What Role Does Conflict Play in Fertilizer Use and Maize Yield Response in Nigeria?

Mulubrhan Amare[1], Kwaw Andam[2], Bedru Balana[2], Opeyemi Olanrewaju[2] and Hyacinth Edeh[2]

[1] Mulubrhan Amare (corresponding author), International Food Policy Research Institute, 1201 Eye St NW, Washington, DC, USA; m.amare@cgiar.org.

[2] Kwaw Andam, International Food Policy Research Institute, Abuja, Nigeria; k.andam@cgiar.org

[2] Bedru Balana, International Food Policy Research Institute, Abuja, Nigeria; b.balana@cgiar.org

[2] Opeyemi Olanrewaju, International Food Policy Research Institute, Abuja, Nigeria opeyemi.olanrewaju@cgiar.org

[2] Hyacinth Edeh International Food Policy Research Institute, Abuja, Nigeria; h.Edeh@cgiar.org

Abstract

While the conventional recommendation emphasizes increasing the use of inorganic fertilizer to enhance maize yields, it is not obvious whether armed conflict affects demand, yield responses and profitability of fertilizers. Our study aims to tackle this question. We analyze how maize yield responds to fertilizer application and conduct a profitability assessment related to fertilizer use. We then investigate how conflict mediates the profitability of fertilizer as armed conflicts are likely to increase input costs, logistical difficulties, and market uncertainties due to conflicts. We combined the geocoded ACLED dataset with the Nigeria LSMS-ISA three-wave panel data. Our objective is to understand how maize yield responds to fertilizer application and to examine the effects of conflicts on both fertilizer use and maize yield response in Nigeria. Our study reveals that yield responses to nitrogen is very low in Nigeria. We also show that households' exposure to conflict decreases the marginal physical productivity of nitrogen in maize farming by reducing input use, including fertilizer, and improved seed. Recognizing this effect of conflict on input use and maize yield response is crucial for targeting and resource allocation decisions among smallholders in similar conflict-affected regions. Moreover, it highlights how external factors, beyond the scope of agronomic experiments, influence the economic incentives for fertilizer application and the yield outcomes of smallholder farmers.

Key Words: Fertilizer Use; Yield Response; Conflicts; Input Use; Nigeria

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1. Introduction

Studies in sub-Saharan Africa have consistently identified low application rates of yield-enhancing agricultural inputs such as inorganic fertilizers and improved seeds as the major factors affecting low productivity of staple cereals such as maize (Palma and Chamberlin 2020; Hurley et al. 2018; Liverpool-Tasie et al. 2017a, 2017b). Key constraints to the low use of fertilizers among smallholder farmers in developing countries like Nigeria include high purchase and transaction costs (Benson and Mogues, 2018), risk aversion and poor access to credit, limited agronomic knowledge, and lack of market access, among others (De Brauw and Eozenou 2014; Dercon and Christiaesen 2011; Emerick et al. 2016; Suri 2011).

Maize is one of the major staple cereals in Nigeria, with an average yield of less than 2 tons per hectare in contrast with its estimated potential yield of between 6 and 8 tons per hectare, contingent upon the agroecological zones across Nigeria (Guilpart et al. 2017; Wossen et al. 2023). This difference between actual and potential yield marks one of the highest figures in the West African region (FAOSTAT 2022). Nitrogen nutrient deficiency emerges as a primary constraint in achieving maize yield potential across several countries in this region (Guilpart et al. 2017; Nziguheba et al. 2009; Rurinda et al. 2020). Consequently, the intensified use of inorganic fertilizer is often recommended to bolster maize productivity. Several studies (Adnan et al. 2017; Liu et al. 2015; Liverpool Tasie 2016; Snapp et al. 2014) indicate that maize yield can rise substantially with high application rates of nitrogen fertilizer, reaching up to 150 kilograms (kg) per hectare, thereby underscoring the urgent need to increase maize yield using chemical fertilizers.

Nevertheless, many farmers, especially in heterogeneous communities, continue to experience low returns from fertilizer use, with variations across locations and time periods (Suri, 2007; Sheahan et al., 2013). Recent empirical studies further emphasize that merely increasing fertilizer quantity is unlikely to yield productivity gains in countries like Nigeria (Burke et al., 2017; Liverpool-Tasie, 2017a; Roobroeck et al., 2021). This is due to various factors, such as soil physical properties characterized by high silt content, textural discontinuity, and shallow tillage practices by smallholder farmers, which can lead to the development of hardened layers that hinder water infiltration, nutrient movement, and root growth (Burke et al. 2017; Marenya and Barrett 2009; Matsumoto and Yamano 2011; Roobroeck et al. 2021; Stoorvogel et al. 1993). Uncertainties and risks arising from conflicts and insecurity threats further contribute to this challenge (Adelaja and George 2019; Callen et al. 2014; Jakiela and Ozier 2015; Nnaji et al. 2022; Rockmoore 2020; Vlassenroot 2008).

In this study, our focus is on exploring the effect of conflicts on fertilizer use and maize yield response as well as ultimate profitability of inorganic fertilizers. While there is ample literature on the relationship between fertilizer use, maize yield response to fertilizer uses and profitability, studies specifically addressing the spatial effects of varying exposure of smallholder farmers to violent conflict on fertilizer and input use and, subsequently, on yield response and fertilizer use profitability are scarce. Conflict may impact the profitability of fertilizer through its influence on access (Nnaji et al. 2022), prices, and productivity (Rockmore 2015), especially affecting inorganic fertilizers and improved seed supplies—key inputs affected by conflict (Kimenyi et al. 2014). Additionally, conflicts disrupt food supply chains, increase farm labor scarcity, and can lead to a reduction in agricultural investments. Violent conflict in Nigeria has also led to a significant decline in cereal yield, including maize, due to widespread destruction of infrastructure (Adelaja and George 2019; Arias, Ibanez, and Zambrano 2019). Consequently, during conflicts, farmers may opt for low-risk, seasonal crops over intensive or perennial crops (Callen et al. 2014; Jakiela and Ozier 2015; Rockmoore 2020; Vlassenroot 2008).

Using farm household data to conduct empirical analyses of maize yield responses to fertilizer application in a conflict-affected context could offer essential insights to guide policy decisions and interventions aimed at improving access to yield-enhancing inputs like fertilizer among smallholder farmers in fragile settings. This paper investigates the effect of exposure to violent conflict on fertilizer use decisions, maize yield response and fertilizer use profitability in Nigeria. Our study contributes to the literature on agricultural technology adoption in fragile settings in several ways. First, we empirically examine the influence of conflict exposure on input use decisions among smallholder farmers, focusing on fertilizer use, maize yield responses and fertilizer use profitability within Nigeria—an important case study given Nigeria's increasing incidence of violent conflict. Second, we use panel data from the LSMS-ISA nationally representative household surveys that include detailed socioeconomic, farmland, and demographic information, and we integrate this data with geo-referenced, long-term, spatial data on violent conflict. Last, our study's findings could offer valuable insights into understanding resource use decisions among smallholder farmers in other conflict-affected countries and contexts of resource-use disputes.

