

Mining-Linked Livelihoods, Institutional Constraints and Community Resilience in Selected Mining-Affected Settlements of Jos South L.G.A., Plateau State, Nigeria

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Abstract: Artisanal and Small-scale Mining (ASM) provides important livelihood opportunities in mining affected communities but may simultaneously weaken the environmental, institutional and adaptive foundations required for long term resilience. This study examined mining linked livelihoods and community resilience among 100 adults in selected mining affected settlements of Jos South L.G.A., Plateau State, Nigeria. Data collected using KoboCollect were analysed through descriptive statistics, a five-component formative Community Resilience Index (CRI), internal consistency diagnostics, exploratory factor analysis, group comparisons, spatial analysis and Heteroskedasticity Consistent (HC3) multivariable regression. 80% of respondents recognised an active or abandoned mining site near their communities, 71% reported living within 1Km of mining activity and 41% reported household involvement in mining. The overall CRI was 1.99 (SD = 0.34; 95% CI = 1.92 – 2.06), with 95% of respondents classified within the study defined low or very low resilience bands. Institutional Support recorded the lowest component mean (1.32), followed by Perceived Environmental Condition (1.96), Adaptive Capacity (1.97), Social Resources (2.16) and Economic Resources (2.55). Component Omega Coefficients ranged from 0.49 to 0.94, while Exploratory Factor Analysis retained four factors, supporting interpretation of the CRI as a multidimensional formative composite rather than a single latent construct. Household mining involvement was not significantly associated with overall CRI, although mining involved households reported significantly lower Institutional Support. Proximity within 1Km was also not significantly associated with overall CRI in the Bivariate Analysis. Although proximity became significant in the adjusted model, this association disappeared when perceived environmental condition were excluded from the composite. Rural residence were associated with lower resilience, whereas longer residence duration was positively associated with CRI. The findings reveal a livelihood resilience paradox in which mining related earning opportunities coexist with weak institutional support, limited financial resources, environmental stress and constrained adaptive capacity. Strengthening local governance, technical services, environmental rehabilitation, access to finance and

realistic livelihood diversification is therefore essential for building durable resilience in mining affected communities.

Keywords: Artisanal and Small-scale Mining, Adaptive Capacity, Community Resilience, Institutional Support, Mining-Linked Livelihoods.

1. Introduction

Artisanal and Small-scale Mining (ASM) occupies an ambiguous position in rural and peri-urban development. It can absorb labour, generate cash income and diversify household economies, but it can also reduce access to farmland and water, intensify environmental risk and create governance problems that households cannot resolve through private coping strategies alone. African evidence increasingly rejects a simple contrast between mining as livelihood and mining as degradation. Instead, mining often becomes one component of diversified livelihood portfolios whose short-term benefits coexist with longer-term social and environmental costs (Hilson & Hu, 2022; Moyo et al., 2022; Brunnschweiler et al., 2024).

This tension is especially relevant on the Jos Plateau, where tin and associated mineral extraction have influenced settlement and livelihood systems for more than a century. Artisanal cassiterite extraction continues to provide income and employment (Ebikemefa, 2020), while historical and contemporary mining have also left excavations, water-filled pits, degraded surfaces and contested resource spaces. Nigerian evidence further shows the difficulty of aligning informal livelihood practices with formal regulatory systems (Oramah et al., 2015).

A resilience perspective shifts attention from whether mining is simply beneficial or harmful to whether households and communities have the resources and institutions needed to withstand disturbance, adapt and recover. Resilience is not equivalent to self-reliance. Adaptive Capacity is shaped by

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assets, social networks, institutions, knowledge and access to decision-making structures (Engle, 2011). A household may increase cash income through mining while remaining vulnerable because income is unstable, productive assets are weak, credit is unavailable, environmental conditions are deteriorating or public institutions provide little support.

Measurement is therefore central to any resilience claim. Community-resilience indicators require explicit conceptual justification and validation because different indicators may capture exposure, current conditions, resources or Adaptive Capacity rather than a single latent trait (Gu *et al.*, 2023; Gerst *et al.*, 2025). Self-report instruments can provide valuable bottom-up evidence, but their domains and scoring rules need transparent interpretation (Leykin *et al.*, 2013).

This paper analyses the household and community survey component of a broader geospatial study in part of Jos South. It addresses four questions: (1) how widespread are mining-linked livelihood involvement and reported proximity to mining among surveyed households; (2) which components of resilience appear comparatively stronger or weaker; (3) do the component scores depart materially from the neutral midpoint of the five-point response scale; and (4) what exploratory spatial variation is visible across sampled settlements? The paper does not infer chemical contamination from perception data, does not claim that the sample represents the entire population of Jos South, and does not treat small settlement subsamples as precise community estimates.

