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*Research*

# Impact of Petroleum Contamination on Crop Production and Remediation Strategies: A Case Study of Ese-Odo Local Government Area, Ondo State.

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## Highlights

- Oil spills from pipeline vandalism and illegal bunkering have drastically reduced crop yields and household incomes in Ese-Odo, Ondo State.
- Despite community belief in modern remediation, awareness, technical capacity, and government support remain critically low.
- Sustainable recovery is hindered by recurrent contamination, poor compensation, and lack of funding and equipment.

## Abstract

Tropical monsoon climates present unique challenges and opportunities for solar energy utilization due to seasonal variability in cloud cover and solar radiation. This study examines the solar energy dynamics of Ogbomoso, Nigeria, a representative tropical monsoon region, through an integrated analysis of measured and predicted solar radiation (MJ/m²/day), monthly sunshine duration (hrs), and clearness index (CI). Using data spanning a full annual cycle, the study identifies pronounced seasonal trends: solar radiation peaks at 6.5–7.0 MJ/m²/day during the dry season (March–April) but declines sharply to 4.0–4.5 MJ/m²/day in the monsoon months (June–August), coinciding with reduced sunshine hours (3.5–4.5 hrs) and lower CI values (0.45–0.50). These patterns align with the West African monsoon, which drives increased cloud cover and rainfall, attenuating solar penetration. While predictive models broadly align with measured radiation, systematic overestimations during monsoon months highlight gaps in accounting for cloud microphysics and aerosol interactions. The clearness index emerges as a critical bridge between sunshine duration and solar radiation, quantifying cloud attenuation effects that sunshine metrics alone fail to capture. To address seasonal energy shortfalls, the study proposes adaptive strategies, including hybrid solar-biogas systems, machine learning-enhanced radiation modeling, and agrovoltaic land-use practices. Policy recommendations emphasize decentralized energy solutions and community engagement to bolster climate resilience. By contextualizing localized findings within broader tropical energy research, this work underscores the necessity of integrating meteorological data and adaptive infrastructure in monsoon-affected regions. The results offer a replicable framework for optimizing solar energy planning in similar climates, balancing abundant dry-season potential with monsoon-driven constraints to advance sustainable, low-carbon energy transitions.

**Keywords:** Petroleum Contamination, Oil spills, Agricultural impact, Remediation strategies, Food security.

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# 1.0 Introduction

Our modern world, powered by the massive energy of petroleum, relies heavily on its extraction, transportation and processing. This reliance, however, comes with an inherent and often devastating risk; oil spills. Global ecosystems, economies and human livelihoods are all negatively impacted by these environmental perturbations, whether they are large-scale events or persistent little leaks (NOAA, 2023). When these spills occur on land, particularly on fertile agricultural grounds, the consequences are profoundly felt, threatening the very source of sustenance for countless communities. The immediate impact of crude oil on soil and vegetation is visually striking and scientifically complex. It disrupts the delicate balance of ecosystems, leading to widespread contamination that can persist for decades if left unaddressed (EPA, 2024). The vulnerability of food systems to such contamination is a growing concern, as agricultural lands are not merely plots of soil but intricate living systems that support biodiversity and human populations.

In Nigeria, a nation heavily reliant on its oil and gas sector, the issue of petroleum contamination has becomes a serious concern. The Niger Delta region, the heart of the country's oil wealth, has become a center for oil spills globally with numerous cases reported annually due to pipeline vandalism, operational failures and illegal refining activities (Okoro & Adebayo, 2018). Despite the facts that oil supports the country's economy, it also contaminates the soil that provides food for its citizens. Agricultural industry which contributes significantly to Nigeria GDP is greatly affected by this environmental deterioration resulting to declines in crop yields and loss of arable land (Nwosu & Eze, 2020).