We use the fixed effects model applied to longitudinal data to analyze the relationship between fertilizer application and maize yield under conflict conditions in Nigeria, while also examining pathways through which these conflicts affect fertilizer use profitability Our study reveals that yield responsiveness to nitrogen is very low in the country. A significant percentage (about 57 percent) of maize farmers have an estimated average value cost ratio (AVCR) of greater than or equal to two, the threshold required for fertilizer to be profitable in low-income countries with substantial transaction costs. This implies that the costs associated with higher levels of inorganic fertilizer application surpass the potential economic benefits for a significant proportion (43%) of maize farmers in Nigeria. We also find that conflict in Nigeria influences farmers' decisions about fertilizer use, with these effects varying depending on the specific nature of the conflicts. Our study reveals that exposure to conflict reduces the marginal physical productivity of nitrogen in maize farming, consequently diminishing profitability. Additionally, we observe that the interactions between nitrogen fertilizer application rates and conflicts at various distances along the spatial continuum have differing effects on maize yield. In addition, there is a gender disparity in how conflict affects nitrogen profitability in maize yield, with conflicts leading to a more significant reduction in the profitability of fertilizer use for plots headed by women.

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. Section 4 details the data sources, variable construction process, and descriptive outcomes. Our empirical approach is discussed in Section 5. Section 6 presents the findings and discussions stemming from the econometric results. The concluding section encapsulates our final remarks.

2. Overview of Fertilizer Polices and Conflict Situations in Nigeria

2.1. Fertilizer polices in Nigeria

Since the 1980s, Nigeria's fertilizer sector has experienced various government interventions. At one point, fertilizer subsidies made up as much as 68% of agricultural expenditure (Takeshima and Liverpool-Tasie 2013). However, due to fiscal challenges, the government sought to liberalize the sector and phase out subsidies, which led to reduced fertilizer use. The introduction of the Federal Market Stabilization Program (FMSP) in 1999 provided a 25% discount on fertilizer, but supply struggled to meet demand, resulting in two market channels: an unsubsidized open market and a subsidized government market (Takeshima and Nkonya 2014).

To improve transparency, the Growth Enhancement Support Scheme (GESS) implemented an e-wallet voucher system from 2011 to 2015, allowing farmers to access subsidized inputs via mobile phones (Liverpool-Tasie 2013). From 2016 to 2020, the Presidential Fertilizer Initiative (PFI) focused on supply-side subsidies, aiming to lower production costs and promote local blending. This initiative helped revitalize 52 fertilizer-blending plants (NSIA 2022). Despite these efforts, fertilizer subsidy programs have seen limited success (Devadoss 2016; Nasrin 2021). Challenges in implementation, poor policy performance, and increasing security threats over the past decade have significantly obstructed farmers' access to fertilizer. The following sections will explore these conflicts and their effects on the fertilizer sector.

2.2. Conflict situations in Nigeria

Conflict and general security threats, such as the herder–farmer conflict, the Boko Haram insurgency, armed banditry attacks, communal clashes, ethno-religious crises, and kidnappings, pose major security concerns in Nigeria, affecting household livelihoods, agricultural investment, production activities, productivity, and food security (Adelaja and George 2019; Arias et al. 2019). Over the last 15 years, the nature of conflicts has changed in Nigeria, with increases in the number of actors and perpetrators, fatalities, and incidents (Odozi et al. 2021). How conflict is expressed depends on the drivers and processes through which it originates, and the groups involved in it. The key drivers could be competition over resources (Abdul et al. 2014) or historical, ideological/cultural, ethnic, and religious factors (Ningxin et al. 2018).

A major source of insecurity threat and conflict that has jolted the security landscape in Nigeria has been the Boko Haram (BH) insurgents or terrorists, who launch their attacks mainly in the Northern and Northeastern part of Nigeria. Other parts of Nigeria, however, are not spared from other types of violent conflict. For example, ACLED data show that the Lagos state of Nigeria reported the highest number of conflict incidences in 2020 (65,390 conflicts), mirroring how other conflict types such as communal clashes and kidnapping are mostly clustered in large urban areas. While the Northeast experiences conflicts primarily because of the BH terrorist strikes, the North-Central region is beset by both the farmer–herder conflicts and sporadic BH attacks (Abul et al. 2018; Kaila & Azad 2019). On the other hand, the oil-rich Southern parts of Nigeria face conflicts mainly related to communal violence and struggles for control over oil revenues.

In particular, the conflict between Nigerian farmers and herders resulted in a third of the increase in deaths and the displacement of approximately 300,000 people in 2018 across Nigeria (Global Terrorism Index 2019). The North-Central geopolitical zone, the region accounting for the majority of Nigeria's agricultural production, was the most affected region. Conflict incidences in this region incapacitate farmers' ability to access their farms and subsequently delay essential farm activities and investment in yield-enhancing modern inputs such as fertilizer, thereby negatively affecting agricultural productivity and rural livelihoods. Thus, understanding the magnitude and pathways through which violent conflict affect agricultural productivity is key for decisions and interventions to mitigate the challenges. This paper aims to fill the evidence gap on how violent conflict affects agricultural productivity through its effects on access to and farmers' decisions on application rates of inorganic fertilizer.

3. Conceptual Framework and Hypotheses

3.1. Conflict and input use decisions

The fundamental microeconomic principle that informs input use decisions for a rational firm or farm is that, all else being constant, profit is maximized when the amount of input used corresponds to the point where the marginal value product (MVP) of the input equals the marginal cost of that input. However, market imperfections and a high-risk production environment such as violent conflict could lead to suboptimal resource allocation (Ragasa and Chapoto 2017; Sheahan et al. 2013; Xu et al. 2009). By impeding the smallholder farmers' decisions on where and how much to invest in fertilizer, violent conflict could have a negative impact on productivity and profitability of fertilizer use. Existing evidence on the effects of violent conflict on smallholders' agriculture demonstrate that farm households in conflict-prone regions respond to the uncertainties and risks posed by conflicts by adjusting crop types and choosing suboptimal agricultural practices (Arias et al. 2019; Bozzoli and Brück 2009; Deininger 2003). Examples include switching from perennial cash crops, which are highly profitable, to seasonal food crops, which are less profitable, and to subsistence farming.

