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by

Giacomo Roberto Lupi

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Artisanal mining and land for agriculture in Liberia

Giacomo Roberto Lupi[1,2]

[1] University of Ferrara, Ferrara, Italy

[2] Seeds, Sustainability Environmental Economics and Dynamics Studies

Abstract

The paper explores the impact of artisanal and small-scale mining on agricultural land use in Liberia between 2013 and 2019 using a difference-in-differences methodology. The main findings indicate that households near mines tend to use more land for agriculture after the mines open. The paper also identifies a positive impact on households' wealth.

1. Introduction

In 2024, many African countries are crucial for the world's supply of minerals, and the social conditions of people living close to where these minerals are extracted remain a topic of debate in academic literature. The technological innovations of the last two decades have led to an increase in the production of critical minerals, with Sub-Saharan African countries being among the most important suppliers worldwide (IRENA Report, 2023). A rising phenomenon is the one concerning artisanal and small-scale mines (ASM), a labour-intensive method of mineral extraction that in 2022 involved around 60 million people on the African continent (Girard et al., 2022) but about which little is still known. Hilson (2016) considers it to be the most important nonfarm activity in rural Sub-Saharan Africa and demonstrates that in a poor country such as Liberia almost 600,000 people work or are directly affected by the ASM.

Using data on mining, this work investigates how much the opening of a mine in Liberia between 2013 and 2019 is associated with the percentage of agricultural land use by households residing near mining sites. In the years under in consideration, agriculture was a crucial activity in Liberia for the sustainability of people living in rural areas (Rutherford et al., 2016). To assess the impact of artisanal extraction activities expansion on the percentage of acres farmed by households, we employ a difference-in-differences approach, looking at the changes in outcome following the ASM boom in the country.

The main result indicates that during the pre-treatment period, individuals residing within 5 kilometres of the future mine site use on average 24.7% of the area at their disposal for agricultural use compared to those living between 5-25 kilometres away, who use a higher share of land (29.6%). After the opening of the site, the acres farmed by the treated group (households living within 5 kilometres of the mine) increased by an average of 33.6% relative to the control group, underscoring that mine proximity positively stimulates entrepreneurial work for these communities in the post-treatment period.

To better understand the mechanisms behind this result, we also look at how the wealth of communities adjacent to extraction areas changed after the opening of an artisanal and small-scale mining activity. To take a step forward with respect to the economic sphere, we use an index that takes into consideration health services, vaccination campaigns, education, and other essential interventions reaching the poorest. The association is positive and significant, confirming that the opening of a mine in Liberia has a positive impact on wellbeing in the surrounding area and could push people to cultivate more. Information on

Liberians' households encompass detailed information on village residence, educational achievement, and individual characteristics, which have been sourced from the Demographic and Health Surveys (DHS).

This paper aims to broaden the existing literature on the nexus between mineral resources and agriculture in countries where these activities are fundamental for the sustainability of the people. Our results in particular support the vast literature that highlights a positive ASM-agriculture interface in African countries (Maconachie, 2011; Hilson and Garforth, 2013; Pijpers, 2014; Mkodzongi and Spiegel, 2019; Hilson et al., 2019). Nevertheless, a non-negligible share of literature points out a negative interface (Ncube-Phiri et al., 2015; Boadi et al., 2016; Arthur et al., 2016; Girard et al., 2022). The fact that the literature finds both negative and positive aspects demonstrates that this subject still requires extensive study.

This paper is structured as follows. Section 2 provides the background literature on the relationship between mines and land use in Liberia; Section 3 introduces the data used and their sources, along with descriptive statistics; Section 4 describes the empirical strategy, while baseline results are presented in Section 5, along with a series of robustness checks. Finally, Section 6 summarizes the key conclusions of the paper.