The direct effects of petroleum on agricultural plants are complex and severe. When crude oil coats plant surfaces, it physically blocks stomata, impairing important processes like photosynthesis and transpiration, effectively suffocating the plant (Wang & Fingas, 2018). Beyond physical obstruction, the chemical components of petroleum, particularly hydrocarbons, are inherently toxic. These compounds can disrupt cell membranes, inhibit enzyme activity, and interfere with metabolic pathways within the plant, leading to cellular damage and physiological stress (Chikere & Ekwuabu, 2014). Moreover, oil contamination in the soil severely impairs the plant's ability to absorb water and essential nutrients. Oil's inability to combine with water diminishes soil aeration and water infiltration, resulting in anaerobic conditions that are harmful to root formation. Stunted growth, wilting, chlorosis (leaf yellowing), and eventually a huge drop in crop output or even total plant death are all signs of this reduced intake. This directly results in food instability and severe financial losses for farmers (Jacob *et al*., 2024).

The indirect effects of oil spills on agricultural land are equally concerning, often leading to long-term environmental degradation. Petroleum alters the physicochemical properties of the soil, changing its pH, reducing nutrient availability and profoundly impacting the delicate balance of microbial communities essential for soil health (Njoku *et al.,* 2019). These changes can render the soil infertile for extended periods, making future cultivation extremely challenging. Furthermore, some hydrocarbons can persist in the soil for years, slowly leaching into groundwater or being taken up by plants, potentially contaminating the food chain (Osuji & Nwoye, 2017). This raises serious public health concerns about the consumption of crops grown on contaminated land. The cumulative effect of these direct and indirect impacts creates a complex environmental challenge that demands urgent attention and effective solutions.

Given the severity and persistence of petroleum contamination, traditional farming methods and natural attenuation processes are often insufficient to restore agricultural land to its productive state. Farmers in affected areas are often left grappling with reduced yields, infertile lands and a profound sense of helplessness. This highlights the critical need for effective remediation strategies that can accelerate the detoxification and restoration of oil-spilled agricultural lands (Ekundayo & Obuekwe, 2018).

Ese-Odo Local Government area, is a significant area within Ondo State, Nigeria. Strategically located with a mix of coastal, riverine and agricultural lands, Ese-Odo LGA is particularly exposed to the repercussions of petroleum activities due to its proximity to oil infrastructure and waterways that serve as conduits for spills (Ondo State Ministry of Environment, 2022). The residents of Ese-Odo are predominantly farmers and fishermen, have reported persistent challenges related to the contamination of their agricultural lands, raising serious concerns about food security and economic stability. The observed impacts on crop production in this area are not merely incidental; they represent a

tangible threat to the well-being of the local populace. Understanding the precise nature of these impacts and the effectiveness of current responses is paramount for observing a path towards recovery and resilience. Thus, this study aims to provide comprehensive and reliable information on the ways in which petroleum contamination particularly impacts farmlands in Ese-Odo and to identify the strategies required to provide solutions to these terrible consequences.

## *1.1 Objectives of the study*

The specific objectives of this study include;

1. to determine the sources of petroleum contamination on farmlands in Ese-Odo Local Government Area.
2. to determine the perceived economic losses suffered by farmers as a result of petroleum contamination on their farmlands.
3. to determine the level of awareness and knowledge of farmers and community members regarding effective and modern remediation techniques for oil-spilled farmlands.
4. to determine key challenges faced by farmers and communities in the implementation of effective remediation strategies for petroleum-contaminated farmlands.

## *1.2 Research Questions*

The following are the research questions for this study;

1. What are the perceived sources and frequency of petroleum contamination incidents affecting agricultural lands in Ese-Odo Local Government Area?
2. What are the perceived economic losses suffered by farmers as a result of petroleum contamination on their farmlands?
3. What is the level of awareness and knowledge among farmers and community members regarding effective and modern remediation techniques for oil-spilled agricultural lands?
4. What are the key challenges faced by farmers and communities in the implementation of effective remediation strategies for petroleum-contaminated agricultural lands?

