Environmental Research Letters

OPEN ACCESS

RECEIVED
23 June 2020

REVISED
5 August 2020

ACCEPTED FOR PUBLICATION
1 September 2020

PUBLISHED
9 October 2020

LETTER

Brazilian amazon indigenous peoples threatened by mining bill

Ana C Rorato[1,2], Gilberto Camara[3], Maria Isabel S Escada[3], Michelle C A Picoli[3], Tiago Moreira[4] and Judith A Verstegen[2]

[1] National Institute for Space Research (INPE), Earth System Science Center, São José dos Campos, 12227-010, Brazil
[2] University of Muenster, Institute for Geoinformatics, Muenster, 48149, Germany
[3] National Institute for Space Research (INPE), General Coordination of Earth Observation (OBT), São José dos Campos, 12227-010, Brazil
[4] Socio-Environmental Institute (ISA), Monitoring of Protected Areas, São Paulo, 01238-001, Brazil

E-mail: ana.rorato@inpe.br

Keywords: indigenous peoples, indigenous lands, mining, policy, amazon

Supplementary material for this article is available online

Abstract

The Brazilian Amazon has the highest concentration of indigenous peoples in the world. Recently, the Brazilian government sent a bill to Congress to regulate commercial mining in indigenous lands. This work analyzes the risks of the proposed mining bill to Amazonian indigenous peoples and their lands. To evaluate the possible impact of the new mining bill, we consider all mining license requests registered in Brazil's National Mining Agency that overlap indigenous lands as potential mining areas in the future. The existing mining requests cover 176 000 km^2 of indigenous lands, a factor 3000 more than the area of current illegal mining. Considering only these existing requests, about 15% of the total area of ILs in the region could be directly affected by mining if the bill is approved. Ethnic groups like Yudjá, Kayapó, Apalaí, Wayana, and Katuena may have between 47% and 87% of their lands impacted. Gold mining, which has previously shown to cause mercury contamination, death of indigenous people due to diseases, and biodiversity degradation, accounts for 64% of the requested areas. We conclude that the proposed bill is a significant threat to Amazonian indigenous peoples, further exposing indigenous peoples to rural violence, contamination by toxic pollutants, and contagious diseases. The obligation of the government is to enforce existing laws and regulations that put indigenous rights and livelihoods above economic consideration and not to reduce such protections.

1. Introduction

The Indigenous Lands (ILs) in the Brazilian Amazon are home to the highest concentration of indigenous peoples in the world, housing close to 355 thousand people divided into more than 150 ethnic groups. Currently, 383 ILs in the Brazilian Legal Amazon[5] region cover more than 1,160,000 km^2, representing 22% of this biome and 98% of the total area of ILs in Brazil. They are territories established by federal jurisdiction to guarantee the land rights of indigenous peoples, their social organization, and the maintenance of their cultural values (Le Tourneau 2015). Besides, these lands are crucial to preserving tropical forests and the ecosystem services they provide (Garnett *et al* 2018, Walker *et al* 2014). In recent years, Brazil's political and economic crisis has resulted in the suppression and weakening of territorial and environmental monitoring institutions (Abessa *et al* 2019, Pereira *et al* 2019). The work of the National Indian Foundation (FUNAI), the federal agency responsible for executing policy and guaranteeing indigenous rights, has been severely hampered by cuts in budgets and staff. Indigenous lands are increasingly under threat from illegal

[5] The so-called Brazilian Legal Amazon (BLA) is a political-administrative region covering approximately 5 million km^2. The BLA comprises the states of Acre (AC), Amapá (AP), Amazonas (AM), Pará (PA), Rondônia (RO), Roraima (RR), Mato Grosso (MT), Tocantins (TO), and part of Maranhão (MA) (Brazilian Executive Power 1966).

actions (Begotti and Peres 2019). As the Brazilian government reduced protections in these areas, loggers, farmers, squatters, and gold miners have extensively established illegal occupation in several ILs in the Amazon. Their action has intensified conflicts, environmental degradation, and is placing indigenous peoples in a vulnerable situation (CIMI 2019). One issue of particular concern is the increasing pressure by the private sector to open ILs for legal mineral exploration (Villen-Perez *et al* 2018, Ferreira *et al* 2014, Begotti and Peres 2020, Coelho *et al* 2017). Intense lobbying action by the mining sector over the Brazilian government is threatening indigenous territories, especially in the Amazon (Agência Câmara de Notícias 2020a, Angelo 2020).

Mining is an activity that causes intense socio-environmental impacts (Hilson 2002, Horowitz *et al* 2018). The mining infrastructure (digs, roads, railways, tailings dams, and waste piles) causes significant environmental damage (Horowitz *et al* 2018). Besides, mineral exploration contaminates waterways, soil, and wildlife through toxic waste and heavy metals released into the environment, threatening the health of and food availability to indigenous peoples (Vega *et al* 2018, CIMI 2019, Horowitz *et al* 2018). In addition, studies show that mining increases deforestation in the Amazon region (Alvarez-Berríos and Aide 2015, Sonter *et al* 2017, Asner and Tupayachi 2017). In mining concession areas, deforestation is three times larger than the average rate of nearby regions and the impacts of mining on deforestation extend up to 70 km beyond the limits of mining concessions (Sonter *et al* 2017).

