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Conflict and Agricultural Inputs

Impacts on Maize Yields in Nigeria

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Abstract

While standard agronomic recommendations advocate for increased application of inorganic fertilizer to boost maize yields across sub-Saharan Africa, there is limited understanding of how violent conflict influences smallholder farmers' fertilizer demand, yield responses, and the overall profitability of fertilizer use. This study addresses this gap by analyzing how exposure to conflict affects input use decisions and the economic returns to fertilizer among maize farmers in Nigeria. Using detailed household-level data and spatially referenced conflict events, we estimate maize yield response functions with respect to nitrogen application and assess the profitability of fertilizer under varying levels of conflict exposure. Our findings reveal three key results. First, the marginal physical product (MPP) of nitrogen is low across the study sample, indicating limited agronomic responsiveness. Second, conflict exposure significantly reduces the likelihood and intensity of fertilizer use, suggesting that insecurity constrains both input access and willingness to invest. Third, conflict lowers the MPP of nitrogen even further, thereby reducing the marginal value-cost ratio (MVCR) and undermining the profitability of fertilizer use. These results highlight the importance of considering conflict as a key external factor that distorts input-output relationships in agricultural production. Insecurity not only affects access to inputs through higher prices and disrupted supply chains, but also alters expected returns, making fertilizer investments less attractive for risk-averse farmers. Recognizing the effects of conflict on fertilizer use and yield response is essential for designing more effective input subsidy programs, targeting strategies, and resilience-building interventions in fragile agricultural systems.

Keywords: Fertilizer use, yield response, maize, conflict, input use, Nigeria

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1. Introduction

Low application rates of productivity-enhancing inputs such as inorganic fertilizer and improved seeds are widely recognized as key constraints to cereal yield growth in sub-Saharan Africa (Palmas and Chamberlin 2020; Amare et al. 2024a; Hurley et al. 2018; Liverpool-Tasie et al. 2017a, 2017b; Ricker-Gilbert et al. 2011). In Nigeria, as in many developing countries, smallholder adoption of these inputs remains limited due to a range of barriers, including high purchase and transaction costs (Benson and Mogues 2018), credit constraints, risk aversion, limited agronomic knowledge, and poor market access (de Brauw and Eozenou 2014; Dercon and Christiaensen 2011; Emerick et al. 2016; Suri 2011; Amare et al. 2024c). At the policy level, successive national agricultural policies, including the Agricultural Transformation Agenda (2011–2016), the Agricultural Promotion Policy (2016–2020), and the National Agricultural Technology and Innovation Policy (2022–2027), explicitly identify low use of modern inputs as a central challenge to improving agricultural productivity.

Agricultural productivity in sub-Saharan Africa faces multiple, compounding challenges, including stagnating yield growth, declining fertilizer responsiveness, and increasing vulnerability to environmental and man-made shocks. Recent evidence documents a marked slowdown in productivity growth across the region (Suri and Udry 2022; Wollburg et al. 2024), alongside declining fertilizer efficiency attributable to unbalanced application, poor soil management, erosion, and adverse climate effects (Nkonya et al. 2016; Nyondo et al. 2023; Marenya and Barrett 2009; Sheahan et al. 2013; Ragasa et al. 2025). These trends are further aggravated by rising insecurity and fragility, raising concerns among researchers, policymakers, and farmers regarding the continent's capacity to sustain food production amid rapid population growth and escalating climate risks (Ricker-Gilbert et al. 2011; Sheahan et al. 2013; Adelaja and George 2019a; Kaila and Azad 2019; Odozi and Oyelere 2022; Ricker-Gilbert et al. 2024b; Amare et al. 2025; Ragasa et al. 2025; Amare et al. 2024b).

Maize, a major staple crop in Nigeria, yields less than 2 tons per hectare on average—substantially lower than its potential yield of 6 to 8 tons per hectare, depending on agroecological conditions (Guilpart et al. 2017; Wossen et al. 2023). This yield gap is among the largest in West Africa (FAOSTAT 2022). Nitrogen deficiency is a critical limiting factor, widely documented in the region (Guilpart et al. 2017; Nziguheba et al. 2009; Rurinda et al. 2020). Consequently, increased application of inorganic, nitrogen-based fertilizers is often recommended to enhance maize productivity. Empirical studies demonstrate strong yield responses to nitrogen rates up to 150 kilograms per hectare (Adnan et al. 2017; Liu et al. 2015; Liverpool-Tasie 2017a; Snapp et al. 2014), underscoring fertilizer's potential to close yield gaps.

An increasingly important yet underexamined factor in this context is violent conflict. In fragile environments, conflict poses a persistent threat to rural livelihoods, agricultural markets, and the adoption of productivity-enhancing technologies. While prior research has extensively explored agronomic and environmental determinants of fertilizer use and its productivity, such as soil fertility, rainfall variability, land access, and input access (Marenya and Barrett 2009; Ricker-Gilbert et al. 2011; Liverpool-Tasie et al. 2017a, 2017b; Suri and Udry 2022; Wollburg et al. 2024; Amare et al. 2023; Ricker-Gilbert et al. 2024b; Ragasa et al. 2025), the effects of conflict exposure on input decisions remain poorly understood. Conflict disrupts input and output markets, displaces labor, restricts mobility, and heightens production risks, potentially undermining farmers' willingness and ability to invest in inputs like fertilizer.

In Nigeria, recent escalations in conflict have severely disrupted agricultural systems. Armed violence has damaged infrastructure, restricted market access, and contributed to notable declines in cereal yields, including maize (Adelaja and George 2019a; Arias et al. 2019; Hatzenbuehler et al. 2023; Amare et al. 2025). Concurrently, fertilizer profitability has declined, evidenced by rising fertilizer-to-maize price ratios during 2021–2022 (Ricker-Gilbert et al. 2024a; Ricker-Gilbert et al. 2024b; Liverpool-Tasie et al. 2017a, 2017b). Although fertilizer use and productivity have been studied extensively in sub-Saharan Africa, few analyses have empirically examined how spatial variation in conflict exposure influences input use, yield response, and the profitability of fertilizer investments.

This study addresses this gap by analyzing how violent conflict affects smallholder farmers' fertilizer use, maize yield response, and fertilizer profitability in Nigeria. We utilize nationally representative panel data from the Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA), merged with detailed conflict data from the Armed Conflict Location and Event Data Project (ACLED).[1] We construct annual conflict exposure measures for each household using three indicators: the number of incidents of violence against civilians (VAC), battles, and their

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[1] ACLED is an independent, impartial global monitor that collects, analyses, and maps data on conflict and protest. It is a publicly available dataset that provides detailed information on patterns and trends in conflict and crisis situations around the world.

aggregate. ACLED defines a battle as "a violent interaction between two politically organized armed groups at a particular time and location," and VAC as "an occurrence when any armed or violent group attacks civilians, including actions by rebels, governments, militias, and rioters."[2] These indicators are calculated within three spatial buffers (0–15 km, 16–30 km, and 31–45 km) to capture direct and indirect effects of conflict, while avoiding double-counting.

Our study makes several key contributions. First, we contribute to the growing literature on how different shocks affect agricultural input use (e.g. Ricker-Gilbert et al. 2011; Sheahan et al. 2013; Adelaja and George 2019a; Amare et al. 2025). We provide new empirical evidence on how conflict influences both the use of inputs and farm productivity in a high-conflict, data-scarce setting. Second, we extend the literature on input profitability by examining how conflict influences both access to inputs and the profitability of fertilizer, an essential input for cereal production. In doing so, we build on prior work that estimates the returns to input use in settings that do not explicitly account for conflict dynamics (Marenya and Barrett 2009; Ricker-Gilbert et al. 2011; Liverpool-Tasie et al. 2017a, 2017b; Suri and Udry 2022; Wollburg et al. 2024; Amare et al. 2023; Ricker-Gilbert et al. 2024b; Ragasa et al. 2025), providing new insights into how conflict reshapes the economic calculus of input use. Third, we integrate spatially detailed conflict data with rich household panel surveys to more accurately capture the geographic and temporal dynamics of farming decisions under insecurity. Fourth, we document important gendered differences in conflict impacts, highlighting how men and women farmers face distinct challenges and adopt different coping strategies.