2. Conceptual Framing and Measurement Logic

The analysis draws on social-ecological resilience and adaptive-capacity perspectives. Resilience is understood as the capacity to maintain or reorganise essential livelihood and community functions when exposed to mining-related pressures. This framing distinguishes resources that enable adaptation from the environmental conditions that shape the severity of the challenge.

Five components were retained from the original survey design. Economic resources comprise income opportunities, diversity, stability, productive assets and access to finance. Social resources comprise trust, participation, collective action, conflict resolution and support during hardship. Institutional support comprises local institutional effectiveness, mining rules, responsiveness, government support and technical services. Adaptive Capacity comprises coping with income loss, recovery from shocks, collective problem solving, support during shocks and preparedness. The original environmental-resilience component is relabelled here as perceived environmental condition because its items measure reported degradation, erosion, vegetation loss, water-quality deterioration, dust/noise and drainage problems rather than Adaptive Capacity itself. The scoring direction is unchanged: negative environmental items were reverse scored so that higher values denote a more favourable perceived condition.

The overall CRI is therefore interpreted as a formative composite: the components contribute different pieces of information to the broader resilience profile and are not assumed to be interchangeable manifestations of one

underlying trait. This distinction matters for reliability assessment. Internal-consistency coefficients can diagnose coherence within multi-item components, but high alpha is neither necessary nor sufficient for the validity of a multidimensional formative index (McNeish, 2018).

Potential semantic overlap was handled conservatively within the a priori measurement architecture. Participation in collective community action was retained under social resources because it represents engagement in organised community activity, whereas collective problem-solving capacity was retained under Adaptive Capacity because it reflects the ability to respond collectively to disruption. Availability of government support was retained under institutional support as a general enabling resource, while access to institutional support during shocks was retained under Adaptive Capacity as event-specific assistance. These pairs are conceptually related but are not treated as duplicate causal predictors.

3. Methods

A. Study Area

The study was conducted in selected mining-affected settlements within part of Jos South L.G.A., Plateau State, Northcentral Nigeria. The mapped analytical extent lies approximately between 9° 45' and 9° 55' N and 8° 45' and 8° 58' E on the Jos Plateau. The landscape comprises undulating highland terrain, rocky outcrops, Guinea Savanna vegetation, cultivated land and rapidly expanding peri-urban settlement, particularly along the Jos-Bukuru corridor. It also forms part of the historic tin and cassiterite mining belt, where active and abandoned workings, water-filled excavation pits and other mining-modified spaces occur alongside farms and settlements (Ebikemefa, 2020).

The social survey was restricted to inhabited settlements within this mapped mining-affected context. The study-area map is used to establish the environmental and settlement setting; the separate long-term land-cover analysis is not reproduced in this paper.

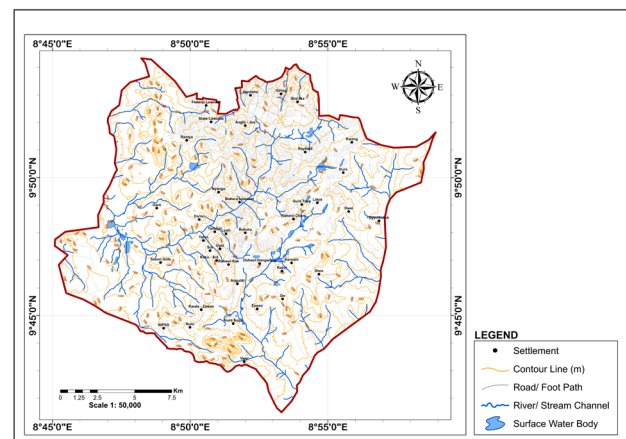


Fig. 1. Map of the study area (Part of Jos South L.G.A., Plateau State)

B. Study Design and Sampling

A cross-sectional household survey was conducted among

adult residents of selected mining-affected settlements. Communities exhibiting mining sites, water-filled excavations, disturbed surfaces or other evidence of mining exposure were purposively selected at the community stage. Within selected settlements, households were approached using systematic or simple-random procedures where settlement structure permitted; in irregular or access-constrained locations, spaced household intervals were used to preserve geographic spread. One adult with knowledge of local livelihood and environmental conditions was selected from each participating household. The final analytical sample comprised 100 valid questionnaires.

This design supports description of experiences within the sampled mining-affected context but is not a probability sample of Jos South as a whole. Results are therefore reported as respondent or sampled-household estimates rather than population estimates for the entire local government area.

C. Instrument, Administration and Exposure Variables

Questionnaires were administered digitally with KoboCollect and covered socio-demographic characteristics, livelihood activities, household mining involvement, length of residence, perceived proximity to mining, perceived land and water impacts and 26 Likert-type items used in the resilience components. The instrument was reviewed and piloted before the main survey, and ambiguous items were revised. Incomplete questionnaires were excluded during data cleaning.

