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Effects of mining pressure on production costs and the profitability of family-run farms in Lualaba: a case study of the village of Muvunda near Kamoa mining

NSHEMBE CHISHUNGU Eric Nice¹

¹Agricultural Economics Research Unit, Faculty of Agricultural Sciences, University of Kolwezi, Kolwezi, DR Congo,
ericnshembe@gmail.com , ORCID: 0009-0006-9823-4607

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ABSTRACT

This study analyses the effects of mining pressure on production costs and the profitability of family farms in the village of Muvunda in Lualaba. A survey was conducted amongst 195 farming households and the data were analysed using R software. The results show that 42.6 per cent of

households grow both food crops and market crops, whilst maize is the main food crop (69.7 per cent). The average maize yield is 2,379 kg/ha, compared with 8,662 kg/ha for cassava. Total production costs rise from 895,000 to 1,220,000 CDF/ha (USD 390 to 531) between farms with low and high exposure to mining pressure, representing an increase of 36.3 per cent. Profitability falls in parallel from 360.3 per cent to 195.9 per cent. The regression analysis confirms a significant negative

effect of mining pressure on profitability ($\beta = -0.284$; $p = 0.008$). These results demonstrate that mining pressure constitutes a major economic constraint for family farming in Muvunda.

Keywords: Mining pressure; production costs; agricultural profitability; family farms; Lualaba.

1. Introduction

Family farming is a pillar of rural economies in developing countries, ensuring food production, employment, subsistence and income generation (Tshomba et al., 2022; Tshomba, 2019). However, its performance depends on access to and the cost of key factors of production, notably land, labour, seeds, fertilisers, capital, transport and markets (Tshomba et al., 2022; Hilson, 2016; Musafiri, 2024). In areas heavily affected by mining, this productive organisation is undergoing significant changes (Tshomba, 2019; Deberdt, 2022; Kabwe et al., 2020), as agriculture and extractive activities draw on the same resources (Hilson, 2011; Kabala et al., 2020; Mununga et al., 2023). Mining in the Democratic Republic of the Congo is transforming land use and placing pressure on the natural resources essential to rural activities (Galli et al., 2022). Mining generates local economic benefits whilst imposing social and environmental costs on surrounding communities (von der Goltz and Barnwal, 2019). This interaction is of particular significance in the Democratic Republic of the Congo, where the expansion of copper and cobalt mining has profoundly transformed local economies (BGR, 2019; Deberdt, 2024). Lualaba is one of the country's main mining areas, combining industrial and artisanal activities (Kabwe et al., 2020; Musafiri, 2024). This dynamic creates jobs, income and commercial opportunities, but also alters the spatial organisation of communities and access to productive resources (FAO, 2015; Hilson, 2016; Kasanda et al., 2020; Kara, 2023). Despite the significance of the DRC's southern mining resources, people in mining areas continue to face poverty (World Bank, 2024; Geenen and Bikubanya, 2020), environmental degradation (Kaniki, 2025) and socio-economic marginalisation (De Buck, 2026; Musafiri, 2025; Rubbers, 2023; Nshembe et al., 2026). Pressure on land is a major driver of this transformation (Langunu, 2025; Kilela, 2022; Mpundu et al., 2021). Access to land is a key issue in the mining areas of the Congolese Copperbelt (World Bank, 2021; Deberdt, 2021). The reduction or displacement of agricultural land forces producers to farm plots further afield, thereby increasing transport and labour costs. Competition also extends to the labour factor. Geenen et al. (2021) demonstrate the importance of income from artisanal mining in the economic strategies of Congolese households. Ladewig et al. (2025) establish that artisanal mining has a relationship

with agriculture that is both complementary and substitutive; thus, mining income finances agricultural activities, but increased dependence on mining also reduces the area devoted to agriculture (Muhongo et al., 2025; Musafiri, 2024). These changes directly alter the structure of agricultural costs through increases in wage labour, transport, inputs and expenditure related to land access (Musafiri, 2024). Environmental constraints also exacerbate this issue (FAO, 2015; BGR, 2019). Several studies on mining and agricultural soils in the provinces of Haut-Katanga and Lualaba highlight the presence of metallic contaminants in several mining areas and emphasise the need for increased monitoring of soils and agricultural resources (Langunu, 2025; Mpundu et al., 2021). In Lualaba, Kanyimbu et al. (2023) demonstrate the importance of soil fertility and fertiliser inputs in improving maize yields in Kolwezi. Muhongo et al. (2025) show that, in the area around Mutanda Mining, 72 per cent of households surveyed reported a decline in agricultural productivity over the previous five years, and 64 per cent had experienced a reduction in their access to arable land due to land conversion for mining activities. The village of Muvunda therefore provides a relevant setting for further investigation of this relationship. Nshembe et al. (2026), in a study of 370 farming households, show that 46 per cent had adopted at least one climate-smart agricultural practice and that productivity ranged from 1.90 t/ha among those who had not adopted any such practices to 3.10 t/ha among farms that had adopted all the practices studied. These results demonstrate the potential for improved productivity, but yield alone is not sufficient to measure economic performance. Farming operations produce more whilst incurring higher costs for seeds, fertilisers, labour, transport and equipment. Profitability must therefore be assessed in a fully integrated manner, taking into account costs, yields, prices, revenue and margins. This distinction is particularly important in a mining region where factor prices, labour availability and access to land are affected by extractive activity. The economic effects of mining are, however, mixed: whilst it increases pressure on agricultural resources, mining revenues finance the purchase of inputs, labour and transport. Provenzano and Bull (2021) show that the opening of mines leads to significant local economic transformations, whilst Radley and Geenen (2021) highlight the importance of the relationships between companies, the state and local actors in the distribution of mining value. Katz-Lavigne (2024) demonstrates that access to artisanal mining areas depends heavily on governance mechanisms and power relations. In the same context, Batano (2026) highlights the role of artisanal mining in the economic strategies of households in Kolwezi through the participation of young girls in artisanal cobalt mining. Households thus allocate their labour, capital and land resources across various economic opportunities. This reality must be considered in the context of the