Beyond measuring these effects, we examine how smallholder farmers in Nigeria respond to conflict, and the ways in which conflict reduces the effectiveness of fertilizer use including disruptions to supply chains, shifts in household labor allocation, and changes in risk preferences. We also analyze how conflict exposure shapes farmers' decisions about profit-driven fertilizer. Farmers typically apply fertilizer up to the point where the marginal value of additional output equals its marginal cost. Conflict can reduce expected returns by lowering crop yields or market prices and raise costs through increased fertilizer prices or scarcity. These combined effects reduce profitability

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[2] The ACLED dataset classifies conflict into six event types: (1) Battles (government regains territory, non-state actor captures territory, armed clashes); (2) Explosions/remote violence (chemical attacks, air/drone strikes, suicide bombs, shelling/missile attacks, landmines/IEDs, grenades); (3) Violence against civilians (sexual violence, attacks, abductions/forced disappearances); (4) Riots (violent demonstrations, mob violence); (5) Protests (peaceful protests, excessive force against protesters, protests with intervention); and (6) Strategic developments (agreements, arrests, changes in group activity, disrupted weapons use, establishment of bases, looting/property destruction, non-violent territorial transfers, and related actions) (ACLED 2019).

and discourage adoption of fertilizer. By unpacking these mechanisms, our study enhances understanding of how fragility and violence shape agricultural technology adoption and informs policies aimed at building resilience in conflict-affected regions. Crucially, we treat profitability as endogenous, showing how conflict alters both returns to and costs of fertilizer use. This approach provides new insights into technology adoption and productivity dynamics in fragile and conflict-affected settings.

We employ a fixed effects model on longitudinal data to examine the relationship between fertilizer application and maize yield under conflict conditions, while investigating the pathways through which conflict affects fertilizer profitability. Our findings indicate low yield responsiveness to nitrogen fertilizer in Nigeria, with negative implications for profitability. Approximately 57 percent of maize farmers achieve an average value-cost ratio (AVCR) of at least two, the benchmark for profitable fertilizer use in low-income contexts with substantial transaction costs, implying that for 43 percent of farmers, the economic costs of increased inorganic fertilizer exceed potential benefits. Moreover, we find that conflict shapes farmers' fertilizer use decisions, with effects varying by conflict type and proximity. Exposure to conflict reduces the marginal physical productivity (MPP) of nitrogen, thereby lowering profitability. Interaction effects between nitrogen application and conflict intensity at varying spatial distances also differentially influence maize yields. Finally, we uncover a gender disparity, conflicts disproportionately reduce fertilizer profitability on plots managed or operated by women, highlighting gendered vulnerabilities in conflict-affected agricultural settings.

The remainder of the paper is organized as follows. Section 2 provides an overview of fertilizer policies and the conflict landscape in Nigeria. Section 3 delves into the conceptual framework and presents our hypothesis. Our empirical approach is discussed in Section 4. Section 5 details the data sources, variable construction, and descriptive outcomes. Section 6 presents the findings and discussions stemming from the econometric results. The concluding section encapsulates our final remarks with policy suggestion.

2. Overview of Fertilizer Polices and Conflict in Nigeria

2.1. Fertilizer polices in Nigeria

Since the 1980s, Nigeria's fertilizer sector has been shaped by a series of government interventions. Fertilizer subsidies once comprised of as much as 68 percent of agricultural spending (Takeshima and Liverpool-Tasie 2013). However, fiscal pressures led to sectoral liberalization and a gradual phase-out of subsidies, resulting in a decline in fertilizer use. The Federal Market Stabilization Program, introduced in 1999, offered a 25 percent discount, but persistent supply shortfalls created a dual market structure: a subsidized public market and an unsubsidized open market (Takeshima and Nkonya 2014; Amare et al. 2024b).

To address inefficiencies in fertilizer distribution, the Nigerian government introduced the Growth Enhancement Support Scheme in 2011, an e-wallet system that delivered input subsidies directly to farmers via mobile phones. The program was operated until 2015 (Takeshima and Liverpool-Tasie 2013). Between 2016 and 2020, the policy shifted toward supply-side subsidies under the Presidential Fertilizer Initiative, which aimed to reduce production costs and support domestic blending. This led to the rehabilitation of 52 blending plants (NSIA 2021). Despite these efforts, fertilizer subsidy programs have had limited success due to implementation bottlenecks, inconsistent policy execution, and rising insecurity (Devadoss et al. 2016; Nasrin et al. 2021).

2.2. Conflict in Nigeria

Conflict and insecurity, stemming from farmer–herder clashes, Boko-Haram insurgency, banditry attacks, communal violence, and kidnappings pose serious threats to livelihoods, agricultural investment, productivity, and food security in Nigeria (Adelaja and George 2019a; Arias et al. 2019; Kafando and Sakurai 2024; Amare et al. 2025). Over the past 15 years, the nature of conflict has evolved, with a growing number of actors, fatalities, and incidents (Odozi et al. 2021). Conflict types vary by region, driven by competition over resources, as well as ethnic, religious, or historical factors (Li 2018).

Boko-Haram, a major driver of insecurity, is mainly active in northern and northeastern Nigeria. However, other regions face diverse conflict types. For instance, Lagos recorded the highest number of conflict incidents in 2020, often linked to urban clashes and kidnappings, while North-Central Nigeria faces both farmer–herder and Boko-Haram related violence, and in the South, conflicts are often tied to control over oil revenues (Adelaja and George 2019a; Odozi and Oyelere 2022; Kaila and Azad 2019; Amare et al. 2025).The North-Central zone, critical for Nigeria’s agricultural output, has been particularly affected. Conflicts in this region restrict farm access, delay key agricultural activities, and limit the use of yield-enhancing inputs like fertilizer, ultimately reducing productivity (Adelaja and George 2019a; George et al. 2021; Amare et al. 2025).

3. Conceptual Framework, Conflict, and Input Use Decisions

Our conceptual framework builds on the standard farm household model (de Janvry and Sadoulet 2005; Taylor and Adelman 2003). In well-functioning markets, production and consumption decisions are separable and unaffected by household endowments. However, in contexts of market imperfections, uncertainty, and conflict-related risks, this separability breaks down. Input use, labor allocation, and output decisions become endogenous to constraints such as insecurity-induced damage to infrastructure, destruction of immediate farm and production assets, loss of family member , liquidity limits, and risk aversion, leading to inefficient resource use and welfare losses. We apply this framework to analyze fertilizer demand under such conditions. Following Sadoulet and de Janvry (1995), we derive reduced-form equations for input demand, technology adoption, and output supply from a constrained utility-maximizing model. A core microeconomic principle holds that profit-maximizing farms use inputs up to the point where marginal value product equals marginal cost. However, market imperfections and high-risk environments, such as violent conflict, can lead to suboptimal input use (Ragasa et al.,2017; Sheahan et al. 2013; Xu et al. 2009). Conflict can undermine farmers' fertilizer investment decisions, affecting productivity and profitability. Studies show that farmers in conflict-prone areas adjust practices, shifting to subsistence or less profitable crops, to cope with risks (Arias et al. 2019; Bozzoli and Brück 2009; Deininger 2003).

Conflict affects input use through several channels. It can disrupt markets and limit access to input dealers (Adelaja and George 2019a; George et al. 2021; George and Adelaja 2022), create insecurity that delays timely application (Collier and Hoeffler 1998; 2004), raise input prices (Arias et al. 2014), and damage infrastructure critical to fertilizer distribution. These constraints are compounded by credit limitations faced by smallholders. Conflict also shapes risk perception and behavior—more risk-averse farmers apply less fertilizer and rent less land (Collier and Hoeffler 1998; 2004; Nnaji et al. 2022; Arias et al. 2019). Additionally, conflict-induced disruptions in supply chains and output markets reduce income and input affordability, further lowering fertilizer use and productivity (Arias et al. 2014; George et al. 2021; Adelaja and George 2019a; Amare et al. 2024b; Amare et al. 2025). For example, Nnaji et al. (2023) show that in areas with high farmer–herder conflict, households reduce fertilizer use and adjust labor allocations. We hypothesize that violent conflict, as a non-agronomic shock, alters optimal input use decisions and lowers fertilizer application and yield response.