Mining-linked livelihood involvement was defined conservatively as the presence of at least one household member engaged in mining-related activity. This is described as involvement rather than livelihood dependence because the questionnaire summaries available for this paper do not quantify the proportion of household income derived from mining. Proximity was reported in five categories: less than 500m, 500m – 1Km, 1 – 2Km, 2 – 5Km and more than 5Km. The present analysis therefore treats proximity as respondent-reported exposure rather than GIS-measured household-to-mine distance.

Geographic coordinates were collected for spatial interpretation. Figure 2 presents respondent locations only at manuscript map scale and without household identifiers. Because household georeferences are potentially sensitive, the underlying coordinate data are not reproduced in the text or tables and should be handled using appropriate disclosure controls in any public data release.

D. Community Resilience Composite

Each component item was scored on a five-point scale. Negative environmental-condition items were reverse scored so that higher scores consistently represented a more favourable condition. Item means were calculated within each component.

The overall Community Resilience Index was the unweighted mean of five component scores: economic resources, social resources, perceived environmental condition, institutional support and Adaptive Capacity. Equal weighting prevented components with more items from dominating the composite.

The original cut-points (1.00 – 1.80 very low; 1.81– 2.60 low; 2.61 – 3.40 moderate; 3.41 – 4.20 high; 4.21 – 5.00 very high) are retained only as descriptive interpretation bands. They are not treated as externally validated thresholds. Inferential interpretation in this paper instead uses confidence intervals and comparison with the neutral midpoint of 3.0.

E. Statistical Analysis and Ethics

All 100 records contained complete responses for the 26 CRI items. Component scores were recomputed directly from the raw item responses, and the overall CRI was recalculated as the unweighted mean of the five component scores. Descriptive proportions are reported with Wilson 95% confidence intervals, while means are reported with t-based 95% confidence intervals. Exact Cronbach alpha and McDonald's omega total were calculated for each component. Omega was estimated from a one-factor maximum-likelihood model within each component. Because the overall CRI is specified as a formative multidimensional composite rather than a single reflective scale, a single overall omega coefficient was not used as evidence of composite validity (McNeish, 2018).

Item structure was examined using exploratory factor analysis of the 26 scored indicators. Sampling adequacy was assessed with the Kaiser-Meyer-Olkin statistic and Bartlett's test of sphericity. Principal-axis factoring with oblimin rotation was used because the underlying resilience dimensions were expected to be related. The number of factors was evaluated with Horn parallel analysis based on 1,000 random datasets; an observed eigenvalue was retained only when it exceeded the corresponding 95th-percentile random eigenvalue (Finch, 2025). Corrected item-total correlations, alpha if item deleted, communalities, primary loadings and cross-loadings were examined to identify weak or redundant indicators. Given the five-point response format and sample size, the factor analysis is treated as exploratory rather than confirmatory.

Mining-involvement comparisons used Welch independent-samples t tests with 95% confidence intervals for mean differences and Hedges g effect sizes; Mann-Whitney tests were used as a distribution-free sensitivity check. Proximity was analysed primarily as residence within Km versus more than 1Km from mining, with an additional Spearman test across the ordered distance categories. A prespecified ordinary least-squares model with HC3 robust standard errors estimated associations with the corrected CRI. Predictors were household mining involvement, residence within 1Km, farmland use, sex, settlement type (urban reference; semi-urban and rural

Table 1
Measurement architecture of the five-component CRI

Component	Operational Content	Items	Interpretive Role
Economic resources	Income opportunities, diversity, stability, assets, finance	5	Enabling resources
Social resources	Trust, associations, collective action, conflict resolution, support	5	Enabling resources
Perceived environmental condition	Reverse-scored degradation, erosion, vegetation, water quality, dust/noise, drainage	6	Context/condition
Institutional support	Local institutions, rules, responsiveness, government support, technical services	5	Enabling resources
Adaptive Capacity	Coping, recovery, collective problem solving, support during shocks, preparedness	5	Response capacity

indicators) and ordered residence duration. Variance-inflation factors were examined for collinearity. A sensitivity model repeated the HC3 analysis using a capacity-only composite that excluded the perceived environmental-condition component. All tests were two-sided at $\alpha = 0.05$ and are interpreted as associations, not causal effects.

For settlement-level exploration, CRI values were reported only where at least two respondents had an identifiable settlement location. Because many local subsamples remained small, these rankings were treated as exploratory. The survey did not infer chemical water contamination from perceived water-quality responses, and all statistical relationships were interpreted as associations rather than causal effects.

