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# Climate Change Adaptation Strategies and Farm-level Efficiency in Food Crop Production in Southwestern, Nigeria

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Keywords: Climate change- Adaptation strategies- Technical efficiency- Nigeria

## Summary

*Food crop yields depend largely on prevailing climate conditions, especially in Africa, where rain-fed agriculture predominate. The extent to which climate impacts are felt depends principally on the adaptation measures used by farmers. This study focused on the effect of climate change adaptation strategies on farm-level technical efficiency. The study used primary data collected from 360 randomly selected farmers in Southwest Nigeria. Cobb-Douglass stochastic frontier production model was used to analyse the data. Multiple cropping, land fragmentation, multiple planting dates, mulching and cover cropping were the major climate change adaptation strategies employed by the farmers. While land fragmentation and multiple planting dates had significant positive relationships, years of climate change awareness and social capital had significant inverse relationships, with technical inefficiency. This may be because while land fragmentation may hinder farm mechanization, multiple planting dates may increase the monotonousness and drudgery of farming. On the other hand, social capital and climate change awareness could help ameliorate the effects of, particularly, land fragmentation through resource pooling. It is therefore recommended that the farmers be encouraged to form cooperative societies so as to leverage their resource status through collective efforts.*

## Résumé

**Stratégies d'adaptation au changement climatique et efficience des exploitations agricoles vivrières au sud-ouest du Nigeria**

*Les rendements des cultures alimentaires dépendent largement des conditions climatiques qui prévalent, notamment en Afrique, où l'agriculture pluviale prédomine. La mesure dans laquelle les impacts du changement climatique se font sentir dépend principalement des mesures d'adaptation utilisées par les agriculteurs. Cette étude a porté sur l'effet des stratégies d'adaptation aux changements climatiques sur l'efficience technique au niveau des exploitations. L'étude a utilisé des données primaires collectées auprès de 360 agriculteurs choisis au hasard dans le sud-ouest du Nigeria. Le modèle Cobb-Douglass de production avec la frontière stochastique a été utilisé pour analyser les données. Les cultures associées, la fragmentation des terres, les différentes dates de plantation, le paillage et les cultures de couverture ont été les principales stratégies d'adaptation au changement climatique employées par les agriculteurs. Alors que la fragmentation des terres et les différentes dates de plantation avaient des relations positives significatives, les années de changement climatique et le capital social avaient une relation inverse significative. Le morcellement des terres peut entraver la mécanisation agricole et plusieurs dates de plantation peuvent augmenter la monotonie et la corvée de l'agriculture d'une part. D'autre part, le capital social et la sensibilisation au changement climatique pourraient aider à atténuer les effets, en particulier, du morcellement des terres. Cela pourrait se faire à travers la*

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*mutualisation des ressources. Il est donc recommandé que les agriculteurs soient encouragés à former des coopératives afin de tirer parti de l'état de leurs ressources grâce à des efforts collectifs.*

## Introduction

The process of producing food requires resources, which could be natural and/or man-made. The natural resources that are most essential for food crop production are land, water, sunshine, air, temperature and soil conditions. Man-made resources (including labour, capital or entrepreneurship) are supplied by man (32). Among the natural resources, climate is the predominant factor that influences food crop production. Climate refers to the state of the atmosphere, created by weather events over a period of time. A slight change in the climate will affect food crop production.

According to Intergovernmental Panel on Climate Change (IPCC) report, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity (anthropogenic) that alters the composition of the global and/or regional atmosphere, and which is, in addition to natural climate variability (biogeographical), observed over comparable time periods (16). Climate change is already affecting people, their livelihoods and ecosystems and presents a great development challenge for the global community in general and for the poor people in developing countries in particular (19).

Available literature show that for the past decades, anthropogenic factors like urbanization, deforestation, population explosion, industrialization and the release of green house gases (GHGs) are the major contributing factors to the depletion of the ozone layer and its associated global warming and climate change (5, 28, 32). For example, unsustainable industrialization, which releases green house gases (GHGs), is viewed as the main cause (31). The increased level of GHGs has created a greenhouse effect which subsequently altered precipitation patterns and global temperatures around the world. Areas usually affected by these alterations include agriculture, forestry, water resources, biodiversity, desertification, human health, and ecosystems goods and services globally (19, 39).

