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Effect of Crop Residues on Sorghum Output in Sokoto and Zamfara States, Nigeria: Using Four Functional Forms of OLS Model

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ABSTRACT

The importance of organic fertilizer such as crop residues cannot be over emphasized or overrated particularly in the production of cereal crops such as sorghum. The effect of crop residues on sorghum output was unknown due to its poor usage. There also exist limited empirical evidences on what effect crop residues have on sorghum output in the northern part of Nigeria. This study was carried out to know the effect of crop residues on sorghum output in Zamfara and Sokoto States, Nigeria. A multi-stage sampling technique was used to select 160 farmers in Sokoto State and 150 farmers in Zamfara State with a total of 310 sorghum farmers selected from the study area. Data were collected with the aid of structured questionnaire and personal interviews. Data collected were analyzed using the four functional forms of OLS regression model (linear, exponential, semi-log and log-log models). The findings revealed that farm size, quantity of crop residue applied, quantity of sorghum seeds planted, quantity of agro-chemicals used, farm income and crop residue access were statistically significant on sorghum output in the study area. The results also showed that with trials of the four functional forms of the OLS regression and based on the R^2*-values, the F-statistics, signs and magnitudes of the coefficients and the number of variables that were significant, the log-log model was selected as the lead equation and most fit for the OLS regression in the study area. The study recommended adoption of crop residue technology, increase in the quantity of sorghum seeds planted and training of sorghum farmers to improve on adoption of crop residue technology through extension services.*

INTRODUCTION

Sorghum (*Sorghum bicolor*) is produced usually as a mixed crop with millet, maize, cassava, cowpea, groundnut, soybeans, yam and cocoyam. From research, sorghum production does not require heavy technology and usually planted with limited inorganic fertilizer usage. Organic fertilizers such as: farmyard manure, compost and crop residues is becoming popular even in the event of Nigerian government poor intervention in sorghum production compared to other cereal crops like maize, rice and millet. Sorghum is one of the most staple cereal crops world over with USA as the largest producer (8.7million tons), Nigeria (6.9million tons), Ethiopia (5.3million tons) and Sudan (3.7million tons) (FAO, 2019). Nigeria is the largest producer of sorghum in Africa; this accounted for 50% of the total output and occupies about 45% of the total farmland area used for cereal crops in Nigeria. Between 2010 and 2022, sorghum production increased in Nigeria, as at

2022, the sorghum production in Nigeria was estimated at 7 million MT (World Bank, 2023). Sorghum is useful in many areas, fermented to produce malt drinks, beverages, and confectioneries, animal feed, crop residues as organic manure, can be processed into snacks, pancakes and thick paste (Ogi in Yoruba), local drinks, Tuwo (swallow in Hausa).

According to Food and Agriculture Organization (2018) the sorghum-based world economy has two distinct segments: a traditional, smallholder farming sector largely in Asia and Africa as subsistence farming, and a modern high-input, large-scale farming sector principally in the developed nations and Latin America. Sancho *et al*. (2022) reported that sorghum grain moisture content typically varies between (25-40)% depending on selection and growing conditions. The total time from flowering to physiological maturity is approximately 40-45 days. Sorghum is called Oka baba (Yoruba) and Dawa/Jero (Hausa). Abubakar *et al*. (2023) also reported that Sandy soil is the most suitable soil for sorghum. In Nigeria, the soil should be well drained with pH between 6.0 and 7.0.

METHODOLOGY

This study was conducted in the four agricultural development zones (A, B, C and D) in Sokoto State and the three zones (Northern, Central and Southern) in Zamfara State.

Sokoto State is located on 13^0 05'N 05^0 15'E Coordinates in extreme northwestern, Nigeria popularly called 'Seat of the Caliphate' was created on 3rd February, 1976. Sokoto with total land area of 25,973km^2, GDP of $18.44 billion and $3,174 billion per capital income and estimated population of about 6, 391,000 million people (NBS, 2021). Sokoto is bounded by Republic of Niger to north and west for 363km, and State of Zamfara to the east, and Kebbi to the south and west, partly across the Ka River. Sokoto houses the Sultan who is the spiritual leader of Nigerian Muslims. The modern day Sokoto is a major trade center in leather crafts used for significant export, kola nuts, goatskins, sheepskins, cattle hides, camel hides, sorghum, pearl millet, rice, fish, peanuts, cottons, onions and tobacco. Sokoto is dominated by Fulani and Hausa with minorities like Zabarmawa and Tuareg. The Hausa people are made of Gobirawa, Zamfarawa, Kabawa, Adarawa and Arawa. Sokoto is made up of 23 local government areas namely: Binji, Bodinga, Dange-shnsi, Gada, Goronyo, Gudu, Gawabawa, Illela, Isa, Kware, Kebbi, Rabah, Sabon-Birnim, Shagari, Silame, Sokoto-North, Sokoto-South, Tambuwal, Tangaza, Tureta, Wamako, Wurno and Yabo respectively.