Respondents were informed of the purpose of the study, participation was voluntary, identities were not reported, and geographic coordinates were used only for analytical purposes. The respondent-location map is presented without household identifiers, while the underlying coordinate dataset remains sensitive and is not publicly reproduced in the manuscript.

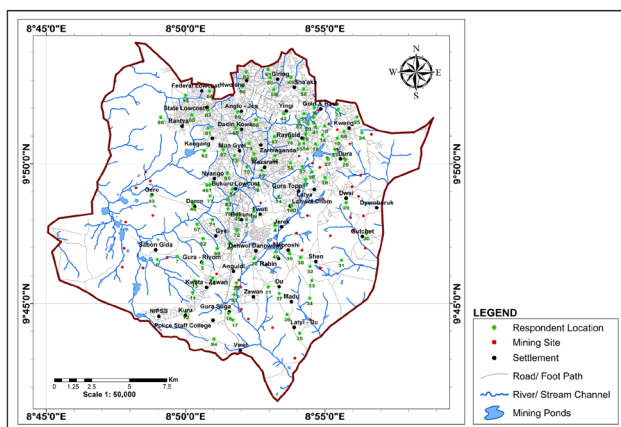


Fig. 2. Spatial distribution of respondents

4. Results

A. Sample Characteristics, Mining Exposure and Livelihood Involvement

The sample was predominantly urban or semi-urban (54% urban, 26% semi-urban and 20% rural). Men constituted 78% of respondents, 75% were aged 25-54 years, and 76% had lived in the study area for more than ten years. Forty-five per cent reported household use of farmland. The gender imbalance means that women's experiences are underrepresented and should not be assumed to mirror those of the full mining-affected population.

Mining exposure was widely reported. Eighty-seven per cent

recognised an active or abandoned mining site near their community (95% CI 79.0 – 92.2), and 71% reported living within 1Km of a mining site (61.5 – 79.0). 65% identified artisanal mining as the dominant form. Mining was the principal occupation of 12%, whereas 41% reported at least one household member involved in mining (31.9 – 50.8). The difference demonstrates that occupational labels alone understate the reach of mining-linked livelihood participation, but it does not establish the share of household income derived from mining.

B. Livelihood Effects and Environmental Concerns

Perceptions of mining's livelihood effects were divided: 42% described the effect as negative or very negative, 47% selected mixed or neutral, and 11% selected positive or very positive. The large mixed category is substantively important because income from extraction, mineral trading, transport or related services can coexist with farmland pressure, unstable earnings and environmental risk. Seventy-one per cent stated that mining should not continue under current conditions, which is better interpreted as dissatisfaction with current governance and environmental arrangements than as categorical rejection of mineral extraction.

Perceived environmental pressure was substantial. 57% reported increased bare land, 44% farmland reduction and 43% mining pits or waste. 86% agreed or strongly agreed that mining contributed to vegetation loss, while 64% linked mining with soil erosion. Water-related concerns were especially pronounced: 82% perceived mining as contributing to water-quality deterioration and 76% linked it with poor drainage. In the direct water-quality item, 94% selected the two most adverse response categories. These are perception data and do not constitute laboratory evidence of chemical contamination.

C. Measurement Diagnostics and Item Structure

The raw respondent-level data confirmed heterogeneous internal consistency across the five components. Economic resources showed weak reflective coherence ($\alpha = 0.30$; $\omega = 0.49$), supporting its treatment as a formative bundle of distinct enabling resources rather than a single latent trait. Social resources demonstrated acceptable consistency ($\alpha = 0.79$; $\omega = 0.81$), institutional support was borderline ($\alpha = 0.65$; $\omega = 0.70$), and Adaptive Capacity showed good consistency ($\alpha = 0.85$; $\omega = 0.84$). Perceived environmental condition was highly internally consistent ($\alpha = 0.94$; $\omega = 0.94$), which supports a strong common environmental dimension but also raises the possibility of item redundancy.

Table 2
Selected mining-exposure and livelihood indicators (n=100)

Indicator	n	%	Wilson 95% CI (%)
Active or Abandoned Mine recognised nearby	87	87.0	79.0 – 92.2
Reported proximity ≤ 1 Km from Mining	71	71.0	61.5 – 79.0
Household Member involved in Mining	41	41.0	31.9 – 50.8
Household Uses Farmland	45	45.0	35.6 – 54.8
Observed Land-Use Change	74	74.0	64.6 – 81.6
Mining should not continue under current conditions	71	71.0	61.5 – 79.0
Negative/ Very Negative Livelihood Effect	42	42.0	32.8 – 51.8
Mixed/ Neutral Livelihood Effect	47	47.0	37.5 – 56.7
Positive/ Very Positive Livelihood Effect	11	11.0	6.3 – 18.6

Item-level diagnostics clarified the principal measurement weaknesses. Within the economic component, diversity of household income sources had a negative corrected item-total correlation ($r = -0.075$), and removing it would increase alpha from 0.30 to 0.57; nevertheless, it was retained because the economic component is formative and income diversity is substantively important. In the social component, local conflict resolution had a low corrected item-total correlation ($r = 0.238$), and deleting it would raise alpha to 0.84. The environmental items were strongly intercorrelated, including land degradation with soil erosion ($r = 0.881$) and dust/noise with poor drainage ($r = 0.851$). No institutional item improved alpha materially when deleted, whereas all adaptive-capacity items contributed positively to the scale.

