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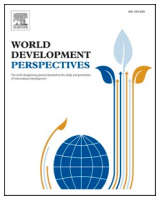

Research paper

The joint effects of terrorism and land access on livestock production decisions: Evidence from northern Nigeria

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ABSTRACT

Livestock production is an integral part of the livelihoods of many households around the developing world and plays a significant role in farming households' food and nutrition security. However, conflict is a major challenge for livestock production in Africa and Nigeria in particular. We employ the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) panel data for Nigeria with a global georeferenced conflict dataset to examine the effect of terrorism on small-scale livestock production and the role of agricultural land access. Terrorism is an important factor that undermines livestock production. We find that increase in the incidents of terrorism reduces cattle herd size but does not reduce the herd size of households that manage a larger area of land. Also, terrorism significantly increases livestock diversification independently and jointly with land access. However, higher fatalities from terrorism reduces herd size irrespective of the size of land managed by households. Our findings suggest a plausible land abandonment in areas where terrorism is severe. Curbing terrorism in Nigeria would ensure farmers have physical access to their land and sustain livestock production.

1. Introduction

Livestock production is important for the food and nutrition security of countries around the world, with a more direct influence on the socioeconomic status of developing countries, especially in Sub-Saharan Africa (SSA), where it constitutes a significant source of livelihood. However, many challenges, including global climate change, regulatory policies, population increase, urbanization, and conflict, confront livestock production (Latino, Pica-Ciamarra, & Wisser, 2020; Simpkin et al., 2020; Thornton, 2010). More importantly and in recent years, armed conflicts have increased in some countries in SSA (ACLED, 2019). The immediate impacts are the destruction of lives, livelihoods, properties, and infrastructure. Furthermore, exposure to armed conflicts creates a level of risk that influences agricultural production decisions, with attendant effects on the food and nutrition security of the affected population (FAO et al., 2017, 2019).

Empirical evidence on the impacts of armed conflicts on agricultural production – crops and livestock, including land use or access has grown in recent years (Adelaja & George, 2019a, 2019b; George, Adelaja, & Awokuse, 2021; Rockmore, 2020). Armed conflicts are shown to have a devastating effect on livestock production by direct destruction or indirectly through their effects on institutions and services that support livestock production (Adelaja & George, 2019a; Anne-Judith & Kinsumba, 2019; Gebreyes et al., 2016). Furthermore, armed conflict effects on agricultural land include farmland abandonment, reduced land use, and cultivation of previously uncultivated land (Baumann & Kuemmerle, 2016; Eklund et al., 2017; Gorsevski et al., 2012). However, some of the findings on the effects of armed conflicts on agricultural land are not empirically verified and lack contextual reality.

Evidence on the types of agricultural production farmers practice on agricultural land in conflict situations is mixed (Adelaja & George, 2019b; Chauveau & Richards, 2008). More importantly, land use for small-scale livestock production during conflict has not received sufficient research attention despite land being an essential asset in livestock production. Further evidence from the study by Adelaja and George (2019b) in Nigeria shows that terrorism intensity increased the average size of plots farmed and the total area of land managed by households, albeit increasing the percentage of land left fallow. Though it seems counter-intuitive, the study suggests that households might have claimed the management or control of lands belonging to neighbours, friends, and family members that fled their land to other locations.

There is evidence that increased land size managed by households in conflict situations encouraged farmers to produce crops less susceptible to conflict risk as farmers embraced crop diversification (Adelaja &

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George, 2019b). Such production decisions may be strategies for households to cope with conflict and mitigate its effects on agricultural livelihoods, as studies have shown that households learn to live with conflict over time by devising strategies to safeguard livelihoods and food consumption (Arias, Ibáñez, & Zambrano, 2019; Martin-Shields & Stojetz, 2019; Verpoorten, 2009). However, empirical studies suggesting that access to agricultural land may shape small-scale livestock production decisions in conflict situations are limited, especially in Nigeria. This paucity of evidence limits policy options toward mitigating conflict effects on livestock production. Our study is therefore motivated based on the need to understand land access's role in small-scale livestock production in conflict situations.

This study examines the effects of terrorism on livestock herd size and diversification and the role access to agricultural land plays in mitigating the effect of conflict on livestock production decisions. We focus our study on northern Nigeria as the region is home to a significant proportion of livestock-holding households in Nigeria, with vast hectares of land used for agricultural activities and where the highest incidents of terrorism are recorded (ACLED, 2019). The northeast region of Nigeria started experiencing terrorism in mid-2009 following a series of attacks in the region by the Boko Haram Islamic sect, from where terrorism spread to other northern regions. Many of the attacks were targeted at communities where agricultural production is the main livelihood activity of about 80 per cent of the population (Kah, 2017).

We use nationally representative household panel data with global georeferenced conflict data to quantify the effects of terrorism from Boko Haram on livestock production. We use two dimensions of conflict, incidents of terrorism and fatalities from terrorism, to provide more insights into households' livestock production response to different degrees of terrorism exposure. We employ a random-effects Tobit regression estimation strategy and explore the time-varying information in the ongoing terrorism situation. This approach has limited application in most empirical studies of this nature.

Our findings confirm the destructive effects of terrorism on livestock production in Nigeria. However, households diversify livestock production to cope with conflict. We find that terrorism reduces household herd size, but households with more access to agricultural land may increase cattle herd size only where attacks are associated with fewer fatalities. This study makes two significant contributions to the existing literature. First, it shows that access to agricultural land has a mitigating role in terrorism's effect on livestock production and may help households build resilience. Second, households are likely to build resilience in conflict situations where attacks are associated with fewer fatalities but are likely to abandon land assets and agricultural activities where and when attacks are fatal. This study shows, among others, the imperative of curtailing the severity of conflict among farming communities. It is relevant for designing conflict-sensitive interventions toward sustainable livestock production in Nigeria.

The rest of the paper is structured as follows. The second section provides a background on terrorism in Nigeria and explores existing literature to discuss small-scale livestock production and agricultural land access/use in conflict situations. The third section presents the data and empirical strategy. Results and discussion of findings are presented in the fourth section, while the fifth section concludes by summarizing key findings and drawing implications of the study for policy.