Zamfara State is located on Coordinates 12^0 10'N 06^0 15'E with estimated population of 5, 833,494 people (NPC, 2022). Zamfara is located in northwestern Nigeria with capital at Gusau, mainly populated by Hausa and Fulani people including: Zabarwa, Bussawa, Dukawa, Kambari, Kamuku and Gwari. There are 14 local government areas namely: Zurmi, Maradum, Talata, Mafara, Gusau, Kaura-Namoda, Bungudu, Chafe, Maru, Anka, Bukkuyum, Gunmi, Bakura, Birin/Kiyaw and Shikafa. Zamfara State has a land area of 39,762km^2 was created on 1st October, 1996 from Sokoto State with GDP of $11.18 billion and $2,108 billion per capital in 2021. Zamfara is bordered to the east by Sokoto and Niger States, to the north by Republic of Niger and to the South by Kaduna State. the slogan of Zamfara State is 'Farming is our pride" with maize, sorghum, pearl millet, onions, sugar cane, vegetables and nomadic farming of cattle, sheep and goats. The natural resources in Zamfara includes: iron-ore, gold, chromate, granite, clay, limestone, chamovita, quartz and kaolin.

A multi-stage sampling procedure was adopted for this study. In stage one, a purposive selection of two States namely Sokoto and Zamfara States was made. Sokoto and Zamfara States have similar demographic data, socio-economic features, climatic and weather conditions, farming household characteristics, soil type, food consumption, agricultural crops grown, and trade types.

Sorghum is commonly grown in the two States over large areas of farmland in addition to other cereal crops like maize, pearl millet, sugar cane, etc. In stage two, a purposive sampling of the four and three agricultural zones in Sokoto and Zamfara States was made. This enabled fair representations of farmers in the study area. In stage three, a random selection of four blocks in Sokoto and three blocks in Zamfara was made to have a total of seven blocks in the study area. In stage four, a random selection of two cells each from the four blocks in Sokoto State and three blocks in Zamfara State was made. This makes a total of 8 cells in Sokoto State and 6 cells in Zamfara State respectively. In stage five, a random selection of 20 farmers was made from each of the 8 cells in Sokoto State to have a total of 160 farmers. Similarly, a random selection of 25 farmers was made from the 6 cells in Zamfara State to make a total of 150 farmers. The total sample size for the study is 310 farmers. Primary data were collected with the aid of structured questionnaire and personal interviews. Data were analyzed by trying the four functional forms of OLS regression. These are: linear, exponential, semi-log and double-log. A total of twelve regression analysis was carried out for the study.

Model Specification

The Ordinary Least Square (OLS) regression analysis was used to determine the effect of crop residues on sorghum output in the study area. Twelve different regression analyses were carried out to determine the lead equation that is best fit in estimating the effect of crop residue use on sorghum output in Sokoto and Zamfara States. The four OLS functional forms namely: linear, exponential, semi-log and log-log were each tried. The conditions for the choice of lead equation most fit for the OLS regression among the four functional forms includes: the level of statistical significance of overall regression (F-value), the magnitude of R-Squared, the magnitude of the coefficients, the signs of the coefficients, the number of variables that are significant and conformity with a priori expectation. These functional forms are as specified below:

$Y = ß_0 + ß_1X_1 \ldots\ldots ß_8X_8 + ei$ (Linear)

$\text{Log } Y = ß_0 + ß_0X_1X_2 \ldots\ldots ß_7ß_8X_8 + ei$ (Exponential)

$Y = ß_0 + ß_1\log X_1 \ldots\ldots ß_8\log X_8 + ei$ (Semi-log)

$\text{Log } Y = ß_0 + ß_1\log X_1 \ldots\ldots ß_8.\log X_8 + ei$ (Double-log)

Where:

Y = quantity of sorghum output (kg/ha)

X_1= Farmland cultivated for sorghum production (hectares)

X_2 = crop residue availability, (1 if available, 0 if otherwise)

X_3 = Quantity of crop residue applied (kg/ha)

X_4 = Quantity of sorghum seeds planted (kg)

X_5= Quantity of labor (man-days)

X_6 = Quantity of agro-chemicals (herbicides or pesticides) applied in litres

X_7 = Crop residue access (1, if accessed, 0 if otherwise)