D. Resilience Component Scores and Statistical Uncertainty

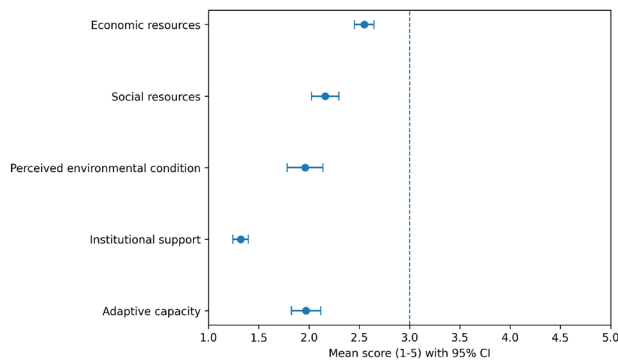


Fig. 3. Mean CRI component scores with 95% confidence intervals (The dashed line marks the Neutral Scale Midpoint, 3.0)

The overall CRI was 1.99 (SD = 0.34; 95% CI 1.92 – 2.06). 95 respondents were in the study-defined low or very – low

bands (Wilson 95% CI 88.8 – 97.8), 5 were moderate, and none were high or very high. Because the category cut-points are descriptive rather than externally validated, the main inferential result is the scale-midpoint analysis. Every component mean was significantly below 3.0 (all $p < .001$), with large negative standardised departures. Institutional support showed the largest deficit relative to the midpoint ($d = -4.31$), followed by Adaptive Capacity ($d = -1.41$), social resources ($d = -1.22$), perceived environmental condition ($d = -1.16$) and economic resources ($d = -0.92$).

E. Mining Involvement and Proximity Tests

Household mining involvement was not associated with the overall CRI. Mining-involved households ($n = 41$) had a mean CRI of 1.988 compared with 1.992 among households without mining involvement ($n = 59$), a Mean Difference of -0.004 (95% CI -0.136 to 0.129; Welch $p = 0.957$; Hedges $g = -0.01$). The clearest component-level difference was Institutional Support, which was lower among mining-involved households (1.210 versus 1.390; Mean Difference = -0.180, 95% CI -0.324 to -0.036; $p = 0.015$; $g = -0.47$). No other mining-involvement component difference reached the 0.05 level.

Proximity produced a more complex pattern. Respondents within 1Km had a somewhat higher overall CRI than those farther away (2.025 versus 1.905), but the bivariate difference did not reach statistical significance (mean difference = 0.121, 95% CI -0.020 to 0.261; $p = 0.091$). The reverse-scored environmental-condition component was substantially higher within 1Km (mean difference = 0.761; $p < .001$; $g = 0.90$), whereas institutional support was lower (mean difference = -0.245; $p = 0.011$; $g = -0.65$). Across the five ordered proximity categories, distance was not associated with overall CRI

Table 3

Internal-consistency diagnostics for the five CRI components

Component	k	Mean (SD)	Cronbach alpha	McDonald's omega	Measurement interpretation
Economic Resources	5	2.55 (0.49)	0.301	0.490	Weak reflective coherence; retain as formative resources
Social Resources	5	2.16 (0.69)	0.787	0.811	Acceptable Consistency
Perceived Environmental Condition	6	1.96 (0.90)	0.938	0.939	Very High Consistency; Redundancy Check Warranted
Institutional Support	5	1.32 (0.39)	0.646	0.696	Borderline/ Modest Consistency
Adaptive Capacity	5	1.97 (0.73)	0.846	0.842	Good Consistency

Table 4

Exploratory factor-analysis summary for the 26 CRI indicators

Retained Factor	Salient Indicators	Loading Range	Interpretation
F1 Social/ Local Collective	Income-Source Diversity; Associations; Collective Action; Trust; Social Support; Mining Bylaws; Local Institutions	0.647 – 0.840	Local Social and Institutional Embeddedness
F2 Environmental Condition	Land Degradation; Soil Erosion; Vegetation Loss; Water-Quality Deterioration; Dust/ Noise; Poor Drainage	0.830 – 0.904	Strong Common Environmental-Condition Dimension
F3 Material/ Adaptive Capacity	Credit; Productive Assets; Conflict Resolution; Coping; Shock Recovery; Collective Problem-Solving; Preparedness	0.503 – 0.678	Material Resources and Adaptive Response Capacity
F4 Formal Institutional Support	Extension/ Technical Services; Government Support	0.608 – 0.775	Formal Service and Government Support

