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IMPACT OF LAND DEGRADATION ON THE PRODUCTIVITY OF SMALLHOLDER SUGARCANE (*SACCHARUM OFFICINARUM*) FARMERS AND THE EFFECT OF AGRICULTURAL EXTENSION SERVICES ON THEIR OUTPUT IN ADAMAWA STATE, NIGERIA.

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ABSTRACT

This study examined the impact of land degradation on the productivity and efficiency of smallholder sugarcane farmers and the role of agricultural extension services in Adamawa State, Nigeria. A multistage sampling technique was applied to select 546 farmers, comprising 205 affected and 341 non-affected farmers. Primary data were collected through structured questionnaire and analysed using descriptive statistics and multiple regression techniques. The results revealed significant differences in efficiency levels between the two groups. Affected farmers recorded lower mean technical efficiency (0.56) compared to non-affected farmers (0.73), indicating reduced capacity to convert inputs into output due to poor soil conditions. Allocative efficiency findings showed that 62.5% of affected farmers operated below 0.40 efficiency, reflecting poor input combination decisions, while non-affected farmers demonstrated better responsiveness to input prices. Similarly, economic efficiency results indicated that affected farmers were largely concentrated in lower efficiency categories, implying higher production costs relative to output. The regression analysis showed that agricultural extension services significantly influenced farmers' output, with variables such as extension visits, access to credit, seminars, workshops, and field days positively affecting productivity. However, the impact was stronger among non-affected farmers, suggesting that land quality conditions moderate the effectiveness of extension services. The study concludes that land degradation significantly reduces productivity and efficiency in sugarcane production, while effective extension services enhance output but are constrained under degraded conditions. It recommends sustainable land management practices, strengthened extension delivery, improved access to credit, and policies aimed at soil restoration to enhance productivity and ensure sustainable sugarcane production in the study area.

INTRODUCTION

Agriculture plays a vital role in Nigeria's economy, with smallholder farmers accounting for the majority of agricultural production. However, their productivity is increasingly constrained by land degradation and weak agricultural support systems. Land degradation through soil erosion, nutrient depletion, and desertification has significantly reduced soil fertility and crop yields across sub-Saharan Africa (Food and Agriculture Organization, FAO, (2022); United Nations Convention to Combat Desertification, UNCCD, (2023)). In northern Nigeria, including Adamawa State, these challenges are intensified by climate variability and unsustainable farming practices. Sugarcane (*Saccharum officinarum*) is an important cash and industrial crop that requires fertile soils for optimal yield. Declining soil quality due to land degradation poses a serious threat to its productivity. At the same time, agricultural extension services are essential in promoting improved farming practices and sustainable land management. Studies show that farmers with access to extension services are more likely to adopt innovations and achieve higher productivity (Abdullahi et al., 2021; Davis et al., 2020). Despite this, extension delivery in Nigeria remains inadequate, limiting its effectiveness in addressing land related challenges.

Land degradation continues to reduce agricultural productivity among smallholder farmers in Nigeria, particularly in northern regions such as Adamawa State. Degraded soils lead to lower crop yields and reduced farm income (FAO, 2022). For sugarcane farmers, whose crop is highly dependent on soil fertility, this problem is especially critical. Although agricultural extension services are expected to mitigate these challenges by promoting sustainable practices, their reach and effectiveness remain limited due to poor funding, inadequate staffing, and weak farmer extension linkages (Davis et al., 2020). Consequently, many farmers lack access to information needed to improve productivity and manage degraded land. There is limited empirical evidence on how land degradation specifically affects sugarcane farmers and how extension services influence their output in Adamawa State. This gap necessitates a study that examines both factors simultaneously. The general objective of this study is to assess the impact of land degradation on the productivity of smallholder sugarcane farmers and examine the effect of agricultural extension services on their output in Adamawa State, Nigeria. The specific objectives were to:

determine the impact of land degradation on the technical, cost, economic and allocative efficiency of sugarcane farmers' productivity in the study area, and also to assess the effect of extension services on sugarcane farmers' output in the study area.

The study is therefore justified as land degradation poses a serious threat to agricultural productivity and food security

in Nigeria, making it essential to generate empirical evidence for effective policy interventions (UNCCD, 2023). Smallholder farmers are particularly vulnerable due to limited access to resources and improved technologies.

