IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 15, Issue 10 Ser. I (October 2021), PP 23-29
www.iosrjournals.org

Temporal Dynamics in Climate Smart Agricultural Practices Among Smallholder Farmers In Nigeria

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Abstract:
The recent experience of Nigerian farmers with respect to the challenges of climate change make it imperative to promote the adoption of climate smart agriculture (CSA) practices. While the FAO has been trying to promote CSA practices particularly in the North-eastern part of the country, there is considerable knowledge-gap of how these practices change over time. This temporal dimension has been considered more critical for policy formulation than the singe period adoption estimates. This study therefore adopted a panel data approach using the GHS panel data collected by NBS over two periods of 2012/2013 and 2014/2015 to examine how adoption of CSA practices changes among smallholder farmers in Nigeria. Findings from the two periods (2012 and 2015) indicate that while there was an increase in the CSA practices of crop diversification, there was a decline in the use of improved seeds and the practice of soil conservation. Adoption of CSA practices was shown as non-sustainable over time; and is significantly influenced by age, time, sector, and zonal variations. The study, therefore, recommends the need to promote zonal-based incentives and policy that could stabilize the adoption of CSA practice over time to achieve sustainable food production in Nigeria.

Keywords: *Climate Smart Agriculture, Temporal, Dynamics, Smallholder farmers*

Date of Submission: 01-10-2021 Date of Acceptance: 15-10-2021

I. Introduction

One of the major and current threats to food crop production among Nigerian smallholders is climate change. This is mainly because the natural climate and environment determines vegetation patterns, types, and yield of crops as well as duration of cropping season. As such, any change in climate will significantly affect food crop production and agricultural production in general. According to FAO, (2010), climate change is expected to cause considerable losses in crop yield and will, therefore, adversely affect smallholder livelihoods in Africa. Similarly, studies have projected that crop yield in Africa due to climate change may fall by 10-20 per cent by 2050 (Jones, 2003; Nwaobiala, 2013).

Nigerian farmers are also not spared in this yield loss due to the negative impact of climate change, which have manifested in lower produce yield and poorer livelihood. The Department of Climate Change in the Federal Ministry of Environment has predicted national agricultural productivity decline of 10-25 per cent by 2080, while yield of rainfed agriculture in some northern areas that are highly vulnerable to decline by up to 50 per cent. This has been estimated to result in a 4.5 per cent reduction in GDP by 2050; accounting for critical loss of livelihoods and increased poverty for over 80 per cent of smallholder farming households in Nigeria, (Fadairo et al., 2019).

Following from the most recent recession; from which the Nigerian economy has not fully recovered from; an Economic sustainability plan (New Economic Sustainability Plan-NESP) was formulated to set the economy on the path of sustainable growth (FGN, 2020). The expected growth trajectory has also been predicated mainly on the development of the agricultural sector. As such, except appropriate step is taken to minimize the adverse effects of climate change on agricultural production, the much-needed impact of the sector on economic growth may not be realizable. Meanwhile, one major way that has been recognized globally to minimize the adverse effects of climate change on agricultural production is the adoption of climate smart agriculture (CSA). This is the adoption of some sustainable agricultural production practices in response to the threat posed by climate change. Thus, CSA is an adaptation of strategy that helps smallholders to be resilient to and cope with the effects of climate change.

In view of the challenges pose by climate change therefore, it is important that Nigeria began to promote the adoption of climate smart agriculture practices. We posit that this will allow smallholders and large-scale farmers to adapt to climate change whilst reducing emission, while maintaining appreciable levels of production and livelihood outcomes. While the above concern may be significant, a comprehensive and nationwide knowledge of the practice of some CSA practices is still extremely limited. Although the FAO has been trying to track and promote CSA practices particularly in the North-eastern part of the country, empirical evidence of how these practices have been known to change over time. Moreover, the attendant effects of use versus non-use as well as the dynamism of adoption on food crop production is still very lacking. Other studies in Nigeria that have tried to document these practices are also much localized such that outcome of such studies have limited policy utilization (Onyeneke et al., 2018; FAO, 2019; Oyawole et al., 2020). Therefore, this study attempts to examine the dynamics of CSA practices among smallholders in Nigeria with emphasis on factors that influence adoption over two periods using a nationally collected panel data.

