SHORT COMMUNICATION

The outbreak of illegal gold mining in the Brazilian Amazon boosts deforestation

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Abstract

Increased prices and political pressure are boosting illegal gold mining in the Brazilian Amazon, threatening forests, indigenous people, and conservation of biodiversity in protected areas. The rate of illegal mining deforestation increased more than 90% from 2017 to 2020, reaching 101.7 km^2 annually in 2020 compared to 52.9 km^2 annually in 2017. In that period, illegal mining deforestation rate grew more than the rate of clearing within mining leases. While formal mining is required to comply with environmental regulations, most small-scale or artisanal mining and especially illegal mining areas are abandoned after reserves are exhausted, without proper rehabilitation. Deforestation due to illegal mining is likely to increase in the next years, calling for coordination between local and regional policies as well as for strengthening and expanding international mechanisms to increase traceability of mineral supply chains with certification schemes to help to curb illegal mining.

Keywords Artisanal and small-scale mining · *Garimpo* · Environmental impacts · Forest degradation

Illegal gold mining has expanded significantly in the Amazon in the last decade (Asner et al. 2013; Alvarez-Berríos and Aide 2015; Asner and Tupayachi 2016), up to 18% annually in some regions (Swenson et al. 2011). This expansion is driven by the increase in gold prices in international markets (Alvarez-Berríos and Aide 2015; USGS 2020). In Brazil specifically, since 2018, it is bolstered by political support from the government of President Bolsonaro (Solomon 2020).

The occupation of illegal miners, mostly in search of gold, is encroaching on protected areas (Espejo et al. 2018) and threatening Indigenous peoples' well-being (CIMI 2018; Souza et al. 2019; Calvimontes et al. 2020; Siqueira-Gay et al. 2020a). Illegal gold mining pollutes water with heavy metals (Lobo et al. 2016; Abe et al. 2019), affecting aquatic (Swenson et al. 2011) and terrestrial ecosystems (Schueler et al. 2011; Asamoah et al. 2017; Dezécache et al. 2017), leading to negative impacts on human health (Castilhos et al. 2015). In addition to local

consequences, effects such as water contamination and increased sedimentation can be traced far beyond the mining sites, threatening communities and ecosystems hundreds of kilometers away (Alvarez-Berríos and Aide 2015; Sánchez-Cuervo et al. 2020). These small-scale activities are claimed to cause minor direct adverse impacts on forests (World Bank 2019); however, they can lead to extensive environmental impacts when associated with other drivers of change, such as large infrastructure development (Sánchez-Cuervo et al. 2020). Combined with broader infrastructural interventions, illegal gold mining can cumulatively degrade forests and reduce their area over time (Asner and Tupayachi 2016).

Two satellite monitoring systems are currently used to map the entire Brazilian Amazon (Assis et al. 2019). PRODES provides the annual extent of forest cover and deforestation rates (INPE 2017), and DETER-B (Diniz et al. 2015) issues daily warnings of deforestation to support direct field inspections and control (Assis et al. 2019). Data from DETER-B show that the annual rate of clearing due to illegal mining activities, i.e., the sum of all warnings in a year, increased more than 90% from 2017 to 2020, reaching 101.7 km^2 in 2020 compared to 52.9 km^2 in 2017, the year before Bolsonaro's term started (Fig. 1). In contrast, by overlaying deforestation data from PRODES to mining leases from the National Mining Agency (ANM 2020) (Fig. 1), the same trend is not observed inside areas with lease permits (Table S1-S4).

