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RESEARCH ARTICLE

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Environmental degradation and food security effects: evidence from the crude oil spillage in Nigeria

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ABSTRACT

There are increasing concerns over the environmental impact of oil spills, given the over-reliance on this source of energy in developing countries. The effects of oil spillage range from impacts on agricultural productivity to issues of food security. Meanwhile, the charges associated with alternative energy sources and increased budget pressure may make transitioning toward sustainability very difficult for households and the economy as a whole. Therefore, with Nigeria as a focus, this study investigates whether crude oil spillage in household locations affects local-level food security in Nigeria. We geographically match new spatial data from the National Oil Spill Detection and Response Agency (NOSDRA) on oil spill locations over the period 2010–2016 with approximately 5000 households from three Living Standards Measurement Study (LSMS) surveys conducted over the same period. Specifically, we used repeated rounds (post-planting and post-harvest) over 2010/2011, 2012/2013, and 2015/2016. The findings consistently show an increase in food insecurity experiences for households around spillage sites compared to residents in locations without any crude oil spill.

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Oil spillage; environment; degradation; livelihoods; food security

1. Introduction

Among the 17 United Nations Sustainable Development Goals, about 64.7% (eleven) are directly or indirectly related to the environment. Environmental degradation can cause higher poverty, vulnerability, human deprivation, inequality, and ecological challenges, with severe consequences for sustainable development. Hence, the poor are the most vulnerable, with a higher burden from environmental degradation, for diverse reasons, including poor adaptation and coping mechanisms (UN 2019; UNICEF 2022). While the focus of the economic literature has been on climate change, with significant attention directed at greenhouse gas emissions from the extraction and burning of fossil fuels, we analyze the effects of crude oil spillage—a form of pollution from a crucial energy source that some developing countries depend on. The activities of oil drilling and distribution are largely associated with bunkering, theft, spillages, and pollution. Nigeria, for example, produces about 1.7 million barrels per day, with 37 billion barrels of proven crude oil reserves, being the country with the second-largest amount in Africa after Libya (US-EIA 2020). Incidentally, the activities of oil drilling in the Niger Delta of Nigeria have been associated with 35 million metric tons of CO_2, methane, and other GHGs annually between 2013 and 2021 from gas flaring (Giwa, Adama and Akinyemi 2014). Additionally, since 1958, reports have shown over 10 million barrels of oil spillages, 7000 oil spill incidents, and a yearly average of about 240,000 barrels as of 2023 (Odesa, Ozulu, Eyankware, Mba-Otike and Okudibie 2024).

Concerns over the environmental impact of oil spillage loom with a growing reliance on this energy source in developing countries. The cost of alternative energy sources and the increased budget pressure may cause on households and the economy make transitioning towards sustainability very difficult. Critics claim that pollution from oil spillage creates a significant social and ecological burden, including effects on individuals' physical and mental health, income, and other environmental damages that affect species

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(Eklund et al. 2019; Ha and Cheong 2017; US-EIA 2021). Other studies highlight the damage to factors of production within households caused by oil spillage (Manotas-Hidalgo 2021). Therefore, considering the low regulatory environment in Nigeria and the fact that oil spillage is caused by formal and informal activities in the crude oil drilling process, with the latter (including bunkering) accounting for 15% of Nigeria's daily drilling capacity (Campbell 2015), evaluating the effects of this form of pollution is central.

Until recently, there has been a lack of systematic empirical evidence on the effects of crude oil spillage in a developing country's context, such as Nigeria. Unlike other forms of pollution, verifiably captured by pollutant concentrations in the atmosphere taken from NASA satellite data (Adhvaryu et al. 2024), crude oil spillage data are often inconsistent and contradictory. Thus, data from this sector are described as epistemological vertigo – that is, nothing quite seems to add up (Watts and Zalik 2020). While acknowledging this limitation in this study's main data source for analysis (i.e. the National Oil Spill Detection and Response Agency), the comprehensiveness of this data source allows for a systematic quantitative analysis of the effects of crude oil spillage in Nigeria.

We investigate whether crude oil spillage in household locations affects local-level food security in Nigeria. More specifically, we ask 1) whether oil spillage results in adverse food security consequences for households around the spillage locations and, if so, 2) what drives this effect? – This implies the mechanisms that explain the findings of the nexus between crude oil spillage and food security. This inquiry is particularly relevant in Nigeria, a country ranked 97th (out of 113 countries) in the overall global food security environment in 2021, with over 50% of West Africa's food-insecure population in 2019 residing in the country (ReliefWeb 2020; The Economist Group 2022). To this end, we geographically match a new georeferenced dataset on the subnational distribution of crude oil spillage in Nigeria from 2010/2011 to 2015/2016, with about 5000 households followed by the World Bank Living Standards Measurement Study survey team. We derive a difference-in-difference type of estimate that controls for unobservable time-invariant characteristics that may influence the selection of spillage sites. We do this by comparing the food security experiences of households that reside in locations close to the spillage sites at the time of the survey (six months prior) to those residing in locations without any form of crude oil spillage during the survey period.

The empirical results consistently indicate that households around spillage sites experience an increase in food insecurity compared to residents in locations without crude oil drilling. We do not observe any significant discrepancies in the pattern when the result is subjected to different data and variable definition manipulations. The observed adverse effect from crude oil spillage is also observed for household agricultural output and health outcomes, suggesting that household food insecurity pattern exists because the spillage affects household agricultural production and health for productive economic engagement for food access. Indeed, using the data on remittance receipt reports from the main dataset, the results suggest that crude oil spillage fuels food insecurity only for households with little or no remittance inflow. Considering the advocacy for a liquidity boost or a push for vulnerable households to cope with environmental shocks.

This paper relates to the broad literature on the sociogeopolitical consequences of environmental degradation or pollution, including effects on labor productivity (Graff-Zivin and Neidell 2012), labor supply (Hanna and Oliva 2011), human capital accumulation (Bruederle and Hodler 2019; Currie et al. 2009; Jayanchadran 2009), and agricultural productivity (Aragon and Rud 2016; Manotas-Hidalgo 2021), to mention a few. Considering the many adverse consequences of environmental pollution, interest in identifying food security effects from crude oil spillage requires a sensible approach that investigates sub-national variations in spillage incidence and food security experiences over time. Studies focused on food security effects from crude oil spillage in Nigeria consider only limited survey responses, making attribution difficult (Ordinioha and Brisibe 2013; Osuagwu and Olaifa 2018). Further, the present paper differs from the above studies in that it focuses on food security effects from measures that consider household experiences of food access and availability around spillage sites rather than estimates from a narrower and less systematic consideration of the issue. As such, we also contribute to the emerging literature by using subnational geocoded data to explore the impacts of the distribution of oil spillage within a developing country's context (Bruederle and Hodler 2019; Manotas-Hidalgo 2021).

In line with the results of this paper, but focusing on an in-depth literature review on the food security consequences of air pollution, Sun, Yun, and Yu (2017) find that not only does air pollution affect plant growth and animal health, but it also shifts the market equilibrium of both agro inputs and outputs in the food supply chain, leading to food insecurity. This current study is most closely related to that of Manotas-Hidalgo (2021), who investigated the effects of spillage on agricultural productivity, finding a relative reduction in agricultural output of approximately 2.73% for farmers residing closest to the site. This study builds on these findings by evaluating the food security effect, arguing that adverse effects on household farm production and health outcomes limit the capacity for access to sufficient, safe, and nutritious food. Nonetheless, addressing household liquidity constraints is an action-based policy recommendation from this study's analysis. This study is the first to use systematically geocoded spillage site-level data to investigate the effects of pollution on local food security. Considering the rising vulnerability of households in developing countries to pollution and the climate crisis, as well as the increasing engagement in polluting actions by the most vulnerable households, empirical evidence on the potential food security effects (a key welfare indicator) remains a central inquiry.