THEORY AND CONCEPT

Theoretical Framework for CSA Adoption

The theoretical framework underpinning this study is rooted in the theory of utility. Literature has shown that , "deciding whether to adopt any CSA practice or not falls under utility and profit maximization theoretical frameworks" (Terdoo and Adekola, 2014). The theory of utility explains the behavior of individuals on the basis that individuals can consistently rank their choices based on their preferences (Baumo and Blinder, 2015). With the theory of utility, what is deemed necessary about utility concerning choices being made is whether an option has a higher utility than another and not the measure of the difference between the available options. The consideration of choices made on which CSA practices to be adopted by farmers hangs on the concept of ordering available options based on the benefits they stand to receive from the practices. There is the assumption that economic agents, including small-scale farmers, adopt CSA practices when the expected utility or net benefit is significantly higher than when they do not adopt (Terdoo and Adekola, 2015). As utility cannot be directly observed, the activities of economic agents could be observed through their choices. Consider a rational farmer whose aim is to maximize the proceeds from production over a specific period and has a set of *j* CSA practice options to choose from. The farmer *i* decides to adopt CSA practice *j* if the utility from *j* is perceived to be more than that from other options (assume, *k*).
This relationship is expressed as:

$$U_{ij}\left(\beta_j X_i + \varepsilon_j\right) > U_{ik}\left(\beta_k X_i + \varepsilon_j\right); k \neq j \quad (1)$$

Where U_{ij} and U_{ik} denote the perceived utility by farmer *i* from CSA practice options *j* and *k*, respectively; X_i is a vector of regressor that influence the CSA practice option the farmer chooses; β_j andβ_k are parameters of the independent variables; and *j* and *k* are the error terms, which based on an econometric assumption are independently and identically distributed (Greene, 2012; Brooks, 2019). Under the preference assumption that the farmer decides to adopt a CSA practice option which is more beneficial or generates net benefits and does not practice otherwise, the observable discrete choice of practice can be related to the latent continuous net benefit variable as Equations (2) and (3):

$$Y_{ij} = 1 \; if \; U_{ij} > 0; \quad (2)$$

$$Y_{ij} = 0 \; if \; U_{ij} < 0 \quad (3)$$

Y_{ij} is thus a binary dependent variable valued as 1 when the farmer opts for CSA practice and, 0 if otherwise.

Concept and Application of Climate Smart Agriculture Practices in Nigeria

The concept of CSA has been viewed as an integrated approach to managing cropland, livestock, forest, and fisheries and addresses the interlinked of the challenges of food security and climate change (FAO, 2014). Although the concept of CSA is said to be relatively new in Nigeria, some agricultural practices and technologies that make up CSA already exist and have been identified and classified (FAO, 2019). These practices are broadly grouped along the three major outcomes of CSA (productivity, adaptation, and mitigation) and these practices include:
a).***Conservation Agriculture***: involving the practice of minimum or zero tillage cover cropping or mulching and crop rotation [Giller et al., 2009). These practices offer multiple benefits of reducing rum-off, increased water infiltration, improved soil organic matter and improve soil moisture retention.
b). ***Intercropping / Crop Diversification:*** significantly reduces the risk of crop failure and provide farmers with important safety nets in case one crop fails to perform as expected (Bala, 2018).
c).***Improved Seeds***: which involve the adoption of the planting improved and high yielding early maturing seed varieties that are resistant to extreme weather conditions.

d).***Integrated Soil Fertility Management:*** which includes practices such as application of organic fertilizer such as animal manure, compost, crop residues to complement chemical fertilizer application. This practice improves soil fertility through decomposition and nitrogen mineralization helps in reducing the Greenhouse Gas (GHG) emission that would have accomplished the use of large quantities of chemical fertilizer (Tubiello et al., 2013).

This study focused on the dimensions of Conservative agriculture, (CA), Crop Diversification (CD) and improved seeds in its analysis.

II. Materials And Methods

Types and Sources of Data

This study engages mainly secondary data which are sets of panel data collected by National Bureau of Statistics (NBS) in a Generalized Households Survey (GHS) across the country. The NBS_GHS data is a set of panel data collected at household and plots levels during post planting and harvesting season. The first wave was collected in 2011/2012 while the second and third waves were collected in 2012/2013 and 2014/2015 respectively. Even though the fourth wave of the data set has been collected by NBS the micro-data has not been available for public use as at the time of carrying out this study. As such, this study only adopts the two most current sets. These two periods are 2012/2013 and 2014/2015 otherwise often refers to as wave 2 and 3, respectively. These two periods provided opportunity for understanding the dynamics of CSA practices among smallholder farmers across the six geo-political zones in the country. The analytical approach in-volved the use of descriptive and inferential statistics to illustrate the observed changes while changes in the rate of adoption of CSA practices over the two periods was computed and factors influencing adoption analyzed using panel logistic regression. The unit of analysis is basically households as information collected at plots levels are aggregated for each household.