The intended opening of ILs to mining has the potential to increase the vulnerability of indigenous peoples. Recently, attacks and acts of violence against indigenous peoples have increased; particularly those arising in the context of large-scale projects involving extractive industries (United Nations 2018). According to a recent report published by Global Witness (2020), mining was the sector linked to the most murders of environmental activists and human rights defenders, with 50 killed in 2019. Brazil has the third highest number of murders of environmental defenders. In 2019, of the 24 defenders killed in the country, 10 were indigenous. Like the cases of the murders of the indigenous leadership Emyra Wajãpi, of the Wajãpi ethnic group, in July last year, and of the two Yanomami indigenous youths, in June this year, murdered by illegal gold miners present in their lands (Oiveira 2020, Phillips 2019).

Brazil's 1988 Constitution includes a provision that mining rights in indigenous lands could be granted if regulated by law. Until recently, the political consensus in Brazil considered that the social risks of allowing mining in ILs outweighed possible economic benefits; thus, no law regulating such activities has been approved by the Brazilian Congress. However, Brazil's current government has since come out on the side of the mining sector; it is pressuring the Brazilian Congress to pass a law favoring the mining sector's interests (Agência Câmara de Notícias 2020a, Angelo 2020).

In February 2020, Brazil's president Jair Bolsonaro sent a bill to Congress (Projeto de Lei - PL 191/2020) that regulates the opening of indigenous lands for economic exploration (Brazilian Executive Power 2020). The proposed legislation sets conditions for private activities in these areas with a particular focus on commercial mining. The bill does not cover social, cultural, or health matters. It sets conditions for mining of mineral resources in ILs and financial compensation to indigenous peoples. According to the bill, indigenous populations would be consulted before the start of activities; however, they would have no veto power to extensive mining. Should this legislation be approved, mining would become a significant socio-environmental threat to indigenous peoples and their territories in the future (Villen-Perez *et al* 2018, Horowitz *et al* 2018, Villén-Pérez *et al* 2020).

The mining bill contradicts the Declaration on Rights of Indigenous Peoples of the United Nations (UN), which Brazil has signed (Assembly 2007). Under this Declaration, indigenous peoples have the right to Free, Prior, and Informed Consent, which allows them to agree or reject a project that affects their livelihoods. Such rights are also enshrined in the Indigenous and Tribal Peoples Convention No.169 of the International Labour Organization (ILO 1989), which was ratified by Brazil in 2004. Despite these violations of international treaties to which Brazil is a part of and the rejection of the vast majority of the indigenous peoples to open their lands for mining, there is intense pressure for the bill to be approved by the Brazilian Congress. Given this imminent threat, this work evaluates the risks to the Amazonian indigenous peoples of the proposed mining expansion in their territories and compares it with current illegal mining in these areas.

2. Methods

2.1. Data

2.1.1. Indigenous lands

The polygon data set with limits for all ILs in Brazil was obtained from the FUNAI website (FUNAI 2019). This layer also contains information about the ethnic groups living in each IL.

In this study, we considered all ILs entirely within the Legal Amazon with any legal status. The legal

status refers to the recognition status of the indigenous peoples' rights to land by the State. The recognition process of indigenous territories comprises several steps and generally takes several years. Currently, in the Legal Amazon, 325 ILs are Regularized while the rest is in one of the following recognition stages, listed from the earliest step: In Study (6), Delimited (11), Declared (31), Forwarded with Indigenous Reserve (7), and Homologated (3) (FUNAI 2019). A detailed description of the stages of the indigenous lands recognition process is presented in table A1 in the appendix.

2.1.2. Illegal mining and deforestation in ILs

Data on current mining areas in the Legal Amazon were obtained from the Real-time Deforestation Detection System (DETER) from the Brazilian National Institute for Space Research (INPE) (INPE 2020b). These data refer to evidence warnings of forest cover change between August 2016 to April 2020. Deforested areas are mapped when satellites detect the withdrawal of native forests, then these areas are classified into the following classes: selective cut (geometrical and disordered), degradation (burning scar and degradation), clear-cut deforestation, deforestation with vegetation, and mining (Diniz *et al* 2015). The DETER system operates with a spatial resolution of around 60 m. This resolution allows monitoring with a minimum area of 3 ha mapping. In the present study, we considered only the deforested areas classified as mining in the years fully available (2017, 2018, 2019) to explore the number and area of mining polygons inside ILs. Since mining is prohibited within ILs, all mining polygons are considered to be illegal mining areas. Data on increments of deforestation in the same region and time frame were obtained from Amazon Deforestation Monitoring Program (PRODES) also from INPE (INPE 2020a). The mapping scale of the deforested data from PRODES and DETER, as well as the boundaries of indigenous lands from FUNAI, is 1:250 000.

2.1.3. Potential mining exploitation areas

The mining activity in Brazil is regulated by a process of licensing mediated by Brazil's National Mining Agency (ANM) (ANM 2020). This process encompasses several phases, from mineral research authorization until the final step that configures the approval of licensing to exploitation. A mining request consists of an administrative process applied to ANM, in which an area, geographically delimited by a polygon defined by the applicant, is requested for mineral exploration.

The georeferenced mining requests were obtained from the ANM database on February 17, 2020 (ANM 2020). The polygon data file, publicly available from the ANM, contains all mining processes, approved or under consideration, with their respective information, such as the applicant's name, the mineral to be exploited, and the licensing-process phase it is in. We separated the mining requests processes by this 'phase' attribute, only selecting the polygons in one of the following phases: research requirement, research authorization, availability, mining requirement, gold digger mining requirement, licensing requirement, extraction registration requirement, and right to request mining. Our final selection thus contains all pending mining licensing applications that have not yet been approved.