Table 5

CRI component scores, 95% confidence intervals and midpoint tests ($n=100$)

Component	Mean	SD	95% CI	t(99) vs 3	p	Cohen d	Band
Economic Resources	2.55	0.49	2.45 – 2.65	-9.18	<.001	-0.92	Low
Social Resources	2.16	0.69	2.02 – 2.30	-12.17	<.001	-1.22	Low
Perceived Environmental Condition	1.96	0.90	1.78 – 2.14	-11.56	<.001	-1.16	Low
Institutional Support	1.32	0.39	1.24 – 1.40	-43.08	<.001	-4.31	Very low
Adaptive Capacity	1.97	0.73	1.83 – 2.11	-14.11	<.001	-1.41	Low
Overall CRI	1.99	0.34	1.92 – 2.06	-29.71	<.001	-2.97	Low

Table 6
Mining-involvement and proximity comparisons for CRI outcomes

Contrast	Outcome	Group 1 mean	Group 0 mean	Difference (95% CI)	Welch p	Hedges g
Mining yes vs no	Overall CRI	1.988	1.992	-0.004 (-0.136, 0.129)	0.9574	-0.010
Mining yes vs no	Economic	2.498	2.586	-0.089 (-0.280, 0.102)	0.3588	-0.180
Mining yes vs no	Social	2.268	2.078	0.190 (-0.080, 0.461)	0.1660	0.276
Mining yes vs no	Environmental	2.098	1.864	0.233 (-0.130, 0.597)	0.2056	0.257
Mining yes vs no	Institutional	1.210	1.390	-0.180 (-0.324, -0.036)	0.0147	-0.468
Mining yes vs no	Adaptive	1.868	2.041	-0.172 (-0.459, 0.114)	0.2356	-0.236
<=1Km vs >1Km	Overall CRI	2.025	1.905	0.121 (-0.020, 0.261)	0.0905	0.358
<=1Km vs >1Km	Economic	2.577	2.483	0.095 (-0.126, 0.316)	0.3933	0.192
<=1Km vs >1Km	Social	2.127	2.228	-0.101 (-0.399, 0.198)	0.5014	-0.145
<=1Km vs >1Km	Environmental	2.181	1.420	0.761 (0.443, 1.080)	0.0000	0.902
<=1Km vs >1Km	Institutional	1.245	1.490	-0.245 (-0.430, -0.059)	0.0109	-0.646
<=1Km vs >1Km	Adaptive	1.997	1.903	0.094 (-0.214, 0.402)	0.5445	0.128

Table 7
HC3 multivariable model for the corrected Community Resilience Index

Predictor	Beta	HC3 SE	95% CI	p	Interpretation
Mining involvement (yes)	0.021	0.115	-0.208 to 0.250	0.8563	Not Independently Significant
Within 1Km	0.183	0.074	0.035 to 0.330	0.0156	Positive Association; Sensitivity-Dependent
Farmland use (yes)	-0.114	0.122	-0.356 to 0.128	0.3502	Not Independently Significant
Female	-0.131	0.108	-0.346 to 0.085	0.2315	Not Independently Significant
Semi-urban	0.009	0.089	-0.168 to 0.185	0.9239	Not Independently Significant
Rural	-0.208	0.101	-0.409 to -0.008	0.0414	Lower CRI than Urban Reference
Residence duration (ordinal)	0.105	0.045	0.015 to 0.196	0.0229	Higher CRI with Longer Residence

Table 8
Strongest and weakest indicators within each CRI Component

Component	Highest Item	Mean	Lowest Item	Mean
Economic	Non-Farm Income Opportunities	4.59	Credit/ Financial Support	1.33
Social	Trust among Community Members	2.52	Support during hardship	1.87
Environmental condition	Land Degradation (Reverse Scored)	2.42	Vegetation Loss (Reverse Scored)	1.62
Institutional	Local Institutional Effectiveness	1.51	Extension/ Technical Services	1.07
Adaptive Capacity	Ability to cope with Income Loss	2.24	Preparedness For Future Risks	1.71

(Spearman rho = -0.067, $p = 0.511$), although farther distance correlated with lower environmental-condition scores (rho = -0.376, $p < 0.001$) and higher institutional support (rho = 0.310, $p = 0.002$). These opposing component patterns explain why the overall proximity relationship was weak.