2. Background

2.1. Overview of terrorism in Nigeria

Nigeria has witnessed a significant rise in armed conflicts since 2009, majorly terrorism – a class of armed conflicts with a notable presence in northeast Nigeria. The act of terrorism from Boko Haram or the Islamic State West Africa stems from an ideology to establish an Islamic state in Nigeria using violence and intimidation to achieve their objectives (Walker, 2012). As of 2019, Nigeria was ranked third in the global terrorism index and recorded the second-largest terrorism-related fatalities worldwide (Institute for Economics & Peace, 2020). Terrorist attacks are often expressed through detonations of an improvised explosive device (IED) in communities and public places and gunfire at civilians by armed non-state actors such as Boko Haram. According to the monitoring estimates of Action on Armed Violence (AOAV) (2021), IEDs accounted for about 92 per cent of civilian deaths and injuries between 2011 and 2020. Terrorism constitutes the most significant threat to Nigeria's farming communities, with severe consequences for food production (Kaila & Azad, 2019).

Armed conflicts in Nigeria are ongoing and have taken different forms, including the activities of Fulani Ethnic Militia (FEM), bandits or "unknown gunmen", perpetrating mass kidnapping for ransom, cattle rustling, and killing of innocent citizens (Chinwokwu & Michael, 2019). Evidence has shown that proceeds from these acts of criminalities, abduction for ransom and cattle rustling, in particular, are partly used by terrorist groups to finance arms purchases (FATF-GIABA-GABAC, 2016; Forest, 2012). For example, there is a high correlation between increasing incidents of cattle rustling in northern Nigeria and the rise in violent attacks from Boko Haram (Okoli, 2019).

Armed conflicts took a new turn in 2009 following a series of attacks by Boko Haram in the northeast, and subsequent clashes between the sect and the Nigerian military led to some government security forces losing their lives (Maiangwa et al., 2012; Walker, 2012). Terrorism and the rise in other forms of armed conflicts are also connected (Monteleone, 2016). This linkage is further reinforced in countries with high economic, political, and social fragility that are often exposed to a vicious circle of conflicts, given their weak institutional and social capacity to prevent reprisal attacks and protect livelihoods (McKay & Thorbecke, 2019).

2.2. Small-scale livestock production and agricultural land access/use in conflict situations

In Nigeria, livestock production is dominated by smallholders, mainly in the subsistence crop-livestock production system. The Tropical Livestock Unit (TLU) in Nigeria is 7.4 on average and mainly from cattle, sheep, goats, and poultry (National Bureau of Statistics & World Bank, 2016). Regarding the production system, cattle, sometimes with sheep and goats, are largely reared through pastoralism –free grazing and about 78 per cent of poultry birds are kept in free-range or semi-intensive production systems (FAO, 2018).

Land and livestock are essential assets upon which farmers make production decisions to maximize livelihood outcomes. In Nigeria, however, livestock production is most vulnerable to external factors, chief of which is the rising level of conflicts, including terrorism. Terrorism's effects on the agricultural sector can be classified as direct or indirect (Adelaja & George, 2019a) and transmitted through different channels (Arias et al., 2019), including disruption to farming operations and supporting services and destruction of farm inputs or outputs. The direct effects of terrorism on cultivated land and livestock assets and labour use or access may cause households to alter their agricultural production behaviour. However, households in conflict often adjust production decisions to curtail losses, mitigate production risk, and build resilience (Arias et al., 2019; Rockmore, 2020).

Agricultural land is an essential input in livestock production, which can improve production as land can be used to grow hay or crop for livestock feed or leased out for income to increase farm investment. However, agricultural land use change in terms of land abandonment in conflict (Baumann et al., 2015), and farmers cultivating previously uncultivated land in farther and safer locations are often suggested (Eklund et al., 2017). According to the study by Adelaja and George (2019b), households adjust where and what is cultivated on land by engaging in mixed-farming or crop diversification and expanding farming activities in other locations that are less prone to conflict. Further evidence suggests that households in conflict regions allocate more land to the

cultivation of crops like cassava or engage in agroforestry that requires less attention or management (Chauveau & Richards, 2008; Quandt & McCabe, 2017).

The consequences of conflict exposure for land use change are further explained in Adelaja and George (2019b). Their study shows that households in regions with increased terrorist attacks manage more land size, suggesting that such land may belong to neighbours, friends, and family that have abandoned their farmland. Again, they show a fall in land value in conflict-prone regions as land investment risk increases, which is another plausible reason some households may have more land areas in their possession. Evidence suggests that risk-tolerant farmers may acquire more land as victims of armed conflicts are more likely to take risks than nonvictims (Fatas et al., 2021). Even though Adelaja and George's study finds no significant relationship between conflict exposure and an increase in land purchase in Nigeria.

The broad literature on risk and livelihood activities reveals that livelihood risk perception is associated with livelihood diversification (Block & Webb, 2001). Agricultural production diversification is often a risk mitigation strategy that helps spread risk among alternative production activities to sustain household income, ensure food access, and smooth consumption (Perry, 2002). For example, livestock-holding households may diversify livestock production in response to conflict risk. However, the degree of diversification as a strategy for mitigating risk may vary according to the risk-bearing capacities of households vis-à-vis their asset ownership, such as land assets, institutional support services, and perception of conflict risk (Mekuria & Mekonnen, 2018). Households with fewer assets (e.g., small landholders) and lower risk management capacity may be pushed to diversify livestock or settle for species less susceptible to shocks in response to limitations imposed on them by high conflict exposure (Gebreyes et al., 2016). Conversely, livestock diversification may be driven by higher risk-bearing capacity for households with more agricultural assets (Gebreyes et al., 2016).