Communicated by Chandni Singh

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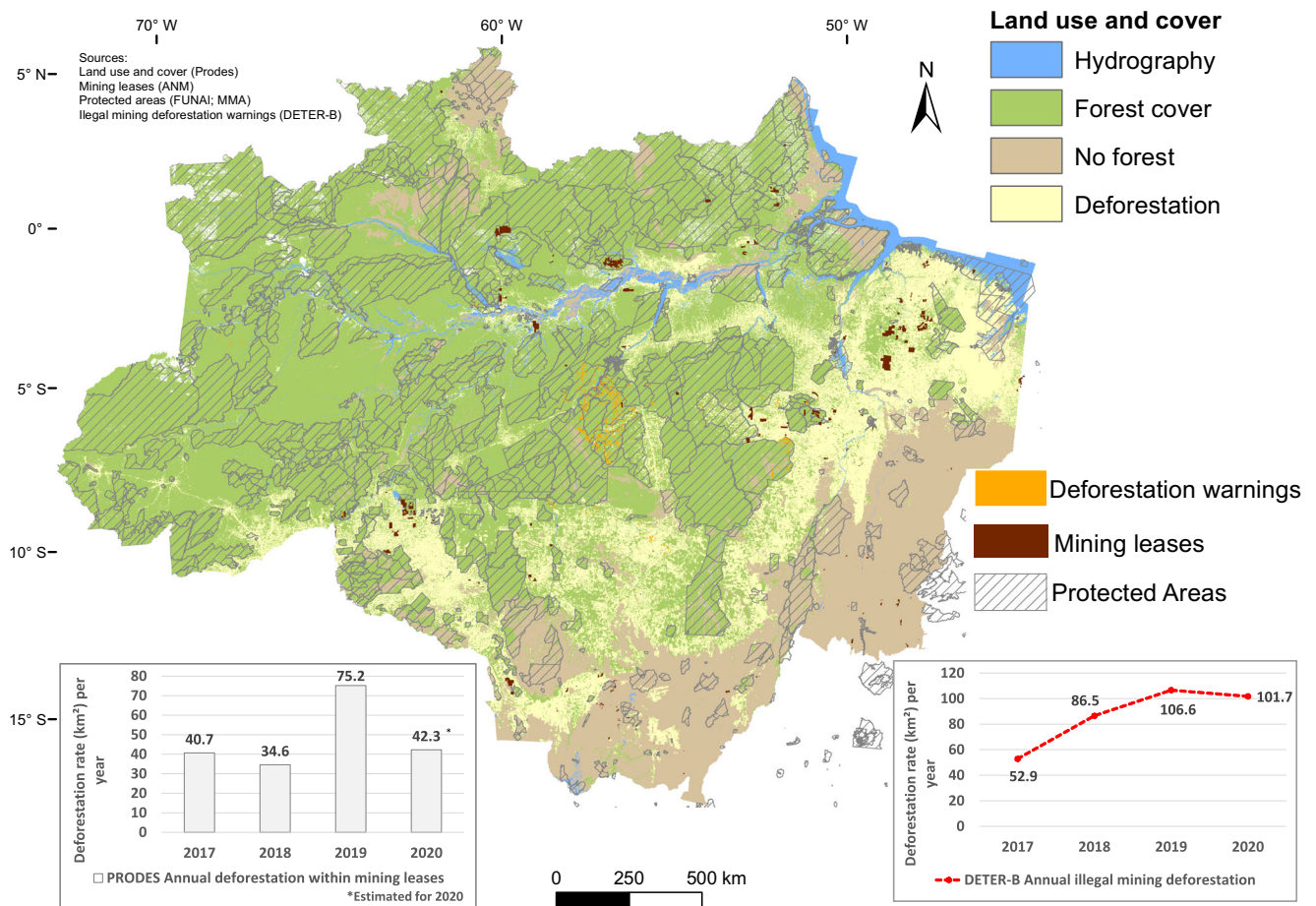1   Escola Politécnica, University of São Paulo, São Paulo, Brazil

Fig. 1 Deforestation in the Brazilian Legal Amazon, industrial mining leases, and deforestation warnings due to illegal mining. In the graph, the gray bars are the annual deforestation rates within mining leases, and the red line features the sum of deforestation warnings per year due to illegal mining

The types of gold mining in Brazil are twofold: (i) industrial mining, which are required to have a lease permit, and (ii) small-scale (seldom artisanal) mining, known as *garimpos*, where simplified forms of exploration, extraction, processing, and transportation are used (OECD 2016; Sousa et al. 2011). Several *garimpos* use heavy machinery to extract gold and are not considered artisanal but small-scale mining (Calvimontes et al. 2020). Most artisanal and small-scale mining of gold in Brazil is illegal (Sousa et al. 2011), but obtaining a *garimpo* lease is possible. *Garimpos* are not required to comprehensively assess and mitigate their social and environmental impacts (Ministério Público Federal 2020).