2. Pollution from crude oil spillage and food security

The Niger Delta region of Nigeria, the world's second-largest delta and home to significant crude oil deposits, is also the largest wetland in Africa, ranking as the third-largest in the world, located on the Atlantic coast of southern Nigeria (Kadafa 2012). The Niger Delta area includes rivers, creeks, estuaries, and stagnant swamps covering approximately 8600 sq km. The delta mangrove swamp spans approximately 1900 sq km, making it the largest mangrove swamp in Africa (Kadafa 2012).

Crude oil was first discovered in Nigeria in the Niger Delta region in 1956. The end of the Biafran war in 1970 coincided with a rise in the world oil price, leading to a rapid accumulation of capital by the Nigerian government and its subsequent membership in the Organization of the Petroleum Exporting Countries (OPEC) in 1971. Such industrial-scale drilling in Nigeria has resulted in pollution from oil. This is in addition to operational and mechanical failures, as well as other illicit activities, including oil theft, sabotage, and pipeline vandalism. Since such spillage occurs in coastal areas, a spill in one location could spread over a large area of land, regardless of its size. Other effects on wetland soil include lowering soil fertility by increasing the soil pH by up to 80% and alkalizing marsh soil, which affects soil fertility and contributes to the deterioration of wetlands (Manotas-Hidalgo 2021). Fire from oil spills also releases respirable particulate matter into the atmosphere, and such pollutants can lead to acidic rain that is directly absorbed by plants and contaminated air, resulting in adverse human health effects (Bruederle and Hodler 2019; Li, Du, and Zhang 2020; Manotas-Hidalgo 2021).

In light of this background, two main pollution features from crude oil spillage could affect local food security. First, spillage, regardless of its volume, can cause significant damage to the surrounding habitat, particularly in sensitive environments such as mangroves and wetlands (NOAA 2020). Many observers of pollution in other contexts record contamination that spans and extends beyond the immediate site in wetlands or waterways. For example, as described in the news media, the California oil spill off the coast of Orange County had workers in protective gear continue to comb the sand for tar balls, washing ashore along more than 113 km of coastline (National Public Radio 2021). Furthermore, oil spills in the Arabian Gulf resulted in broader contamination of soil within a 100 km radius of the incident location. The soil salt content has increased in areas up to 200 km away from the main incident (Issa and Vempatti 2019). As shown in Figure 1, such adverse environmental effects could significantly affect farm activities as well as food production and food for consumption (Manotas-Hidalgo 2021).

Second, there are health effects associated with the contamination of soil, water, and air from crude oil spillage. Little, Sheppard, and Hulme (2021) documented the diverse effects of oil spills, including their impact on human health. Such deleterious impact matters for productive economic engagement – in farm and non-farm activities (Asiedu, Jin, and Kanyama 2015) – with an indirect effect on food security (Seume-Fosso 2008). Indeed, the Food and Agriculture Organization's 2015 report, which focuses on climate change and food security, highlights the increasing pressure on the climate posed by pollution, which affects food production and availability. The report acknowledges the effects of pollution on agricultural production systems and human health (FAO 2015).

Hence, both economic and health effects arguably show the possibility of crude oil pollution fuelling local food insecurity. Nonetheless, an overwhelming argument for liquidity intervention could ease cash

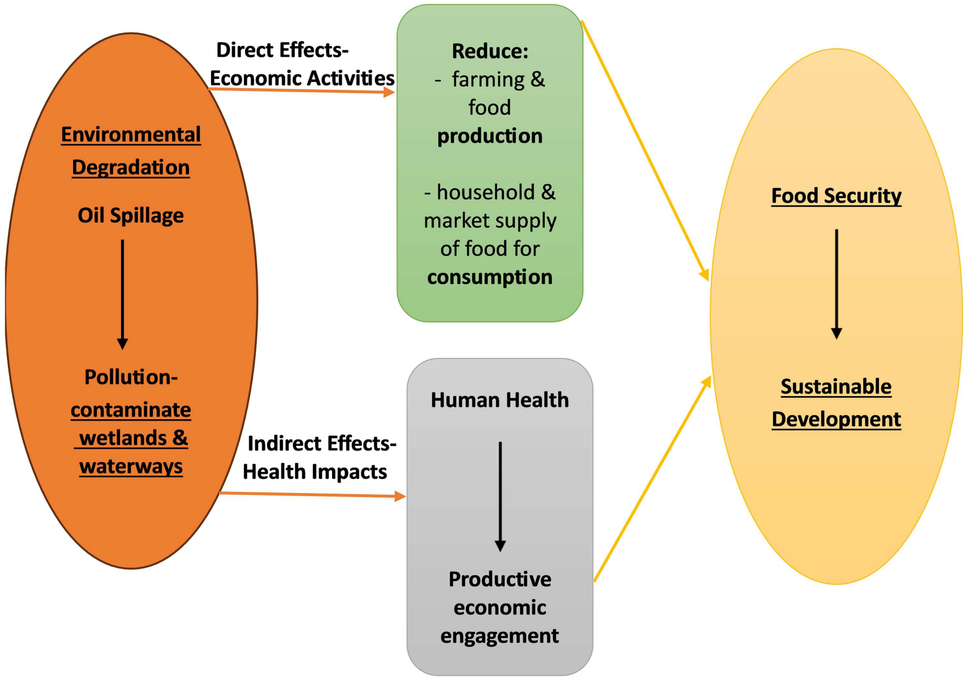

Figure 1. Transmission mechanism between oil spillage and food security.

constraints for vulnerable households' coping strategies (Wood 2011; Asfaw et al. 2017; Haile 2021). The next section discusses how to approach these issues empirically, including considerations of how liquidity availability to households can help cushion the effects of food insecurity caused by crude oil spillage.

3. Data and empirical strategy

To analyze the effects of crude oil spillage on the food security of locals, we geographically matched new spatial data on oil spillage locations over the period 2010–2016. We matched approximately 5000 households from three living standards measurement study (LSMS) surveys conducted in repeated rounds (post-planting and post-harvest) over the years 2010/2011, 2012/2013, and 2015/2016. As discussed later, we do not include the 2018/2019 survey rounds because of the difference in the survey instrument regarding the question related to the primary outcome variable – food security.

The crude oil spillage data were obtained from geo-referenced oil spill monitoring data of the National Oil Spill Detection and Response Agency (NOSDRA). This agency is under the Federal Ministry of Environment, Nigeria. It was established to coordinate the implementation of the National Oil Spill Contingency Plan, in compliance with the 1990 International Convention on Oil Pollution Preparedness, Response, and Cooperation, to which Nigeria is a signatory. These data are geocoded, with spill sites reviewed and confirmed by the agency, based on the paper records of the agency's joint investigation visits (JIVs) carried out when an oil spill occurred. These JIVs involve representatives from specific energy sector operator, community representatives, and relevant government agencies to visit oil spill sites for a common agreement on the cause, impact, and scale of the spill. These sites are geo-located, and the data are kept up to date by NOSDRA. This agency monitors oil spills through its zonal offices and intense interactions with volunteers, local communities, and state governments. Furthermore, information is obtained from operators in the energy sector in compliance with regulations that mandate the provision of data, quantity estimates, soil/water samples, and details about other cleanup operations.

