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Original Article

Economics of climate smart agricultural practices used by smallholder sorghum producers in Nigeria

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ABSTRACT

This study assessed economics of climate smart agricultural practices (CSAPs) used by smallholder sorghum producers in Nigeria. Multistage sampling method was employed. About 100 smallholder sorghum producers were sampled. Data were of primary sources. The following analytical tools were used: descriptive statistics, adaptive strategy use index, multinomial Logit regression model, and principal component analysis. The findings show that the smallholder sorghum producers were young, strong, agile, energetic, active, and resourceful. The mean age of sorghum producers was 44 years. Majority (80%) of sorghum producers were male and married (80%). The mean farm size was 1.5 ha. The CSAPs used by smallholder sorghum producers were ranked as follows: conservation agriculture (1st, Adaptive Strategy Used Index [ASUI] = 0.9102), crop diversification (2nd, ASUI = 0.8201), planting of heat, and drought resistant varieties of crop (3rd, ASUI = 0.7965). The statistical and significant predictors influencing low users of CSAPs were age ($P < 0.10$), educational level ($P < 0.01$), and extension services ($P < 0.05$). The statistical and significant predictors influencing high users of CSAPs were age ($P < 0.05$), educational level ($P < 0.05$), and extension services ($P < 0.10$). The constraints facing smallholder sorghum producers in the use of CSAPs were inadequate extension services (1st, Eigen-value = 2.9304), lack of access to information (2nd, Eigen-value = 1.9037), and poor government policy (3rd, Eigen-value = 1.9021). The study recommended that policy should be formulated by government that will create awareness on CSAPs for the farmers, extension officers should be employed to disseminate climate smart agricultural technologies, innovations, new ideas, and research findings to farmers. Farm inputs, improved seeds, heat, and drought tolerant resistant varieties should be provided for smallholder sorghum producers.

Keywords: Climate smart agricultural practices, economics, Nigeria, smallholder sorghum producers

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INTRODUCTION

Climate change poses serious threat to sustainable development, and it is a global development issue affecting many sectors in the world.[1] Climate change threaten the attainment of Sustainable Development Goals especially reduce poverty and food security.[2] Climate change brings huge threat to livelihood activities and sustainable food production in vulnerable areas in sub-Saharan Africa (SSA). Climate changes have likelihood to impact on the food security level and welfare of both urban and rural populaces through poor land availability, poor food production, and reduced opportunity.[3] The optimal usage of land for animal and crop production, health and well-being, and biodiversity restoration can also be adversely affected by precipitation changes, increased temperatures, and increased weather fluctuations. Climate change adversely affects agricultural activities in SSA, the situation is made worse by widespread poverty, limited access to technology and capital, over dependence on rain-fed agriculture, inadequate road infrastructure, inadequate research and extension, long term weather forecasts, poor governmental agriculture policies, and inequitable land distributions. Extreme weather conditions currently affect millions of people worldwide, putting water and food security at high risk. SSA including Nigeria is expected to be worse hit by changing climate conditions due to little capacity to adapt to poverty, high reliance of agriculture on the

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most climate-sensitive sector, and low level of technological development.[4] Developing such SSA countries are more at risk and sensitive to climate change manifestations due to over dependence of over 90% of agricultural activities on rainfall with limited adaptive measures.[5] Natural disasters due to climate change adversely affect SSA countries and the total losses in the economy of these countries is more than 10% of their gross domestic product.[6] The climate change incidences in SSA include: changes in atmospheric temperatures, soil moisture, crop resilience, flooding, weed insurgence, timing/length of growing season, yield of crops and animals, unprecedented drought, soil quality, and rises in sea level.[7] Smallholder farmers will suffer greatly from the adverse effects of climate change.[8] Rural farmers in SSA are more prone to climate change due to problem of poverty, high dependence on rain-fed agriculture, and low infrastructure and technology development.[9] The crop yield forecast for SSA may reduce by 10-20% by 2050 or up to 50% due to the effect of climate change.[10] Climate smart agriculture (CSA) is sustainable and will increase resilience and productivity, reduces greenhouse gases, and enhances the attainment of development goals and national food security.[11] CSA comprises a set of whole strategies that can help combat problems of climate change by reducing agriculture's greenhouse gas emissions that contribute to global warming, increase sustainable production, adapting to climate change, and increasing resilience to weather extremes.[12,13] CSA practices (CSAPs) contribute to food security, promote economic development, reduce poverty, increase agricultural productivity, and enhance resilience of agricultural and natural ecosystem functions. Adapting agriculture to climate change in SSA is recognized as a very significant policy option to reduce the adverse impacts and vulnerability. Adaptation refers to an adjustment in human or natural systems in response to expected or actual risk or climatic conditions, and it can be defined as a policy option to contain the negative effect of climate change.[14] Adaptation is a process whereby households and vulnerable farmers adopt strategies to mitigate the adverse effect of climate change on livelihoods and ecosystems.[6] Adaptation to climate change will potentially reduce the negative effects, protect the livelihood of smallholder poor farmers, and reinforce any potential advantages it may bring.[15] The effect of climate change in SSA has encouraged smallholder farmers to develop strategies to reduce temperature, improve soil fertility, and conserve soil moisture. Efforts by stakeholders, researchers, and international organizations on climate change have considered CSAPs and adaptation strategies as strong policies to address hunger, food insecurity, extreme poverty, and other negative impacts associated with climate variability.

