



The CLEAN PAPER

WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Mining n̄ gé ju mine funra rẹ lọ — hidden forest loss yí extraction ká

Nature study kan lóri mine clusters 16,627 ní sub-Saharan Africa rí direct deforestation tó tó 187,000 hectares láti 2001 sí 2020, ògbón offsite loss ni story tó tobi. Lẹyin ọdún mewaá, deforestation within 1 km jẹ 8 points higher lóri 0-to-100 scale relative sí unmined areas. Ní separate five-year calculation, hectare direct loss kan associated pẹlú 33.9 additional hectares offsite forest loss ní average. Èyí kò sọ pé energy transition buru; ó sọ pé mineral supply chains ní geography àti forest costs tó kọjá pít.

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Footprint kì í ẹ̀se ihò tó wà nínú igbó nìkan

Mine kan ní shape tó hàn gbangba. Pit kan, tailings pond, spoil heap, road tí a gé sínú igbó. Wònyí ni marks tí satellite lè rí, tí regulator sì lè fa ààlà yí ká.

Şùgbón extraction tún n yí ilẹ̀ tó yí i ká padà. Àwọn ènìyàn n dé. Roads n jẹ́ kí igbó rọ̀rùn láti wọ́lé sí. Settlements n dagba. Agriculture n fẹ́ síí. Mine kì í ẹ̀se scar kan lórí map nìkan; ó lè di tuntun center of agbára walẹ̀.

Nature ìwé ìwádíí kan fi numbers sí ìyàtò yíi kọ́já sub-Saharan Africa. Àwọn olùkòwé ìşíró àfojúsùn taara mining-driven deforestation nínú dense igbó láti 2001 sí 2020, lẹ́yìn náà wọn béèrè iye additional igbó loss tó hàn yí mines ká ní ifiwéra pẹ̀lú similar places tí a kò tì mine. Conclusion wọn rọ̀rùn, şùgbón uncomfortable: taara mine footprint jẹ́ visible part nìkan.



Natural-color Landsat image kan fi large-scale àti artisanal gold-mining scars hàn nínú Ashanti gold belt ní Ghana. Ìwádíí yíí béèrè bí mining-related igbó loss ẹ̀ jìn tó kọ́já mine footprint funra rẹ̀.

NASA Earth Observatory / Lauren Dauphin Public domain

Èyí jẹ èsì tó wúlò fún climate àti biodiversity politics, nítorí ó pa thoughts méjì mọ nínú frame kan. Modern infrastructure àti agbára transition nílò minerals. ẚùgbón minerals kò wá láti ibikíbi. Clean ibèèrè kì í ẹ̀ bóyá mining “dára” tàbí “buru” nínú slogan. Ó jẹ bóyá a ní wọn full igbó cost pèlú honesty.

Ohun tí àwọn olùkòwé ẹ̀

Ìwádíí nàà darapọ̀ continent-scale igbó àti land-use dátà pèlú causal-inference àpẹrẹ̀. Àwọn olùkòwé map **mine clusters 16,627** nínú forested areas ti sub-Saharan Africa láàárín 2001 àti 2020. Wọn yà igbó loss sí oríṣi méjì.

Àkókọ̀ ni **taara mining-driven deforestation**: clearing nínú mine footprint funra rẹ̀, pèlú pits, tailings ponds, spoil heaps, shafts àti àbùdá mǐràn tí mining operations taara related sí.

Èkejì ni **offsite deforestation**: igbó loss yí mine ká tí kì í ẹ̀ pit funra rẹ̀, ẚùgbón tí mine establishment lè trigger nípasẹ̀ ancillary activity — agriculture, settlements, roads àti access mǐràn.

Láti ìṣíró àfojúsùn apá kejì, ònkòwé lo difference-in-differences àgbékalẹ̀. Ní ọ̀rọ̀ tó rọ̀rùn, wọn fi igbó loss yí mines ká ẚáájú àti léyìn mining start wé igbó loss yí places tó jọra ká tí a kò tì mine. Léyìn nàà wọn wo concentric distances láti mine center: nínú 1 km, 1-5 km, 5-10 km àti 10-20 km.

Design yí ẹ̀ pàtàkì nítorí ìwé ìwádíí kò kan ní ka igbó loss near mines. Ó ní gbìyànjú láti ìṣíró àfojúsùn additional loss attributable sí mine establishment, ní ìfiwéra pèlú counterfactual trend nínú unmined areas.

Ohun tí wọn rí

Direct mining loss tóbi. Kọ́já dense igbó ní sub-Saharan Africa, ònkòwé ìṣíró àfojúsùn **187,070 hectares** ti taara mining-induced deforestation láàárín 2001 àti 2020. Democratic Republic of the Congo, Ghana àti Côte d'Ivoire papọ̀ jẹ **45%** ti taara loss yẹn.