This data source was used by Bruederle and Hodler (2019) to study the effects of crude oil spillage on infant mortality and by Manotas-Hidalgo (2021) to examine the effects on agricultural productivity. Despite this, there have been criticisms about this data source, including discrepancies between this data source and the company data (energy companies), as well as other Nigerian official regulatory bodies, such as the Department of Petroleum Resources and the Nigerian National Petroleum Corporation (Watts and Zalik

2020). Nonetheless, this data source is the only official source with geo-located information about crude oil spillage in Nigeria. Therefore, the limitations of this data source should be taken into account when interpreting the results of this study. This study's analysis may underestimate the effect of crude oil spillage in Nigeria, assuming that the NOSDRA data underreport all the likely spillages that coincide with the periods of analysis.

The NOSDRA geo-coded data assign latitude and longitude coordinates and information about the precision of the location identified, as well as information about the precision of the identified location, including the precision of the location itself (see NOSDRA 2019). All crude oil spills are typically confined to a limited geographical area, such as a village or community. There is no evidence of crude oil spills at a greater administrative level, such as in the United States. Since this paper focuses on the food security conditions of locals affected by environmental degradation, we emphasize only spills with recorded locations that are confirmed during the JIVs and related to crude oil. This study focuses on spillage with physical environmental implications by restricting the analysis to only spillage locations with precise geocodes.

We use the point coordinates in the NOSDRA data to link crude oil spillage that occurred six months before the survey to local respondents in the LSMS. The coordinates of the surveyed LSMS households' locations of residence in enumeration areas, which consist of one or several geographically close villages or neighborhoods, are used to match households to crude oil spillage data for which we have precise point coordinates. We measure the distance from the center points of the enumeration areas to the crude oil spillage location and rely on this measure to estimate the effects, testing whether such environmental degradation significantly affects the food security of households in locations closest to the spillage site. Pending further discussion in the subsequent analysis, we identify the enumeration areas within a cut-off distance of at least one crude oil spillage site, preferably a buffer within 75 km. The motivation for this cut-off is discussed in a later section. Nonetheless, Brown et al. noted that coastal region, like most of the crude oil drilling sites, provides critical services for households living within 100 km of coast or estuaries and inland populations. Therefore, pollution that contaminates waterways can have a broader impact, extending beyond the immediate location of the spill.

Figure 2 shows the total number of confirmed crude oil spillages corresponding to the survey periods, suggesting a steady increase in the periods 2010/2011 and 2012/2013 but a sharp decline in the periods 2015/2016 onward. This trend is consistent with the outlook in Manotas-Hidalgo (2021).

We employ the point coordinates in the NOSDRA data to link crude oil spillage that occurred 6 months before the survey to local respondents in the LSMS.

The post-planting and post-harvest rounds of the LSMS survey waves covered in this study provide a unique opportunity to study the food security experiences of Nigerian households. Specifically, this study's main dependent variables focus on household experiences with food access/availability, quality, and intake,

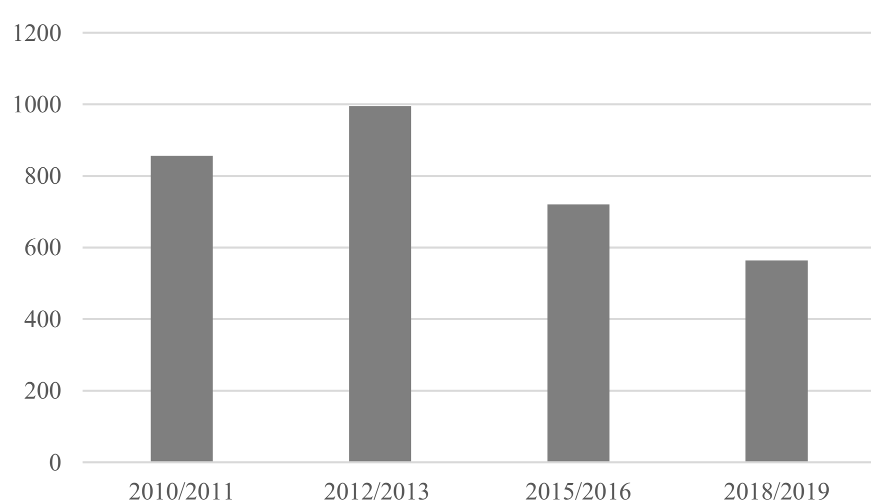

Figure 2. Crude oil spillage corresponding with LSMS survey periods. Note: We only include estimates from 2018/2019 in this figure to show the trend.

which fit the definition of food security adopted at the 1996 World Food Summit. That is, a household is considered food secure when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for a healthy and active life (FAO 1998). Therefore, we employ multiple LSMS questions to assess experiences with food access and the quality of food intake over the past seven days. In the LSMS later round (i.e. 2018/2019), the food security questions, howbeit diverse, focus on binary indicators (yes/no) if the households experienced any food (in) security experiences in the past 30 days. Noting this difference in the survey instrument, this study does not include information from the 2018/2019 LSMS round for its analysis. In the earlier rounds until the 2015/2016 survey rounds, the respondents were asked to recollect the number of days (in the past seven days) if they or any member of the household had to: (a) Rely on less preferred foods. (b) Limit the variety of foods eaten. (c) Limit portion size at mealtimes. (d) Reduce the number of meals eaten in a day. (e) Restrict consumption by adults for small children to eat. (f) Borrow food or rely on help from a friend or relative. (g) Have no food of any kind in your household. (h) Go to sleep at night hungry because there is not enough food. (i) Go a whole day and night without eating anything. The responses to these questions are the number of days of such experiences. Relying on these responses, we create a *food security* measure that computes the likelihood of the average household or any member of the household experiencing at least one day of any food insecurity occurrences.

We also compute additional indicators reflecting households having physical and economic access to sufficient, safe, and nutritious food, as implied by the FAO (1998)'s definition of food security. These indicators are: (i). *Limit portion size* – the likelihood of experiencing at least one day in a week of limiting portion size at mealtimes. (ii.) *Less preferred food* – the likelihood of experiencing at least one day in a week of relying on less preferred foods; and (iii) *Limit variety* – the likelihood of experiencing at least one day in a week of limiting the variety of foods eaten.

As seen in Table 1, 21.4% of the households in the sample experienced at least one day of any of the nine food insecurity scenarios. For the individual indicators, the summary statistics in Table 1 also show that 31.2% of the sample households have experienced at least one day of limiting the portion size at mealtimes, 43.07% have relied on less preferred foods for at least one day, and 40.08% have limited the variety of foods eaten for at least one day. These experiences have been examined for the past seven days based on the data covered by the LSMS.

This study's primary explanatory variable, subsequently described in greater detail, focuses on residing in locations closer to the confirmed crude oil spillage sites. We are not concerned about the volume of spillage in this study,[1] as the main objective of the analysis is to understand the immediate effect of spillage on households, irrespective of whether it is a small or large spillage. Large oil spills are major, dangerous disasters; likewise, smaller spills can also cause significant damage to the surrounding habitat, mainly in sensitive environments such as mangroves and wetlands, as is the context of this study (NOAA 2020).

Table 1. Descriptive statistics.

