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# COMPARING CLIMATE ADAPTATION STRATEGIES ON TECHNICAL EFFICIENCY OF CASSAVA PRODUCTION IN SOUTHWEST, NIGERIA

***Purpose.*** *The purpose of the article – to assess the technical efficiency of climate adaptation practices on cassava production in two different agro-ecological zones within the study area to know where the climate adaptation practices are more productive. To achieve the main objective of the study, the specific objectives were stated as follows: (a) describe relevant socio-economic characteristics of cassava farmers in southwestern region of Nigeria; (b) assess the influence of the used climate change adaptation strategies on technical efficiency of cassava production in both agro-ecological zones.*

***Methodology / approach.*** *The study was carried out in Ekiti, Osun and Oyo State in the southwestern region of Nigeria, where two different agro-ecological zones (AEZ) (rain forest and guinea savannah) were chosen for the study. The study used multi-stage sampling procedures, with well-structured questionnaire, to select 150 cassava producers from each AEZ, making a total of 300 cassava producers for the study. Data analysis was done using descriptive statistics and stochastic frontier production function.*

***Results.*** *From the study, it was revealed that cassava farmers in the study area were relatively young, fairly educated, mostly married, well experienced, adequately aware of climate change, but operated on a small scale. The result on the influence of climate adaptation strategies on technical efficiency of cassava production in both rain forest and savannah AEZs within the study area revealed that technical inefficiency existed in cassava production as confirmed by the gamma values of 0.687 and 0.639 in rain forest and savannah respectively*

***Originality / scientific novelty.*** *The study has really revealed diverse climate adaptation options available to cassava farmers in order to sustain its production as a means of employment to the unemployed, food consumption and contribution to the national gross domestic product. Studies comparing climate adaptation practices on the technical efficiency of cassava production in different agro-ecological zones in southwestern part of Nigeria are relatively scarce considering the mixture of socio-economic and climate variables to assess technical efficiency of cassava production.*

***Practical value / implications.*** *The study has succeeded in identifying key factors that will enables policy makers to formulate a sustained policy framework that would encourage the use of multiple climate adaptation practices by the cassava farmers. To ensure sustainability of cassava production, it is therefore recommended that farmers should use different adaptation strategies to climate change e.g crop diversification, multiple planting dates, land fragmentation, use of improved varieties and off farm income activities that would bring increase in their scale of operation as most of the cassava farmers in the study areas cultivated less than 2 hectares of land for cassava production.*

***Key words:*** *climate adaptation strategies, technical efficiency, cassava production, Nigeria.*

**Introduction and review of literature.** The changing of the global climate system is now undeniable and it is human induced as it has been concluded to a large extent by scientists during the past decade (Intergovernmental Panel on Climate Change (IPCC), 2014). For the rest of 21st century, the global climate will be affected by the ongoing increase in concentrations of atmospheric greenhouse gases (IPCC, 2014). In a number of regions, climate change manifests in an increase in the number of heavy rainfall, extreme increase in temperature, high sea levels and decrease in cold temperature (IPCC, 2014). In the coming years, changes in temperature, carbon dioxide ($CO_2$) concentration, and precipitation under the climate change scenarios present a challenge to crop production globally. In various parts of the world, climate change is expected to affect agriculture differently and it depends on several factors including: soil and climatic conditions as well as resources to cope up with these changes (Olesen et al., 2011)

In addressing the challenges of global warming and climate change, the focus for a while, has been on reducing greenhouse gas emissions. There has been little progress on reducing these emissions and the climate has continued to change, affecting the agricultural sector negatively in many developing countries, Guthiga and Newsham (2011). In Nigeria, where a higher percentage of the employed persons are in the agricultural sector, the continued impact of climate change is and will continue to have devastating effects on the economy, food security and threaten the stability of the country (Okoli and Ifeakor, 2014). Large-scale farmers are more adapted to climate change because they have more capital and resources (Nhemachena and Hassan, 2007; Sekumade and Owoeye, 2016). Productive resources such as capital, land and labor serve as important factors for coping with and adapting to climate change (Osanyinlusi and Adenegan, 2018). The choice of the suitable adaptation measure depends on factor endowments (i.e. family size, land area and capital resources) at the disposal of farming households (Otitoju and Enete, 2014). If adaptation of various kinds is used as effective ways of responding to climate change, measures are needed to increase adaptive capacity (Khanal et al., 2017). It is crucial for Nigeria to invest in terms of financial resources and research on adaptation measures that farmers could implement to cope with climatic changes especially in the agricultural sector (Okoli and Ifeakor, 2014). Guthiga and Newsham (2011) confirm that in recent years, indigenous people have been recognized as powerful knowledge holders of climate change and key actors in developing policy to cope with and adapt to its effect.