Conflict can affect farmers' input use through direct and indirect pathways. First, by disrupting the input markets and constraining access to input dealers, conflicts can severely disrupt the flow of agricultural input supply chains. Second, violent conflict creates an atmosphere of insecurity and fear, which can deter farmers from accessing their fields promptly and affects their routine activities, such as timely fertilizer application, resulting in suboptimal fertilizer use and reduced crop productivity. Third, by disrupting the input supply chains, conflict can cause an increase in input prices, making these inputs unaffordable to smallholders. Credit constraints that most smallholders face in developing countries can confound fertilizer unaffordability. The fourth channel through which violent conflict can affect fertilizer use is the destruction of infrastructure, including agricultural facilities and storage infrastructures. This destruction may affect the availability, accessibility, and affordability of fertilizers, further hindering smallholder farmers' ability to obtain and use them. Fifth, violent conflict can lead to behavioral changes or farmers' perception of risk. Nnaji et al. (2022) note that higher risk perception of conflict reduces fertilizer use, and that risk-averse households rent-in significantly less cropland compared with risk-taking households. Risk aversion may lead to suboptimal resource use, such as in fertilizer use decisions. Arias et al. (2019), in their study on smallholder agricultural decisions in Columbia, show that during times of uncertainty occasioned by conflict, farmers tend to lower investments and shift to short-term and less-productive seasonal crops.

Violent conflicts can also severely disrupt agricultural supply chains and transportation networks, restricting farmers' access to essential output markets. These disruptions create price distortions and market instability, making crucial inputs like fertilizers and improved seeds less affordable. As a result, crop production is jeopardized on multiple levels. Conflicts that impede farmers' participation in output markets can compromise their income. This chain reaction can significantly affect crop yields, creating a cycle of reduced productivity and economic instability in regions impacted by conflict. These pathways are likely to induce nonavailability, reduced accessibility, and unaffordability of fertilizer, which could be partly triggered through risk-aversion behavioral responses of smallholders. For instance, Nnaji et al. (2022) found that less fertilizer is used, and more time is set aside for agricultural labor, when there is a high likelihood of farmer–herder conflict, and risk-averse households rented in considerably less cropland than risk-taking households. Based on these impact pathways, we hypothesize that violent conflict as a non-agronomic factor disrupts a rational farmer's optimal input use decision, fertilizer application rates in the present study, and lower crop yield response to the fertilizer. Thus, the overall aim of this paper is to establish empirical bases for the pathways and test the hypothesis using panel data and econometric analytical tools.

3.2. Conflict and Fertilizer use, Yield Response, and Profitability

Conflict and welfare outcomes have long been demonstrated to be related and to display spatial clustering in a number of geographical locations (Peterson and Krivo 2010). Apart from that, social processes such as collective efficacy and neighborhood trust also cluster in space, and over the past 40 years, there has been a high spatial covariation between welfare outcomes and neighborhood dynamics (Sampson and Graif 2009). However, although they differ from one area of location to another, the relationships between local welfare and violence typically hold true for a number of neighborhoods that are in close proximity (Sampson and Graif 2009).

The majority of studies implicitly assume that characteristics of the area where a person lives adequately reflect risk exposures (such as violent conflict). This ignores the reality that a person's daily activities expose them to a variety of neighborhoods on an ongoing basis. This is known as the "residential trap," according to Chaix (2009). Though these everyday routines of individual people expose them to various neighborhoods beyond their immediate residential neighborhood, only a few studies have looked at how routine exposure to various nonresidential neighborhood risks may affect crime and violence. Thus, it is surprising that developments in our collective understanding of spatial dynamics at the ecological level have not been incorporated into the analytical framework of neighborhood effects on individuals, given the progress made in highlighting the ecological levels of covariation between welfare and violence (for an exception, see Sampson et al. 1999).

In this study, to account for the neighborhood effects on maize yield response to nitrogen use and the mechanisms through which this is expressed, we incorporate incidences of violent conflict that are beyond immediate household residences, such as conflicts between a 15–30 kilometer (km) and a 30–45 km radius of residential households. Following Anselin et al. (2000) and Tita and Griffiths (2005), we conceptualize that beyond conflict incidents occurring near household residences, the processes of diffusion or contagion extend to non-residential areas, crossing neighborhood boundaries and increasing exposure to risk factors in nearby neighborhoods. This occurs due to clustering and the daily movements of residents. This could be especially true if the effects of spatial proximity are largely caused by overlapping activity spaces, largely driven by people's frequent movement (such as daily commuting) across space, which underscores a more general form of interdependence. This is especially relevant because products and purchased inputs frequently move between neighborhoods, and their supply chains are likely to be disrupted by conflicts

Generally, conflict has spillover effects on neighboring areas, including through the arrival of displaced populations. This factor can contribute to labor force expansion and lead to a decrease in per capita income due to migration, market closures, road blockades, disrupted trade flows, and decisions on resource allocation, including farm resources and input use decisions and allocations. In this paper, we opine that a more complete understanding of neighborhood effects of violence may result in a comprehensive understanding of nitrogen fertilizer use decisions and corresponding maize yield response. These spillover effects from conflict within close proximity to households could affect input and the nitrogen use mechanism by introducing instability and uncertainty into the broader communities and neighborhood, similar to the effects of a negative shock. A region may see a decline in trust when faced with violent conflict, with communities less likely to engage in the interpersonal interactions necessary to make and fulfill economic decisions and objectives.

4. Empirical Approach

4.1. Yield response to fertilizer use

Our empirical approach to the smallholder's resource allocation (input use) decisions and farm yield is based on the standard farm household model (de Janvry et al. 1991; de Janvry and Sadoulet 2005; Taylor and Adelman 2003). With perfect markets, the production and consumption decisions of a farm household are separable and unaffected by endowments. However, when markets are missing and uncertainties and risks overshadow rationality, input use decisions, household labor allocation, and outputs are affected by the prevailing exogenous constraints, such as insecurity threats, risk-averse behavior, and liquidity constraints. These constraints lead to suboptimal resource allocation and the consequent negative welfare outcomes. We approach smallholder farmers' demand for fertilizer using this standard model of household behavior under conditions of market failures and uncertainties. A reduced form specifications for demand for inputs, technologies, and supply of outputs can be derived from this utility maximization model of households under market failures and uncertainties (Sadoulet and de Janvry 1995).

Studies provide a succinct summary of a quadratic yield function, which we base our study on; this function has been frequently used in previous studies of crop yield response analysis (e.g., Kouka et al. 1995; Traxler and Byerlee 1993) and is seen to be a good approximation to the underlying functional form (Liverpool-Tasie et al. 2017a; Marenya and Barrett 2009; Sheahan et al. 2013). Following the selection of an input, the impact of fertilizer use on a farmer's maize yield can be described using this yield function:

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

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. Maize productivity is measured as the output index of maize yield per hectare. Output index is used here because all inputs are at plot level, and maize is mainly intercropped. These inputs cannot be separately allocated to maize. Yi $= \frac{\sum Y p_j Y_{ij}}{p_1}$, where Yi is the output index, p_i is the market price of crop j, Y_{ij} is the yield of j in field j, and crop 1 is maize.