		Obs.	Mean	Std. dev
Main outcome variables				
Food security	A binary indicator if any member of the household has experienced at least a day of any of the nine-food insecurity incidence.	28,846	0.214	0.279
Limit portion size	A binary indicator if any member of the household has experienced at least a day of limiting portion size at mealtimes.	28,846	0.312	0.463
Less preferred food	A binary indicator if any member of the household experienced at least a day of relying on eating less preferred meals.	28,846	0.431	0.495
Limit variety	A binary indicator if any member of the household experienced at least a day of limiting the variety of food eaten.	28,846	0.401	0.490
Crude oil spillage				
Distance to closest spillage site	This variable measures the actual distance from the closest spillage site to the household. It was used to construct the variable 'proximity 75 km'.	28,828	212.1	180.941
Proximity 75 km	A binary indicator if the household resides in locations within 75 km of the closest spillage site.	28,808	0.289	0.453
Comparison	A binary indicator for households residing in locations outside the Niger Delta states.	28,495	0.753	0.431
Other variables				
Gender of HH head	A binary indicator if the head of the household is a male.	28,620	0.832	0.374
Age of HH head	Actual age of the household head, measured in years.	27,803	43.584	27.420
HH size	Total number of individuals living within the household.	28,623	6.302	3.352
Urban	A binary indicator if the household's residence is in an urban location.	28,495	0.316	0.465

Therefore, to accurately measure exposure and in keeping with the approach of Akresh, Caruso, and Thirumurthy (2022) to measure the effects from a geographic-specific occurrence, we use global positioning system (GPS) data on the site and household location to compute the distance. This calculation accurately measures households' likely exposure to the incidence of environmental degradation. Akresh, Caruso, and Thirumurthy's study shows that GPS data make a difference in the estimated effects, as expected effects are firmly and correctly seen for households closer to geographic incidence. Table 1 shows that the average household resides 212.1 km from the closest spillage sites.

This study analysis estimates the effect on households residing in locations in a selected buffer within a specific radius of 75 km. This indicator creates proximity measures, distance to the nearest spillage site, to explore the extent of effect decline as the household's location moves farther from the spillage site beyond this specified buffer.

3.1. Estimation strategy

Studying the effects of crude oil spillage on the food security of local communities presents challenges for causal identification. Although oil spillage can be attributed to several exogenous events, including the location of oil wells and the placement of pipeline infrastructure, other non-random events may also contribute to spillage. These findings suggest that, presumably, oil spillage could be correlated with some characteristics of individuals residing in sub-national location. Of particular relevance to this study, pre-existing poverty and food crisis levels, as well as other factors correlated with lower well-being (such as infrastructural deficits and a low potential for economic engagement in pipeline communities), are likely to influence criminal activities around pipeline locations. An example is illegal bunkering, which leads to higher levels of oil spillage in the community. Alternatively, an energy company with a poor social responsibility culture may be more negligent in its operations in locations with vulnerable populations, who may not have the ability to influence and demand corporate change. Such a population is also likely to be those with poor well-being, including food insecurity. While acknowledging that non-random events are infinite and the exact nature of endogeneity is difficult to ascertain, it does not seem plausible to assume ex ante that there is no relationship between oil spill locations and the pre-existing conditions of such locations. As such, the proximity to the spillage location may be picking up these issues. Hence, it is problematic to determine the causal effect of such environmental degradation on food security by considering only the localized distance to the spillage sites.

This study uses a spatial–temporal estimation strategy resembling that in Kotsadam and Tolonen (2016) and Isaksson and Kotsadam (2018) to address these identification problems. In particular, it compares the food security experiences of survey households residing in locations closer to spillage sites and those of households residing in locations outside of the Niger-Delta region of Nigeria. The non-Niger Delta clusters of Nigeria include every other cluster in States in Nigeria apart from those in Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers. These states are those in the Niger-Delta region of Nigeria (see Figure A1 in the appendix). As at the LSMS survey rounds, the Niger-Delta states are the only states with crude oil drilling sites.

The LSMS data are even more beneficial in this study's identification, as they typically follow the same household in the same localities over time. With this estimation strategy, we use the time variation in the data by leveraging the spillage data's ability to identify the spillage timing and localities affected, overlapping with the LSMS survey data covering different localities at similar points in time. Specifically, in the analysis, we utilize the availability of the specific timing of the oil spillage, what localities such spillage is sited, and the survey data spread across different localities at different points in time. This approach allows the identification of local households residing in areas where an active spillage site is recorded at periods of 6 months prior to the time of the survey and compares them with households residing in areas where there are no crude oil drilling sites at the time of the survey, mostly in the non-Niger-Delta region.

Therefore, apart from the household's distance to the site location, the primary identification strategy also assumes that food security is affected within a cut-off distance. The analysis considers two main groups of households, namely, those a) within 75 km of at least one spillage site and b) residing in a non-Niger-Delta cluster, which is absent from any form of crude oil spillage (comparison). We attempt to control for other non-random events that may determine spillage by imposing cut-offs and comparing food security for households at different distances to the spillage sites and those residents at other locations without any form of spillage.

The mathematical computation for this set of regression is:

$$Y_{het} = \alpha + \beta_1 \text{Dist\_cutoff}_{ht} + \beta_2 \text{Comparison}_{ht} + \lambda .\ X_{ht} + \varrho_e + \tau_t + \varepsilon_{het}, \quad (1)$$

where the food security outcome Y for household h resident in locality e at survey year t is regressed in the OLS set-up on the binary variable determined by the distance cut-offs as previously discussed (Dist_cutoff_{ht}) and a binary variable determined by residence in a non-Niger-Delta cluster (Comparison_{ht}). To control for variation in average food security levels across time and space, the regressions include spatial fixed effects ϱ_e (at the enumeration area level)[2] and survey year τ_t (at the post-planting/post-harvest survey-year rounds). In addition, we account for state-specific heterogeneity that changes at a constant rate over time by including a state-specific time trend in the regression analysis. Finally, we control for some observable household-level controls from the LSMS survey data X_{ht}, including the age and gender of the household head, household size, and urban/rural residence. The standard errors ε_{het} are clustered at the geographical cluster level, typically an enumeration area, such as a village, community, or neighborhood, to account for correlated errors. For a full variable description, see Table 1.

The coefficient β_1 Model (1) captures the effects of spillage on the food security of local households. The closeness to the oil spillage site used for analysis is specified within a buffer, assuming that the spillage location is not correlated with pre-existing structural or systemic issues distinctive to the location. As discussed earlier, making such an assumption is simplistic. Hence, including the *comparison* variation allows one to compare spillage locations to other areas where the spillage does not occur at the time of the survey. For this regression (1), the focus is thus on the parameter difference between Dist_cutoff_{ht} and Comparison_{ht} (i.e. the difference = $\beta_1 - \beta_2$) with other associated test results. This analysis employs a difference-in-difference approach that controls for unobservable, time-invariant characteristics that may influence the likelihood of selecting a location experiencing a crude oil spill.

Notably, the identification of the spillage location status depends on the actual confirmed presence of crude oil spillage in the specific area in question within six months. Hence, it is unlikely that the spillage status is misclassified in each survey round. Moreover, given the interest in whether crude oil spillage has a significant effect on local food security, this study assumes that households near spillage sites are likely to experience such effects. In contrast, those residing in locations farther from the spillage sites are likely not to experience such effects. The distance in this study is the actual distance to the site in kilometers, defined by a cutoff of 75 km to the nearest site. However, identifying an appropriate cutoff remains an empirical question requiring a trade-off between noise and the size of the affected group (Isaksson and Kotsadam 2018). A too-small cutoff distance will identify a small sample of households linked to spillage sites. Likewise, a too-large cutoff would include too many likely unaffected households in the so-called treatment group (or spillage affected group), leading to attenuation bias (Isaksson and Kotsadam 2018). This study's choice of a 75 km cutoff follows a similar reasoning as the main specification in Isaksson and Kotsadam (2018) to increase the power of the analysis.