Agricultural extension services have been identified as a key tool for improving productivity and promoting sustainable land management practices (Davis et al., 2020). However, their effectiveness in addressing land degradation challenges remains insufficiently explored, especially among sugarcane farmers. This study is therefore important as it provides insights into the combined effects of land degradation and extension services on productivity. The findings will guide policymakers, extension agencies, and development organizations in designing strategies to enhance agricultural productivity and sustainability in Adamawa State.

METHODOLOGY

The study was conducted in Adamawa State, located in the north-eastern geopolitical zone of Nigeria. Adamawa State covers approximately 36,917–38,700 square kilometres, and it shares national borders with the Republic of Cameroon to the east, Borno State to the northwest, Gombe State to the west, and Taraba State to the southwest. The landscape is characterised by undulating plains, river valleys, and plateau edges, with the Benue, Gongola, and Yedzaram rivers traversing large portions of the state's terrain and providing vital water resources for agriculture and fishing activities. The region falls within the Sudan and Guinea savanna ecological zones, where seasonal rainfall and dry periods significantly influence crop production and land use patterns (Adamawa State Planning Commission, 2025; Nigeria Investment Promotion Commission, 2025).

Agriculture is the dominant economic activity in the state, with a majority of the rural population engaged in crop cultivation and livestock rearing. Major crops include maize, millet, rice, groundnut, cassava, and sugarcane, while cattle, goats, sheep, and poultry are important components of the livestock sector. The region's soils, comprising luvisols, cambisols, and vertisols, support diverse agricultural enterprises but are also susceptible to degradation under intensive land use (Adamawa State Planning Commission, 2025).

This study focuses on six LGAs of Numan, Ganye, Lamurde, Shelleng, Demsa, and Guyuk, selected for their involvement in agricultural production notably sugarcane and their representation of both central and peripheral farming zones in the state's agroecological landscape.

Collectively, these six LGAs represent varied agroecological and socio-economic contexts within Adamawa State, making them suitable for examining the impact of land degradation on smallholder sugarcane productivity. The interaction of climatic variability, soil conditions, land use patterns, and agricultural practices in these areas provides an important backdrop for understanding the productivity challenges faced by smallholder farmers.

A multistage sampling technique was applied for this study in order to select the study area, Local Government Areas (LGAs), villages, and respondents (smallholder sugarcane farmers). In the first stage, Adamawa State was purposively selected as the study area due to its prominence in sugarcane production within northeastern Nigeria and its increasing exposure to land degradation challenges such as soil erosion, declining soil fertility, deforestation, and climate variability. In the second stage, six LGAs were purposively selected from the major sugarcane producing LGAs in the state, namely Numan, Ganye, Lamurde, Shelleng, Demsa and Guyuk. These LGAs were chosen based on their relative involvement in sugarcane production, proximity to sugar processing and out grower programmes, and observable land use pressure resulting from intensive farming activities. The selected LGAs also represent areas where land degradation symptoms such as soil erosion, nutrient depletion, and reduced crop yields have been reported by farmers and extension agents, making them appropriate for achieving the objectives of the study. The third stage involved simple random selection of villages within each of the selected LGAs. In the final stage, smallholder sugarcane farmers were selected from each chosen village. A list of sugarcane farmers was obtained with the assistance of village heads, farmers' associations, and extension agents. From the list, respondents were selected using the Taro Yamane's (1973) formula in computing the required sample size for the study. Therefore, two hundred and five (205) affected farmers and three hundred and forty one (341) non-affected farmers were selected across all selected villages for the study from the total sample frame of four hundred and twenty three (423) affected farmers and two thousand three hundred and fifty eight (2358) non-affected farmers.