Therefore, using locals is believed to lead to the development of effective mitigation and adaptation strategies that are cost-effective, participatory and sustainable. Adaptation generally takes place at the micro and macro levels (Guthiga and Newsham, 2011). Smallholder farmers in Nigeria have varying adaptive capacities to the impact of climate change consequently influencing the status of food security among farming communities differently. Most regions in Nigeria have been seriously impacted by climate change and climate variability including South west region, whereby there have been increased frequency of drought and floods, changes in the timing of rainfall, rain comes late than expected followed by terrible drought and hunger (Enete et al., 2014). Smallholder farmers in the South west region have various adaptive capacities towards the challenges resulting from climate change (Enete et al., 2014). Also they have vast perceptions and capacities on adaptation strategies with various limitations which need to be addressed (El-ladan, 2014).

Cassava production has been already established by crop enterprise in southwestern part of Nigeria and its economic importance, in terms of food consumption, source of livelihood for the unemployed and gross domestic product, cannot be overemphasized. Despite its adaptive features, its production is most hindered by the erratic nature of climatic variables. This usually poses threats to its production in terms of pest and disease infestation, stunted growth and reduced yield. Cassava farmers have therefore adopted some climate adaptation practices like the use of improved (drought tolerant, disease resistant and early maturing) varieties of cassava. Based on this, this paper aims at comparing the influence of climate change adaptation strategies on technical efficiency of cassava production in different agro-ecological zones (savannah and rain forest) in the southwest, Nigeria.

Different studies conducted in sub-Saharan Africa used various empirical methods to analyze impacts of climate adaptation strategies on technical efficiency of food crop production. Different empirical findings confirmed that different demographic factors (age of farmers, years of farming experience and years of education) as well as climate adaptation options (multiple planting dates, crop diversification, land fragmentation and off-farm income generating activities) were identified as significant factors influencing technical efficiency of food crop production to climate change (Otitoju and Enete, 2014; Fosu-Mensah et al., 2010).

Roco et al. (2017) showed that factors such as dependence on annual crop production for income and high levels of specialization in production are associated with elevated technical efficiency levels. The use of meteorological information is also positively related with technical efficiency. In addition, farm size is positively related to efficiency while distance to a major city shows a negative relationship. Farmers who adopted irrigation technologies have higher technical efficiency levels. These results suggest that climate change adaptation is significant for agricultural production, especially for the intensity of climate change adaptation.

Torres et al. (2019) showed that there is a need to take advantage of available resources in order to face the adverse effects of climate change. Adopting the use of improved seeds and changing crops are among the most important actions according to farmers’ preferences. Agricultural policy-makers should generate incentives for farmers in the region to adopt these types of adaptation actions, and disseminate technical information on best practices to encourage them to put these actions into practice. In relation to farmers with less technical efficiency, whose environmental attitude was more eccentric, their ecological efficiency should also be accounted for through more sustainable use of water resources, as this is one of the main factors that negatively affects agricultural performance. In the agricultural sector, the economic policies that are implemented should be aimed at increasing the income and improving the livelihoods of rural households in order to improve their capacities and productive assets through the sustainable use of resources.

**The purpose of the article** – to assess the technical efficiency of climate adaptation practices on cassava production in two different agro-ecological zones within the study area to know where the climate adaptation practices are more productive. To achieve the main objective of the study, the specific objectives were stated as follows: (a) describe relevant socio-economic characteristics of cassava farmers in southwestern region of Nigeria; (b) assess the influence of the used climate change adaptation strategies on technical efficiency of cassava production in both agro-ecological zones.