# 2.0 Methodology

## *2.1 Study Area*

The research was conducted in Ese-Odo Local Government Area of Ondo State, Nigeria. Its located on latitude 6° 13′ 2.64″ N and longitude 4° 57′ 52.2″ E. It has an area of 762 km$^2$ and a population of 154,978 at the 2006 census (NPC, 2006). Ese-Odo lies in the low-lying coastal zone that stretches eastward from the Niger Delta to the Atlantic Ocean and the western border between Ondo and Delta States ((Afe *et al*., 2015). It shares boundary with Edo State in eastern Nigeria. It's one of the two local governments that serve as the main border settlements between southwestern Nigeria and the rest of Niger Delta. It is bordered to the east by Edo State's Ovia South Local Government, to the north by Ondo State's Irele Local Government, to the west by Ondo State's Ilaje Local Government and to the south by Delta State's Warri South West Local Government. It's one of the oil producing LGA in the State. The main occupations in the area are; fishing, Local trade across waterways, subsistence farming and canoe carving Palm oil production. Most of the crop cultivated in the area include, cassava, maize and palm oil.

Ese-Odo LGA is selected for this study due to its significant agricultural activities and its proximity to petroleum exploration, making it highly susceptible to oil spill incidents. The area is characterized by a mix of riverine communities, agricultural lands and some developing settlements. Its unique geographical features and reliance on natural resources for livelihoods make it an important location for understanding the localized impacts of petroleum contamination. The selection of this area is justified by the documented history of oil spills and the observed challenges faced by its farming communities (OSEPA, 2022).

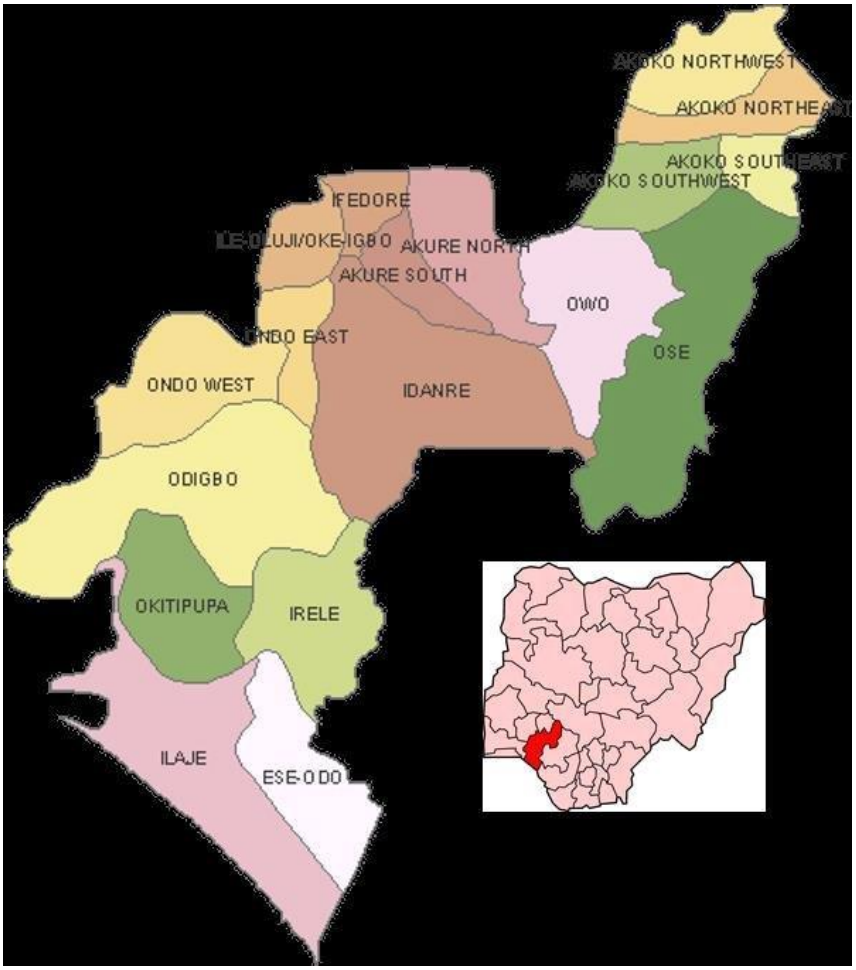


**Figure 1:** Showing Map of Ondo State showing eighteen (18) local Government Area (Salau et al., 2016)

## *2.2 Study Design*

A cross-sectional survey design was adopted for this research, which is particularly suitable for gathering information about the characteristics of a population. This approach allows us to describe the current state of petroleum contamination, its perceived effects on farmlands and existing remediation practices. By utilizing a cross-sectional survey, we can effectively identify contamination sources, assess economic losses, document strategies and evaluate awareness levels. However, inability to establish causal relationships and the potential for sampling bias, which may affect the validity of the findings are the limitations of this design. The survey was administered by the researchers.

