnic, Aba, Nigeria.*

<sup>2</sup>*Department of Geography and Meteorology, Enugu University of Science and Technology, Nigeria.*

### **Authors' contributions**

*This work was carried out in collaboration among all the authors. Author EOO designed the study and wrote the first draft of the manuscript. Authors VUOD and CSO wrote the protocol and managed the literature searches. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/IJECC/2020/V10i930240

#### **Editor(s):**

(1) Dr. Wen-Cheng Liu, National United University, Taiwan.

#### **Reviewers:**

(1) Romer C. Castillo, Batangas State University, Philippines.

(2) Virendra Singh, IFTM University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/56103>

**Review Article**

**Received 06 February 2020**

**Accepted 11 April 2020**

**Published 29 August 2020**

---

### **ABSTRACT**

Farming is a prime livelihood activity of people of Southeast (SE) Nigeria. In the age of climate change, farmers have to cope with highly variable, short and unpredicted rainfall to sustain their enterprise. This study reviews the effects of climate change on agriculture production, identifies farmer's views on the impact of climate change on crop production in the southeast, reviews the adoption of CSA in Nigeria and identifies the importance of climate information service in agriculture in Southeast Nigeria. From the review, farmers within the SE are aware of climate change and they have adopted improved innovative strategies to adapt to the negative implication associated with climate change and variability but more awareness is needed in the area of climate information services (CIS) to assist them to cope better. Therefore, this study recommends the Participatory Integrated Climate Services for Agriculture (PICSA) approach to educate farmers more on how to manage their enterprise in the face of climate change and variability.

*Keywords: Climate-smart; agriculture; farmers; mitigation; adaptation.*

---

\*Corresponding author: E-mail: [okoro.enyinnaya@abiastatepolytechnic.edu.ng](mailto:okoro.enyinnaya@abiastatepolytechnic.edu.ng);

## 1. INTRODUCTION

In Nigeria and several other parts of Africa, (the agricultural production system is predominantly rain-fed) more than 60% of essential foods are produced from rain-fed agriculture which is practiced by more than 80% and 90% [1]. Increasing temperature and changes in rainfall distribution (interseasonal fluctuations and erratic rainfall patterns) has become a critical food production risk to farmers. Over 70 percent of the Nigerian population is engaged in one form of agriculture as their primary means of livelihood [2]. According to the Food and Agriculture Organization (FAO) [3] reports, climate change is likely to cause significant crop yield losses thereby adversely affecting smallholder livelihoods in Africa. As a result, food security and income generation opportunities for the farming households that rely on agriculture are in danger. As documented by [4], crop yield in Africa may fall by 10-20% by 2050 or even up to 50% due to climate change. More than one-third of crop yield variation on a global level is due to variation in climate and weather, and in large areas of the breadbaskets of the world, more than 60% of crop yield variation depends on climate variation [5]. An increase of 1°C would have a severe global impact on maize yield than rice and a decrease in maize yield in the United States would be twice those grown in India [6]. To reduce the negative impact of climate change on agriculture, adaptation is considered a vital component in response to climate change [7,8]. Although the choice of adaptation interventions is determined by the country's peculiar circumstances. Department of Environmental Affairs (DEA) [9], outlined adaptation measure to include: research and development of indigenous knowledge and technology; identification of groups and communities most vulnerable to climate change impacts; sensitization of the public on climate change; improvement of irrigation and drainage system; groundwater management and sustainable farming systems among many others. Consequently, the increasing focus on the adaptation of agriculture to climate change indicates the need for climate-smart agricultural (CSA) practices which could see to the reduction of greenhouse gas emissions and their negative effects.

In sub-Saharan Africa, there is an increased level of investment of CSA by the organization within the next decade [10]. Organizations such as the New Partnership for Africa's Development (NEPAD) have targeted to reach 25 million

farmers by 2025 with climate-smart agriculture technologies and approaches through its Alliance for Climate-smart Agriculture (ACSA). However, there is very limited direct data available to show how increased climate risk (e.g. drought and heat stress) will affect specific cropping system performance in Nigeria. For the adoption of CSA in Nigeria especially in the Southeast region, climate information service must be readily available for farmers to identify the trend of climate to enable them to select appropriate climate smart options to increase their yields. Based on this, the study identifies CIS as an effective means to encourage farmers' production in Southeast Nigeria. The objectives of the study are: to review the effects of climate change on agriculture production, to identify farmers view on the impact of climate change on crop production in southeastern Nigeria, to review adoption of CSA in Nigeria and to identify the importance of climate information service in agriculture in Southeastern Nigeria.