*Methodology.* A multi-stage sampling procedure was used in the selection of location and respondents for the study. At the first stage, three States; Ekiti, Osun and Oyo were randomly selected. The second stage involved purposive selection of two Local Government Areas (LGAs), different Agricultural Ecological Zones (AEZ) i.e rain forest and savannah from each State based on the volume of cassava output. In Ekiti State, Emure and Moba LGAs were selected because they are the highest cassava producing LGAs in the State based on their respective AEZs (Ekiti State Ministry of Agriculture and Rural Development). While Emure LGA belongs to rain forest zone, Moba falls into the savannah zone. Also, Irepodun and Atakunmosa East LGAs were purposively selected as savannah and rain forest zones in Osun State respectively based on their level of involvement in cassava production (Osun State Ministry of Agriculture and Food Security, 2018) while Olorunsogo and Ibarapa East LGAs were chosen as savannah and rain forest zones in Oyo State based on their output level in cassava production in the State (Oyo State Ministry of Agriculture, Natural Resources and Rural Development, 2018). In totality, six (6) LGAs were chosen for the study. The third stage involved purposive selection of three communities from each LGA chosen based on their level of involvement in cassava production. Overall, the study used eighteen (18) communities. Based on the population of the communities selected for this study, simple random sampling procedure was used to select between 15 to 20 respondents per community, indicating that equal number of respondents were not chosen from each community, but a total of 50 respondents per LGA remained consistent. A total of 300 respondents were interviewed for the study. Primary data were collected from 300 cassava farmers with the aid of a well-structured questionnaire, personal interview and Focus Group Discussion (FGD) sessions. The data comprised of socio-economic characteristics of the cassava farmers such as age, educational level and gender among others.

The influence of used climate change adaptation strategies on technical efficiency of cassava production was analyzed using Cobb-Douglas production forms of Stochastic Frontier Production Function. It was used in a related study conducted by Otitoju and Enete (2014) on climate change adaptation strategies and farm-level efficiency in food crop production in southwestern Nigeria. Explicitly, Cobb-Douglass production form is stated as:

$$InY_i = \beta_0 + \sum \delta_i \, In(X_i) + (V_i - U_i) \quad (1)$$

where $\beta_0$ – is parameter estimates;

$Y_i$ – output measured in Naira value;

$X_i$ – are efficiency factors (i.e. $X_1$ – cost of labour (Naira), $X_2$ – farm size (ha), $X_3$ – cost of cassava cuttings (Naira), $X_4$ – value of fertilizer used (Naira), $X_5$ – value of other agrochemicals (Naira), $X_6$ – depreciated value of farm implements (Purchasing cost of the asset-salvage value / life span of the asset in years) (Naira));

$V_i$ – random error that is assumed to be independently and identically distributed as N ~ (0, $\sigma v^2$) random variables;

*Ui* – Non-negative technical inefficiency effects that are assumed to be independently distributed.

In order to test for inefficiency effect, it is explicitly defined as:

$$U_i = \delta_0 + \sum_{i-1}^{\infty} \delta_i \, Z_{ji} \quad (2)$$

where *Ui* – inefficiency effect;

$\delta_i$ – coefficient of climate change adaptation strategies and socio-economic factors (i.e. hypothesized efficiency changing variables) defined as: $Z_1$ – use of improved varieties (yes = 1, otherwise = 0), $Z_2$ – off-farm income (amount (₦) realized from engaging in non-farming activities), $Z_3$ – increasing farm size (yes = 1, otherwise = 0), $Z_4$ – multiple planting dates (number of planting dates as a result of climate change in the cropping season), $Z_5$ – crop diversification (number of crop mix practiced by the cassava farmers as a result of climate change), $Z_6$ – livestock ownership (yes =1, otherwise = 0), $Z_7$ – years spent in schooling (number), $Z_8$ – age (years), $Z_9$ – years of awareness of climate change (number).