X_8 = Farm income (Naira)

ei = Error term

ßs = coefficients to be estimated

$ß_0$ = intercept

RESULTS AND DISCUSSIONS

Table 1: Functional forms of crop residue adoption on sorghum output in Sokoto and Zamfara States

Variables	Linear	Exponential	Semi-log	Double-log
	Coefficient	**Coefficient**	**Coefficient**	**Coefficient**
Farm size	343.41)0.000)***	0.233(0.000)***	870.36(0.000)***	0.59(0.000)***
Crop residue avail	-38.155(0.359)NS	-0.025(0.349)NS	-58.76(0.268)NS	-0.051(0.045)**
Qty of Crop residue	1.844(0.000)***	0.001(0.000)s***	326.21(0.000)***	0.176 (0.000)***
Qty of sorghum seeds	0.0001(0.053)*	2.15 (0.000)***	-122.9 (0.000)***	-0.05 (0.000)***
Quantity of labour	0.405 (0.968)NS	-0.024 (0.708)NS	62.02 (0.663)NS	0.083 (0.225)NS
Quantity of Agro Chem	81.44 (0.000)***	0.056 (0.000)***	154.9 (0.428)NS	0.057 (0.542)NS
Crop residue access	76.72(0.136)NS	0.064 (0.053) *	164.4 (0.011)***	0.055 (0.076)*
Farm income	0.002 (0.000) ***	4.6 (0.002)***	723.20 (0.000)***	0.403 (0.000)***
Constant	-872.91 (0.000) ***	5.694 (0.000)***	-8965.92(0.000)***	
No of observation	**310**	**310**	**310**	**310**
F (8, 300)	**260.63**	**211.13**	**145.32**	**239.06**
Prob> F	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R^2	**0.8574**	**0.8297**	**0.7703**	**0.8465**
Adjusted R^2	**0.8541**	**0.8258**	**0.7650**	**0.8430**
Root MSE	**406.49**	**0.259**	**0.217**	**0.246**
Df	**399**	**399**	**399**	**399**

Source: Field Survey, 2023
Values in parentheses are the P-values
*, ** and ***represents level of significance at 10%, 5% and 1% respectively

Table 1 gives the detailed results of crop residues adoption on sorghum output in Sokoto and Zamfara States. The F-values of 0.000 revealed that the model used and overall regression is statistically significant at ($p<0.00$), indicating that the variables combined adequately explained the output of sorghum in the study area. The high R^2 values obtained indicates that all variables in the model combined were able to explain a very high percentage of the variability in sorghum output. The model is therefore fit for the regression. The values of the adjusted R^2 implies that the predictors enhances the model below what would be obtained by probability and larger percentage of the data are located around the line of best fit. The Root Means Square Error values are very low. This indicates a more precise and reliable prediction with limited errors and high concentration of data around the line of best fit. The average square difference between the predicted values and actual values within the data set is very small, thus the data is best fit for the model. Farm size coefficients were 343.41, 0.233, 870.36 and 0.59 for linear, exponential, semi-log and log-log functional forms respectively. The coefficients were all directly related to sorghum output and statistically significant at ($p<0.01$). The coefficients of linear and semi-log functional forms indicates that for one hectare increase in farm size, there was increase of 343.41 kg and 870.36 kg in sorghum output in the study area.

Crop residue availability was at ($p<0.05$) in log-log functional form but insignificant at all levels in linear, exponential and semi-log functional forms respectively. The implication is that in increase in availability of crop residues would decrease sorghum output by 0.051kg.

The quantity of crop residue used has coefficients of 1.844, 0.001, 326.21 and 0.176 under linear, exponential, semi-log and log-log functional forms respectively. the coefficients were positively associated and statistically significant at ($p<0.01$) on sorghum output in the study area. The semi-log functional form has the highest coefficient compared to other functional forms, this implies that for every one kilogram increase in the quantity of crop residue used by the farmer there is an increase of 326.21kg in the quantity of sorghum output produced.

Quantity of sorghum seeds used has coefficients of 0.0001, 2.15, -122-9 and -0.05 under linear, exponential, semi-log and log-log functional forms, though, linear form is significant at ($p<0.05$) while exponential, semi-log and log-log functional forms were each significant at ($p<0.01$) respectively. the semi-log and log-log functional forms were negatively correlated while linear and exponential functional forms were positively related to sorghum output. The implications are that the quantity of sorghum seeds used increased sorghum output under linear and exponential forms as the quantity of sorghum output under semi-log and log-log functional forms.