## *2.3 Study Population and Sample size*

The target population for this study comprises farmers and community leaders within Ese-Odo Local Government Area. These groups are directly impacted by petroleum contamination, possess valuable traditional knowledge, or hold institutional insights into environmental management. Based on preliminary assessments and consultation with local authorities, two communities, Igbobini and Awoye within Ese-Odo LGA are said to have experienced significant petroleum contamination on their farmlands and as such were purposively selected for this study. This is to ensure that the study focuses on areas where the problem is most predominant. Within each selected community, a systematic random sampling technique was used to select a predetermined number of active farmers to ensure a representative sample of the farming population. However, the respondents selected for this study most certified the following inclusion and exclusion criterias;

**Inclusion Criteria:**

1. Participants must be indigene of Ese-Odo Local Government and above 20 years of aged
2. Participants must be actively engaged in farming within Ese-Odo Local Government Area to provide relevant information on crop production and contamination experiences.
3. Participants should have some awareness or experience with petroleum contamination affecting their farmland
4. Participants must have cultivated crops in the area for at least one growing season

**Exclusion Criteria:**

1. Individuals who are not indigene of Ese-Odo Local Government and less than 20 years of aged are excluded
2. Individuals who are not involved in agricultural activities or do not reside in the area will be excluded to maintain the focus on relevant stakeholders.
3. Those who have farmed in the area for less than a season may be excluded, as they may not have sufficient experience to provide meaningful insights.
4. Individuals who refuse to participate in the survey or do not consent to share their experiences related to petroleum contamination will be excluded from the study.

The sample size was determined using Yamane's formula (1967),

$$n = \frac{N}{1 + N(e)^2}$$

Where,
n = sample size,
N = (10,721)
e = (0.05)

The sample size was calculated as, $n = \frac{10,721}{1+10,721(0.05)^2}$

The sample size (n) is approximately 400

## *2.4 Methods of Data Collection and Analysis*

Self-structured questionnaire was used to collect data from farmers and community members within the selected communities for this study. The data was collected during the rainy season between April to September, 2024. To ensure the reliability and validity of the questionnaire, it was subjected to validation by experts in the field of environmental study for necessary corrections, inputs and suggestions. The questionnaire were administered by the researchers. All the 400 questionnaire were completed and returned for coalation. The data collected were analyzed using simple mean and standard deviation.

# 3.0 Results and Discussion

## *3.1 Presentation of Results*

### 3.1.1 Demographic Data of the Respondents

The demographic data of the 400 respondents from Ese-Odo Local Government Area is shown in Table 1, as this allows the researchers understand the background of the respondents.

**Table 1:** Demographic Characteristics of Respondents (N=400)

| Characteristic | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| **Age (in years)** | 18 – 30 | 80 | 20.0 |
| | 31 – 45 | 160 | 40.0 |
| | 46 – 60 | 120 | 30.0 |
| | 61 and above | 40 | 10.0 |

| | | | |
|---|---|---|---|
| | Total | 400 | 100.0 |
| **Gender** | Male | 260 | 65.0 |
| | Female | 140 | 35.0 |
| | Total | 400 | 100.0 |
| **Highest Level of Education** | No formal education | 100 | 25.0 |
| | Primary education | 150 | 37.5 |
| | Secondary education | 100 | 25.0 |
| | Tertiary education | 50 | 12.5 |
| | Total | 400 | 100.0 |
| **Years of Farming Experience** | Less than 5 years | 60 | 15.0 |
| | 5 - 10 years | 120 | 30.0 |
| | 11 - 20 years | 140 | 35.0 |
| | More than 20 years | 80 | 20.0 |
| | Total | 400 | 100.0 |

## *3.2 Section B: Analysis of Questionnaire items*

This section presents the analysis of responses from Section B of the questionnaire. The Likert scale responses were assigned numerical values: Strongly Agree = 4, Agree = 3, Disagree = 2, Strongly Disagree = 1. The mean score indicates the average level of agreement and the standard deviation measures the dispersion of responses around the mean.

