Journal of Scientific Research & Reports

25(2): 1-19, 2019; Article no.JSRR.31431
ISSN: 2320-0227

A Study on Relationship between Technical Efficiency and Climate Change Manifestations among Sesame Farmers in Benue State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author MPN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BCA and MPN managed the analyses of the study. Author BCA and GCA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2019/v25i230184
Editor(s):
(1) Dr. Grigorios L. Kyriakopoulos, School of Electrical and Computer Engineering, National Technical University of Athens (NTUA), Athens, Greece.
Reviewers:
(1) Dr. Govind Pal, India.
(2) Wole Luqman Agboola, University of Ibadan, Nigeria.
Complete Peer review History: http://www.sdiarticle4.com/review-history/31431

Original Research Article

Received 02 January 2019
Accepted 07 March 2019
Published 25 October 2019

ABSTRACT

The present study aims to analyse the relationship between technical efficiency and the adverse effect of climate change manifestations among sesame farmers in Benue State, Nigeria. A combination of purposive and random sampling techniques was used to select 372 sesame producers. Data were analysed by using the Cobb-Douglas stochastic frontier production function and Spearman correlation. The stochastic production function showed that farm size, seed, fertilizer, agrochemical and family labour significantly affect sesame output. The study also showed that education, farming experience, household size, access to extension; access to credit, access to market and membership to farmer association were positively related to technical efficiency of sesame farmers. The result further showed that the average technical efficiency of sesame farmers was 0.53. The result also revealed that there is a significant negative relationship between the level of adverse effects of climate change manifestation and technical efficiency among sesame farmers in the study area. It was therefore recommended that readily available farming inputs and subsidies

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should be entrenched. Credit facility, extension services and good market access should be provided to farmers. Education, information and training of farmers to adapt to climate change by changing their farming practices such as bush burning, de-forestation, rain-fed agriculture and land tenure systems should be encouraged.

Keywords: Climate change; technical efficiency; sesame farmers.

1. INTRODUCTION

Climate change is one of the environmental life-threatening phenomena to economic development and sustainability of man-kind worldwide. Natural climate cycle and human activities have contributed to an increase in the accumulation of heat-trapping "greenhouse" gases in the atmosphere thereby contributing to increasing in temperature in the global climate (global warming) [1].

Global warming causes unpredictable and extreme weather events impact and increasingly affect on crop growth, availability of soil water, forest fires, soil erosion, droughts, floods, sea level rises with prevalent infection of diseases and pest infestations [2,3]. These environmental problems result to low and unpredictable crop yields, which invariably make farmers more vulnerable, especially in Africa [4,1]. Available evidence showed that Nigeria is already being plagued with diverse ecological problems which have been directly linked to the on-going climate change [5,6]. The resource-poor farmers faced the prospects of tragic crop failures which reduced agricultural productivity, increased hunger, poverty, malnutrition and diseases [3,7].

In Nigeria, sesame is cultivated on over 80,000 ha across most of the Northern States for food and oil. Benue and Nasarawa States are the highest sesame producers in Nigeria with an annual average output of not less than 40,000MT [8]. Sesame is one of the cultivated oilseed crops in the world. According to [9], since its introduction to Nigeria after the Second World War, it has been regarded as a crop of insignificant importance compared to groundnut and other cash crops [10]. The demand for sesame and its products is growing both at the National and International levels. Thus a vast market potential exists for sesame. Owing to its previous status as a minor crop, there have been little research efforts on the crop. Therefore, investigating the relationship between climate change manifestations and technical efficiency in sesame production is very necessary, particularly among sesame farmers in Benue State where vulnerability to climate variability seems to be high.

2. REVIEW OF RELATED STUDIES

2.1 Quantification of Major Indicators of Climate Change on Agriculture.

Past studies have used a variety of approaches to capture climate change effects on agriculture [11] (Wang 2009; Deressa and Hassan, 2010). These approaches range from simply equating average future impacts to yield losses observed in historical droughts to more quantitative crop simulation modelling, statistical time series and cross-sectional analyses. To date, simulation studies have been limited by a lack of reliable data on soil properties and management practices, and have provided only `best-guess' estimates with little to no information on uncertainties that result from choices in model structure, parameter values and scaling techniques (Frost and Thompson, 2000; [12]). In addition, past studies have observed that statistical analyses have been limited by the poor quantity and quality of historical agricultural data relative to other regions, resulting in model estimates with wide confidence intervals [13], (Wang et al., 2009). Besides, studies have shown that Statistical and econometric techniques can be employed to establish a logical association between climate variation and change (Tebaldi and Knutti, 2007; Niggol and Mendelsohn, 2008). A substantial amount of research has been conducted on the potential impacts of climate change on agricultural productivity [11,14] (Deressa and Hassan, 2010). Attempts are made in these studies to link the state-of-the-art models developed by researchers in separate disciplines, including climatology, agronomy and economics, in order to project future impact of climate change on agriculture and implication for population growth. Some of these studies include Kane [15]; Rosenzweig et al., [16]; Rosenzweig & Parry, [17]; Reilly, [18] and Ayinde, [19] that used climate-induced changes in crop yields to estimate potential global economic impacts. Others have examined the indirect impact on economic variables such as farm revenue and income, e.g. Mendelsohn [20] and Adams [21]. The review of these studies helped to have an understanding of the physical and economic responses, and adjustments on climate change and agricultural production. However, in line with adaptation scenario of how farmers are coping or surviving under this climate variability, these studies assumed that farmers could adapt to climate change by changing crop varieties and timing of planting and harvesting, while in the without adaptation scenario it is assumed that farmers do not make any adjustments over time.