## 2. LITERATURE REVIEW

### 2.1 Impact of Climate Change on Crop Agriculture Production

Climate and weather influence crop production in different ways, for instance, changes in temperature, atmospheric carbon dioxide (CO<sub>2</sub>), and the frequency and intensity of extreme rainfall have significant impacts on crop yields. For any crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction [11]. The overall effect of climate change on agriculture could be positive or negative; the degree of impact varies from very low to very high, depending on regional or geographical location and status of socioeconomic development [12]. Every 1°C increase in temperature and a 0.2-meter rise in sea-level has a positive impact in member-countries of the Organization for Economic Cooperation and Development (OECD), Middle East countries, and China [13,14]. In China there is a rapid increase in temperature since the early 1980s, conversely, the number of frost days has decreased across most cropland regions [15], leading to the development of multiple cropping systems in the middle and high latitude regions. Other regions like African experience the negative impact, that is temperature is increasing and rainfall is erratic. The increase in temperature also increases evapotranspiration, which harms crop yields. During the growth cycle of the plant, water is needed at the initial stages

of production, but not during the final stages. Low levels of precipitation harm the germination of the seeds. Dry conditions, frequency and severity of dust storms all result in decreased production of major grains. Given the potential changes in production variables [16], estimated that the average potential crop yields may fall by 10-30% across the prairies crops but it will vary based on locations. Future climate change will likely have negative effects on crop production in low latitude countries, while effects in northern latitudes may be positive or negative [17]. Therefore, the effect of climate change on agriculture is linked to variabilities in local climates rather than in global climate patterns. A study [18] provided empirical support for the distributional impact of climate change by investigating the impacts of climate change between poor and rich countries. Findings from the study revealed that the poorest half of the world's nations suffer the majority of the damages from climate change, while the wealthiest nations experience almost no net impact. The emphasis on location as the main reason—poor nations bear the brunt of climate change damages mainly because they are located in the low latitudes, which are already very hot [18]. Another study [19] confirmed the findings of [18] and noted the effects of climate change on farming would be most severe in low-income, agriculture-dependent, tropical countries because these countries are least equipped to manage climate change. For instance, in Nigeria, where the temperature has been increasing and is economically less developed—fits in [18] classification.

## **2.2 Farmers Perception of Climate Change in Southeast and Their Adaptation Strategies**

Climate change impacts countries, regions, and communities in different ways and thus their adaptation strategies differ [20]. The factors responsible for the variation in adaptive responses across counties are the agro-ecological system, socio-economics, climatic impact, and existing infrastructure and capacity [20,21]. Therefore, adaptation approaches that are vital to aid the local communities to cope with extreme weather conditions and related climatic variations [20,22]. The strategies are, however, not likely to be effective without an understanding of the farmer's perceptions of climate change and access to appropriate technology, institutions, and policies [20]. For instance, climate change perceived by farmers in Nigeria is

expressed in high temperature, frequent floods, erratic rainfall and droughts these posed constraints on agriculture [23]. The smallholder farmers who are the major producer of food crops are increasingly finding it difficult to cope with the dangers of climate change and variability because higher temperatures and lower rainfall reduces agricultural farmland and lower crop productivity [24]. As documented by [25] erratic rainfall, heat stress and drought can cause food insecurity which will result in food shortages. Consequently, the lengths and intensities of rainfall have increased, producing large runoffs and flooding in many parts of Nigeria [26]. As a result, farmers in Ebonyi state have noticed the impact of climate change in rice cultivation [27]. The farmers observed an increase in swamp size implying more land area available for swamp rice cultivation. The increase was attributed to climate change by the majority of rice farmers resulting from the increase of rainfall in recent times as compared to previous years. In Imo state, the majority of farmers have observed in recent times, that flooding had increased which indicated climate change [28]. The decline of crop yields, soil fertility, drought events and increased heatwave were the perceived impacts of climate change on farming in Imo state as noted by [29]. A study [30] further explained that temperature and rainfall have exhibited increasing trends within southeast Nigeria, thus farmers in the area have commenced planting of choice cropping systems, and cover crops. In Anambra State [31] acknowledged that there is an uneven distribution of seasonal rainfall from 2007-2016 and a wide variation in dates of onset and cessation of rainy season, men and women responses show that there were statistically significant changes in the inception of the rainy season, early cessation of annual rainfall; shift of growing seasons; recurrent flooding and drought. Women felt more impact on food insecurity, water shortage and the burden of migration due to changes in rainfall. As rainfall continues to be more erratic, [26] documented that all traditional crops in Enugu with the exception of cassava and pepper had a substantial field decrease. The eight major constraints faced by cocoyam farmers in acclimatizing to climate change: the high cost of farm inputs and low soil fertility, land and labor challenges, poor access to information and incompetence of cooperatives, unable to access fund and credit facilities and poor government support, lack of improved varieties of cocoyam, the poor value attached to cocoyam, lack of infrastructural capacity and transportation challenge [32]. The key impact of climate change

on cocoyam production includes the decline in yield of cocoyam, reduction of soil fertility, stunted growth, uncertainty in planting and harvesting date, increase in the decay of planted corms and increase loss during storage in the barns.