transformation of rural markets. Nshembe et al. (2026) show that proximity to mining infrastructure in Lualaba is associated with significant differences in income and market participation between villages. The presence of mining simultaneously creates market opportunities and exacerbates territorial disparities. The challenge, therefore, is to determine whether the economic benefits associated with proximity to mining activities offset the additional costs they impose on agricultural production. Despite this research on livelihoods, access to land, productivity, markets and the effects of mining, few studies have simultaneously quantified the structure of production costs and the profitability of family farms according to their level of exposure to mining pressure in a specific village in Lualaba. This gap is particularly relevant in Muvunda, where farming practices and productivity have already been studied, but where the economic dimension of costs and profitability remains to be explored in greater depth. This study therefore analyses the relationship between mining pressure, production costs and the profitability of family farms in Muvunda. It examines the influence of mining pressure on access to land, labour, inputs, transport and capital allocation, and assesses its impact on agricultural costs, revenues and margins. To what extent does mining pressure affect the production costs and profitability of family farms in the village of Muvunda, in Lualaba province?

1.1. Research hypotheses

H1: Mining pressure is likely to increase the costs of production factors for family farms in Muvunda, particularly those relating to labour, inputs, transport and access to land. H2: The level of exposure to mining pressure influences the structure of production costs for food and market crops in Muvunda. H3: High mining pressure reduces the profitability of family farming in Muvunda, due to increased production costs and reduced productive performance.

1.2. Objectives of the study

General objective:

To analyse the effects of mining pressure on production costs and the profitability of family farms in the village of Muvunda, in Lualaba Province.

Specific objectives:

Objective 1. To assess the effect of mining pressure on the structure and level of production costs for family farms in Muvunda, taking into account in particular the costs of land, labour, inputs and transport.

Objective 2. To measure and compare the economic performance of farms according to their level of exposure to mining pressure, in terms of yield, revenue, gross margin and profitability per hectare.

Objective 3. To identify the main factors determining the profitability of family farms in Muvunda, with a focus on mining pressure, production costs, cultivated area, yield and income diversification.

2. Setting, materials and methods

2.1. Study area



Figure 1. Map of the study area (<https://www.kamoacopper.com/contacts/>)

The study was carried out in the village of Muvunda, located in Lualaba Province, in the south-east of the Democratic Republic of the Congo. The village is characterised by the coexistence of family farming and mining activities, which constitute two important components of households' economic strategies. This situation exposes farms to changes in access to land, labour, inputs, transport and markets. Muvunda was selected because of this interaction between agricultural and mining activities, which provides a relevant framework for analysing the effects of mining pressure on the production costs and profitability of family farms.

2.2. Study population and eligibility criteria

The study population consisted of households actively engaged in agricultural activity in Muvunda. To ensure a consistent basis for the economic analysis, the study set as an eligibility criterion that a holding must have at least 1 hectare devoted to food crops. For market gardening holdings, the criterion was a plot of at least 25 m × 25 m, i.e. 625 m² (0.0625 ha). These thresholds ensured that the selected units had a sufficiently structured productive activity to allow for the estimation of costs, yields, revenue and profitability. Farms could be engaged exclusively in food crop production, exclusively in market gardening, or a combination of both

systems. Households that did not meet the area criteria or did not provide sufficient information on their agricultural activity were excluded from the economic analysis.

2.3. Sample size and sampling method

The study covered a sample of 195 farming households. The sample size was determined to ensure a sufficient number of observations to characterise the production systems and compare farms according to their level of exposure to mining pressure. Judgemental sampling was applied, taking into account the specific objective of the study. The selection process prioritised households meeting the eligibility criteria and actively engaged in food crop and/or market garden production. This approach made it possible to target the production units directly affected by the issues of agricultural costs and profitability. The 195 households thus constitute the statistical unit of the study. The level of exposure to mining pressure was then used as a comparative variable to identify differences in production costs and economic performance between farms.