Although mining is currently forbidden in indigenous lands, there is a large number of applications for mineral exploration licenses in ILs registered in ANM, pending a change in the law. The first mining requests overlapping indigenous lands date back to 1971 (figure A1 in the appendix). It is noteworthy that many of these indigenous lands had not yet been regularized when part of these requests was made. However, even after the regularization of these areas as indigenous lands, requests for mineral exploration remain on the ANM registry and can be approved if the legislation permits.

For comparison of the requested minerals, information on current mineral exports and tax collection were obtained in the Mineral Sector Report-First Quarter 2020, of the Brazilian Mining Institute (Brazilian Mining Institute 2020).

2.2. Estimating indigenous lands and ethnic groups at risk by the potential mining exploitation

To evaluate the possible impact of the new mining bill, we included mining requests that have an overlap of 5% or more with an IL. We consider this minimal overlap between the mining areas and ILs to avoid inconsistencies in georeferencing of the IL and mining requests layers. The two layers, ILs and mining requests were clipped with the boundary of the Legal Amazon region, obtained from the Ministry of the Environment database (Ministry of the Environment 2020). For each IL in the Legal Amazon, the area covered by mining requests is presented in table 1 and table S1 in the Supplementary Material (SM) (https://stacks.iop.org/ERL/15/1040a3/mmedia).

In addition, we evaluated the risk of each ethnic group to be affected by mining. In the Legal Amazon region, 155 ethnic groups are divided over 383 ILs. Different ethnic groups can inhabit a single IL and a single ethnic group can be present in more than one IL. First, we calculated the total territory occupied by each ethnic group considering the sum of the area of ILs inhabited by each group. Thereafter, we calculated the respective area of each group territory covered by mining requests (table S2 in SM).

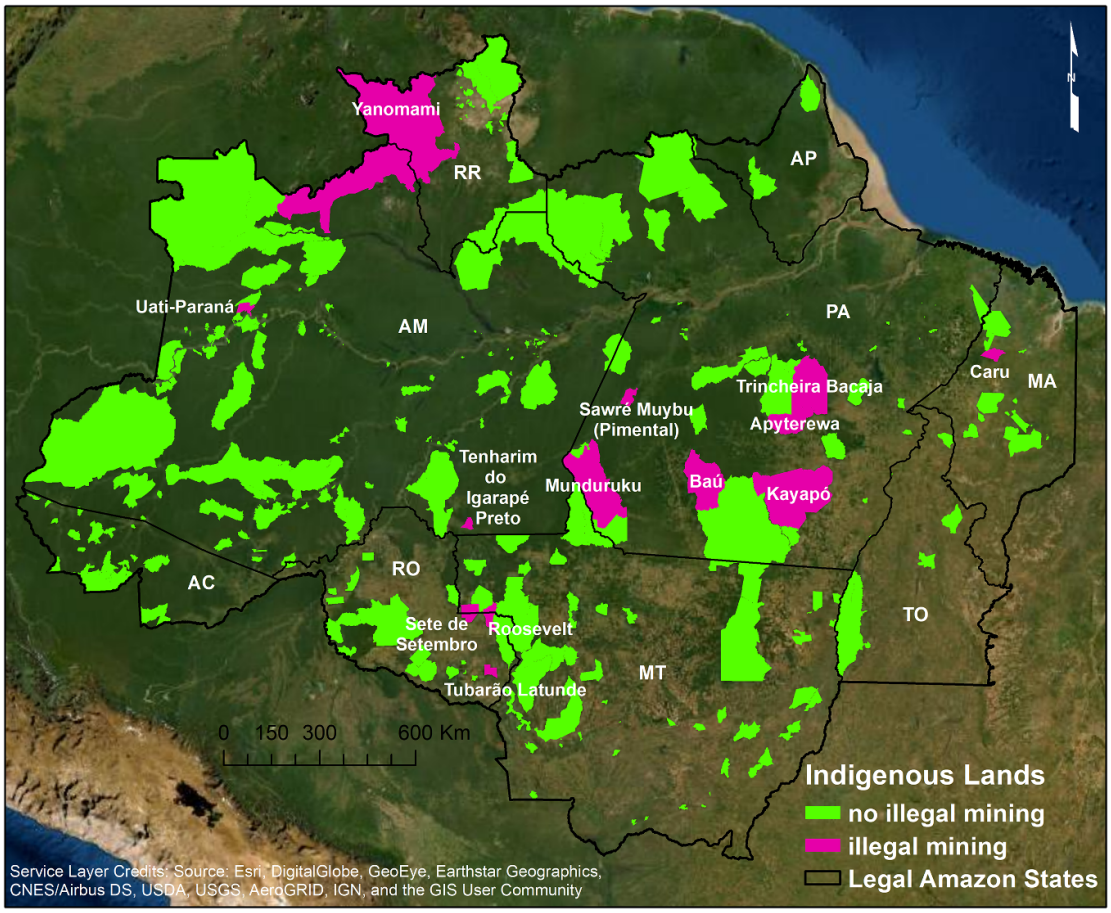

Figure 1. Indigenous lands with illegal mining detected by DETER between 2017–2019. In white are indicated the names of the indigenous lands with illegal mining and the abbreviations of the states of the Legal Amazon region. Data Source: FUNAI (2019), ANM (2020).