Moreover, given that such spillage sites are located in one of Africa's largest wetlands and the world's third-largest mangrove forest (Wetlands International 2022), the 75 km cutoff is reasonable for exploring livelihood impacts. 28.9% of the sample in the LSMS data from 2010/2011 to 2015/2016 resides in locations within these radii. The robustness check shows that the alternative cutoff at 50 km maintains similar signs but lower significant values in some of the analyses because of a loss of power in identifying the effect, which implies that fewer households are close to the spillage sites.

4. Results

4.1. Main results: crude oil spillage and food security

The results indicate that crude oil spillage fuels food insecurity for households within the 75 km radius of the spillage sites. Table 2 presents the results of our baseline regressions, which focus on the average number of days a household reports experiencing any of the nine food insecurity incidences (column 1).

The individual indicators of food insecurity, including the number of days the household limits portion size (column 2), consume less preferred food (column 3), and limit the variety of food consumed (column 4). These questions are asked regarding the experiences in the past seven days, and the analysis includes household-level controls, community (411 communities), and year fixed effects, and the state time trend to capture state-specific heterogeneity that changes at a constant rate over time.

Looking at the coefficients on 75 km proximity to the closest spillage site, one can note that living within such proximity where crude oil spillage occurs is, indeed, associated with a significant likelihood of experiencing any of the nine food insecurity incidences for at least a day (see column 1). In particular, compared to households that do not reside close to any of the spillage sites (within a 75 km radius, to be precise), those living closest to the sites are significantly more likely to report experiencing any food insecurity incidence by 5.7-percentage points or 26.6% increase compared to the food insecurity experiences of the average household in the sample.

We find similar increases in the likelihood of the household residing closest to the spillage site reporting at least a day experience of limiting the portion size in a typical meal (by 7-percentage points), relying on less preferred foods (by 8.6-percentage points), and limiting the variety of foods consumed (by 9.1-percentage points). These effects are respectively significant at the 5% and 1% levels, pointing to the conclusion of a positive correlation between residences in locations closer to oil spillage sites and food insecurity.

As noted, interpreting the coefficient of proximity within a 75 km radius in isolation as capturing the effect of crude oil spillage on food security requires that the location of spillage sites is not correlated with pre-existing food security incidence among the locals or the pre-existing conditions of such locations. As explained earlier, we do not deem this assumption plausible; hence, to account for the likely endogenous location of spillage sites, we instead compare the food security experiences of households in locations close to the spillage sites and those in areas without any occurrence of oil drilling or spillages (i.e., comparison).

Looking at the coefficients on *comparison*, one can note that, unlike in areas with active oil drilling, we see no clear divergent pattern in food security experiences. Hence, there is no evidence of a systematic difference in food security incidence in locations where crude oil drilling may be occurring and other locations. Nevertheless, one should account for the strong possibility that oil spillage locations could differ from other areas with respect to determining food security experiences.

As it turns out, the difference-in-difference estimates [and associated test results presented in the third to the last row of Table 2 indicate more intense experiences of food insecurity close to spillage sites than locations without such spillage sites. In comparison with households living in locations outside the Niger-Delta region, those residing closer to the spillage sites are 9.5-percentage points significantly more likely to report experiences of at least one day of any food insecurity incidences. For the likelihood of experiencing at least one day of limiting portion size, consuming less preferred food, and limiting the variety of food consumed, the equivalent difference is 16.8-percentage points, 16-percentage points, and 17.3-percentage points, respectively. In the four different cases, the parameter differences are statistically and economically

Table 2. Crude oil spillage and household food security experiences.

	Food security	Limit portion size	Less preferred food	Limit variety
Proximity 75 km	0.057**	0.070**	0.086**	0.091***
	(0.023)	(0.029)	(0.034)	(0.031)
Comparison	−0.038	−0.098*	−0.074	−0.082
	(0.031)	(0.050)	(0.046)	(0.051)
Observations	27,685	27,685	27,685	27,685
R-squared	0.227	0.196	0.185	0.212
Controls	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes
Cluster FE	Yes	Yes	Yes	Yes
Mean dependent variable	0.214	0.312	0.431	0.408
Difference in differences	0.095	0.168	0.160	0.173
F-test: proximity 50 km − comparison = 0	1600.37	1540.55	1326.33	1562.30
p-value, F-test	0.000	0.000	0.000	0.000

The parsimonious controls are the gender and age of the household head, the household size, and a binary indicator if the household resides in an urban location. The 'Difference in difference' result gives the difference between the proximity 75 km and comparison areas, and we present the associated *F*-test and the *p*-value of the *F*-test. Standard errors (clustered by the survey clusters) are in parentheses; *** $p < 0.01$ and ** $p < 0.05$.

significant, implying a 44.4% increase in the likelihood of experiencing food insecurity, 53.8% increase in the likelihood of limiting portion size, 37.1% increase in consuming less preferred food, and 42.4% increase in the likelihood of limiting the variety of food consumed.

4.2. Sensitivity analysis

The finding (particularly the effect sign) that crude oil spillage fuels food insecurity is stable across various specifications and sub-samples. The results of a first set of robustness are presented in Table 3 for each of the outcome variables, as presented in Table 2. First, we test whether altering the cut-off distance from spillage sites changes the results (see panel A). Using a 50 km cut-off the results still indicate more food insecurity (although not consistently significant) for households in locations near the spillage sites as compared to those in the non-drilling locations, and the difference is highly significant for all the outcome variables.

Table 3. Crude oil spillage and household food security experiences.

	Food security	Limit portion size	Less preferred food	Limit variety
Panel A: Adjusting proximity cutoff				
Proximity 50 km	0.041	0.047	0.064*	0.069**
	(0.025)	(0.033)	(0.035)	(0.034)
Comparison	−0.052	−0.117*	−0.093*	−0.102*
	(0.033)	(0.062)	(0.048)	(0.055)
Observations	27,706	27,706	27,706	27,706
R-squared	0.226	0.196	0.185	0.212
Difference in differences	0.093	0.164	0.157	0.171
F-test: proximity 50 km − comparison = 0	1600.86	1549.05	1337.31	1571.75
p-value, *F*-test	0.000	0.000	0.000	0.000
Panel B: response variables measured in days				
Proximity 75 km	0.139**	0.176**	0.245***	0.264***
	(0.054)	(0.081)	(0.092)	(0.094)
Comparison	−0.065	−0.267*	0.016	−0.114
	(0.084)	(0.143)	(0.147)	(0.156)
Observations	27,554	27,402	27,391	27,432
R-squared	0.192	0.169	0.158	0.171
Difference in differences	0.204	0.443	0.229	0.378
F-test: proximity 75 km − comparison = 0	988.86	998.73	455.74	756.44
p-value, *F*-test	0.000	0.000	0.000	0.000
Panel C: exclude households residing around spillage sites				
Proximity 75 km	0.088***	0.114***	0.107***	0.130***
	(0.025)	(0.031)	(0.039)	(0.035)
Comparison	0.006	−0.033	−0.038	−0.025
	(0.034)	(0.054)	(0.053)	(0.058)
Observations	26,447	26,447	26,447	26,447
R-squared	0.228	0.198	0.191	0.216
Difference in differences	0.082	0.147	0.145	0.155
F-test: proximity 75 km − comparison = 0	1295.65	1287.14	1146.55	1328.30
p-value, *F*-test	0.000	0.000	0.000	0.000
Panel D: include households residing around spillage sites with spillage volume in the 25thpercentile of total oil spillage volumes				
Proximity 75 km	0.037**	0.063**	0.077**	0.084***
	(0.017)	(0.027)	(0.031)	(0.028)
Comparison	−0.021	−0.059	−0.020	−0.029
	(0.029)	(0.049)	(0.043)	(0.047)
Observations	18,288	18,288	18,288	18,288
R-squared	0.310	0.267	0.226	0.251
Difference in differences	0.058	0.122	0.097	0.113
F-test: proximity 75 km − comparison = 0	814.55	811.70	570.75	681.85
p-value, *F*-test	0.000	0.000	0.000	0.000
Panel E: addressing potential household migration				
Proximity 75 km	0.051*	0.059*	0.081**	0.080**
	(0.028)	(0.033)	(0.040)	(0.036)
Comparison	−0.053	−0.125*	−0.092*	−0.110*
	(0.037)	(0.066)	(0.054)	(0.058)
Observations	26,882	26,882	26,882	26,882
R-squared	0.232	0.201	0.189	0.218
Difference in differences	0.104	0.184	0.173	0.190
F-test: proximity 75 km − comparison = 0	1585.98	1522.48	1301.01	1544.48
p-value, *F*-test	0.000	0.000	0.000	0.000

