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Research Article

Assessment of the Effects of Lithium Exploration Activities on Soil Quality in Agricultural Areas of Nasarawa Local Government Area, Nasarawa State, Nigeria

Abdullahi Yusuf Agwai [a], Yusuf Amina Tanko [a], Falalu Muhammad Muhammad [a],

[a] Department of Geography, Federal University Lafia, Nasarawa State, Nigeria. [b] Department of Environmental Science and Management Technology, Federal Polytechnic Nasarawa, Nasarawa State, Nigeria. [c] Department of Geography, Federal University Lafia, Nasarawa State, Nigeria.

ABSTRACT

This study investigates the environmental and socio-economic effect of lithium exploration on agricultural communities in Nasarawa Local Government Area, Nasarawa State, Nigeria with emphasis on soil quality, water resources, and agricultural productivity. A convergent mixed-methods research design was adopted, integrating household surveys, laboratory analysis of soil samples, focus group discussions, and key informant interviews. Quantitative data were analyzed using descriptive and inferential statistics, while qualitative data were analyzed thematically. The findings revealed that lithium exploration significantly degraded soil quality through reductions in soil pH, organic matter, nitrogen, and phosphorus, accompanied by increased soil erosion and heavy metal contamination. These environmental changes contributed to declining agricultural productivity, reflected in a 20% reduction in crop yield and a 26.7% decline in average household income among farming households. The study recommends the establishment of pilot soil rehabilitation and environmental monitoring programmes, supported by stronger enforcement of environmental regulations and collaboration among government agencies, mining companies, and host communities to promote sustainable lithium development while protecting agricultural livelihoods.

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1 Introduction

Lithium has become one of the world's most strategically important minerals because of its essential role in rechargeable batteries used in electric vehicles, renewable energy storage systems, and other low-carbon technologies (Abdulfattah et al., 2023). The rapid global transition toward clean energy has substantially increased the demand for lithium, resulting in accelerated mineral exploration and mining activities across many countries like Australia, Chile, China, and Argentina (IEA, 2024). Lithium exploration refers to geological investigations undertaken to identify and evaluate economically viable lithium deposits, whereas lithium extraction involves the physical mining and processing of identified ore deposits for commercial production (Sahoo et al., 2024).

Although exploration generally precedes extraction, both activities can alter land use and affect surrounding ecosystems through vegetation clearance, road construction, drilling, excavation, and increased human activities (Wang et al., 2024). The environmental implications of lithium development vary according to the extraction method and geological setting (Flexer et al., 2018). In hard-rock lithium deposits, which dominate Australia, Zimbabwe, and Nigeria, mining activities primarily disturb land surfaces through excavation, waste generation, and soil erosion. Conversely, brine-based lithium extraction, common in Chile and Argentina, is associated mainly with groundwater depletion and increased soil salinity (Liu & Agusdinata, 2020).

Similarly, the African lithium deposits are poorly documented or under-reported despite massive mineral extraction and processing happening in Nigeria and several other Sub-Saharan African countries (Han et al., 2023; Kavanagh et al., 2018). Despite these differences, both systems can adversely affect agricultural land, reduce soil quality, and threaten rural livelihoods when environmental safeguards are inadequate (Clinton & Basu, 2024).

Nigeria has recently emerged as an important destination for lithium exploration following the identification of economically significant lithium-caesium-tantalum (LCT) pegmatites across Nasarawa, Kogi, Kwara, Plateau, Ekiti, Osun, Oyo, Cross River and other parts of the Nigerian Basement Complex (Olajuyi et al., 2025; Abdulfattah et al., 2023). Recent geological investigations identify Nasarawa State, particularly Kokona, Nasarawa, and adjoining Local Government Areas, as one of the country's most promising hard-rock lithium provinces due to the abundance of spodumene-bearing pegmatites and increasing private-sector investment in exploration and mineral processing (Olajuyi et al., 2025).