**Results and discussion.** The result in Table 1 revealed the distribution of cassava farmers in both AEZs based on their relevant socio-economic characteristics. The result showed that 78.67 and 21.33 percent of the respondents sampled in rain forest AEZ were found to be males and females respectively while 84.67 and 15.33 percent of the respondents from savannah were males and females respectively. This implies that cassava production in the study area was dominated by males, and this could be attributed to the fact that cassava production is labor-intensive and requires physical effort which could be easily gotten from masculine strength. This is in agreement with Otitoju and Enete (2014) who noted males were more involved in cassava production in Benue State. The result further reported 54 and 48 years as the mean age of cassava farmers in rain forest and savannah AEZs respectively, implying that cassava farmers in the study area were ageing. The cassava farmers in the study area were fairly educated as 46 and 25.3 percent of the cassava farmers in the rainforest and savannah AEZs acquired at least secondary education respectively, implying more educated people involved in cassava production in the rainforest AEZ. This is expected to help the farmers in resource allocation in order to optimize productivity. The mean values of farm size cultivated in both the rainforest and savannah AEZs were 1.9 and 1.2 hectares of land respectively. This implies that these cassava farmers were still operating on small scale and this will have a tendency to reduce the production of cassava in the study areas. This is in consonance with Osanyinlusi and Adenegan (2018) who noted half of the farmers (50 %) cultivated between 1–3 hectares of land for cassava production in Ekiti State. The result further reported 9 and 13 years as the mean values of years of farming experience in the rainforest and savannah AEZs respectively, indicating that cassava farmers in the savannah AEZ were more experienced than their counterparts in the rainforest AEZ.

*Table 1*

**Distribution of cassava farmers based on relevant socio-economic characteristics**

| Indicators | Rain forest | | Savannah | |
|---|---|---|---|---|
| Socio-economic variables | frequency | percentage | frequency | percentage |
| Sex | | | | |
| Female | 32 | 21.33 | 23 | 15.33 |
| Male | 118 | 78.67 | 127 | 84.67 |
| Age | | | | |
| ≤30 | 5 | 3.3 | 15 | 10 |
| 31-40 | 22 | 14.7 | 20 | 13.3 |
| 41-50 | 41 | 27.3 | 58 | 38.7 |
| 51-60 | 61 | 40.7 | 40 | 26.7 |
| >60 | 21 | 14 | 17 | 11.3 |
| Mean | | 54 | | 48 |
| Level of education | | | | |
| No primary education | 18 | 12 | 40 | 26.7 |
| Primary education | 63 | 42 | 72 | 48 |
| Secondary education | 42 | 28 | 30 | 20 |
| Tertiary education | 27 | 18 | 8 | 5.3 |
| Mean | | 5 | | 3 |
| Farm size | | | | |
| ≤2.0 | 85 | 66.7 | 104 | 69.3 |
| 2.1-5.0 | 54 | 36 | 41 | 27.3 |
| >5.0 | 11 | 7.3 | 5 | 3.4 |
| Mean | | 1.9 | | 1.2 |
| Farming experience | | | | |
| 1-5 | 33 | 22 | 27 | 18 |
| 6-10 | 47 | 31.3 | 42 | 28 |
| 11-15 | 58 | 38.7 | 20 | 13.3 |
| >15 | 12 | 8 | 61 | 40.7 |
| Mean | | 9 | | 13 |
| Awareness of climate change | | | | |
| Aware | 108 | 72 | 145 | 96.7 |
| Not aware | 42 | 28 | 5 | 3.3 |
| Cassava income | | | | |
| ≤100,000 | 17 | 11.3 | 30 | 20 |
| 101,000-200,000 | 29 | 19.3 | 38 | 25.3 |
| 201,000-300,000 | 46 | 30.7 | 40 | 26.7 |
| 301,000-400,000 | 32 | 21.4 | 27 | 18 |
| 401,000-500,000 | 17 | 11.3 | 11 | 7.3 |
| >500,000 | 9 | 6 | 4 | 2.7 |
| Mean | | 273,814 | | 215,650 |

*Source:* computed from field survey data, 2018.

This is expected to boost their production as they are familiar with the practices involved in cassava production and they would be able to mitigate against the loss or challenges they face as a result of climate change in the course of production as it is often said ‘experience is the best teacher’. It was clearly reported that majority (72 %) of the rainforest cassava farmers indicated that they were aware of climate change while the remaining 28 % said they were not. Likewise, majority (96.7 %) of the savannah cassava farmers indicated that they were aware of climate change while the remaining 3.3 % said they were not. The result further showed the mean values of income generated in rain forest and savannah AEZs as ₦273,814 and ₦215,650 respectively, implying that the cassava farmers in the rainforest AEZ realized ₦58,164 more than their counterparts in the savannah AEZ on every single hectare of land cultivated for cassava production.