### *3.2.1 Responses of the Respondents*

**1. Response on Perceived petroleum Contamination incidence (Research question one)**

**Table 2:** Presents the Mean and Standard Deviation of Perceived Petroleum Contamination Incidents In Igbonini and Awoye

Mean Scores =2.50 as benchmark

| S/N | Petroleum Contamination Incidents In Igbonini and Awoye | Mean | Standard Deviation |
|---|---|---|---|
| 1 | Oil spills occur frequently on agricultural lands in my community. | 3.45 | 0.68 |
| 2 | Pipeline vandalism is the primary cause of petroleum contamination on farmlands in our area. | 3.60 | 0.55 |
| 3 | Illegal bunkering activities are a significant source of petroleum contamination here. | 3.20 | 0.72 |
| 4 | A large portion of my own farmland has been visibly affected by petroleum contamination. | 2.95 | 0.85 |

Mean < 2.50: indicates disagreement, Mean ≥ 2.50: indicates agreement.

The results from the table above (Table 2) shows that, mean scores greater than or equal to 2.50, indicating a general agreement among respondents on all points regarding petroleum contamination incidents. Specifically, the high mean scores for item 1 (3.45), 2 (3.60) suggest a strong consensus by the respondents in Igbonini and Awoye that oil spills are frequent and pipeline vandalism is a primary cause. Item 3 (3.20) from the table above also shows clear agreement, indicating illegal bunkering is also a significant source of petroleum contamination on farmland in the two communities. Moreover, Results of item 4 (2.95) also falls within the "Agree" range, suggesting that a notable portion of farmers have personally experienced visible contamination on their plots. The relatively low standard deviations for items like "Pipeline vandalism is the primary cause" (0.55) indicate a strong consensus among respondents in the two communities (Igbonini and Awoye ) on this point. Higher standard deviations (e.g., for "A large portion of my own farmland has been visibly affected," 0.85) suggest more varied experiences among individual farmers even within the general agreement.

**2. Responses on Perceived Economic losses (Research Question Two)**
The table below represents the responses of the respondents on Perceived economic losses (Impact on Farmers)

**Table 3:** Mean and Standard Deviation of Perceived Economic Losses

| S/N | Perceived Economic Losses (Impact on Farmers) In Igbonini and Awoye | Mean | Standard Deviation |
|---|---|---|---|
| 5 | Petroleum contamination has led to a significant reduction in my overall crop yields. | 3.70 | 0.48 |
| 6 | I have incurred substantial financial losses due to the damage caused by oil contamination. | 3.65 | 0.52 |
| 7 | My household's income has significantly decreased because of petroleum contamination. | 3.50 | 0.65 |
| 8 | Petroleum contamination has negatively impacted my household's food security. | 3.40 | 0.70 |

All mean scores in Table 3 are well above the 2.50 benchmark, indicating strong agreement that petroleum contamination led to significant economic losses. Farmers strongly perceive reductions in crop yields, substantial financial losses, decreased household income and negative impacts on food security. The low standard deviations suggest a high consensus on these severe economic consequences.

**3. Responses on Awareness and Knowledge of Modern Remediation Techniques (Research Question Three)**
The table below shows results of farmers and community members' awareness and knowledge of modern remediation techniques.