The quantities of agro-chemicals used were 81.44, 0.056, 154.9 and 0.057 for linear, exponential, semi-log and log-log functional forms respectively. The coefficients were positively associated with sorghum output in the study area. The coefficients of linear and exponential forms were statistically significant at ($p<0.01$) but insignificant at any levels under semi-log and log-log forms. This implies that a one liter increase in the quantity agro-chemicals applied to sorghum farms leads to 81.44 kg addition to sorghum output under linear functional in the study area.

Crop residues access coefficients were 76.72, 0.064, 164.4 and 0.055 for linear, exponential, semi-log and log-log forms respectively. the coefficients have direct relationship with sorghum output, significant at ($p<0.1$) for exponential and log-log forms and insignificant at any levels under linear forms. This implies that for every one kilogram crop residue accessed by farmers, there is an increase of 164.4 kg increase in sorghum output in the study area.

Farm income with coefficients of 0.002, 4.6, 723.20 and 0.403 for linear, exponential, semi-log and log-log were positively associated with sorghum output in the study area. the coefficients were all significant at ($p<0.01$) for all the functional forms. The implications are that for every N1.00 increase in farm income, there is increase of 4.6 kg and 723.20 kg in sorghum output under exponential and semi-log functional forms respectively. This means that all the four functional forms increased sorghum output in the study area.

Based on the criteria stated above for choosing the lead equation which most fit the OLS regression, the findings revealed the semi-log functional form as the lead equation and the most fit for improved sorghum output in the study area. This is because the semi-log functional form has the highest number of variables that were statistically significant with most coefficients signs positive. The semi-log form also has the highest magnitudes for the coefficients with R^2 value reasonably high (77.03 %) and overall regression statistically significant at ($p<0.000$). The R-Square value showed that all variables in the model (X 1 – X 8) were able to pool about 77 03% of the variability in sorghum output and the remaining 22.97% was due to the non-inclusion of other variables in the model. The adjusted-R^2 value of 0.7650 indicates that 76.5% of the data are located around the line of best fit.

Table 2: Functional Forms Effect of Crop Residue Adoption on Sorghum Output in Sokoto State.

Variables	Linear	Exponential	Semi-log	Log-log
	Coefficient	**Coefficient**	**Coefficient**	**Coefficient**
Farm size	0.231(0.000)***	0.234 (0.000)***	608.8 (0.000)***	0.559 (0.000)***
Crop residue avail	-0.02 (0.564)NS	-0.021 (0.537)NS	71.23 (0.296)NS	-0.044 (0.172)NS
Qty of crop residue	0.002 (0.000)***	0.002 (0.000)***	344.8 (0.000)***	0.237 (0.000)***
Qty of sorghum seeds	3.66 (0.000) ***	3.31 (0.000) ***	-132.64 (0.000)***	-0.07 (0.000)***
Quantity of Labour	-0.009 (0.327) NS	-0.009 (0.322)NS	40.05 (0.637)NS	0.65 (0.0103)NS
Quantity of Agro Chem	0.055 (0.000)***	0.055 (0.000)***	226.8 (0.006)**	0.119 (0.002)***
Crop residue access	-0.039 (0.286)NS	-0.03 (0.424)NS	86.14 (0.255)NS	-0.02 (0.574)NS
Farm income	8.91 (0.618)NS	6.75 (0.709)NS	680.9 (0.000)***	0.346 (0.000)***
Constant	5.701 (0.000)***	5.67 (0.000)***	-8191.7 (0.000)***	1.536 (0.000)***
F (8, 150)	**168.14**	**149.32**	**84.53**	**166.45**
No of observation	**160**	**160**	**160**	**160**
Prob> F	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R^2	**0.8605**	**0.8610**	**0.7781**	**0.8735**
Adjusted R^2	**0.8534**	**0.8552**	**0.7689**	**0.8682**
Root MSE	**0.234**	**0.217**	**0.1802**	**0.2234**
Df	**226**	**226**	**226**	**226**

Source: Field Survey, 2023
Values in parenthesis are P-values
*, ** and *** are significant levels at 10%, 5% and 1% respectively.

Table 2 reveals the effects of functional forms on sorghum output in Sokoto State. The semi-log functional form was chosen as the lead equation. Farm size with coefficient of 608.8 units is positively related and significant at ($p<0.01$) on sorghum output in the study area this implies that a one hectare increase in farm size would lead to 608.8 kg increase in sorghum output.

A one kilogram increase in quantity of crop residues used increased sorghum output by 344.8 kg as it has positive association and significant at ($p<0.01$). The finding s also showed that for every one kilogram increase in quantity of sorghum seeds used, there is a reduction of 132.64 kg in sorghum output produced. The quantity of sorghum output is negatively associated with sorghum output and significant at ($p<0.01$), this implies that the more the quantity of sorghum seeds used the less the quantity of sorghum output produced in Sokoto State.