3. Data and empirical strategy

3.1. Data

We use data from the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria with a corresponding global georeferenced conflict dataset, the Armed conflicts Location and Event Data (ACLED), covering the period from 2010 to 2016. We merge the LSMS-ISA datasets with the ACLED dataset using the households survey locations (the local government areas – LGAs[1]) and time (year) corresponding to the locations (LGAs) and time (year) of conflict events in the ACLED. The ACLED is the highest quality real-time data that reports on political violence and unrest worldwide (Raleigh et al., 2010). The data records fatalities from conflict and types of conflict events such as violent conflicts (battles, explosions/remote violence, violence against civilians) and non-violent conflicts (riots and protests). From the event types, and sub-event types, including detailed information notes, one can distil events further into categories and perpetrators and compute the incidents of conflict events by actors. This method has been widely used; see, for example, Dabalen and Paulm (2014) and Adelaja and George (2019). For this present study, we focused on events perpetrated by the Boko Haram terrorist group as the prevailing conflict events in northern Nigeria during the periods this study covers.

The LSMS-ISA is a panel data and nationally representative, being an effort by the World Bank and the Nigeria National Bureau of Statistics (NBS). The survey is in Waves[2]. Wave 1, which started in 2010, was collected in post-planting and post-harvest agricultural seasons, respectively, in 2010 and 2011, and consisted of 5,000 households, comprising 66 per cent of agricultural households. We use the agricultural household[3] sub-sample for northern Nigeria with sample sizes of 2,023 in 2010/11 (Wave 1), 1,913 in 2012/13 (Wave 2), and 1,863 in 2015/16 (Wave 3). The LSMS-ISA has detailed information on livestock ownership and is integrated with a wide range of household socioeconomic characteristics.

3.1.1. Measurement of livestock production and the main determinants

a. Measurement of livestock production

We employ-two dimensions of livestock production decisions as our outcome variables. First is the herd size, measured by the Tropical Livestock Unit (TLU), which describes livestock numbers across species and indicates the total livestock owned in kilograms. We measure the herd size of cattle and small livestock (sheep, goats, and poultry) separately. The TLU calculation involves assigning a score of 1.0 TLU to a single animal weighing 250 kg, thereby generating a weighting factor for each animal (Jahnke & Jahnke, 1982). The number of each species of animal owned by the household is multiplied by the animal TLU coefficient. Studies have shown that TLU is a valuable proxy for household economic status, food security and resilience in most shock situations (Ducrotoy et al., 2017).

The second dimension of livestock production is the livestock diversification index (LDI), which we derived using the Herfindahl Index (HI) as used by Pal and Kar (2012). The value of livestock species owned by the households is provided in the data. The share in the total value of livestock owned by each household is calculated as follows: $S_k = \frac{R_k}{\sum_{k=1}^{n} R_k}$, where S_k is the share for the k^{th} value of livestock species in the total for all value of livestock own by household. The value for the k^{th} livestock for a sample household is represented as R_k; and $\sum_{k=1}^{n} R_k$ is the total value from livestock $k = 1, 2,\ldots, n$ represents the number of species own. Given the HI to be: $HI_L = \sum_{k=1}^{n} S_k^2$. From the HI_L we compute the Simpson Diversity Index (SDI) to represent our LDI as: SDI = 1–HI_L. where HI_L is the computed Herfindahl Index. The LDI gives the extent of diversification with a high level of diversification tending towards one (1) and specialisation tending towards zero (0). Using this index provides a more accurate measure of livestock diversification than the number of livestock species produced by the household (Murendo et al., 2019).

b. Measurement of terrorism

Terrorism from Boko Haram is measured using three indicators. First, households that live in the LGAs where at least one terrorist attack from Boko Haram happened within a year are exposed to terrorism; hence *exposure to terrorism* is a binary variable that takes the value of one (1) if a household is exposed to terrorism and zero (0) if not. We employ this variable in the descriptive analysis. Second is the *incidents of terrorism* variable, captured by the number of terrorist attacks within a year in an LGA, and measures conflict intensity. The third is the *fatalities from terrorism* variable, which measures conflict severity and represents the number of casualties attributed to terrorism within a year in an LGA. The last two measures are employed in the empirical analysis as continuous

[1] LGAs are the third tier of government next to the states in Nigeria. There are 774 LGAs in Nigeria across the 36 states, including the Federal Capital Territory in Abuja.

[2] We exclude Wave 4 (2018/2019) in this study, as insecurity in the locations and displacement of more households in the baseline necessitated a sample redesigning, returning <30 per cent of the base households in the panel.

[3] An agricultural household is a household with livestock and/or agricultural land with some under cultivation.

variables. Employing these two conflict measures could provide additional insights into household livestock production response to different degrees of terrorism. Some other studies have used different measures of conflict to show their effect on agricultural production, but with mixed results (Adelaja & George, 2019a; Arias et al., 2019; Rockmore, 2011). However, employing these measures as determining factors in livestock production may yield different results.

c. Measurement of agricultural land access

The agricultural land access variable is proxied by the total agricultural land size (including plots cultivated, fallow, or pastureland) presently owned or managed by households. We adopt the definition of agricultural land access in Brück and Schindler (2009) which consider land access as the ability of a household to claim a parcel of land for current productive use or as fallow for future cultivation or usage. Therefore, in our definition, the more land size owned or managed by a household, the more land access the household has. However, this may not necessarily mean physical access in conflict situations. Nevertheless, it is worth investigating whether such land access still influences farming household livestock production decisions through direct use of land for grazing or indirectly through crop/hay production for feed and capital accumulation.

d. Other control variables

As informed by literature, other variables that may influence livestock production decisions are added to our empirical estimations as controls. One of these variables is family labour supply, as proxied by the number of household members disaggregated by age categories (35 years and above, 18–35 years, below 18 years old). Other variables are access to extension advice, education of household head, women's decision making on income and assets ownership computed as the share of women in the household, and household economic status using the wealth index.[4] We also include rainfall variable as livestock production could respond well to optimal rainfall as it increases the chances that livestock will have adequate access to water and feeds/folders. The geographical locations where households live are also controlled. Household distance to the nearest population centre was used to proxy for household location in rural or urban, and the geopolitical region dummies were used to control for geographical heterogeneity in livestock production. Variables used and descriptions are presented in Table 1.

3.2. Empirical strategy

This section presents the empirical strategy for modelling the relationship between terrorism, land access, and livestock production decisions. The following hypotheses are tested. Hypothesis 1: terrorism decreases the herd size of cattle and small livestock, but the effect varies with land access. Hypothesis 2: terrorism increases livestock diversification, but the effect varies with land access. Hypothesis 3: incidents of terrorism cause households to adjust livestock production differently from fatalities from terrorism.