**Table 4:** Mean and Standard Deviation of Awareness and Knowledge of Modern Remediation Techniques (N=400)

| S/N | Awareness and Knowledge of Modern Remediation Techniques by farmers in In Igbonini and Awoye | Mean | Standard Deviation |
|---|---|---|---|
| 9 | I am aware of scientific techniques (e.g., bioremediation) for cleaning oil-spilled farmlands. | 2.10 | 0.88 |
| 10 | I understand how modern remediation techniques work to clean up petroleum contamination. | 1.95 | 0.75 |
| 11 | I receive information about modern oil spill clean-up methods from government agencies. | 1.80 | 0.70 |
| 12 | I believe modern remediation techniques could significantly improve the recovery of our farmlands. | 3.25 | 0.62 |

Items on 9, 10 and 11 have mean scores below 2.50, indicating a general disagreement or low level of awareness and understanding regarding scientific remediation techniques and the receipt of information from government agencies. However, item 12, "I believe modern remediation techniques could significantly improve the recovery of our farmlands," has a high mean of 3.25, suggesting that despite low awareness, there is a strong belief in the potential effectiveness of modern methods. This highlights a critical knowledge gap coupled with a desire for better solutions.

**4. Responses on Challenges in Remediation Implementation (Research Question Four)**
The table below presents the responses of the respondents regarding challenges to remediation implementation

**Table 5:** Mean and Standard Deviation of Challenges in Remediation Implementation (N=400)

| S/N | Challenges in Remediation Implementation by farmers in In Igbonini and Awoye | Mean | Standard Deviation |
|---|---|---|---|
| 13 | Lack of sufficient funds is a major barrier to cleaning up oil-contaminated land effectively. | 3.85 | 0.38 |
| 14 | We lack the necessary technical knowledge or training to implement effective remediation. | 3.70 | 0.45 |

| | | | |
|---|---|---|---|
| 15 | Government support for oil spill clean-up and remediation efforts is insufficient. | 3.60 | 0.50 |
| 16 | Oil companies do not adequately compensate farmers for losses or assist with remediation. | 3.75 | 0.42 |
| 17 | The recurrent nature of oil spills makes long-term remediation efforts futile. | 3.50 | 0.60 |

All mean scores in Table 6 are very high (well above 2.50), indicating strong agreement among respondents on all listed challenges. Lack of sufficient funds (3.85) is perceived as the most significant barrier, followed closely by inadequate compensation from oil companies (3.75) and lack of technical knowledge/training (3.70). Insufficient government support (3.60) and the recurrent nature of spills (3.50) also represent major obstacles, leading to a sense of futility in remediation efforts. The low standard deviations across these statements suggest a strong consensus on the severity of these challenges.

# 4.0 Discussion

These findings resonate deeply with the broader environmental and socio-economic realities of oil-producing regions, particularly in the Niger Delta, where the quest for energy often clashes with the imperative of sustainable livelihoods. Our analysis, guided by a 2.50 mean benchmark for agreement, reveals critical insights into the perceived frequency, sources and substantial impacts of oil spills, as well as the existing remediation efforts and formidable barriers to effective recovery.

The data unequivocally indicates that oil spills are not an anomaly but a frequent and distressing reality for agricultural lands in Ese-Odo LGA. The high mean score of 3.45 for the statement "Oil spills occur frequently on agricultural lands in my community" (Table 2) reflects a strong consensus among farmers that these incidents are a pervasive and recurring threat. This perception aligns with numerous reports highlighting the chronic nature of oil pollution in the Niger Delta, where spills are often a daily occurrence rather than isolated events (ERA, 2021). The low standard deviation (0.68) further underscores this shared experience, suggesting that almost every farmer has witnessed or been directly affected by these spills.

When it comes to the culprits, the respondents' perceptions are remarkably clear. "Pipeline vandalism is the primary cause of petroleum contamination on farmlands in our area" received the highest mean score of 3.60 (Table 2), indicating an overwhelming agreement. This finding is consistent with official reports and academic studies that identify sabotage and illegal activities as major drivers of oil spills in the region, often surpassing operational failures as the leading cause (Nwankwo & Olayinka, 2019; NOSDRA, 2023). While "Illegal bunkering activities are a significant source" also garnered strong agreement (mean = 3.20), its slightly lower mean compared to pipeline vandalism suggests that while both are problematic, vandalism is perceived as the more direct and frequent cause of agricultural land contamination. This findings is in disagreement with the findings of Jacob *et al*. (2024) who reported that in 40 years of oil exploitation in Nigeria, Over 6000 spills have been recorded with an average of 150 spills per annum resulting in the spillage of 2,369,407.04 barrels of crude oil. With only 549,060.38 barrels recovered, 1,820,410.50 barrels of oil were lost to the ecosystem. Indicating that oil spills is a major source of soil contamination