The conversion of land to agricultural use and exploitation of diverse other natural resources has generally increased the capacity of Earth to support human beings. In recent decades, however, the human enterprise has grown so large that it is seriously altering the global environment (Holdren & Ehrlich, 1974; FAO, UNFPA and IIASA 1982; Kane [15]; Fischer [12] and Wang 2009). Humanity is now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources, to support its growing population [22,21]. This resource depletion, coupled with other human pressures on the environment (e.g., production of toxic wastes, changing the composition of the atmosphere) is undermining the capacity of the planet to support virtually all forms of life [23].

The magnitude and pace of change that climatologists believe probable are unprecedented in human history (Abrahamson [24]; Cairns and Zweifel 1989; Lashof 1989; NAS 1987; Schneider 1989). Should such change occur, there will inevitably be wide-ranging effects on many facets of human societies. Current patterns and future plans of energy use and industrialization will require major revision [17,18,20]. International tensions are likely to heighten over claims on freshwater where scarce supplies are further reduced [12,14,19], trans-national migration of environmental refugees (Jacobson 1988), and ultimate responsibility for global warming and its effects [21].

The global production and distribution of food is inadequate for a large fraction of the rapidly expanding global population of 5.8 billion people under present and foreseeable economic systems (WRI, 1987; Brown 1988; Brown & Young 1990) [22]. The agricultural and food-distribution systems may be further stressed by shifting of temperature and precipitation belts, especially if changes are rapid and not planned for Adams [21].

2.2 Social Impact of Climate Change on Smallholder and Subsistence Agriculture

Climate change adds a new threat to rural livelihoods—especially for subsistence or smallholder farmers — because it affects economic growth and efforts to reduce poverty, thereby jeopardizing many of the development gains made in recent decades [25]. Furthermore, rural area is very vulnerable to changes in climate patterns because a significant percentage of its economy and some of its workforce depend primarily on weather-sensitive agriculture. The changing climate could also hurt the productivity of rural workers and the health of their families because it may affect the quality and quantity of farming produce.

Most of the rural poor live in heterogeneous risk-prone areas with marginal resources and fragile ecosystems whose agriculture depends on rainfall. Climate variability will push these poor people, who are the least responsible for climate change, further beyond their capacity to cope with such changes. Many small farmers in rural areas—who already live in harsh environments—may become very vulnerable to climate change impacts because of their geographic exposure to extreme events, low incomes, dependence on agriculture, and few options to pursue other livelihoods. Poor rural people may face a growing scarcity of land viable for agriculture, increasing difficulty in obtaining enough food, and a significant reduction of fresh water as the climate becomes more erratic. For example, many people in Nigeria will suffer lack of dry- season water (whose uses vary from drinking, irrigation, and sanitation to hydropower) whereas another many people living in drought-prone areas will be under water stress due to climate change [26]. Women will be among those suffering most because they are the main providers of food, fuel, and water for their households [27]. Rural communities may be negatively affected because of the inability to enjoy their culture due to climate change's impact on lands and ecosystems of historical, cultural, and spiritual significance [26].

Changes in water quantity and availability due to climate change will affect food availability, stability, access, and use. Furthermore, average per capita food availability may decrease at least

300 calories (12 percent reduction) by 2050 due to climate change, which will eliminate any progress on fighting malnutrition [28]. There will be also about 6.4 million malnourished children in 2050—that is, about 1.4 million more than in a no-climate change scenario. Other social implications due to the changing climate are related to human health, income inequality, rural migration, and conflict. Climate change will also affect how agriculture uses energy and food consumption patterns. Governments should, therefore, invest now in adapting agriculture to climate change, which should be science-driven due to the uncertainty on the effects of climate change on agriculture in the long term [29].

2.3 Global Warming and Impacts on Agriculture

The Earth warmed between 1850 and 2010 at a rate of 0.5°C per century, but that increased to 0.7°C per century from 1900, to 1.3°C per century since 1950, and to 1.8°C per century for the last 35 years. The last two decades are among the warmest since temperature recording started. Annual losses in barley, maize, and wheat output due to global warming since 1981 amount to 40 million tons (or US$5 billion as of 2002) (Lobell and Field, 2007), although these were offset by yield gains due to crop breeding and other agro-technology advances [12].

It appears that high seasonal temperatures, beyond what has been already noted in the last 50 years, may become further widespread in several Mesoamerican and South American locations in the remainder of this century [30]. The temperature increase could vary between 0.4°C and 1.8°C for 2020, being more severe in tropical locations. High temperatures (particularly >3°C) will dramatically affect agricultural productivity, farm incomes, and food security. Several crops that are important staples for large numbers of food-insecure people will be negatively affected in their yields, although scenarios seem to be more uncertain for some crops than for others [14]. For example, rice's grain yield declines by 10 percent for each 1°C increase in minimum temperature during the dry growing season [31], while a 10 percent loss in maize production may be expected by 2055 [32]. Likewise, global warming may favor wheat in some regions but this grain crop could reduce its productivity significantly in areas where optimal temperatures already occur, or it may expand to cool, temperate environments where wheat does not yet grow [33]. Many insects and mites affecting some crops may increase due to increasing temperatures and atmospheric carbon dioxide (CO2).

2.4 Greenhouse Gas (GHG) Emissions and Climate Change Mitigation

Agriculture accounts for about one-third of global GHGs, mainly due to tropical deforestation, methane emissions from livestock and crop farming, and nitrous oxide emissions from fertilized soils with nitrogen and manure. Most of the GHG emissions derive from land use change [29].

Avoiding deforestation and using appropriate land use management system is very important for curbing GHG emissions (Galford 2010). Agricultural intensification is a primary factor for both ensuring food production and mitigating climate change (DeFries and Rosenzweig, 2010). Crop productivity gains should be prominent in the strategy to reduce GHG emissions—higher crop yields due to the Green Revolution, for instance, avoided emissions of up to 161 gigatons of carbon (GtC) (590 GtCO2e) since 1961 (Burney 2010). Increasing yields on existing croplands also helps to curtail the expansion of agriculture into tropical forests. Protected areas in the Amazon forests can further reduce CO2 emissions (Soares-Filho 2010). Likewise, not burning crop residues and weeds will be very important for mitigating GHG emissions and preserving soils.