Garimpos not only clear but also degrade forests (Espejo et al. 2018), severely limiting the recovery of ecosystems after disturbance (Kalamandeen et al. 2020) and particularly degrading riparian vegetation. Clearing forest and other native vegetation for industrial mining requires legal authorization and the corresponding adherence to specific terms and conditions, including the commitment to rehabilitate degraded areas. However, deforestation in illegal gold mines is not held to similar conditions, and the mined areas are usually abandoned after

the reserves are exhausted, without any rehabilitation (Sousa et al. 2011).

There is growing knowledge and experience around restoring Amazon forests (da Cruz et al. 2020), including after large-scale mining (Gastauer et al. 2019). Post-mining restoration experiences date back to the 1990s (Parrotta and Knowles 2001), but the success of these interventions are highly dependent on how the rehabilitation process is managed (Neri and Sánchez 2010). Key ingredients for successful restoration, such as contextual knowledge, adequate financial resources, and long-time frames necessary to monitor a restoration trajectory (da Cruz et al. 2020; Kalamandeen et al. 2020), are lacking in areas where illegal gold mining occurs.

In order to curb extensive illegal mining deforestation, recommendations are twofold. First, it is critical to track the source of minerals to distinguish gold mined illegally from legal and formalized gold mining, and this can be done through certification schemes. Second, strengthening national and local policies to tackle illegal deforestation is needed. Investigations by the Federal Police and inquiries conducted by the Federal Prosecutor Office found that a significant

amount of illegally mined gold is falsely declared as coming from legal sources—i.e., legalized *garimpos*—in order to be sold to authorized buyers (Solomon 2020). Initiatives such as the Chain of Custody Standard of the Responsible Jewellery Council (RJC 2019), the Minerals Due Diligence of the Responsible Minerals Initiative (RMI 2020), and the Fairmined Standard for Gold (Alliance for Responsible Mining Foundation 2014) have been developed to assist buyers of gold and other precious metals to verify their suppliers' compliance with environmental and social standards for responsible mining (World Bank 2019) and have potential to contribute to minimize gold trade originated from illegal *garimpos*.

Although these schemes have limitations (Sippl 2020), certification that is informed by regular audits and inspections could encourage international gold buyers to join international investors in supporting fair enforcement of Brazilian environmental legislation, as a way to curb illegal mining supply chain (World Bank 2019). Promisingly, there is growing awareness around this (Nazareno and Laurance 2020). On April 23 2020, an open letter signed by 30 financial institutions holding more than US$ 3.7 trillion total assets (Harris 2020) warned that "the escalating deforestation in recent years, combined with reports of a dismantling of environmental and human rights policies and enforcement agencies, are creating widespread uncertainty about the conditions for investing in or providing financial services to Brazil" (Storebrand Asset Management et al. 2020).

Since 2004, public policies to tackle deforestation in the Amazon were strengthened by the Action Plan to Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) responsible for the creation of protected areas and regulatory instruments (Silva Junior et al. 2020; Siqueira-Gay et al. 2020b). However, since 2018 (Silva Junior et al. 2020), trust in the government's willingness to curb deforestation has drastically decreased, given the roll back of environmental protection legislation in Brazil (Abessa et al. 2019; Ferrante and Fearnside 2019) as well as the continuous erosion of most regulations promoted by the Ministry of the Environment (Pereira et al. 2019). In contrast to present moves towards weakening environmental regulations in Brazil, previous initiatives to tackle mining-driven deforestation in the Amazon have demonstrated the importance of local and regional cooperation to support and implement national policies (Dezécache et al. 2017).