Note: In Panel E, the sample is restricted to only households that had not moved before the subsequent survey visits

In Panel B Table 3, we use the equivalent dependent variables described in the LSMS data as the number of days that the household has experienced any food insecurity incidences in the past seven days. Compared to the binary indicators used as dependent variables in the initial results presented in Table 2, these variables may have the advantage of containing more information (captured in the number of days) on the prevalence of food insecurity but arguably do not come with an equally straightforward interpretation. The results remain qualitatively similar, although the ambiguity of its interpretation concerns the number of days the household experienced each incidence in the past seven days.

In Panel C Table 3, we restrict the sample by excluding households that may reside around the spillage sites but beyond the 75 km buffer, thus comparing the food security experiences of households directly with those not affected by the spillage in any way, rather than in relation to households nearby the spillage sites. Again, we see that the results for the different outcome variables are similar to those in Table 2, despite the slight reduction in sample size.

One may still argue that the magnitude of the crude oil spillage matters. A site with a gallon of crude oil spillage may have a lower impact than a site with 1000 gallons. Recall the earlier argument that such spillages are mainly in coastal locations: large and small oil spills can equally cause significant damage to the surrounding habitat, especially in sensitive environments such as mangroves and wetlands (NOAA 2020). Nonetheless, we only compute the distance from the household to spillage sites with spillage volumes equal to or above the 25th[3] percentile total spillage volume recorded 6 months before the survey date. We do not include the 2010/2011 wave survey in computing the spillage volume. The NOSDRA data do not accurately capture the volume of crude oil spillage compared to later coinciding survey years. One can note from Panel B that our results are robust to the consideration of the distance from the household to the nearest crude oil spillage sites, with spillage volume being in the 25th percentile and above the total spillage volume in the survey period.

Panel E presents estimates when we control for potential household migration across communities/villages. We restrict the sample only to those households that remain in the communities across survey waves and have not moved to other communities. Again, the results are robust or consistent, particularly in the coefficient sign, although the significant values vary for some of the outcome variables. Although not reported, the estimated results are also robust to controlling for community-level time trend to account for heterogeneities at the community level that change at a constant rate over time and a two-way fixed effect at the community and survey year level.[4]

To summarize the findings so far, they consistently indicate that crude oil spillage fuels the food insecurity of locals in spillage site locations. The following section explores the theoretical mechanisms potentially underlying this result.

4.3. Exploring theoretical mechanisms

In this theoretical discussion, we present diverse mechanisms tying crude oil spillage to local food insecurity and argue that changes in a household's economy (labor input and production) and health due to spillage could fuel the consumption ability of households. While the data do not allow for a clear distinction between these channels, one can explore suggestive evidence that supports or contradicts the respective mechanisms.

If food insecurity increases in locations around spillage sites, primarily due to a decline in agricultural productivity and labor input arising from damage to natural resources (land and waterways) from the spillage, one would expect to observe an adverse effect of the spillage on household economic situations, with significant consequences for food security. To capture the implications for the economic situations of the locals, primarily input and output from farm and non-farm activities, we use LSMS data on farm and non-farm labor input and actual crop yields in units of each harvested crop as a potential proxy for economic engagement. Assuming that an oil spill destroys farmland, which eventually affects other non-farm businesses through the sale of farm produce, for instance, one could expect adverse effects on the number of hours worked by both farm and non-farm labors. We do not distinguish between types of economic activities, as the primary interest of the analysis of mechanisms is to understand the likely changes to any indicators of the household economic outlook resulting from crude oil spillage. These measures have been shown to reflect economic activity at the household level (e.g. Fermont and Benson

2011; Nagler and Naude 2017), and the latter measure – crop yield – is a standard measurement of agricultural productivity that abstracts from deflation and output aggregation issues (Manotas-Hidalgo 2021).

Columns 1 and 2 of Table 4 show that this crude oil spillage is adversely correlated with household labor engagement and agricultural outputs/yields. Specifically, while the effect for labor engagement is not statistically significant, although the sign of the coefficient is consistent, the coefficient for agricultural outputs/yields is significant at the 5% level. Suggesting that compared to non-affected households, households located within the 75 km buffer closer to the spillage sites are more likely to record lower crop yields by 38.2%. Hence, these evidences suggest that the relationship between crude oil spillage and food security is driven by adverse effects on the agricultural production of the household in locations closer to the site.

Regarding the health channel, crude oil spillage, like other forms of environmental pollution, is expected to adversely affect household health outcomes. Suarez et al. (2005) found potential health effects from injuries and toxic deposits resulting from long-term exposure to oil spill. Similarly, D'Andrea and Reddy (2018) highlight that oil spill exposure has a long-term and persistent effect on alterations or worsening of hematological, hepatic, pulmonary, and cardiac functions, as well as prolonged or worsening illness symptoms years after exposure to the oil spill. Recent reviews and case reports also demonstrated similar persistent health effects, as noted by Levy and Nassetta (2011), Anderson (2015), and Laffon, Pasaro, and Valdiglesias (2016). Such adverse effects could significantly impact households' ability to engage in economic activities, as healthy workers are generally more productive than those who are sick (Asiedu, Jin, and Kanyama 2015). The effect of such a health status, including a decline in work capacity and productivity, is also manifested in how the household secures its food (Seume-Fosso 2008).

We consider household health expenditure from the LSMS data as a likely indicator of household health status, noting that this indicator reflects associated household expenditures that could arise due to the adverse health effects of pollution (Li, Du, and Zhang 2020; Shen, Wang, and Shen 2021). The estimates in Table 4 are consistent with this prediction. Specifically, the results indicate that households residing closer to crude oil spillage sites (within a 75 km radius) experience increased health expenditure by 27.2%. Compared to other households not affected by the spillage, those residing closer to the site experienced a 40.6% increase. An interpretation of this finding could be that the decline in food security is due to the deterioration in work capacity and productivity from poor health outcomes, especially since we also find a negative labor engagement correlation.

