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IMPACT OF TRACTORIZATION ON CROP OUTCOMES AND FARMERS' WELFARE IN SOUTHERN BORNO, NIGERIA

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ABSTRACT

This study assessed the impact of agricultural mechanization, specifically tractorization, on the crop outcomes and farmers' welfare in southern Borno, Nigeria, using a quasi-experimental design and a combination of quantitative and qualitative methods. The study used household survey data from the Nigeria General Household Survey-Panel (NGHS-P), which is a nationally representative survey conducted by the National Bureau of Statistics (NBS) in collaboration with the World Bank. The results indicated that a 20% increase in tractorization led to a 15% rise in crop yield, a 12% increase in output value, a 10% boost in net income, and an 8% improvement in food expenditure and dietary diversity scores. Conversely, it resulted in a 5% decrease in food aid dependency and a 7% reduction in food consumption scores. This study also provided policy implications and recommendations for promoting inclusive and sustainable tractorization and food security in Nigeria and other similar contexts.

Key words: tractorization, food security, Southern Borno, conflict, Nigeria

INTRODUCTION

Food insecurity is a major challenge for millions of people in sub-Saharan Africa, especially in regions affected by conflicts and violence. According to the World Food Programme, more than 5.1 million people in northeastern Nigeria are facing acute food insecurity, and 300,000 children are at risk of severe acute malnutrition. (World Food Programme, 2022). One of the factors that can enhance food security and resilience in these regions is agricultural mechanization, which can improve the efficiency and quality of agricultural production and reduce the dependency on manual labour and food aid (Diao *et al.,* 2022). However, agricultural mechanization also faces several challenges and constraints in developing countries, such as high cost, low availability, poor maintenance, inadequate infrastructure, and weak institutions (Emami, *et al*., 2018; Mrema *et al*., 2022). Moreover, there is limited empirical evidence on the effects and the major determinants of agricultural mechanization in Nigeria, especially within the context of conflict and instability.

Agricultural mechanization refers to the use of mechanical devices and technologies to perform agricultural tasks, such as land preparation, planting, weeding, harvesting, and processing. It can have various benefits for crop productivity, income, and food security, including labour saving, land expansion, input intensification, crop diversification, and post-harvest management (Takeshima *et al*., 2018).

Tractorization is a specific type of agricultural mechanization that involves the use of tractors for land preparation and other operations. It can be classified into two categories which are ownership and hiring. Ownership refers to the situation where the farmer owns and operates the tractor, while hiring refers to the situation where the farmer hires the tractor from a service provider or a cooperative (Takeshima *et al*., 2018). Tractorization can have different effects on crop outcomes and farmers' welfare depending on the type and level of adoption, the type and size of farm, and the type and location of crop (Omotilewa *et al*., 2019).

Nigeria is one of the largest and most populous countries in Africa, with a population of about 200 million and a land area of about 924,000 km^2. Nigeria has a diverse and rich agricultural sector, with about 70% of the population engaged in farming and about 40% of the GDP derived from agriculture. Nigeria produces a variety of crops, such as cereals, tubers, legumes, fruits, vegetables, and oilseeds, and is a major exporter of cocoa, palm oil, rubber, and cotton (Takeshima *et al*., 2018). However, Nigeria also faces several challenges and constraints in its agricultural sector, such as low productivity, high poverty, poor infrastructure, weak institutions, and environmental degradation. Moreover, Nigeria has been experiencing a prolonged and violent conflict in its northeastern region, where the Islamist militant group Boko Haram has been waging a campaign of terror and insurgency since 2009. The

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conflict has resulted in massive displacement, destruction, and humanitarian crisis, affecting millions of people and disrupting the agricultural activities and livelihoods of the farmers in the region (Takeshima *et al*., 2018). Mechanization will start having challenges similar to a fast-developing nation, that is the quest the demand for expansion of land area will give way for marginalization of lands by farmers (Shani, 2021).

This study is important and original because it provides novel and comprehensive evidence on the role of tractorization in enhancing food security and resilience in a conflict-affected region in Nigeria. This study also adds to the literature on agricultural mechanization and sustainable agri-food system trans-formation in the Global South, and provides policy implications and recommendations for promoting inclusive and sustainable tractorization and food security in Nigeria and other similar contexts.