2. Background Literature

The technological innovations of the last two decades have led to an increase in the demand for natural resources and in the production of critical raw minerals, with Sub-Saharan African countries being among the most important world suppliers (IRENA Report, 2023). Liberia has a natural abundance of gold and diamonds (Gunn et al., 2018), and in 2022 the mining industry accounted for 56.61% of national GDP (LEITI Report, 2023). These minerals are not extracted in large industrial mines but rather in ASM, usually located in peripheral regions and outside state control, characterized by a high level of informality (Verbrugge et al., 2015; McQuilken and Hilson, 2016) and where vulnerability could have more severe consequences on population (Ofosu et al., 2020). According to the USGS (2018)[1], in 2017/2018 half of the gold production in Liberia came from artisanal mines, and the major operating companies were only four: Liberia Cement Corp. Ltd. (cement), Bea Mountain Mining Corp. (gold), ArcelorMittal Ltd. (iron ore), and the China Union Investment Bong Mines Co. (iron ore).

[1] The Mineral Industry of Liberia by Meralis Plaza-Toledo. The Mineral Industry of Liberia, 2017-18 (PDF). Sources/Usage: Public Domain.

An unresolved question in academic literature is the extent to which the expansion of artisanal and small-scale mines impacts local communities, and the effects are quite contrasting. Hunter (2020) focuses on Liberia too and investigates the effect of artisanal and small-scale gold mining in generating illicit financial flows, that in turn fuels conflicts, instability and criminality. Ofosu et al. (2020) emphasize negative outcomes such as land degradation, water pollution and labour shifts. The environmental problem regarding extraction activities have been well debated in the last twenty years of research (Peck and Sinding, 2003; Ncube-Phiri et al., 2015; Jacka, 2018). On the other side of the coin Maconachie and Conteh (2020) reflect on the issue that ASM in Sub-Saharan Africa are a major source of direct and indirect employment. Chuhan-Pole et al. (2015) reveal that in the studied areas in Ghana men are more likely to benefit from direct employment as miners, while women are more likely to find opportunities in indirect employment within services. They also demonstrate that long-established households in mining communities gain access to infrastructure like electricity and radios and infant mortality rates in these communities decrease significantly. In addition, Kamlongera (2011) shows that ASM sector -if properly managed- provides employment to rural communities and contributes to the national economy of Malawi by generating foreign exchange.
From an older time, agriculture has maintained a key role in many Sub-Saharan countries, and it is crucial for the subsistence of millions of people and for the national economies. This happens even if at world level the share of people working in the field is declining due to industrialization and urbanisation (ACET, 2017). In Liberia agriculture is practiced as a family activity (Gräser, 2023) and according to World Bank data the sector employed almost 40% of the workforce and accounted for one third of national GDP between 2013 and 2019 (table 1). These two sectors together are the primary drivers of the nation's economy and for many poor Liberians, they are lifelines. Thus, the prosperity of mineral extraction and agriculture, under the constant and rising menace of climate change (Zinnah and Jackollie, 2020), is crucial not only for the national economy but also for the livelihoods of millions of citizens who rely on them for their daily needs and long-term development.

2.1 Complementary or alternative?

The relationship between artisanal and small-scale mines and agriculture is debated. Cartier and Bürge (2011) show that ASM and agriculture can be seen both as complementary and alternative activities. What is certain is that artisanal and small-scale mining is a phenomenon that is both growing and widespread (Owusu et al., 2019) and it tends to overlap activities in the already existing land, previously used for agriculture (Cuba et al., 2014; Mitchell, 2016). In addition, both sectors rely on a young labour force (Okoh and Hilson, 2011). Consequently, many young farmers leave the agriculture to join the low-tech ASM industry that, due to low entry barriers, absorbs many low skilled farmers (Banchirigah and Hilson, 2010). Recently, Gräser (2023) provides causal evidence of a boom-and-bust cycle due to artisanal mining on employment. In particular, she shows that a boom in artisanal mining seems to shift employment from subsistence agriculture to more productive sectors. In contrast, the opening of industrial gold mines appears to decrease employment in more productive sectors and increase employment in agriculture, while industrial iron ore mines have no effect. This effect is only partially consistent with our findings. We agree that an increase in artisanal mineral extraction could lead to higher wellbeing and a shift from more rural and agricultural activities to the secondary sector. However, it is also true that changes in the job market are slow and, at the same time, people who remain working in agriculture improve their income and consequently the investment potential in their activity and the ability to cultivate more land in an increasingly profitable way. This theory has been presented also by Fritz et al. (2022), who states that ASM in Ghana in the last decade represented *"a primary source of income for a large proportion of the population, as well as a supplementary source of income for those involved in agricultural activities".* Similar results are presented by Hilson and Garforth (2013), who show that families turn to ASM to supplement their farming incomes and to purchase new agricultural inputs. Similarly, in his analysis of the post-war rural economy in Sierra Leone, Maconachie (2011) discovers that income generated from ASM offers essential investment funds for revitalizing agricultural institutions and social networks, both crucial to the post-war rural economy. On the other side, Aragon and Rud (2016) estimated an agricultural production function and discovered that farmers situated near mines in Ghana experienced a nearly 40% decrease in total factor productivity between 1997 and 2005 due to pollution.