It is unlikely that the findings in the analysis of the mechanism are driven by the potential health and economic conditions in the spillage communities, significantly disadvantaging those households' residents in such communities, hence exacerbating food insecurity. Although this study's analysis accounts for community fixed effects to address such idiosyncrasies, Table A1 in the appendix shows that residents within a 75 km radius do not report low access to specific infrastructures relevant to improving economic engagement and health conditions. As it turns out, there is better reporting of the presence of financial institutions, markets and health facilities in the spillage locations compared to locations outside the specified buffer.

Table 4. Economic and health outcomes as potential mechanisms.

	Labor Input	Agricultural yield (log)	HH health expenditure (log)
Proximity 75 km	−0.024	−0.589**	0.272***
	(0.032)	(0.275)	(0.094)
Comparison	0.005	−0.207	−0.134
	(0.042)	(0.248)	(0.092)
Observations	19,488	9634	11,500
R-squared	0.116	0.417	0.180
Difference in differences	−0.029	−0.382	0.406
F-test: proximity 75 km − comparison = 0	5.52	17.77	197.05
p-value, *F*-test	0.019	0.000	0.000

Note: The following control variables are the gender and age of the household head, the household size, and a binary indicator if the household resides in an urban location. The regressions also account for the survey year FE and cluster FE. The 'Difference in difference' result represents the difference between the proximity of 75 km and the comparison areas, and we present the associated *F*-test and the *p*-value of the *F*-test. Standard errors (clustered by the survey clusters) are in parentheses; ***$p < 0.01$ and **$p < 0.05$.

4.4. The role of remittances as a cushioning mechanism

As it turns out, we find a consistent pattern for the food security indicators (or insecurity), as the coefficient for *proximity 75 km* is positive (i.e. higher food insecurity) and statistically significantly different from zero, but not for the *comparison* cohort. On the other hand, how can households experiencing food insecurity due to oil spillage in their locality cope with such a crisis, considering the other adverse effects on agricultural and health outcomes? This question is both academic and policy-relevant, particularly in a context such as Nigeria, where there is a poor distributive policy and a weak social protection policy to assist the most vulnerable groups in society to cope with environmental issues. Specifically, the percentage of GDP spent on social protection in Nigeria is approximately 2%, and social insurance programs in Nigeria covered only about 3.3% of the population as of 2018 (ILO 2019; World Bank 2022). This issue is consistent with other developing countries. Hence, studies have identified cash transfers as an essential social protection program to improve households' liquidity and their ability to cope with looming shocks (Asfaw et al. 2017; Blattman, Fiala, and Martinez 2020).

Remittance inflow, an altruistic private transfer, is also an important policy tool encouraged for households' coping strategies in the face of environmental shocks (Yang and Choi 2007) because of its capacity to improve household consumption, economic engagement, savings, and investments for long-term welfare gains (World Bank 2006). Therefore, this study considers the cushioning role of remittance while acknowledging the non-availability of objective cash transfer information and the data limitations in assessing the remittance recipient status of the households in our primary dataset. The remittance data come from the same dataset – LSMS data, rounds 2010/2011, 2012/2013, and 2015/2016 – with reportage at the individual/household level. The survey reports a binary indicator if any adult member of the household has received remittance inflow from anyone not residing in the household at the time of the survey and a follow-up question that asks how much such a receipt was. We relied on the first and second measures for the analysis in this section. We converted all reported inflows to the local currency using the prevailing exchange rate during the survey collection period for the second measure.

Relying on the same strategy used for the previous analysis, Table 5 explores heterogeneity in the impacts of spillage on the indicators of food security by interacting *Proximity 75 km* with two indicators of remittance receipt: (a) a binary indicator if any member of the household reported receiving remittance inflow in the past 12 months and (b) the monetary value of such receipt in the local currency unit. *Proximity 75 km* is a binary indicator if the household resides within 75 km of the closest crude oil spillage site, and *comparison* remains as previously defined. This analysis demonstrates the relevance of liquidity intervention, in the form of remittance inflows, for households to mitigate the adverse effects of spillage on food access and availability. Before the results are explored, one important caveat must be mentioned: the variable 'remittance' could be endogenous. Characteristics that explain remittances may also shape household expenditure patterns (McKenzie and Sasin 2007). Therefore, this result should be interpreted as correlational evidence, showing food security patterns for households closer to spillage sites (compared to those farther from the sites) relative to remittance receipts.

Table 5. Heterogeneous impacts of crude oil spillage on household food security.

	Food security		Limit portion size		Less preferred food		Limit variety	
	Remittance receipt (1 if yes)	Remittance receipt (log of LCU)	Remittance receipt (1 if yes)	Remittance receipt (log of LCU)	Remittance receipt (1 if yes)	Remittance receipt (log of LCU)	Remittance receipt (1 if yes)	Remittance receipt (log of LCU)
Proximity 75 km	0.077**	0.073***	0.101**	0.104**	0.125***	0.114**	0.144***	0.130***
	(0.030)	(0.027)	(0.046)	(0.044)	(0.045)	(0.045)	(0.047)	(0.047)
Comparison	−0.020	−0.020	−0.061	−0.060	−0.050	−0.050	−0.057	−0.056
	(0.033)	(0.033)	(0.046)	(0.046)	(0.050)	(0.050)	(0.049)	(0.049)
Proximity 75 km × Remittance	−0.014	−0.007**	−0.001	−0.010**	−0.033	−0.010*	−0.040*	−0.012**
	(0.019)	(0.003)	(0.026)	(0.005)	(0.024)	(0.005)	(0.023)	(0.006)
Observations	21,024	21,024	21,024	21,024	21,024	21,024	21,024	21,024
R-squared	0.250	0.250	0.211	0.211	0.214	0.214	0.236	0.236

Note: Although not reported, all the specifications in the table include the following control variables – the gender and age of the household head, the household size, and a binary indicator if the household resides in an urban location. The regressions also account for the survey year FE and cluster FE. Other results, such as the difference in differences, *F*-test, proximity 75 km − comparison = 0, and *p*-value, *F*-test, are not reported but are available upon request. Standard errors (clustered by the survey clusters) in parentheses; ***$p < 0.01$ and **$p < 0.05$.

Indeed, the results show that the impacts of crude oil spillage on food insecurity are cushioned for households that receive remittances. Although the effects are consistently adverse, we find a significant reduction in food insecurity (by 0.7 percentage points) with a corresponding increase in the monetary amount of remittances from households residing in locations closer to the spillage site. In other words, families living in areas closer to the spillage site (within 75 km) are less likely to experience at least one day of food insecurity incidence with a percentage increase in remittance inflow. This significant cushioning effect is also evident in the likelihood of the household recording at least one day of limiting food portion size at meals and reducing the variety of foods eaten. The consistency in the coefficient signs (all negative) is reassuring of the cushioning effect of remittance inflows on household food security in the context of burgeoning environmental degradation.

5. Conclusions

The study examines the relationship between an environmental degradation incidence – crude oil spillage – and food (in)security incidence, including a composite measure of whether the household experienced at least a day incidence of any of the following nine occurrences. That is, (a) Rely on less preferred foods. (b) Limit the variety of foods eaten. (c.) Limit portion size at mealtimes. (d.) Reduce the number of meals eaten in a day. (e.) Restrict consumption by adults to prevent small children from eating. (f.) Borrow food or rely on help from a friend or relative. (g.) Have no food of any kind in your household. (h.) Go to sleep at night hungry because there is not enough food. (i.) Go a whole day and night without eating anything. We also consider three additional specific indicators, including the likelihood of experiencing at least one day in a week of limiting portion size at mealtimes, experiencing at least one day in a week of relying on less preferred foods, and experiencing at least one day in a week of limiting the variety of foods eaten. We find that crude oil spillage reduces food security, as measured by both composite and direct measures. These findings are robust to different data and computational manipulations. Crude oil spillage also has an adverse effect on the agricultural output of households and health (the total household health expenditure).

