



Mathematical Analysis of The Negative Impacts of Local Mining of Monazite Using a Linear Programming Model: A Case Study of Hong Local Government Area of Adamawa State, Nigeria

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Abstract

This research work aimed at mathematical analysis of the negative impacts of local mining of monazite using a linear programming model: a case study of Hong local government area of Adamawa state, Nigeria. Ten communities selected are Kala'a, Kwatau, Kwakwa'ah, Gaya-fa'a, Gashala, Pella, Garaha, Mijili, Hyema, and Dakza of Hong Local government. The computation of result is to identify the effect on local monazite mining on the health of the people in the communities, rate of students' dropout due to mining activities and level conflict mining activities generated using of MATLAB. Health impacts were most pronounced in localities C and D by percentage, indicating that more than one-third of clinic cases in those localities were mining-related. Education disruption, measured by dropout rate, was highest in locality H and D. Conflict impacts were unusually high in locality B by percentage, but this is influenced by a small baseline of total police cases; therefore both absolute counts and rates should be considered when drawing conclusions. The results demonstrate that mining activities are associated with measurable adverse outcomes across health, education, and social stability. Health burden contributes the largest share of the combined impact, suggesting persistent community exposure and elevated clinical presentations in mining-affected localities. Education disruption is substantial in specific areas, indicating that mining pressures may be contributing to withdrawal from schooling through labour participation, displacement, household economic shock, or insecurity. Conflict results suggest that mining also drives social instability through disputes, tensions, and insecurity.

Keywords: local mining, monazite, negative impacts, mathematical analysis, linear programming model

I. Introduction

Mining is the extraction of minerals and other geological materials value from deposits of the earth. It is characteristically a destructive industry, as the effect of a single mining operation can have a severe impact on life, farmlands, and environment at large. Although there are some regulations set in place with good intention to minimize the damage, but are not sufficient enough to allow mining, livelihoods, and wildlife to exist in harmony, especially where those regulations are hard to enforce. For the purpose development and good health to be sustained, the conversion of natural capital should result in the creation of equivalent social and or economic capital (Pegesus, 2017).

Mining activities involve scraping away earth and rocks surfaces to get to the deposit buried under or near the surface. In many case, river banks and mountains are literally blasted apart to reach mineral deposits within this activity tends to leave permanent scars on the landscape and health system of the dwellers in the area (Dontalaa, et al, 2015).

Nigeria has been marked as one of the countries that have been blessed with abundant solid minerals on the continent. Hong Local Government and its environment were rich in mineral deposits especially Monazite, which have drawn attention of dwellers and migrant to put aside their farming activities and moves in to local mining.

Mineral exploration and processing have caused varying degree of environmental damage in Nigeria. These include alteration of ecological state, air, water, soil pollution, destruction of soil flora and fauna, loss of vegetation, landscape degradation and radiation emission. Since mineral exploration is still at the developmental state and in the hands of artisanal miners in most developing nations, the environmental impact of their ill-fated activities is inevitable. For a robust, sustainable eco-mining to be achieved, government agencies environmentalist and industrial prospectors must take sound precautionary measures in remedying polluted sites



and limiting re-introduction of hazardous material into the environment.

II. Materials and methods

Area of the Study: The study area is Hong Local Government Area of Adamawa State, Nigeria. Hong is situated about 153 km away from the state capital to the north with an estimated population of 260,900. It has an approximate area of about 2,588 km² at coordinates 10°13'54"N 12°55'49"E. The recent discovery of monazite in Hong has brought about local mining for children, youths, and adults.

Research Design: The study will employ a descriptive survey research design because it is cost-efficient and reliable.

Method of Data Collection: Data will be sourced from primary sources (structured questionnaires, oral interviews, and measurement of the size of land damaged by mining and schools area). Secondary data will be from related journal papers.