Livestock is a key driver of environmental change (Pelletier and Tyedmers, 2010). Managing livestock to make the most efficient use of feeds often reduces amounts of methane produced. For example, forage legumes with low tannin content can improve the diet quality in ruminants. Adoption of improved pastures, intensifying ruminant diets, changes in land use practices, and changing breeds of large ruminants on the production of methane and CO_2 may account for 7 percent of the global agricultural mitigation potential to 2030 [34]. The objective will be therefore to minimize emissions per unit of the animal product when managing livestock with the aim of increasing their productivity. The biodigesters will be another approach for mitigating emissions for animals confined in small areas (such as swine and dairy). The processing of their waste and capturing of methane will be of further use for flaring (thereby generating carbon credits because they are less potent as GHGs than methane) or for generating electricity on-farm or for local use [35,36]. Silvi-pastoral systems combining productive forage grasses and trees can also be used to recover degraded pasturelands because they can capture significant amounts of carbon from the atmosphere and retain it in their deep root systems. They can be a more efficient and less destructive alternative to cattle ranching.

2.5 Technical Efficiency in Agricultural Production

Amaza and Maurice [37] examined factors that influence technical efficiency in rice-based production systems among fadama farmers in Adamawa State, Nigeria. A Cobb-Douglas stochastic frontier production function, which incorporates technical inefficiency model, was estimated using the maximum likelihood estimation (MLE) technique. Technical efficiencies vary greatly among farms, ranging between 0.26 and 0.97 and a mean technical efficiency of 0.80 implying that efficiency in rice production among fadama farmers in Adamawa State could be increased by 20 percent through better use of available resources, given the current state of technology. The inefficiency model reveals that farming experience and education significantly affect farmers' efficiency levels.

Umeh and Asogwa [38] analyzed the effect of some government policy packages on the technical efficiency of cassava farmers in Benue State, Nigeria. The study used the Cobb-Douglas frontier production function and assumed a truncated normal distribution for the inefficiency term. Cross-sectional data were used. The parameters of the model were estimated by the maximum likelihood estimation method. The results showed that 63.6% of the cassava farmers operated close to the frontier production function. The estimated technical efficiency scores varied between 31% and 100% with a mean score of 89%. The outcomes showed that cassava production in the state can be improved by increasing farmers' access to policy packages such as extension services, market access, improved cassava variety and processing technology [39].

Amaza, Bila and Iheanacho [40] used stochastic frontier production function to examine the determinants of food crop production and technical efficiency in the guinea savannas of Bornu State, Nigeria. Maximum likelihood estimation (MLE) technique was applied to the data collected from 1086 respondents. The results showed that farm size, fertilizer, and hired labour are major factors that are associated with changes in the output of food crops. The study also revealed that farmer-specific efficiency factors include age, education, credit, extension and crop diversifications which were found to be significant factors that accounted for the observed variation in efficiency among the farmers. The mean farmers' technical efficiency index was found to be 0.68.

Ogundari and Ojo [41-43] examined the production efficiency of cassava farms in Osun state of Nigeria using farm level data. The stochastic frontier production and cost function model were employed to predict the farm level technical and economic efficiencies, respectively. The results showed that mean TE, EE and AE of 0.903, 0.89 and 0.807 were obtained from the analysis respectively indicating that TE appears to be more significant than AE as a source of gain in EE.

Okoruwa, Ogundele and Oyewusi (2006) analysed technical, allocative and economic efficiency of upland and lowland rice producers in Niger State Nigeria using a stochastic production function efficiency decomposition methodology. The mean technical efficiency of 81.6% for upland rice and 76.9% for lowland rice were obtained. The analysis of variance (ANOVA) was used to examine the association between EE, TE and AE, and seven socioeconomic characteristics. The results showed that experience, household size, farm size, sex and improved rice variety has a significant impact on rice farmers. The results also showed that farmers could increase output and household income through better use of available resources given the state of technology in terms of improved varieties of rice seeds.

2.6 Theoretical Framework

2.6.1 Climate change and crop yields

There are various and sometimes contradictory scenarios regarding quantification of climate change's impacts on agriculture. Some authors indicate that these impacts on crop outputs remain unknown and that more research will be needed to further understand the complexity of crop responses to the climate change due to its variability and what could be the long-term average climate [44]. They differ in their approach, method, and complexity level, to make it difficult to compare among country estimates. Several authors also question models to say that changes in climate will significantly affect agriculture and food supply in Latin America [45].

2.6.2 Theory of production and production efficiency

The economic theory of production provides the analytical framework for most empirical research on productivity and efficiency. Production is a process whereby some goods and services called inputs are transformed into other goods and services, called output. In agriculture, the physical inputs may include land, labour, capital, management and water resources. These resources are organized into a producing unit, whose objectives may be profit maximization, output maximization, cost minimization, or the maximization of satisfaction, or a combination of these motives of enterprise. Production efficiency means the attainment of a production goal without a waste. Beginning from this basic idea of ‘‘no waste", economists have built up a variety of theories of efficiency. The fundamental idea underlying all efficiency measures, however, is that of the number of goods and services per unit of input. Consequently, a production unit is said to be technically inefficient if too little output is being produced from a given bundle of inputs.

There are two basic methods of measuring efficiency – the classical approach and the frontier approach. The classical approach is based on the ratio of output to a particular input and is termed partial productivity measure. Dissatisfaction with the shortcomings of this approach led economists to develop advanced econometric and linear programming methods for analysing productivity and efficiency. The frontier measure of efficiency implies that efficient firms are those operating on the production frontier. The amount by which a firm lies below its production frontier is regarded as the measure of inefficiency.