The results are seen to the extent that households are remittance recipients. That is, the remittance receipt cushions the adverse effect on food security from crude oil spillage. This finding supports a liquidity availability policy option for vulnerable households to cope with the negative impacts of environmental degradation. Taken together, the findings of this study add evidence to the literature on the food security consequences of environmental degradation actions, providing additional insights into how agricultural production and health exacerbate adverse effects. In particular, we argued that such adverse effects could occur through agricultural production, health, and liquidity pathways. Environmental degradation affects household agricultural production and health for a productive economic engagement. However, with access to liquidity, households can improve their ability to achieve food security, allowing them to adapt to a food-secure situation.

Although this study focuses on remittance, other policies to enhance household liquidity, such as cash transfer, have been touted for other environmental-related shocks (see Wood 2011; Asfaw et al. 2017; Haile 2021), which could be an essential policy for household adaptation or building resilience. Such support mechanisms have the potential to degrade, mitigating the adverse effects for households. Thus, providing a significant boost to food consumption by relaxing households' liquidity constraints in the face of environmental degradation that affects agricultural production and health may be a pathway to improving food security for vulnerable groups.

We close by acknowledging two limitations that could be considered in future research. First, we refrain from implying causality despite arguing for the strength of our identification strategy. Maybe a field survey that compares households exposed to such shocks to other unexposed households in periods before and after the spillage could fully substantiate the causal claim on food security. We encourage such fieldwork in locations beyond Nigeria and environmental degradation issues beyond crude oil spillage. Second, due to power issues (that is, the number of households at the spillage site), we cannot show evidence for the most vulnerable households, those that reside, for example, within 10 km closer to the spillage sites. An actual field survey will greatly power such evidence, and such an inquiry could be interesting for future research to test and confirm this more comprehensively. It may also be worthwhile to obtain more evidence on whether crude oil spillage can also affect psychological well-being. This issue is highly relevant from a policy perspective, given the increasing focus on the economic cost of environmental-related psychological issues of the most vulnerable groups in society (Cianconi, Betro, and Janiri 2020).

Endnotes

1. Although the robustness check considers the relevance of the spillage volume.
2. Note that we cannot include the state-fixed effects as this would sweep out the effect of residence in a non-Niger-Delta cluster (i.e. Comparison).
3. We consider sites with spillage volume within the 25th percentile to capture more households that may be included in the cohort of those affected by the crude oil spillage incidences.
4. These results are available upon request.

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Appendix

Table A1. Community infrastructure by spillage site.

	Outside the 75 km buffer	Within the 75 km buffer	Difference	T-value
Presence of a health facility	0.811	0.836	−0.025	−3.356
Presence of a financial institution	0.443	0.481	−0.038	−4.066
Presence of a market	0.530	0.601	−0.071	−7.541

Note: The data for this study were derived from the post-harvest survey collection round of each survey wave because this round clearly accounts for the presence of these infrastructures in the community of the households. Health facilities include public and private health facilities, clinics, midwives, or dentist offices. Financial institutions include banks and microfinance institutions.

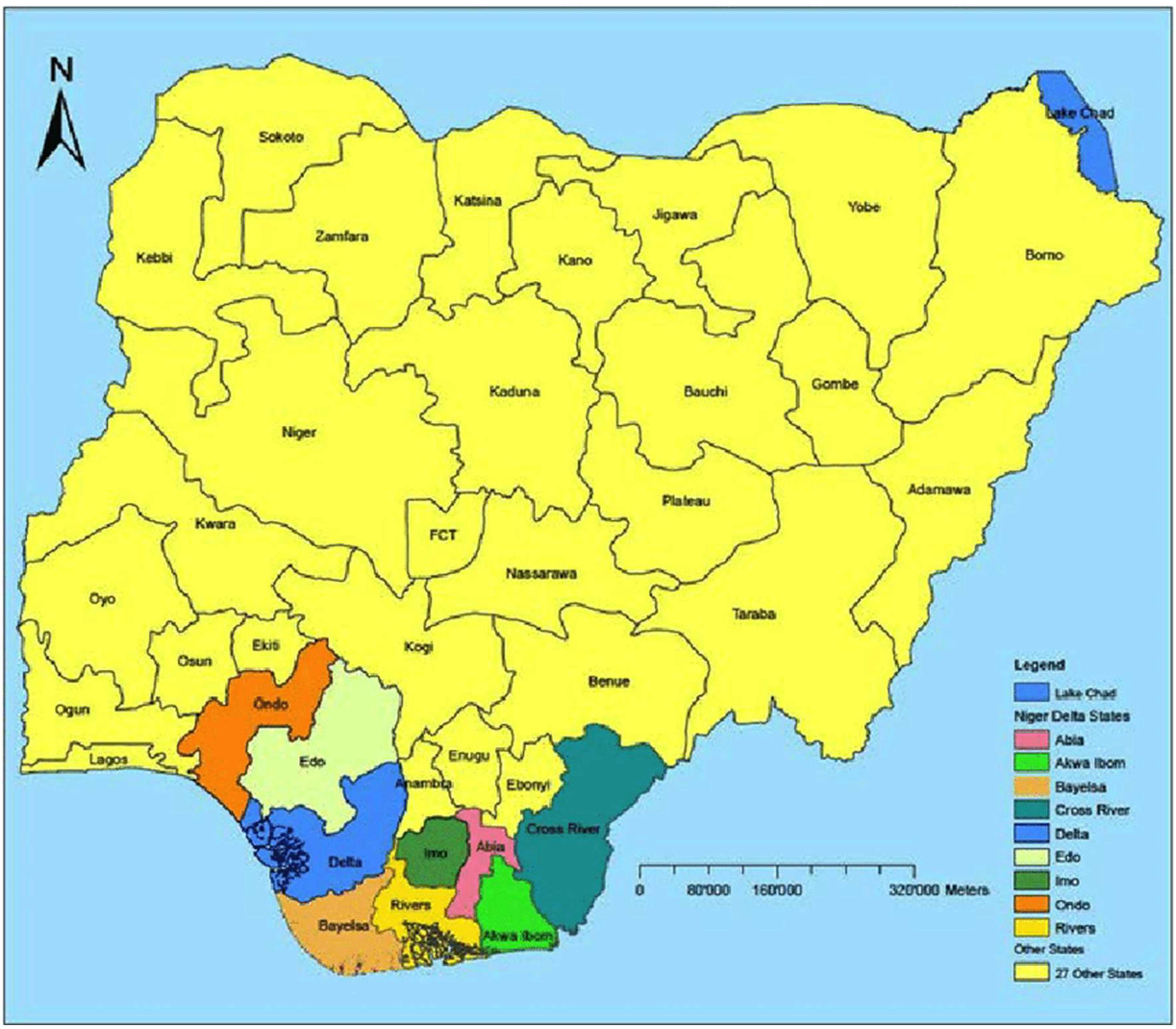

Figure A1. The Graph of Nigeria showing the Niger-Delta region.