Loss tó yí footprint ká tóbi ju footprint funra rẹ̀. Léyìn mine establishment, cumulative deforestation nínú 1 km jẹ **8 kókó higher lórí 0-to-100 scale** léyìn ọ̀dún mewaá ní ìfiwéra pèlú unmined areas. Èyí jẹ absolute gap nínú deforestation rate, kì í ẹ̀ 8% relative mú pọ̀ sí i. Effect dín pèlú ìjinnà, ẚùgbón kò parí: léyìn ọ̀dún mewaá ìwádíí ìṣíró àfojúsùn additional gaps 3.6 kókó ní 1-5 km, 1.9 kókó ní 5-10 km, àti 1.1 kókó ní 10-20 km.

Numbers wọn yí time-specific ní. Ten-year ipa ní, kì í ẹ̀ immediate losses.

Offsite/taara ratio nàà striking. Nínú separate calculation, ònkòwé ìṣíró àfojúsùn pé fún hectare kọ̀kan tí taara mine footprint clear, additional **33.9 hectares** ti dense igbó sọ̀nù offsite nínú five years. Ọ̀pọ̀ jù lọ additional offsite loss nàà linked sí agricultural expansion tí mine establishment trigger, settlement expansion tún ẹ̀ pàtàkì, roads sì jẹ smaller share nínú breakdown wọn.

Number yí tún time-specific: five-year offsite/taara ratio ni. Kò yẹ ká da a pò mọ ten-year 0-to-100-scale ipa.

Effect kò jẹ ohun kan náà ní gbogbo ibi. ìwádíí rọ̀yìn severe concern fún Democratic Republic of the Congo nítorí ó darapọ̀ large taara mining footprint pẹ̀lú large additional offsite loss. Countries mǐràn ní high relative offsite impacts, ẹ̀gbọ̀n taara footprints kéré. Ní commodity ìpele, mines extracting cobalt àti copper — minerals tó ẹ̀ pàtàkì fún batteries, electrical infrastructure àti agbára transition — fa highest total additional deforestation nínú ìṣíró àfojúsùn ìwádíí.

Kí nìdí tí offsite part fi ẹ̀ pàtàkì?

Environmental assessment sáà bẹ̀rẹ̀ pẹ̀lú taara project ààlà. Ó ní sense. Pit hàn, permit ní perimeter, company lè ẹ̀làyẹ̀ infrastructure tó fẹ̀ kọ.

Ẹ̀gbọ̀n igbó kò fèsì sí legal boundaries nìkan. Wọ̀n fèsì sí access àti incentives. Mine kan lè mú roads, workers, money, settlements àti demand fún food. Èyí lè yí nearby igbó sí land tí ó rọ̀rùn, profitable tàbí necessary sí láti clear.

Ìdí niyẹn tí strongest idea ìwé ìwádíí kì í ẹ̀ number kan. Ó jẹ̀ ìyàtọ̀ láàárín **taara** àti **triggered** loss.

Tí supply chain bá ka mine footprint nìkan, ó lè undercount land-use change tí extraction fa. Tí environmental impact assessment bá dúró ní lease ààlà, ó lè miss igbó loss tí project ẹ̀ likely sí. Tí product bá jẹ̀ marketed bí clean nítorí ó ẹ̀ àtílẹ̀yìn fún renewable agbára, èyí kò automatic make ohun èlò chain clean.

Ohun tí èyí kò fi ẹ̀rí múlẹ̀

- Kò fi hàn pé agbára transition buru. Ó fi hàn pé minerals tí modern infrastructure, pẹ̀lú energy-transition minerals, ní ló lè ní large land-use costs.
- Kò tún mọ̀ sí pé mine kọ̀ọkan fa exactly 33.9 hectares offsite loss fún taara hectare kan. Average ìṣíró àfojúsùn ní kọjá mine clusters púpọ̀, kì í ẹ̀ prediction fún project kan.
- Kò fi ẹ̀rí múlẹ̀ pé gbogbo tree tí sọ̀nù near mine ni a gé nítorí mine náà. ìwádíí lo quasi-experimental àpẹ̀rẹ̀ láti ìṣíró àfojúsùn additional loss ní population scale.
- Kò assign responsibility sí individual companies, permits tàbí buyers. Èyí nílò project-level tracing kọjá article yí.
- Kò cover gbogbo mining impacts. Water pollution, labor conditions, biodiversity fragmentation, rights conflicts àti social displacement wà outside pàtàkì forest-loss measurement.
- Kò cover gbogbo world. ìtupalẹ̀ focus lórí dense igbó nínú sub-Saharan Africa.

Báwo ni ẹrí ẹ lágbara tó?

Fún direct-deforestation ìṣírò àfojúsùn, ẹrí lágbara ní continental scale. ìwádíí lo published land-use àti forest-cover datasets láti identify igbó loss taara associated pẹ̀lú mining àbùdá.

Fún additional offsite loss, ẹrí tún substantial, ṣùgbón model-based. Difference-in-differences jẹ àpẹrẹ fún causal ipa láti observational dátà, pàápàá níbi tí randomized ìdánwò impossible. ònkòwé lo recent heterogeneity-robust ọ̀nà, wọn sì ìdánwò robustness pẹ̀lú alternative estimators. Good practice ni.