The predominance of rain-fed agriculture, the scarcity of capital for adaptation measures, warmer baseline climates and heightened exposure to extreme events (26) in Africa make agriculture more vulnerable to climate change. Food crop is particularly sensitive to climate change because crop yields depend largely on prevailing climate conditions (temperature and rainfall patterns) (38), As climate is changing, mitigation efforts to reduce sources or enhance the sinks of greenhouse gases will take time. Adaptation is therefore critical and of concern in developing countries, particularly Africa (including Nigeria) where vulnerability is high because the ability to adapt is low (10, 17).

Adaptation is identified as one of the options to reduce the negative impact of climate change (3, 21). Adaptation of agronomic techniques and farm strategies is already happening (9). The modification of agricultural practices and production in order to cope with climate change will be imperative in order to meet and continue meeting the growing food demands of Nigerians. Evidence shows that farming systems and farming technologies within the region have been changing in response to the effects of climate change. In their study conducted in Southwest Nigeria, Adebayo *et al*. (2) showed that the farmers agreed that climate change mainly reduces their productivity. Adapting to climate change at the farm-level, especially through the modification of agricultural practices and farming systems has been recognized as the main coping strategies. It is believed that these strategies are supposed to help the farmers improve their efficiency (productivity) in food crop production. Technical efficiency is the ability of farmers to derive maximum output from the inputs used in a farm. Although there have been some climate-related studies (13, 12, 27, 25) in Nigeria, none has examined the effect of climate change adaptation on technical efficiency of farmers. Available literatures on efficiency (e.g. 1, 29, 30, 35, 36, 37) have tended to concentrate on determinants of efficiency using farmers' characteristics (e.g. age, education, years of farming experience, etc.) and farm-specific and institutional factors (e.g. extension visit/contact, access to credit, etc.). None has looked at the effects of climate change adaptation strategies as farm-specific variables on technical efficiency. Against this backdrop, this study aims to bridge this gap in knowledge.

## Methodology

### Method of data collection

Multistage sampling technique was used in the selection of respondents (food crop farmers). Firstly, 2 states namely Ekiti and Ondo were randomly selected from five south-western states, considering the two dominant agro-ecological zones (i.e. savanna and rainforest) in the region. While Ekiti state was selected from the savanna, Ondo state was from the rainforest, agro-ecological zones. Secondly, the 4 agricultural zones in the 2 states were selected. Thirdly, 3 extension blocks were randomly selected from each agricultural zone, making 12 extension blocks in all. Fourthly, 2 farming communities were randomly selected from each extension block making a total of 24 communities. Lastly, in each community, with the assistance of the local extension personnel, a list of food crop farm households was compiled and then 15 households randomly selected, making a sample size of 360 farmers, 180 from each state.

### Model specification: Stochastic Frontier Production Function

The data were fitted into Cobb-Douglas and average production forms of stochastic frontier production function. The model was selected through the use of generalized log-likelihood (for meeting the econometric requirements), as the functional form that best fit the data.

Cobb-Douglass production form:

$$ln Y_i = \beta_0 + \sum \delta_i \ln(X_i) + (V_i - U_i) \qquad \text{I}$$

Where: $\beta_{is}$ = parameter estimates, $Y_i$= the value of output in naira, $X_1$=the total labour used in mandays/ha; $X_2$=the total land area (farm size) used ha; $X_3$= the total quantity of fertilizer used in kilogrammes; $X_4$= the total value of other agrochemicals (i.e. pesticides and herbicides) used in Nigerian Naira, and $X_5$= the depreciated value of farm implements (i.e. hoes, cutlasses, watering can, etc.) in Nigerian Naira. It was calculated using straight line method. That is, (Purchasing cost of the asset-Salvage value)/(Life span of the asset in years).