Determinants of CSA Adoption

The probability of CSA adoption among the small-scale farmers in Nigeria is modeled according to equations 2 and 3. However, since the interest in the study is the dynamics of adoption between the two periods, a panel Logistic Regression Model was used to model the determinants of CSA utilisation across the two periods under review. Therefore, if.

$Y_{ij1} = 1 \; if \; U_{ij} > 0$; represents adoption rate in period 1 (4)

and $Y_{ij2} = 1 \; if \; U_{ij} > 0$; adoption rate in period 2 then, (5)

Change in adoption can be estimated as:

$$(Y_{ij1} = 1 \; if \; U_{ij} > 0) - (Y_{ij2} = 1 \; if \; U_{ij} > 0) \neq 0 \quad (6)$$

The combined outcomes Y_{ij} will be estimated in the panel model as:

$$P\left(\frac{U_{ij} > U_{ik}}{X}\right) = P\,\frac{(\beta_j X_i + \varepsilon''_j) - (\beta_k X_i - \varepsilon''_k) > 0}{X} \quad (7)$$

$$= P\,\frac{\beta^* X_i + \varepsilon^* > 0}{X} = F(\beta^* X_i \quad (8)$$

Where *P* is a probability function; $\varepsilon''* = \varepsilon''j - \varepsilon''k$ is a random disturbance term; $\beta^* = (\beta j - \beta k)$ is a vector of unknown parameters that can be explained as the net influence of the determinants (X_i) of the choice of CSA practice; and $F(\beta^* X_i)$ is a cumulative distribution of ε^* estimated at $\beta^* X_i$ (Stergiou, 2015; Hill et al., 2018;Victor et al., 2019).

The explanatory variables are stated as follows:

X_i=Age (Years);

X_2= Sex(0=Female; 1=Male)

X_3=Literacy (0=No, 1=Yes)

X_4=Marital status (0=Unmarried' 1=Married)

X_5= Sector (0=Rural, 1=Urban)

X_6=Time (0=2012; 1=2015)

X_7= Geopolitical Zones1: (1=North Central; 2=Northeast; 3=Northwest; 4=Southeast; 5=South-South; 6=Southwest)

III. Results And Discussion

In this section, we present and discuss the results of findings from the analysis of the data used in this study. The results of the analysis of changes in CSA practices among the small-scale farmers in Nigeria over the two periods is presented in Figure 1 while the profile of farmers and their use of CSA practice between 2012 and 2015 is also presented in Table 1. The determinants of adoption of CSA are discussed from the results in Table 2.

i. Changes in The State of CSA Practices Among Smallholder Farmers in Nigeria

The results confirmed the fact that an extremely low proportion of smallholder farmers in the country engaged in CSA practices over the two periods. Findings revealed that the most important CSA practice across the two period was the use of Improved seeds as reported by 15.68% and 9.31% of farmers in 2012 and 2015, respectively. Conservation agricultural practices (agroforestry, and relay cropping) also witnessed a decline between the two periods(7.4% to 5.5%). Crop diversification (intercropping) was the only CSA practice that witnessed an improvement from 2012 to 2015 but was also low at 2.69% to 3.73%.