2.6.3 Technical efficiency

According to Vensher (2001), a firm is said to be technically efficient when it produces as much output as possible with a given amount of inputs or produces a given output with the minimum possible quantity of inputs. Similarly, Ellis [46] defines technical efficiency as the maximum possible level of outputs obtainable from a given set of inputs, given a range of alternative technologies available.

Classical textbook exposition views a technically efficient firm as producing on the isoquant/ production possibility frontier [47]. These mainstream definitions have been criticized by Ellis [46] for associating technical efficiency only with input quantities and not with input cost monetary terms.

Though technical efficiency is as old as neoclassical economics, its measurement is not. Probably this is explained by the fact that neoclassical economics assumes full technical efficiency. Two main reasons justify the measurement of technical efficiency [48]. First, a gap exists between realized efficiency and theoretical assumption of full technical efficiency. It has been observed by Kalarijan and Shad [48] that where technical inefficiency exists, it will exert a negative influence on allocative efficiency with a resultant effect on economic efficiency.

The issue of technological efficiency has also caught the attention of researchers. Technological change occurs through processes, which can yield more output for the same or less quantity of input than older processes. Some researchers argue that the introduction of such a new process can be thought of as rendering all previous processes technically inefficient [46]. According to Meier (1995), under this view, ' technology' comprises the series of all known techniques for producing a particular output – though the invention of a new technology does not guarantee its availability to all producers. It should, therefore, be realized that there is a difference between inefficiency due to operating off the isoquant for a given technology as opposed to inefficiency due to failure to move to a different isoquant made possible by new technology [46]. The former can be exemplified by a situation in which the same output of sesame can be obtained by using a lesser quantity of the input. An example of the latter will be a situation in which new technology is introduced and the firm is unable to use it for various reasons.

Ellis [46] notes two forms of technological change; the first is process innovation, which improves the production of existing products; the second is product innovation, which develops sustainably improved outputs. While technological change represents innovation, improving technical efficiency under a given technology is essentially about catching up with what is technologically possible (Farell et al., 1957). The basic concept underlying the estimation of technical efficiency lies in the description of production technology. Production technologies are usually represented by isoquants, production functions, costs functions or profit functions.

Economically, productivity describes the ratio between output and input [49]. Furthermore, Olaoye (1985) stated that productivity is a concept that can be viewed from two dimensions, namely the Total Factor Production (TFP) and partial productivity [10]. Partial productivity is the average production of a production factor that measured as quotient of total production and total production factor used. Chamber [50] reported the total factor productivity is a measure of the ability of all production factors as an integral factor in the overall production output (aggregate output). Formulation of total factor productivity can be determined by the production function approach. If the production function is defined as: Q = AF (L, K), where A is a parameter called technology index or productivity, the productivity index is formulated as (Nadiri, 1970):

Total factor productivity index: A = Q/F(L.K), or A = Q/(aL + bK   (1)

where Q, L, and K, respectively are aggregate level of output, labor input and capital: a and b are a weight adjustment.

Increased productivity can be caused by five different relationships between input and output (Misterik, 1992):

1. Output and input increases, but proportionately increased input smaller than increased output;
2. Output increases with the same input;
3. Output increases with reduced input;
4. Same output with reduced input;
5. Output decreases with more reduced input.

The success of sesame farming can be approximated by the efficiency principle [51]. The Economic basic principle is effective in producing maximum output value with limited input (s) or producing a certain output or input by using the lowest possible cost.

Efficiency in economic theory terms can be viewed from two aspects, viz., as technical sense (technical efficiency) and economic terms (price or allocative efficiency). Technical efficiency implies the achievement of the maximum output quantity that can be generated from a particular use of a number of production factors. The greater the output quantity produced relative to inputs quantity used, the higher technical efficiency level achieved by input (Yotopoulus and Nugent, 1976). Technical efficiency achievement can be achieved through the physical productivity maximization of production factors.

Farming technique efficiency has several definitions. One definition commonly used is the ratio between the production of farm observations with output (production) of production function frontier [52]. In econometrics, Technical Efficiency of a Farm Business, TERi, is defined as ratio of the farm production average at ith, ui is positive, and at the level of a particular input (xi) with average production ui = 0.

Technical efficiency measures the extent a farmer transform inputs into outputs at an economic optimum level with specific technological factors. This means, two farmers who use the same number and type of inputs and technologies could produce different output. Most of the difference is due to diversity found in almost all life aspects. Others caused by individual characteristics and public policy factors. Ortega [53] says the factors such as extensive farming, management, demographic characteristics of producers have contributed to differences in the technical efficiency level among farmers.

Technical efficiency can be measured using a frontier production function. This function describes the technical position of potential output that could be achieved by a business or cropping (sesame or other crops) with a number of specific production factors [54,55]. Sesame cropping or other planting efforts did not achieve the maximum output based on existing technology level and quantity of inputs if the actual output quantity produced will be under frontier function. Indexes of technical efficiency is measured by comparing the planting effort between production level (output) that can actually achieved (y) with the production level (output) potential "frontier" (y1) using X input. Cropping effort to reach a perfect technical efficiency will get the index of one [56], Battese, [55]; G.E. Battese and T.J. Coelli, [57].

2.6.4 Relationship between climate change and agricultural production

According to Ortiz [29], the impacts of climate change in agriculture can be measured by productivity loss due to extreme temperatures, which affect growth cycles, and water stresses that reduce yield. Solar radiation changes can also influence biomass accumulation, whereas CO2 concentration levels will affect photosynthesis, water, and nitrogen efficiency. Climate change will cause further declines in water runoff, which may affect the water supply for agriculture. The impacts of the changing climate on agro-ecosystems and food availability and prices depend on the farming system, size, and location.