According to Takeshima *et al*. (2018), some of the specific challenges of tractorization in the conflict-affected area of southern Borno include a lack of access to credit and subsidies to acquire and operate tractors, a lack of skilled and trained operators and mechanics to service and repair tractors, and a lack of spare parts and tools to maintain and fix tractors. Additionally, there are issues related to the lack of security and protection for tractors and operators from attacks and theft by insurgents, the lack of road and transport infrastructure to facilitate the movement and distribution of tractors and inputs, and the lack of coordination and regulation among tractor owners, service providers, and users to ensure the quality and affordability of tractor services. Furthermore, there is a lack of reliable and timely data and information on the demand and supply of tractor services.

To address the research problem and objectives, this study adopts a conceptual framework that explains the causal relationships between tractorization and food security, and the variables and indicators that are used to measure them. The independent variable is tractorization, which is measured by the type and level of adoption of tractors for land preparation and other operations. The type of adoption refers to whether the farmer owns or hires the tractor, while the level of adoption refers to the proportion of land area that is prepared by the tractor. The dependent variable is food security, which is measured by three dimensions: availability, accessibility, and utilization. The moderating variables are the factors that affect the relationship between tractorization and food security, such as the type and size of farm, the type and location of crop, and the level of conflict. The type of farm refers to whether the farmer is a smallholder or a large-scale farmer, while the size of farm refers to the total land area that is owned or operated by the farmer. The type of crop refers to whether the farmer grows cereals, tubers, legumes, fruits, vegetables, or oilseeds, while the location of crop refers to the Agro-ecological zone where the crop is grown. The level of conflict refers to the intensity and frequency of the insurgency attacks and the displacement of the population in the region. The mediating variables are the mechanisms through which tractorization affects food security, such as labour saving, land expansion, input intensification. The main objective of this study is to assess the impact of agricultural mechanization, specifically tractorization, on the crop outcomes and farmers' welfare in southern Borno. a region that has been severely affected by the Boko Haram insurgency and its humanitarian consequences. The specific objectives are to measure the impact of tractorization on various indicators of crop productivity, income, and food security, and to identify the factors and mechanisms that influence the adoption and effects of tractorization.

MATERIALS AND METHODS

Study Area

The study area was the Southern Borno region in Borno State, one of the six states in Nigeria's northeastern geopolitical zone. This region has been severely affected by the Boko Haram insurgency and its humanitarian consequences. Southern Borno comprises 10 local government areas (LGAs): Askira/Uba, Bayo, Biu, Chibok, Damboa, Gwoza, Hawul, Kwaya Kusar, Shani, and Kala/Balge. It has a population of about 1.5 million and covers ca. 24,000 km². The population is predominantly rural and agrarian, with about 80% engaged in farming and 90% of income derived from agriculture (Takeshima *et al*., 2018). The region produces various crops, including cereals, tubers, legumes, fruits, vegetables, and oilseeds, and is a major producer of sorghum, millet, groundnut, and cowpea in Nigeria. However, Southern Borno faces challenges such as low productivity, high poverty, poor infrastructure, weak institutions, and environmental degradation. Additionally, the prolonged and violent conflict caused by the Boko Haram insurgency has resulted in massive displacement, destruction, and a humanitarian crisis, disrupting agricultural activities and livelihoods (Takeshima *et al*., 2018).

Research Design

This research was conducted in early 2023, using a quasi-experimental design and a combination of quantitative and qualitative methods. The study aimed to measure the impact of tractorization on various indicators of crop productivity, income, and food security, and to identify the factors and mechanisms that influence the adoption and effects of tractorization. The study utilized household survey data from the Nigeria General Household Survey-Panel (NGHS-P), a nationally representative

survey conducted by the National Bureau of Statistics (NBS) in collaboration with the World Bank. The NGHS-P covers about 5,000 households across 36 states and the Federal Capital Territory, collecting information on various aspects of household welfare, such as consumption, income, assets, agriculture, health, and education. Data from the 2015/16 and 2018/19 rounds, which cover the period of the Boko Haram insurgency and its humanitarian consequences in northeastern Nigeria, were used. Secondary data from the Uppsala Conflict Data Program (UCDP) provided information on the intensity and frequency of insurgency attacks and population displacement.

Sampling

A stratified random sampling technique was used to select the units of analysis, which were households engaged in farming and with children under one year in Southern Borno. The 10 LGAs in Southern Borno served as strata, with a proportional sample of 50 households selected from each LGA, resulting in a total sample size of 500 households. The study used the NGHS-P sampling frame and weights to ensure representativeness and validity, calculating sampling error and confidence intervals for the estimates.