In the same way, we also computed the relative contribution of each mineral to be exploited to the total mining requests in the territories of the ethnic groups. For visualization purposes, we only list the 9 minerals with the largest relative area separately while all others are grouped into the 'other' category. To avoid overestimation due to overlapping mining requests, we converted the potential mining polygon data to raster, using the ArcGIS 'polygon-to-raster' tool. In this conversion, the choice of features overlapping the same cell was based on the smallest feature identification (FID) number (i.e. the identification code for all georeferenced mining requests). Since FIDs are given out in order, the lowest FID number refers to the first request of mining in that area. The mining requests registered with ANM can be considered as a kind of 'waiting list' and, once the law is authorized, the list will dictate the priority of the mining companies' requests. Therefore, our approach obtains the mining request most likely to be granted. Next, we applied the 'tabulate area' function in ArcGIS using the raster with the values of the minerals and the vector data of the ILs. Thus, the resulting table provided the area of each mineral in each IL, without overlap (table S2 in SM). All analyzes and maps were conducted using R (R Core Team 2014) and ArcGIS 10.4 (ESRI 2016).

3. Results and discussion

3.1. Current illegal mining in indigenous lands

Currently, mining inside ILs is prohibited. Yet, the encroachment of illegal mining in indigenous territories has been increasing in the last three years (CIMI 2019, INPE 2020b). This activity has been encouraged by the current rise in the value of gold (World Gold Council 2020), the favorable signs from the government, and reduced surveillance of the ILs. According to our analysis of data from the Real-time Deforestation Detection System (DETER), 551 deforested areas classified as mining were detected in 13 Amazonian ILs between 2017 and 2019 (2017 = 92; 2018 = 155; and 2019 = 304) totaling 57.8 km^2 (figure 1 and 2(A)). These ILs are mainly concentrated in the state of Pará (figure 1). The illegal mining that occurs in these ILs is mainly related to artisanal gold-mining (Coelho *et al* 2017, Camargos 2019).

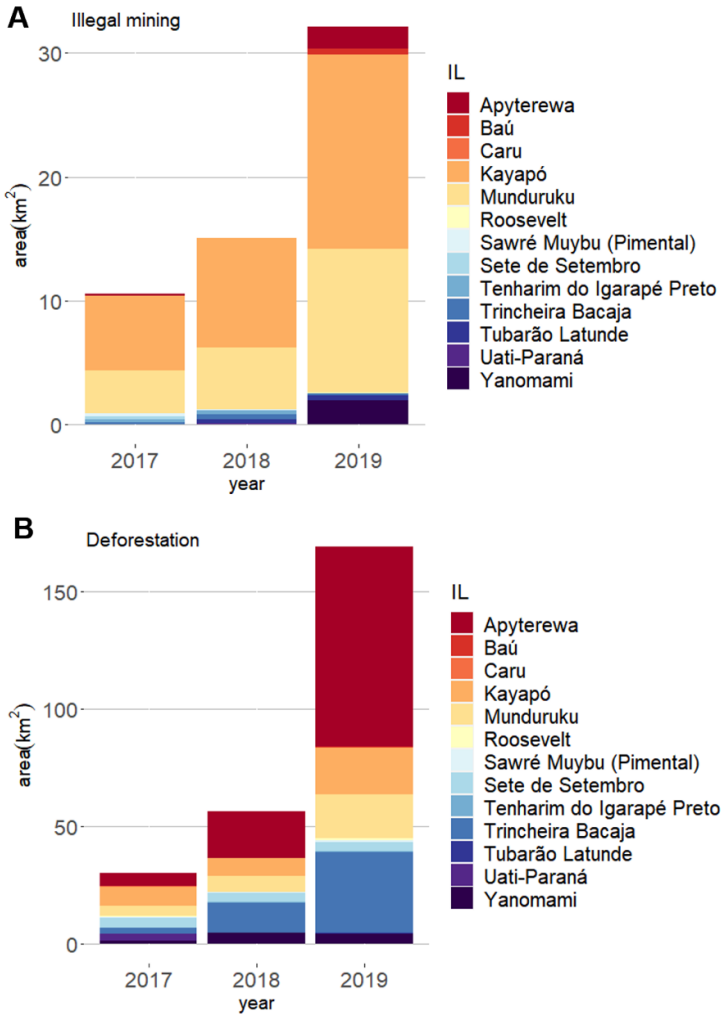

Figure 2. Illegal mining and deforestation within indigenous lands in the Legal Amazon between 2017–2019. Illegal mining areas detected by DETER (A), deforested areas detected by PRODES (B). Data Source: INPE (2020a), INPE (2020b), FUNAI (2019).

The Amazon Deforestation Monitoring Program (PRODES) detected that yearly deforestation increased by 458% between 2017 and 2019 in these ILs, from 30.3 km^2 in the first year to 169.1 km^2 in the latter, totaling 255.6 km^2 in this period (figure 2(B)). Part of these deforested areas represent the direct and short-term impacts of mineral exploration. For example, in Apyterewa IL, deforestation is mainly related to land-use change for agricultural activities by illegal non-indigenous squatters, while, in Kayapó and Munduruku ILs, a large part of deforestation is associated with illegal mining activity. Besides the direct effect of deforestation, the indirect effects of mining have the potential to cause several long-lasting environmental impacts (Horowitz *et al* 2018), such as forest fragmentation and degradation in relatively undisturbed regions with negative impacts on biodiversity (Siqueira-Gay *et al* 2020). The total areas detected by DETER and PRODES for the three years are detailed in tables A2 and A3 in the appendix.