Table 1 – Employment in agriculture (column i) and agriculture value added (column ii) in Liberia between 2012 and 2022

Year	(i) Employment in agriculture (% of total employment) Source: World Bank[2]	(ii) Agriculture, forestry, and fishing, value added (% of GDP) Source: World Bank[3]
2012	45	46.7
2013	43	39.5
2014	43	36.5
2015	42	34.4
2016	42	35.9
2017	41	35.9
2018	40	35.5
2019	40	36.4
2020	40	41.1
2021	40	37.0
2022	39	36.2

3. Data and descriptive statistics

This work exploits an original dataset constructed from two main sources. The data on mines come from the Online Repository of the Ministry of Mines and Energy, Government of Liberia[4], while the data on households come from the Demographic and Health Survey (DHS).

3.1 Data on small scale and artisanal mines

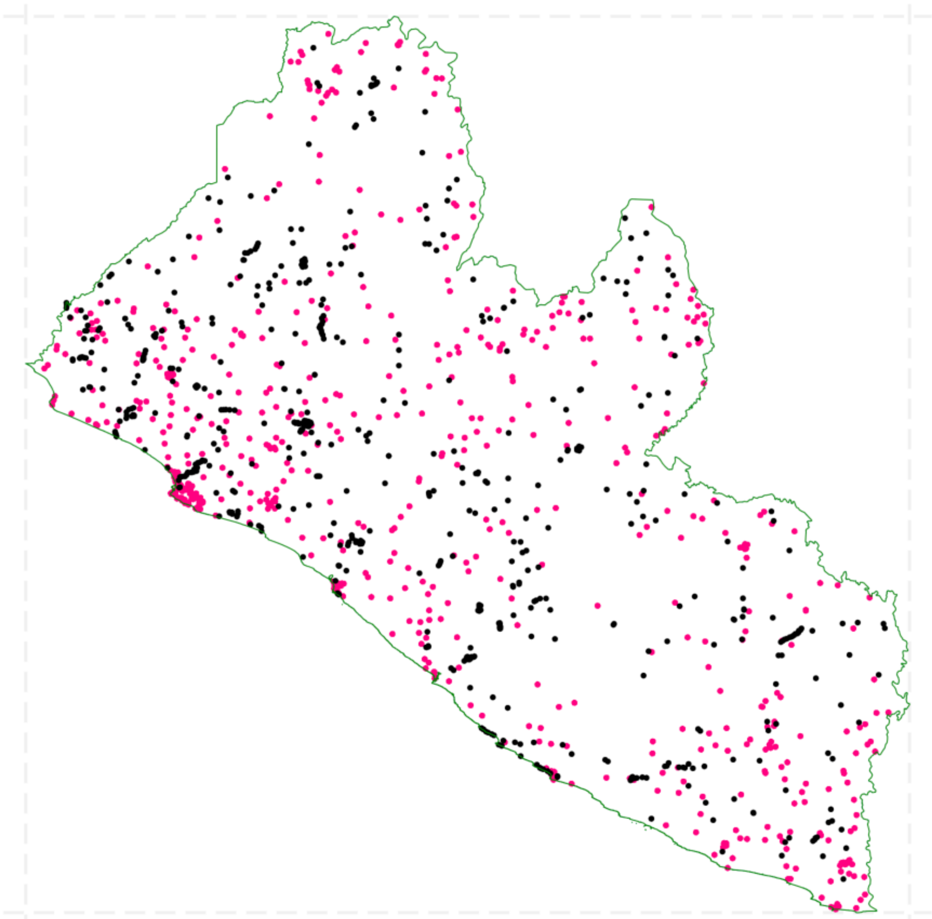
We collected data on small scale and artisanal mines from the Liberian Ministry of Mines and Energy. This repository contains data and information on all issued mineral rights, exploration, mining, dealers and exporters licenses, and related payments. For our research, we geolocate the centroid of 644 different mines, each of which opened at least one year between 2013 and 2019. From a location perspective, mines do not tend to be spatially clustered at a geographic level (Figure 1), and more than half of them (380 out of 644) are involved in the extraction of gold. Our dataset suffers from two important limitations: firstly, it does not provide information on the quantity produced by each mine; secondly, it contains only information on registered artisanal mining and not on illegal/unregistered mines.