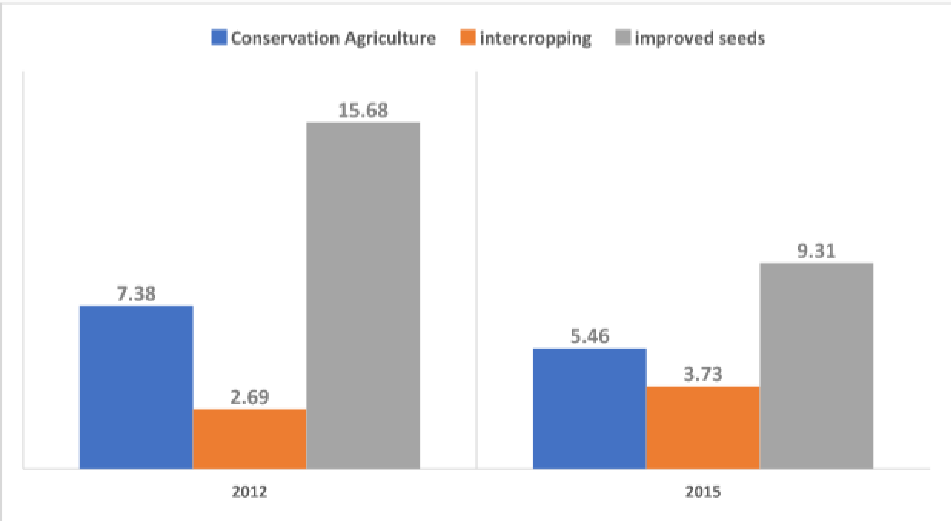

Figure 1: Changes in CSA Practices among Farmers in Nigeria (2012 and 2015)
Source: NBS_GHS wave 2 and 3 Panel Data

Characteristics of Smallholder Farmers by Type of CSA Practices

An important consideration in this study was to explore who uses CSA practices and how does the usage of these practices change over time? The results revealed interesting changes in the farmers' utilization of CSA practice across the two periods when examined by their socioeconomic characteristics.

The results indicated that CSA practices was higher among male headed farming households during the two periods. However, while the practice of intercropping reduced (85.5% in 2012 to 77.9% in 2015), those of conservation agriculture and improved seed witnessed increases in adoption. In the corollary, the practice of intercropping increased from 14.5% in 2012 to 22% in 2015 among female farmers. The low use among female farmers may suggest some form of technology, cultural or financial constraints that prevent female farmers from accessing the opportunities in CSA.

Table 1: Characteristics of farmers by Changes in CSA Practices

Variables	Intercropping (IC)		Conservation agriculture (CA)		Improved Seed (IS)	
	2012	2015	2012	2015	2012	2015
Sex						
Male	85.53	77.88	86.71667	88.86	82.92	86.82
Female	14.47	22.12	13.28333	11.14	17.08	13.18
Age group						
Youth(<35 years)	17.33	4.76	11.59667	8.53	12.13	9.41
Adult (36-65 years)	65.33	74.29	64.27333	66.90333	68.28	67.6
Elderly(>65 years)	17.33	20.95	24.13333	24.56667	19.59	23
Literacy						
Yes	56.76	47.79	56.45667	50.2	56.33	57.79
No	43.24	52.21	43.54333	49.8	43.67	42.21
Marital status						
Married	84	69.52	82.26	84.47333	74.81	82.93

Unmarried	16	30.48	17.74667	15.52667	25.19	17.07
ZONE						
North Central	1.32	29.2	13.82	11.79	7.39	21.86
Northeast	11.84	25.55	13.88	13.04	12.5	11.58
Northwest	60.53	12.02	41.54	38.22	31.87	21.86
Southeast	14.47	9.33	14.13	13.51	27.82	23.47
South South	2.63	20.07	3.21	2.70	13.91	17.04
Southwest	9.21	5.72	13.43	20.74	6.51	4.18

Source: NBS_GHS wave 2 and 3 Panel Data

Age distribution also showed that adults headed households were also more likely to sustain the use of CSAs over time than either the youth or elderly farmers. Also, not surprising is the finding that married farmers were more likely to practice CSA over time than unmarried farmers. However, we found that while IC use witnessed a decline (84%-69.5%) among married farmers, between 2012 and 2015; there was an increase in use among unmarried farmers (16% -30.5%).

The CSA practices witnessed zonal variations across the two periods as well. Our results presented farmers from the Northwest as the main adopters of CSA practices in 2012 (60.5%-IC; 41.5%- CA and 31.9%-IS); albeit there was significant decline in usage of all CSA practices in 2015. The Northeast witnessed an increase in utilization of CA and IS, but a decline in IC, while the North Central witnessed increased usage of all the CSA practices over the two periods considered. In the south, we find that overall, the Southeast had higher utilization of all practices in 2012; but witnessed a decline in all by 2015.Whereas, the South South witnessed an increase in IC (2.6%-20.1%) and IS (13.9%-17%); and the Southwest also reported increased use only in CA (13.4%-20.7%).