Table 2 presented the t-test analysis of the productive resources used in both the rainforest and savannah AEZs in Southwest, Nigeria. The result revealed that there was a significant difference (t = 5.937) at 1 percent in the amount of income generated by cassava farmers in the rainforest and savannah AEZs with a wide variability. This implies that cassava farmers in the rainforest AEZ realized more amount of income from cassava production than their counterparts in the savannah AEZ. This can be attributed to the longer days of rainfall enjoyed or experienced by the cassava farmers in the rain forest AEZ which availed them the opportunity to practice multiple planting dates unlike their counterparts in the savannah AEZ. Also, a significant difference at 1 percent level (t = 7.720) was reported on the use of agrochemicals between the two AEZs, implying that using agrochemicals in the rainforest AEZ brought about an improved yield to the cassava farmers in the rainforest AEZ than their counterparts in the savannah AEZ. The result reported further a significant difference, at 1 percent (t = 9.669), on average amount of money on depreciation of farm tools in both AEZs. This is an indication that more farm tools were used in the rainforest AEZ due to their farm size.

*Table 2*

**T-test analysis showing the productive resources used in the rainforest and savannah AEZs in the study area**

| Productive resources | Rainforest AEZ | | Savannah AEZ | | Std. error mean | t-value |
|---|---|---|---|---|---|---|
| | Mean | Std. dev. | Mean | Std. dev. | | |
| Output | 401500 | 350876 | 285750 | 195120 | 57875 | 5.937 |
| Agro-chemicals | 17518 | 1915 | 13500 | 1421 | 2009 | 7.720 |
| Depreciated | 5169 | 4076 | 4200 | 3201 | 484.5 | 9.669 |
| Farm size | 1.90 | 1.04 | 1.20 | 0.85 | 0.350 | 4.429 |
| Fertilizer | 9150 | 7540 | 7250 | 5780 | 950 | 8.632 |
| Labour | 59600 | 62713 | 45400 | 32731 | 7100 | 7.394 |
| Cassava stem | 18750 | 19810 | 13500 | 12312 | 2625 | 6.143 |

*Note.* Min. = minimum; Max. = maximum; Std. dev. = standard deviation.
*Source:* computed from field survey data, 2018.

A significant difference at 1 percent level (t = 4.429) was also reported on the farm size cultivated by the cassava farmers in the both AEZs. Though little or no mechanized activities were taken place in both AEZs based on the reported mean values of farm size, it was clearly stated that cassava farmers in the rainforest AEZ were more involved in cassava production in terms of farm size cultivated. Further, the result showed that a significant difference at 1 percent level (t = 8.632) was reported as regards the use of fertilizer in both AEZs. This is an indication that cassava farmers in the rainforest used more quantities of fertilizer to better their yields than their counterparts in the savannah AEZ. Regarding the cost incurred in hiring labour for cassava production in both AEZ, a significant difference at 1 percent level (t = 7.394) was reported. This implies that cassava farmers in the rain forest AEZ spent more money on hired labour than their counterparts in savannah AEZ. This might be attributed to the fact that cassava farmers in the rain forest AEZ had larger farm size and practiced multiple planting dates more than their counterparts in the savannah AEZ. A significant difference at 1 percent level (t = 6.143) was also reported on the cost incurred in purchasing cassava stem in both AEZs, indicating that more amount of money was spent in acquiring cassava stem in rainforest AEZ.

*Maximum likelihood estimates of the stochastic frontier production function.* The result in Table 3 compared the estimates of the stochastic frontier production function of cassava production in rain forest and savannah AEZs. Estimates of the parameters of the stochastic frontier production model of cassava production in rain forest AEZ revealed that farm size, fertilizer, labour and cassava stem were all statistically significant at 1 %. The result revealed that cassava stem and farm size were statistically significant at 5 % each while fertilizer and agrochemicals were statistically significant at 1 and 10 % respectively in cassava production in savannah AEZ. The estimated value for the gamma ($\gamma$) parameter of the Cobb-Douglas stochastic frontier production function was 0.686 in the rain forest AEZ while it was 0.639 in the savannah AEZ. The values were significant at the 1 % level of probability, indicating that technical inefficiency was highly significant in the cassava production activities. The $\gamma$ parameter showed the relative magnitude of the variance in output associated with technical efficiency. The coefficients of the variables derived from the Maximum Likelihood Estimation (MLE) represented percentage change in the dependent variables as a result of percentage change in the independent variables.