### 2.3 Nigeria and Climate Smart Agriculture

According to [33], CSA is a method of agriculture that sustainably increases production, resilience (adaptation), reduces/removes greenhouse gases (mitigation) while enhancing the achievement of national food security and developmental goals. CSA aims to simultaneously increase agricultural production, food security, and farmers' adaptive capacity to climate extremes, while also lowering greenhouse gas emissions [34]. Three key pillars of the CSA approach: the sustainable increase in agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions. Therefore, agriculture is considered to be climate-smart when it achieves these three aims. The concept of CSA is not only a technology per se but a set of technologies, approaches and management practices that together make a landscape climate-smart [35].

International Assessment of Agricultural Knowledge Science and Technology for Development [36], suggests that the implementation of CSA practices in the Northern part of Nigeria will improve indigenous agricultural systems as well as improve the practice of agro-ecological agricultural systems. However, it has not been empirically established but few studies are supporting this argument. Therefore the establishment of the potential application of climate-smart agriculture in the background of developing societies is vital in creating a wide adoption by farmers.

Table 1 below discussed the technologies, practices and services directly or indirectly contribute to improve productivity, enhance resilience and reduce GHG emission. These technologies/practices that help to improve at least one component can be considered as CSA. Same technology can also help to improve all three elements of CSA.

In accessing farmer's prioritization of climate smart agricultural technologies, [38] revealed that in Nigeria CSA involves participation and sustainable use of resources but it is fragile in the aspect of reward and equal sharing of

benefits and cost. Consequently, the practice of CSA lacks a coherent climate mitigation method and institutional structures. However, sustainable agriculture in the form of CSA requires an extensive societal change towards growing the balance between agriculture and environmental change. A study [39] reported that 68.1% of farmers are eager to pay N126.32 per year for CIS with factors like farmer's level of experience, level of education, rainfall variability etc. as major determinants of willing to pay in South-Western Nigeria. In SE, South-South (SS) rainfall is significant for farming activities, excess rains cause flooding and erosion on farmers' fields causing crop destruction and removal of topsoils. The use of ingenious approaches such as stone bund and contour/tie ridges for reducing erosion and collecting run-off water for farming activities have become popular among farmers in SE Nigeria [40]. As documented by [41], irrigation had a positive and significant impact on agricultural production including other agricultural subsectors. The findings recommend the need to minimize the effect of climate-induced agricultural production risks through CSA, which involves harmonizing the development of more arable land under irrigation in Nigeria. This will enhance agricultural water management and increase food security and viable agricultural production under widespread climate change and variability.

The major determinants of CSA in SE include: income, extension, credit, education, farming experience, the land area cultivated, livestock ownership, distance to the market and gender, household size, water resources, leadership position, risk orientation, mass media exposure and land ownership [42].

### 2.4 Climate Information Services for Agriculture in Southeast Nigeria

Climate information services are a piece of information that provide a full range of advice about climate, its effects on crops, livestock, fisheries and management practices to be followed by farmers to prevent, reduce and manage climate risks in agricultural production. This tailored information supports farmers to make management decisions that will lessen the risks and increase advantage from the opportunities of our variable and changing climate. Farmers are the key final or end-users of climate services considering that agriculture is one of the sectors of importance for the economies of African countries. Climate services