Oyekale [58] observed that the major direct effects of climatic change on agricultural production in Nigeria are through changes in temperature, precipitation, length of growing season, and timing of extreme or critical threshold events. Specifically, sensitivity of sesame production to hours of sunshine, rainfall, soil conditions and temperature makes it vulnerable to climatic change. Changing climate can also alter the development of pests and diseases and modify the host's resistance. Extended drought will cause the young sesame plants and some mature sesame plants to wither, while major pests and diseases of sesame are promoted by unfavourable climatic situations. More importantly, the leaf curl virus disease is a major threat to sesame production under climatic conditions favourable to the virus [9].

Onyibo [9] pointed out that sesame yields are affected by the length of growing season rainfall, weather and plant density among other factors. Several pests attack sesame with the potential to reduce the yield of the crop. Some of these cause moderate to severe yield losses as a result of foliar feeding or damage to seed or other harvestable portions of the plant. Furthermore, weeds are a very serious problem in sesame production because they often cause drastic reduction in yield [9].

Onyibo [9] noted that sesame is susceptible to pests and diseases. Every aspect of sesame production from seedling to matured plant has one form or the other types of pests and diseases. Most of these field problems, including insects, cause a drastic reduction in the yield of sesame. Depending on the weather and time of the year, the sesame crop is constantly attacked by a wide range of insect pests. These pests range from the species that defoliate the plant to those attacking flower heads and young fruits. All stages of sesame are attacked on the field. White fly that transmits leaf curl virus is the major insect pest of sesame [9].

Evidence from literature and past studies has revealed that the recent global warming has influenced agricultural productivity leading to declining food production Kurukulasuriya & Mendelsohn, 2006; [59,14,60]. In order to meet the increasing food and non-food needs due to population increase, man is now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources to meet his needs [24,22]. This resource depletion was linked with other human pressures on the environment. Possibly the most serious of human impacts is the injection of greenhouse gases into the atmosphere. The reality of the impact of climate change on agricultural development has started showing signs [61,12,62]. A substantial body of research has documented these wide-ranging effects on many facets of human societies [63], ODI, 2007; [64].

Rough estimates suggest that over the next 50 years or so, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008). Specifically, population, income, and economic growth could all affect the severity of climate change impacts in terms of food security, hunger, and nutritional adequacy. If climate change adversely affects agriculture, effects on human are likely to be more severe in a poorer world. Wolfe [63], Stige [65], Orindi [66] worry that rising demand for food over the next century, due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries.

3. METHODOLOGY

3.1 The Study Area

Benue State derives its name from River Benue, the second largest River in Nigeria. The State, created in 1976, is located in the middle Belt region of Nigeria, approximately between latitudes $6½^0$ and $8½^0$ North and longitude $7½^0$ and 10^0 East. The State shares boundaries with five states namely, Nasarawa to the North, Taraba to the East, Cross River to the South-

East, Enugu to the South- West, and Kogi to the West. The Southern part of the State also shares boundary with the Republic of Cameroon. The State is also bordered on the North by 280 km River Benue, and is traversed by 202 km of River Katsina-Ala in the inland areas. Benue State is acclaimed as the nation's "food basket" because of its rich and diverse agricultural production. The state is blessed with fertile soil that produces a wide range of vegetables, fruits and pasture for livestock. The state also accounts for over 70 per cent of the nation's Soya bean production. It boasts of one of the longest stretches of river systems in the country with potential for a viable fishing industry, dry season farming through irrigation and for an inland waterway through irrigation and for an inland waterway. It has a variety of crops grown in irrigated and rain areas.

These include yams, rice, beans, cassava, potato, maize, Soya beans, sorghum, millet, beniseed (sesame), groundnuts, fruits, and coco-yam.

3.2 Population and Sampling Procedure

A combination of purposive and random sampling techniques was used for sample selection. Benue State is divided into three (3) agricultural zones such as Zone A, Zone B and Zone C. Two local government areas each were purposely selected from Zone A and Zone B while three local government areas were purposely selected from zone C on the basis of the high level of sesame production. Based on this, Kwande and Logo Local Government Areas were purposively selected from Zone A. Guma and Tarka Local Government Areas were purposively selected from Zone B. Oju, Obi and Ohimini Local Government Areas were purposively selected from Zone C. From each of the selected Local Government Areas, households were randomly selected on the basis of its population size using 0.2% sampling fraction. Based on the foregoing, 372 sesame producers were randomly selected for this study.

3.3 Data Collection and Analysis

The primary data were obtained through the use of a structured questionnaire, copies of which were administered to the selected 372 sesame farmers in Benue State in 2015. Data were analysed using the Cobb-Douglas stochastic frontier production function and Spearman correlation.

3.4 Model Specification

3.4.1 Cobb-douglas stochastic frontier production function

In this study, Cobb-Douglas stochastic frontier production function is assumed to be the appropriate model for the analysis of the technical efficiency of sesame farmers in sesame production in the study area. Following [52], the model to be estimated is defined by:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_i - U_i \quad (1)$$

Where:

ln = natural logarithm to base e

Y = the total sesame output of the farmers (in kilograms)

β_i = the unknown parameters associated with the explanatory variables in the production function (i = 0,1,2,3,4,5,6)

X_1 = farm size (ha)

X_2 = sesame seed (kg)

X_3 = fertilizer (kg)

X_4 = family labour (man-days)

X_5 = hired labour cost (Naira)

X_6 = Pesticide cost (Naira)

βs = Parameters to be estimated

Vi = is the random error that is assumed to be normally distributed with zero mean and constant variance ($\sigma^2 V_1$) and U is technical inefficiency effects independent of V_i and half normal distribution with mean zero and constant ($\sigma^2 U_1$)