4. Empirical Approach

4.1. Yield response to fertilizer use

Our empirical strategy for estimating yield response to fertilizer is based on a household fixed-effects model, which explores within-household variation of fertilizer use over time to identify its impact on maize productivity. This approach mitigates potential bias from unobserved, time-invariant household characteristics that may be correlated with fertilizer decisions (Wooldridge 2010). We adopt a standard quadratic yield function, a widely used specification in the literature (Kouka et al. 1995; Traxler and Byerlee 1993; Marenya and Barrett 2009; Sheahan et al. 2013; Ragasa et al. 2025). Despite concerns about overfitting or functional form rigidity (Grimm et al. 1987), the quadratic function captures key features of neoclassical production theory, including allowing for zero input use and diminishing marginal returns (Xu et al. 2009; Burke 2012; Liverpool-Tasie et al. 2017a; Sarkar et al. 2022).

The yield function is used to estimate both marginal and average returns to fertilizer:

$$Yield_{iht} = f(N_{iht}, X_{iht}) \quad (1)$$

where $Yield_{iht}$ is maize output per hectare (in kg) on plot i for household h in time t, N_{iht} is the amount of fertilizer applied per hectare, and X_{iht} is a vector of other inputs and controls such as irrigation, insecticides, machinery, agronomic factors, or household characteristics that are likely to affect maize yields.

Because maize is predominantly intercropped, typically with crops such as cowpea, soybean, cassava, groundnuts and inputs are recorded at the plot level, we measure maize productivity using an output index per hectare, following Liu and Myers (2009). The index is defined as:

$$Y_i = \frac{\sum Yp_jY_{ij}}{p_1} \quad (2)$$

where Y_i is the output index for plot i, p_j is the market price of crop j, Y_{ij} is the yield of crop i on plot j, and crop p_1 is maize. This measure captures yield variability due to intercropping and avoids the downward bias that may result from attributing full input use to maize alone. With an average maize yield of about 1.7kg/ha (see table 1), the maize yield per hectare, measured along an output index, ranges from as low as below 0.1 tons per hectare to about 7.2 tons per hectare, reflecting substantial heterogeneity typical of intercropped smallholder systems. Our yield estimate is consistent with a similar study in Kenya on maize production that calculated a maize output index ranging from 0.069 tons per hectare to 4.4 tons (Liu and Myres 2009).

To estimate the effect of nitrogen application, we specify the following household fixed-effects mode:

$$Yield_{iht} = \beta_1 \mathrm{N}_{iht} + \beta_2 \mathrm{N}_{iht}{}^2 + \beta_3 X_{iht} + \beta_4 T_i + \mu_h + \epsilon_{iht} \tag{3}$$

where N_{iht} is the amount of nitrogen applied per hectare on plot i by a household h in time t, X_{iht} is as defined in Equation 1, T_i is wave dummies, and $\mu_h + \epsilon_{iht}$ is a composite error term comprised of a time-varying unobserved error (ϵ_{iht}) and a time-invariant error (μ_h).While this approach accounts for time-invariant unobserved heterogeneity, it does not fully address time-varying unobservable heterogeneity, such as changes in plot conditions, soil quality, location, or farmer behavior, that may simultaneously affect fertilizer use and yield outcomes. To improve robustness and mitigate concerns about endogeneity, we supplement our analysis with both a correlated random effects (CRE) model and an instrumental variables (IV) strategy.

4.2. Profitability of fertilizer use

A farmer's decision to use fertilizer is fundamentally guided by marginal analysis aimed at profit maximization. The optimal application occurs when the marginal value of productivity (MVP) of fertilizer, calculated as the additional maize yield generated by one more unit of fertilizer multiplied by the market price of maize, equals the marginal cost of the input. That is, fertilizer use is optimized when the value of the marginal physical product (MPP) matches that marginal cost of fertilizer. Fertilizer use is considered economically efficient and profitable when MVP exceeds the input cost, and unprofitable when the MVP falls below the marginal cost of the input. To achieve optimal resource allocation, the farmer seeks to apply fertilizer up to the point where the additional revenue from the last unit applied just offsets its marginal cost.

Based on the fixed effects yield estimates, following (Liverpool-Tasie et al. 2017a; Sheahan et al. 2013), we define the average physical product (APP) as the increase in maize yield per unit of nitrogen fertilizer applied, relative to not using nitrogen fertilizer:

$$APP_{nijt} = \frac{\widehat{MY_{N>0}} - \widehat{MY_{N=0}}}{N} \tag{4}$$

where $\widehat{MY_{N>0}}$ is the predicted maize yield (kg per hectare) from Equation (3) using the observed positive quantity of nitrogen (N), and $\widehat{MY_{N=0}}$ is the predicted maize yield when nitrogen is set to zero using Equation (1). We then use APP_{nijt} to compute the average value-cost ratio (AVCR) (Equ. 5), a profitability metric that compares the value of additional maize output to the cost of nitrogen input:

$$AVCR_{nijt} = \frac{(P_{mijt} * APP_{nijt})}{P_{nijt}} \quad (5)$$

where P_{nijt} is the acquisition price of nitrogen (including market price and transportation cost). P_{mijt} is the price of maize.

In addition, we compute the MPP of nitrogen—defined as the additional maize yield resulting from a one-unit increase in nitrogen application, holding other inputs constant. The MPP is derived by taking the partial derivative of the estimated production function (Equ. 3) with respect to applied nitrogen. Together with the APP, the MPP is calculated based on the functional form of the nitrogen-yield response. Using the MPP, we then construct the marginal value–cost ratio (MVCR), which compares the marginal value of output to the marginal cost of nitrogen input, providing an economically meaningful measure of fertilizer profitability under varying conditions of conflict exposure.

4.3. The effect of conflict on profitability of fertilizer use

Upon establishing the plot-specific structural yield function (Equ. 3), a farmer selects nitrogen application rates not solely to boost mean yield but also to mitigate yield risk (Hazell and Norton 1982). Consequently, we posit that conflict introduces productivity risks that could impact not only the quantity of nitrogen used per plot but also the maize yield associated with nitrogen application. The joint effect of conflict and the application rate of nitrogen fertilizer on maize yield response is presented in the yield function:

$$Yield_{iht} = \gamma_1 N_{iht} + \gamma_2 {N_{iht}}^2 + \gamma_3\, N_{iht} * conflict_{iht} + \gamma_4 X_{iht} + \gamma_5 T_i + \mu_h + \mu_t + \epsilon_{iht} \quad (6)$$

where the coefficient γ_3 captures the combined effects of nitrogen and conflict at specific radiuses to households. If $\gamma_3 < 0$, it indicates a negative interaction effect, suggesting that the use of nitrogen in the presence of the household's exposure to conflict leads to lower maize yield than expected.

5. Data and Descriptive Results

5.1. The data

This study employs three-wave panel datasets from the LSMS-ISA in Nigeria. These nationally representative surveys provide detailed information on assets, agricultural productivity, non-farm income, other sources of income, labor allocation, and access to service within households. The agriculture module, among others, contains information on agricultural and livestock production, farm technology, use of modern inputs, and productivity of crops. The LSMS-ISA includes georeferenced information related to household and plot data that allows us to link corresponding georeferenced conflict datasets to households. Thus, we merge the survey panel data with the geocoded data on conflict events collected through the ACLED project. While this study focuses on conflict types such as battles and VAC, the ACLED database provides detailed event-level data on a broader set of conflict types, including remote violence, protests, and riots.