3.2. Indigenous lands potentially affected by mining bill

Given that mining in ILs is prohibited, currently only mining requests outside of ILs are approved (figure 3(A)). To evaluate the possible impact of the new mining bill, we consider all mining license requests (registered in ANM) that overlap ILs as potential mining areas in the future. Until February 2020, no less than 2760 mining requests overlap ILs in the Brazilian Amazon, covering a total area of ≈ 176.9 thousand km^2 (figure 3(B)). Mining requests in ILs represent 6.7% of the total of 41,413 existing requests for the entire Legal Amazon and 17% of the total requested area (figure 3(B)). Considering only these existing requests, about 15% of the total area of ILs in the region could be directly

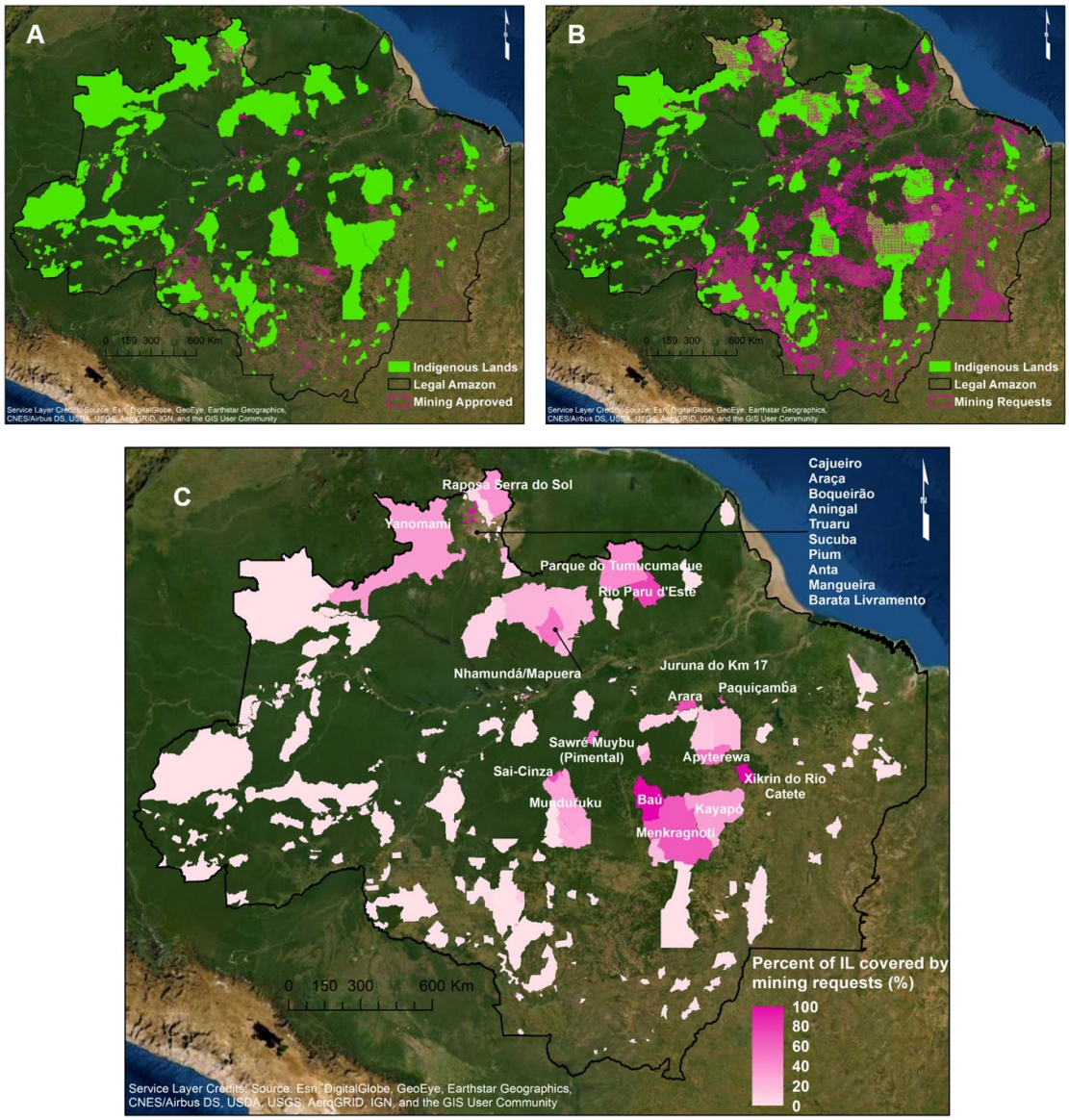

Figure 3. Mining areas in the Legal Amazon region as of February 2020. Approved mining areas (A), requested mining areas (B), and percentage of ILs covered by mining requests (C). Data Source: FUNAI (2019), ANM (2020).

affected by mining if the bill is approved. When compared the total illegal mining area in ILs verified between 2017 and 2019, the proposed new law has the potential to increase the mining area within ILs by 305,728%. In total, 66 ILs have more than 1% of their total area overlaid with requested mining areas. Herein, 16 ILs have more than 80% of their area covered by potential mining areas, 7 ILs have between 60% and 80%, 7 ILs have between 40 and 60%, 12 ILs have between 20 and 40%, and 24 ILs have between 1 and 20%. The Pará (PA) and Roraima (RR) states have the largest area at risk (figure 3(C)).

Four ILs – Cajueiro (RR), Araça (RR), Boqueirão (RR), and Aningal (RR) – have over 98% of their area covered by mining requests (figure 3(C); table 1). Other ILs with substantial potential impact are Truaru (RR), Barata Livramento (RR), Sucuba (RR), Pium (RR), Xikrin do Rio Catete (PA), Anta (RR), Baú (PA) and Mangueira (RR); mining requests overlap 90% or more of these lands. In terms of size (absolute area), the ILs with the highest areas of incidence of mining requests are Yanomami (RR), Menkragnoti (PA/MT), Baú (PA), Parque do Tumucumaque (PA), and Kayapó (PA) (figure 3(C); table 1).