Following [52] model, the mean of farm specific technical inefficiency U_i is define as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 \quad (2)$$

Where;

Z_1 = Age (years)
Z_2 = Education (years)
Z_3 = Household size (number)
Z_4 = Farming experience (years)

Z_5 = access to extension services (Access = 1; 0 otherwise)
Z_6 = access to credit (Access = 1; 0 otherwise)
Z_7 = access to market (Access = 1; 0 otherwise)
Z_8 = Membership of farmer association (Member = 1; 0 otherwise)
δs = Parameters to be estimated

TE is technical efficiency. Whenever the producer is on the efficient frontier of production, *TE* = 1. Otherwise, *TE* < 1 because *TE* a measure of the distance of the production level that is observed with respect to the frontier level of production. Thus, the measurement of technical efficiency can be summarized as follows:

$$TE = \frac{Y_i}{f(I_i, \beta)e^{v_i}} \qquad (3)$$

3.4.2 Spearman rank correlation analysis

For a sample of size *n*, the *n* raw scores are converted to ranks, and ρ is computed from these:

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

Tied values are assigned a rank equal to the average of their positions in the ascending order of the values. In applications where ties are known to be absent, a simpler procedure can be used to calculate ρ [68,69]. Differences between the ranks of each observation on the two variables are calculated, and ρ is given by:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

The sign of the Spearman correlation indicates the direction of association between *X* (the independent variable) and *Y* (the dependent variable). If *Y* tends to increase when *X* increases, the Spearman correlation coefficient is positive. If *Y* tends to decrease when *X* increases, the Spearman correlation coefficient is negative. A Spearman correlation of zero indicates that there is no tendency for *Y* to either increase or decrease when *X* increases. The Spearman correlation increases in magnitude as *X* and *Y* become closer to being perfect monotone functions of each other. When *X* and *Y* are perfectly monotonically related, the Spearman correlation coefficient becomes 1. A perfect monotone increasing relationship implies that for any two pairs of data values *Xi*, *Yi* and *Xj*, *Yj*, that *Xi* − *Xj* and *Yi* − *Yj* always have the same sign. A perfect monotone decreasing relationship implies that these differences always have opposite signs.

3.4.3 Scale of variables

In order to analyse the relationship between the level of adverse effect of perceived dimensions of climate change manifestations and technical efficiency among the respondents, the Spearman correlation analysis was used. The level of adverse effect was measured on 5-point Likert Scale based on the perception of the respondents as Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5). Variables were specified as follows:

Y = Technical efficiency estimates (measured on continuous scale from 0 to 1)
X_1 = Changed timing of rains (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)

Table 1. Sample size selection (sampling plan at 0.2 percent)

S/No	Zone	LGA	Sampling frame	Sampling proportion (percent)	Sample size
1	North East	Kwande	26,100	0.002	52
2		Logo	24,500	0.002	49
3	North West	Guma	39,400	0.002	79
4		Tarka	33,200	0.002	66
5	Southern Zone	Oju	23,200	0.002	46
6		Obi	21,600	0.002	43
7		Ohimini	18,700	0.002	37
		Total	**186700**	**0.002**	**372**

Source: BNARDA, 2014 [67]

X_2 = Drought (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_3 = Extreme temperatures (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_4 = Floods (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_5 = Excess rainfall (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_6 = Nutrient leaching (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_7 = Soil erosion (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)
X_8 = Pest/disease infestation (Very low level of adverse effect = 1; Low level of adverse effect = 2; Moderate level of adverse effect = 3; High level of adverse effect = 4; Very high level of adverse effect = 5)

The Spearman rank correlation coefficient r, can take any value between -1 and +1. A statistically significant correlation coefficient in the range $0 < r \leq 0.3$ was regarded as week correlation; $0.3 < r \leq 0.6$ was regarded as moderate correlation; $0.6 < r < 1$ was regarded as strong correlation, while a correlation coefficient of 1 was regarded as perfect correlation.

4. RESULTS AND DISCUSSION

4.1 Maximum Likelihood Estimates of the Stochastic Frontier Production Function

The result in Table 2 shows that five of the estimated coefficients in the stochastic frontier models are statistically significant, while one of them is not statistically significant. Using the maximum-likelihood estimates for the parameters of the production frontier (Table 2), the elasticities of frontier output with respect to farm size, seed quantity, fertilizer, agrochemical and family labour were estimated at the means of the input variables to be 1.11, 0.47, 0.52, 0.69 and 0.44 respectively. Given the specification of the Cobb-Douglas frontier models the results show that the elasticity of mean value of sesame output is estimated to be an increasing function of farm size, seed quantity, fertilizer use, agrochemical use and labour.

The high farm size elasticity (greater than unity value) suggests that expansion in production among the sesame farmers in the study area was mainly due to an increase in farm size rather than an increase in technical efficiency. The returns-to-scale parameter was found to be 3.77, implying increasing return-to-scale for production among the respondents. This suggests that a proportionate increase in all the inputs would result in more than proportionate increase in the sesame output of the farmers. The increasing return-to-scale in this study implies increasing productivity per unit of input, suggesting that the farmers are not using their resources efficiently.

This means that the farmers can still increase their level of output at the current level of resources. This implies that an increase in production efficiency among the respondents would result in higher sesame output in Benue State. The implication is that policy that will help to increase technical efficiency among the farmers would bring about an increase in sesame output of the farmers in the study area.