The ACLED database is widely used in conflict research and related studies aimed at understanding the impacts of conflict across various contexts (for example, Fadare et al. 2022; George and Adelaja 2019a). For this study, we used the 2009, 2012, and 2015 ACLED datasets, which correspond to waves 1–3 of the Nigeria LSMS-ISA surveys. In Nigeria, VAC and battles accounted for approximately two-thirds of all recorded conflict events between 2000 and 2022. One of ACLED's key strengths lies in its extensive coverage of both violent and nonviolent events (i.e., peaceful protests), making it well-suited for analyzing a wide range of conflict dynamics. Additionally, its disaggregated and georeferenced event data enables detailed microlevel analysis of conflict incidence. Nevertheless, ACLED's reliance on media sources may introduce bias, especially in regions with limited reporting capacity.

5.2. Construction of main variables of interest

Fertilizer and other inputs

We determine fertilizer use by measuring the quantity of nitrogen used per hectare of maize plot, using the expected quantity of nitrogen formulated in each kg of fertilizer used on each maize plot. We define indicator variables for other input use, such as use of improved seeds, herbicide use, and pesticide use, which take the value of 1 if the farmer used these inputs and 0 otherwise.

Maize productivity

We measure maize productivity as the output index of maize yield per hectare. As in Liu and Myers (2009), we use an output index as the productivity measure because most inputs (land and fertilizer) are at the field level, and because maize plots are intercropped, the amount of inputs cannot be separately allocated to maize yield only.

Exposure to conflict incidence

We measure household exposure to violent conflict using three indicators: (1) the number of incidents of VAC, (2) the number of battles, and (3) their combined total. Each measure is calculated annually within three concentric distance bands from the household, within 15 km, 16–30 km, and 31–45 km, ensuring no double counting across bands. Conflict within 15 km captures immediate disruptions, while the outer bands allow us to assess the effects of violence at increasing distances on fertilizer use, crop productivity, and farming practices. According to ACLED, VAC refers to deliberate violent acts committed by organized political groups, including rebels, militias, or government forces, against unarmed noncombatants. These incidents involve harm or killing of civilians and are the only conflict type in which civilians are recorded as actors. Importantly, there is no minimum victim threshold for an incident to be classified as VAC.

5.3. Descriptive results

Table 1 presents the summary statistics of the key variables used in econometric analysis. The average age of household heads is 47 years, with an average household size comprising about eight people. The pooled sample shows that women-headed households account for only 9 percent of the sample. About 14 percent of sample households are involved in wage employment, 13 percent have access to credit, and 52 percent have access to the market. Regarding use of agricultural inputs, the pooled sample also shows that 90 percent use hired labor, 29 percent use herbicides, and 42 percent use pesticides.

The overall average farm size cultivated by maize farmers (including fertilizer users and nonusers) is about 1 hectare, indicating the dominance of smallholder farming in Nigeria. About 80 percent of farmers intercrop their maize plots, and 13 percent use organic fertilizer. All sampled plots received an average of 1,251 millimeters (mm) of precipitation across the three waves, reflecting the average precipitation often observed across Nigeria's ecological zones typically between 1000-1500mm for the Guinea Savanna of Nigeria's central belt, 2000-3000 mm for the lowland rain forest of the Southern humid forests, and about 1200-1500mm for the Derived savanna of the transition zone in central-south. Precipitation was highest in 2015 and lowest in 2012. Average maize productivity, measured as the output index for all farmers, is 1,718 kg per hectare. The conditional mean pooled value of nitrogen use is about 90 kg per hectare. Specifically, the conditional mean of nitrogen use was highest in 2012, estimated at 102 kg per hectare, and lowest in 2015.

Table 1: Descriptive statistics of dependent and explanatory variables (fertilizer users only)

	Pooled		**Wave 1**		**Wave 2**		**Wave 3**	
Variable (N = 1908)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Household head age (years)	47.01	13.81	47.67	13.77	47.25	13.92	46.50	13.74
Household size (no.)	7.70	3.69	7.14	3.59	8.54	3.94	7.35	3.38
Woman household head	0.08	0.27	0.07	0.26	0.05	0.21	0.11	0.32
Wage employment (yes = 1)	0.14	0.35	0.15	0.36	0.12	0.32	0.15	0.36
Cooperative membership (yes = 1)	0.15	0.36	0.15	0.35	0.17	0.38	0.14	0.35
Access to credit (yes = 1)	0.13	0.34	0.13	0.33	0.13	0.34	0.14	0.35
Access to market (yes = 1)	0.52	0.50	0.51	0.50	0.47	0.50	0.58	0.50
Distance to market (km)	60.37	35.52	60.53	38.18	57.61	34.38	62.57	34.54
Yield, input, and plot characteristics								
Yield (output index in kg/ha)	1718	1865	1794	1587	1515	1683	1839	2147
Plot size (ha)	1.13	2.15	0.81	0.71	1.37	2.32	1.04	1.80
Quantity of nitrogen per ha (kg)	90.03	207.2	92.08	100.76	101.9	216.6	78.75	246.6
Hired labor (yes = 1)	0.90	0.30	0.92	0.27	0.88	0.33	0.91	0.29
Used herbicide (yes = 1)	0.29	0.45	0.23	0.41	0.24	0.42	0.30	0.46
Used organic fertilizer (yes = 1)	0.13	0.33	0.002	0.05	0.12	0.11	0.30	0.46
Used pesticide (yes = 1)	0.42	0.49	0.43	0.50	0.40	0.49	0.44	0.50
Used improved seeds (yes = 1)	0.29	0.45	0.59	0.49	0.16	0.37	0.20	0.40
Plots intercropped	0.80	0.40	0.77	0.42	0.86	0.35	0.78	0.42
Soil quality	-0.11	1.05	0.12	1.02	-0.37	1.02	-0.04	1.05
Annual mean temperature (°C)	256.8	13.45	256.2	12.55	255.5	13.66	258.4	13.70
Annual mean rainfall (mm)	1251	456	1252	438	1172	421	1316	484
Conflict variable								
No. of total conflicts, 0–15 km	0.66	2.58	0.09	0.40	0.33	1.73	1.29	3.62
No. of total conflicts, 16–30 km	2.21	5.02	0.55	1.22	1.26	3.45	4.07	6.73
No. of total conflicts, 31–45 km	2.62	4.63	0.59	1.24	1.45	3.35	4.91	5.19
No. of battles, 0–15 km	0.19	0.70	0.04	0.24	0.08	0.48	0.38	0.96
No. of battles, 16–30 km	0.73	1.52	0.34	0.82	0.44	1.17	1.22	1.94
No. of battles, 31–45 km	0.10	1.96	0.31	0.66	0.33	0.67	1.99	2.70
No. of VAC, 0–15 km	0.47	1.98	0.05	0.28	0.25	1.31	0.91	2.80
No. of VAC, 16–30 km	1.48	3.88	0.21	0.70	0.82	2.35	2.85	5.39
No. of VAC, 31–45 km	1.63	3.00	0.29	0.75	1.12	2.93	2.92	3.43

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED database.

Note: SD = standard deviation; VAC = violence against civilians; ha = hectares; km = kilometers.

6. Results and Discussions

6.1. Maize yield response to fertilizer use

In this section, we first present the main estimation results based on Equation 3. We use fixed effects regression models to estimate the MPP of nitrogen use on maize yield. While our discussion centers primarily on the fixed effects model results, the random effect estimate (also in Table 2), yields a consistent estimate similar to that of the fixed effects model. The differences observed between the results of the random and fixed effects models highlight the importance of accounting for unobserved household-specific characteristics and time-invariant factors when analyzing nitrogen yield response functions. The yield estimate reveals a diminishing return to applied nitrogen consistent with the standard monotonicity assumption of production economics. This result aligns with the findings of Liverpool-Tasie et al. (2017a) and Ragasa et al. (2025), who similarly observed a diminishing return to scale of nitrogen application in maize yield in Nigeria.