Most indigenous lands where illegal mining was detected by DETER (figure 1) have mining requests inside their limits. Among them, the most affected are Apyterewa IL with 54.5% of its area requested to mining, Baú with 92.4%, Kayapó 33.4%, Munduruku 31.4%, Sawré Muybu (Pimental) 56.8%, and Yanomami 34.4%. The main minerals requested for exploration in these ILs, in terms of relative area and

Table 1. Area and percentage of Indigenous lands covered by mining requests. Only Indigenous lands with an affected area of more than 30% are listed.

Indigenous Lands	Ethnic group	Legal status	Area (km^2)	Requested mining area (km^2)	Requested mining area (%)	Illegal mining area (km^2)
Cajueiro	Makuxí	R	43.04	42.72	99.26	
Araça	Wapixana	R	500.18	494.30	98.82	
Boqueirão	Makuxí, Wapixana	R	163.54	160.89	98.38	
Aningal	Makuxí	R	76.27	74.89	98.19	
Truaru	Makuxí, Wapixana	R	56.53	54.73	96.82	
Barata Livramento	Makuxí, Wapixana	R	128.83	124.48	96.62	
Sucuba	Makuxí	R	59.83	57.37	95.89	
Pium	Wapixana	R	46.08	43.67	94.77	
Xikrin do Rio Catete	Kayapó	R	4 391.51	4 066.06	92.59	
Anta	Wapixana	R	31.74	29.37	92.55	
Baú	Kayapó	R	15 409.30	14 241.10	92.42	0.50
Mangueira	Makuxí	R	40.64	36.85	90.68	
Paquiçamba	Yudjá	DC	157.33	135.14	85.90	
Anaro	Wapixana	R	304.74	258.67	84.88	
Paquiçamba	Yudjá	R	43.84	35.85	81.76	
Raimundão	Makuxí, Wapixana	R	42.77	34.78	81.33	
Juruna do Km 17	Yudjá	FI	23.82	18.51	77.69	
Paukalirajausu	Nambikwára	DL	84.00	64.72	77.05	
Rio Paru d'Este	Wayana, Apalaí	R	11 957.86	9 026.03	75.48	
Sai-Cinza	Mundurukú	R	1 255.52	916.23	72.98	
Arara	Arara do Pará	R	2 740.10	1 915.22	69.90	
Praia do Índio	Mundurukú	FI	0.32	0.21	66.76	
Menkragnoti	Kayapó	R	49 142.55	32 301.12	65.73	
Sawré Muybu (Pimental)	Mundurukú	DL	1 781.73	1 012.14	56.81	0.40
Apyterewa	Parakanã	R	7 734.70	4 218.97	54.55	1.99
Nhamundá/ Mapuera	Hixkaryána, Wai Wai	R	10 495.20	5 700.82	54.32	
Karajá Santana do Araguaia	Karajá	R	14.86	7.88	53.03	
Arara da Volta Grande do Xingu	Arara do Pará	R	255.25	128.87	50.49	
Jauary	Múra	DL	248.31	124.02	49.95	
Parque do Tumucumaque	Wayana, Apalaí	R	30 710.68	13 304.22	43.32	
Raposa Serra do Sol	Taulipáng, Makuxí, Ingarikó, Wapixana	R	17 474.65	6 850.00	39.20	
Yanomami	Yanomámi	R	96 649.75	33 262.77	34.42	1.95
Kayapó	Kayapó	R	32 840.05	10 962.70	33.38	30.48
Munduruku	Mundurukú	R	23 817.96	7 475.00	31.38	20.01

R = Regularized, **DL** = Delimited, **DC** = Declared, and **FI** = Forwarded with IR.

in decreasing order, are gold, iron, copper, silver, and tin. The other ILs with detected illegal mining – Caru, Tenharim do Igarapé Preto, Tubarão Latunde, and Uati-Paraná – do not have mining requests.

3.3. Ethnic groups at risk

Our results indicate that the Yudjá ethnic group is the potentially most affected by mining, with around 87% of territory overlapped by requested mining