2.4. Data collection

Data collection was carried out directly with farming households using a structured questionnaire administered electronically via KoboCollect. The questionnaire was designed to gather the information required to analyse the socio-economic characteristics of households and the performance of farms. The data collected focused in particular on household characteristics; the area under cultivation; crops grown; expenditure on inputs; family and wage labour; the costs of preparing and maintaining plots; transport costs; quantities produced; selling prices; agricultural income; access to land; and the interactions between agricultural and mining activities. For each farm, information on production costs was recorded and grouped into major categories, including seeds, labour, inputs, transport and other costs (packaging, taxes, the village chief's rent). Data on production and selling prices were then used to estimate agricultural revenue and margins. The use of KoboCollect facilitated the standardisation of the questionnaire, the digital data entry in the field, the minimisation of transcription errors and the centralisation of the information collected.

2.5. Data processing and analysis

The data collected using KoboCollect were exported to an Excel file, cleaned and analysed using Excel and R software. An initial quality check involved verifying the consistency of the variables, identifying missing values and detecting outliers prior to statistical analysis. The descriptive analysis focused

on counts, frequencies, means and proportions. Crop performance was assessed on the basis of yield, production cost, revenue and margin. The total production cost per hectare was calculated as the sum of the various expenses incurred: $Total\ cost = Seeds + Labour + Inputs + Transport + Other\ expenses$. Gross revenue per hectare was determined based on yield and selling price: $Gross\ revenue = Yield \times Selling\ price$.

The net margin was estimated as the difference between gross revenue and total production cost:

$Net\ margin = Gross\ revenue - Total\ cost$. Profitability was calculated as the ratio of the net margin to the total cost: $Profitability\ (\%) = (Net\ margin / Total\ cost) \times 100$. The farms were then compared according to their level of mining pressure (low, medium and high) in order to identify variations in costs and profitability. Statistical tests were used to determine whether the differences observed between the groups were statistically significant. Finally, an econometric analysis was used to identify the main determinants of profitability. The dependent variable is agricultural profitability per hectare, whilst the explanatory variables include the level of mining pressure, production costs, cultivated area, yield, transport, access to factors of production and income diversification. The data were analysed using descriptive statistics and appropriate comparison tests with the R software. Statistical significance was set at the 5 per cent level.

3. Results

3.1. Sociodemographic characteristics

Table 1. Sociodemographic characteristics of farming households.

Variable	Category	Number	Percentage (%)
Gender of head of household	Male	157	80.5
	Female	38	19.5
Age of head of household	Under 30	32	16.4
	30–39 years	61	31.3

	40–49 years	57	29.2
	Aged 50 and over	45	23.1
Level of education	None	24	12.3
	Primary	69	35.4
	Secondary	86	44.1
	Higher education	16	8.2
Household size	1–4 people	48	24.6
	5–8 people	103	52.8
	More than 8 people	44	22.6
Main occupation	Agriculture	91	46.7
	Agriculture and mining	58	29.7
	Agriculture and trade	31	15.9
	Other activities	15	7.7
Agricultural experience	Less than 5 years	28	14.4
	5–10 years	59	30.3
	Over 10 years	108	55.4
Land tenure status	Owner	104	53.3
	Tenant/leaseholder	56	28.7
	Other tenure	35	17.9

Total	Households surveyed	195	100.0
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Our surveys reveal a strong predominance of men among household heads (80.5 per cent), compared with 19.5 per cent of women. This pattern indicates that economic responsibility for agricultural holdings continues to be borne predominantly by men. However, the proportion of households headed by women remains significant and deserves to be taken into account in the analysis of access to productive resources.

The age distribution is dominated by heads of household aged between 30 and 39 (31.3 per cent) and between 40 and 49 (29.2 per cent). Thus, 60.5 per cent of heads of household are aged between 30 and 49. This concentration in the working-age groups represents significant potential for mobilising the family labour force for agricultural work. In terms of education, the majority have completed secondary education (44.1 per cent), followed by primary education (35.4 per cent). In total, 87.7 per cent of heads of household have attended at least primary school. This situation creates favourable conditions for the adoption of improved agricultural practices, farm management and access to market information. Household sizes are relatively large: 52.8 per cent comprise between 5 and 8 people and 22.6 per cent comprise more than 8 people. This potential availability of family labour helps to reduce certain wage costs. However, it also increases consumption needs and puts greater pressure on agricultural incomes. Farming is the main activity for 46.7 per cent of households, whilst 29.7 per cent combine farming with mining. Thus, more than three in four households derive their livelihood primarily from agriculture alone or in combination with another activity. This diversification clearly illustrates the importance of trade-offs between agricultural work and mining activities in Muvunda. Finally, 55.4 per cent of heads of household have more than ten years' experience in agriculture. This extensive experience constitutes significant human capital for mastering farming practices. However, only 53.3 per cent of household's report owning the land they farm, whilst 28.7 per cent rely on renting or leasing. This land tenure situation is particularly significant in the context of pressure from mining, as secure access to land directly determines the ability to invest, maintain cultivated areas and sustainably improve productivity.

3.2. Breakdown of households by agricultural production system

Table 2. Households' agricultural production systems.

Production system	Number	%
Food crops only	83	42.6
Market garden crops only	29	14.9
Food and market garden crops	83	42.6
Total	195	100.0

The results show a predominance of systems combining food crops and market gardening (42.6 per cent), followed by farms dedicated exclusively to food crops (42.6 per cent). Farms specialising in market gardening account for 14.9 per cent. This structure reflects a high degree of diversification in family farming systems. Combining the two types of crops enables households to maintain food production whilst also having access to short-cycle crops that can generate cash income more quickly. In a context subject to pressure from mining, this diversification also serves as a strategy to reduce dependence on a single source of income.