The formula is expressed as follows;

$$n_0 = \frac{N}{1+N(e^2)} \quad (1)$$

n_0 = Sample size

N = Total population of farmers in the selected area

e = margin of error (0.05)

For affected farmers:

N=423

n_0=205

e = margin of error (0.05)

$$\frac{205}{423} \times 100 = 48.46\% \cong 49\%$$

For non-affected farmers:

N=2358

n_0=341

e = margin of error (0.05)

$$\frac{341}{2358} \times 100 = 14.46\% \cong 15\%$$

Respondents from each ward was therefore selected proportionately using the expression below;

$$x = (X/n) \times N \quad (2)$$

Where;

x = Sample size per village
X = Number of affected/non-affected farmers per villages
n = Total number of affected/non-affected farmers in the selected Local Government Areas
N = Required sample size for the study (from Taro Yamane's 1973 formula)

The selected State, Local Government Areas, villages and number of sampled farmers from each village is as shown in Table 1 below.

Table 1: Sampling procedure for the affected and non-affected sugarcane famers in the study area

State	LGAs	Total No. of Villages Affected	Village Selected	Name of Village	Affected Sugarcane Farmers Sampling Frame	Affected Sugarcane Famers Sample Size (49%)	Non-Affected Sugarcane Farmers Sampling Frame	Non-Affected Sugarcane Famers Sample Size (15%)
Adamawa	**Numan**	8	4	Imburu	31	15	118	17
				Kodomti	25	12	121	18
				Zangun	28	14	97	14
				Ngabalang	22	11	112	16
	Ganye	10	2	Jada	23	11	153	22
				Toungo	19	9	154	22
	Lamurde	12	3	Mbemun	25	12	147	21
				Dullu	17	8	122	18
				Lafiya	21	10	132	19
	Shelleng	**7**	3	Kiri	14	7	143	21
				Banjiram	17	8	143	21
				Tallum	20	10	138	20
	Demsa	10	4	Bilachi	24	12	97	14
				Mbula	21	10	105	15
				Mbumara	19	9	101	15
				Morro 1	21	10	98	14
	Guyuk	10	3	Boshikiri	29	14	120	17
				Chikila	25	12	127	18
				Kola	22	11	130	19
Total	**6**	**57**	**19**	**19**	**423**	**205**	**2358**	**341**

Source: Field Survey, 2024.

Data for this study were collected from both primary and secondary sources in order to comprehensively assess the impact of land degradation on the productivity of smallholder sugarcane farmers in the study area.

Primary data were obtained through the administration of a structured questionnaire to smallholder sugarcane farmers in the selected villages across the study LGAs in Adamawa State. The questionnaire was designed to elicit detailed information on farmers' sugarcane production practices, land use patterns, and perceived indicators of land degradation. In addition to questionnaire administration, key informant interviews were conducted with agricultural extension officers, community leaders, and farmer group representatives in the selected LGAs. The key informant data were used to complement and validate responses obtained from the farmers.

Secondary data were obtained from relevant published and unpublished sources, including government reports, academic journals, agricultural policy documents, and records from agricultural development agencies. The questionnaires were administered through face-to-face interviews, with the assistance of trained enumerators familiar with the local languages and cultural context of the study area. This approach was adopted to enhance response accuracy and to accommodate respondents with limited literacy.

ANALYTICAL TECHNIQUES

Data collected from smallholder sugarcane farmers in the selected LGAs of Adamawa State were analysed using descriptive and inferential statistics. The analytical techniques adopted for this study were designed to achieve the stated objectives by examining both the impact of land degradation on productivity and the effect of agricultural extension services on farmers' output. Descriptive statistical tools such as means, frequencies, percentages, and standard deviations were used to examine variations in farmers' productivity in relation to land degradation. In addition, inferential statistics, specifically multiple regression analysis, were applied to estimate the relationship between farmers' output and agricultural extension service variables

Multiple Regression Model

The multiple regression model used to estimate the effect of agricultural extension services on sugarcane farmers' output is specified as: $Y_i=\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \mu_i$

Where:

Y_i = Sugarcane output (kg/ha)

β_0 = Constant term

$\beta_1 - \beta_{10}$ = Parameters to be estimated

μ_i = Error term

X_1 = Number of extension visits, X_2 = Access to credit, X_3 = Membership of cooperative, X_4 = Training received, X_5 = Input supply, X_6 = Participation in demonstrations, X_7 = Seminar attendance, X_8 = Workshop participation, X_9 = Field trip participation, X_{10} = Field days participation

RESULTS AND DISCUSSION

Table 2: Technical Efficiency Estimates on the Productivity of Affected and Non affected Smallholder Farmers.