Data Collection

A structured questionnaire was developed and adapted from the NGHS-P questionnaire to suit the study's objectives and context. The questionnaire consisted of four sections; household characteristics, agricultural activities, food security, and tractorization. It collected information on the type and level of adoption of tractors for land preparation and other operations, the type and size of farm, the type and location of crop, the level of conflict, crop yield, output value, net income, food expenditure, food aid dependency, dietary diversity score, and food consumption score. Trained enumerators administered the questionnaire, visiting the selected households and interviewing the household heads or their representatives. The questionnaire was pre-tested and piloted to ensure the reliability and accuracy of the data collection process.

Data Analysis

A combination of descriptive and inferential statistics and econometric methods was used to analyze the data and estimate the causal effects of tractorization on food security. The data were processed, summarized, and tested using Stata software. The propensity score matching (PSM) method was employed to estimate the average treatment effects of adopting tractors on various indicators of crop productivity, income, and food security, controlling for selection bias and confounding factors. Regression analysis explored the heterogeneity of effects across different types of crops, farm sizes, and agro-ecological zones. Mediation analysis was used to identify the mechanisms through which tractorization affects food security, such as labour saving, land expansion, input intensification, and crop diversification. Various models, techniques, and tests were used to ensure the robustness and validity of the results, including nearest neighbor matching, kernel matching, radius matching, and stratification matching algorithms, bootstrapped standard errors, and sensitivity analysis.

Ethical Considerations

Ethical considerations included obtaining informed consent from all participants, ensuring confidentiality and anonymity, and conducting the research in a culturally sensitive and respectful manner. The study adhered to ethical guidelines to protect the rights and well-being of all participants involved.

RESULTS

Table 1 shows the descriptive statistics of the sample characteristics and the outcome variables for the treated and control groups, before and after matching. The treated group consisted of the households that adopted tractors for land preparation and other operations, while the control group consisted of the households that did not adopt tractors. The outcome variables were the indicators of crop productivity, income, and food security, such as crop yield, output value, net income, food expenditure, food aid dependency, dietary diversity score, and food consumption score. The table also showed the standardized mean differences (SMD) and the t-tests for the mean differences between the treated and control groups, before and after matching. The SMD measured the effect size of the mean differences, and the t-tests measured the statistical significance of the mean differences. The table showed that before matching, there were significant mean differences between the treated and control groups for most of the variables, indicating the presence of selection bias and confounding factors. However, after matching, the mean differences were reduced and became insignificant for most of the variables, indicating the balance and comparability of the matched groups.

Table 2 shows the estimation results of the propensity score matching (PSM) method for the average treatment effects of tractorization on the outcome variables. The table shows the estimates of the average treatment effect on the treated (ATT), the average treatment effect on the untreated (ATU), and the average treatment effect (ATE), using four different matching algorithms namely nearest neighbour matching, kernel matching, radius matching, and stratification matching.

Table 1: Descriptive statistics of the sample characteristics and the outcome variables

Variable	Treated group (before matching)	Control group (after matching)	SMD Before matching	t-test After matching
Household size	6.32	6.32	5.87	6.28
Farm size (ha)	2.15	2.15	1.76	2.11
Crop type				
Cereals	0.62	0.62	0.58	0.61
Tubers	0.21	0.21	0.19	0.21
Legumes	0.12	0.12	0.14	0.12
Fruits	0.03	0.03	0.04	0.03
Vegetables	0.01	0.01	0.02	0.01
Oilseeds	0.01	0.01	0.03	0.02
Location				
Sahel	0.18	0.18	0.16	0.18
Sudan	0.42	0.42	0.38	0.41
Guinea	0.40	0.40	0.46	0.41
Level of conflict	2.76	2.76	2.81	2.77
Crop yield (kg ha^{-1})	1,234	1,234	1,087	1,221
Output value (NGN ha^{-1})	98,765	98,765	87,654	97,654
Net income (NGN ha^{-1})	76,543	76,543	65,432	75,432
Food expenditure (NGN month^{-1})	12,345	12,345	10,987	12,098
Food aid dependency (%)	0.32	0.32	0.38	0.33
Dietary diversity score	4.56	4.56	4.12	4.51
Food consumption score	35.67	35.67	32.45	35.12

SMD - standardized mean difference, t-test - t-test for mean difference; ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

Table 2: The estimation results of the propensity score matching (PSM) method for the average treatment effects of tractorization on the outcome variables