The commissioning of Africa's largest lithium processing facility in Endo Community, Nasarawa Local Government Area, further demonstrates the strategic

Corresponding Author: Agwai, A. Y. yusufagwai4@gmail.com Department of Geography, Federal University Lafia, Nasarawa State, Nigeria.

importance of the area to Nigeria's emerging critical minerals sector (Outa, 2026). However, this rapid expansion has also intensified concerns regarding agricultural land conversion, soil degradation, and the sustainability of farming livelihoods. Previous studies have documented the environmental implications of mining in Nigeria, including land degradation, vegetation loss, soil contamination, and declining agricultural productivity. Similarly, studies from Zimbabwe and other African lithium-producing countries have reported reductions in soil fertility, loss of farmland, and increasing livelihood vulnerability in mining communities (Han et al., 2023). However, most existing studies focus either on geological resource assessment, mineral potential, or the economic prospects of lithium development, while relatively few have empirically examined how lithium exploration activities influence soil quality and the socio-economic well-being of agricultural communities. Moreover, available Nigerian studies have largely concentrated on state-level assessments or other mining locations, with limited empirical evidence from Nasarawa Local Government Area, where exploration activities and processing infrastructure have expanded rapidly in recent years.

The focus on Nasarawa Local Government Area is therefore justified because it represents one of Nigeria's fastest-growing lithium exploration corridors, where intensive exploration activities directly overlap with productive agricultural landscapes. The coexistence of expanding lithium development and predominantly agrarian livelihoods provides an important opportunity to examine the interactions between mineral exploration, soil quality, agricultural productivity, and household resilience within a rapidly changing rural environment. It is against this background that the study assesses the lithium exploration activities on soil quality in agricultural areas of Nasarawa Local Government Area of Nasarawa State, Nigeria. The objectives of the study are to:

i. assess the environmental impacts of lithium exploration activities on soil quality in agricultural areas in Nasarawa Local Government Area.
ii. examine the socio-economic impacts of lithium exploration on local agricultural communities in Nasarawa State.

2 Materials and Methods

2.1 Study Area

The study was conducted in Nasarawa Local Government Area, Nasarawa State, Nigeria, an emerging lithium exploration zone in north-central Nigeria. The area was purposively selected because of the rapid expansion of lithium exploration activities and the predominance of agriculture as the main livelihood, making it suitable for assessing the environmental and socio-economic implications of mining on farming communities.

2.2 Research Design

The study adopted a convergent mixed-methods research design, integrating quantitative and qualitative approaches to assess the environmental and socio-economic impacts of lithium exploration on agricultural communities. Quantitative data were obtained through household surveys and laboratory analyses of soil samples, while qualitative data were collected through focus group discussions and key informant interviews. Both datasets were collected concurrently, analyzed separately, and integrated during interpretation to provide a comprehensive understanding of the effects of lithium exploration on soil quality, agricultural productivity, and rural livelihoods.

2.3 Sampling Technique and Data Collection

A multi-stage sampling technique was employed. Communities experiencing active lithium exploration were purposively selected, after which farming households were selected using systematic random sampling. Key informants, including community leaders, agricultural extension officers, environmental officials, and mining representatives, were selected purposively based on their knowledge and experience. Focus group discussions were conducted with farmers to explore community perceptions and livelihood changes associated with lithium exploration.

Primary data were collected using structured questionnaires, soil sampling, focus group discussions, and semi-structured interviews. Soil samples were collected from farms located within lithium exploration areas and comparable control farms and analyzed using standard laboratory procedures for pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, water-holding capacity, and selected heavy metals (lead, cadmium, and arsenic). The questionnaire elicited information on household income, crop yield, employment, access to agricultural inputs, livelihood diversification, and community perceptions of lithium exploration.

2.4 Data Analysis

Quantitative data were analyzed using IBM SPSS Statistics (Version 29). Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarize respondents' characteristics, soil quality parameters, and socio-economic indicators. Independent-samples *t*-tests were used to compare soil quality and agricultural productivity between lithium exploration-affected farms and control farms, while one-way analysis of variance (ANOVA) examined differences among communities or levels of mining exposure. Pearson's correlation analysis assessed relationships among lithium exploration, soil quality, and agricultural productivity, whereas multiple linear regression determined the extent to which lithium exploration and soil quality variables predicted agricultural productivity and selected socio-economic outcomes. Statistical significance was determined at the 5% level ($p < 0.05$). Before inferential analyses, assumptions of normality, homogeneity of variance, linearity, independence of errors, and multicollinearity were assessed using the Shapiro–Wilk test, Levene's test, scatterplots, the Durbin–Watson statistic, and Variance Inflation Factors (VIFs), respectively.