The response of maize yield to nitrogen fertilizer use is represented by a quadratic yield function, as demonstrated in the studies by Sarkar et al. (2022) and Liverpool-Tasie et al. (2019). We chose this functional form due to its ability to accommodate zero inputs and exhibit concavity in the yield response curves. Because our primary interest is in estimating the extent to which nitrogen affects maize productivity, we specifically express the effect of nitrogen on maize yield as follows:

$$Yield_{iht} = \beta_1 \text{Nitrogen}_{iht} + \beta_2 \text{Nitrogen}_{iht}{}^2 + \beta_3 X_{iht} + \beta_4 T_i + \mu_h + \epsilon_{iht}, \tag{2}$$

where Nitrogen_{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 round dummies, and $\mu_h + \epsilon_{iht}$ is a composite error term comprising time-varying unobserved error (ϵ_{iht}) and time-invariant error (μ_h).[1]

4.2. Profitability of fertilizer use

A risk-neutral farmer aiming to maximize profit will find fertilizer use profitable when the average value product (AVP), representing maize yield per kg of fertilizer, exceeds the fertilizer's cost per kg. Conversely, if the AVP falls below the fertilizer's price, using fertilizer becomes unprofitable because the maize yield would not cover the cost. Therefore, despite using fertilizer to maximize earnings, the farmer must ensure that the MVP, indicating the additional maize yield from each unit of fertilizer, matches its value.

Based on our fixed-effects yield estimates above, we define the average physical product (APP) as the increase in maize yield per unit of nitrogen applied, compared with not using any nitrogen (Liverpool-Tasie et al. 2017; Sheahan et al. 2013). Subsequently, we use these APPs to calculate our profitability metric, the AVCR,[2] as follows:

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[1] All regression estimates are based on conditional fertilizer use by maize farmers (that is, only maize farmers who use fertilizer are used for the production regression estimates).

[2] We also calculate the expected marginal physical returns (MPPs) to fertilizer, which represents the additional maize output from using one more unit of nitrogen while keeping everything else constant, as described in Equation (3), alongside APP. We then use these MPPs to determine our profitability metric, the marginal value cost ratio (MVCR). However, the MVCR results are not included here (refer to the Appendix) but can be provided upon request.

$$AVCR_{nijt} = \frac{(P_{mijt} * APP_{nijt})}{APP_{nijt}}, \tag{3}$$

where P_{nijt} is the acquisition price of nitrogen[3] (that is, the market price for nitrogen plus transportation cost), and P_{mijt} is the price of maize.

4.3. The effect of conflict on profitability of fertilizer use

Upon establishing the plot-specific structural yield function (Equation 2), This 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 yield 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 application rate of nitrogen fertilizer on maize yield response is presented in yield function, as follows:

$$Yield_{iht} = \gamma_1 Nitrogen_{iht} + \gamma_2 Nitrogen_{iht}{}^2 + +\gamma_3\, Nitrogen_{iht} * conflict_{iht} + \gamma_4 X_{iht} + \gamma_5 T_i + \mu_h + \mu_t + \epsilon_{iht}, \tag{4}$$

where the coefficient γ_2 captures the combined effects of nitrogen and conflict at specific radii 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 lesser maize yield than expected.

5. Data and Descriptive Analysis

5.1. The data

This study employs three wave panel datasets from the Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) in Nigeria. These nationally representative surveys provide detailed information on assets, agricultural productivity, nonfarm income, other sources of income, labor allocation, and access to service within households. The agriculture

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[3] Due to limited data availability, we calculate our profitability ratio using the selling price, assuming farmers were well-informed about these prices at planting time. We substitute missing maize price values with zonal medians. The market price for nitrogen is based on farmers' reported fertilizer purchase price, adjusted for the nitrogen components of urea. Transportation costs per kg of nitrogen are factored in using farmers' reported costs of transporting fertilizer at purchase, further adjusted for the nitrogen component. Where the resulting fertilizer price was unavailable, we use the zonal mean price obtained from the available data.

module, among others, contains information on agricultural and livestock production, farm technology, use of modern inputs, and productivity of crops. The LSMS-ISA includes geo-referenced information related to household and plot data that allows us to link corresponding geo-referenced conflicts datasets to households. Thus, we merge the survey panel data with the geocoded data on conflict events collected through the Armed Conflict Location and Event Data (ACLED) project. While this study focuses on conflict types such as battles and VAC, the ACLED database[4] provides detailed records of event-based information for other types of conflict, including battles, VAC, remote violence, protests, and riots. Particularly, ACLED defines a battle as "a violent interaction between two politically organized armed groups at a particular time and location" and defines VAC as "occurrence when any armed/violent group attacks civilians. This includes attacks on civilians by Rebels, governments, militias, and rioters."

5.2. Construction of main variables of interest

Fertilizer and other inputs.

We measure 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, 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 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

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[4] The ACLED database is widely used in conflict literature and other studies (e.g Fadare et al., 2022; George and Adelaja 2019) aiming to understand the consequences of conflicts in different settings. We used the 2009, 2012 and 2015 ACLED datasets corresponding with the Nigeria LSMS-ISA wave 1-3 datasets. In Nigeria, violence against civilians and battles accounts for about two-thirds of the conflicts during the period 2000–2022.

We measure exposure of households to violent conflict using three indicators: (1) the number of incidences of violence against civilians within a 15 km radius, between a 15 and 30 km radius, and between a 30 and 45 km radius of the household's residence each year;[5] (2) the number of battles within a 15 km radius, between a 15 and 30 km radius, and between a 30 and 45 km radius of the household. In such a way, we avoid double counting conflict at different radiuses. Choosing a radius of 15 km allows us to evaluate the immediate impact of conflict on areas closest to violence, where disruptions are likely to be most severe. By modeling various radii beyond 15 km, up to 30 km, we can examine how conflict zones affect farmers' use of fertilizers and their ability to maintain productivity. Additionally, analyzing different radii helps us understand how varying intensities of conflict at different distances influence crop yield, fertilizer use, and agricultural practices.

5.3. Descriptive results

Tables 1 presents the summary statistics of the key variables used in the econometric analysis. The average age of household heads is 49 years, with an average household size comprising about seven people. The pooled sample shows that female-headed households account for only 13 percent of the sample. About 13 percent of sample households are involved in wage employment, 12 percent have access to credit, and 52 percent have access to the market. Regarding use of agricultural inputs, the pooled sample also shows that 91 percent use hired labor, 18 percent use herbicides, and 36 percent use pesticides.

The overall average farm size cultivated by the maize farmers (including fertilizer users and non-users) was about 1 hectare indicating the dominance of smallholders farming in Nigeria. About 80 percent of the farmers intercropped their maize plots, and 11 percent used organic fertilizer. All sampled plots received an average of 1,386 mm of precipitation across the three waves. Precipitation was highest in 2015 and lowest in 2012. The average maize productivity, measured as output index for all farmers, is 1,817 kg per hectare, whether or not they use fertilizer. The unconditional mean pooled value of nitrogen use per hectare (Table 1) is 43.80 kg per hectare, and the conditional use (that is, fertilizer users only) is about 90 kg per

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[5] ACLED's "violence against civilians (VAC)" is defined as deliberate violent acts perpetrated by an organized political group such as a rebel, militia, or government force against unarmed noncombatants. These conflict events harm or kill civilians and are the sole act in which civilians are an actor. There is no minimum number of victims needed to qualify as an ACLED event.

hectare. Specifically, the unconditional mean of nitrogen use was highest in 2012—estimated at 52 kg per hectare—and lowest in 2015.