The policy implication of the foregoing finding is that any policy that would enhance the access of sesame farmers to land, improved sesame seed, fertilizer, agrochemicals and labour would improve the profitability of sesame production. This is possible because the farmers through the expansion of input use would be able to move from the production phase of increasing return to scale to the phase of decreasing return to scale where profit would be maximized. The result further showed that the estimated coefficients of education, farming experience, household size, access to extension services, access to credits, access to markets and membership of farmer association are negative and significant at 5 percent level of significance. This implies that education, farming experience, household size, access to extension services, access to credits, access to markets and membership of farmer association are significant determinants of technical inefficiency among the respondents. The negative coefficients of education, farming experience, household size, access to extension services, access to credits, access to markets and membership of farmer association imply that an increase in any of or in all of these variables would lead to decline (increase) in the level of technical inefficiency (technical efficiency). In other words, sesame farmers with better education and better experience in sesame production, large household size and who had relatively more access to extension services, credits, markets, membership of farmer association achieved higher levels of technical efficiency in sesame production in Benue State.

The foregoing results agree with finding by [70] who reported that formal education is likely to increase farm-level efficiency for two related reasons: (i) educated farmers are able to gather, understand and use information from research and extension more easily than illiterate farmers can and (ii) educated farmers are very likely to be less risk-averse and therefore more willing to try out modern technologies.

Access to extension services was found to negative as expected and significantly related to inefficiency effects. This finding indicates the important role information plays in increasing farm-level efficiency. The availability of an extension worker in the community and the usefulness of the extension messages (as perceived by the respondents) are significant determinants of technical efficiency. This finding is consistent with the findings of [71,72].

The estimate for the variance parameter, γ, is estimated to be close to one. If this parameter is zero, then σ_u^2 in (3) is zero, and the model reduces to a traditional production function with the variables education, farming experience, household size, access to extension services, access to credits, access to markets and membership of farmer association all included in the production function meaning that inefficiency effects are not stochastic.

The estimated sigma squared was significantly different from zero at 1 percent level of significance. This indicates a good fit and the correctness of the specified distributional assumption of the composite error term. In addition, the magnitude of the variance ratio, γ, was estimated to be high and close to one, suggesting that the systematic influences that are unexplained by the production function are the dominant sources of errors. This means that 89 percent of the variation in output among the sesame farmers is due to differences in technical efficiency. This confirms the relevance of stochastic frontier production function, using the Maximum Likelihood Estimator (MLE).

Table 2. Maximum likelihood estimates for parameters of the stochastic frontier production model for sesame farmers in Benue state

Variable	Parameter	Estimate	T-ratio
Stochastic frontier			
Constant	β_0	0.31	2.68
Ln (Farm size)	β_1	1.11	3.23**
Ln (Seed)	β_2	0.47	4.74**
Ln (Fertilizer)	β_3	0.52	2.65**
Ln (Agrochemical)	β_4	0.69	5.12**
Ln (Family labour)	β_5	0.44	2.52**
Ln (Hired labour cost)	β_6	-0.54	1.35
Inefficiency model			
Constant	δ_0	6.11	2.15
Age	δ_1	1.35	1.43
Education	δ_2	-1.87	-2.28**
Farming experience	δ_3	-1.12	-2.65**
Household size	δ_4	-1.33	-2.35**
Access to extension	δ_5	-4.35	-3.24**
Access to credit	δ_6	-3.54	-3.78**
Access to markets	δ_7	-3.25	-4.14**
membership of farmer association	δ_8	-2.61	-3.68**
Variance parameters			
Sigma squared	σ^2	274.35	3.22**
Gamma	Γ	0.89	8.47**
Ln likelihood function		-458.73	

*Source: Field Survey, 2015; **t-ratio is significant at 1percent level of significance*

Access to agricultural credit had a negative effect on the size of the technical inefficiency effects. This is because the higher the access to agricultural credit, the more productive resources farmers could acquire for their farm production. When low-income farmers can access agricultural credit, they generally can start and expand a business. This is because households with access to agricultural credits are able to acquire more productive resources for their farm production thereby increasing their farm income. The result contrast with the finding of [72] who found that access to credit had no significant impact on technical, allocative and cost efficiency.

Access to markets and improvement in road networks among the farming households are likely to increase the quality of available farm labour resources directly with a consequent positive effect on production efficiency. This in agreement with [73] who had noted that access to markets is an important policy and institutional variable that positively influence efficiency because they improve farmers' liquidity and the affordability of the inputs required for production. [73] also pointed out that the institutional and policy issues such as markets and other public provisions are just as important as technological factors in improving overall efficiency in the smallholder subsector.

Membership of farmer association (membership of extension/market/credit related organizations) had a negative effect on the size of the technical inefficiency effects. This is because collective farmers' institutions provide opportunities for risk sharing and improved bargaining power that are not available to individual farmers. Hence, technical inefficiency can be attributed to the low profitability that results from inadequate organization of farmers into collective farmers' institutions that can provide opportunities for risk sharing and improved bargaining power. Improving the way farmers are organized has also been proven to improve their access to markets and to inputs and technology. This result is consistent with findings of [74].

4.2 Test of Hypothesis

The result of the t-test in Table 3 shows that the null that the sampled sesame farming households are technically efficient is rejected at 5percent level of significance. This result implies that the predicted mean technical efficiency is significantly different from the frontier technical efficiency level, suggesting that the farmers are still operating below the frontiers of technical efficiency. This implies that farmers are not technically efficient.

4.3 Efficiency Estimates from the Stochastic Frontier Models

The result in Table 4 shows that majority of the respondents (41.13 percent) operated within a technical efficiency range of between 0.30 and less than 0.60. The wide range of values indicates large variations in performance across farms. The implication of these results is that sesame farmers in the study area were not utilizing their production resources efficiently.