[4] The wealth index is measured as the first principal component of indicators of household assets (see Rutstein & Johnson, 2004). We compute the wealth index using principal components analysis on variables such as the type of materials use for housing–wall material, roofing material, and flooring material; ownership of car, motor-bike, bicycle, sewing machine, furniture, generator, mattress, fan, radio, cassette recorder, television set, iron, DVD player, refrigerator, mobile phone, wheelbarrow, cutlass, and hoe; and the use of or access to public facilities like water, electricity, and refuse disposal.

Table 1
Description of variables used for analysis.

Variable	Description
Livestock production outcomes	
TLU of cattle	Tropical Livestock Unit (TLU) of cattle
TLU of small livestock	Tropical Livestock Unit (TLU) of small livestock (sheep, goat, and poultry)
Livestock diversification index	Livestock Diversification Index (LDI)
Explanatory variables	
Exposure to terrorism	1 if household lives in LGA that experienced at least one terrorist attack within the past 12 months preceding the survey month
Incidents of terrorism	The total number of terrorist attacks in LGA within the past 12 months preceding the survey month
Fatalities from terrorism	The total number of deaths attributed to terrorist attacks in LGA within the past 12 months preceding the survey month
Land size	Total agricultural land available to a household in hectares (cultivated, fallow/pasture)
Control variables	
Access to extension services	Household received extension advice on animal care & diseases
Adult household members	Number of household members above 35 years old
Youth household members	Number of household members 18–35 years old
Children household members	Number of household members <18 years old
Wealth index	Wealth index calculated from durable assets owned, excluding livestock and land
Household head years of education	Years of education completed by the household head
Women decide on income	Share of women in the household that participated in the decision on household income
Women own assets	1 if women own any of these assets – crop, animal, and household assets
Total rainfall	12-month total rainfall (mm) in Jan-Dec, starting January to December
Household distance to population centre	Household Distance in (kms) to nearest population centre with + 20,000
Northcentral region	Household is in Northcentral
Northeast region	Household is in Northeast
Northwest region (Based category)	Household is in Northwest

3.2.1. Regression model

Our hypotheses are tested using random-effects Tobit model. Tobit regression is appropriate for a corner solution outcome variable such as our dependent variables, which have a censored distribution with a finite probability of a zero outcome and a normal distributed positive value. Also, due to the panel nature of our data, ordinary least squares and fixed effects estimation will fail to yield an unbiased estimation of the model. However, random-effects assume that the unobserved time-invariant random component of the model is unrelated to the regressors, which helps to estimate the values of the time-invariant coefficients in our model. The model is thus specified:

$$Y_{hlt} = \beta_0 + \beta_1 terrorism_{lt} + \beta_2 landsize_{hlt} + \beta_3 terrorism_{lt} * landsize_{hlt} + \beta_4 X_{hlt} + \mu_h + \varepsilon_{hlt} \cdots \quad (1)$$

where Y_{hlt} represents the three outcome variables; TLU of cattle (cattle herd size), TLU of small livestock (small livestock herd size), and LDI (livestock diversification index) of household (h) in LGA (l) at time (t), with each outcome regressed separately in the model. These outcomes are explained by $landsize_{hlt}$, and $terrorism_{lt}$, which entered the models as either fatalities from terrorism or incidents from terrorism. Other control variables include a set of household and regional characteristics captured in vector X_{hlt}. The household random effect is μ_h, and ε_{hlt} is the error term.

4. Results and discussion

4.1. Descriptive results

In Table 2, the summary statistics results of our variables show the mean comparison between households that are exposed to terrorism and those that are not. About 23 per cent of the households are exposed to terrorism, out of which 38 per cent are in the northcentral and 40 per cent are in the northeast. Households not exposed to terrorism own more cattle (average of 1.97 TLU) than households in locations that are exposed to terrorism, with an average of 0.99 TLU. The result further shows that households that are exposed to terrorism have an average of 0.63 TLU for small livestock, a little higher than the TLU in areas with no terrorism. There are some theoretical underpinnings to support the findings. For example, some studies suggest that livestock keepers diversify livestock production to species that are less susceptible to conflict shocks and constitute less burden to manage (Arias et al., 2019).

We present the violin plots (Fig. 1) of livestock diversification of households that are exposed to terrorism and those not exposed to terrorism using a density plot function – a rotated and smoothed histogram. Violin plots show the shapes (density plot) of the LDI for the two categories of households and the summary statistics. The width of the density plot shows how frequently the value occurs in the dataset. Thus, the broader regions represent values that occur more frequently, which is between 0 and 0.1 and represent the first quartile regions. In contrast, values in the narrow regions occur less frequently, third quartile regions. The median is represented by the white dot in the box's centre, while the box's length is the interquartile range, and the line protruding outside the box is the range. The results show more skewness in the distribution of the median and quantiles of livestock diversification for the population not exposed to terrorism toward a high level of species specialization than those exposed to terrorism, and respectively having a mean of 0.13 and 0.17, as shown in Table 2.

Also, households exposed to terrorism have less access to agricultural land and extension services than their counterparts in no-conflict locations. Moreover, there are also more educated heads, more adult members, and more women owning assets and deciding on income in locations under terrorist attacks than areas with no attacks.

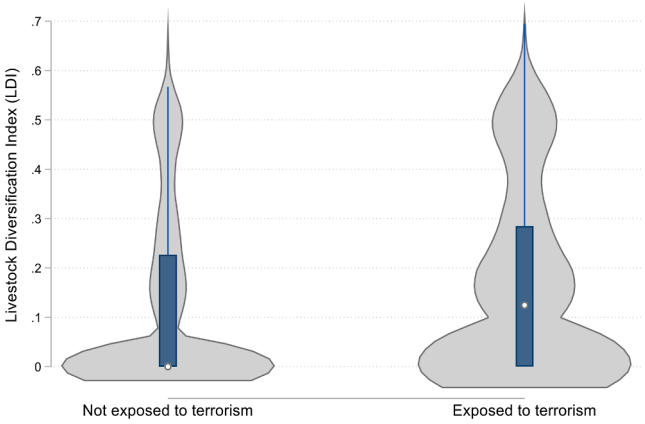

Fig. 1. Violin plots of Livestock Diversity Index by exposure to terrorism.