Table 1: Descriptive statistics of dependent and explanatory variables (all maize farmers)

	Pooled		Wave 1		Wave 2		Wave 3	
Variable (N = 3,949)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Household head age (years)	49.0	14.91	50.06	14.93	49.32	15.20	48.13	14.62
Household size (no.)	6.98	3.60	6.48	3.48	7.71	3.82	6.73	3.42
Female household head	0.13	0.34	0.12	0.32	0.10	0.30	0.08	0.27
Wage employment (yes = 1)	0.13	0.33	0.13	0.34	0.10	0.30	0.15	0.35
Cooperative membership (yes = 1)	0.12	0.33	0.13	0.33	0.13	0.34	0.11	0.31
Access to credit (yes = 1)	0.12	0.33	0.12	0.33	0.12	0.33	0.12	0.33
Access to market (yes = 1)	0.60	0.49	0.54	0.50	0.60	0.49	0.64	0.48
Distance to market (km)	69.42	41.04	69.68	40.96	67.99	41.82	70.35	40.48
Yield, input, and plot characteristics								
Yield (output index in kg/ha)	1817	1958	1847	1592	1615	1760	1953	2278
Plot size (ha)	0.97	2.00	0.86	2.08	1.07	1.96	0.97	1.98
Quantity of nitrogen per ha (kg)	43.80	151.3	44.28	83.64	52.02	162.9	37.11	173.4
Hired labor (yes = 1)	0.91	0.29	0.92	0.26	0.89	0.32	0.91	0.29
Used herbicide (yes = 1)	0.18	0.38	0.14	0.34	0.17	0.38	0.21	0.41
Used organic fertilizer (yes = 1)	0.11	0.31	0.03	0.17	0.03	0.17	0.22	0.42
Used pesticide (yes = 1)	0.36	0.48	0.35	0.48	0.35	0.48	0.38	0.49
Used improved seeds (yes = 1)	0.29	0.45	0.61	0.49	0.17	0.38	0.17	0.38
Plots intercropped	0.80	0.40	0.81	0.40	0.85	0.36	0.77	0.42
Soil quality index	−0.01	1.00	0.21	0.10	−0.22	0.99	0.01	1.01
Annual mean temperature (°C)	260.3	11.76	259.8	10.88	259.6	12.72	261.1	11.48
Annual mean rainfall (mm)	1,386	491	1,363	474	1,338	481	1,437	504
Conflict variable								
No. of total conflicts, 0–15 km	0.70	2.34	0.11	0.41	0.25	1.40	1.43	3.27
No. of total conflicts, 15–30 km	2.00	4.41	0.47	1.07	0.87	2.79	3.86	5.86
No. of total conflicts, 15–30 km	2.68	4.67	0.76	1.88	1.02	2.84	5.19	5.38
No. of battles, 0–15 km	0.21	0.73	0.05	0.26	0.06	0.40	0.43	1.02
No. of battles, 15–30 km	0.66	1.42	0.27	0.72	0.30	0.94	1.20	1.84
No. of battles, 30–45 km	0.97	1.82	0.42	1.08	0.26	0.60	1.87	2.37
No. of VAC, 0–15 km	0.49	1.78	0.07	0.31	0.19	1.06	1.01	2.51
No. of VAC, 15–30 km	1.34	3.37	0.20	0.61	0.57	1.93	2.67	4.61
No. of VAC, 30–45 km	1.71	3.22	0.34	0.95	0.76	2.47	3.32	3.90

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.

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 2. We use fixed effects regression models to estimate the marginal physical product of nitrogen use on maize yield. While our discussion centers primarily on the fixed effects model results, we also include the random effects estimates of the yield function in Table 2. 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. This result aligns with the findings of Liverpool-Tasie et al. (2017a), who similarly observed a diminishing return to scale of nitrogen application in maize yield in Nigeria.

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 soil condition (the slope percentage) and plot size appear to have a negative effect on maize yield. 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, which is consistent with previous studies showing an inverse relationship between productivity and land area (Chayanov 1966; Liverpool-Tasie et al. 2017a; Sen 1962).

Table 2: Maize yield estimates (conditional fertilizer use)

	Fixed effects (FEs)	**Random effects (REs)**
Nitrogen (kg)	6.761***	7.159***
	(0.412)	(0.302)
Nitrogen squared	−0.002***	−0.002***
	(0.0002)	(0.0002)
Household head age	4.226	3.017
	(14.591)	(2.961)
Female household head	−295.260	120.246
	(452.635)	(153.278)
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)
Year fixed effects	Yes	Yes
N	1,896	1,896
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 enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.2. Profitability of fertilizer use

In this section, we delve into the effect of conflict on the profitability of fertilizer use employing AVRC. With a low marginal physical product (MPP) of nitrogen for maize yield, which is less than 7 kg per hectare, approximately 57 percent of maize farmers have an estimated AVCR of > = 2, the threshold required for fertilizer to be profitable in low-income countries with substantial transaction costs.[6] This suggests that the net benefit from nitrogen application is negative for around 43 percent of maize plots, indicating that many farmers who could profitably use fertilizer are currently using suboptimal amounts. Additionally, it suggests that a significant 43 percent of maize plots have already reached optimal levels of nitrogen application. This finding is consistent with similar studies, such as Liverpool-Tasie et al. (2017a), which focused on major maize production areas in Nigeria and reported a relatively low fertilizer yield response, with an MPP of 7.5 kg.

Table 3: Profitability of nitrogen use

	Full sample	Nitrogen user only
Variable	**Mean**	**Mean**
MPP	6.603	6.437
APP	6.682	6.598
AVCR	2.141	2.118

Source: Author's calculations.

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

6.2. Effect of conflict on maize yield response

We use household fixed effects yield function estimates to initially explore the interaction effects of conflict within varying kilometer radiuses of households on nitrogen use. Table 4 displays the interaction between conflict intensity and MPP of nitrogen use, encompassing both battles and VAC combined, within specific radius bands (less than 15 km, 15–30 km, and 30–45 km from the household). The analysis reveals a moderating influence of conflict on the response of maize yield to nitrogen use, particularly noting a negative and statistically significant coefficient when conflict incidents occur within a 15 km radius from the households. We identified a moderating effect of conflict intensity within the 15–30 km range from households but were unable to detect any moderating effect within the 30–45 km range. This suggests that the proximity of conflict intensities may indeed influence the moderation of maize yield response to nitrogen use in production. Nevertheless, treating conflict incidences as dummy variables resulted in statistically significant and negative coefficients across all distance

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[6] We also calculate the expected MPPs to fertilizer, which represents the additional maize output from using one more unit of nitrogen while keeping everything else constant, as described in Equation (3), alongside APP. These MPPs are then used to determine our profitability metric, the marginal value cost ratio (MVCR). However, the MVCR results are not included here (refer to the Appendix) but can be provided upon request.

radiuses of households considered (refer to A1), highlighting the potential impact of conflict in moderating the response of maize yield to nitrogen.