The result revealed a positive relationship between farm size and cassava output in both rain forest and savannah AEZs, implying that the more the cassava farmers increased their farm size, the higher the cassava output harvested on their farms. This could be attributable to proper agronomic management practices and the adoption of suitable adaptation strategies used by the farmers to mitigate the damage or adversity of climate change. Also, it was revealed from the result that fertilizer had a positive relationship with the cassava output in both AEZs. This means that continuous use of fertilizer would keep increasing the output of cassava in the study area. This is because some of the lands used for cassava production were exhausted due to multiple planting dates, land fragmentation and crop diversification adaptation strategies being practiced by the farmers. Therefore, the need to apply fertilizer, in order to improve soil fertility, became a necessity to boost cassava output. The result revealed that a positive relationship existed between labour and cassava output in both AEZs, implying that the more the availability of labour to engage in cassava production, the more the cassava output in the study area. It is possible because labour availability would bring about an increase in farm size, thereby improving cassava output.

*Table 3*

**The maximum likelihood estimates of the stochastic frontier production (Cobb-Douglas functional form)**

| Variables | Rain forest AEZ | | | Savannah AEZ | | |
|---|---|---|---|---|---|---|
| | Coeffi-cients | Std. error | t-ratio | Coeffi-cients | Std. error | t-ratio |
| **Production model** | | | | | | |
| Constant | 6.781*** | 0.454 | 9.114 | 4.824*** | 0.341 | 5.711 |
| Ln (Cost of Agrochemicals) | -0.197 | 0.368 | -0.718 | -0.093* | 0.041 | 1.985 |
| Ln (Depreciation | -0.149 | 0.328 | -0.163 | 0.176 | 0.098 | 1.580 |
| Ln (Farm Cost i.e. farmland) (₦/ha) | 0.411*** | 0.035 | 4.986 | 0.672** | 0.456 | 2.275 |
| Ln (Cost of Fertilizer) | 0.187*** | 0.059 | 3.230 | 0.159*** | 0.041 | 4.659. |
| Ln (Cost of Labour) | 0.364*** | 0.097 | 3.138 | 0.228 | 0.128 | 1.032 |
| Ln (Cost of Cassava stem) | 0.309*** | 0.058 | 3.661 | 0.258** | 0.196 | 2.269 |
| **Technical inefficiency model** | | | | | | |
| Constant | 3.543*** | 0.219 | 6.873 | 5.783*** | 2.414 | 5.173 |
| Use of improved varieties | -0.309*** | 0.095 | -2.976 | -0.348*** | 0.250 | 4.651 |
| Off farm income | 0.313*** | 0.987 | 2.985 | 0.413 | 0.309 | 1.454 |
| Farming experience | -0.185* | 0.046 | -2.007 | 0.532** | 0.431 | 2.291 |
| Multiple planting dates | -0.124*** | 0.056 | -2.610 | 0.091 | 0.072 | 1.260 |
| Crop diversification | -0.761*** | 0.231 | -2.867 | -0.532*** | 0.362 | 6.438 |
| Land fragmentation | 0.084 | 0.242 | 0.217 | 0.012 | 0.008 | 0.242 |
| Years spent in school | -0.203** | 0.095 | -2.426 | -0.321 | 0.185 | 1.658 |
| Age | 0.109 | 0.228 | 0.487 | 0.237 | 0.169 | 0.973 |
| Years of climate change awareness | -0.130*** | 0.025 | -3.227 | -0.358*** | 0.232 | 4.794 |
| **Variance parameters** | | | | | | |
| Sigma-squared ($\delta^2$) | 0.294 | 0.111 | 2.696 | 0.264 | 0.102 | 2.471 |
| Gamma ($\gamma$) | 0.686*** | 0.133 | 5.158 | 0.639*** | 0.167 | 3.826 |
| Log likelihood function (LLF) | 278701 | | | 250651 | | |

*Note.* *, **, *** stand for level of significance at 10 %, 5 %, and 1 %, respectively.
*Source:* computed from field survey data, 2018.