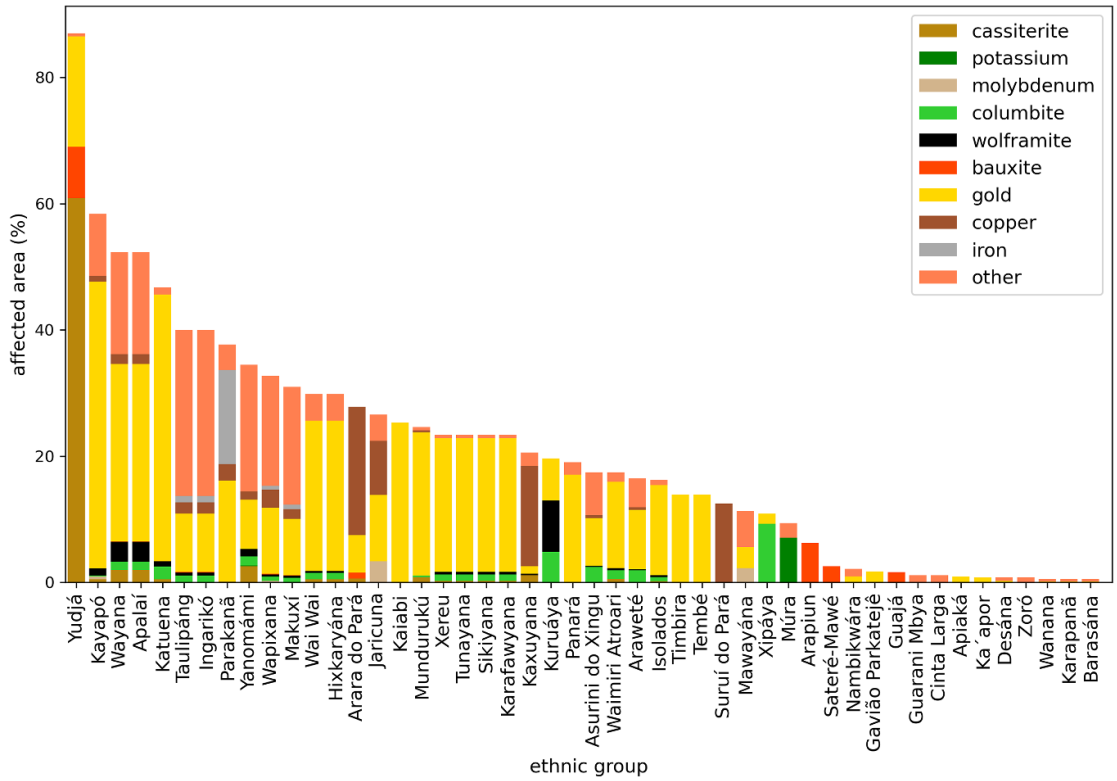

Figure 4. Percentage of ethnic group territories covered by mining requests. Colour indicates the mineral. Only ethnic groups with an affected area of more than 0.5% are shown. Data Source: FUNAI (2019), ANM (2020).

areas (figure 4; table S2 in SM). Other important concerned ethic groups are the Kayapó], Apalaí, Wayana and Katuena indigenous peoples with 58%, 52%, 52%, and 47% of their territories to be affected. In terms of territorial size, the ethnic groups with the highest area of mining requests in their territories are Kayapó with ≈ 62.3 thousand km^2, Yanomami with ≈ 33.3 thousand km^2, Apalaí and Wayana with ≈ 22.3 thousand km^2, and Katuena with ≈ 18.6 thousand km^2.

In total, the mining requests cover 75 different minerals. Around 64% of the total mining area requested within ILs is for gold exploitation, followed by copper (3.7%), columbite (3%), wolframite (2.4%), and cassiterite (2.2%) (figure 4; table S2 in SM). Iron ore, which dominated around 66% of Brazil's mineral exports and 77% of tax collection in the first quarter of 2020, according to the Brazilian Mining Institute (2020), accounted for only 0.76% of the requested mining areas in ILs. In contrast, gold represented 14% of exports and only 6% of total tax collection in the same period.

Up to now, in particular the Munduruku and Kayapó peoples have suffered intensely from illegal mining in their territories (CIMI 2019). Among 551 illegal mining areas detected in indigenous territories between 2017 and 2019, 497 occurred only in the Munduruku and Kayapó ILs in Pará. In the Munduruku IL, there was a 239% increase in the illegal mining area in this period, totaling 20 km^2 (figure 2(A)), spread over 211 different mining areas (INPE 2020b). While in the Kayapó IL, the increase of illegal mining was 161%, totaling an area of 30.5 km^2 distributed over 286 mining areas. Together, Kayapó (35.9 km^2) and Munduruku ILs (29.2 km^2) accounted for 25% of total deforestation in ILs occupied by mining activity in this period (figure 2(B)). Due to the invasions of their territories, without alternatives and in the absence of government protection, the Kayapó and Munduruku peoples are organizing themselves to monitor and expel the illegal miners from their lands. They created groups responsible for patrolling their territories, destroying bridges, and removing machinery used by the invaders, risking their own lives (Camargos 2019).

For the legal mining that may be allowed under the new bill, the Yanomami people are facing 448 mining license requests, the largest number among all ILs. For these people, the strong pressure on their territory through the invasions by gold miners and the negative impacts on the population is an old reality. In the 80 and 90 s, high mortality rates among the Yanomami people were registered due to the transmission of diseases by illegal miners (Le Tourneau 2015, Hilson 2002). Also, recent research has found

that some Yanomami groups are contaminated by mercury, a toxic chemical residue from illegal gold mining in their territory (Vega *et al* 2018). According to DETER, 13 new deforested areas to illegal mining were detected in 2019 and 4 until April 2020. This may be an underestimation, because illegal mining in this IL takes place mainly through ferries and dredges floating in rivers, making detection by remote monitoring systems difficult. As reported in recent months, there are records that around 20,000 gold miners are working illegally in Yanomami IL, increasing the tension of the conflict, the impacts of mining, and the risk of spreading diseases to the indigenous population (Phillips 2020, ISA 2020).

3.4. The road ahead

In countries where mining in indigenous territories has been legalized, such as the United States, Australia, and Canada, several negative impacts have affected indigenous peoples (Horowitz *et al* 2018, Milanez 2020), such as the demographic changes caused by the migration of foreign workers (Hilson 2002), the increased exposure of indigenous peoples to diseases (Hilson 2002, Le Tourneau 2015), a displacement from their territories, the establishment of new frontiers for urban development, and the fact that indigenous people are co-opted to work in mining, resulting in a break in the social dynamics of these peoples (Hilson 2002, Horowitz *et al* 2018, Milanez 2020).

To try to avoid similar problems from what is happening in Brazil, indigenous organizations are articulating themselves to resist. One month after the federal government proposed the mining bill, indigenous leader Davi Kopenawa Yanomami filed a complaint against government violations of the rights of indigenous peoples at the United Nations Human Rights Council (Chade 2020). The complaint aimed to alert the international community about the vulnerable situation of indigenous peoples in Brazil and about the recent threat of the proposed mining bill. Likewise, some indigenous leaders have already met with the president of the National Congress requesting that the mining bill not be voted on (Agência Câmara de Notícias 2020b).