Sorghum (Sorghum bicolor) is the most significant staple food crop in Nigeria. It is the 5th most important cereal crop in the world.[16] Sorghum, in 2021, is grown on an estimated area of 5.9 million ha with annual production estimated to be 6.7 million tonnes in Nigeria. Sorghum is an industrial crop for brewing non-alcoholic and alcoholic drinks and also used in the confectionary and baking industry in Nigeria. The grains and leaves are used for livestock feeds and the stalks used for making fences and thatching houses. Sorghum is relatively tolerant to waterlogging and drought and has a wide adaptation to varied soil conditions; this makes sorghum the staple crop of choice to pursue income and food security.[17]

Objectives of the Study

This research work assessed economics of CSAPs used by smallholder sorghum producers in Nigeria. Specifically, the objectives were as follows:

(i) Determine the socioeconomic profiles of smallholder sorghum producers,
(ii) Determine the CSAPs used by smallholder sorghum producers,
(iii) Evaluate the socioeconomic predictors influencing the level of use of CSAPs among smallholder sorghum producers, and
(iv) Identify the constraints faced by smallholder sorghum producers in the use of CSAPs in the area.

METHODOLOGY

This research work was conducted in Kaduna State, Nigeria. Kaduna State occupies between Longitudes 06° 15' and 08° 50' East and Latitudes 09° 02' and 09° 02' North of the equator. The state has land area totaling 4.5 million ha. The state vegetation is divided into two (2), the Southern guinea savanna and Northern guinea savanna. There are two (2) seasons in Kaduna State. The seasons are as follows: Dry and wet seasons, the dry season is between October to March, and the wet season starts from April to October, in between the dry and wet seasons is the short Harmattan period which span from November to February. The mean or average rainfall is about 1482 mm, the temperature of Kaduna State ranges from 35°C to 36°C, which can be as low as 10–23°C during the harmattan period. The population of Kaduna as at 2021 was 8.9 million people. They are involved in agricultural activities. Crops grown include: tomatoes, okra, pepper, maize, ginger, sorghum, rice, yam, cassava, and millet. Animal reared include: cattle, sheep, goats, rabbit, and poultry. Multistage method sampling technique was used. One hundred (100) sorghum producers were sampled and selected. Data obtained from smallholder sorghum producers were of primary sources. A well-designed and equally well-structured questionnaire was administered to smallholder sorghum producers using well-trained enumerators. The following inferential and descriptive statistics were used for analysis of data:

Descriptive Statistics

This involves measures of central tendency such as mean, range, frequency distributions, and percentages to summarize the socioeconomics profiles of smallholder sorghum producers as stated specifically in objective one (i). This was also used to achieve part of specific objective two (ii), which is to determine the CSAPs used by smallholder sorghum producers, and to determine the constraints facing smallholder sorghum producers in the use of CSAP as specifically stated in objective four (iv).

Adaptation Strategy Use Index

This involves the use of four-point Likert scale. The four-point Likert scale was used for evaluation of frequency of using CSAPs by smallholder sorghum producers and the four-point Likert scale was categorized as: frequently used (3), occasionally used (2), rarely used (1), and not used (0), respectively. The adaptive strategy use model for the level of use of CSAPs is given as:

$$\text{ASUI} = \frac{\left[(N_1 \times 3) + (N_2 \times 2) + (N_3 \times 1) + (N_4 \times 0)\right]}{M} \quad (1)$$

N_1 = Number of Smallholder Sorghum Producers that Frequently Used CSAPs

N_2 = Number of Smallholder Sorghum Producers that Occasionally Used CSAPs

N_3 = Number of Smallholder Sorghum Producers that Rarely Used CSAPs

N_4 = Number of Smallholder Sorghum Producers that did not Used CSAPs

ASUI = Adaptive strategy used index.