From the Table 3, it was also known that there was a positive correlation between cassava stem and cassava output in both AEZs, indicating that the higher the quantity of cassava stem planted, the more the output. This is because most of the farmers had been introduced to improved varieties of cassava in terms of early maturing, drought tolerant and disease resistant, thereby enhancing productivity based on the quantity planted. The above results conformed to the findings of Khanal et al. (2017) who concluded that positive relationship existed between agricultural production and labour, farm size, fertilizer and capital. On the other hand, the negative coefficient of agrochemical in both AEZs implies that cassava output decreased with an increase in the variable. The reason for this is that excessive use of herbicides and insecticides always alters the ecosystems which adversely destroys the microbes present in the soil, and eventually leads to soil depletion. Agrochemicals and depreciation on farm tools did not exert any significant effect on cassava output as shown by their t-ratio values in the rain forest AEZ. The implication is that increase in the level of use of agrochemical and farm tools would not influence output of cassava in the study area. This study is consistent with the findings of Otitoju and Enete (2014) on climate change adaptation strategies and farm-level efficiency in food crop production in southwestern, Nigeria who established a negative correlation between agrochemicals. Contrarily, the result revealed a positive relationship between depreciation of farm tools and cassava output in savannah AEZ. This implies that an increase in the level of use of farm tools would bring about increased cassava output. This is because the farm tools purchased by the cassava farmers in savannah AEZ had a greater tendency to serve them (cassava farmers) longer since they cultivated lesser farm size.

*The influence of climate change adaptation strategies on the technical efficiency of respondents*. This section presented the results (Table 3) of the analysis of the factors (climate change adaptation practices and selected socio-economic variables) that determined technical efficiency in cassava production in both rain forest and savannah AEZs. The result of the inefficiency model of cassava production in both rain forest and savannah AEZs in the study area revealed that the following variables; use of improved varieties, farming experience, multiple planting dates, crop diversification and years spent in school had significant negative relationship with technical inefficiency. The variables with positive coefficients indicated that they had the tendency to increase the level of technical inefficiency, meaning that any increase in the value of such variables would lead to an increase in the level of technical inefficiency. The inverse relationship implied that any increase in the value of the variables would amount to a decrease in the technical inefficiency. In a nutshell, any variable that increases technical inefficiency is indirectly reducing technical efficiency, and vice-versa.

It was revealed that the estimated coefficient of improved varieties was negatively and significantly related with technical inefficiency in both AEZs. This implies that as the use of improved varieties was increasing, the level of technical inefficiency kept reducing (i.e. increased technical efficiency). Continuous use of drought tolerant, early maturing and disease resistant varieties of cassava, in the savannah AEZ, would ensure efficient use of productive resources and, at the same time, encourage two planting periods within a year in the rain forest AEZ, thereby increasing technical efficiency. The result revealed a positive relationship between off-farm income and technical inefficiency in both AEZs, implying that an increase in off-farm income would result in increased technical inefficiency. This is because there would not be sufficient time for the cassava farmers to manage the farm effectively. Though there might be money to hire labour, purchase improved varieties of cassava stem and other productive resources, the presence of the cassava farmers is also important in decision making in terms of supervision and allocating the resources. This was in line with the findings of Otitoju and Enete (2014) who reported that increased off-farm income brought about a decrease in technical efficiency due to reallocation of time away from farm related activities.

Farming experience was found to be negatively, but significantly related with technical inefficiency in both the rain forest and savannah AEZs as revealed from the result. This implies that the more experienced the farmers are, the more they are technically efficient. Their years of farming experience would have acquainted them with the best agronomic management practices to be performed on a timely basis. This would also help them to choose the most profitable climate change adaptation strategies in the study area. The result further revealed that the estimated coefficient for multiple planting dates was negative and significantly related with technical inefficiency in rain forest AEZ in the study area, implying that consistent practice of multiple planting dates would amount to an increase in technical efficiency. With multiple planting dates, mastering of climatic conditions becomes easier. It would enable the cassava farmers to predict or forecast the erratic nature of climate. Also, appropriate varieties to plant as climate changes become part and parcel of the cassava farmers.

As the result, it was revealed that a negative, but statistically significant ($p \leq 0.01$) relationship existed between technical inefficiency and crop diversification in both AEZs, implying that further diversification of crops may lead to higher technical efficiency because it could act as insurance against crop failure and hence reduce farm income and improve technical efficiency. Nhemachena and Hassan (2008) reported that increased diversification was a strong climate change adaptation measure.