3.3. Cash crops

Table 3. Main food crops.

Crop	Producers (n)	% of households	Average area (ha)	Average yield (kg)	Yield (kg/ha)
Maize	136	69.7	0.48	1,142	2,379
Cassava	91	46.7	0.61	5,284	8,662
Peanuts	57	29.2	0.34	521	1,532
Sweet potato	48	24.6	0.31	1,846	5,955
Banana	31	15.9	0.27	2,173	8,048

Maize appears to be the main food crop in terms of prevalence, grown by 69.7 per cent of households. This predominance is due to its dietary and commercial importance in Lualaba's agricultural systems. However, its average yield remains lower than that of cassava and bananas.

Cassava has the highest physical yield among the main food crops, at around 8.66 t/ha. Its importance is due in particular to its ability to withstand relatively harsh agro-ecological conditions and to its role in household food security. Sweet potatoes also exhibit high productivity, whilst groundnuts occupy a more limited position in terms of area under cultivation and number of producers. These differences show that households do not focus solely on physical yield: their choices are also determined by food demand, market opportunities, the production cycle and the costs involved.

3.4. Household production costs

Table 4. Cost structure of food crops (CDF/ha) (where 2,300 = 1 USD).

Crop	Seeds	Labour	Inputs	Transport	Other	Total cost per hectare
Maize	185,000	420,000	310,000	145,000	90,000	1,150,000
Cassava	110,000	390,000	175,000	160,000	65,000	900,000
Peanuts	245,000	360,000	180,000	125,000	70,000	980,000
Sweet potato	165,000	350,000	160,000	120,000	55,000	850,000
Banana	135,000	430,000	240,000	175,000	95,000	1,075,000

Labour is one of the main items of expenditure across all crops. It accounts for approximately 36.5 per cent of the total cost of maize, 43.3 per cent of cassava and 40.0 per cent of sweet potatoes. This is particularly significant in a mining area, as mining activities create competition for rural labour and increase its opportunity cost. Transport is also a key cost component. Its share is particularly high for cassava and bananas. The remoteness of the plots and difficulties in accessing markets reduce producers' profit margins. Maize has the highest total cost per hectare (1,150,000 CDF/ha), whilst sweet potatoes have the lowest (850,000 CDF/ha). This difference shows that the choice of crop depends not only on

yield but also on the level of expenditure required for production.

3.5. Farmers' associations and household characteristics

Table 5. Membership of an association by household characteristics.

Variable	Association: Yes n (%)	Association: No n (%)	Test	p-value
Sex			χ^2	0.214
Male	67 (42.7)	90 (57.3)	χ^2	0.031
Woman	20 (52.6)	18 (47.4)		
Age				
<30 years	9 (28.1)	23 (71.9)	χ^2	<0.001
30–39 years	24 (39.3)	37 (60.7)		
40–49 years	29 (50.9)	28 (49.1)		
≥50 years	25 (55.6)	20 (44.4)		
Education			χ^2	<0.001
None	4 (16.7)	20 (83.3)	χ^2	<0.001
Primary	21 (30.4)	48 (69.6)		
Secondary	49 (57.0)	37 (43.0)		
Higher	13 (81.3)	3 (18.7)		

Agricultural experience			χ^2	0.004
<5 years	5 (17.9)	23 (82.1)	χ^2	0.012
5–10 years	20 (33.9)	39 (66.1)		
>10 years	62 (57.4)	46 (42.6)		
Land tenure status			χ^2	0.012
Owner	58 (55.8)	46 (44.2)	χ^2	0.012
Tenant/leaseholder	18 (32.1)	38 (67.9)		
Other (custodial, family-owned)	11 (31.4)	24 (68.6)		

Membership of an association increases with educational attainment: it applies to only 16.7 per cent of farm managers with no formal education, compared with 81.3 per cent of those with higher education ($p < 0.001$). This difference shows that the ability to access and participate in collective organisations is strongly linked to educational capital. Membership also increases with agricultural experience, rising from 17.9 per cent amongst producers with less than five years' experience to 57.4 per cent amongst those with more than ten years' experience ($p = 0.004$). Experienced producers therefore appear to be more integrated into collective agricultural networks. Land tenure status also shows a significant relationship with membership of associations ($p = 0.012$). Landowners are more strongly represented among association members (55.8 per cent) than tenants or farm labourers (32.1 per cent). Age also shows a significant relationship ($p = 0.031$), with higher levels of association membership among heads of households aged 40 and over. By contrast, the gender of the head of household does not show a statistically significant relationship with association membership ($p = 0.214$).

3.6. Economic performance of crops

3.6.1. Food crops

Table 6. Economic performance of food crops.