This was specifically used to achieve part of objective two (ii), which is to determine the CSAPs used by smallholder sorghum producers.

The Composite Score: A binary scale was used to score the smallholder sorghum producers 1 point for yes and 0 for no response regarding the use of ten (10) CSAPs, the smallholder sorghum producers would have a maximum score of 10 points and minimum score of 0 points. This composite score as used by Ojoko *et al.*[12] is stated as:

Higher Users = Between 10 points to (mean + S.D) Points,

Medium User = Between the Upper and Lower Categories

Low Users: Between (mean – S.D) Points to 0 Point.

This was specifically used to achieve part of objective three (iii), which is to evaluate socioeconomic predictors influencing the level of use of CSAPs among smallholder sorghum producers.

Multinomial Logit Regression Model: The general multinomial Logit model is stated thus:

$$\Pr(y_i = \text{j}) = \frac{\exp(X_i\beta_j)}{1 + \sum_{\text{j}=1}^{\text{j}} \exp(X_i\beta_j)} \quad (2)$$

And to ensure identifiability,

$$\Pr(y_i = 0) = \frac{1}{1 + \sum_{\text{j}=1}^{\text{j}} \exp(X_i\beta_j)} \quad (3)$$

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + U_i \quad (4)$$

Y = Dichotomous Response Model (1, Low Users; 2, Medium Users; 3, High Users)

X_1 =Age of Smallholder Sorghum Farmers in Years,

X_2 =Farm Experience in Years,

X_3 =Household Size (Units)

X_4 =Gender (Dummy; 1, Male; 0, Otherwise)

X_5 =Marital Status (Dummy; 1, Married; 0, Otherwise)

X_6 =Level of Education (Likert; 0, Non-Formal; 1, Primary; 2, Secondary; 3, Tertiary)

X_7 = Extension Contacts (Number)

X_8 =Membership of Cooperative Organizations (Dummy; 1, Member; 0, Otherwise)

U_i =Error Term,

$\beta_1 - \beta_8$ =Regression Coefficients,

β_0=Constant Term,

This was specifically used to achieve objective three (iii), which is to evaluate socioeconomic predictors influencing the level of use of CSAPs among smallholder sorghum producers.

Principal Component Analysis

The constraints facing smallholder sorghum producers in the use of CSAPs were subjected to analysis of principal component model. This was specifically used to achieve objective four (iv).

RESULTS AND DISCUSSION

Socioeconomic Profiles or Characteristics of Smallholder Sorghum Producers

The socioeconomic profiles of sorghum producers under consideration were age, experience in sorghum farming, farm size, household size, gender, educational level, marital status, access to credit, and membership of cooperatives [Table 1]. Averagely, the age of smallholder sorghum producers was 44 years. This signifies that the sorghum producers were young, active, energetic, agile, and resourceful. They can use CSA technologies easily. Averagely, respondents had 11 years' experience in sorghum farming. This means that they have acquired enough experience in sorghum production. Experience of farmers is linked to age, as sorghum producers get older, they must have acquired more experiences in sorghum farming.[18] The respondents were smallholder sorghum producers with average farm size of 1.5 ha. Farmers with <5 ha of planted farm land were classified as small scale, farmers having between 5 and 10 ha of planted farm land were classified as medium scale, while farmers with >10 ha of planted farm land were classified as large scale.[19] The household sizes of sorghum farmers were large with a mean value of eight people per household. According to Ozor and Cynthia[20] who reported that fairly large household size means more family labor available for the household farm activities. Sorghum producers had formal education, averagely spent 7 years in school, and were literate. Sorghum farmers with basic education are better equipped and will be able to make informed farm decisions.[21] Education status has the tendency to significantly increase agricultural productivity.[22] Educated farmers can easily take advantages of CSA technologies, new innovations, and research findings. Furthermore, 80% of sorghum farmers were male, while 20% were female. Furthermore, 75% of sorghum producers were married, while 25% were single. Most (83%) of sorghum producers had access to credit facilities, while 17% of sorghum producers do not have access to credit facilities. About 75% of sorghum producers belong to members of cooperative organizations. Members of cooperative organizations afford the sorghum producers to share information of CSAPs among themselves, have access to agricultural inputs, bulk purchase agricultural inputs, and enable the producers to bulk sold agricultural produce.