The $V_{is}$ are random errors that are assumed to be independently and identically distributed as N $(0,\sigma v^2)$ random variables; and the $U_{is}$ are non-negative technical inefficiency effects that are assumed to be independently distributed among themselves and between the Vis such that $U_i$ is defined by the truncation of the $N(U_i,\sigma)$ distribution, where $U_i$ is defined by:

$$U_i = \delta_0 + \sum_{i=1}^{8} \delta_i Z_{ji} \qquad \text{II}$$

Where: $U_i$= inefficiency effect; $\delta_i$= coefficients of climate change adaptation strategies and socio-economic factors. $Z_{ji}$= climate change adaptation strategies and socio-economic factors (i.e. hypothesised efficiency changing variables) defined as:

$Z_1$= land fragmentation (number of fragmented farm land used for food crop production as a result of change in climate); $Z_2$= off-farm income (income from off-farm employment engaged in order to adapt to climate change in Nigerian Naira); $Z_3$= adjustment in farm size (if adjusted 1, 0 otherwise); $Z_4$= 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 farmer as a result of climate change); $Z_6$= level of education in years (number of years of schooling); $Z_7$= years of awareness of climate change, and $Z_8$= social capital (number of relatives involved in the discussion of farm management issues in the farming village, excluding the farmer's household).

### Technical Inefficiency Effects Model

To choose the functional form that best describes the inefficiency effect, the following hypothesis was tested;

$H_0$: $\gamma = \delta_0 = \delta_1 = ...... \delta_8 = 0$, this hypothesis specifies that the technical inefficiency effects are not present in the model. If this hypothesis is accepted, then the food crop farmers are fully technically efficient. Then, the data will be better analyzed using average production function rather than frontier function, which assumes the presence of inefficiency in food crop production.

Test of the above hypothesis was obtained by using the generalized likelihood-ratio statistic, which is defined by;

$$\lambda = -2 \ln [L(H_0)/L(H_1)] = -2 \ln[L(H_o)-L(H_i)] \qquad \text{III}$$

Where $L(H_0)$ is the value of the likelihood function for the average production function (Model 1), in which the parameter restrictions specified by the null hypothesis, $H_0$ were imposed; and $L(H_1)$ is the value of the likelihood function for the general frontier model.

## Result and discussion

### Climate change adaptation strategies used by the respondents

About 14% of the respondents used multiple cropping as a crop management practice to adapt to climate change while mulching was used by about 12% of them in this regard. Downing *et al*. (10) reported that increasing the use of organic matters such as mulch could prevent excessive soil moisture loss, increase soil aeration and soil moisture holding capacity. Multiple planting dates was used by about 11% of the respondents. About 11% of them used land fragmentation as a land management practice to adapt to climate change while about 10% of them used cover cropping. Fertilizer application was used by about 8% of the respondents as a climate change adaptation strategy (Table 1). Increased use of fertilizers including organic manure was observed as one of the important climate change adaptation strategies in southeast Nigeria. This was because declining soil fertility was one of the land degradation sources that was overwhelmingly reported to have been on the increase in the last ten years. High fertilizer application was therefore expected as an adaptation practice in order to maintain soil fertility (13). In addition, all the farmers agreed that they held regular discussions with relatives on how to cope with the issue of climate change.

**Table 1**
Frequency Distribution of Farm-level Climate Change Adaptation.

Strategies Used by Food Crop Farmers in Southwestern Nigeria

| Adaptation Strategies | Frequency | Percentage |
|---|---|---|
| Multiple crop types/varieties | 355 | 14.1 |
| Land fragmentation | 277 | 11.0 |
| Alternative fallow /tillage practices | 141 | 5.6 |
| Multiple Planting Dates | 286 | 11.4 |
| Irrigation practices | 52 | 2.1 |
| Crop Diversification | 183 | 7.3 |
| Off-farm Employment | 162 | 6.4 |
| Mulching | 303 | 12.0 |
| Cover Cropping | 264 | 10.5 |
| Fertilizer Application | 196 | 7.8 |
| Planting of Trees | 61 | 2.4 |
| Shading/ Sheltering | 37 | 1.5 |
| Adjustment in farm size | 199 | 7.9 |

Source: Computed from survey data, 2011.

### Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function

Maximum likelihood estimates for parameters of the two estimated models are presented in table 2. Labour, farm size and other agrochemicals were highly significant at 1% level of probability. The estimated value for the γ parameter in the preferred model (Cobb-Douglas stochastic frontier production function) was 0.287. The value was significant at 1% level of probability. This value indicates that technical inefficiency was highly significant in the food crop production activities. The γ parameter shows the relative magnitude of the variance in output associated with technical efficiency. The coefficients of the variables derived from the Maximum Likelihood Estimation (MLE) represent percentage change in the dependent variables as a result of percentage change in the independent variables.

### Technical efficiency estimates for the farmers

Technical efficiency shows the ability of farmers to derive maximum output from the inputs used in food crop production. Given the results of the preferred model (Cobb-Douglas stochastic frontier model), the technical efficiency estimates (Figure 1) showed high variability among the farmers; the computed technical efficiency varied between 0.48 and 0.98 with a mean of 0.84 for the respondents. This mean efficiency (0.84) is similar to the finding of Otitoju (35) on small-scale soybean farmers in Benue State, Nigeria and the work of Kurkalova and Jesen (20) who found average technical efficiency of grain-producing farms in Ukraine to be 0.82 in 1989 cropping year. This variation in the level of technical efficiencies in food crop production imply there is opportunity to improve the current level of technical efficiency by 16% for the sampled farmers in this study.

### The influence of climate change adaptation strategies on the technical efficiency of respondents

This section presents the results of the analysis of the factors (climate change adaptation strategies) that determine technical efficiency in food crop production in the area. The result of the inefficiency model is presented in table 2. The following variables, land fragmentation and multiple planting dates had significant positive relationship with technical inefficiency while years of climate change awareness, and social capital had significant inverse relationship with technical inefficiency (Table 2). The positive coefficients imply that the variables have the effect of increasing the level of

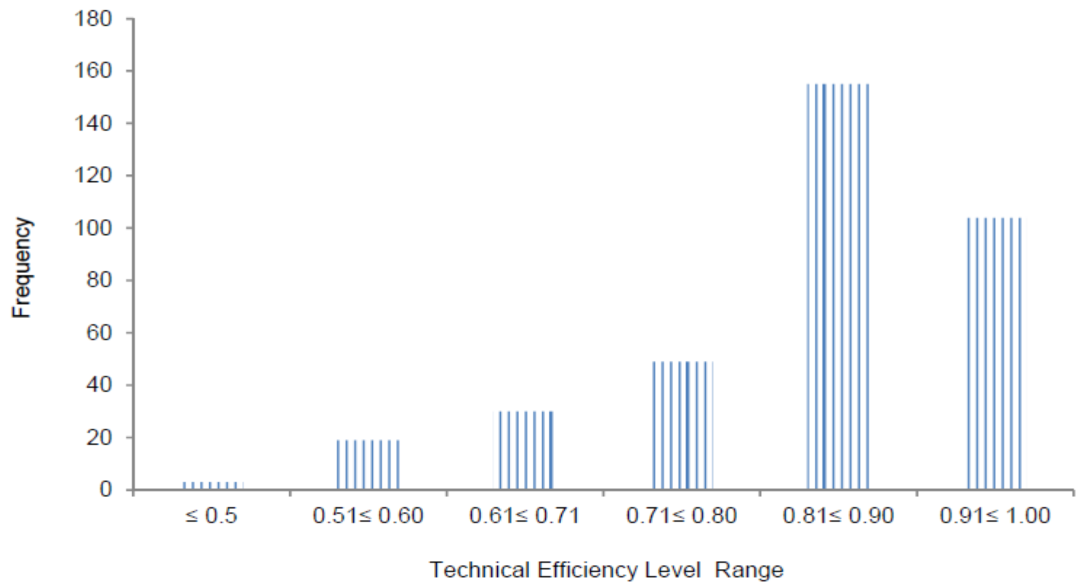


**Figure 1:** Frequency distribution of technical efficiency of food crop farmers in Southwestern Nigeria.

Source: Computed from field survey, 2011.

technical inefficiency. Any increase in the value of such variables would lead to an increase in the level of technical inefficiency. The inverse relationship implies that any increase in the value of the variable would lead to a decrease in the technical inefficiency (or an increase in technical efficiency).