Sample Size and Sampling Techniques: Two sampling techniques will be employed: simple random sampling and stratified sampling. The sample size is one thousand (1,000), which will be drawn from the estimated population of Hong Local Government Area. Stratified sampling technique will be used; one hundred (100) samples will be selected at random from each of the selected communities: Kala'a, Kwatau, Kwakwa'ah, Gaya-fa'a, Gashala, Pella, Garaha, Mijili, Hyema, and Dakza.

Method of Data Analysis and Interpretation: MATLAB or Python mathematics software will be used to run and interpret the linear programming model.

Linear Programming Model:

Model equation

$$\text{Min } Z = 1210X_1 + 274X_2 + 275X_3$$

Subject to:

$$150X_1 + 38X_2 + 80X_3 \leq 268$$

$$135X_1 + 9X_2 + 14X_3 \leq 158$$

$$90X_1 + 11X_2 + 20X_3 \leq 121$$

$$162X_1 + 57X_2 + 10X_3 \leq 229$$

$$110X_1 + 40X_2 + 28X_3 \leq 178$$

$$120X_1 + 25X_2 + 17X_3 \leq 162$$

$$109X_1 + 18X_2 + 21X_3 \leq 148$$

$$158X_1 + 31X_2 + 18X_3 \leq 207$$

$$91X_1 + 28X_2 + 24X_3 \leq 143$$

$$85X_1 + 17X_2 + 43X_3 \leq 145$$

$$X_i \geq 0, i=1, 2, 3$$

Where X_1 = effect of mining activities on the health of the people

X_2 = effect of mining activities on the education of the people

X_3 = effect of mining activities on the peaceful coexistence of the people

a_{1j} = number of health mining related health cases represented in j locality

a_{2j} = number of student dropout due to mining activities in j locality

a_{3j} = number of conflict due to mining in j locality

b_j = total number of people affected in the 3 categories in j locality

c_i = total number of $i(i \leq 3)$ problem associated with mining in 10 locality

III. Results and Discussion

Introduction

This chapter presents the data, analysis, and results for mining-associated impacts observed between September and December 2025 across ten localities (A to J). The analysis focuses on three outcome domains linked to mining activities: health burden, conflict and peace, and education disruption measured through student dropout.

Data and indicator definition

For each locality, absolute counts were recorded for: (i) total clinic cases and mining-related health cases, (ii) total students and dropouts, and (iii) total police station cases and mining-related conflict cases. To support cross-locality comparison, percentage indicators were computed as follows: mining health rate equals mining-related health cases divided by total clinic cases; dropout rate equals dropouts divided by total students; conflict rate equals mining-related conflict cases divided by total police cases. A peace index was computed as 1 minus the conflict rate.

Table 1.0: Overall totals across all localities (Sep to Dec 2025)

Domain	Mining-related cases	Total baseline cases/population	Mining-related share (%)
Health	1210	4845	24.97
Education	274	4282	6.4
Conflict	275	2458	11.19



Results tables

Table 1.1: Extracted raw data set by locality (Sep to Dec 2025)

Locality	Total health cases	Mining-related health cases	Total students	Student dropouts	Total police cases	Mining-related conflict cases
A	540	150	560	38	384	80
B	700	135	428	9	20	14
C	250	90	310	11	150	20
D	470	162	600	57	183	10
E	620	110	510	40	400	28
F	550	120	455	25	188	17
G	435	109	285	18	233	21
H	640	158	250	31	347	18
I	340	91	412	28	246	24
J	300	85	472	17	307	43

Data validation note: the health percentage for locality I, is recalculated using the raw counts. Mining-related health cases are 91 out of 340 total health cases, which equal 26.76%.