[2] https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?end=2022&locations=LR&start=2011
[3] https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?end=2022&locations=LR&start=2007
[4] https://liberia.revenuedev.org/dashboard

3.2 Data on households

The second source of data is the Demographic and Health Surveys (DHS). The DHS Program is a public access, nationally representative and geo-referenced cross-sectional survey on population and health. It was established by the United States Agency for International Development (USAID) in 1984 and since then it has provided technical surveys about health and population trends in over 90 developing countries. For our research, we selected two waves. The initial round was conducted in 2012, with the results being published in 2013. Households belonging to this group total 9,333. This survey enables us to assess the situation during the pre-treatment period. Subsequent interviews for the second round were conducted between 2018 and 2019, with results published in 2019. Households belonging to this group total 9,068. The households are spread out across 647 different DHS clusters. Each cluster is a village, and it is geolocated by the DHS. The availability of geographical information allows us to match this data with the locations of mines.

Figure 1 – Position of ASM and DHS's households in Liberia



The pink dots are the 18,401 households interviewed in the two DHS waves. The black dots are the 644 mines opened at least one year between 2013 and 2019.

3.3 The difference-in-difference set-up

The geographical variation of mining facilities in Liberia, combined with the households surveyed in the two DHS rounds, one before and one after the mining boom, allows for the construction of treatment and control groups, thereby enabling the utilization of a difference-in-difference methodology. Households are categorized into two groups for analysis: those residing within a 5 kilometres radius of the closest mine and those situated at a distance ranging from 5 kilometres to 25 kilometres. The threshold distance of 5 kilometres was chosen based on existing literature (Aragon and Rud, 2013, 2016; Benshaul-Tolonen, 2018), which focuses on the impact of mining activities on local communities. Also, Shaver et al., (2019) and Kung et al., (2014) find mine treatment effects to be concentrated among people living within 5–20 kilometres from the mine. However, we also consider the possibility that the mines affect households living at further distances in the robustness checks. To be consistent with our methodological framework, we selected only mines that were not yet open in 2013 and were open in 2019, excluding mines that closed before the first survey or that opened after the second one.

Table 2 – Treated and untreated individual in our final sample

	DHS 2013	DHS 2019
Untreated households (5-25 km from nearest mine)	3,858	3,447
Treated households (0-5 km from nearest mine)	2,359	2,371
Total households	6,217	5,818

3.4 The acres of land for agriculture

The objective of the paper is to assess the number of acres of agricultural land for these two groups in 2011, prior to the opening of a mine, and then in 2019. The variable of interest in this study is the answer to the DHS survey regarding the percentage of acres farmed for agricultural purposes for any household. Overall, the average number of acres farmed is 28.5%, with a standard deviation of 41.6. In 2011, the average at more than 5 km from a mine ($\bar{Y}_{00}$) was 30.6% and the average at less than 5 km from a mine ($\bar{Y}_{10}$) was 25.8%. In the second survey, the number of acres farmed by households living far from the mine ($\bar{Y}_{01}$) rose to

36.7%, while the number of acres farmed by households living close to the mine ($\bar{Y}_{11}$) rose to 35.6%. Descriptive statistics regarding the variable are reported in table A1 of the Appendix, together with the main variables used in the baseline regression.