### Land fragmentation

Land fragmentation is the number of plots or fragments of land the farmer deliberately used in food crop production in the cropping season in order to cope with climate change. The result shows that the coefficient for land fragmentation was positive and significant at 5% level of probability. This suggests that an increase in land fragmentation tends to increase the level of their technical inefficiency. This is not surprising because land fragmentation could reduce the ability of the farmer to mechanize his farm. Land fragmentation is inherent in African land tenure, which is part and parcel of the African farming systems. It has also for long been the focus of major criticism of the system. This finding agrees with the findings of Obwona (29, 30) and partly with the findings of Otitoju (35) of small-scale soybean production in Benue state, Nigeria, which found that increased land fragmentation tended to decrease technical efficiency.

### Off-farm income

The estimated coefficient for off-farm income was negative but not significantly related with technical inefficiency (Table 2). This positive relationship implies that as off-farm income increases, the level of technical inefficiency tended to increase (i.e. decrease technical efficiency). This may be because increases in nonfarm work could be accompanied by a reallocation of time, away from farm-related activities, such as adoption of new technologies, intensification of other crop management practices such as adaptation strategies and gathering of technical information that is essential for enhancing production efficiency. This finding agrees with the finding of Abdulai and Huffman (1) in which inefficiency increased with off-farm employment.

### Multiple planting dates

Multiple planting dates mean the number of planting dates practiced as a result of change in climate. This could result from high temperature/excessive heat which smolders crops planted thereby necessitating re-planting. The estimated coefficient of multiple planting dates for respondents was positive and statistically significant. Multiple planting dates could make farming monotonous and hence increase its drudgery, which may introduce inefficiency.

**Table 2**

Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function for Food Crop Farmers in Southwestern Nigeria.

| Variable | | Model 1 | | Model 2[a] | |
|---|---|---|---|---|---|
| | Parameter | Coefficient | t-ratio | Coefficient | t-ratio |
| Production Model | | | | | |
| Constant | $\beta_0$ | 10.179 (0.319) | 31.889*** | 10.861 (0.306) | 35.44*** |
| Ln (Labour) ($X_1$) | $\beta_1$ | 0.486 (0.0562) | 8.658*** | 0.401 (0.055) | 7.275*** |
| Ln (Farm size) ($X_2$) | $\beta_2$ | 0.358 (0.0372) | 9.622*** | 0.377 (0.0338) | 11.137*** |
| Ln (Fertilizer) ($X_3$) | $\beta_3$ | 0.00372 (0.00809) | 0.460 | 0.00783 (0.00769) | 1.019 |
| Ln (other agrochemical) ($X_4$) | $\beta_4$ | 0.0262 (-0.0205) | 4.175*** | 0.0202 (0.00579) | 3.493*** |
| Ln (Depreciation) ($X_5$) | $\beta_5$ | -0.0205 (0.0317) | -0.649 | -0.0233 (0.304) | -0.767 |
| Technical Inefficiency Model | | | | | |
| Constant | $Z_0$ | 0 | - | 0.344 (0.162) | 2.127** |
| Land fragmentation | $Z_1$ | 0 | - | 0.0729 (0.0376) | 1.939* |
| Off-farm income | $Z_2$ | 0 | - | 0.00000016 (0.000000258) | -0.623 |
| Adjustment in farm size | $Z_3$ | 0 | - | 0.00754 (0.112) | -0.622 |
| Multiple planting dates | $Z_4$ | 0 | - | 0.133 (0.0474) | 2.802*** |
| Crop Diversification | $Z_5$ | 0 | - | -0.0119 (0.0383) | -0.310 |
| Education level | $Z_6$ | 0 | - | -0.00169 (0.0383) | -0.269 |
| Years of awareness of climate change | $Z_7$ | 0 | - | -0.0183 (0.00879) | -2.078** |
| Social capital | $Z_8$ | 0 | - | -0.0416 (0.00668) | -6.231*** |
| Variance Parameters | | | | | |
| Total Variance | $\delta^2_s$ | 0.174 | | 0.183 (0.0208) | 8.833*** |
| Gamma | $\gamma$ | 0.0500 | | 0.287 (0.0937) | 3.064*** |
| Log likelihood function | Llf | -190.614 | | -165.505 | |