Increasing gold prices (Cherrington et al. 2020) contribute to the prospect of rapidly increasing forest degradation by illegal gold miners in the coming years. Restraining deforestation is unlikely to happen without sustained pressure on investors and consumers for strengthening and expanding international mechanisms to increase traceability of mineral supply chains. Likewise, national support for increasing cooperation between federal and local policies

and instruments is needed to restrain the growth of illegal mining and consequent deforestation in the Brazilian Amazon.

References

Abe CA, Lobo FL, Novo EML, Costa M, Yonas D (2019) Modeling the effects of land cover change on sediment concentrations in a gold-mined Amazonian basin. Reg Environ Chang 19:1801–1813. https://doi.org/10.1007/s10113-019-01513-8

Abessa D, Famá A, Buruaem L (2019) The systematic dismantling of Brazilian environmental laws risks losses on all fronts. Nat Ecol Evol 3:510–511. https://doi.org/10.1038/s41559-019-0855-9

Agência Nacional de Mineração (ANM) (2020) Processos minerários: Sistema de Informação Geográficas da Mineração (SIGMINE). Available at: http://sigmine.dnpm.gov.br/. Accessed Jan 2021

Alliance for Responsible Mining Foundation. (2014) Fairmined standard for gold from artisanal and small-scale mining, including associated precious metals. https://fairmined.org. Accessed Sept 2020

Alvarez-Berríos NL, Aide TM (2015) Global demand for gold is another threat for tropical forests. Environ Res Lett 10:014006. https://doi.org/10.1088/1748-9326/10/2/029501

Asamoah E, Zhang L, Liu G, Owusu-Prempeh N, Rukundo E (2017) Estimating the "Forgone" ESVs for small-scale gold mining using historical image data. Sustainability 9:1976. https://doi.org/10.3390/su9111976

Asner GP, Tupayachi R (2016) Accelerated losses of protected forests from gold mining in the Peruvian Amazon. Environ Res Lett 12:094004. https://doi.org/10.1088/1748-9326/aa7dab

Asner GP, Llactayo W, Tupayachi R, Luna ER (2013) Elevated rates of gold mining in the Amazon revealed through high-resolution

monitoring. Proc Natl Acad Sci 110:18454–18459. https://doi.org/10.1073/pnas.1318271110

Assis LFFG, Ferreira KR, Vinhas L, Maurano L, Almeida C et al (2019) TerraBrasilis: a spatial data analytics infrastructure for large-scale thematic mapping. ISPRS Int J Geo-Information 8:513. https://doi.org/10.3390/ijgi8110513

Calvimontes J, Massaro L, Araujo CHX, Moraes RR, Mello J et al (2020) Small-scale gold mining and the COVID-19 pandemic: conflict and cooperation in the Brazilian Amazon. Extr Ind Soc:1–4. https://doi.org/10.1016/j.exis.2020.08.013

Castilhos Z, Rodrigues-Filho S, Cesar R, Rodrigues AP, Villas-Bôas R et al (2015) Human exposure and risk assessment associated with mercury contamination in artisanal gold mining areas in the Brazilian Amazon. Environ Sci Pollut Res 22:11255–11264. https://doi.org/10.1007/s11356-015-4340-y

Cherrington B, Todorova M, Falcidia L, Tejerina A (2020) Gold report 2020. World Gold Council. https://global-business-reports-2.preview.foleon.com/ie/gbr-gold-report-2020/gold-2020-cover. Accessed Sept 2020

Conselho Indigenista Missionário - CIMI (2018) Violência contra os povos indígenas do Brasil - Dados 2018. 156 p. https://cimi.org.br/2019/09/a-maior-violencia-contra-os-povos-indigenas-e-a-apropriacao-e-destruicao-de-seus-territorios-aponta-relatorio-do-cimi/. Accessed Dec 2020

da Cruz DC, Benayas JMR, Ferreira GC, Santos SR, Schwartz G (2020) An overview of forest loss and restoration in the Brazilian Amazon. New For. https://doi.org/10.1007/s11056-020-09777-3