Table 1.2: Derived impact indicators and peace index by locality

Locality	Mining health rate (%)	Dropout rate (%)	Conflict rate (%)	Peace index (1 - conflict rate)	Total burden (cases)
A	27.78	6.79	20.83	0.792	268
B	19.29	2.1	70.0	0.3	158
C	36.0	3.55	13.33	0.867	121
D	34.47	9.5	5.46	0.945	229
E	17.74	7.84	7.0	0.93	178
F	21.82	5.49	9.04	0.91	162
G	25.06	6.32	9.01	0.91	148
H	24.69	12.4	5.19	0.948	207
I	26.76	6.8	9.76	0.902	143
J	28.33	3.6	14.01	0.86	145

Table 1.3: Locality ranking by total combined burden (health + dropout + conflict)

Rank	Locality	Total burden (cases)
1	A	268
2	D	229
3	H	207
4	E	178
5	F	162
6	B	158
7	G	148
8	J	145
9	I	143
10	C	121

Visualization of mining impacts

Figures 1.0 to 1.2 provide visual summaries of the mining-associated impacts. Figure 1.0 compares the percentage indicators across localities, Figure 1.1 shows absolute case burden, and Figure 1.2 shows how conflict rate relates to the derived peace index.

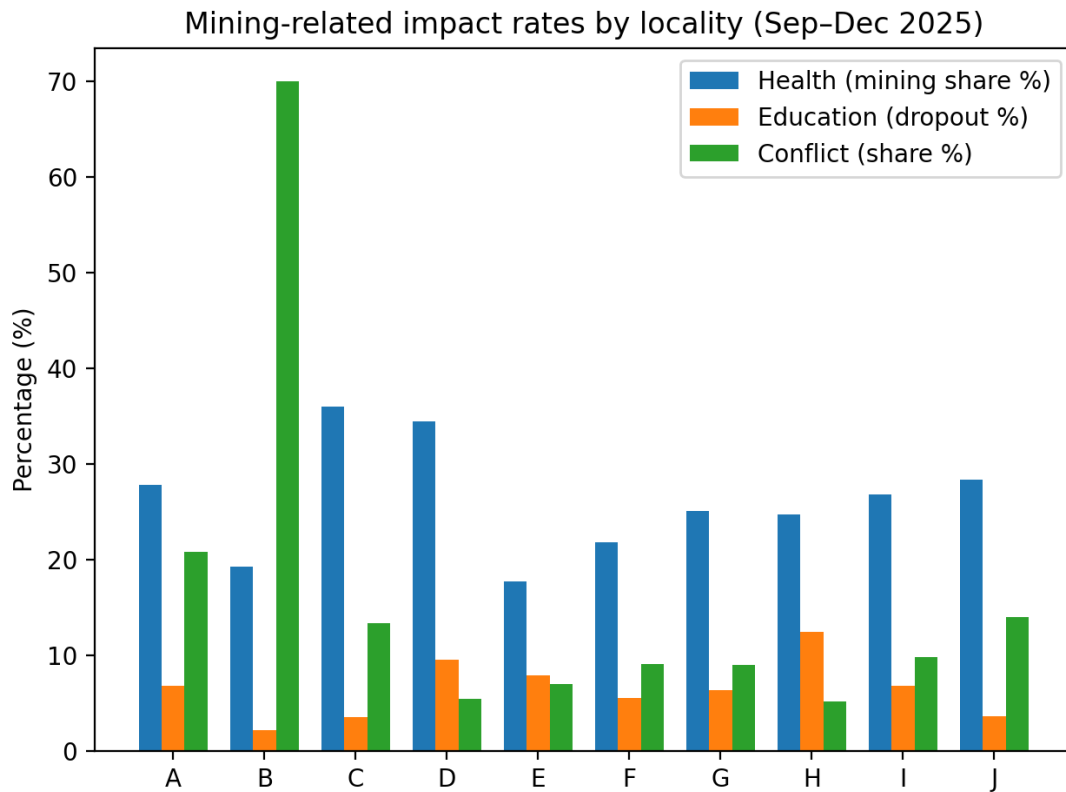


Figure 1.0: Mining-related impact rates by locality (health rate, dropout rate, conflict rate)