Qualitative data obtained from focus group discussions and key informant interviews were transcribed verbatim and analysed using thematic analysis following the six-step procedure proposed by Braun and Clarke (2006). Emerging themes relating to soil degradation, livelihood changes, employment, migration, and community adaptation were compared with the quantitative findings to corroborate and explain observed patterns. The integration of quantitative and qualitative evidence enhanced the credibility and completeness of the study through methodological triangulation.

3 Results

3.1 Environmental Impacts of Lithium Exploration on Soil Quality

This study aimed to evaluate the environmental effects of lithium exploration on soil quality by comparing soil samples collected from areas impacted by mining activities with those from control areas that had not been exposed to such activities. Several key soil quality indicators were analyzed, including soil pH, nitrogen, phosphorus, potassium, and organic matter content (Table 1). The results clearly indicate that lithium exploration activities have significantly degraded soil quality. Specifically, there was a notable decrease in soil pH, nitrogen levels, phosphorus content, and organic matter in the impacted agricultural areas when compared to the control sites. These changes suggest that mining activities are adversely affecting soil health, which could reduce agricultural productivity and long-term sustainability in the region.

Table 1: Soil Quality Parameters in Agricultural Areas Impacted by Lithium Exploration

Soil Parameter	Impacted Areas (Mean ± SD)	Control Areas (Mean ± SD)	p-Value	Interpretation
pH	5.8 ± 0.3	6.5 ± 0.2	0.04	Significant decrease in soil pH due to mining activities
Nitrogen (%)	0.15 ± 0.01	0.22 ± 0.02	0.01	Significant reduction in nitrogen levels
Phosphorus (mg/kg)	25 ± 4	38 ± 6	0.02	Phosphorus levels lower in impacted areas
Potassium (mg/kg)	150 ± 10	175 ± 8	0.06	Slight reduction in potassium, but not significant
Organic Matter (%)	2.1 ± 0.3	3.5 ± 0.4	0.01	Organic matter significantly lower in impacted areas

3.2 Soil Erosion and Sedimentation Impact

Soil erosion and sedimentation are critical environmental issues associated with mining activities. Erosion rates were measured at both impacted and control sites. Erosion rates in impacted areas were significantly higher (mean ± SD = 7.8 ± 2.3 tons/hectare) compared to control areas (mean ± SD = 3.2 ± 1.4 tons/hectare), with a p-value of 0.03. The data indicate that mining activities have accelerated soil erosion, further compromising soil quality and agricultural productivity.

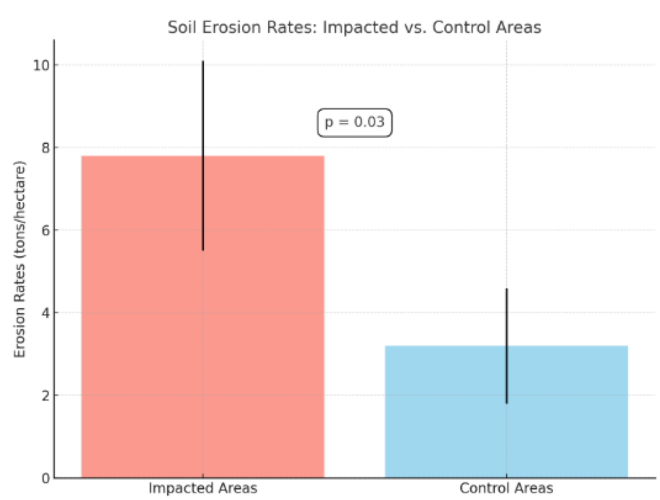

Figure 1: Soil Erosion Rates in Impacted vs. Control Areas

3.3 Heavy Metal Contamination in Soil

The concentration of heavy metals, such as lead, cadmium, and arsenic, was evaluated in soil samples from both the impacted and control areas (Table 2). The data reveal that areas impacted by lithium exploration exhibited elevated levels of heavy metals, particularly lead, cadmium, and arsenic, which may pose risks to soil health and agricultural productivity. The presence of these metals could also contaminate water sources, affecting both the ecosystem and human health.