*, **, *** stand for level of significance at 10%, 5%, and 1%, respectively.

[a] is the preferred model.

Values in parentheses are standard errors.

Source: Computed from Field survey, 2011.

## Crop diversification

This has to do with the number of crops the farmer plants in the same or different farms as a result of climate change, knowing very well that different crops respond differently to different climate scenarios. An inverse and statistically insignificant relationship was found between crop diversification and technical inefficiency. This implies that further diversification of crops may lead to higher technical efficiency perhaps because this could act as insurance against crop failure and hence reduce their farm income/resource variability and hence improve their technical efficiency. Enete *et al.* (13) reported that multiple/intercropping, though a tradition for smallholder farming in Nigeria may have been intensified as a result of climate change because different crops have different levels of resilience to weather variability, hence, planting many crops in a field could ensure that the farmer get some output in the face of extreme weather situations. Benhin (7) reports that growing a variety of crops on the same plot is an appropriate adaptation strategy for farmers because it helps to avoid complete crop failure as different crops may be affected differently by climate change. It is also a measure of diversification by the farmers. Hassan and Nkemechena (15) had reported that increased diversification is a strong climate change adaptation measure.

### Years of climate change awareness

A negative and statistically significant relationship is found between years of climate change awareness and technical inefficiency. This implies that an increase in the years of awareness tends to increase technical efficiency (i.e. decrease technical inefficiency). This is in line with a priori expectation. The awareness of climate problems and the potential benefits of taking action is an important determinant of adoption of agricultural technologies (15). Maddison (22) argued that farmer awareness of change in climate attributes (temperature and precipitation) is important to adaptation decision making. For example, Araya and Adjaye (5) and Anim (4) reported that farmers awareness and perceptions of soil erosion problem as a result of changes in climate, positively and significantly affected their decisions to adopt soil conservation measures.

### Social capital

Social capital was defined here to mean the number of relatives/friends that a particular farmer held discussions with on how to cope with climate change. A negative and statistically significant relationship was found between social capital and technical inefficiency. This implies that the more the number of relatives that were able to discuss issues of climate change adaptation, the more technically efficient the farmers were. This suggests a great potential for social capital in the farmers' abilities to surmount adverse events such as climate change. Generally, the severity of income and food supply shocks and what coping strategies families may choose to utilize to cope with the shocks may depend primarily on the strength of the social networks they have access to Mtika (23) and Muga & Onyango-Ouma (24).

## Conclusion

Multiple cropping, land fragmentation, multiple planting dates, mulching and cover cropping were presented in this study as the major climate change adaptation strategies employed by the farmers. The computed mean technical efficiency estimate was 0.84, thus suggesting that technical efficiency of the average farmer could still be improved by about 16%. The technical inefficiency model showed that land fragmentation and multiple planting dates had significant positive relationship, while years of climate change awareness and social capital had significant inverse relationship, with technical inefficiency. The positive effects of land fragmentation and multiple planting dates could be because while the former may hinder farm mechanization, the later may increase the monotonousness and drudgery of farming. However, the negative effects of social capital and climate change awareness suggest that the two factors could help to ameliorate the effects of, particularly, land fragmentation. It is therefore recommended that the farmers be encouraged to form cooperative societies so as to leverage their resource status through collective efforts.

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