4. Empirical strategy

To understand the relationship between the opening of a mine and the acres farmed, we begin by exploiting the quasi-experimental setting induced by the opening of a mine between 2013 and 2019. This section quantifies the association between the opening of a mine and land use for agricultural purposes.

The baseline specification (equation 1) follows a difference-in-difference strategy estimated with fixed-effects, exploiting the geographical variation of mines in Liberia and the temporal variation provided by the boom in mining production. We expect to find a significantly different from zero increase in acres for agriculture by households living in villages surrounding a mine. The empirical specification is presented as follows:

$$y_{itcr} = \alpha_1 D_i + \alpha_2 P_t + \alpha_3 (D_i * P_t) + \alpha_4 X_i + FE_{rt} + \varepsilon_{itcr} \quad (1)$$

The outcome variable y_{itcr} denotes the percentage of acres used by households for agriculture in household i in year t in cluster c in region r. D_i is a dummy variable that takes the value 1 if the distance between the household and the mine is less than the 5 kilometres threshold and takes the value 0 if the distance between the household and the mine is greater than 5 kilometres and less than 25 kilometres. P_t is a dummy variable that takes the value 1 if the observation is in the post-treatment period (i.e., year equal to 2019). X_i is a vector of covariates to control for confounding factors including a dummy for the type of residence (urban versus rural) and the cluster altitude in meters. The household's altitude can have a negative effect since it may be more difficult to engage in agriculture on hills. By adjusting for these variables, the study aims to isolate the specific impact of the mine's presence on agricultural land. Since regions might have implemented local interventions after the opening of a mine, we interact the regions' fixed effect with P_t and we control for region-year fixed effects. ε_{itcr} is the error term. Finally, $D_i * P_t$ is the interaction between treated households D_i and the dummy variable P, equal to one in the post-treatment period. α_3 is our parameter of interest, and it shows the difference-in-differences estimates of the impact of the opening of a mine on the acres of land used for agriculture by people living close -less than 5 kilometres- to the site.

5. Results

5.1 Baseline

In the analysis conducted using the Difference-in-Differences regression model, the findings provide substantial evidence of the impact of proximity to a higher percentage of acres cultivated by households. Baseline results of equation (1) are reported in table 3. Column (i) shows the results for the baseline equation without covariates X_{it}, while column (ii) includes the altitude of the cluster and the type of residence. The baseline results show a negative and statistically significant coefficient for the variable "treated," which reflects the distance from the mine. Before the mine opened, treated households (residing near the mine) used a significantly lower amount of land for agricultural purposes compared to those untreated (living farther from the mine). Specifically, before the intervention, the treated group used approximately 3.36% less land for agricultural work than the control group. In the pre-treatment period, people living closer to a mine in Liberia cultivated less land compared to those living farther away, likely due to poverty and lack of economic opportunities. Areas near mines might have initially been poorer, with limited agricultural resources and infrastructure.

The coefficient of the interaction term α_3 - the average treatment effect on the treated - is positive and statistically significant, indicating that, following the mine's opening, the amount of land cultivated by those treated relative to the untreated increased by 5.3%. The statistical significance at the 10% level of the estimated coefficients for the three main variables corroborates our research hypotheses with strong empirical support.

Previous research provides evidence that a boom in mining shifts employment from subsistence agriculture to more productive sectors and a bust decreases the likelihood for individuals to work. Conversely, the opening of industrial gold mines seems to decrease employment in more productive sectors and increase employment in agriculture (Gräser, 2023). Our conclusion is that the shift needs time and meanwhile, the wealth generated by the site could boost agricultural activities.