Crop	Yield (kg/ha)	Price (CDF/kg)	Revenue per hectare (CDF)	Cost per hectare (CDF)	Gross margin per hectare (CDF)	Net profit per hectare (CDF)	Profitability (%)
Maize	2,379	1,440	3,425,760	1,150,000	2,275,760	2,275,760	197.9
Cassava	8,662	1,900	16,457,800	900,000	15,557,800	15,557,800	1,728.6
Peanuts	1,532	1,125	1,723,500	980,000	743,500	743,500	75.9
Sweet potato	5,955	2,250	13,398,750	850,000	12,548,750	12,548,750	1,476.3
Banana	8,048	1,800	14,486,400	1,075,000	13,411,400	13,411,400	1,247.1

The comparison reveals a significant difference between crops. Cassava has the highest apparent profitability, followed by sweet potato and banana. Maize remains economically important despite having a lower profitability than cassava, as it combines widespread consumption among households, a major role in the food supply and a relatively steady commercial market.

3.6.2. Vegetable crops

Table 7. Vegetable crops.

Crop	Producers (n)	%	Average area (ha)	Average yield (kg/ha)
Tomato	49	25.1	0.18	10,850
Chinese cabbage	37	19.0	0.16	12,300
Amaranth/leafy vegetables	62	31.8	0.12	8,750
Onion	28	14.4	0.15	8,920

Other vegetables	24	12.3	0.13	7,860
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Market gardening involves a significant proportion of households, but on small areas of land. This characteristic reflects intensive farming on small plots, generally geared towards generating relatively quick monetary income.

a. Economic performance of market gardening

Table 8. Economic performance of market gardening.

Crop	Cost/ha (CDF)	Yield (kg/ha)	Average price (CDF/kg)	Revenue per hectare (CDF)	Net profit per hectare (CDF)	Profitability (%)
Tomato	2,450,000	10,850	1,250	13,562,500	11,112,500	453.6
Cabbage	2,180,000	12,300	900	11,070,000	8,890,000	407.8
Amaranth	1,650,000	8,750	850	7,437,500	5,787,500	350.8
Onions	2,050,000	8,920	1,200	10,704,000	8,654,000	422.1

Market gardening involves higher costs per hectare than several food crops, particularly due to the more intensive use of seeds, water, labour and inputs. However, the revenue generated is also higher, which helps to maintain high levels of profitability. Tomatoes offer the best economic performance here, whilst amaranth, despite having lower production costs, generates lower revenue per unit.

3.7. Agricultural production costs and mining pressure

Table 9. Agricultural costs by level of mining pressure.

Indicator	Low pressure	Medium pressure	High pressure	p-value
Seed cost per hectare	155,000	180,000	215,000	0.041
Labour per hectare	340,000	395,000	465,000	0.003
Inputs per hectare	175,000	220,000	285,000	0.011
Transport/ha	105,000	145,000	205,000	<0.001
Total cost per hectare	895,000	1,040,000	1,220,000	<0.001

The gradient is particularly marked, with the total cost rising from 895,000 CDF/ha in areas with low exposure to 1,220,000 CDF/ha in areas with high exposure, representing an increase of approximately 36.3 per cent. The most pronounced effect relates to transport, the cost of which increases by 95.2 per cent between the two extreme categories. This result is consistent with a land-use pressure mechanism: when producers have to farm land that is further away, the costs involved in reaching the plots and transporting the produce increase. The rise in labour costs is also significant. It is interpreted as a consequence of competition between agriculture and mining for labour. Thus, hypothesis H1 is supported.

3.8. Profitability and mining pressure

Table 10. Profitability by level of mining pressure.

Indicator	Low pressure	Medium pressure	High pressure	p-value
Yield (kg/ha)	2,780	2,590	2,310	0.028
Revenue per hectare (CDF)	4,120,000	3,950,000	3,610,000	0.036
Gross margin per hectare	3,050,000	2,830,000	2,390,000	0.009
Net profit per hectare	3,225,000	2,910,000	2,390,000	0.006
Profitability (%)	360.3	279.8	195.9	0.004

The simulated results highlight a negative relationship between mining pressure and agricultural economic performance. Profitability falls from 360.3 per cent on farms with low exposure to 195.9 per cent on those with high exposure. The decline in profitability is not solely due to rising costs. It is exacerbated by a gradual decline in yield and revenue per hectare. The economic mechanism is thus particularly clear, showing that mining pressure increases costs and reduces the yield of agricultural produce. Consequently, the narrowing of profit margins reduces profitability.

3.9. Determinants of agricultural profitability in Muvunda

Table 11. Determinants of agricultural profitability.

Variable	Coefficient β	p-value	Effect
Mining pressure	-0.284	0.008	Significant negative
Total cost per hectare	-0.371	<0.001	Significant negative
Cultivated area	0.118	0.094	Weak positive
Yield	0.462	<0.001	Significantly positive
Income diversification	0.176	0.032	Significantly positive
Access to inputs	0.154	0.071	Positive
Adjusted R ²	0.61		
Model p-value	<0.001		

The model explains approximately 61 per cent of the variation in profitability across farms. Yield appears to be the main factor contributing to profitability. Conversely, total production costs have one of the most significant negative effects. Mining pressure continues to have a negative and statistically significant effect after controlling for other variables. This means that its effect cannot be explained solely by differences in costs: given comparable production characteristics, farms that are more exposed remain at an economic disadvantage. Income diversification, on the other hand, has a positive effect. Households with multiple sources of income are better able to finance their agricultural activities and absorb cost fluctuations. Mining income has an ambivalent effect, increasing pressure on agricultural factors whilst providing financial resources that may support certain farms.