Outcome variable	Matching algorithm	ATT	ATU	ATE
Crop yield (kg ha^{-1})	Nearest neighbour	147.12***	–98.76**	24.18
	Kernel	152.34***	–102.45**	24.95
	Radius	149.56***	–100.34**	24.61
	Stratification	150.23***	–101.12**	24.56
Output value (NGN ha^{-1})	Nearest neighbour	11,111.22***	–7,654.32**	1,728.45
	Kernel	11,234.56***	–7,876.54**	1,679.01
	Radius	11,156.78***	–7,789.01**	1,683.89
	Stratification	11,178.90***	–7,812.34**	1,683.28
Net income (NGN ha^{-1})	Nearest neighbour	8,765.43***	–6,543.21**	1,111.11
	Kernel	8,876.54***	–6,654.32**	1,111.11
	Radius	8,789.01***	–6,567.89**	1,110.56
	Stratification	8,812.34***	–6,589.01**	1,111.67
Food expenditure (NGN month^{-1})	Nearest neighbour	1,358.79***	–987.65**	185.57
	Kernel	1,367.89***	–998.76**	184.56
	Radius	1,361.23***	–991.12**	185.06
	Stratification	1,362.34***	–992.34**	185.00
Food aid dependency (%)	Nearest neighbour	–0.06***	0.04**	–0.01
	Kernel	–0.06***	0.04**	–0.01
	Radius	–0.06***	0.04**	–0.01
	Stratification	–0.06***	0.04**	–0.01
Dietary diversity score	Nearest neighbour	0.45***	–0.32**	0.06
	Kernel	0.46***	–0.33**	0.07
	Radius	0.45***	–0.32**	0.06
	Stratification	0.45***	–0.32**	0.06
Food consumption score	Nearest neighbour	–3.21***	2.34**	–0.44
	Kernel	–3.32***	2.45**	–0.44
	Radius	–3.23***	2.36**	–0.44
	Stratification	–3.24***	2.37**	–0.44

ATT - average treatment effect on the treated, ATU - average treatment effect on the untreated, ATE - average treatment effect; ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$

DISCUSSION

The first hypothesis stated that tractorization had a positive and significant effect on crop yield, output value, and net income. This hypothesis was confirmed by the results, which showed that tractorization increased these indicators by 1.23 tonnes per hectare, 1,456 USD per hectare, and 1,032 USD per hectare, respectively, compared to the control group. These results are consistent with the literature that suggests that tractorization can improve the efficiency and quality of agricultural production and increase the profitability and income of the farmers. For instance, Mrema *et al*. (2008) highlighted that mechanization, including tractorization, significantly contributes to improved agricultural productivity and farmer income in developing countries. Similarly, Binswanger (1986) discussed the positive impacts of agricultural mechanization on crop yield and farm income, emphasizing the efficiency gains from mechanized farming. Takeshima *et al*. (2013) provided empirical evidence on the benefits of tractorization for crop productivity and farm income in Nigeria, which aligns with the findings of this study. Sims

and Kienzle (2017) also demonstrated how agricultural mechanization, particularly through the use of tractors, enhances productivity and profitability for smallholder farmers. Additionally, Daum and Birner (2020) offered insights into the role of mechanization in increasing agricultural productivity and income in sub-Saharan Africa. Therefore, the positive effects of tractorization on crop yields, output value, and net income as observed in the present study are well-supported by the existing body of literature.

The second hypothesis stated that tractorization had a positive and significant effect on food expenditure and dietary diversity score, and a negative and significant effect on food aid dependency and food consumption score. This hypothesis was also confirmed by the results, which show that tractorization increased food expenditure by 123 USD per month and dietary diversity score by 1.56 points, and decreased food aid dependency by 0.23 points and food consumption score by 2.34 points, on average, compared to the non-tractorized households. These results imply that tractorization enhanced the food security and resilience of the farmers by increasing the availability and diversity of food crops and reducing the dependency on food aid. These results are also in line with the literature that indicates that tractorization can improve the food security and nutrition of the rural households (Pingali *et al*.,1987; Diao *et al*., 2016).

The third hypothesis stated that the effects of tractorization varied across different types of crops, farm sizes, and Agro-ecological zones. This hypothesis was supported by the results, which showed that the effects of tractorization were larger and more significant for maize, medium-sized farms, and humid zones, respectively, than for other subgroups. These results suggest that tractorization had different impacts on different types of crops, depending on the suitability and compatibility of the technology with the crop characteristics and the environmental conditions. These results also imply that tractorization had different effects on different sizes of farms, depending on the economies of scale and the access and affordability of the technology. These results are supported by the literature that shows that tractorization can have heterogeneous effects on different types of crops and farms (Pingali *et al*., 1987; Diao *et al*., 2016).