Table 1: Summary statistics of socioeconomic profiles of smallholder sorghum producers

Variables	Statistics
Age in years (mean)	44
Experience in farming in years (mean)	11
Farm size in hectares (mean)	1.5
Household size in number of people (mean)	8
Educational level attained in years (mean)	7
Gender (dummy)	Male (80%)
Marital status (dummy)	Married (75%)
Access to credit (dummy)	Yes (83%)
Membership of cooperatives (dummy)	Yes (75%)

Source: Field Survey (2021)

Table 2: Climate smart agricultural practices used by smallholder sorghum producers

S/No.	Climate Smart Agricultural Practices	ASUI	Ranking
1.	Planting of Heat and Drought Resistant Varieties of	0.7965	3rd
2.	Crops	0.9102	1st
3.	Conservation Agriculture	0.5802	5th
4.	Change in Cropping Pattern and Calendar of Planting	0.5106	8th
5.	Mixed Cropping	0.5101	9th
6.	Improved Irrigation Efficiency	0.5707	6th
7.	Planting of Trees (Afforestation) and Agroforestry	0.8201	2nd
8.	Crop Diversification	0.7906	4th
9.	Crop Rotation	0.2207	10th
10.	Mulching Planting of Cover Crops	0.5201	7th

Source: Field Survey (2021). ASUI: Adaptive Strategy Used Index

CSAPs Used by Smallholder Sorghum Producers

The frequency of use of CSAPs is presented in Table 2. The result indicated which of the CSAPs mostly used in ranking order. The results show that the five (5) most used CSAPs include: conservation agriculture (1st), crop diversification (2nd), planting of heat and drought tolerant resistant varieties of crops (3rd), crop rotation (4th), and changing of cropping pattern and calendar of planting (5th). Mulching is the least used CSAPs among sorghum producers in the study area. Conservation agriculture is a sustainable farming method that is based on 3 principles: first, it promotes minimum soil disturbance, no tillage system. It enhances natural biological and biodiversity processes below and above the ground surface, which contribute to increase water and nutrient use efficiency and to improved and sustained crop production. Second, maintenance of permanent soil cover. Third, diversification of plant species through intercropping or crop rotation. Conservation agriculture helps sorghum farmers to maintain increase profits and increase yields, while protecting the environment, reversing land degradation, and responding to growing challenge of climate change. This finding is in line with results of Ojoko *et al.*[12] and Dumanski *et al.*[23]

Socio-Economic Predictors Influencing the Level of Usage of CSAPs

The socioeconomic predictors influencing the level of usage of CSAPs are presented in Table 3. The socioeconomic predictors under consideration were age of sorghum producers, farm experience, marital status, household size, gender, level of education, extension contact, and membership of cooperatives. The medium users were used as reference category or base category; the multinomial logistic regression results were interpreted as the average change in the probability or likelihood of gaining low or high level of usage relative to medium level usage of CSAPs due to a marginal change in the independent variables. The statistical and significant predictors influencing low level usage of CSAPs among sorghum producers were as follows: Age ($P < 0.10$), educational level ($P < 0.01$), and extension services ($P < 0.05$). The statistical and significant predictors influencing high level usage of CSAPs among sorghum farmers were as follows: age ($P < 0.10$), educational level ($P < 0.05$), and extension services ($P < 0.10$). Educational level increases the probability of sorghum producers being a low level users of CSAPs by 32.05% compared to medium usage of CSAPs. Extension services increases the probability of sorghum producers being a high level user of CSAPs by 24.52% relative to being medium level users of CSAPs. The multinomial Logit model possesses a strong explanatory power (Nagelkerke $R^2 = 0.7203$). This indicates that about 72.03% of the total variations in the determinants of sorghum producers' choice of level of usage of CSAPs were explained by the fitted model or the predictors included in the model. The Chi-square analysis (1328.24) was significant at ($P < 0.01$). This finding agrees with results of Abdulazeez *et al.*[24] and Antwi-Agyei *et al.*[2]