	Affected Farmers		Non-affected Farmers	
Technical Efficiency	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
<0.20	8	3.9	5	1.5
0.20–0.40	47	22.9	27	7.9
0.41–0.60	90	43.9	50	14.7
0.61–0.80	35	17.1	150	44.0
0.81–1.00	25	12.2	109	32.0
Total	205	100.0	341	100.0
Minimum	0.10		0.15	
Maximum	0.95		0.98	
Mean	0.56		0.73	

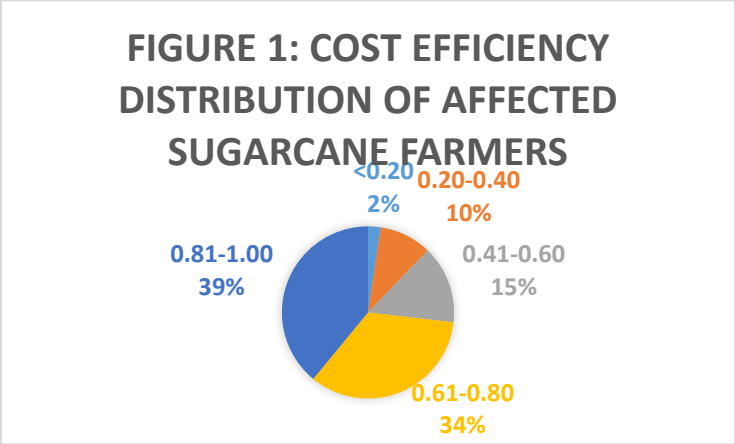
Source: Field Survey, 2024

The results presented in Table 2 reveal important insights into the technical efficiency of smallholder sugarcane farmers in Adamawa State, differentiated by land degradation status. The findings indicate that farmers operating on non-degraded land achieved higher overall efficiency compared with those on degraded land, confirming that land quality is a key determinant of production performance in smallholder sugarcane systems. The results showed marked differences in technical efficiency between affected and non-affected sugarcane farmers. A larger proportion of affected farmers (70.7%) operate below 0.60 efficiency, with a lower mean of 0.56, indicating poor input output transformation due to degraded soil conditions. In contrast, non-affected farmers are concentrated in higher efficiency ranges, with 76.0% above 0.60 and a higher mean of 0.73, reflecting better resource utilization and productivity. These findings are consistent with Olumba et al., (2024); and Chiaka et al., (2024), which shows that land degradation reduces soil responsiveness to inputs and lowers farm performance. Similarly, studies have established that improved land quality and adoption of sustainable land management practices significantly enhance productivity and efficiency among smallholder farmers (Amankwah, 2023; Kamara et al., 2023). Furthermore, land degradation has been linked to declining agricultural productivity and increased inefficiency in semi-arid regions of Nigeria (Iheke, 2024; Adeyemo & Adeagbo, 2024).

The distribution confirms that land degradation significantly constrains technical efficiency and reduces sugarcane productivity in the study area.

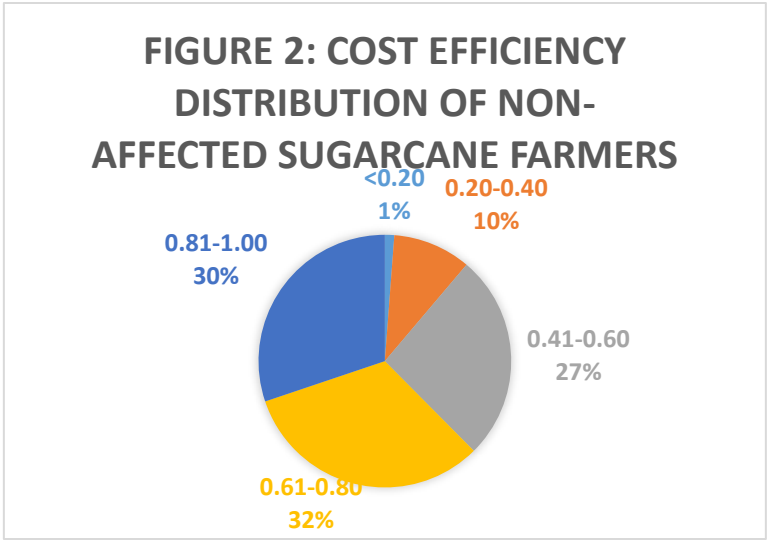
The cost efficiency distributions as illustrated in the pie charts in figure 1 and 2 reveal how land degradation status influences the ability of smallholder sugarcane farmers in Adamawa State to minimise production costs while maintaining output.