As an additional robustness check, we estimate two commonly used models that address time-invariant unobserved heterogeneity: a CRE model and an IV approach. The CRE model includes controls for location, soil type, and household demographics to account for time-invariant factors. In the IV estimation, we use fertilizer prices and transportation costs as instruments, which are strongly correlated with fertilizer use but plausibly exogenous to yield outcomes. The CRE and IV results, reported in the appendix (Table A1), are consistent with the fixed effects estimates. These instruments pass standard diagnostic tests, including the under-identification (Anderson LM), weak identification (Cragg–Donald Wald F), and over-identification (Sargan) tests. Hausman tests (Table A2) indicate that fertilizer use is not endogenous, which supports the use of fixed effects as the main specification.

From our yield estimates, we find a positive and statistically significant effect of improved seeds use in the presence of applied nitrogen on maize yield. Access to credit also tends to have significant and positive effects on maize yield, while the slope percentage and plot size appear to have a negative effect. This supports the findings of several studies (Marenya and Barrett 2009; Liverpool-Tasie et al. 2017a; Snapp et al. 2014) on the importance of soil quality for the yield response of applied nitrogen. The plot size variable indicates a statistically significant negative relationship with yield, consistent with previous studies showing an inverse relationship between productivity and land area (Liverpool-Tasie et al. 2017a).

Table 2: Maize yield estimates (conditional fertilizer use)

	Fixed effects (FEs)	**Correlated random effects (CREs)**
Nitrogen (kg)	6.761^{***}	7.159^{***}
	(0.412)	(0.302)
Nitrogen squared	-0.002^{***}	-0.002^{***}
	(0.0002)	(0.0002)
Household size	5.380	0.489
	(34.621)	(11.757)
Plot size (ha)	-144.582^{***}	155.448^{***}
	(25.218)	(17.058)
Used improved seeds	227.224^{**}	166.047**
	(104.742)	(75.687)
Used pesticide	−7.564	−44.564
	(122.315)	(78.687)
Used herbicide	−47.982	101.412
	(122.428)	(84.268)
Cooperative membership	0.922	−129.577
	(322.805)	(115.841)
Access to credit	29.394^{***}	−102.686
	(325.134)	(119.194)
Hired labor	429.46	83.335^{***}
	(846.024)	(150.462)
Soil quality	−71.528	21.382
	(47.035)	(34.795)
Slope percentage	-530.659^{**}	-42.837^{***}
	(82.200)	(16.679)
Household distance to market	−48.977	0.875
	(50.341)	(1.229)
Mean temp of wettest quarters	-125.509^{***}	-13.247^{***}
	(42.756)	(3.613)
Annual precipitation	−0.730	-0.151^{***}
	(7.946)	(0.109)
Household fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
N	1896	1896
R squared	0.331	0.295

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.2. Profitability of fertilizer use

Table 3 presents the effects of conflict on the profitability of fertilizer use, measured using the AVCR and MVCR. With the MPP of nitrogen falling below 7 kg per hectare, only 57 percent of maize farmers achieve an AVCR of 2 or higher, the commonly used profitability threshold in low-income settings characterized by high transaction costs. This implies that approximately 43 percent of maize plots experience negative net returns from nitrogen use, either due to under-application or diminishing marginal returns. These patterns suggest that many farmers are applying fertilizer at suboptimal levels, while others may already be operating near or at optimal application. These findings are consistent with Liverpool-Tasie et al. (2017a), who reported similarly low fertilizer responsiveness in major maize-producing regions of Nigeria, with an average MPP of 7.5 kg. In our analysis, the MPP of nitrogen is calculated as the partial derivative of the yield function with respect to nitrogen, capturing the additional maize yield from a marginal unit of nitrogen while holding other inputs constant. We also compute the expected marginal physical products (MPPs) of nitrogen, which capture the additional maize output associated with a one-unit increase in nitrogen application, holding other inputs constant (see Equ. 5).

Table 3: Profitability of nitrogen use

	Nitrogen users
Variable	**Mean**
MPP	6.437
APP	6.598
AVCR	2.118
MVCR	2.065

Source: Author's calculations.

Note: APP = average physical product; AVCR = average value cost ratio; MPP = marginal physical product.

6.2. Effect of conflict on maize yield response

We use household fixed effects estimates of the yield function to examine whether violent conflict moderates the maize yield response to nitrogen use.[3] Table 4 presents interaction effects between nitrogen application and conflict intensity; measured by the combined number of VAC incidents and battles; within three distance bands: 0–15 km, 16–30 km, and 31–45 km from the household (with each band including its upper bound). Conflict within 15 km significantly reduces the marginal yield response to nitrogen, indicating that nearby violence disrupts production efficiency. A weaker but still negative moderating effect is observed within the 16–30 km band, while no significant effect is found beyond 30 km.[4]

When conflict exposure is disaggregated to battles (Equ. 4), we find statistically significant negative interaction effects with nitrogen use across all three distance bands. The largest effect occurs within 0–15 km, suggesting that nearby battles are more likely to reduce the MPP of nitrogen. Battles occurring 16–30 km and 31–45 km from households also

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[3] We also included a new regression model in Appendix Table A3 that explicitly examines the direct effect of conflict on maize yields. This model incorporates conflict exposure variables as stand-alone regressors, while controlling for the full set of covariates and fixed effects used in our main specification. The results indicate that conflict occurring within 0–15 km; battles and violence against civilians; have statistically significant and negative impact on maize yields. Although the effects weaken with distance, they remain negative.

[4] When using binary indicators of conflict, the interaction terms with battles still remain negative and statistically significant across all radii (see Table A4). But beyond 30 km, the interaction of fertilizer with VAC results is a positive and significant coefficient, implying the 'distance decay' nature of VAC compared to battles.

significantly lower nitrogen productivity, indicating that the disruptive effects of conflict extend well beyond the immediate vicinity of the farm. We also analyze VAC incidents separately. The interaction between nitrogen use, and VAC exposure is negative and statistically significant within both the 0–15 km and 16–30 km bands but turns positive and significant within 31–45 km. This spatially varying pattern may reflect adaptive farmer responses or localized coping strategies that differ with the proximity of conflict events.

Table 4: The effect of conflict on maize yield

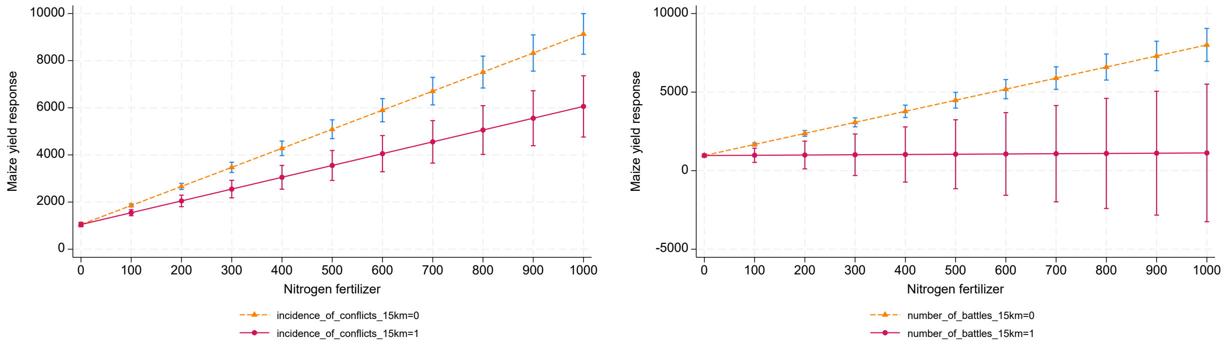
	Maize yield		
	Conflict	**Battles**	**VAC**
Nitrogen (kg)	6.864***	6.984***	7.325***
	(0.470)	(0.552)	(0.430)
Nitrogen squared	−0.002***	−0.002***	−0.002
	(0.0002)	(0.0002)	(0.0002)
Nitrogen *no. of conflicts, 0–15 km	−1.963**		
	(0.821)		
Nitrogen * no. of conflicts, 16–30 km	0.065		
	(0.329)		
Nitrogen * no. of conflicts, 31–45 km	0.532		
	(0.383)		
Nitrogen * no. of battles, 0–15 km		−6.877***	
		(1.888)	
Nitrogen * no. of battles, 16–30 km		−0.783***	
		(0.243)	
Nitrogen * no. of battles, 31–45 km		−1.549***	
		(0.495)	
Nitrogen * no. of VAC, 0–15 km			−2.345***
			(0.852)
Nitrogen * no. of VAC, 16–30 km			−0.783***
			(0.158)
Nitrogen * no. of VAC, 31–45 km			0.616***
			(0.272)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
No. of observations	1896	1896	1896
R squared	0.34	0.34	0.34