When we analyze conflicts further by disaggregating them into battles, we find statistically significant negative estimates for maize yield response to nitrogen when battles occur within 15 km, between 15 and 30 km, and between 30 and 45 km radiuses of households. Specifically, our findings indicate a substantial coefficient of nitrogen quantity applied on maize farm plots when households experience battles within a radius of less than 15 km. This suggests a substitution effect where the occurrence of battles in close proximity significantly reduces the marginal physical productivity of nitrogen use in maize yield. Additionally, the interaction effects of the number of battles within 15–30 km and 30–45 km radiuses with the quantity of nitrogen used also demonstrate a clear negative impact on the marginal returns of nitrogen use on maize yield, indicating that battles moderate the response of maize yield to nitrogen use. The statistically significant negative interaction estimates for battles occurring within a 30–45 km radius of households are particularly noteworthy because they highlight the potential impact of conflict incidents that extend beyond immediate spatial areas of households on the response of maize yield to nitrogen use.

Similarly, we explore how VAC within different radiuses (less than 15 km, 15–30 km, and 30–45 km from households) interacts with the yield response to nitrogen use (Table 3). The estimated marginal yield effect of nitrogen fertilizer varies significantly with the total of VAC incidents across these radiuses. Notably, we find statistically significant negative joint interaction effects of nitrogen and VAC on maize yield within less than 15 km and between 15 and 30 km radiuses of households, indicating a moderating effect of violent conflict on nitrogen's impact on maize yield. However, the interaction effect of VAC and the quantity of nitrogen used on maize yield is positive and statistically significant when VAC occurs between 30 and 45 km of households. One possible explanation for this is that the impact of violence exposure differs based on the proximity to residential households and neighborhoods.

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, 15–30 km	0.065		
	(0.329)		
Nitrogen * no. of conflicts, 30–45 km	0.532		
	(0.383)		
Nitrogen * no. of battles, 0–15 km		−6.877***	
		(1.888)	
Nitrogen * no. of battles, 15–30 km		−0.783***	
		(0.243)	
Nitrogen * no. of battles, 30–45 km		−1.549***	
		(0.495)	
Nitrogen * no. of VAC, 0–15 km			−2.345***
			(0.852)
Nitrogen * no. of VAC, 15–30 km			−0.783***
			(0.158)
Nitrogen * no. of VAC, 30–45 km			0.616***
			(0.272)
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
No. of observations	1,896	1,896	1,896
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: VAC = violence against civilians. 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.

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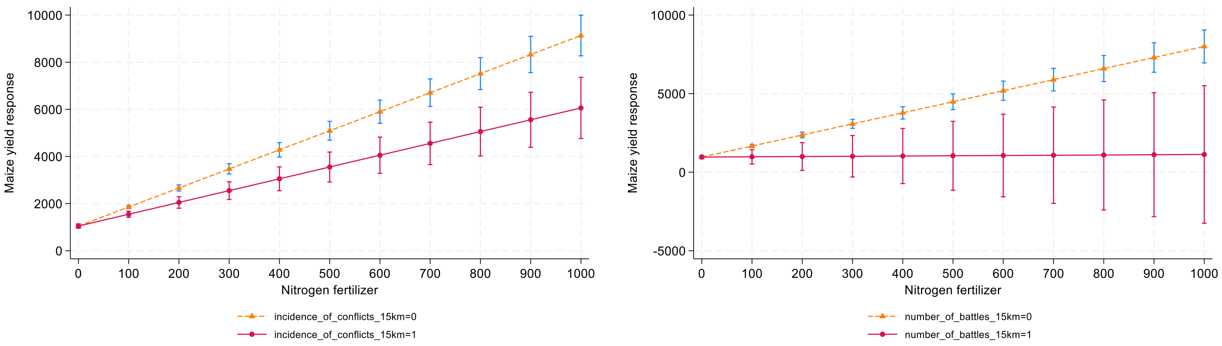
To better comprehend the interaction between maize yield response to nitrogen use and conflict indicators, we evaluate the influence of conflict measures on maize yield response to nitrogen by marginal analyzing effects. This analysis enables us to further explore the connection between conflict and the response of maize yield to nitrogen use. The plots indicate that maize yield response improves with increased fertilizer use, regardless of the presence of conflict, battles, or VAC (Figures 2a, 2b, and 2c). However, the positive effect of fertilizer use is more noticeable for households that do not experience any conflict, battle, or VAC within a 15 km radius. This is clear from the steeper rise of the line graph depicting maize yield response in these scenarios compared to situations where households do not experience these incidents.

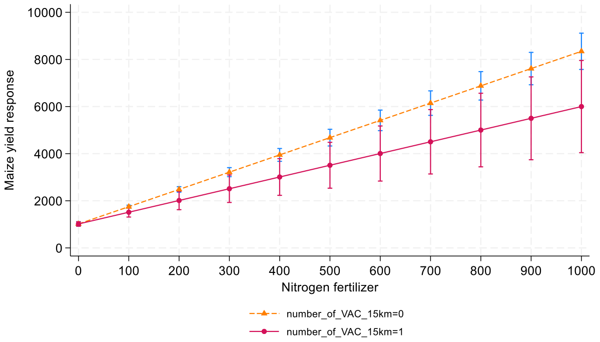
Figure 2: The marginal effects of nitrogen use within the context of conflict status within a 15 km radius

a) Maize yield 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



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 (less than 15 km, 15–30 km, and 30–45 km from households) on the profitability of fertilizer, as indicated by the AVCR[7]. The results show significant negative effects on nitrogen use profitability when total number of conflicts, battles, and VAC occur at various distances from households (mainly less than 15 km). This indicates a notable decrease in nitrogen fertilizer profitability during periods of conflict. This decline can be explained by several factors. First, conflict disrupts agricultural processes, causing damage to crop, livestock, and infrastructure. These disruptions directly affect farmers' ability to profit from nitrogen-enhanced yields.

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[7] We also assess the impact of conflicts on the MVCR as an indicator of nitrogen use profitability. The results mirror those of the AVCR, and for brevity, we provide the detailed findings in the Appendix or upon request.