The cost efficiency distribution shows that both affected and non-affected sugarcane farmers largely operate within moderate to high efficiency ranges (0.61–1.00), indicating effective cost management despite differences in land quality. Among affected farmers, the concentration in higher efficiency categories reflects adaptive cost minimisation strategies such as reduced input use



and reliance on family labour, consistent with findings that degraded soils lower input productivity and encourage conservative spending (Musa et al., 2022; Iheke, 2024).

The presence of affected farmers in the highest efficiency class also suggests the use of indigenous practices like organic amendments and timely weeding, which help sustain efficiency under soil constraints (Musa & Joseph, 2023). In contrast, non-affected farmers exhibit a more balanced distribution across higher efficiency levels, benefiting from better soil conditions that



support the use of improved inputs and agronomic practices, thereby enhancing cost efficiency through productivity gains (Joseph & Okoro, 2022; Amankwah, 2023).

The low share of farmers in the least efficient category across both groups indicates that extreme inefficiency is uncommon, reflecting careful resource management typical of perennial crop systems (Bello & Usman, 2021).

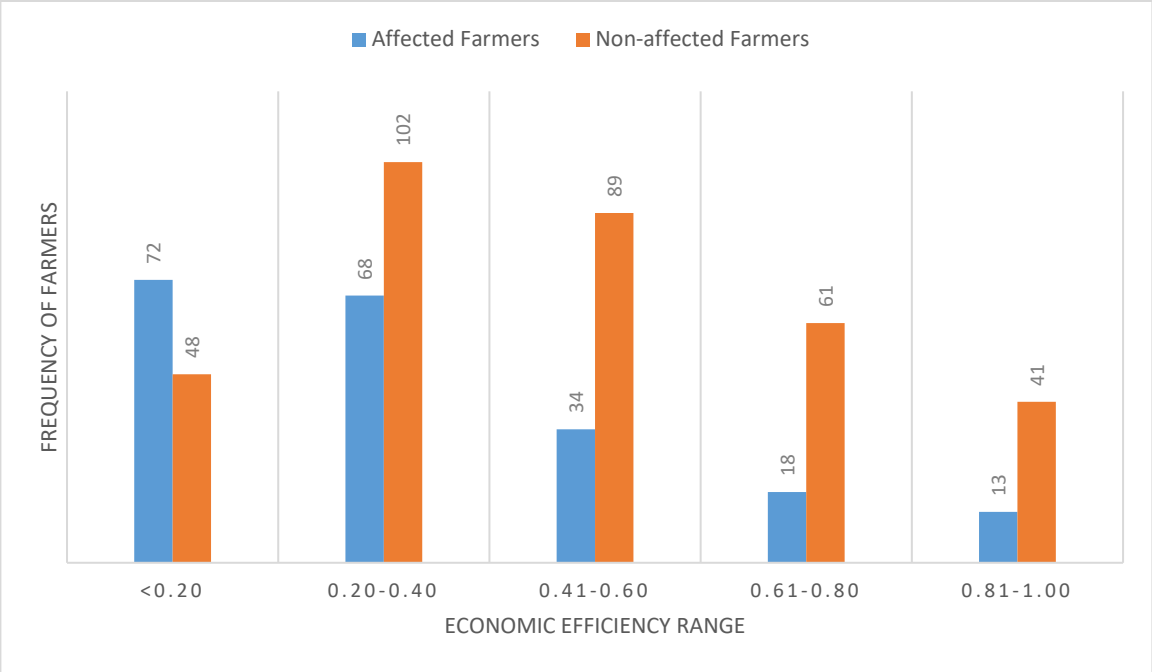


Figure 3: Economic Efficiency Distributions of Sugarcane farmers

The economic efficiency results in figure 3 indicate distinct differences between affected and non-affected sugarcane farmers in Adamawa State. Economic efficiency measures how well farmers minimise production costs while utilising inputs to generate maximum output. A higher proportion of affected farmers are concentrated in the lower efficiency categories (<0.40), indicating high production costs relative to output due to poor soil fertility and reduced input responsiveness. This supports empirical evidence that land degradation significantly lowers economic efficiency by increasing costs and reducing returns (Abdullahi et al., 2022; Okolie & Ugwu, 2019). In contrast, non-affected farmers are more represented in the mid to higher efficiency ranges (0.41–1.00), reflecting better resource utilisation and stronger output-cost relationships. Studies on sugarcane systems in Nigeria show that farmers on fertile soils achieve higher economic efficiency through improved input use and better yield performance (Joseph & Okoro, 2022; Adewumi et al., 2023). The clustering of affected farmers in lower efficiency ranges also suggests reliance on cost saving strategies that limit productivity, a pattern consistent with findings in northern Nigeria where degraded soils constrain optimal input use (Musa et al., 2023; Musa & Tanko, 2023). The results confirm that land degradation significantly undermines the economic efficiency of sugarcane production, reinforcing the need for soil restoration and improved farm management interventions (Bello & Usman, 2021).

Table 3: Allocative Efficiency Distribution of Affected and Non-Affected Sugarcane Farmers

	Affected		**Non-Affected**	