4.2. Empirical results and discussion

In this section, we report the regression results of the joint effects of terrorism and land access on livestock production decisions in Tables 3A, 3B and 3C. The Tables respectively represent the results with cattle herd size (TLU), small livestock herd size (TLU), and livestock diversification index as dependent variables. We also discuss the main findings. The Tables present the regression coefficients and the coefficients of the corresponding Average Marginal Effects (AME), which we report and discuss. AME is estimated by calculating marginal effects for every observation in the sample and then averaging across the effects. In all the Tables, we first present models without the interaction of terrorism and land access (Models 1 and 2) before presenting our main model specification in Eq. (1) in Models 3 and 4, which estimates the combined effect of terrorism and land access on livestock production decisions. The Models are also distinguished by their choice of terrorism measures. Models 1 and 3 employ incidents of terrorism, while Models 2

Table 2
Summary statistics of variables used for analysis.

	Pooled		Not exposed to terrorism		Exposed to terrorism		Mean difference
	Mean	SD	Mean	SD	Mean	SD	
Dependent variables							
TLU of cattle (index)	1.75	9.04	1.97	10.00	0.99	4.32	−0.98***
TLU of small livestock (index)	0.61	0.96	0.60	0.97	0.63	0.94	0.03
Livestock diversification (index)	0.15	0.19	0.13	0.18	0.17	0.19	0.04***
Explanatory variables							
Exposure to terrorism	0.23						
Incidents of terrorism (number)	0.59	2.13					
Fatalities from terrorism (number)	3.29	16.00					
Land size (hectare)	2.24	3.35	2.32	3.49	1.93	2.76	−0.39***
Access to extension services (1/0)	0.29		0.30		0.23		−0.07***
Adult household members (number)	1.48	1.05	1.46	1.03	1.54	1.11	0.08**
Youth household members (number)	1.48	1.18	1.45	1.12	1.58	1.37	0.14***
Children household members (number)	5.03	3.07	5.03	3.07	5.03	3.06	−0.00
Wealth index (index)	−0.77	1.93	−0.87	1.86	−0.44	2.15	0.43***
Household head years of education (year)	8.73	5.81	8.44	5.74	9.74	5.95	1.30***
Women decide on income (share)	0.09	0.14	0.08	0.14	0.11	0.15	0.02***
Women own assets (1/0)	0.57		0.55		0.62		0.07***
Total rainfall (mm)	979.16	286.49	955.69	282.16	1059.81	286.70	104.13***
Household distance to population center (km)	31.05	21.17	31.26	21.32	30.32	20.66	−0.94*
Northcentral region (1/0)	0.29		0.26		0.38		0.12***
Northeast region (1/0)	0.32		0.30		0.40		0.11***
Northwest region (1/0)	0.39		0.44		0.21		−0.22***
Sample size	5,753 (4,487)		4,456 (3,532)		1,297 (955)		

Note: The significance of the mean difference in characteristics between households that are exposed to terrorism and those not exposed are based on independent sample t-tests for continuous variables and Pearson chi-square test for categorical variables.
Sample size in parentheses is for livestock holding households used for analyzing livestock diversification.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ denote significance at 1 %, 5 % and 10 % significance levels respectively. SD is the standard deviation.

Table 3A
Results of the relationship between terrorism, land access and cattle herd size.

	Random Effects Tobit estimates				Average Marginal Effects (AME)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Incidents of terrorism	−1.450**		−2.654***		−0.281**		−0.223*	
	(0.626)		(0.806)		(0.122)		(0.130)	
Fatalities from terrorism		−0.109***		−0.097**		−0.021***		−0.022***
		(0.040)		(0.049)		(0.008)		(0.009)
Incidents of terrorism*Land size			0.602***					
			(0.212)					
Fatalities from terrorism*Land size				−0.007				
				(0.019)				
Land size	0.178*	0.179*	0.075	0.186*	0.034*	0.035*	0.039*	0.033
	(0.108)	(0.108)	(0.114)	(0.109)	(0.020)	(0.021)	(0.021)	(0.021)
Access to extension services	6.178***	6.211***	6.281***	6.199***	1.196***	1.202***	1.215***	1.200***
	(0.813)	(0.813)	(0.814)	(0.814)	(0.161)	(0.161)	(0.161)	(0.161)
Adult household members	2.429***	2.439***	2.422***	2.439***	0.473***	0.475***	0.471***	0.475***
	(0.417)	(0.417)	(0.417)	(0.417)	(0.082)	(0.082)	(0.082)	(0.082)
Youth household members	1.947***	1.958***	1.917***	1.960***	0.378***	0.380***	0.372***	0.381***
	(0.380)	(0.381)	(0.381)	(0.381)	(0.075)	(0.075)	(0.075)	(0.075)
Children household members	0.456***	0.450***	0.441***	0.451***	0.089***	0.087***	0.086***	0.088***
	(0.147)	(0.147)	(0.147)	(0.147)	(0.029)	(0.029)	(0.029)	(0.029)
Wealth index	−2.114***	−2.085***	−2.073***	−2.086***	−0.408***	−0.403***	−0.400***	−0.403***
	(0.293)	(0.293)	(0.294)	(0.293)	(0.059)	(0.059)	(0.059)	(0.059)
Household head years of education	−0.582***	−0.584***	−0.585***	−0.583***	−0.113***	−0.114***	−0.114***	−0.113***
	(0.082)	(0.082)	(0.082)	(0.082)	(0.016)	(0.016)	(0.016)	(0.016)
Women decide on income	27.343***	27.534***	27.232***	27.527***	5.326***	5.360***	5.299***	5.359***
	(2.489)	(2.492)	(2.490)	(2.491)	(0.503)	(0.504)	(0.503)	(0.504)
Women own assets	0.328	0.378	0.361	0.376	0.056	0.066	0.062	0.065
	(0.791)	(0.792)	(0.791)	(0.792)	(0.154)	(0.154)	(0.154)	(0.154)
Total rainfall	−0.001	−0.001	−0.001	−0.001	−0.000	−0.000	−0.000	−0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Distance to population center	0.061***	0.060***	0.061***	0.060***	0.012***	0.012***	0.012***	0.012***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.004)	(0.004)	(0.004)	(0.004)
Northcentral region	−3.618***	−3.569***	−3.565***	−3.571***	−0.686***	−0.677***	−0.675***	−0.677***
	(1.326)	(1.326)	(1.327)	(1.326)	(0.259)	(0.259)	(0.259)	(0.259)
Northeast region	0.876	0.819	0.808	0.834	0.172	0.161	0.159	0.164
	(1.057)	(1.051)	(1.059)	(1.052)	(0.206)	(0.205)	(0.206)	(0.205)
Constant	−29.374***	−29.413***	−28.762***	−29.458***				
	(2.294)	(2.294)	(2.303)	(2.298)				
sigma_u	12.023***	12.035***	12.059***	12.039***				
	(0.579)	(0.579)	(0.578)	(0.579)				
sigma_e	16.805***	16.802***	16.782***	16.799***				
	(0.396)	(0.396)	(0.396)	(0.396)				
Observations	5,799	5,799	5,799	5,799				
Number of households	2,148	2,148	2,148	2,148				
Log likelihoods	−7408	−7406	−7404	−7406				
Chi-squared	428.5	429.1	432.8	429.3				