5.2 Robustness checks

In this section, we test if our estimates hold against a variety of robustness checks, conducted to reinforce the validity of our main findings. Results are shown in table 4. In column (i), we excluded the 1% of households that could represent outliers. Our interaction term underwent minimal change, moving from 5.3% to 5.5%, and increasing in significance to 5%. Excluding outliers is a crucial step in refining the analysis by minimizing the distortion effects on the overall results, ensuring that the conclusions drawn are representative of the general population.

5.2.1 Heterogeneous effect of distance

The selection of a 5 kilometres distance to differentiate between treated and control subjects in assessing the impact of mining exposure on acres dedicated to farming is a critical methodological decision. This threshold was adopted based on prior research that explored the effects of mining exposure, including studies by Aragon and Rud (2013, 2016) and Benshaul-Tolonen (2018). This choice is supported by empirical evidence suggesting that the immediate vicinity to a mine, typically within a 5 kilometres radius, experiences the most direct environmental and socio-economic impacts. This threshold also serves to ensure that the treatment group is distinctly affected by mining activities, whereas the control group is less likely to be directly influenced. In this part of the study, the baseline model is reproposed to investigate the varying impacts of doubling the distance from a mining site on our variable of interest. This assumption underpins the study's hypothesis that geographical proximity to mining activities directly correlates with the observable effects on household production. The model specification includes the usual fixed effects and individual-level controls, as in the baseline difference-in-differences equation. The results from this alternative model, presented in column (ii) of table 4, demonstrate that the effects of mine exposure on the percentage of acres cultivated by households are positive and significant even among households living within 10 kilometres of a deposit. The coefficient of the interaction term reduces in magnitude, dropping from +5.3% to +4.8%, as we expected with increasing distance. This confirms that as one moves further away from a mine, the effect continues to diminish, highlighting the diminishing effect of the treatment's impact over distance. This finding underscores the critical importance of considering geographical proximity when evaluating the environmental and social impacts of mining activities.

5.2.2 Assessing Proximity Effects

In this section, we explore an additional dimension of the relationship between the opening of a mine and the percentage of acres cultivated. This further examination provides a more profound understanding of the temporal and spatial variations in the impact over time. Contrary to the previous estimations, households are categorized based on their proximity to the event, within a distance interval of 0-5 kilometres (the baseline distance) and compared against a baseline group situated 10-25 kilometres away. This model incorporates the same fixed effects, trends, and personal controls as those utilized in the baseline model specification. We exclude all households between 5 and 10 kilometres, creating a sort of “grey zone”. This methodological decision to omit households within a specific distance range presents an innovative approach to addressing heterogeneity in the treatment effect. It enables a clearer distinction between treated and control groups by reducing the potential for intermediate effects that could obscure the impact of proximity to the mine. The results are shown in column (iii) of table 4. Excluding this intermediary group modifies the magnitude of the fundamental relationship observed: the coefficient of the interaction, which is now statistically significant at the 5% level, rises from 5.3% to 7.5%.

5.3 Investigating the impact of mines on households’ wealth index

To better explain the mechanism behind our regression, we investigate the wealth index of households. The idea is that the opening of a mine increases the wellbeing of households living near it more than for people living farther away. This broader association provides additional evidence for the baseline findings. The empirical specification is presented as follows:

$$\mathrm{w}_{\mathrm{itcr}} = \alpha_1 D_i + \alpha_2 P_t + \alpha_3 (D_i * P_t) + \alpha_4 X_i + FE_{rt} + \varepsilon_{itcr} \quad (2)$$

The dependent variable is the Wealth Index Factor Score Combined (descriptive statistics of the main variable is shown in appendix A1) provided by the DHS for the households studied before.