Dezécache C, Faure E, Gond V, Salles JM, Vieilledent G et al (2017) Gold-rush in a forested El Dorado: deforestation leakages and the need for regional cooperation. Environ Res Lett 12:034013. https://doi.org/10.1088/1748-9326/aa6082

Diniz CG, Souza AADA, Santos DC, Dias MC, Luz NC et al (2015) DETER-B: The new amazon near real-time deforestation detection system. IEEE J Sel Top Appl Earth Obs Remote Sens 8:3619–3628. https://doi.org/10.1109/JSTARS.2015.2437075

Espejo JC, Messinger M, Román F, Ascorra C, Fernandez LE et al (2018) Deforestation and forest degradation due to gold mining in the Peruvian Amazon: a 34-year perspective. Remote Sens 10:1903. https://doi.org/10.20944/preprints201811.0113.v1

Federal MP (2020) Mineração ilegal de ouro na Amazônia: marcos jurídicos e questões controversas. MPF, Brasília

Ferrante L, Fearnside PM (2019) Brazil's new president and "ruralists" threaten Amazonia's environment, traditional peoples and the global climate. Environ Conserv 46:261–263. https://doi.org/10.1017/S0376892919000213

Gastauer M, Souza Filho PWM, Ramos SJ, Caldeira CF, Silva JR et al (2019) Mine land rehabilitation in Brazil: goals and techniques in the context of legal requirements. Ambio 48:74–88. https://doi.org/10.1007/s13280-018-1053-8

Harris B (2020) Investors warn Brazil to stop Amazon destruction. Financ. Times. https//www.ft.com/content/ad1d7176-ce6c-4a9b-9bbc-cbdb6691084f. Accessed Sept 2020

Instituto Nacional de Pesquisas, Espaciais (INPE) (2017) Projeto PRODES Digital: Mapeamento do desmatamento da Amazônia com Imagens de Satélite. http://terrabrasilis.dpi.inpe.br/. Accessed Jan 2021

Kalamandeen M, Gloor E, Johnson I, Agard S, Katow M et al (2020) Limited biomass recovery from gold mining in Amazonian forests. J Appl Ecol 1:11. https://doi.org/10.1111/1365-2664.13669

Lobo FDL, Costa M, Novo EMLM, Telmer K (2016) Distribution of artisanal and small-scale gold mining in the Tapajós River Basin (Brazilian Amazon) over the past 40 years and relationship with water Siltation. Remote Sens 8:579. https://doi.org/10.3390/rs8070579

Nazareno AG, Laurance WF (2020) Investidors can help rein in Amazon deforestation. Sci Lett 369:635–636. https://doi.org/10.1126/science.abd7578

Neri AC, Sánchez LE (2010) A procedure to evaluate environmental rehabilitation in limestone quarries. J Environ Manag 91:2225–2237. https://doi.org/10.1016/j.jenvman.2010.06.005

OECD (2016) OECD due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas. Available at: https://www.oecd.org/daf/inv/mne/OECD-Due-Diligence-Guidance-Minerals-Edition3.pdf

Parrotta JA, Knowles OH (2001) Restoring tropical forests on lands mined for bauxite: examples from the Brazilian Amazon. Ecol Eng 17:219–239. https://doi.org/10.1016/S0925-8574(00)00141-5

Pereira EJ de AL, Ferreira PJS, Ribeiro LC de S et al (2019) Policy in Brazil (2016–2019) threaten conservation of the Amazon rainforest. Environ Sci Pol 100:8–12. https://doi.org/10.1016/j.envsci.2019.06.001

Responsible Jewellery Council (RJC) (2019) Chain of custody standard. https://www.responsiblejewellery.com/wp-content/uploads/RJC-CoC-2017-V2-Standard-2.pdf. Accessed Sept 2020

Responsible Minerals Initiative (RMI) (2020) Minerals Due Diligence. http://www.responsiblemineralsinitiative.org/minerals-due-diligence/. Accessed Sept 2020