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. Furthermore, conflict influences farmers' risk perceptions, leading to risk-averse behaviors such as reducing investments in nitrogen fertilizer or opting for less risky but lower-yielding activities. These 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, 15–30 km	−0.071** (0.036)		
No. of conflicts, 30–45 km	−0.327*** (0.034)		
No. of battles, 0–15 km		−0.429*** (0.080)	
No. of battles, 15–30 km		−0.002 (0.026)	
No. of battles, 30–45 km		−0.211*** (0.046)	
No. of VAC, 0–15 km			−0.096*** (0.033)
No. of VAC, 15–30 km			−0.150*** (0.023)
No. of VAC, 30–45 km			0.068*** (0.019)
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
R squared	0.649	0.574	0.576
N	1,896	1,896	1,896

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

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

6.4. Heterogeneous effects of conflict on profitability of fertilizer use

The effect of conflict on our outcome variable may differ depending on the gender of the plot head within the affected population. This can be captured by modeling an interaction between conflict type/indicator and the gender of the plot head (where female = 1). The coefficient of the interaction term isolates the unique effects of conflict for a female plot head. Table 6 displays the estimation results of the varied effects of the total number of conflicts, number of battles, and total number of VAC incidents on the profitability of fertilizer use. The results presented in Table 6 demonstrate statistically significant differences in the effect of conflict on the profitability of fertilizer use between male and female plot heads. We observe a greater but significant effect of the total number of conflicts for women compared with men (as shown in column 1 for total conflict within a 15 km radius and column 2 for battles within a 15 km radius). Our findings suggest that conflict has resulted in a more pronounced reduction in the profitability of fertilizer use for women, indicating their heightened vulnerability to conflict effects compared with men. This underscores the importance of gender-specific measures in conflict-affected areas, as conflict appears to have a varying impact on agricultural productivity based on gender.

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, 15–30 km	−0.136***		
	(0.037)		
No. of conflicts, 30–45 km	−0.291***		
	(0.034)		
Plot head gender (female = 1; 0 otherwise)	0.148		
	(0.216)		
No. of conflicts, 0–15 km * plot head female	−0.272**		
	(0.113)		
No. of conflicts, 15–30 km * plot head female	0.556***		
	(0.169)		
No. of conflicts, 30–45 km * plot head female	−0.290		
	(0.216)		
No. of battles, 0–15 km		−0.378***	
		(0.080)	
No. of battles, 15–30 km		−0.046	
		(0.029)	
No. of battles, 30–45 km		−0.179***	
		(0.047)	
Plot head gender (female = 1; 0 otherwise)		−0.100	
		(0.289)	
No. of battles, 0–15 km * plot head female		−1.834**	
		(0.870)	
No. of battles, 15–30 km * plot head female		0.109	
		(0.120)	
No. of battles, 30–45 km * plot head female		−0.096	
		(0.259)	
No. of VAC, 0–15 km			−0.067**
			(0.033)
No. of VAC, 15–30 km			−0.157***
			(0.024)
No. of VAC, 30–45 km			0.064***
			(0.018)
Plot head gender (female = 1; 0 otherwise)			0.334***
			(0.128)
No. of VAC, 0–5 km * plot head female			−0.044
			(0.370)
No. of VAC, 15–30 km * plot head female			−0.620
			(0.393)
No. of VAC, 30–45 km * plot head female			0.408
			(0.275)
Household fixed effects	Yes	Yes	Yes
R squared	0.660	0.587	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: AVCR = average value cost ratio; VAC = violence against civilians. All continuous variables are in log form. Standard errors, clustered at enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6.5 The effect of conflict on input use

In this section, we conduct tests on the pathways through which conflict could reduce maize yield fertilizer response. Our hypothesis suggests that conflict, considered a non-agronomic factor, disrupts a rational farmer's optimal decision-making regarding input use. This disruption ultimately leads to a lower crop yield response to the fertilizer. Table 7 presents the estimates for the effects of conflict on nitrogen use on maize plots. Our estimates show a statistically significant negative relationship between the number of conflicts within less than 15 km of households. Conflict within a 15 km radius of households reduces the likelihood of nitrogen use by about 6 percent. Disaggregating conflict incidences (within a 15 km radius of households) to battles and VAC, we obtained similar results with that of the overall conflicts. Battles reduce the likelihood of nitrogen use by about 6 percent and VAC by about 3 percent.

However, as the conflict moves further away from the households, nitrogen use seems to increase. The number of conflicts within a 15–30 km and a 30–45 km radius tends to increase the likelihood of nitrogen use by about 4 percent and 3 percent, respectively. Therefore, as evidenced by our estimates for the number of conflicts within a 30–45 km radius of households, either in the neighborhood or in close proximity to households, input use decisions would be affected, just like in other economic activities, because household activities both inside and outside of neighborhoods are frequently interdependent. The decline in fertilizer use caused by violent conflicts can result in reduced agricultural output, lower income, and heightened food insecurity. This disruption exacerbates poverty, restricts market access, and negatively impacts the overall stability and growth of the region

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, 15–30 km	0.043** (0.017)		
No. of conflicts, 30–45 km	0.027* (0.014)		
No. of battles, 0–15 km		−0.063* (0.036)	
No. of battles, 15–30 km		0.007 (0.013)	
No. of battles, 30–45 km		0.054*** (0.017)	
No. of VAC, 0–15 km			−0.034* (0.018)
No. of VAC, 15–30 km			0.017 (0.012)
No. of VAC, 30–45 km			0.001 (0.009)
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
No. of observations	3,915	3,915	3,915
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: VAC = violence against civilians. 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.

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Table 8 presents the effects of conflict on improved seeds use. Our estimates show that conflicts within a 15 km, 15–30 km, and 30–45 km radius of households all have a negative relationship with the use of improved seeds. Only conflicts within the 30–45 km radius of households are statistically significant, however. We obtain similar results when we disaggregate conflicts into battles and VAC and obtain a negative relationship between battles and VAC and the use of improved seeds. Particularly, battles (within less than a 15 km and between a 30 and 45 km radius) are statistically significant and reduce the likelihood of using improved seeds on the maize plots. The number of VAC between a 15 and 30 km and a 30 and 45 km radius statistically reduces the likelihood of improved seed use. When violent conflicts restrict the use of improved seeds, it is likely to hinder yields, reduce farmers' income, and exacerbate food insecurity.

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, 15–30 km	−0.033 (0.021)		
No. of conflicts, 30–45 km	−0.122*** (0.018)		
No. of battles, 0–15 km		−0.165*** (0.047)	
No. of battles, 15–30 km		−0.016 (0.017)	
No. of battles, 30–45 km		−0.059*** (0.022)	
No. of VAC, 0–15 km			−0.036 (0.024)
No. of VAC, 15–30 km			−0.056*** (0.016)
No. of VAC, 15–30 km			−0.048*** (0.012)
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
No. of observations	3,915	3,915	3,915
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: VAC = violence against civilians 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 9 presents the effects of conflict on use of hired labor on maize plots. Our estimates show that conflicts within 15–30 km reduce the likelihood of hiring labor on maize farm plots. Odozi and Uwaifo (2021) similarly found that violent conflict drastically lowers the overall number of hours that a family spends working in agriculture. When we consider battles and VAC separately, we observe that the number of battles within a 15 km radius of households has a positive relationship with the use of hired labor on maize farm plots, whereas the number of battles within a 15–30 km and a 30–45 km radius has a negative relationship with use of hired labor, showing its potential role in reducing the number of maize farming households that use hired labor. However, VAC does not statistically affect the use of hired labor within any radius of households.