Table 2: Heavy Metal Concentrations in Soil

Metal	Impacted Areas (Mean ± SD, mg/kg)	Control Areas (Mean ± SD, mg/kg)	p-Value	Interpretation
Lead (Pb)	3.2 ± 0.6	1.1 ± 0.3	0.02	Significant increase in lead concentration
Cadmium (Cd)	0.5 ± 0.1	0.1 ± 0.05	0.01	Significant increase in cadmium concentration
Arsenic (As)	0.8 ± 0.2	0.3 ± 0.1	0.03	Significant increase in arsenic concentration

3.4 Water Holding Capacity of Soil

The water holding capacity (WHC) of the soil, which influences the soil's ability to retain moisture for crops, was assessed at both the impacted and control sites. The WHC in impacted areas was significantly lower (mean ± SD = 22.5 ± 3.5%) compared to control areas (mean ± SD = 30.2 ± 4.1%), with a p-value of 0.04. The reduced WHC in the impacted areas suggests that soil degradation due to lithium exploration has led to a diminished capacity to retain water, potentially increasing irrigation demands and threatening crop yields.

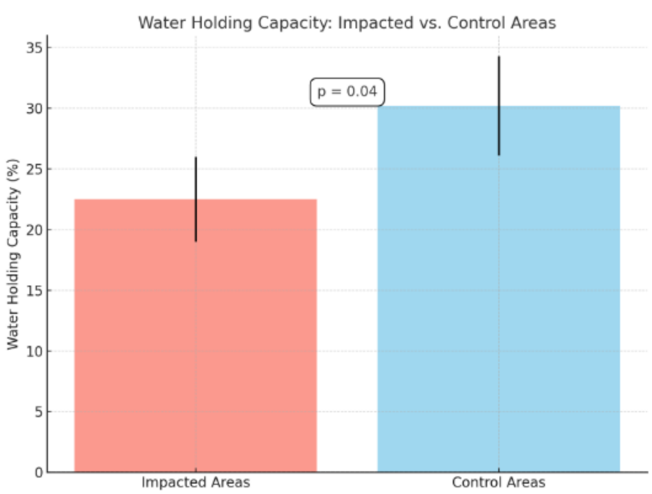

Figure 2: Water Holding Capacity in Impacted vs. Control Areas

3.5 Soil Microbial Diversity

Soil microbial diversity was analyzed to understand the effect of lithium exploration on soil ecosystems (Table 3). The total number of microbial species was compared between impacted and control sites. The study found a significant decline in both bacterial and fungal species in the impacted areas compared to the control sites. This reduction in microbial diversity is concerning as it can affect soil health, nutrient cycling, and overall ecosystem functioning, further degrading the soil quality in regions impacted by lithium exploration.

Table 3: Soil Microbial Diversity in Impacted vs. Control Areas

Microbial Parameter	Impacted Areas (Mean ± SD)	Control Areas (Mean ± SD)	p-Value	Interpretation
Total Microbial Species (cfu/g)	$1.2 \times 10^7 \pm 2.4 \times 10^6$	$2.3 \times 10^7 \pm 1.9 \times 10^6$	0.01	Significant reduction in microbial diversity
Fungal Species (cfu/g)	$4.5 \times 10^6 \pm 1.3 \times 10^6$	$8.9 \times 10^6 \pm 2.1 \times 10^6$	0.03	Reduced fungal species in impacted areas
Bacterial Species (cfu/g)	$7.4 \times 10^6 \pm 1.6 \times 10^6$	$1.3 \times 10^7 \pm 2.2 \times 10^6$	0.02	Reduced bacterial species in impacted areas

3.6 Socio-Economic Impacts of Lithium Exploration on Local Agricultural Communities

The socio-economic impacts of lithium exploration were assessed through a combination of structured surveys, focus group discussions, and key informant interviews (Table 4). The study examined key economic indicators, including household income, crop yields, employment opportunities, and access to agricultural inputs, as well as community perceptions of the impact of mining activities on their livelihoods. The socio-economic impacts of lithium exploration on the agricultural community are mixed. While mining activities have created new employment opportunities, especially in terms of short-term and low-paying jobs, agricultural productivity has significantly declined. Average household incomes dropped by 26.7%, and crop yields decreased by 20%. Farmers attributed these declines to soil degradation, water contamination, and competition for resources between agriculture and mining. Additionally, the availability of agricultural inputs, such as fertilisers, has declined by 30% due to a shift toward mining operations. Community members expressed concerns over the long-term viability of their agricultural livelihoods as mining activities continue to expand in the region.