The perception that "The extent of petroleum contamination on farmlands in my community has been increasing over time" (mean = 3.30) is particularly alarming. This suggests a worsening environmental crisis, where past spills are not adequately remediated before new ones occur, leading to cumulative degradation. This continuous assault on the land undermines any recovery efforts and perpetuates a cycle of environmental damage. Furthermore, the data highlights the direct threat to food security: "The contamination primarily affects food crops (e.g., cassava, yam, maize)" with a very high mean of 3.55. This is a significant challenge for communities that rely on subsistence farming as their primary food sources are directly compromised. While "Cash crops (e.g., oil palm, cocoa) on our farmlands are also significantly impacted" (mean = 3.10), the emphasis on food crops underscores the immediate humanitarian concern. These findings collectively revealed a persistent pressure on livelihoods and well-being of the farmers in the two communities.

The data on perceived economic losses (Table 3) paints a stark picture of the severe financial and livelihood impacts on farmers in Ese-Odo LGA. The agreement is almost universal across all statements in this section, with mean scores consistently well above the 2.50 benchmark. The statement "Petroleum contamination has led to a significant reduction in my overall crop yields" received the highest mean of 3.70 (SD = 0.48). This directly translates the

environmental damage into tangible agricultural failure, validating concerns about the productivity of contaminated lands (Chikere & Ekwuabu, 2014). Reduction in the overall crop yields leads to significant losses or reduction in farmers' incomes.

Indeed, farmers strongly agree that they have "incurred substantial financial losses due to the damage caused by oil contamination" (mean = 3.65, SD = 0.52). These losses are not merely theoretical; they represent lost income from sales, wasted labor, and the cost of attempting to salvage or remediate affected plots. The impact extends directly to household well-being, as evidenced by the high mean for "My household's income has significantly decreased because of petroleum contamination" (mean = 3.50, SD = 0.65). This financial strain can push vulnerable families deeper into poverty, limiting their access to education, healthcare, and other basic necessities (World Bank, 2023).

Perhaps most critically, the data reveals a strong perception that "Petroleum contamination has negatively impacted my household's food security" (mean = 3.40, SD = 0.70). This underscores the direct link between environmental degradation and human survival. When farmlands are contaminated, the ability of families to produce or afford sufficient, nutritious food is severely compromised, leading to increased vulnerability to hunger and malnutrition (FAO, 2023). The consistency of these high mean scores and relatively low standard deviations across all economic loss statements demonstrates a shared and profound experience of hardship among the farming population, highlighting the urgent need for comprehensive compensation and livelihood restoration programs. Restoration programs involve adding lime to the soil to bring its pH down to 6.0–6.5. In order to stimulate and maintain microbial activity, the carbon to nutrient ratios must be restored to the ideal level through the application of adequate and suitable inorganic NPK fertilizer (Jacob *et al.,* 2024).

The results presented in Table 4 reveal a critical knowledge gap regarding modern remediation techniques among farmers and community members in Ese-Odo LGA. Statements related to awareness and understanding of scientific techniques (e.g., bioremediation) received mean scores below the 2.50 benchmark ("I am aware of scientific techniques..." mean = 2.10, SD = 0.88; "I understand how modern remediation techniques work..." mean = 1.95, SD = 0.75). This indicates a general lack of exposure to and comprehension of advanced methods for oil spill cleanup. The low mean for "I receive information about modern oil spill clean-up methods from government agencies" (mean = 1.80, SD = 0.70) further underscores a significant failing in information dissemination from official channels. This suggests that current outreach and extension services are not effectively reaching the affected communities with vital knowledge.