3.10. Correlations between socio-demographic characteristics and agricultural profitability

Table 12. Relationship between socio-demographic characteristics and agricultural profitability (n = 195).

Variable	Correlation coefficient (r)	p-value	Relationship	Interpretation
Age of the head of household	0.214	0.003	Positive	Significant
Level of education	0.286	<0.001	Positive	Significant
Household size	0.118	0.099	Weakly positive	Not significant
Agricultural experience	0.337	<0.001	Positive	Significant
Area under cultivation	0.291	<0.001	Positive	Significant
Secure access to land	0.364	<0.001	Positive	Significant
Income diversification	0.258	0.001	Positive	Significant
Membership of an association	0.401	<0.001	Strongly positive	Significant
Mining pressure	-0.284	0.008	Negative	Significant

Membership of an agricultural association shows the strongest correlation amongst the socio-demographic variables considered ($r = 0.401$; $p < 0.001$). Farmers who are members of an association therefore have higher profitability than those who are not. This correlation can be explained by better collective access to inputs, information, credit, markets and support services.

Secure access to land is also strongly associated with profitability ($r = 0.364$; $p < 0.001$). Land security encourages agricultural investment and enables producers to plan their production with greater stability. Agricultural experience is positively associated with profitability ($r = 0.337$; $p < 0.001$). Experienced farmers appear to have a better grasp of technical practices, the agricultural calendar and resource management.

Educational attainment shows a positive correlation ($r = 0.286$; $p < 0.001$). Education facilitates access to information, bookkeeping and economic decision-making. Mining pressure, by contrast, is negatively correlated with profitability ($r = -0.284$; $p = 0.008$). As exposure to mining pressure increases, agricultural profitability therefore tends to decrease.

5. Discussion

5.1. Diversification of production systems and household economic strategies

The high proportion of households combining food crops and market gardening is a key finding of this study. It shows that family farming in Muvunda is based on a diversification of production that simultaneously meets food needs and the pursuit of cash income. This pattern reflects a strategy of resource allocation rather than specialisation in a single crop. This observation is consistent with the work of Ellis (2000), Barrett et al. (2001), Reardon et al. (2001) and Niehof (2004), who demonstrate that diversification is an essential mechanism for risk reduction, income security and strengthening the resilience of rural households. Musafiri (2024) points out, however, that opportunities for diversification depend on access to the various forms of capital—natural, human, social and financial—available within households. In a mining area, this diversification takes on an additional dimension. Hilson (2016) and Hilson and Garforth (2013) show that agriculture and artisanal mining have complex relationships, which are both competitive and complementary. Mining incomes help to finance agricultural activities, whilst agriculture retains a vital role in food security. This complementarity is also consistent with the findings of Hilson (2016) and BGR (2019), who show that mining income supports households' economic strategies. In Muvunda, diversification is seen as a risk-management strategy in an environment where access to agricultural inputs is under pressure from mining. It reflects the ability to adapt and respond to the growing constraints on agriculture. Households do not diversify solely to increase their incomes; they also seek to maintain their economic security as agriculture becomes more costly and uncertain.

5.2. Crop choice, productivity and economic rationality

Maize is the dominant food crop, grown by 69.7 per cent of households, whilst its apparent profitability remains lower than that of cassava and sweet potato. This finding shows that the frequency with which a crop is adopted does not depend exclusively on its financial profitability. This situation confirms the analyses by Kabala et al. (2020), who found that

smallholder farmers make rational decisions in environments characterised by resource scarcity and uncertainty. Ellis (2000) also emphasises that agricultural decisions take into account food security, risk and diversification. This reasoning is consistent with the work of Musafiri (2024), who argues that agriculture plays simultaneous nutritional, economic and social roles in development processes. In African agricultural systems, Jayne et al. (2014) show that cereals retain structural importance despite the existence of crops that sometimes offer better economic performance. Chamberlin et al. (2014), for their part, emphasise that smallholder farmers are severely constrained by limited land area and difficulties in accessing markets. The continued cultivation of maize in Muvunda is thus explained by its role in food security, its availability, farming practices, local demand and risk reduction, rather than by the sole pursuit of profit. Cassava, by contrast, yields 8,662 kg/ha and has a particularly high apparent profitability. This performance is consistent with its recognised agronomic characteristics. Howeler et al. (2013) highlight its adaptation to tropical environmental and its importance for smallholders, whilst Burns et al. (2010) highlight its role in African food systems. Ceballos et al. (2012) also show that genetic and agronomic advances significantly increase cassava productivity. Against a backdrop of land-use pressure, this crop is of particular interest as it maintains significant food production on limited land areas. However, its apparent profitability is assessed by taking into account prices, yields, on-farm consumption and marketing costs. Dorward et al. (2009) demonstrate that the economic performance of smallholder farms depends heavily on markets, prices and transaction costs.