Factors Influencing Adoption of CSA Practices in Nigeria

The panel Logistic regression was to estimate parameters of the factors that influence the use of CSA practice among the rural households for a longitudinal data set such as this. Our results show that a Random Effects (RE) model was more suitable for the analysis than the Fixed Effects (FE) model for two main reasons. First, it captures the effects of the omitted variables particularly when they are uncorrelated with explanatory variables included in the model. Second, some of the included variables (gender, literacy rate, marital status, sectors etc.) are mostly time invariant in terms of values and their effects. It has been observed that “if variables change a little or not at across time, a fixed effects model may not work very well even at all” (Williams, 2018).

Gender of household heads play a significant role in adoption of CSA practices with female headed households having higher probability of increasing adoption than their male-headed counterparts. On the same trajectory, we found that the time factor reduced the probability of CSA practices among the respondents suggesting non-sustainability in the practice of CSA which may be more closely related to intermittent changing in agricultural policy in Nigeria. The Year 2012 witnessed an improvement in input use and agricultural market orientation through the Agricultural Transformation Agenda (ATA). However, in subsequent years, attention began to reduce, and the proper oversight of its function began to dwindle. This therefore implies the role of continuity in government policies in ore to sustain positive changes.

The result also indicated that age had positive (0.01) and significant ($p<0.01$) influence in driving adoption of CSA practices over the two periods. Age, which is closely related to experience is clearly important in some cases in driving and sustain adoption of good agricultural practices (Ojoko et al.,2017; Wekesa et al., 2018). On the other hand, however, a negative correlation be-tween the use of CSA practices and the age of the farmers (Ali and Erenstein, 2017)], while found a mix of positive and negative influence for different components of CSAs among smallholders in India (Khantri-Chhetri et al.,2017).

Table 2: Estimates of Determinants of CSA Practices between 2012 and 2015 in Nigeria (RE-Model)

Variables	Coefficients	Standard error
Sex of Household head (Ref: - Female)	-0.358**	0.176
Age (years)	0.011***	0.003
Literacy (Ref-No)	0.209***	0.081
Marita status (Ref- unmarried)	-0.030	0.151
Sector (Ref:Rural)	1.250***	0.105
Geopolitical Zone (Ref-North Central)		
Northeast	0.623***	0.143
Northwest	1.409***	0.134
Southeast	0.915***	0.144
South-South	-0.127	0.156
South-West	0.939**	0.153
Time (Ref-2012)	-0.715***	0.064

The findings revealed further that literacy is a key element that drives and sustains CSA among the smallholder farmers; increasing the probability of CSA use by up to 0.21 ($p<0.01$). Slightly more inclusive than the use of educational attainment (Everest, 2020), we decided to assess if the ability to read and write in any language could translate to a higher intellectual capacity in understanding the issues around CSA practices among the smallholder farmers. Thus, this study showed that CSA practices could be structured to account for the different literacy styles of different socioeconomic inclination without loss of value.

Interestingly, we found that urban based smallholders were more likely to use CSA practices suggesting increased access to incentives for promoting CSA adoption. This may suggest a greater need to intensively utilize the limited resources (especially land) in urban centre within the context of climate change and yield.

Zonal variations reveal again that local based knowledge is important in sustaining CSAs in Nigeria (Pagliacci et al., 2020). Using the North Central as the reference point, the study found that adoption of CSA practices is more significant in the Northern zones relative to their Southern counterparts. This may suggest larger arable farming activities in Northern Nigeria with large expanses of land, as compared to other zones, especially the South South Zones with larger aquatic resources.

IV. Conclusions

This study explored a dynamic assessment of Climate Smart Agricultural practices among smallholder farmers in Nigeria. The focus was on Crop diversification (Intercropping), Conservation agriculture (cover cropping, relay cropping and agro-forestry) and Improved Seeds. We found periodic upward and downward changes in the utilization of CSA practices across farmer characteristics in the study. Zonal variations were also observed with respect to the CSA practices over time. The result showed among all other variables that it is important to factor in the element of “time” when there is a need to understand the sustainability of CSA.

Our finding reflects the need to provide time specific intervention in improving access to and adoption of climate smart agricultural practices with consequences for farmers’ productivity. This is key to sustaining such practices with consequence for improved and sustained agricultural productivity and other desirable outcomes. As a result of geomorphological differences across the zones in Nigeria, we also recommend a zonal-based intervention mechanism which will leverage on the strength of a small farming system, while taking advantage of these geomorphological characteristics in the adoption of CSA practices.

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Olorunfemi. O. OGUNDELE, et. al. "Temporal Dynamics in Climate Smart Agricultural Practices Among Smallholder Farmers In Nigeria." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 15(10), (2021): pp 23-29.