Note: Standard errors in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

and 4 employ fatalities from terrorism. Next, we graphically present in Fig. 2 the results of the AME from Eq. (1) estimates for intuitive interpretation of the findings.

Results in Table 3A show that an increase in incidents of terrorism reduces the TLU of cattle by 0.281 (Model 1) and by 0.223 (Model 3) when households have access to land, but no significant effect on the TLU of small livestock as shown in Table 3B. However, an increase in fatalities from terrorism significantly reduces cattle herd size (Table 3A) and small livestock herd size (Table 3B) regardless of whether households have access to land. In the study by George, Adelaja, and Awokuse (2021) in Nigeria, fatalities from farmer-herder conflict have no significant effect on total livestock herd size but showed a negative effect on cattle herd size. Their finding is relatable as conflict between farmers and herders is an attack on cattle and may not affect small livestock species, unlike fatalities from the Boko Haram terrorist that have direct and indirect effects on livestock production (Adelaja & George, 2019a).

Some other studies also found that conflicts significantly reduced livestock herd size across livestock species (Anne-Judith & Kinsumba, 2019; Okafor & Chikalipah, 2021; Rockmore, 2011; Verpoorten, 2009). However, these studies do not show how access to land may mitigate such an effect. We find that access to land remains positive in Table 3A after the interaction with incidents of terrorism and increases the TLU of cattle by 0.04 (Model 3). The statistically significant negative effect of terrorism on livestock herd size follows the direction of results in our descriptive analysis and the tested hypotheses. The results also show that fatalities from terrorism have more substantial adverse effects on cattle and small livestock herd size than incidents from terrorism.

We further understand from Fig. 2 that the negative effect of incidents of terrorism (Panel A left) on cattle production attenuates in the positive direction as land access increases. In contrast, the negative effect of fatalities (Panel A right) on cattle production deepens as land access increases. Further in Panel B, access to agricultural land plays no significant role in mitigating the effect of terrorism on small livestock production. Even though small livestock may not require much land as cattle, access to land may indirectly contribute to small livestock production through crop residue.

In Table 3C, the results of livestock diversification show that an increase in the incidents of terrorism increases livestock diversification index by 0.008 (Model 1) and 0.01 (Model 4) as households have more access to land, while there is a significant relationship between an increase in fatalities and livestock diversification. Our result agrees with past studies that show conflict exposure pushes households to diversify livestock production to multiple species of small livestock to spread risk (e.g., Perry, 2002). Furthermore, the result in Fig. 2 (Panel C left) shows

Table 3B
Results of the relationship between terrorism, land access and small livestock herd size.

	Random Effects Tobit estimates				Average Marginal Effects (AME)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Incidents of terrorism	−0.015		−0.018		−0.009		−0.008	
	(0.020)		(0.024)		(0.013)		(0.014)	
Fatalities from terrorism		−0.002**		−0.002*		−0.002**		−0.002**
		(0.001)		(0.001)		(0.001)		(0.001)
Incidents of terrorism*Land size			0.002					
			(0.009)					
Fatalities from terrorism*Land size				−0.000				
				(0.000)				
Land size	0.015***	0.015***	0.014***	0.015***	0.008***	0.008***	0.009***	0.008***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Access to extension services	0.331***	0.329***	0.331***	0.329***	0.199***	0.198***	0.199***	0.198***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.021)	(0.021)	(0.021)	(0.021)
Adult household members	0.098***	0.098***	0.098***	0.098***	0.061***	0.061***	0.061***	0.061***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.010)	(0.010)	(0.010)	(0.010)
Youth household members	0.057***	0.058***	0.057***	0.058***	0.035***	0.035***	0.035***	0.035***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.009)	(0.009)	(0.009)	(0.009)
Children household members	0.027***	0.027***	0.027***	0.027***	0.016***	0.016***	0.016***	0.016***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)
Wealth index	−0.065***	−0.063***	−0.065***	−0.064***	−0.038***	−0.037***	−0.038***	−0.037***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.006)	(0.006)	(0.006)	(0.006)
Household head years of education	−0.004	−0.004	−0.004	−0.004	−0.002	−0.002	−0.002	−0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Women decide on income	2.196***	2.209***	2.195***	2.209***	1.350***	1.357***	1.349***	1.358***
	(0.107)	(0.107)	(0.107)	(0.107)	(0.066)	(0.066)	(0.066)	(0.066)
Women own assets	0.426***	0.428***	0.426***	0.428***	0.264***	0.265***	0.264***	0.265***
	(0.032)	(0.032)	(0.032)	(0.032)	(0.020)	(0.020)	(0.020)	(0.020)
Total rainfall	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distance to population center	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Northcentral region	−0.235***	−0.231***	−0.234***	−0.231***	−0.140***	−0.137***	−0.139***	−0.137***
	(0.049)	(0.049)	(0.049)	(0.049)	(0.030)	(0.030)	(0.030)	(0.030)
Northeast region	−0.023	−0.016	−0.023	−0.016	−0.013	−0.008	−0.013	−0.008
	(0.043)	(0.043)	(0.043)	(0.043)	(0.027)	(0.027)	(0.027)	(0.027)
Constant	−0.777***	−0.777***	−0.775***	−0.778***				
	(0.086)	(0.086)	(0.087)	(0.086)				
sigma_u	0.460***	0.458***	0.460***	0.458***				
	(0.024)	(0.024)	(0.024)	(0.024)				
sigma_e	0.997***	0.997***	0.997***	0.997***				
	(0.013)	(0.013)	(0.013)	(0.013)				
Observations	5,799	5,799	5,799	5,799				
Number of households	2,148	2,148	2,148	2,148				
Log likelihoods	−7475	−7472	−7475	−7472				
Chi-squared	1059	1065	1060	1065				