**Table 1. Selected climate smart options for farmers' preferences**

<b>Technology</b>	<b>Adaptation/mitigation potential</b>
<b>1. Water-smart</b>	<b>Interventions that improve water use efficiency</b>
<ul style="list-style-type: none"> <li>• Rainwater Harvesting (RH)</li> <li>• Drip Irrigation (DI)</li> <li>• Laser Land Levelling (LL)</li> <li>• Furrow Irrigated Bed Planting (FIBP)</li> <li>• Cover Crops Method (CCM)</li> </ul>	<p>Collection of rainwater not allowing to run-off and use for agricultural in rainfed/dry areas and other purposes on-site.</p> <p>Application of water directly to the root zone of crops and minimize water loss</p> <p>Levelling the field ensures uniform distribution of water in the field and reduces water loss (also improves nutrient use efficiency)</p> <p>This method offers more effective control over irrigation and drainage as well as rainwater management during the monsoon (also improve nutrient use efficiency)</p> <p>Removal of excess water (flood) through water control structure</p>
<b>2. Energy smart</b>	<b>Interventions that improve energy use efficiency</b>
<ul style="list-style-type: none"> <li>• Zero Tillage/Minimum Tillage (ZT/MT)</li> </ul>	Reduce amount of energy use in land preparation. In long-run, it also improves water infiltration and organic matter retention into the soil
<b>3. Nutrient-smart</b>	<b>Interventions that improve nutrient use efficiency</b>
<ul style="list-style-type: none"> <li>• Site Specific Integrated Nutrient Management (SINM)</li> <li>• Green Manuring (GM)</li> <li>• Leaf Color Chart (LCC)</li> <li>• Intercropping with Legumes (ICL)</li> </ul>	<p>Optimum supply of soil nutrients over time and space matching to the requirements of crops with right product, rate, time and place</p> <p>Cultivation of legumes in a cropping system. This practice improves nitrogen supply and soil quality.</p> <p>Quantify the required amount of nitrogen use based on greenness of crops. Mostly used for split does application in rice but also applicable for maize and wheat crops to detect nitrogen deficiency.</p> <p>Cultivation of legumes with other main crops in alternate rows or mixed. This practice improves nitrogen supply and soil quality.</p>
<b>4. Carbon-smart</b>	<b>Interventions that reduce GHG emissions</b>
<ul style="list-style-type: none"> <li>• Agro Forestry (AF)</li> <li>• Concentrate Feeding for Livestock (CF)</li> <li>• Fodder Management (FM)</li> <li>• Integrated Pest Management (IPM)</li> </ul>	<p>Promote carbon sequestration including sustainable land use management</p> <p>Reduces nutrient losses and livestock requires low amount of feed</p> <p>Promote carbon sequestration including sustainable land use management</p> <p>Reduces use of chemicals</p>
<b>5. Weather-smart</b>	<b>Interventions that provide services related to income security and weather advisories to farmers.</b>
<ul style="list-style-type: none"> <li>• Climate Smart Housing for livestock (CSH)</li> <li>• Weather based Crop Agro-advisory (CA)</li> <li>• Crop Insurance (CI)</li> </ul>	<p>Protection of livestock from extreme climatic events (e.g. heat/cold stresses)</p> <p>Climate information based value added agro-advisories to the farmers</p> <p>Crop-specific insurance to compensate income loss due vagaries of weather</p>
<b>6. Knowledge-smart</b>	<b>Use of combination of science and local knowledge</b>
<ul style="list-style-type: none"> <li>• Contingent Crop Planning (CC)</li> <li>• Improved Crop Varieties (ICV)</li> <li>• Seed and Fodder Banks (SFB)</li> </ul>	<p>Climatic risk management plan to cope with major weather related contingencies like drought, flood, heat/cold stress during the crop season</p> <p>Crop varieties that are tolerant to drought, flood and heat/cold stresses</p> <p>Conservation of seeds of crops and fodders to manage climatic risks</p>

Source: [37]

constitute an important element of the climate adaptation agenda. It provides proof on the value-added of modifying climatic information in the hands of users based on improved forecasting capability.

According to the World Meteorological Organization (WMO), climate service could be effective only when it meets the prerequisite of end-users. The quality that helps to define the usefulness of climate service includes availability, timeliness, dependable, usable, credible, authentic responsive and flexible [43,44]. The basic criteria for measuring the benefits of climate service include economic benefits such as increasing household economic status and welfare, reducing the cost of key commodities, land, insurance and agricultural costs; and providing benefits to health, well-being, and livelihoods [45]. The service requires an appropriate commitment to producing an optional significant to the needs of the user to aid decision-making under uncertainty and facilitate early guide action and preparedness. It also implies the effective access and delivery mechanism of all the climate services to respond to the user's needs [46].

For climate service to be useful, it must be integrated into a farm-level decision, for this reason, climate information must be provided well ahead of the agricultural season. However, most farmers do not receive forecast information early enough, and in formats they can understand through communication channels they find relevant or with content they find salient, thus limiting the possibility of realizing the full value of the forecast, and measuring outcomes or impacts [47,48], the scale of information about the forecasts and models must be local so that farmers can understand it well and make their decisions on crop cultivation, land conservation, fertilizer and other inputs, and planting dates that relate specifically to their livelihoods and their farms [49,47].

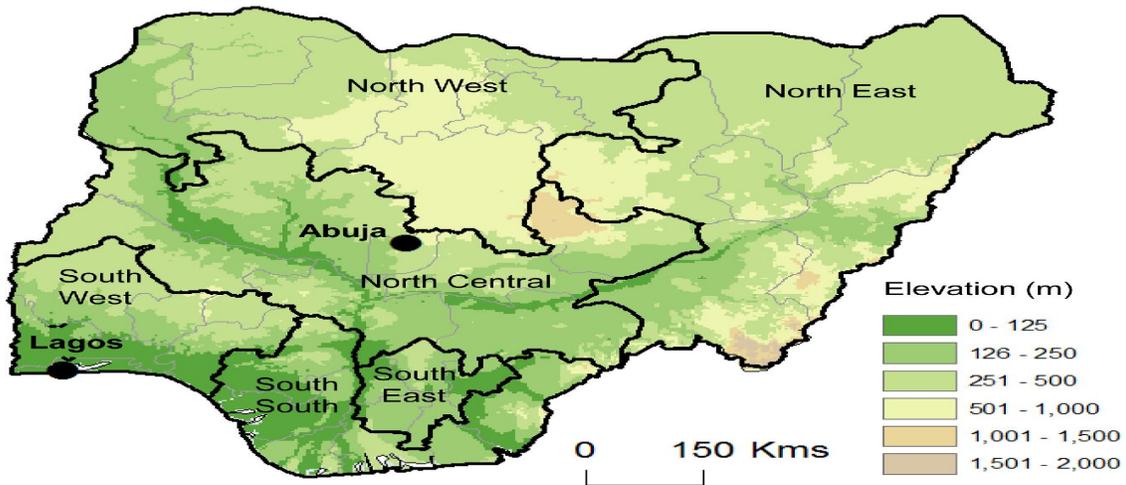
In Enugu State Nigeria, [50] identify poor extension services and infrastructure as the major challenges to effective communication of climate change information to farmers. Nigerian media has not given adequate and efficient information on climate change issues to farmers [51]. A study by [52] further explained that the degree of information available to farmers impacts their level of awareness. When adequate and reliable weather information is given to farmers there can easily make their decisions,