Also, an inverse and statistically significant ($p \leq 0.01$) relationship was found between educational level and technical inefficiency in both AEZs. This implies that further educational level may lead to higher technical efficiency perhaps because the level of education influences efficiency in agricultural production in terms of quality and quantity as well as the speed at which farmers adopt new technologies and rationalize inputs to enhance output.

A negative and statistically significant (at 1 %) relationship is found between years of climate change awareness and technical inefficiency in both AEZs. This implies that an increase in the years of climate awareness tends to increase technical efficiency (i.e. decrease technical inefficiency). The awareness of climate problems and the potential benefits of taking action is an important determinant of adoption of agricultural technologies (Nhemachena and Hassan, 2008).

*Return to scale analysis in rain forest and savannah AEZs.* The return to scale

(RTS) analysis which served as a measure of resource productivity is given in Table 4. The RTS parameters (0.925 and 0.874) were obtained from the summation of the coefficients of the estimated inputs (elasticities) in rain forest and savannah AEZ respectively which indicated that cassava production in the study area was in Stage I of the production surface and thus the production was inefficient. The RTS reported in this study was in conformity with the research work of Sekumade and Owoeye (2016) who reported a RTS value of 0.937 in a study on climate change adaptation practices and technical efficiency of cassava production in Ekiti State, Nigeria.

*Table 4*

**Elasticities of production and returns to scale in rain forest and savannah AEZs**

| Variables | Rain forest | Savannah AEZ |
|---|---|---|
| | elasticity of production | elasticity of production |
| Agrochemicals | -0.197 | -0.114 |
| Depreciation | -0.149 | -0.106 |
| Farm size | 0.411 | 0.298 |
| Fertilizer | 0.187 | 0.159 |
| Labour | 0.364 | 0.350 |
| Cassava stem | 0.309 | 0.287 |
| Returns to scale | 0.925 | 0.874 |

*Source:* computed from Field Survey Data, 2018.

*Technical efficiency estimates for the farmers.* The results from (Cobb-Douglas stochastic frontier model) the technical efficiency estimates of cassava production in rain forest and savannah AEZs in the study area (Table 5) showed high variability among the cassava farmers; the computed technical efficiency varied between 0.312 and 0.91 with a mean of 0.71 for the cassava farmers in rain forest AEZ in the study area.

*Table 5*

**Frequency distribution of technical efficiency indices in rain forest and savannah AEZs**

| Technical efficiency range | Rain forest AEZ | | Savannah AEZ | |
|---|---|---|---|---|
| | frequency | percentage | frequency | percentage |
| ≤0.4 | 16 | 10.67 | 21 | 14.00 |
| 0.41-0.6 | 34 | 22.67 | 32 | 21.33 |
| 0.61-0.8 | 85 | 56.66 | 79 | 52.67 |
| 0.81-1.00 | 15 | 10.00 | 18 | 12.00 |
| Mean efficiency | 0.711 | - | 0.685 | - |
| Minimum efficiency | 0.312 | - | 0.291 | - |
| Maximum efficiency | 0.915 | - | 0.885 | - |

*Source:* computed from field survey data, 2018.

This mean efficiency (0.7108) is similar to the finding of Khanal et al. (2017) on: «Do climate change adaptation practices improve technical efficiency of smallholder farmers? Evidence from Nepal». This variation in the level of technical efficiencies in cassava production implies there is an opportunity to improve the current level of technical efficiency by 29 % for the sampled cassava farmers in rain forest AEZ in the study area. The result showed that the computed technical efficiency in savannah AEZ varied between 0.291 and 0.885. The mean value of recorded technical efficiency was 0.685. It was an indication that cassava farmers in the rain forest AEZ were more technically efficient than their counterparts in the savannah AEZ in the study area.

**Conclusions.** From the study it was concluded that cassava farmers in the study area were ageing, fairly educated, mostly married, well experienced, but operated on a small scale. Also, it was inferred that the majority (84.3 %) of the cassava farmers were aware of climate change. The result inferred that most of the productive resources were underutilized as revealed by the values of RTS in both AEZs.

Based on the findings of this research, the following recommendations are made. 1. Farmers should be ready to accept different adaptation strategies to climate change that would bring an increase in their scale of operation as most of the cassava farmers in the study areas cultivated less than 2 hectares of land for cassava production. 2. Farmers should endeavour to scale up their operation as most of them cultivated less than 2 hectares of land for cassava production.

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