F. HC3 Multivariable Model and Sensitivity Analysis

The HC3 model was statistically significant overall (robust $F(7,92) = 3.44$, $p = 0.0026$) and explained 18.0% of CRI variance (adjusted R-squared = 0.118). After adjustment, household mining involvement remained unrelated to CRI (beta = 0.021, $p = 0.856$). Residence within 1Km was associated with a 0.183 point higher CRI (95% CI 0.035 to 0.330; $p = 0.016$), rural residence with a 0.208 point lower CRI relative to urban residence (95% CI -0.409 to -0.008; $p = 0.041$) and each higher category of residence duration with a 0.105 point higher CRI (95% CI 0.015 to 0.196; $p = 0.023$). Farmland use, sex and semi-urban residence were not independently significant. Maximum VIF was 3.47, providing no indication of severe multicollinearity.

The proximity coefficient was not robust to the measurement sensitivity test. When the perceived environmental-condition component was removed and the outcome was restricted to economic, social, institutional and Adaptive Capacity, residence within 1Km was no longer associated with resilience (beta=0.034, 95% CI -0.126 to 0.193; $p=0.677$). Mining involvement also remained non-significant (beta=-0.040, $p=0.729$). This sensitivity result is important because the environmental component itself varied strongly by proximity. The positive coefficient for near-mine residence in the full CRI

should therefore be interpreted as composite-specific and not as evidence that mining proximity improves resilience.

G. Item-Level Strengths and Deficits

Item-level results reveal why the economic component should not be read as general economic security. Access to non-farm income opportunities was the only indicator substantially above the neutral midpoint ($M=4.59$, $SD=0.64$), whereas credit access ($M=1.33$), productive assets ($M=1.65$) and income stability ($M=2.52$) remained weak. Social resources were consistently below the midpoint, with trust ($M=2.52$) and collective action ($M=2.44$) stronger than support during hardship ($M=1.87$) or local conflict resolution ($M=1.90$).

The reverse-scored environmental-condition indicators were weakest for vegetation loss ($M=1.62$) and water-quality deterioration ($M=1.68$), followed by drainage ($M=1.87$). Institutional support was uniformly poor: technical/extension services averaged 1.07, government support 1.24 and institutional responsiveness 1.31. Adaptive Capacity was also weak, especially preparedness for future mining-related risks ($M=1.71$) and institutional support during shocks ($M=1.73$). These patterns indicate that short-term earning opportunities are not matched by strong financial buffers, public support or anticipatory capacity.

H. Exploratory Settlement-Level Variation

Settlement-level means varied from 2.72 in Dura to 1.58 in Gura Suga among locations represented by at least two respondents. These values should not be interpreted as representative community estimates because most local

subsamples contained only two to four respondents. They are retained only as exploratory signals for future stratified sampling. In particular, the Dura value must not be used to infer that specific livelihood, environmental or institutional factors explain greater resilience without a substantially larger local sample.

Table 9
Selected settlement-level CRI estimates

Settlement	n	CRI	Band
Dura	2	2.72	Moderate
Bukuru	3	2.39	Low
Rayfield	3	2.26	Low
Kwang	3	2.13	Low
Zawan	4	1.85	Low
Kwata Zawan	2	1.78	Very low
Sabon Gida	2	1.69	Very low
Gut	4	1.69	Very low
Zarmaganda	2	1.60	Very low
Gura Suga	2	1.58	Very low

Figure 4 provides an exploratory spatial display of settlement-level CRI scores in relation to mapped mining features and settlements. Because most settlement means are based on only two to four respondents, the symbols represent sampled-location summaries rather than precise estimates of whole-Community Resilience. The map is descriptive and should not be read as evidence that mining proximity causes the observed CRI pattern. Underlying respondent-level coordinates are not released.

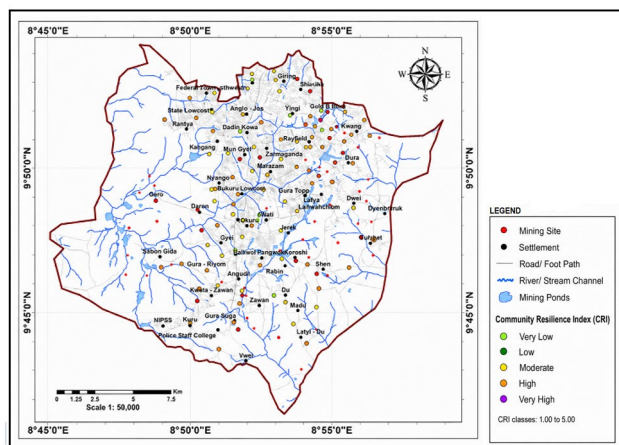


Fig. 4. Spatial pattern of Community Resilience Index scores across surveyed locations

5. Discussions

The central finding is a distinction between access to earning opportunities and durable livelihood security. Household mining involvement was much more common than mining as a stated primary occupation, yet mining involvement was not associated with the overall CRI in either the bivariate or adjusted analysis. The absence of an overall difference should not be read as evidence that mining is benign. Mining-involved households reported significantly weaker institutional support, indicating that engagement in mining may coexist with limited access to governance, technical services and public assistance.