choice and plans. Therefore, access to detailed weather information, early warning and forecast technologies can assist farmers to develop and readjust coping or adaptation strategies [53]. Since farmers do not have forefront knowledge about the climate, [54] ascertain that when rainfall is erratic, it becomes challenging for farmers to plan their operations.

In SE Nigeria farmers prefer information that relates to what works on their farm, rather than blanket generalizations, especially when environmental conditions are extremely variable. Therefore, increasing access to print or digital media would help in spreading awareness of climate change and associated production risk among farmers but most important is training farmers with meteorological information will be the best option before the commencement of the farming season. These climate information services could play a vital role in forming correct perceptions of farmers and a major strategy for climate risk mitigation [55]. Studies by [56,57] attest that planning decisions such as when to start land preparation, when to plant, crop variety selection, plans for fertilizer application are all connected to receiving downscaled seasonal forecast information. The scientific community has continued to improve the coverage and quality of observational networks and the advancement of skill for forecasts across timescales but, there are several scientific and practical barriers impact the utility and uptake of climate information for farmers in Africa [58,59].

### 3. STUDY AREA

The southeast region of Nigeria comprises of five states: Abia, Imo, Anambra, Enugu and Ebonyi States. It is the home of the Igbo speaking language in Nigeria. It is located within latitudes 5°N and 6°N and longitude 4°30'E and 7°30'E in a tropical rainforest zone [60]. The annual mean temperature is 27°C, and total annual rainfall exceeding 2500 mm [61]. According to [62] the zone occupies a total landmass of 10,952,400 hectares with a population of 16,381,729 comprising 8,075,423 females and 8, 306,306 males, making a ratio of 50.70 males to 49.30 females for the zone [63]. There are two major seasons in this zone—the dry season and the rainy season. It experiences dry season between November and March while the rainy season occurs from April and October. The climate constitute an important element of the climate encourages the cultivation of food crops like yam, cassava, vegetables, rice, etc. and



**Fig. 1. Map of Nigeria showing Southeast**

Sources: [64]

livestock production. According to [63] the sex ration in Abia, Imo and Anambra is dominated by the male while Ebonyi and Enugu are dominated by females.

### 3.1 Methodology

The methodology used for this study is based on a general review of related literature of journals published within the Southeast region of Nigeria.

## 4. DISCUSSION OF FINDINGS

The following are the findings of this study:

- i. Farmers within SE agreed there is a climate change but they do not have documented evidence of climate change as a result their adaptation methods are based on their local knowledge and experiences. Adaption practices involve a change in planting dates, the type of fertilizer used, the use of irrigation, change of crop management and cultivation practice for instance mulching, intercropping, planting of food security crop, soil and water conservation technologies.
- ii. Lack of access to credit facilities and funds. The government both the Federal, State and Local should support private insurance firms through policies that would encourage agricultural partnerships since agricultural products are the basis for life. Access to credit facilities through microfinance institutions, especially to the poor farmers, will enable them to adapt to climate change

and compensation of farmers' income loss as a result of weather/climate-related challenges.

- iii. Inadequate extension services/workers within the SE to support farmers. In the face of climate change, there should be an operational climate information service center for farmers in each state, this will enable extension staffs to work effectively with farmers in a participatory and facilitating manner and to support their decision making and planning that takes into account of local climate together with other constraints and opportunities that farmers have. Consequently, detailing how the provision of climate services for agriculture helps improve the management of climate risks and can help to shape future initiatives with these farmers' perception of climate change can be documented.
- iv. No training/education services for farmers on the adoption of CSA: In Nigeria, adoption of CSA can come in form of increasing irrigation especially in the Northern region of Nigeria although Southeast should not be left out. Irrigation scheme involves the collection of rainwater and not allowing them to runoff for agriculture use, construction of dams in dry areas, application of water directly to the root zones of crops to reduce the loss of water. The use of combined science and local knowledge in climatic risk management and related problems like floods, cold stress, drought.