The fourth hypothesis stated that the effects of tractorization were mediated by labour-saving, land expansion, input intensification, and crop diversification. This hypothesis was validated by the results, which showed that tractorization had positive and significant effects on these mechanisms, and that they explained the effects of tractorization on food security. These results reveal the pathways through which tractorization affects food security, and how they are influenced by the moderating variables.

These findings are consistent with the literature, which suggests that tractorization can influence food security through various mechanisms. For example, Pingali *et al*. (1987) discuss the role of agricultural mechanization in enhancing productivity through labour-saving technologies and input intensification. Similarly, Diao *et al*. (2016) emphasize the importance of crop diversification and land expansion in improving food security outcomes.

Moreover, Reardon *et al*. (2021) highlight the significance of input intensification and labour-saving technologies in enhancing agricultural productivity and food security in developing countries. These studies collectively support the notion that tractorization can positively impact food security by improving labour efficiency, expanding cultivated land, intensifying input use, and diversifying crops.

This has many implications and contributions for the research topic and field. First, it provides novel and comprehensive evidence on the role of tractorization in enhancing food security and resilience in a conflict-affected region in Nigeria. This study fills a gap in the literature on the effects and determinants of agricultural mechanization in Nigeria, especially in the context of conflict and instability. Second, this study contributes to the literature on agricultural mechanization and sustainable agri-food system transformation in the Global South, by showing the benefits and challenges of tractorization for crop productivity, income, and food security, and the factors and mechanisms that influence them. Third, it provides policy implications and recommendations for promoting inclusive and sustainable tractorization and food security in southern Borno and other similar contexts; providing subsidies, credits, and insurance schemes, improving the infrastructure, maintenance, and extension services, encouraging the formation and participation of cooperatives, associations, and service providers, promoting the adoption of improved crop varieties and agronomic, enhancing the post-harvest management and marketing of the crops and strengthening the resilience and security of the farmers and the region by providing humanitarian assistance, peacebuilding initiatives, and livelihood diversification opportunities.

CONCLUSION

This study evaluated the impact of tractorization on food security and resilience among conflict-affected farmers in southern Borno, Nigeria. Tractorization involves using tractors for land preparation and other agricultural operations. The study used household survey data and propensity score matching methods to assess how tractorization affected crop productivity, income, and food security indicators. It also reviewed existing literature and data on tractorization and food security in Nigeria and other contexts, comparing the findings with its hypotheses.

The study found that tractorization had positive effects on crop yield, output value, net income, food expenditure, and dietary diversity score. Conversely, it had negative effects on food aid dependency and food consumption score. Its impact varied by crop type, farm size, and agro-ecological zone, and these effects were mediated by labour-saving technologies, land expansion, input intensification, and crop diversification. Overall, the study concluded that tractorization could enhance food security and resilience in southern Borno, while also acknowledging the study's limitations and challenges. It provided implications and recommendations for future research or action.

The study offered 10 recommendations to promote tractorization and enhance food security in southern Borno. Firstly, it suggested providing financial and institutional support to reduce the costs and risks associated with adopting tractors. Secondly, improving infrastructure, maintenance, and extension services was suggested to enhance the accessibility and reliability of tractor services. Thirdly, the study proposed encouraging cooperative, associations, and service providers to facilitate tractor sharing and improve coordination among farmers. Others include promoting the adoption of improved crop varieties and agronomic practices that are compatible with tractorization; enhancing post-harvest management and marketing to increase value addition and reduce losses; and strengthening resilience and security through humanitarian assistance, peace-building, and diversification of means of livelihood.

Moreover, the study suggested expanding the scope of similar studies to include other regions and states within Nigeria and sub-Saharan Africa. It also recommended extending the duration of studies to capture long-term effects and seasonal variations of tractorization. Enriching data and methods with qualitative approaches, such as interviews and focus groups, to gain more perspectives from stakeholders was also recommended. Finally, incorporating other dimensions of food security and welfare to measure broader impacts of tractorization was advised.

These recommendations aim to tackle the challenges identified and maximize the benefits of tractorization for enhancing food security and resilience in southern Borno and similar regions.

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AUTHOR'S CONTRIBUTIONS

I declare that I am the sole author of this paper.

CONFLICT OF INTERESTS

The author declares no conflict of interests.

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