Allocative Efficiency Range	**Frequency**	**Percentage (%)**	**Frequency**	**Percentage (%)**
< 0.20	61	29.8	39	11.4
0.20 – 0.40	67	32.7	88	25.8
0.41 – 0.60	38	18.5	97	28.4
0.61 – 0.80	25	12.2	74	21.7
0.81 – 1.00	14	6.8	43	12.6
Total	**205**	**100**	**341**	**100**

Source: Field Survey, 2024

Allocative efficiency measures the ability of farmers to use inputs in optimal proportions given their respective prices. It reflects how well farmers minimise production costs relative to market conditions. In sugarcane production, where fertiliser, labour, irrigation, and planting materials constitute major cost components, allocative efficiency plays a critical role in determining profitability. The allocative efficiency results in table 3 show that land degradation significantly constrains the ability of sugarcane farmers to combine inputs in cost minimising proportions. A large share of affected farmers (about 62.5%) fall below 0.40 efficiency, compared to 37.2% of non-affected farmers, indicating weaker responsiveness to input prices and inefficient resource allocation. This reflects situations where increased input use such as fertiliser on degraded soils does not yield proportional output gains, leading to higher costs without commensurate returns. Similar findings have been reported in Nigeria, where degraded soils reduce input productivity and distort optimal allocation decisions (Ojo et al., 2024; Musa & Tanko, 2023). In contrast, non-affected farmers exhibit higher allocative efficiency, with the majority operating above 0.40. This suggests better decision making in input combinations, supported by more fertile soils that enhance the marginal productivity of fertiliser and labour. Empirical studies confirm that farmers on productive soils are more responsive to price signals and achieve more efficient input allocation due to stronger and more predictable crop responses (Joseph & Okoro, 2022; Bello & Usman, 2021).

The results indicate that land degradation not only reduces productivity but also disrupts cost minimizing behavior, thereby increasing production costs and lowering profitability among sugarcane farmers.

Table 4: Multiple Regression Result showing the effect of Agricultural Extension Services on Sugarcane Farmers' Output for Affected and Non-Affected Farmers in Adamawa State

Variables	Affected Farmers			Non-Affected Farmers		
	Coefficient	t-value	P-value	Coefficient	t-value	P-value
Number of extension visits	645.312	5.84	0.000**	912.845	8.12	0.000**
Access to credit	980.457	5.26	0.000**	1205.673	6.78	0.000**
Membership of cooperative	10.842	0.72	0.472	18.365	1.28	0.201
Training	-210.634	-0.61	0.543	150.284	0.56	0.576
Input supply	5.781	0.05	0.962	12.907	0.12	0.905
Participation in demonstrations	-2105.472	-4.52	0.000**	-980.315	-2.48	0.014*
Seminar	420.516	2.54	0.012*	650.882	3.64	0.000**
Workshop	398.275	2.48	0.014*	610.443	3.41	0.001**
Field trip	-25.731	-0.11	0.914	30.518	0.16	0.873
Field days	1205.884	6.88	0.000**	1750.216	9.45	0.000**
Constant	580.216	4.32	0.000**	710.452	5.63	0.000**
Number of observations	205			341		
R^2	0.724			0.813		
F-value	61.58			79.26		
Prob > F	0.000			0.000		