Sánchez-Cuervo AM, de Lima LS, Dallmeier F, Garate P, Bravo A et al (2020) Twenty years of land cover change in the southeastern Peruvian Amazon: implications for biodiversity conservation. Reg Environ Chang 20:1. https://doi.org/10.1007/s10113-020-01603-y

Schueler V, Kuemmerle T, Schröder H (2011) Impacts of surface gold mining on land use systems in Western Ghana. Ambio 40:528–539. https://doi.org/10.1007/s13280-011-0141-9

Silva Junior CHL, Pessôa ACM, Carvalho NS, Reis JBC, Anderson LO et al (2020) The Brazilian Amazon deforestation rate in 2020 is the greatest of the decade. Nat Ecol Evol:0–1. https://doi.org/10.1038/s41559-020-01368-x

Sippl K (2020) Southern responses to fair trade gold: cooperation, complaint, competition, supplementation. Ecol Econ 169:106377. https://doi.org/10.1016/j.ecolecon.2019.106377

Siqueira-Gay J, Soares-Filho B, Sánchez LE, Oviedo A, Sonter LJ (2020a) Proposed legislation to mine Brazil's indigenous lands will threaten Amazon forests and their valuable ecosystem services. One Earth 3:1–7. https://doi.org/10.1016/j.oneear.2020.08.008

Siqueira-Gay J, Yanai AM, Lessmann J, Borja D, Canova M et al (2020b) Pathways to positive scenarios for the Amazon forest in Pará state, Brazil. Biota Neotrop 20:e20190905. https://doi.org/10.1590/1676-0611-BN-2019-0905

Solomon M (2020) A nova corrida do ouro na Amazônia. Instituto Escolhas. http://www.escolhas.org/wp-content/uploads/2020/05/TD_04_GARIMPO_A-NOVA-CORRIDA-DO-OURO-NA-AMAZONIA_maio_2020.pdf. Accessed Sept 2020

Sousa R, Veiga M, Van Zyl D, Telmer K, Spiegel S et al (2011) Policies and regulations for Brazil's artisanal gold mining sector: analysis and recommendations. J Clean Prod 19:742–750. https://doi.org/10.1016/j.jclepro.2010.12.001

Souza PF, Xavier DR, Mutis MCS, Mota JC, Peiter PC et al (2019) Spatial spread of malaria and economic frontier expansion in the Brazilian Amazon. PLoS One 14:1–25. https://doi.org/10.1371/journal.pone.0217615

Storebrand Asset Management, KLP, Gjensidige, Sparebank 1 Forsikring, MP Pension, SEB Investment Management, SEB Investment Management, AP4 Fourth Swedish National Pension Fund, Handelsbanken Asset Management, Robeco, ACTIAM, NN Investment Partners, A.s.r, Church Commissioners for England, LGPS Central, Legal and General Investment Management, Brunel Pension Partnership, Boarder to Coast Pension Partnership, BlueBay Asset Management, Surrey Pension Fund, Northern LGPS, The Local Authority Pension Fund Forum, Comgest,

Indep'AM, Domini Impact Investment, Pax World Funds, Sumitomo Mitsui Trust Asset Management, Fram Capital (2020) Open Letter from financial institutions to halt deforestation in Brazil. https://www.actiam.com/49e60f/siteassets/4_verantwoord/documenten/en/open-letter-brazilian-embassy-202006.pdf. Accessed Sept 2020

Swenson JJ, Carter CE, Domec JC, Delgado CI (2011) Gold mining in the Peruvian Amazon: Global prices, deforestation, and mercury imports. PLoS One 6:4. https://doi.org/10.1371/journal.pone.0018875

United States Geological Survey (USGS) (2020) Mineral Commodity Summaries: Gold. https://www.usgs.gov/centers/nmic/gold-statistics-and-information.

World Bank (2019) Forest-smart mining: artisanal & small-scale mining in forest landscapes (ASM). World Bank, Washington DC