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, 15–30 km	−0.015*		
	(0.004)		
No. of conflicts, 30–45 km	0.004		
	(0.003)		
No. of battles, 0–15 km		0.085**	
		(0.040)	
No. of battles, 15–30 km		−0.075***	
		(0.015)	
No. of battles, 30–45 km		−0.033*	
		(0.019)	
No. of VAC, 0–15 km			0.002
			(0.020)
No. of VAC, 15–30 km			−0.008
			(0.014)
No. of VAC, 30–45 km			−0.008
			(0.010)
Year fixed effects	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes
No. of observations	3,915	3,915	3,915
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: VAC = violence against civilians. 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.

7. Conclusions and Policy Implications

Most existing studies emphasize increasing application of inorganic fertilizer to enhance crop yields and often factor the economic (e.g., prices and finance) and biophysical (e.g., soil and weather) conditions into the analysis. In our present study, however, we diverge from this conventional approach and incorporate how conflict events could affect a farmer's decision to use fertilizer, the productivity of fertilizer, and the profitability of fertilizer, using maize yield as a case study in Nigeria. Initially, we analyze how maize yield responds to fertilizer use and assess the profitability linked to fertilizer use. Then, we delve into the effects of conflict on the profitability of fertilizer. We combine the ACLED geocoded longitudinal dataset with the Nigeria LSMS-ISA three-wave panel data. Our objective is to gain insights into the response of maize yields to fertilizer application and to examine how conflicts affect both fertilizer and use of other associated inputs, as well as maize yield responses in Nigeria. We employ household fixed effects specification to estimate the fertilizer–maize yield response within the conflict settings.

Evidence on the effects of conflict on smallholder farmers' investment decisions, including the use of agricultural inputs, has been scanty, despite a general growing body of literature on the implication of conflict on rural households' welfare and livelihood outcomes. Our study reveals that exposure to different conflict types decreases fertilizer productivity in maize farming and lowers profitability of fertilizer. Conflict may directly damage crops, livestock, and infrastructure, as well as affect farmers' profit indirectly through its effect on access to or use of yield-enhancing agricultural inputs such as fertilizer and improved seeds. Market disruptions, such as price fluctuations and limited access due to conflict, make it harder for farmers to sell their produce profitably or get inputs at reasonable prices. Conflict also limits input use, including nitrogen fertilizer, due to logistical challenges, supply shortages, or safety risks, reducing agricultural productivity and profitability. Additionally, conflict influences risk perceptions, leading to risk-averse behaviors such as reducing investments in nitrogen fertilizer or choosing less profitable but safer activities, which further lowers overall agricultural profitability in conflict-affected areas.

From a policy standpoint, these findings provide crucial decision support evidence in two ways: First, in the mainly unsecure rural economy settings, ensuring safe and secure rural households is a crucial way to increase smallholder farmers' productivity and investments. Thus, policies and strategies that guarantee safe and secure agricultural input supply chains need to be developed to lessen the frequent disruptions that now plague input supply chains in many parts of Nigeria. Second, ensuring long-term improved livelihoods and food security requires investments and interventions in agricultural technologies and infrastructure development, as well as targeted interventions that prevent conflict and/or mitigate conflict by building the resilience capacity of households and communities.

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Appendix

Table A1: Maize yield estimates (full sample)

	Maize yield	
	Fixed effects (FEs)	**Random effects (REs)**
Nitrogen (kg)	5.636***	5.649***
	(0.399)	(0.319)
Nitrogen squared	−0.001***	−0.001***
	(0.0002)	(0.0002)
Household head age	−7.296	1.221
	(8.409)	(2.465)
Female head of household	168.609	119.565
	(247.314)	(105.751)
Household size	13.556	−0.289
	(28.420)	(10.584)
Plot size (ha)	−207.993***	−198.385***
	(20.950)	(14.782)
Used improved seeds	30.835	59.064
	(76.546)	(60.244)
Used pesticide	−111.914	−96.756
	(93.728)	(67.220)
Used herbicide	103.031	80.571
	(102.330)	(78.504)
Cooperative membership	6.448	−127.723
	(280.605)	(108.934)
Access to credit	124.757	−91.389
	(256.886)	(104.806)
Hired labor	143.731	−36.048
	(437.745)	(126.337)
Soil quality	5.432	3.902
	(35.148)	(28.388)
Slope percentage	−57.615	−26.778**
	(39.875)	(13.806)
Household distance to market	−19.116	−0.091
	(12.591)	(0.945)
Mean temp of wettest quarters	−4.218	−7.203**
	(2.220)	(3.500)
Annual precipitation	−4.218	−0.467***
	(2.220)	(0.088)
N	3,915	3,915
R squared	0.161	0.161

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: Yield estimates with conflict incidences within different radius bands

	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, 15–30 km (yes = 1)	1.288***		
	(0.414)		
Nitrogen * conflicts, 30–45 km (yes = 1)	−1.365***		
	(0.624)		
Nitrogen * battles, 0–15 km (yes = 1)		−1.125	
		(0.943)	
Nitrogen * battles, 15–30 km (yes = 1)		−0.704	
		(0.649)	
Nitrogen * battles, 30–45 km (yes = 1)		−1.104*	
		(0.583)	
Nitrogen * VAC, 0–15 km (yes = 1)			−6.057***
			(1.022)
Nitrogen * VAC, 15–30 km (yes = 1)			2.156***
			(0.578)
Nitrogen * VAC, 30–45 km (yes = 1)			2.476***
			(0.527
Household fixed effects	Yes	Yes	Yes
R squared	0.354	0.337	0.588
N	1,896	1,896	1896

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

Note: VAC = violence against civilians 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 A3: 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, 15–30 km	−0.048		
	(0.038)		
No. of conflicts, 30–45 km	−0.343***		
	(0.036)		
No. of battles, 0–15 km		−0.385***	
		(0.084)	
No. of battles, 15–30 km		−0.005	
		(0.027)	
No. of battles, 30–45 km		−0.241***	
		(0.049)	
No. of VAC, 0–15 km			−0.073**
			(0.034)
No. of VAC, 15–30 km			−0.154***
			(0.024)
No. of VAC, 30–45 km			0.074***
			(0.020)
Household fixed effects	Yes	Yes	Yes
R squared	0.601	0.536	0.536
N	1,896	1,896	1,896

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

Note: MVCR = marginal value cost ratio; VAC = violence against civilians All continuous variables are in log form. Standard errors, clustered at enumeration area level, are given in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.