Síbẹ, èsì yẹ ká ka ní scale tó tó. ìwé ìwádíí jẹ lágbara ẹrí pé mine establishment associated pẹ̀lú additional deforestation beyond footprint kojá ìwádíí ètò. Kì í ẹ satellite confession láti tree kọ̀kan.

Public reading tó wúlò jù nítorí náà kì í ẹ panic tàbí dismissal. Ó jẹ measurement discipline: tí mining bá ẹ́ landscape, impact assessment yẹ kí ó wo kojá fence.

Kí nìdí tí ó fi ẹ pàtàkì?

Phrase “clean agbára” lè pa ohun èlò world mọ. Solar panels, batteries, transmission lines, electric vehicles àti dátà centers gbogbo wọn nílò mined ohun èlò. Dìẹ ninu ohun èlò wònyí wá láti places tó ní globally important igbó àti biodiversity.

Èyí kò jẹ kí decarbonization di mistake. Alternative — continuing fossil-fuel dependence — ní enormous land, air, water àti climate costs tirẹ. Ṣùgbón ó tùmọ sí pé transition lè cleaner ju fossil ètò lọ, síbẹ kò di clean automatically.

Iye ìwé ìwádíí yí ni pé ó mú hidden geography nira láti fojú kọ. Ó sọ: má ka pit nìkan. Ka igbó changes yí pit ká. Ka roads, farms àti settlements tí extraction ní fa. Fi offsite deforestation sínú environmental impact assessments, no-net-loss claims àti zero-deforestation supply chains.

Èyí jẹ ìtàn tó mature ju “green minerals dára” tàbí “green minerals buru.” Ó jẹ: ohun èlò basis ti transition ní consequences, wọn sì gbọdọ hàn ẹ́ájú supply chain tó pe ara rẹ ní clean.

Àkótán kedere

Nature ìwádíí kan analyze mine clusters **16,627** nínú dense igbó kojá sub-Saharan Africa láti 2001 sí 2020. Ó ìṣírò àfojúsùn **187,070 hectares** taara mining-driven deforestation láti àbùdá bí pits, tailings ponds àti spoil heaps. Pẹ̀lú difference-in-differences àgbékalẹ, ònkòwé tún ìṣírò àfojúsùn additional deforestation yí mines ká relative sí unmined areas: lẹyìn ọ̀dún mẹwàá, cumulative deforestation jẹ **8 kókó higher lóri 0-to-100 scale** nínú 1 km, ipa sì ẹ hàn títi 20 km. Nínú separate five-year calculation, hectare kọ̀kan taara mining deforestation associated pẹ̀lú average **33.9 hectares** additional offsite dense-forest loss, mostly nípasẹ agricultural expansion àti settlements. Mines extracting cobalt àti copper contribute highest total additional deforestation. èsì náà kò sọ pé agbára transition buru. Ó sọ pé mineral supply chains ní land-use costs tí ó kojá mine footprint.

Àyèwò láísí àṣejù

Ohun tí iwé iwádíí fi hàn: Mining nínú dense igbó kojá sub-Saharan Africa fa substantial taara igbó loss 2001-2020; mine establishment tẹlẹ pẹlú additional deforestation yí mines ká relative sí unmixed areas; offsite loss lè ju taara footprint lọ gan-an; diẹ energy-transition minerals associated pẹlú high total additional deforestation nínú dataset yíí.

Ohun tó ṣeé gbà ṣùgbón unproven: Pé individual mines púpọ ní offsite impacts tó tobi ju permit footprints; pé stricter impact assessments àti supply-chain òfin lè dín diẹ loss kù; pé similar hidden ipa lè ṣe pàtàkì ní tropical mining regions mǐràn.

Ohun tí kò fi hàn: Pé gbogbo mining damaging bakanna; pé gbogbo nearby igbó loss caused by specific mine; pé agbára transition buru; pé individual companies tàbí buyers responsible fún losses pàtó láísí project-level tracing; tàbí pé igbó loss ni nìkan environmental/social cost.

Main limitations: Observational causal inference, kì í ṣe randomized ẹrì; continent-scale ìṣírò àfojúsùn, kì í ṣe project-level attribution; focus lórí dense igbó nínú sub-Saharan Africa; taara/offsite ipa depend lórí dátà quality, mine detection àti àwòṣe assumptions.

Ìgbẹkẹlẹ wo ni olùkà gbogboogbo yẹ kí ó ní? Gíga pé taara mining deforestation substantial nínú iwádíí region. Dáadàá pé mine establishment linked sí additional offsite deforestation ní population scale. Kéré fún applying average 33.9:1 ratio sí mine kan. Stance tó yẹ: mineral supply chains lè necessary, wón sì ẹ̀ nílò honest accounting beyond pit.

Àwọn orísun

Nature (2026)

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White Rose Research Online — published version

<https://eprints.whiterose.ac.uk/id/eprint/241799/>

Processed outputs and analysis code — GitHub

https://github.com/OMorton/AFR_MiningForestLoss

Post-deforestation land-use dataset — Zenodo

<https://doi.org/10.5281/zenodo.11065705>