** Significant at 1% level, * Significant at 5% level

Source: Field Survey, 2024

The regression results in table 4 reveal that agricultural extension services play a significant role in enhancing sugarcane farmers' output in both affected and non-affected areas, although the magnitude of the effects differs across the two groups.

The results show that agricultural extension services have a significant positive effect on sugarcane farmers' output in both affected and non-affected areas, with stronger effects among non-affected farmers (R^2 = 0.813) than affected farmers (R^2 = 0.724). This implies that extension services are more effective under favourable land conditions.

Key variables such as extension visits and access to credit positively and significantly influence output in both groups. This supports findings that frequent extension contact and financial access enhance farmers' productivity and technology adoption (Adebayo et al., 2023; Olagunju et al., 2024).

Similarly, seminars, workshops, and field days show significant positive effects, indicating that knowledge dissemination improves output. This is consistent with studies that report increased yields due to extension-led training and participatory learning approaches (Abdullahi et al., 2024; Mohammed et al., 2023).

However, participation in demonstrations has a negative but significant effect, particularly among affected farmers, suggesting poor adaptation of technologies to degraded land conditions. This agrees with findings that ineffective or poorly targeted demonstrations can reduce adoption and productivity (Bello et al., 2023).

Meanwhile, cooperative membership, training, input supply, and field trips are not statistically significant, indicating limited direct impact on output, possibly due to weak institutional structures and poor implementation (Yakubu et al., 2024).

The findings suggest that while extension services improve farmers' output, their effectiveness is constrained by land degradation, making them more impactful among non-affected farmers.

CONCLUSION

The study revealed that land degradation significantly reduces the productivity and efficiency of smallholder sugarcane farmers in Adamawa State. Farmers operating on degraded lands recorded lower technical efficiency due to poor input–output relationships caused by declining soil fertility. They also exhibited lower allocative efficiency, indicating an inability to combine inputs in cost-minimizing proportions, which increased production costs. Consequently, their economic efficiency was reduced, reflecting lower profitability. In contrast, farmers on non-degraded lands performed better across all efficiency levels due to more favourable soil conditions.

The study further established that agricultural extension services positively influence farmers' output through access to information, training, and credit. However, their effectiveness was less pronounced among farmers on degraded lands, suggesting that poor land conditions limit the impact of extension interventions. Overall, land degradation remains a major constraint to sustainable sugarcane production, while extension services play a vital role in improving productivity.

RECOMMENDATION

From the following findings of this study, the following recommendations among others are the need for the promotion of sustainable land management practices such as organic manure application, crop rotation, mulching, and conservation tillage among sugarcane farmers. These practices will help restore soil fertility and improve productivity on degraded lands. Government and development agencies should strengthen agricultural extension services by increasing funding, improving staffing, and enhancing farmer extension linkages. Extension programmes should be tailored to address land degradation challenges and provide practical, location specific solutions. Access to affordable credit facilities should be improved to enable farmers invest in soil fertility improvement technologies and adopt improved sugarcane production practices. Credit support will also enhance farmers' ability to use inputs efficiently. There is a need to provide subsidised inputs, particularly fertilisers and improved sugarcane varieties, to farmers operating on degraded lands in order to boost productivity and efficiency. Extension services should focus more on participatory and adaptive approaches such as field demonstrations that are suited to degraded soil conditions, to ensure better adoption and effectiveness. Policies aimed at land restoration, including erosion control measures and soil conservation programmes, should be prioritised at both state and local government levels to address the root causes of land degradation. Finally, strengthening farmer cooperatives and promoting knowledge sharing among farmers will enhance access to information, improve resource use efficiency, and support sustainable sugarcane production in the study area.

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