## 5. CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

Agriculture aims to increase food production in the face of an increasing population. This difficult challenge is exacerbated by climate change which has a significant impact on food security. In Nigeria, challenges associated with climate change are not the same across the country, Southwest and Southeast are less vulnerable than other parts of the country. To help farmers manage their enterprises in the face of climate variations and change hence the need for the adoption of climate smart agriculture but CSA faces a number of challenges in SE Nigeria: financing, policy, climate information service, etc but recently a new approach to extension and climate information services, namely Participatory Integrated Climate Services for Agriculture has been developed. PICSA makes use of participatory decision-making tools and historical climate records to make forecasts that help farmers to identify and better plan livelihood options that are suitable to local climate features and farmers' environments.

### 5.2 Recommendation

The study recommends a PICSA approach that uses historical climate records, participatory decision-making tools and forecasts to assist farmers to identify and plan better livelihood options that are suitable to local climate features and farmers' own circumstances. The approach enabled farmers to make a premeditated plan long before the planting season, based on their improved knowledge of local climate features. The uniqueness of PICSA is that the facilitator uses historical climate records (at least the past 30 years) for joint training and examination with farmers, this will enlighten their decision-making as it is done long before the planting season starts, with the purpose of developing farming approaches for 'any season'.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

### REFERENCES

1. Wani SP, Rockström J, Oweis T. Rainfed agriculture: Unlocking the potential. CABI, Wallingford, Patancheru, Andhra Pradesh,

India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Colombo, Sri Lanka: International Water Management Institute (IWMI). (Comprehensive Assessment of Water Management in Agriculture Series 7); 2009.

2. Onwutuebe CJ. Patriarchy and women vulnerability to adverse climate change in Nigeria. SAGE. 2019;1–7. DOI: 10.1177/2158244019825914
3. FAO. Adoption of climate-smart agricultural practices: Barriers, incentives, benefits and lessons learnt from the MICCA Pilot Site in Kenya. Final Report Prepared by Morgan C. Mutoko for MICCA Programme in December; 2014.
4. Nwaobiala CU, Nottidge DO. Effect of climate variables on cassava farmers production in Abia State, Nigeria. Nigerian Journal of Agriculture, Food and Environment. 2013;9(4):57-62.
5. Ray DK, Gerber JS, Macdonald GK, West PC. Climate variation explains a third of global crop yield variability. Nature Communication. 2015;6(1):5989.
6. Zhaoa C, Liub B, Piao S, Wanga X, Lobelli DB, Huangj Y, Bassuk S. Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences of the United States of America. 2017;114(35):9326–9331.
7. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environment Change. 2009;19: 248–255.
8. Gbetibouo GA. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin. IFPRI Research Brief. 2009;15-8.
9. DEA (Department of Environmental Affairs). Climate change adaptation: Perspectives for the Southern African Development Community (SADC). Report No. 1 for The Long Term Adaptation Scenarios Flagship Research Program (LTAS), Pretoria, South Africa; 2013.
10. Bell P, Namoi N, Lamann C, Corner-Dollof C, Girvetz E, Thierfelder C, Rosenstock T. A practical guide to climate-smart agricultural technologies in Africa. CCAFS Working Paper no. 224. CGIAR Research Program on Climate Change, Agriculture