However, a crucial and hopeful insight emerges from the data: despite the low awareness and understanding, farmers hold a strong belief in the potential of modern solutions. The statement "I believe modern remediation techniques could significantly improve the recovery of our farmlands" garnered a high mean of 3.25 (SD = 0.62). This indicates a receptive audience that recognizes the limitations of their current informal methods and is open to adopting more effective approaches if provided with the knowledge and resources. This gap between aspiration and current reality highlights a significant opportunity for targeted education and capacity-building programs (Osuji & Nwoye, 2017). There is a pronounced lack of awareness and understanding of modern, scientific remediation techniques for oil-spilled agricultural lands among farmers in Ese-Odo LGA. This knowledge deficit is compounded by a perceived absence of information flow from government agencies. However, farmers express a strong belief in the potential efficacy of modern methods, signaling a willingness to learn and adopt new approaches if given the proper guidance and support.

The data from Table 5 powerfully articulates the formidable challenges that hinder effective remediation efforts in Ese-Odo LGA. All listed challenges received very high mean scores (well above 2.50), indicating a strong and widespread consensus among respondents regarding their severity.

"Lack of sufficient funds is a major barrier to cleaning up oil-contaminated land effectively" emerged as the most critical obstacle, with an exceptionally high mean of 3.85 (SD = 0.38). This financial constraint is a recurring theme in environmental remediation efforts in developing contexts, where affected communities often lack the capital to undertake costly clean-up operations (World Bank, 2023). Closely related are the perceptions that "Oil companies do not adequately compensate farmers for losses or assist with remediation" (mean = 3.75, SD = 0.42) and "Government support for oil spill clean-up and remediation efforts is insufficient" (mean = 3.60, SD = 0.50). These findings point to a profound dissatisfaction with the level of responsibility and assistance from the primary actors

involved in the oil industry and governance, echoing long-standing grievances in the Niger Delta (Amnesty International, 2020).

Furthermore, the lack of technical capacity is a significant barrier. Farmers strongly agree that "We lack the necessary technical knowledge or training to implement effective remediation" (mean = 3.70, SD = 0.45) and that "Access to specialized equipment for oil spill clean-up is difficult for farmers" (mean = 3.75, SD = 0.42). This underscores the need for practical training programs and the provision of appropriate tools beyond rudimentary methods.

Perhaps the most disheartening finding is the strong agreement that "The recurrent nature of oil spills makes long-term remediation efforts futile" (mean = 3.50, SD = 0.60). This statement encapsulates a deep sense of despair and resignation. When communities invest time, effort, and scarce resources into cleaning their land, only for another spill to occur, it creates a cycle of futility that erodes morale and discourages sustained action. This highlights that remediation cannot be effective without addressing the root causes of spills and ensuring their prevention (NOSDRA, 2023).

Farmers and communities in Ese-Odo LGA face a complex web of severe challenges in implementing effective remediation strategies. Financial constraints, inadequate compensation from oil companies, insufficient government support, and a critical lack of technical knowledge and access to specialized equipment are perceived as major barriers. Crucially, the persistent and recurrent nature of oil spills creates a profound sense of futility, undermining any efforts towards long-term land restoration and highlighting the urgent need for a more holistic and committed approach from all stakeholders.

# 5.0 Conclusion

In conclusion the study reveals that petroleum contamination in Ese-Odo Local Government Area is a frequent and worsening crisis for agricultural lands, primarily caused by pipeline vandalism and illegal bunkering, severely impacting food crops. This pervasive pollution inflicts significant economic losses on farmers through reduced yields, financial burdens, decreased household income and compromised food security. Research on the establishment of new and enhanced methods for containing oil spills is important. New technologies that could be more efficient and economical than existing methods are being developed by researchers. However, before these new technologies can be extensively used, a few issues still need to be resolved. Cleanup should begin as soon as the incident is discovered. It is also necessary to start a continuous monitoring program to determine how polluted the soil and nearby water sources are. By educating people on the risks associated with the activity, this will help to stop the threat's spread. To get a higher level of response, the government must also get involved. The government should issue and execute more environmental protection decrees.

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**Conflict of Interest**
The authors declare no conflicts of interest.