Table 4: Socio-Economic Indicators in Agricultural Communities Affected by Lithium Exploration

Indicator	Before Exploration (Mean)	After Exploration (Mean)	% Change	Community Perception
Average Household Income (₦)	150,000	110,000	-26.7%	Perceived decline in income due to reduced crop yield and market disruptions
Crop Yield (kg/ha)	3,500	2,800	-20%	Farmers reported lower crop yields, linked to soil degradation and water contamination
Employment Opportunities	Moderate	High	+35%	Mining provides alternative jobs, but most are short-term or low-paying
Access to Agricultural Inputs	High	Low	-30%	Reduced availability of fertilizers and other inputs as focus shifts to mining

3.7 Changes in Livelihood Strategies

To cope with the socio-economic challenges brought about by lithium exploration, many households have adopted alternative livelihood strategies, including diversifying their income sources. Approximately 45% of respondents reported adopting non-agricultural activities, such as trade and mining-related work, to supplement their income. However, this shift towards non-agricultural work was often seen as a temporary solution rather than a sustainable strategy for long-term livelihood security. The data shows a significant increase in both out-migration (25%) and in-migration (12%) following the onset of lithium exploration. Out-migration has risen by 150%, as residents leave to seek better economic prospects in urban areas or other mining regions. At the same time, there has been a 140% increase in in-migration, as workers from other areas come to the region in search of mining-related jobs.

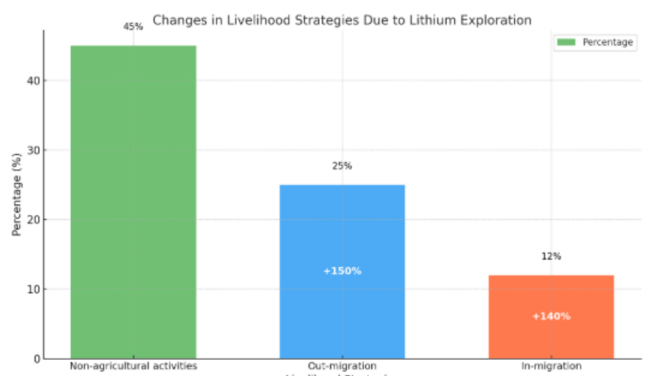

Figure 3: Livelihood Strategy Shifts in Response to Lithium Exploration

3.8 Migration Patterns

Lithium exploration has also influenced migration patterns in the affected communities, as individuals and families seek better economic opportunities elsewhere (Table 5).

Table 5: Migration Trends Before and After Lithium Exploration

Migration Factor	Before Exploration (%)	After Exploration (%)	% Change	Community Perception
Out-migration for Work	10%	25%	+150%	Increased migration due to loss of agricultural income and the promise of mining jobs
In-migration for Work	5%	12%	+140%	Influx of workers from other regions attracted by mining job opportunities

3.9 Impact on Women and Youth Employment

The socio-economic impacts of lithium exploration have been felt disproportionately by women and youth in the community. The exploration activities have led to a 40% increase in female and youth participation in the mining sector. However, these jobs are often short-term, informal, and low-paying. Women, in particular, face challenges in balancing mining-related work with their household responsibilities, while youth employment is often temporary and unstable.

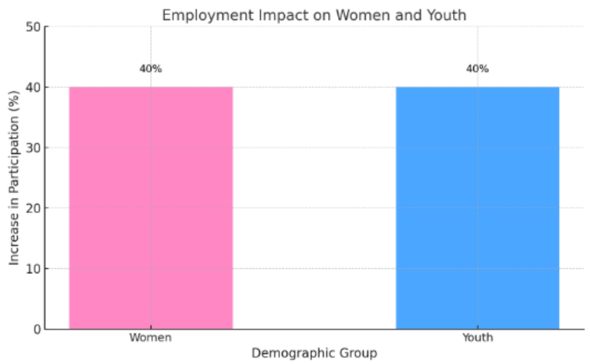

Figure 4: Employment Impact on Women and Youth

3.10 Community Perceptions of Long-Term Sustainability

Despite the short-term economic opportunities created by mining, many community members expressed concerns about the long-term sustainability of their livelihoods (Table 6). A significant majority (70%) of respondents believe that lithium exploration poses a negative long-term impact on their livelihoods due to environmental degradation, soil depletion, and the loss of agricultural land. Only 15% of the community believes that mining activities will have a lasting positive effect on their economic well-being, while another 15% remain uncertain about the long-term consequences.