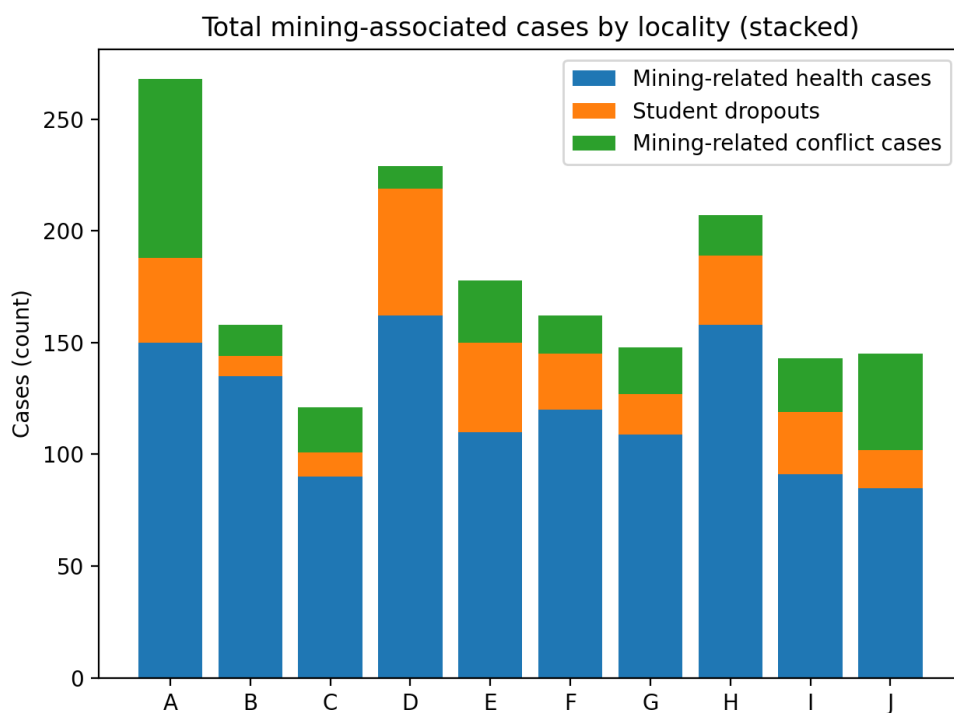


Figure 1.1: Absolute mining-associated cases by locality (stacked: health, dropout, conflict)

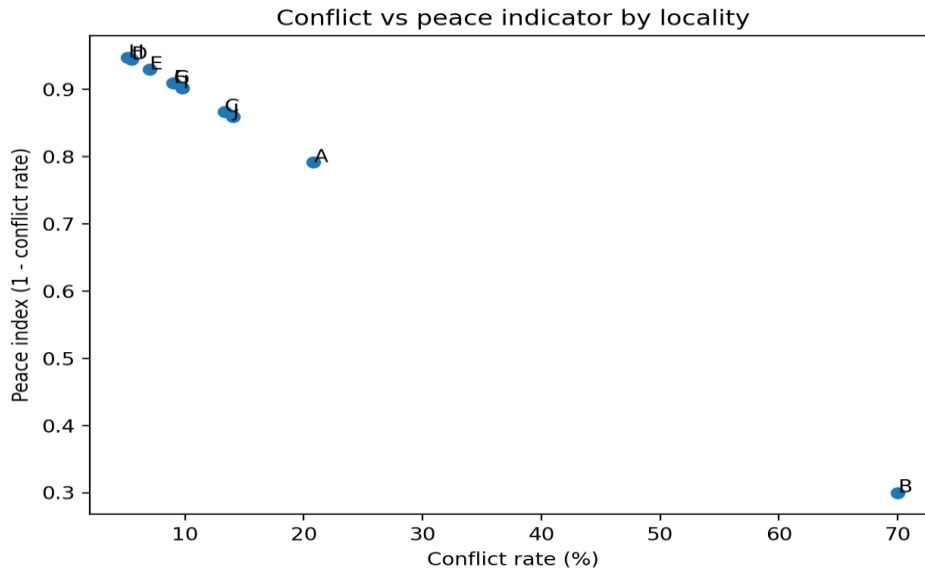


Figure 1.2: Relationship between conflict rate and peace index by locality

Interpretation of results

Health impacts were most pronounced in localities C and D by percentage, indicating that more than one-third of clinic cases in those localities were mining-related. Education disruption, measured by dropout rate, was highest in locality H