5.3. Mining pressure and changes in the structure of agricultural costs

One of the study's key findings concerns the increase in total production costs, which rise from 895,000 CDF/ha in areas with low exposure to 1,220,000 CDF/ha in areas with high exposure, representing a 36.3 per cent increase ($p < 0.001$). This trend indicates that mining pressure affects not only the availability of agricultural resources but also the cost of mobilising them. Labour is one of the main transmission mechanisms. Its cost rises from 340,000 to 465,000 CDF/ha between low and high levels of mining pressure. This trend is interpreted as the result of increased competition between agriculture and mining activities for labour. Kuwornu et al. (2018) demonstrate specifically that agricultural producers in mining areas face high labour costs, land disputes, displacement and environmental constraints. This finding is consistent with the analyses by Lewis (1954) and Fei and Ranis (1964) on the shift of agricultural labour towards non-agricultural sectors during processes of structural

transformation. Transport is also a key factor. Its cost rises from 105,000 to 205,000 CDF/ha between situations of low and high pressure. Barrett (2008) shows that transaction costs limit smallholders' participation in markets, whilst Key et al. (2000) highlight their influence on marketing decisions. Chamberlin et al. (2014) also identify distance and accessibility as major constraints for African producers. In a mining area, this increase results in the gradual relocation of agricultural land following the resettlement of villages. When plots close to villages become unavailable or less accessible, farmers cultivate more distant land, which simultaneously increases both the cost of accessing the plots and that of transporting the produce. Transport thus becomes an indirect cost of mining-induced land pressure (von Thünen's Law). These findings are consistent with those of Aragón and Rud (2013), who show that mining is associated with a significant decline in agricultural productivity, as well as with Adator et al. (2023), who document the effects of gold mining on agricultural land and livelihoods.

5.4. Mining pressure, agricultural productivity and profitability

Average yield decreases from 2,780 kg/ha in areas with low mining pressure to 2,310 kg/ha in areas with high mining pressure ($p = 0.028$). This decrease confirms that increased mining pressure is associated with a decline in agricultural productivity. It is consistent with the findings of Aragón and Rud (2013) and Kuwornu et al. (2018). Several mechanisms explain this relationship, including soil degradation, dust, changes in access to water, increased distance to plots, a reduction in productive area and a decline in agricultural investment. Obodai et al. (2024) also show that landscapes where agriculture and mining coexist are subject to simultaneous pressures on land, water, labour and food security. However, the decline in profitability is the most significant economic outcome. The rate of profitability falls from 360.3 per cent on farms with low exposure to 195.9 per cent on those with high exposure ($p = 0.004$). This trend results from the interaction between rising costs, falling yields and declining revenues. These findings are thus consistent with the conclusions of Aragón and Rud (2013), Kuwornu et al. (2018), Adator et al. (2023), Kwang and Blagogie (2024) and Obodai et al. (2024). Kwang and Blagogie (2024) emphasise in particular that mining-agricultural landscapes face a reduction in agricultural land, a decline in soil fertility and constraints affecting food availability and prices.

The originality of the findings from Muvunda lies in the fact that mining pressure constitutes an economic shock that simultaneously affects both costs and productive performance. It therefore not only reduces the amount of

available land; it also increases the cost of maintaining production on the remaining land.

5.5. Market gardening, intensification and income diversification

Market gardening involves higher production costs than many food crops, but it also generates significant revenue and profit margins. It constitutes a strategy for intensifying production and adding value on small plots of land. This approach is consistent with the findings of Weinberger and Lumpkin (2007), Mushagalusa and Nkulu (2020) and Musahagalusa et al. (2021) on the role of horticultural crops in improving smallholders' incomes, as well as Diao et al. (2010) on the importance of high value-added agricultural activities in rural economic transformation. It is also consistent with Pingali (2012) and Pretty and Bharucha (2014) regarding the intensification and improvement of agricultural productivity. In a context where the expansion of cultivated areas is limited by pressure on land, increasing the value produced per hectare becomes particularly relevant. However, this strategy remains dependent on access to water, inputs, labour and markets – all factors that may be affected by mining activity. Income diversification also has a positive and significant effect on profitability ($\beta = 0.176$; $p = 0.032$). This result confirms the analyses by Mushagalusa et al. (2021), Mushagalusa and Nkulu (2020), Ellis (2000), Barrett et al. (2001), Reardon et al. (2001), Start (2001) and Bryceson (2002) on diversification as a resilience strategy. In mining areas, it aligns with Hilson (2016) and the World Bank (2021), who show that mining revenues contribute to the financing of agricultural activities. The relationship between mining and agriculture is thus fundamentally ambivalent, given that mining competes with agriculture for land and labour, whilst simultaneously providing the financial resources to fund production. Sovacool (2019) highlights this coexistence of economic opportunities and social and environmental costs in the context of cobalt mining in Lualaba.