The quantity of agro-chemicals used has a positive influence and significant at ($p<0.05$) on sorghum output. For every one liter increase in quantity of agro-chemical used, there is an increase of 226.8 kg in sorghum output in Sokoto State. Farm income was directly related and significant on sorghum output at ($p<0.01$). This also implies that an increase in farm income by N1.00 leads to 680.9 kg rise in sorghum output.

Table 3: Functional Forms Effect of Crop Residue Adoption on Sorghum Output in Zamfara State.

Variables	Linear	Exponential	Semi-log	Log-log
	Coefficient	**Coefficient**	**Coefficient**	**Coefficient**
Farm size	399.5(0.000)***	0.217 (0.000)***	1105.6 (0.000)***	0.58 (0.000)***
Crop residue avail	-57.46 (0.37)NS	-0.04 (0.369)NS	-32.51 (0. 69)NS	-0.039 (0.298)NS
Qty of crop residue	1.26 (0.000)***	0.0005 (0.002)***	282.3 (0.006)***	0.05 (0.29)NS
Qty of sorghum seeds	0.0009 (0.28) NS	1.48 (0.012) **	-116.1 (0.022)**	-0.007 (0.747)NS
Quantity of Labour	8.76 (0.540) NS	0.009 (0.339)NS	204.5 (0.018)**	0.116 (0.003)***
Quantity of Agro	54.8 (0.084)**	0.033 (0.103)NS	210.1 (0.027)**	0.07 (0.083)*
Chem	101.8 (0.249)NS	0.155 (0.007)**	163.8 (0.145)NS	0.113 (0.029)**
Crop residue access	0.002 (0.000)***	9.56 (0.000)***	765.2 (0.000)**	0.47 (0.000)***
Farm income	-986.03(0.000)***	5.887 (0.000)***	-9888.3 (0.000)***	0.4404 (0.405)NS
Constant				
F (8,140)	**129.26**	**88.00**	**72.54**	**110.83**
No of observation	**150**	**150**	**150**	**150**
Prob> F	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R^2	**0.8771**	**0.8293**	**0.8002**	**0.8595**
Adjusted R^2	**0.8703**	**0.8199**	**0.7892**	**0.8578**
Root MSE	**404.98**	**0.2594**	**0.537**	**0.235**

Source: Field Survey, 2023
Values in parenthesis are P-values
*, ** and *** are represents 10%, 5% and 1 % levels of significance respectively.

Table 3 reveal the effect of crop residue adoption on sorghum output in Zamfara State. Farm size is significant at ($p<0.01$) and positively related to sorghum output. A one hectare increase in farm size increased sorghum output by 1105.6 kg.

The quantity of crop residue was statistically significant at ($p<0.01$) and directly related to sorghum output. Thus a one kilogram increase in crop residue increased sorghum output by 282.3 kg. The quantity of sorghum seeds was significant at ($p<0.05$) and inversely proportional to sorghum output. An increase of one kilogram in the quantity of sorghum seeds used decreased sorghum output by 116.1 kg, thus the quantity of sorghum seeds reduced sorghum output in Zamfara State. The quantity of labor was significant at ($p< 0.05$) and positively related to sorghum output. The implication is that a one man labor per day increased sorghum output by 204.5 kg. The findings also showed that the quantity of agro-chemicals used was significant at ($p<0.05$) and positively related with sorghum output. An increase in one liter in the quantity of agro-chemicals used increased sorghum output by 210.1 kg. Farm income was significant at ($p<0.05$) and directly associated with sorghum output. An increase in farm income by N1.00 increased sorghum output by 765.2 kg in Zamfara State.

CONCLUSION

Based on the R^2 values, the F-statistics, signs and magnitude of the coefficients and number of variables that were statistically significant, the Cobb-Douglass (Double-log) model was selected as the lead equation and most fit for the OLS regression. Then double-log functional form has the highest magnitudes for the coefficients, highest number of variable that were statistically significant on sorghum output, highest R^2 value, positive sign for the coefficients and overall significance at ($p<0.000$).

RECOMMENDATIONS

Based on the identified results and findings, the following strategies were recommended in the study area.

1. Adoption of crop residue technology by sorghum farmers as this is expected to improve the output of sorghum crop.
2. Sorghum farmers are expected to increase the quantity of sorghum seeds planted to boost their output.
3. Training and retraining of sorghum farmers by extension agents. This is also to encourage sorghum farmers in adoption of crop residue technology.

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