The wealth index is a composite measure of a household’s cumulative living standard. According to the DHS itself, “*it is calculated using easy-to-collect data on a household’s ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities. Generated with a statistical procedure known as principal components analysis, the wealth index places individual households on a continuous scale of relative wealth. The wealth index is presented in the DHS Final Reports and survey datasets as a background characteristic”* (DHS[5]). Moreover, the wealth index allows researchers to identify how much household economic status affects health outcomes by using both bivariate and more sophisticated multivariate methods. Results of equation (2) are reported in table 5. Column (i) shows the results for the regression without covariates X_i, column (ii) includes the same

[5] https://dhsprogram.com/topics/wealth-index/

covariates as baseline equation (1), and in column (iii) we present the dependent variable in logarithmic form. Overall, the results satisfy our theoretical assumptions, showing that the opening of a mine is positively associated with a better wealth index for people living within the first 5 kilometres from the nearest mine compared to people living between 5 and 25 kilometres.

5.4 Falsification Test using households' electricity access

Due to the limitation of having only one year of post-treatment period and one year of treatment period, it is impossible to guarantee that the parallel trend assumption holds using pre-trends. So, we employ a falsification test to validate our Difference-in-Differences methodology (Cunningham, 2021). We use household electricity access as our falsification variable. Liberia faces important challenges in the energy sector, and it is also difficult to estimate the right number of households having access to electricity. According to Yusuf et al. (2024) in 2019 only 3% of the Liberian population had grid electricity, while the World Bank report that in the same year the access to electricity was granted to roughly 23% of the population, while one decade before only to 1.9%.[6] In the DHS surveys used in this paper, in 2013 only 6% of households had access to electricity at home. This number rose to 16% in 2019.

Methodologically, the assumption is that if our DID model correctly identifies the causal impact of the treatment on the primary outcome variable, which is the acres of cultivated land, it should not find a significant effect on an unrelated variable, such as household electricity access. Household electricity access is an ideal falsification variable for several reasons. First, if the treatment specifically targets the acres of cultivated land, it should not directly impact the availability of electricity in individuals' homes, ensuring the variable's independence from the agricultural treatment. Second, access to electricity serves as an indicator of basic service provision and domestic infrastructure, which are typically unaffected by agricultural policies or interventions. Changes in this variable are generally driven by specific interventions in electrical infrastructure or energy policies, not by agricultural initiatives. Third, household electricity availability tends to be relatively stable in the short term, as it requires significant infrastructural changes that do not happen rapidly. This stability makes it a suitable candidate for verifying whether the observed changes in the primary variable (acres of cultivated land) are due to the specific treatment rather than confounding factors. By including the same covariates in the falsification test as in the primary analysis,

[6] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=LR

we control for potential confounding factors consistently across both models. If the treatment effect on household electricity access is found to be non-significant, it supports the validity of our causal inference regarding the treatment's impact on agricultural land use. Conversely, a significant effect would suggest that our DID model may be picking up on other extraneous influences, thereby questioning the robustness of our primary findings. The empirical specification is presented as follows:

$$\mathrm{e}_{\mathrm{itcr}} = \alpha_1 D_i + \alpha_2 P_t + \alpha_3 (D_i * P_t) + \alpha_4 X_i + FE_{rt} + \varepsilon_{itcr} \quad (3)$$

Where e_{it} is a dummy variable indicating if the households have access to electricity in their home. Results are shown in table 6. They indicate that the treatment effect on household electricity access is non-significant, thereby validating the falsification test. This non-significance supports the validity of our causal inference regarding the treatment's impact on agricultural land use, suggesting that our DID model is not unduly influenced by extraneous factors.

Table 3 – Baseline results

	(i)	(ii)
	y_{itcr}	y_{itcr}
Treated	-3.364*	-4.205**
	(1.756)	(1.764)
Treated#Post	5.320*	5.364*
	(2.821)	(2.824)
Altitude		-0.0253***
		(0.00635)
Residence		-1.940
		(1.515)
Constant	30.84***	38.97***
	(0.755)	(3.162)
Region-year FE	Yes	Yes
Observations	4,684	4,684
R-squared	0.035	0.038
F	2.227	5.309