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

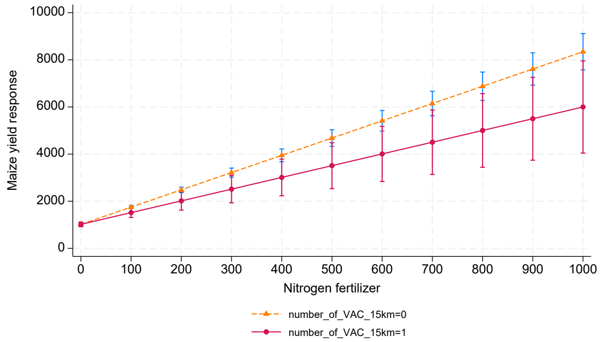
To better understand how conflict influences the maize yield response to nitrogen use, we analyze the marginal effects of nitrogen under varying conflict conditions. This approach allows us to explore how conflict interacts with fertilizer productivity. As shown in Figures 1a–1c, maize yield increases with higher nitrogen use across all scenarios. However, the positive response is more pronounced among households not exposed to conflict, battles, or VAC within a 15-km radius. This is evident from the steeper slopes in the graphs for non-exposed households, indicating that conflict dampens the effectiveness of nitrogen application.

Figure 1: The marginal effects of nitrogen use within the context of conflict within a 15-km radius


a) Maize response to nitrogen use by conflict status

b) Maize yield response to nitrogen use by battle status

c) Maize yield response to nitrogen use by violence against civilians



Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

6.3. The effect of conflict on profitability of fertilizer use

We additionally analyze the effect of conflict; including total conflict, battles, and VAC combined; within different radius bands (0–15 km, 16–30 km, and 31–45 km from households) on the profitability of fertilizer, as indicated by the AVCR.[5] The results show significant negative effects on nitrogen use profitability when the total number of conflicts, battles, and VAC occur at various distances from households (particularly less than 15 km). This notable decrease in nitrogen fertilizer profitability during periods of conflict can be explained by several factors. First, conflict disrupts agricultural processes, causing damage to crop, livestock, and

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[5] We also examine the effect of conflict exposure on the MVCR as an alternative measure of nitrogen use profitability. The results closely mirror those for the AVCR; for brevity, detailed estimates are reported in Appendix Table A5.

infrastructure. These disruptions directly affect farmers' ability to profit from nitrogen-enhanced yields.

Second, conflict-related market disturbances, such as price fluctuations and limited market access due to security issues, disrupt supply chains and make it challenging for farmers to sell their produce profitably or obtain necessary inputs at reasonable prices. Additionally, conflict can lead to constraints on input use, including nitrogen fertilizer, because of logistical difficulties, supply shortages, or safety risks. These constraints further reduce agricultural productivity and profitability. And behaviors contribute to the overall decline in agricultural profitability in conflict-affected areas.

Table 5: The effect of conflict on the AVCR of fertilizer use

	AVCR		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	-0.149^{***}		
	(0.042)		
No. of conflicts, 16–30 km	-0.071^{**}		
	(0.036)		
No. of conflicts, 31–45 km	-0.327^{***}		
	(0.034)		
No. of battles, 0–15 km		-0.429^{***}	
		(0.080)	
No. of battles, 16–30 km		−0.002	
		(0.026)	
No. of battles, 31–45 km		-0.211^{***}	
		(0.046)	
No. of VAC, 0–15 km			-0.096^{***}
			(0.033)
No. of VAC, 16–30 km			-0.150^{***}
			(0.023)
No. of VAC, 31–45 km			0.068^{***}
			(0.019)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
R squared	0.649	0.574	0.576
N	1896	1896	1896

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: AVCR = average value cost ratio. All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.4. Heterogeneous effects of conflict on profitability of fertilizer use

The impact of conflict on fertilizer profitability may vary by the gender of the household head. To capture this heterogeneity, we include interaction terms between conflict indicators and a women plot-head dummy (women= 1). The interaction coefficients isolate the differential effect of conflict for female-headed plots. In rural Nigeria, women face heightened vulnerability to conflicts through several interconnected pathways. First, conflicts intensify existing resource constraints, further limiting women's access to productive inputs (Brück and Schindler, 2009; Greiner, 2022). Second, conflicts disrupt the informal social networks and community-based support systems that women disproportionately rely upon for accessing inputs, participating in labor-sharing arrangements, and obtaining market information (Kayaoglu et al., 2024). Third, conflict-induced displacement and male outmigration increase women's care responsibilities, thereby reducing the time available for farm management decisions and income-generating activities (Adelaja and George, 2019a). These compounding disadvantages suggest that conflicts may erode fertilizer profitability more severely for female-headed plots by simultaneously constraining input access, disrupting support networks, restricting market participation, disrupting farm operations and intensifying poverty.

Table 6 presents the results for total conflict, battles, and VAC incidents. We find statistically significant gender differences in the effect of conflict on fertilizer profitability. Specifically, the negative impact of total conflict and battles within a 15-km radius is more pronounced for women plot heads (columns 1 and 2). These findings suggest that conflict disproportionately reduces fertilizer profitability for women, highlighting their increased vulnerability. This underscores the need for gender-responsive interventions in conflict-affected agricultural areas.

Table 6: The gender differentials of effect of conflict on the AVCR of fertilizer use

	AVCR		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	-0.121^{***}		
	(0.042)		
No. of conflicts, 16–30 km	-0.136^{***}		
	(0.037)		
No. of conflicts, 31–45 km	-0.291^{***}		
	(0.034)		
Plot head gender (woman = 1; 0 otherwise)	0.148		
	(0.216)		
No. of conflicts, 0–15 km * plot head woman	-0.272^{**}		
	(0.113)		
No. of conflicts, 16–30 km * plot head woman	0.556^{***}		
	(0.169)		
No. of conflicts, 31–45 km * plot head woman	−0.290		
	(0.216)		
No. of battles, 0–15 km		-0.378^{***}	
		(0.080)	
No. of battles, 16–30 km		−0.046	
		(0.029)	
No. of battles, 31–45 km		-0.179^{***}	
		(0.047)	
Plot head gender (women = 1; 0 otherwise)		−0.100	
		(0.289)	
No. of battles, 0–15 km * plot head woman		-1.834^{**}	
		(0.870)	
No. of battles, 16–30 km * plot head woman		0.109	
		(0.120)	
No. of battles, 31–45 km * plot head woman		−0.096	
		(0.259)	
No. of VAC, 0–15 km			-0.067^{**}
			(0.033)
No. of VAC, 16–30 km			-0.157^{***}
			(0.024)
No. of VAC, 31–45 km			0.064^{***}
			(0.018)
Plot head gender (woman = 1; 0 otherwise)			0.334^{***}
			(0.128)
No. of VAC, 0–5 km * plot head woman			−0.044
			(0.370)
No. of VAC, 16–30 km * plot head woman			−0.620
			(0.393)
No. of VAC, 31–45 km * plot head woman			0.408
			(0.275)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
N	1896	1896	1896
R squared	0.660	0.587	0.588

Source: Authors’ calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: AVCR = average value cost ratio. All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.5. The effect of conflict on input use

In this section, we test potential pathways through which conflict may reduce maize yield response to fertilizer. We hypothesize that conflict, an external, non-agronomic shock, disrupts farmers' optimal input decisions, lowering fertilizer effectiveness. Table 7 reports estimate conflict effects on nitrogen use. We find a statistically significant negative relationship between conflict incidents and nitrogen application within a 15-km radius of households: conflict reduces the likelihood of nitrogen use by about 6 percent. Disaggregating by type, battles reduce use by approximately 6 percent, and VAC incidents by about 3 percent.