Note: Standard errors in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

that increased incidents of terrorism increases livestock diversification as land size increases. In contrast, increased fatalities from terrorism has no such effect on livestock diversification (Panel C right). In other words, households' decision to diversify livestock production is predicated on their gaining more access to agricultural land in conflict situations.

Our findings suggest that households may have physical access to their land for livestock production only when terrorism is not fatal in their LGA; otherwise, they have limited physical access to land. In addition, studies have shown that an increase in the severity of conflict resulted in land abandonment (Gorsevski et al., 2012). This result further suggests that increased fatalities from terrorism in our study locations made households to abandon land that could have supported livestock production. Thus, we posit that fatalities from conflict is a better measure for understanding the severity of conflict rather than the number of events, as a single event may be more destructive and record more causalities than ten events.

Some other factors also determine livestock production decisions with statistical significance. Access to extension services, household members across age groups, and women participating in major household decisions are positively associated with livestock production. Location far away from the population centre is associated with increased cattle production, while ownership of assets by women and total annual rainfall positively determines small livestock production. Household durable assets (wealth index) are negatively associated with livestock production and diversification, which may be because of the exclusion of land and livestock assets that represent the main household wealth assets in the computation of the wealth index. Household locations in the northcentral and those with educated heads are negatively associated with livestock production. Furthermore, increased years of education of household head, household members across age groups, women's assets ownership and decision on household income, total annual rainfall, and household distance to the population centre are positively associated with livestock diversification. Whereas access to extension services and being in either northcentral or northeast region as against locations in the northwest are negatively associated with livestock diversification.

Those variables exhibiting positive associations with livestock production decisions could help households build resilience for sustainable livestock production, which should be encouraged or protected. Likewise, the negative coefficients of access to extension services, and locations in the northcentral and northeast suggest that receiving extension services, and being in the northcentral and northeast are associated with livestock species specilisation. Providing agricultural

Table 3C
Results of the relationship between terrorism, land access and livestock diversification.

	Random Effects Tobit estimates				Average Marginal Effects (AME)			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Incidents of terrorism	0.016**		0.008		0.008**		0.010**	
	(0.008)		(0.009)		(0.004)		(0.004)	
Fatalities from terrorism		−0.000		−0.000		−0.000		−0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Incidents of terrorism*Land size			0.005					
			(0.003)					
Fatalities from terrorism*Land size				−0.000				
				(0.000)				
Land size	−0.002	−0.002	−0.003*	−0.002	−0.001	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Access to extension services	−0.048***	−0.049***	−0.047***	−0.049***	−0.024***	−0.025***	−0.024***	−0.025***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.006)	(0.006)	(0.006)	(0.006)
Adult household members	0.025***	0.025***	0.025***	0.025***	0.012***	0.012***	0.012***	0.012***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Youth household members	0.020***	0.020***	0.020***	0.020***	0.010***	0.010***	0.010***	0.010***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)
Children household members	0.004**	0.004**	0.004**	0.004**	0.002**	0.002**	0.002**	0.002**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Wealth index	−0.021***	−0.020***	−0.020***	−0.020***	−0.010***	−0.010***	−0.010***	−0.010***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Household head years of education	0.002*	0.002*	0.002*	0.002*	0.001*	0.001*	0.001*	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Women decide on income	0.543***	0.549***	0.541***	0.549***	0.270***	0.273***	0.269***	0.273***
	(0.036)	(0.036)	(0.036)	(0.036)	(0.018)	(0.018)	(0.018)	(0.018)
Women own assets	0.093***	0.093***	0.093***	0.093***	0.046***	0.046***	0.046***	0.046***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.006)	(0.006)	(0.006)	(0.006)
Total rainfall	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Distance to population center	0.001***	0.001***	0.001***	0.001***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Northcentral region	−0.135***	−0.134***	−0.135***	−0.134***	−0.067***	−0.067***	−0.067***	−0.067***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.007)	(0.007)	(0.007)	(0.007)
Northeast region	−0.066***	−0.060***	−0.067***	−0.060***	−0.033***	−0.030***	−0.033***	−0.030***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.006)	(0.006)	(0.006)	(0.006)
Constant	−0.252***	−0.251***	−0.247***	−0.251***				
	(0.029)	(0.029)	(0.029)	(0.029)				
sigma_u	0.000	0.000	0.000	0.000				
	(0.017)	(0.017)	(0.017)	(0.017)				
sigma_e	0.309***	0.310***	0.309***	0.310***				
	(0.005)	(0.005)	(0.005)	(0.005)				
Observations	4,487	4,487	4,487	4,487				
Number of households	1,947	1,947	1,947	1,947				
Log likelihoods	−2012	−2014	−2011	−2014				
Chi-squared	563.2	559.4	565.2	559.5				

Note: Standard errors in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

extension services to farmers is a crucial factor in agricultural production (Owens, Hoddinott, & Kinsey, 2003). The role of quality institutions in providing livelihood-enhancing services such as quality extension services to farmers cannot be over-emphasized in the light of some recent evidence linking institution quality to adequate food production in SSA (Cassimon et al., 2021; Ogunniyi et al., 2020). This argument is also valid for providing rural infrastructure and security to protect the lives and livelihoods of agricultural households.