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 – Robustness checks

	(i)	(ii)	(iii)
	y_{itcr}	y_{itcr}	y_{itcr}
Treated	-3.448**	-2.486	-5.120**
	(1.759)	(1.815)	(2.253)
Treated#Post	5.575*	4.858*	7.513**
	(2.847)	(2.907)	(3.526)
Altitude		-0.0257***	
		(0.00637)	
Residence		-1.601	
		(1.500)	
Constant	31.07***	38.17***	31.27***
	(0.760)	(3.201)	(1.150)
Region-year FE	Yes	Yes	Yes
Observations	4,643	4,684	3,065
R-squared	0.035	0.037	0.029
F	2.373	4.654	2.972

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 – Wealth Index Factor Score Combined

	(i)	(ii)	(ii)
	w_{itcr}	w_{itcr}	$\ln(w_{itcr})$
Treated	19,153***	-7,239***	1.021***
	(2,662)	(2,136)	(0.140)
Treated#Post	6,388*	12,534***	0.465**
	(3,784)	(3,026)	(0.200)
Altitude		-164.9***	
		(7.579)	
Residence		-113,414***	
		(1,657)	
Constant	4,518***	213,449***	4.578***
	(1,135)	(2,997)	(0.0601)
Region-year FE	Yes	Yes	Yes
Observations	12,035	12,035	12,035
R-squared	0.247	0.516	0.202
F	70.98	1513	80.56

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6 – electricity access as falsification test

	(i)	(ii)
	e_{itcr}	e_{itcr}
Treated	0.0388***	0.00266
	(0.00729)	(0.00740)
Treated#Post	-0.00984	-0.000820
	(0.0122)	(0.0118)
Altitude		-0.000184***
		(0.0000223)
Residence		-0.160***
		(0.00577)
Constant	0.0989***	0.387***
	(0.00345)	(0.0120)
Region-year FE	Yes	Yes
Observations	12,029	12,029
R-squared	0.109	0.167
F	18.50	226.3

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

The findings of this paper reveal that the opening of artisanal and small-scale mines (ASM) in Liberia between 2013 and 2019 is associated with an increase in the percentage of land used for agriculture by nearby households. Specifically, households living within 5 kilometres of a mine showed a significant increase in agricultural land use post-mine opening compared to those living farther away. This indicates that proximity to mining operations can stimulate agricultural activities, potentially through increased economic opportunities and resources available to local communities. The wealth generated by ASM activities likely provides these households with the means to invest more in agriculture, thus expanding their farming operations. Additionally, the study finds a positive association between the presence of mines and the overall wealth index of nearby households, suggesting improvements in living standards.

To assess the impact of ASM on agricultural land use, the paper employs a difference-in-differences approach with fixed effects. By comparing households located within 5 kilometres of a mine (treatment group) to those located 5-25 kilometres away (control group), the study isolates the effect of mine proximity on agricultural practices. This method allows for a robust analysis of the causal relationship between mining activities and land use changes, accounting for both spatial and temporal variations.

Studying artisanal and small-scale mining (ASM) is crucial due to its significant role in providing livelihoods for millions in developing countries, especially in Liberia, where it underpins economic stability and employment. ASM offers more accessible economic opportunities compared to large-scale mining, impacting local communities by influencing employment, income distribution, and land use while posing environmental challenges like land degradation and water pollution. Given Liberia's heavy reliance on mining, understanding ASM's impacts is vital for developing policies that enhance its benefits and mitigate its drawbacks.

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Appendix

Table A1 of the appendix reports the descriptive statistics for the main variables of equations (1), (2), and (3). We use the dataset including only the households associated with mines that were closed in 2013 and open in 2019, to be consistent with the dataset dimensions.

Table A1 – descriptive statistics of main variables

Variable	Obs	Mean	Sd	Min	Max
Acre	4,684	30.40	42.45	0.1	99.9
Residence	12,035	1.58	0.49	1	2
Altitude	12,035	125.01	139.14	0	550
Wealth Index	12,035	13,303.77	106,323	-186,367	477,978
Electricity	12,029	0.11	0.32	0	1