Interestingly, conflict beyond the immediate vicinity appears to have the opposite effect. Conflict within radii of 16–30 km and 31–45 km increases the likelihood of nitrogen use by roughly 4 percent and 3 percent, respectively. These findings suggest that even conflicts occurring in nearby communities can influence household decisions, reflecting interdependence across locations. Conflict at moderate distances (16-45km) may lead to labor substitution effects, (i.e., disrupts hired labor availability) (Adelaja and George 2019a), and in turn farmers substitute scarce/expensive labor with nitrogen fertilizer to maintain yields with less labor-intensive practices. Reduced fertilizer use due to local violence likely contributes to lower agricultural output, diminished income, and increased food insecurity, further exacerbating poverty and market disconnection and undermining regional stability and growth.

Table 7: The effect of conflict on fertilizer use

	Nitrogen use		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	−0.056***		
	(0.020)		
No. of conflicts, 16–30 km	0.043**		
	(0.017)		
No. of conflicts, 31–45 km	0.027*		
	(0.014)		
No. of battles, 0–15 km		−0.063*	
		(0.036)	
No. of battles, 16–30 km		0.007	
		(0.013)	
No. of battles, 1–45 km		0.054***	
		(0.017)	
No. of VAC, 0–15 km			−0.034*
			(0.018)
No. of VAC, 16–30 km			0.017
			(0.012)
No. of VAC, 31–45 km			0.001
			(0.009)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
N	1896	1896	1896
R squared	0.103	0.124	0.106

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8 reports the effects of conflict on the use of improved seeds across all distance bands (0–15 km, 16–30 km, and 31–45 km). We observe a negative relationship between conflict and improved seed use, though only conflicts occurring within the 31–45 km radius are statistically significant. Disaggregating conflict into battles and VAC yields similar patterns: both conflict types are negatively associated with improved seed adoption. Battles within the 0–15 km and 31–45 km bands significantly reduce the likelihood of improved seed use, while VAC incidents between 16–30 km and 31–45 km also show statistically significant negative effects. These findings suggest that violent conflict, whether proximate or more distant, constrains the adoption of improved technologies by disrupting input markets, displacing agricultural labor, and increasing transaction costs. These compounding effects reduce crop yields and consequently lower household incomes for farmers who rely on agricultural production for their livelihood, ultimately intensifying food insecurity, particularly among smallholders with limited adaptive capacity.

These spatial variations in the effects of different conflict types may reflect distinct disruption dynamics influencing farm household input use decisions. For example, the negative and significant effect of battles on improved seed use within 15 km, and again beyond 30 km, may reflect patterns of immediate disruption followed by delayed recovery. In areas close to conflict, physical access to input dealers may be limited due to heightened security concerns. In contrast, the impact of VACs observed at a 31–45 km radius may suggest more sustained territorial control rather than acute disruption. This distance range typically represents the space between government-controlled peri-urban centers and peripheral areas where armed groups establish subtle presence. In Nigeria's conflict-affected regions, armed groups operating at these distances often exert influence on rural market towns, secondary transportation routes, and agricultural hinterlands over extended periods, disrupting commercial networks essential to smallholder farming. Unlike proximate conflict which causes immediate displacement and asset destruction, sustained territorial control at 31-45 km creates persistent uncertainty about market access, property security, and future safety. While agricultural activities may still continue within the zones, especially for organized agricultural activities, its enduring instability fundamentally creates uncertainty in surrounding areas and alters farmers' long-term investment decisions.

Table 8: The effect of conflict on improved seed use

	Improved seeds		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	−0.001		
	(0.026)		
No. of conflicts, 16–30 km	−0.033		
	(0.021)		
No. of conflicts, 31–45 km	-0.122^{***}		
	(0.018)		
No. of battles, 0–15 km		-0.165^{***}	
		(0.047)	
No. of battles, 16–30 km		−0.016	
		(0.017)	
No. of battles, 31–45 km		-0.059^{***}	
		(0.022)	
No. of VAC, 0–15 km			−0.036
			(0.024)
No. of VAC, 16–30 km			-0.056^{***}
			(0.016)
No. of VAC, 31–45 km			-0.048^{***}
			(0.012)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
N	1896	1896	1896
R squared	0.112	0.080	0.074

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: AVCR = average value cost ratio. All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9 presents the effects of conflict on the use of hired labor on maize plots. Our estimates indicate that conflicts within the 16–30 km radius reduce the likelihood of hiring labor for maize farming. When disaggregating conflict types, we find that battles within a 15 km radius are positively associated with hired labor use on maize plots, while battles within the 16–30 km and 31–45 km radii show a negative relationship. This suggests that battles within proximity may initially increase labor demand but, as conflict intensifies further away, it has a dampening effect on hired labor use. Conversely, VAC does not significantly affect hired labor use at any distance from households. Intuitively, the positive effects of nearby conflict (within 15 km) on hired labor use may reflect localized labor market adjustments. As some farms reduce operations due to security concerns, displaced workers may remain in the area, increasing the local labor supply and driving down wages, thereby encouraging other farmers to hire more labor. In contrast, at distances beyond 15 km, broader regional disruptions may trigger net out-migration from the conflict zone, reducing labor availability, increasing wages, and ultimately leading to lower levels of hired labor.

Table 9: The effect of conflict on hired labor

	Hired labor		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	0.006		
	(0.005)		
No. of conflicts, 16–30 km	−0.015*		
	(0.004)		
No. of conflicts, 31–45 km	0.004		
	(0.003)		
No. of battles, 0–15 km		0.085**	
		(0.040)	
No. of battles, 16–30 km		−0.075***	
		(0.015)	
No. of battles, 31–45 km		−0.033*	
		(0.019)	
No. of VAC, 0–15 km			0.002
			(0.020)
No. of VAC, 16–30 km			−0.008
			(0.014)
No. of VAC, 31–45 km			−0.008
			(0.010)
Household characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
N	1896	1896	1896
R squared	0.072	0.080	0.080

Source: Authors' calculations based on Nigeria LSMS-ISA 2010/2011, 2012/2013, and 2015/2016 and ACLED data.

Note: AVCR = average value cost ratio. All continuous variables are in log form. Standard errors, clustered at the enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

7. Conclusions

Low application rates of productivity-enhancing inputs such as inorganic fertilizer and improved seeds are widely recognized as key constraints to cereal yield growth in sub-Saharan Africa (Ricker-Gilbert et al. 2011; Hurley et al. 2018; Liverpool-Tasie et al. 2017a, 2017b; Palmas and Chamberlin 2020). Smallholder adoption of these inputs remains limited due to a combination of economic and biophysical barriers. These include high transaction costs (Benson and Mogues 2018), credit constraints, risk aversion, limited agronomic knowledge, and poor access to output and input markets (Suri 2011; Dercon and Christiaensen 2011; de Brauw and Eozenou 2014; Emerick et al. 2016). Consequently, most studies focus on increasing fertilizer use by addressing these economic and agroecological constraints, emphasizing factors like price, credit access, and soil or weather variability (Snapp et al. 2014; Adnan et al. 2017; Guilpart et al. 2017; Amare et al. 2024c; Ragasa et al. 2025). However, these approaches often pay limited attention to an increasingly important factor: violent conflict. While land degradation and climate variability remain major challenges (Sheahan et al. 2013; Nkonya et al. 2016; Ragasa et al. 2025), rising insecurity and institutional fragility have become significant threats to productivity growth across the region.