- and Food Security (CCAFS), Copenhagen, Denmark; 2018.
11. USGCRP. Hatfield J, Takle G, Grotjahn R, Holden P, Izaurralde RC, Mader T, Marshall E, Liverman D. Ch. 6: Agriculture. Climate change impacts in the United States: The Third National climate assessment. J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program. 2014;150-174.
  12. Tripathi A. Socioeconomic backwardness and vulnerability to climate change: Evidence from Uttar Pradesh State in India. *Journal of Environment and Planning Management*. 2016;5:256-274.
  13. Tol RSJ. The damage costs of climate change toward more comprehensive calculations. *Environment Resource and Economics*. 1995;5:353-374.
  14. Tol RSJ, Downing TE, Kuik OJ, Smith JB. Distributional aspects of climate change impacts. *Global Environmental Change*. 2004;14(3):259-272.
  15. Hu X, Huang Y, Sun W, Yu L. Shifts in cultivar and planting date have regulated rice growth duration under climate warming in China since the early 1980s. *Agriculture Forest Meteorology*. 2017;247:34-41.
  16. Wang J, Vanga SK, Saxena R, Orsat V, Raghavan V. Effect of climate change on the yield of cereal crops: A review. *Climate*. 2018;41(6):1-9.
  17. Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Travasso MI. Chapter 7: Food security and food production systems. In: *Food Security and Food Production Systems*. In: *Climate Change 2014: Impacts, Adaptation and Vulnerability*. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Chan. Cambridge University Press. 2014;485-533.
  18. Mendelsohn R, Dinar A, Williams L. The distributional impact of climate change on rich and poor countries. *Environment Development and Economics*. 2006;11(02):159-167.
  19. Hertel TW, Lobell DB. Agricultural adaptation to climate change in rich and poor countries: Current modelling practice and potential for empirical contributions. *Energy Economics*. 2014;46:562-575.
  20. Alam GMM. An assessment of the livelihood vulnerability of the riverbank erosion hazard and its impact on food security for rural households in Bangladesh. PhD Thesis, School of Commerce, University of Southern Queensland, Australia; 2016.
  21. Brulle R, Carmichael J, Jenkins J. Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the U.S., 2002-2010. *Climatic Change*. 2012;114:169-188.
  22. Niles MT, Lubell M, Brown M. How limiting factors drive agricultural adaptation to climate change. *Agricultural Ecosystem and Environment*. 2015;200:178-185.
  23. Ebele NE, Emodi NV. Climate change and its impact in Nigerian economy. *Journal of Scientific Research & Reports*. 2016;10(6):1-13.
  24. Onyeneke R, Madukwe D. Adaptation measures by crop farmers in the southeast rainforest zone of Nigeria to climate change. *Science World Journal*. 2010;5(1):32-36.
  25. Elum ZA, Modise DM, Marr A. Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management*. 2017;16:246-257.
  26. Enete IC. Impacts of climate change on agricultural production in Enugu State, Nigeria. *Journal of Earth Science & Climate Change*. 2014;5:234.
  27. Diagi BE, Nwagbara MO. Perceived impact of climate change on swamp rice cultivation by farmers in Ebonyi State, Southern Nigeria. *Archives of Current Research International*. 2018;14(2):1-10.
  28. Okoro JP, Olaolu MO, Igbokwe EM. Climate change mitigation and adaptation strategies used by farmers in Imo state, Nigeria. *J. Agric. Ext*. 2016;20(2):130-142.
  29. Ozor N, Umunakwe PC, Ani AO, Nnadi FN. Perceived impacts of climate change among rural farmers in Imo State, Nigeria. *African Journal of Agricultural Research*. 2015;10(14):1756-1764.
  30. Nwaiwu IOU, Ohajianya DO, Orebiyi JS, Ibekwe UC, Lemchi LJ, Onyeagocha SUO, Odoemena B, Utazi CO, Osuagwu CO, Tasié CM. Climate change trend and appropriate mitigation and adaptation strategies in Southeast Nigeria. *G.J.B.A.H.S*. 2013;3(1):120-125.
  31. Nnadi OI, Liwenga ET, Lyimo JG, Madukwe MC. Impacts of variability and

- change in rainfall on gender of farmers in Anambra, Southeast Nigeria. *Heliyon*. 2019;5:e02085.
32. Ifeanyi-Obi CC, Togun AO, Lamboll R, Adesope OM, Arokoyu SB. Challenges faced by cocoyam farmers in adapting to climate change in Southeast Nigeria. *Climate Risk Management*. 2017;17:155-164.
  33. FAO. "Climate-Smart" agriculture: Policies, practices and financing for food security, adaptation and mitigation. Food and Agric. Organization of the United Nations, Rome; 2010.
  34. Campbell BM, Thornton P, Zougmore R, van Asten P, Lipper L. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability*. 2014;8:39–43.
  35. Scherr SJ, Shames S, Friedman R. From climate-smart agriculture to climate smart landscapes. *Agricultural Food Security*. 2012;1-12.
  36. IAASTED. Agriculture at a Crossroad. Latin America and the Caribbean (LAC) Report, 3; 2009.
  37. Khatri-Chhetri A, Aggarwal PK, Joshi PK, Vyas S. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems*. 2017;151:184–191.
  38. Terdoof F, Adekola O. Assessing the role of climate-smart agriculture in combating climate change, desertification and improving rural livelihood in Northern Nigeria. *African Journal of Agricultural Research*. 2014;9(15):1180-1191.
  39. Oyekale TO, Oyekale AS, Oyedepo JA. Farm households' perceptions on climate change and willingness to subscribe for advisory weather forecasts in South West Nigeria. *Disaster Adv*. 2015;8(11):8-19.
  40. Mashi SA, Yaro A, Jenkwe ED. Causes and consequences of gully erosion: Perspectives of the local people in Dangara area, Nigeria. *Environ. Dev. Sustain*. 2015;17(6):1431-1450.
  41. Olayide OE, Tetteh IK, Popoola L. Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture? *Agricultural Water Management*. 2016;178: 30–36.
  42. Onyeneke RU, Igberi CO, Uwadoka CO, Aligbe JO. Status of climate-smart agriculture in Southeast Nigeria. *Geo Journal*. 2018;83:333–346.
  43. WMO (World Meteorological Organization). Climate knowledge for action: A global framework for climate services – empowering the most vulnerable. Report of the High-Level Taskforce for the Global Framework for Climate Services (WMO No.1065). Geneva, 240; 2011.
  44. WMO. Valuing weather and climate: Economic assessment of meteorological and hydrological services. Geneva, Switzerland. Valuing-Weather-and-Climate-Economic-Assessment-of-Meteorological-and-Hydrological-Services; 2015.
  45. WMO. Valuing weather and climate: Economic assessment of meteorological and hydrological services. WMO-No. 1153. Geneva, 286; 2014.
  46. Tall A, Njinga J. Developing a methodology to evaluate climate services for farmers in Africa and South Asia Workshop Report. Copenhagen, Denmark: CGIAR Program on Climate Change, Agriculture and Food Security; 2013.
  47. Tall A, Hansen J, Jay A, Campbell B, Kinyangi J, Aggarwal PK, Zougmore R. Scaling up climate services for farmers: Mission possible. Learning from good practice in Africa and South Asia. CCAFS Report No. 13. Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); 2014.
  48. Carr ER, Onzere S, Kalala T, Kwame NOD, Rosko H. Assessing Mali's l'Agence Nationale de La Météorologie's (Mali Meteo) Agrometeorological Advisory Program: Final Report in the Farmer Use of Advisories and the Implications for Climate Service Design. Washington, DC; 2015.
  49. Takle ES, Anderson CJ, Andresen J. Climate forecasts for corn producer decision making. *Earth Interact*. 2014;18: 1–8.
  50. Okoro J, Agwu A, Anugwa I. Climate change information needs of rural farmers in Enugu State. *Journal of Agricultural Extension*. 2016;20(2):215-232.
  51. Ajaero I, Anorue L. Newspaper framing and climate change mitigation in Nigeria and Ghana. *African Population Studies*. 2018;32(2):4228-4238.
  52. Duru NP, Emetumah CF. Evaluating the effects of information literacy on climate change awareness among students in Imo State University. *Archives of Current Research International*. 2016;4(3):1-10.