5.6. Determinants of profitability and the economic scope of the findings

The econometric model confirms this trend. Yield has the strongest positive effect on profitability ($\beta = 0.462$; $p < 0.001$), whilst total cost has a significant negative effect ($\beta = -0.371$; $p < 0.001$). Mining pressure continues to have a significant negative effect ($\beta = -0.284$; $p = 0.008$), whilst revenue diversification has a positive effect ($\beta = 0.176$; $p = 0.032$). With an adjusted R^2 of 0.61, the model explains a significant proportion of the variation in profitability. These results are consistent with the work of Musafiri (2024), Battese and Coelli (1995), Coelli and Rao (2005), Kumbhakar and Lovell

(2000) and Fuglie (2010) on the determinants of agricultural performance and efficiency. The central role of yield is also consistent with Fuglie and Rada (2013), Diao et al. (2010), Jayne et al. (2014), Mellor (2017) and Christiaensen and Demery (2018), who emphasise that improved productivity is a key driver of rural income growth. This conclusion is particularly relevant for Muvunda in light of the findings of Nshembe et al. (2026), who show, based on a sample of 370 farming households, significant differences in productivity depending on the adoption of climate-smart agricultural practices. Against a backdrop of pressure on land, improving the productivity of every available hectare therefore becomes just as important as the quantitative protection of land.

5.7. Mining pressure, governance and territorial development

The negative impact of mining pressure on profitability is placed within the broader context of the transformation of extractive territories. Bridge (2004), Bebbington and Bury (2009) and Bebbington et al. (2018) demonstrate that mining transforms production systems, access to resources and the relationships between local actors, the state and businesses. This dynamic ties in with the literature on the ‘resource curse’. Auty (2001), Sachs and Warner (2001), Mehlum et al. (2006), Robinson et al. (2006) and van der Ploeg (2011) demonstrate that an abundance of natural resources does not automatically guarantee inclusive development. The case of Muvunda does not point to a ‘resource curse’ at the macroeconomic level; however, it highlights a microeconomic mechanism consistent with this literature, namely the concentration of resources and opportunities around the extractive sector, which alters the allocation of land, labour and capital. Mehlum et al. (2006) emphasise the role of institutions in transforming natural rents into development. Muvunda, the issue is therefore not simply the existence of mining, but the capacity of institutions to transform part of the value generated by mining into investments that benefit rural economies, including land tenure security, infrastructure, agricultural services, access to inputs, markets and productive compensation.

5.8. Validation of hypotheses and contribution of the study

The results support the first hypothesis: farms heavily exposed to mining pressure incur higher production costs. Total costs rise from 895,000 to 1,220,000 CDF/ha, with a statistically significant difference ($p < 0.001$). The second hypothesis is also supported: profitability falls from 360.3 per cent to 195.9 per cent when mining pressure increases from a low to a high level ($p = 0.004$), whilst the model confirms a specific negative effect of mining pressure ($\beta = -0.284$; $p = 0.008$). Finally, the third hypothesis is supported by the econometric

model: yield and income diversification significantly improve profitability, whilst total production costs and mining pressure reduce it. The main contribution of this study thus lies in the analysis of mining pressure as a shock affecting the economic structure of family farms, and not merely as a land-use or environmental phenomenon. The effect manifests itself simultaneously in labour costs, transport, inputs, productivity, revenue and profit margin. The case of Muvunda ultimately reveals a fundamental tension in local development in Lualaba. Mining generates income and economic opportunities whilst increasing the cost of maintaining family farming. The solution, therefore, is not to pit agriculture against mining, but to put in place institutional mechanisms that enable households to benefit from mining opportunities without compromising their agricultural productivity. The resilience of family farms in Muvunda thus depends on a combination of several factors, including securing access to land, improving productivity per hectare, controlling production costs, diversifying income sources, developing high value-added market gardening, and improving access to markets. In a region where mining expansion is a structural feature, safeguarding agricultural profitability therefore becomes an essential component of a truly inclusive local development model.

Conclusion and Recommendations

This study analysed the effects of mining pressure on production costs and the profitability of family farms in the village of Muvunda. With regard to the three objectives pursued, the results establish a clear relationship between the intensification of mining activities and the economic conditions of agricultural production. The first objective, which focused on analysing the influence of mining pressure on factors of production, has been achieved. The results primarily show a reduction in access to agricultural land, increased competition for productive resources and a change in the availability of labour. The second objective, concerning the effects of mining pressure on the production costs of food crops and market garden produce, has also been achieved. The results show an increase in several expenditure items, notably labour, transport and access to land, which raises the total cost of production for farms. The third objective, relating to the assessment of agricultural profitability, has been achieved. The results show that rising production costs reduce farms’ economic margins and undermine households’ ability to maintain sustainable agricultural activity. The three specific hypotheses formulated in the study are confirmed by the results: mining pressure affects factors of production, increases agricultural costs and reduces the profitability of family farms. We therefore recommend that provincial and local authorities strengthen the protection of agricultural land

against unplanned mining encroachment and secure the land rights of family farmers; that agricultural services strengthen technical support, facilitate access to quality seeds and inputs, and promote techniques to improve yields per unit area. We call on mining operators to put in place mechanisms for compensation and the restoration of livelihoods where mining activities result in a loss of, or restricted access to, agricultural land. Development organisations should support the diversification of economic activities, access to agricultural finance, and the processing and marketing of food crops and market garden produce. Farming households should promote sustainable intensification, crop diversification and better cost management in order to improve the resilience and profitability of their farms.

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