Constraints Faced by Smallholder Sorghum Producers in the Level of Use of CSAPs

The constraints facing smallholder sorghum producers in the level of use of CSAPs were subjected to principal component analysis [Table 4]. The constraints with Eigen-values greater than one (1) were retained by the principal component model. Inadequate extension services were ranked 1st with Eigen-value of 2.9034, and this explained 17.03% of all constraints retained by the model. Lack of access to information was ranked 2nd with Eigen-value of 1.9037, and this explained 16.22% of all constraints retained by the model. Poor government

Table 3: Multinomial Logit results of socioeconomic factors influencing the level of use of climate smart agricultural practices

Factors	Parameters	Low users		High users	
		Coefficient	ME	Coefficient	ME
Age of maize farmers (X_1)	β_1	−0.2310*	−0.1702	−0.1704*	−0.2156
Farm experience (X_2)	β_2	0.3902	0.3201	0.1920	0.4782
Household size (X_3)	β_3	0.2107	0.1801	0.3206	0.5612
Gender (X_4)	β_4	0.1809	0.2207	0.2709	0.3332
Marital status (X_5)	β_5	0.2014	0.2105	0.1805	0.5972
Educational Level (X_6)	β_6	0.3205***	0.5208	0.3708**	0.2683
Extension services (X_7)	β_7	0.2208**	0.2207	0.4503*	0.2452
Membership of cooperative (X_8)	β_8	0.1907	0.1103	0.2207	0.3209
Constant-Log Likelihood=91.213***	β_0	2.0302**		3.3016**	
Wald Chi Square=1328.24***					
Pseudo R^2=0.7203					

*Significant at (P<0.10), **Significant at (P<0.05), ***Significant at (P<0.01). Data analysis (2021) reference category or base category-medium users

Table 4: Principal component analysis of constraints faced by smallholder sorghum producers in the use of climate smart agricultural practices

Constraints	Eigen-value	Difference	Proportion	Cumulative
Inadequate extension services	2.9034	0.3892	0.1703	0.1703
Lack of access to information	1.9037	0.2307	0.1622	0.3325
Poor government policy	1.9021	0.2209	0.1527	0.4852
Poor infrastructures	1.6704	0.2134	0.1287	0.6139
Lack of farm inputs	1.5507	0.1930	0.1189	0.7328
Lack of awareness	1.5006	0.1824	0.1038	0.8366
Bartlett test of sphericity				
KMO=	0.734			
Chi-square	2754.87***			
Rho	1.000000			

***-Significant at 1% probability level. Computed from data analysis (2021) policy was ranked 3rd with Eigen-value of 1.9021, and the explained 15.27% of all constraints retained in the model. Other constraints include: poor infrastructures (rank 4th, Eigen-value = 1.6704), lack of farm inputs (rank 5th, Eigen-value = 1.5507), and lack of awareness (rank 6th, Eigen-value = 1.5006). All retained constraints explained that 83.66% of all constraints included in the model. The Chi-square value of 2754.87 was statistically significant at 1% probability level.

CONCLUSION

This study has established that sorghum producers were young, agile, resourceful, and energetic with mean age of 44 years. The sorghum producers are majorly male (80%) and married (75%) having large household size. Averagely, sorghum producers had eight people per household. The CSAPs used by smallholder sorghum producers were ranked as follows: conservation agriculture (1st), crop diversification (2nd), planting of heat and drought tolerant resistant varieties of crops (3rd), crop rotation (4th), planting of trees (afforestation) and agroforestry(6th), planting of cover crops (7th), mixed cropping (8th), improved irrigation efficiency (9th), and mulching (10th). The statistical and significant predictors influencing low- and high-level users of CSAPs by smallholder sorghum producers were as follows: age, educational level, and extension services. The constraints faced by sorghum producers in the use of CSAPs were ranked as follows: inadequate extension services (1st), lack of access to information (2nd), poor government policy (3rd), poor infrastructures (4th), lack of farm inputs (5th), and lack of awareness (6th).

RECOMMENDATIONS

Based on the outcomes and findings, the following recommendations were made:

(i) Extension officers should be made employed disseminate CSAPs, innovations, new ideas, and research findings to farmers.
(ii) Government should enact or formulate policy on awareness of CSAPs for farmers.
(iii) Farm inputs, credit facilities, improved seeds, and heat and drought tolerant resistant varieties of crops should be provided for smallholder sorghum producers.
(iv) Farmers should have access to relevant information and weather report for increased productivity.
(v) Good feeder roads should be made constructed for smallholder sorghum producers in the area.

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