53. Otitoju MA, Enete AA. Climate change adaptation: Uncovering constraints to the use of adaptation strategies among food crop farmers in South-west, Nigeria using principal component analysis (PCA). *Cogent Food & Agriculture*. 2016;2.
54. Haider H. Climate change in Nigeria: Impacts and responses. K4D Helpdesk Report 675. Brighton, UK: Institute of Development Studies; 2019.
55. Lodoun T, Sanon M, Giannini A, Traor PS, Som L, Rasolodimby JM. Seasonal forecasts in the Sahel region: The use of rainfall-based predictive variables. *Theor. Appl. Climatol*. 2014;117(34):485-494.
56. Westermann O, Thornton P, Forch W. Reaching more farmers innovative approaches to scaling up climate smart agriculture. CCAFS Working Paper no. 135. In: Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); 2015.
57. Zare A, Barbier B, Bologo-Traore M, Diarra A, Mahe G, Paturel JÉ. Climate forecast perception and needs in Wetlands: A case study in the Inner Niger Delta in Mali. *Wetlands*. 2017;37(5):913-923.
58. Hou AY, Kakar RK, Neeck S, Azarbarzin AA, Kummerow CD, Kojima M, Iguchi T. The global precipitation measurement mission. *Bulletin of the American Meteorological Society*. 2014;95(5):701–722.
59. Hoskins B. The potential for skill across the range of the seamless weather-climate prediction problem: A stimulus for our science. *Quarterly Journal of the Royal Meteorological Society*. 2013;139:573–584.
60. Ezenwaji EE, Awopeju AK, Otti VI, Eduputa BM. Spatial patterns of residential water supply accessibility levels in Anambra State, Nigeria. *Int. J. Eng. Res. Afr*. 2014;4(1):326–336.
61. Ezemonye MN, Emeribe CN. Rainfall erosivity in Southeastern Nigeria. *Ethiopian Journal of Environmental Studies and Management*. 2012;5(2):112-122.
62. National Population Commission (NPC). Official Census Report. Abuja, Nigeria; 2006.
63. Wilson G, Felix JM. Manipulation and politicisation of the sex composition of Nigeria's population census data and the implications for national development. *Int. J. Dev. Strat. Humanit. Manag. Soc. Sci*. 2018;8(1):20.
64. Okorie PN, Ademowo GO, Saka Y, Davies E, Okoronkwo C, Bockaries MJ, Kelly-Hope AL. Lymphatic filariasis in Nigeria; Micro-stratification Overlap Mapping (MOM) as a prerequisite for cost-effective resource utilization in control and surveillance. *PLoS Negl Trop Dis*. 2013;7(9):e2416. DOI: 10.1371/journal.pntd.0002416

© 2020 Okoro et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*  
The peer review history for this paper can be accessed here:  
<http://www.sdiarticle4.com/review-history/56103>