5. Conclusion

Livestock production is an integral part of the livelihoods of many households around the developing world. It plays a major role in food and nutrition security and the general well-being of farming households. However, rising armed conflicts, especially in SSA present a significant threat to the sustainability of livestock production in the region. In this paper, we employ a panel data econometric strategy to examine the effect of terrorism on livestock production decisions and the role access to agricultural land play in sustaining livestock production in conflict situations. This study confirms previous findings on the destructive effect of conflict on livestock production. It, however, further shows that access to agricultural land is an essential factor that needs to be maintained to sustain livestock production in conflict situations. We also demonstrate that larger land availability is not associated with increased livestock production when the households are in LGAs where there are high fatalities due to terrorism. A plausible explanation may be the abandonment of land in such areas or the lack of physical access to land in conflict-affected LGAs. Evidence presented in this study is limited in the literature and may be of interest to policy researchers to substantiate. Among other contributions, this study shows the imperative of curtailing the severity of conflict among farming communities.

Government should make an effort toward curtailing the spread of conflicts, given their negative impact on livestock livelihoods, as highlighted in this study. This study also suggests designing conflict-sensitive livestock-related interventions in protracted conflict. One of such could be the promotion of small livestock production such as family poultry, rabbitry, and other livestock species that are less vulnerable to destruction during conflict. In addition, specific humanitarian intervention should be prioritized for livestock-holding households who may be unable to bounce back due to the severity of conflict on their livestock assets. With the rising middle-income class and African population, the demand for animal source foods has increased. Nigeria, being the most populous country in Africa, is a critical player in the demand and supply of livestock products. Hence, strategies for sustaining livestock

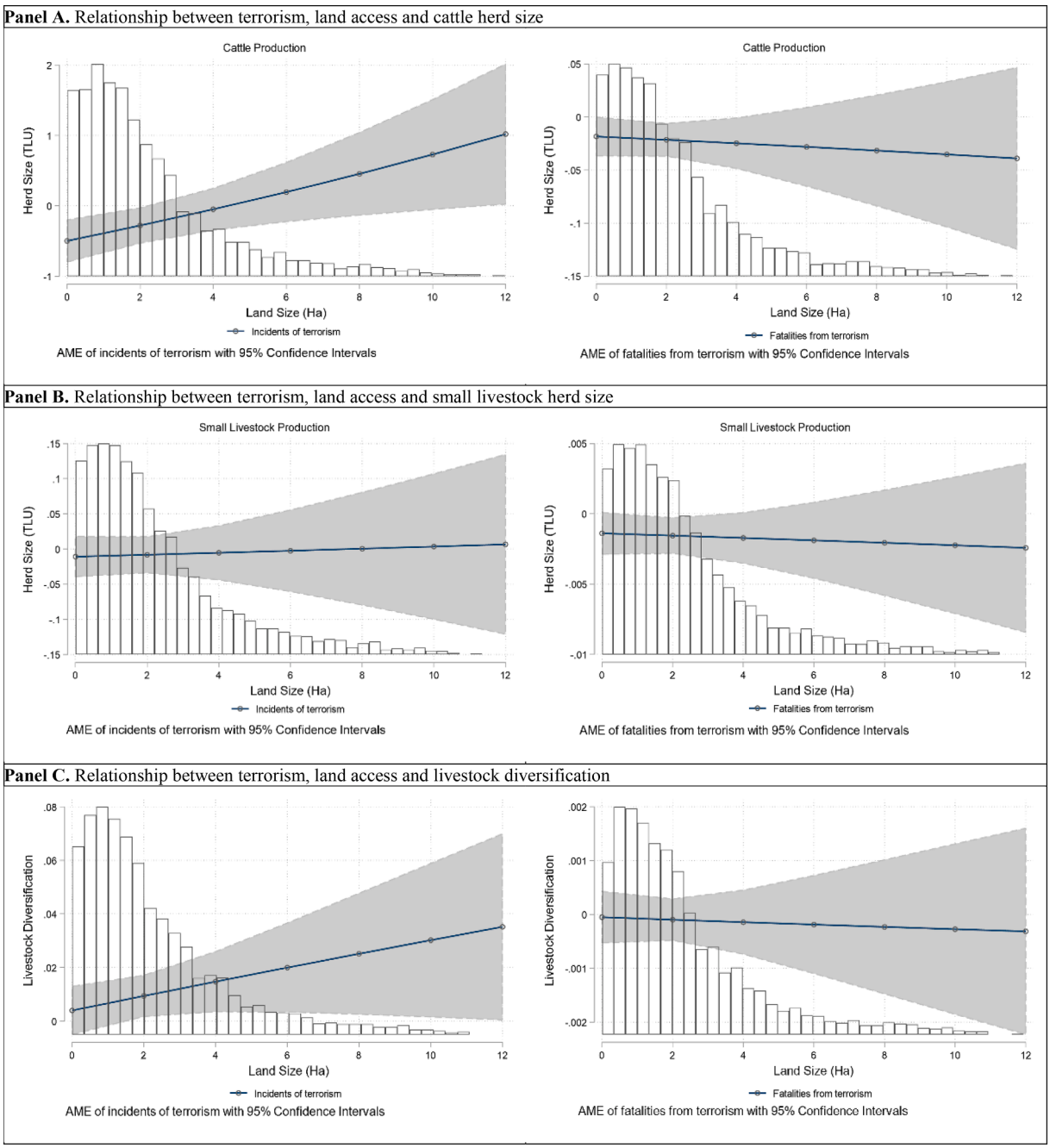

Fig. 2. Average Marginal Effects of the relationship between terrorism, land access and livestock production decisons.

production will position Nigeria to leverage the substantial livestock market for its economic growth.

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CRediT authorship contribution statement

Olusegun Fadare: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Giacomo Zanello:** Conceptualization, Funding acquisition, Formal analysis, Resources, Supervision, Validation, Visualization, Writing – review & editing. **Chittur Srinivasan:** Conceptualization, Funding acquisition, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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