and D. Conflict impacts were unusually high in locality B by percentage, but this is influenced by a small baseline of total police cases; therefore both absolute counts and rates should be considered when drawing conclusions.

Table 1.4: Example mitigation prioritization result (K = 3 localities)

Rank	Locality	Total burden (cases)	Rationale
1	A	268	Highest combined burden (health + dropout + conflict)
2	D	229	Highest combined burden (health + dropout + conflict)
3	H	207	Highest combined burden (health + dropout + conflict)

Using K = 3 as an illustrative capacity constraint for the first phase of intervention, the prioritization model selects localities A, D, H. This selection covers 704 out of 1759 total combined cases (health + dropout + conflict), leaving 1055 cases outside the first intervention phase.

IV. DISCUSSION

The results demonstrate that mining activities are associated with measurable adverse outcomes across health, education, and social stability. Health burden contributes the largest share of the combined impact, suggesting persistent community exposure and elevated clinical presentations in mining-affected localities. Education disruption is substantial in specific areas, indicating that mining pressures may be contributing to withdrawal from schooling through labour participation, displacement, household economic

shock, or insecurity. Conflict results suggest that mining also drives social instability through disputes, tensions, and insecurity.

How conflict affects peace in the locality

In this study, peace is operationalized using police-recorded mining-related conflict cases relative to total police cases. A higher conflict rate implies weaker peaceful coexistence, reduced community trust, and greater insecurity. The derived peace index (peace index = 1 - conflict rate) decreases as conflict rate increases. The conflict-versus-peace plot (Figure 4.3) shows an inverse relationship: localities with higher conflict shares have lower peace indices. This supports the conclusion that mining-related conflict directly undermines peace in affected communities.



Optimization and implications for mitigation planning

The prioritization output provides a practical decision support approach for reducing mining impacts when resources are limited. By selecting a fixed number of localities for intervention (for example, $K = 3$), the model identifies locations with the highest combined burdens. Operationally, this supports phased mitigation planning: first, target the highest-burden localities to reduce the largest number of incidents, and then expand to additional localities as capacity improves.

V. Conclusion

Mining-associated impacts between September and December 2025 were substantial and unevenly distributed across the ten localities. Health burdens represent the largest component of the combined impact, while education dropout and conflict contribute meaningful secondary effects. Localities with high conflict rates exhibit lower peace indices, indicating reduced peaceful coexistence. The results justify targeted interventions to reduce health harms, limit education disruption, and prevent mining-driven conflict.

VI. Recommendations

Health: strengthen health outreach, screening, and treatment capacity in affected areas; implement and enforce environmental and occupational safety controls for mining operations, including dust and water exposure controls, and community risk communication.

Education: introduce dropout prevention mechanisms in high-dropout localities, including school-community monitoring, targeted support for at-risk students, and enforcement against child labour linked to mining activities.

Peace and conflict: establish community-led dispute resolution structures, formal stakeholder engagement between miners and host communities, and support local policing and early-warning response mechanisms around mining hotspots.

Planning and resource allocation: adopt phased mitigation planning using a burden-based prioritization model; begin with the highest-burden localities and scale gradually while monitoring indicators.

Limitations and future work

The study relies on administrative records and does not include household-level exposure measures or independent survey-based peace

indicators. Percentages can be sensitive in localities with small baseline totals. Future work should incorporate mining intensity metrics (site counts, production volume), household health and schooling surveys, and time-series data to test causality and evaluate intervention effectiveness over time.

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