Although nitrogen deficiency is widely recognized as a binding constraint (Nziguheba et al. 2009; Rurinda et al. 2020) and fertilizer responsiveness is often high (Liverpool-Tasie 2017a; Adnan et al. 2017), relatively little attention has been paid to how violent conflict reshapes the relationship between fertilizer use and productivity. Our study contributes to filling this gap by providing empirical evidence on how exposure to different conflict types and intensities alters smallholder farmers' input behavior, fertilizer productivity, and profitability. While prior literature has examined environmental, institutional, and agronomic factors influencing fertilizer adoption (Marenya and Barrett 2009; Ricker-Gilbert et al. 2011; Sheahan et al. 2013), few studies have explored the impacts of conflict on these dynamics, despite growing evidence of its effects on rural livelihoods (Arias et al. 2019; Adelaja and George 2019a; Hatzenbuehler et al. 2023; Amare et al. 2025).

By linking conflict event data from ACLED to geocoded household panel data from Nigeria's LSMS-ISA, our analysis shows that conflict exposure reduces the likelihood and intensity of fertilizer application, lowers its marginal productivity, and diminishes profitability. These effects occur through both direct channels, such as destruction of farm assets and infrastructure, and indirect mechanisms, including market disruptions, input supply constraints, and increased volatility in input and output prices (Nkonya et al. 2016; Nyondo et al. 2023; Amare et al. 2024c). Moreover, conflict alters farmers' behavior. Increased uncertainty influences risk preferences often lead to underinvestment in high-return inputs like fertilizer, or a retreat into lower-risk, less-productive livelihood activities (Suri and Udry 2022; Wollburg et al. 2024a, 2024b). Since profitability is a key determinant of technology adoption in resource-constrained settings (Ricker-Gilbert et al. 2011; Ragasa et al. 2025), these behavioral adjustments can have long-term implications for productivity growth and rural welfare.

The policy implications of these findings are significant. Violent conflict disrupts the foundational assumptions behind many agricultural development strategies, particularly those that rely on uniform responsiveness to productivity-enhancing inputs such as fertilizer. In contexts where insecurity makes fertilizer use more volatile or less profitable, traditional input-subsidy or credit-based interventions may prove ineffective unless they are adapted to reflect the realities of conflict-affected farming systems. Building more resilient agrifood systems therefore requires explicitly integrating conflict sensitivity into agricultural policy, investment, and service delivery. This includes strengthening geospatial data systems and early warning mechanisms to monitor local conflict patterns and identify vulnerable regions. Extension services must be retooled to provide localized, risk-aware agronomic advice, potentially delivered through digital platforms that remain accessible during periods of restricted mobility (Liverpool-Tasie et al. 2017b). In highly insecure settings, input support should be bundled with complementary measures such as social protection programs, weather or conflict-indexed insurance, and peacebuilding initiatives to encourage sustained agricultural engagement despite uncertainty.

Ultimately, strengthening agriculture in Nigeria and across sub-Saharan Africa means embracing the complexity of operating in fragile contexts. Violent conflict should not be treated as a peripheral issue but recognized as a central factor shaping farmers' input decisions, risk behavior, and economic outcomes. Our findings underscore the importance of treating fertilizer profitability as endogenous shaped not only by prices and agronomic potential, but also by institutional fragility and perceived risks. By revealing how conflict reshapes fertilizer use, yield response, and profitability, this study contributes to a more realistic and policy-relevant understanding of technology adoption. These insights are critical for designing inclusive, adaptive agricultural strategies that go beyond improving input access to address the deeper behavioral and structural constraints facing smallholders in insecure environments.

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Appendix

Table A1. Yield response (kg/ha of maize) to 1 kg of nitrogen (plot-level) – IV regression and CRE model for robustness check

Variables	IV-regression	Correlated Random Effect (CRE)
Nitrogen	5.041^{**}	5.978^{***}
	(2.013)	(-0.450)
Nitrogen squared	-0.001^{***}	-0.001^{***}
	(0.0001)	(0.0001)
Household characteristics	Yes	Yes
Year fixed effects	Yes	Yes
Household fixed effects	Yes	Yes
N	1896	1896
R^2	0.095	
p-value (Null hypothesis: under-identified)	0.000	
p-value (Null hypothesis: not over-identified)	0.10	
p-value (Null hypothesis: nitrogen, nitrogen squared are exogenous)	0.354	

Source: Authors' calculations based on Nigeria LSMS-ISA 2010–2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Hausman test results for fixed effects vs random effect model

Test Statistic	Degrees of Freedom	p-value	Model Preference
26.62	2	0.000	Fixed effects

Source: Authors' calculations based on Nigeria LSMS-ISA 2010–2011, 2012/2013, and 2015/2016

Table A3: The effect of conflict on Maize yield (Direct conflict impact)

	Maize yield		
	Conflict	**Battles**	**VAC**
No. of conflicts, 0–15 km	−5.128**		
	(2.041)		
No. of conflicts, 15–30 km	−1.658		
	(1.340)		
No. of conflicts, 30–45 km	−3.299*		
	(2.416)		
No. of battles, 0–15 km		−23.069***	
		(8.226)	
No. of battles, 15–30 km		−2.899	
		(5.750)	
No. of battles, 30–45 km		-5.951	
		(4.660)	
No. of VAC, 0–15 km			−6.527**
			(2.269)
No. of VAC, 15–30 km			−1.345
			(1.323)
No. of VAC, 30–45 km			-1.178
			(2.569)
Household Characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
R squared	0.099	0.100	0.098
N	1896	1896	1896

Table A4: Yield estimates with conflict incidents within different radius bands (using binary indicator)

	Maize Yield		
	Conflict	**Battles**	**VAC**
Nitrogen (kg)	8.26***	7.535***	7.322***
	(0.61)	(0.603)	(0.441)
Nitrogen squared	−0.002***	−0.002***	−0.002***
	(0.0002)	(0.0002)	(0.0002)
Nitrogen *A conflicts, 0–15 km (yes = 1)	−3.076***		
	(0.733)		
Nitrogen * conflicts, 16–30 km (yes = 1)	1.288***		
	(0.414)		
Nitrogen * conflicts, 31–45 km (yes = 1)	−1.365***		
	(0.624)		
Nitrogen * battles, 0–15 km (yes = 1)		−1.125	
		(0.943)	
Nitrogen * battles, 16–30 km (yes = 1)		−0.704	
		(0.649)	
Nitrogen * battles, 31–45 km (yes = 1)		−1.104**	
		(0.583)	
Nitrogen * VAC, 0–15 km (yes = 1)			−6.057***
			(1.022)
Nitrogen * VAC, 16–30 km (yes = 1)			2.156***
			(0.578)
Nitrogen * VAC, 31–45 km (yes = 1)			2.476***
			(0.527)
Household characteristics	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
R squared	0.354	0.337	0.588
N	1896	1896	1896

Source: Authors' calculations based on Nigeria LSMS-ISA 2010–2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: The impact of conflicts on the MVCR of nitrogen use within different radius bands

	MVCR		
	Conflicts	**Battles**	**VAC**
No. of conflicts, 0–15 km	-0.111^{***}		
	(0.045)		
No. of conflicts, 16–30 km	-0.048		
	(0.038)		
No. of conflicts, 31–45 km	-0.343^{***}		
	(0.036)		
No. of battles, 0–15 km		-0.385^{***}	
		(0.084)	
No. of battles, 16–30 km		-0.005	
		(0.027)	
No. of battles, 31–45 km		-0.241^{***}	
		(0.049)	
No. of VAC, 0–15 km			-0.073^{**}
			(0.034)
No. of VAC, 16–30 km			-0.154^{***}
			(0.024)
No. of VAC, 31–45 km			0.074^{***}
			(0.020)
Household characteristics	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
R squared	0.601	0.536	0.536
N	1896	1896	1896

Source: Authors' calculations based on Nigeria LSMS-ISA 2010–2011, 2012/2013, and 2015/2016 and ACLED data.

Note: All continuous variables are in log form. Standard errors, clustered at enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.