The economic component sharpens this interpretation. Non-

farm income access was exceptionally high, yet credit and productive assets were among the weakest indicators. The reconstructed alpha for the economic component was also low, confirming that its indicators do not behave like interchangeable manifestations of one latent trait. This is substantively informative rather than merely a measurement failure: access to work, income diversity, stability, assets and finance represent different economic resources that may not rise together. Policy that evaluates ASM only through employment or cash income may therefore overstate resilience.

The most severe deficit was institutional. Every institutional indicator was below the scale midpoint, and technical services were almost absent. Institutional weakness matters because reclamation, mine-pond safety, drainage management, licensing and technical extension are collective problems that exceed household coping capacity. Contemporary formalisation research similarly argues that sustainable ASM requires rules and incentives that are linked to practical technical, financial and environmental support rather than licensing alone (Delgado Jimenez et al., 2024; Arthur-Holmes & Ofosu, 2024).

The environmental findings should be interpreted as perceived conditions rather than as an independent measure of ecological recovery or contamination. Respondents consistently reported vegetation loss, water-quality deterioration, erosion and drainage problems, and the environmental-condition items displayed very high internal consistency. Comparable community-based mining studies show that perceived land and water change is socially consequential because it can shape livelihood decisions, trust and support for continued extraction (Aggrey et al., 2021; Achina-Obeng & Aram, 2022; Bansah et al., 2024). The appropriate next step is objective environmental testing, not translation of perception scores into unverified chemical-pollution claims.

The measurement diagnostics materially improve interpretation of the CRI. Omega and factor results show that the five components do not behave as interchangeable manifestations of one latent construct. Environmental condition is exceptionally coherent, whereas economic resources are heterogeneous and span more than one empirical factor. Parallel analysis retained four factors rather than the five a priori domains, with social/local institutional embeddedness, environmental condition, material/Adaptive Capacity and formal institutional support emerging as the dominant structure. This does not invalidate the composite; rather, it reinforces the decision to treat it as a formative, theory-guided index and to report component results alongside the overall score.

The exposure results also caution against deterministic spatial interpretation. Living within 1Km was not significantly related to overall CRI in the unadjusted comparison, and ordered distance showed essentially no monotonic association with overall CRI. The adjusted full-CRI model produced a positive near-mine coefficient, but this disappeared completely when the environmental-condition component was removed. The apparent positive association is therefore sensitive to how the composite is constructed and should not be interpreted as a

protective effect of mining proximity. Rural location and shorter residence duration were more consistent markers of lower resilience in the adjusted analysis. Small settlement subsamples still preclude community-specific causal explanations.

The policy implication is not simply to encourage households to cope better. Mining governance needs to be connected to accessible finance, productive-asset formation, technical extension, environmental rehabilitation and preparedness. Abrupt restrictions can remove income without removing vulnerability, particularly where mining is embedded in agrarian livelihood portfolios (Baddianaah, 2024). A stronger intervention model would combine realistic formalisation, locally enforceable environmental rules, rehabilitation of abandoned workings, water and drainage monitoring, credit for diversified enterprises and community participation in risk management.

6. Conclusion

Surveyed households in selected mining-affected settlements of Jos South display a clear livelihood-resilience paradox. Mining-linked activity extends beyond respondents who identify mining as their primary occupation and contributes to a broader set of non-farm income opportunities. Yet the overall resilience composite remains low, with especially pronounced deficits in institutional support, finance, environmental condition and preparedness.

The strengthened respondent-level analysis changes how the CRI should be interpreted. Domain omega ranged from 0.49 for economic resources to 0.94 for environmental condition, and exploratory factor analysis retained four empirical dimensions rather than reproducing the five original domains exactly. Mining involvement was not associated with the overall CRI, although it was associated with weaker institutional support. Proximity likewise showed no simple monotonic relationship with overall resilience; the positive adjusted coefficient for residence within 1Km disappeared in the capacity-only sensitivity analysis. These findings support a multidimensional, formative interpretation in which economic, social, environmental, institutional and adaptive conditions may move in different directions within the same household context.

The policy question is therefore not whether mining is simply good or bad for livelihoods. It is whether institutions and local economic systems allow households to convert mining-linked income opportunities into durable assets, environmental security and Adaptive Capacity. Stronger local governance, technical support, accessible finance, environmental rehabilitation, safer management of abandoned workings and realistic livelihood diversification are necessary if communities are to move from reactive coping towards more durable resilience.

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