Table 6: Community Perceptions of the Sustainability of Lithium Exploration

Perception	Percentage of Respondents (%)	Community Concern
Positive Impact on Long-term Livelihood	15%	Only a small percentage believes mining will benefit their long-term economic stability
Negative Impact on Long-term Livelihood	70%	Majority concerned about depletion of agricultural land, loss of resources, and environmental degradation
Uncertain Impact	15%	Some residents remain undecided, uncertain of the future economic outcomes

4 Discussion

The study revealed that lithium exploration has significantly affected soil quality in the study area, with reductions in soil pH, organic matter, nitrogen, and phosphorus, alongside increased soil erosion and heavy metal contamination. These changes suggest that exploration activities disrupt soil structure and reduce its capacity to sustain agricultural production. Similar environmental impacts have been reported in hard-rock lithium mining regions such as Zimbabwe and Australia, where land clearing, excavation, and waste disposal have contributed to soil degradation and declining ecosystem functions. However, unlike brine-based lithium extraction in Chile and Argentina, where groundwater depletion and salinity are the dominant environmental concerns, the impacts observed in Nasarawa are primarily associated with land disturbance and soil degradation. This comparison highlights the importance of adopting context-specific environmental management measures based on the method of lithium extraction.

The socio-economic findings indicate that lithium exploration has produced both opportunities and challenges for farming households. Although mining created employment opportunities and encouraged livelihood diversification, these benefits were largely temporary and insufficient to compensate for declining crop yields, reduced household income, and limited access to agricultural inputs. The observed increase in migration further reflects the adjustments households make in response to declining agricultural opportunities. These findings support Community Resilience Theory, which posits that communities respond to environmental disturbances by adapting their livelihood strategies. In this study, diversification into mining-related employment and non-farm activities represents adaptive responses; however, their temporary nature suggests that community resilience remains constrained by declining environmental resources and limited institutional support. The findings also align with the Political Ecology perspective, which emphasizes that competing demands for land and natural resources between mining and agriculture can increase environmental vulnerability and livelihood insecurity.

5 Conclusion

This study demonstrates that lithium exploration is associated with declining soil quality and increasing socio-economic pressures on agricultural communities in Nasarawa Local Government Area. While exploration activities generated some employment opportunities, these benefits did not offset the adverse effects of soil degradation, reduced agricultural productivity, and declining household income. The findings reinforce Community Resilience Theory by showing that environmental degradation weakens the adaptive capacity of farming households, forcing them to adopt alternative livelihood strategies that may not be sustainable in the long term. However, the findings should be interpreted cautiously because the study was limited to one Local Government Area and employed a cross-sectional design, which limits their generalizability and does not capture long-term environmental changes. Future studies should undertake longitudinal and comparative assessments across multiple lithium-producing regions in Nigeria to provide broader evidence for sustainable mining policies. Strengthening environmental regulation, promoting mine-site rehabilitation, and supporting livelihood diversification will be essential for balancing lithium development with agricultural sustainability and rural resilience.

Based on the findings of the study, the following recommendations are made:

i. Given the significant decline in soil quality, the study recommends that the Federal Ministry of Environment, the Nasarawa State Ministry of Environment, and mining companies should prioritize the establishment of pilot soil rehabilitation programmes in communities affected by lithium exploration before scaling them up across other mining areas. These programmes should promote affordable and locally adaptable practices such as organic soil amendments, cover cropping, agroforestry, and reforestation to restore soil fertility and reduce erosion.

ii. To address the socio-economic impacts of lithium exploration on farmers, government agencies should strengthen the enforcement of existing environmental and mining regulations by ensuring that land compensation reflects both the market value of acquired land and the long-term loss of agricultural livelihoods. Recognizing the practical challenges associated with revenue-sharing in Nigeria, pilot Community Development Agreements (CDAs) involving mining companies, local governments, and host communities should be implemented to support agricultural livelihoods through subsidized farm inputs, skills training, irrigation development, and livelihood diversification programmes.

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