Table 3. Test of the null hypothesis that the predicted mean efficiency is not significantly different from the frontier efficiency level among sesame farmers in Benue State

Item	Value
Mean	0.53
t-statistics	73.95
Degree of Freedom	370
*Critical Value	1.97
Decision	Reject H_0

*Source: Field Survey, 2015; *Critical value is significant at 5percent level of significance*

Table 4. Distribution of the respondents by technical efficiency estimates

Technical efficiency range	Frequency	Percentage
0.0 - 0.30	121	32.53
0.30 - 0.60	153	41.13
0.60 - 0.90	75	20.16
0.90-1.0	23	6.18
Total	**372**	**100**
Minimum efficiency	0.25	
Maximum efficiency	0.91	
Mean efficiency	0.53	

Source: Field Survey, 2015

Furthermore, technical efficiency among sesame farmers in the study area varied substantially ranging between 0.25 and 0.91, with a mean technical efficiency of 0.53 (Table 4). The foregoing result suggests that most of the sesame farmers in the study area had not yet reached the production frontier, indicating that they were not obtaining maximum output possible from their given quantum of inputs. In other words, technical efficiency among the respondents could be increased by 47percent in the study area through better use of available production resources, given the current state of technology. This would enable the farmers to obtain maximum output possible from their given quantum of inputs, and hence increase their farm incomes thereby facilitating expansion in sesame production.

The implication of the foregoing result is that if the average sesame farmer in the sample was to achieve the technical efficiency level of his or her most efficient counterpart in Benue State, he or she would realize 41.76percent more productivity in the study area. This suggests that the scope for efficiency gains is large (Percentage increase in mean efficiency = [1 – (mean efficiency/maximum efficiency)]*100). Technical efficiency in sesame farming in the study area could be increased by up to 41.76percent on average, using the current production technology. By simple analogy, this implies that sesame productivity in the study area could be greatly enhanced using current production technology if key factors that currently constrain production efficiency are adequately addressed.

4.4 Relationship between Level of Adverse Effects of Climate Change Manifestations and Technical Efficiency

The result in Table 5 shows that at 5 percent level of significance, the hypothesis that there is no significant relationship between level of adverse effects of perceived dimensions of climate change manifestations and technical efficiency among the respondents is rejected. This suggests that there is a significant negative relationship between level of adverse effects of climate change manifestations and technical efficiency among the respondents. This implies that technical efficiency among the respondents is inversely related to level of adverse effects of climate change manifestations among the respondents. The implication is that as the level of adverse effects of climate change manifestations among the respondents increases (decreases), production efficiency decreases (increases).

These results are consistent with the findings of previous studies. [2] and [3] reported that climate change (global warming) causes unpredictable and extreme weather events impact and increasingly affect crop growth, availability of soil water, forest fires, soil erosion, droughts, floods, sea level rises with prevalent infection of diseases and pest infestations.

[4] and [1] found that climate change related problems result in low and unpredictable crop yields, which invariably make farmers more vulnerable, especially in Africa. [3] observed that climate change related problems adversely affected agriculture and food supply, freshwater resources, natural ecosystems, biodiversity and human health, threatening human development and their social, political and economic survival. [3] and [7] found that as a result of climate change related problems, the resource poor farmers faced tragic crop failures which reduced agricultural productivity, increased hunger and poverty.

Y = Technical efficiency estimates
X_1 = Level of adverse effect of changed timing of rains
X_2 = Level of adverse effect of drought

Table 5. Correlation coefficients matrix of relationship between level of adverse effects of climate change manifestations and technical efficiency among sesame farmers in Benue state

Variables	Y	X1	X2	X3	X4	X5	X6	X7	X8
Y	1.00								
X1	-0.84*	1.00							
X2	-0.76*	0.43	1.00						
X3	-0.64*	0.45	0.47	1.00					
X4	-0.51*	0.51	-0.38	0.42	1.00				
X5	-0.62*	0.35	-0.35	0.39	0.35	1.00			
X6	-0.72*	0.33	-0.53	0.45	0.37	0.52	1.00		
X7	-0.65*	0.41	-0.42	0.36	0.48	0.46	0.44	1.00	
X8	-0.68*	0.55	0.51	0.51	0.53	0.49	0.56	0.43	1.00

*Source: Field Survey, 2015; *Correlation coefficient (r) is significant at 5percent level (2-tailed)*

X_3 = Level of adverse effect of extreme temperatures
X_4 = Level of adverse effect of floods
X_5 = Level of adverse effect of excess rainfall
X_6 = Level of adverse effect of nutrient leaching
X_7 = Level of adverse effect of soil erosion
X_8 = Level of adverse effect of pest and disease infestation

5. CONCLUSION

This study was carried out to investigate the relationship between the adverse effect of climate change manifestations and technical efficiency among sesame farmers in Benue State, Nigeria. The study also showed that the farmers were still operating below the frontiers of technical efficiency, implying that the farmers were not technically efficient. The study further showed that technical efficiency among the respondents was negatively related to the level of adverse effects of perceived dimensions of climate change manifestations among the respondents. The implication is that as the level of adverse effects of perceived dimensions of climate change manifestations among the respondent's increases (decreases), production efficiency decreases (increases).

6. RECOMMENDATIONS

Readily available farming inputs (inorganic fertilizers, improved seeds and chemicals) and subsidies should be entrenched. Credit facility, extension services and good market access should be provided to farmers. Education, information and training of farmers to adapt to climate change by changing their farming practices such as bush burning, de-forestation, rain-fed agriculture and land tenure systems should be encouraged.

With the decreasing rainfall amount and duration, frequent drought and desertification, drought resistant and short duration high yielding crops should be developed and made available to farmers.

Encouragement of formation of farmer groups, and agricultural adaptation to climate change should be main-streamed into government's poverty alleviation programme.

The policy implication of the foregoing finding is that any policy that would enhance the access of sesame farmers to land, improved sesame seed, fertilizer, agrochemicals, mitigate the adverse effect of climate change and labour would improve the profitability of sesame production. This is possible because the farmers through the expansion of input use would be able to move from the production phase of increasing return to scale to the phase of decreasing return to scale where profit would be maximized.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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