However it is not enough, institutions such as FUNAI and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) must be strengthened and their actions must be strongly supported by the government. Joint inspection operations, punishment, and expulsion of those responsible for illegal mining in indigenous lands must be carried out in an exemplary manner, showing that such activity cannot be admitted in these areas. Complementary, we believe that organized actions by civil society are also important, adopting the values of a market-based society (Nepstad *et al* 2006). For this, it is important to put pressure on large mining companies and other companies that are part of the mineral production chain to join this initiative. The international public opinion combined with civil society is crucial helping to pressure the Brazilian government to avoid legal mining in indigenous lands. The combination of public actions based on a command and control strategy and private supply chain arrangements proved to be highly effective in reducing deforestation rates in the Amazon from 2004 to 2012.

4. Conclusion

Preserving the indigenous lands of the Brazilian Amazon is essential to safeguard the rights of close to 355 thousand indigenous people and their 155 ethnic groups. Their livelihoods and culture have their rights guaranteed in the Brazilian Constitution and various international treaties that Brazil has signed. Still, requested mining areas cover around 176 000 km^2 of indigenous lands. If turned into law, the mining bill proposed by the current Brazilian government is likely to cause major social and environmental degradation in these areas. There is a high risk of land conflicts involving indigenous territories, further exposing indigenous peoples to rural violence, contamination by toxic pollutants, and contagious diseases. Furthermore, substantial environmental impacts in these territories can be expected, such as extensive deforestation, loss of local biodiversity, and contamination of rivers and soil. Financial compensation cannot compensate for the loss of welfare, livelihoods, and the violation of rights of indigenous peoples. Brazil has sound strong environmental legislation. The obligation of the government is to enforce existing laws and regulations that put indigenous rights and livelihoods above economic consideration and not to reduce such protections.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001". As well as, by the Co-financed Short-Term Research Grant Brazil, 2019 (57479963) – A joint agreement between German Academic Exchange Service (DAAD) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). We would also like to thank the support from the Open Access Publication Fund of the University of Muenster.

Appendix A. Tables: A1, A2, and A3, and figure A1

Table A1. Stages of the recognition process of Indigenous Lands in Brazil. Source: FUNAI.

Stage	Description
In study	Conducting anthropological, historical, land, cartographic and environmental studies, which support the identification and delimitation of indigenous land.
Delimited	Lands that had their studies approved by the Funai Presidency, with their conclusion published in the Official Gazette of the Union and the State, and that are in the administrative contradictory phase or under analysis by the Ministry of Justice, for a decision on the issuing of a Declaratory Ordinance traditional indigenous possession.
Declarated	Lands that obtained the expedition of the Declaratory Ordinance by the Minister of Justice and are authorized to be physically demarcated, with the materialization of the landmarks and georeferencing.
Homologated	Lands that have their materialized and georeferenced limits, whose administrative demarcation was approved by Presidential decree.
Regularized	Land that, after the homologation decree, was registered in a Notary's Office in the name of the Union and in the Federal Heritage Secretariat.
Forwarded with Indigenous Reserve	The Indigenous Reserve constitutes a differentiated category of Indigenous Land, mainly due to the way it is acquired by the State and intended for the indigenous population. In this way, this category is out of the stages of the recognition process cited above. The Indigenous Reserves are areas that are in the administrative process of acquisition by the Union (direct purchase, expropriation or donation) intended for the possession and occupation of indigenous peoples; where they can live and obtain means of subsistence, with the right to enjoy and use natural resources, guaranteeing the conditions for their physical and cultural reproduction.

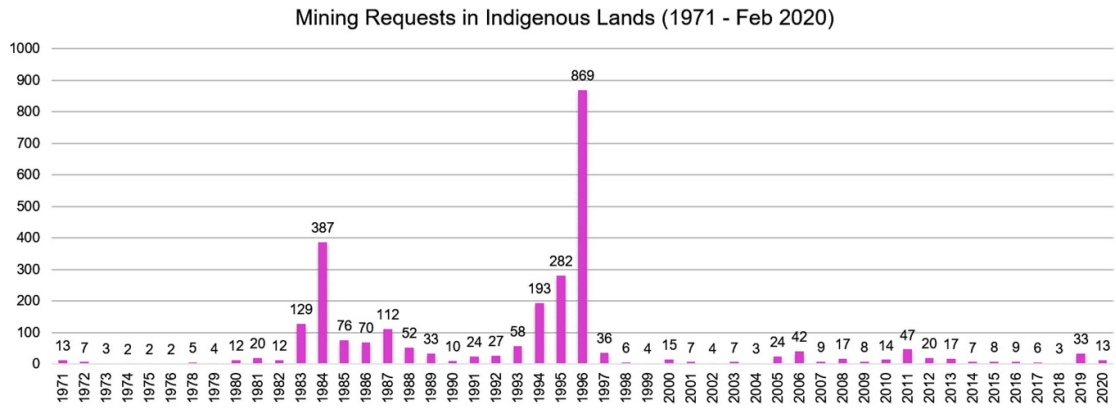

Figure A1. Mining requests in Indigenous Lands in the Amazon between 1971–Feb 2020. Data Source: FUNAI (2019), ANM (2020).

Table A2. The total area of mining polygons (km^2) detected by DETER monitoring in the Legal Amazon region and Indigenous Lands.

Year	Legal Amazon	Total ILs with mining*	Kayapó*	Munduruku*	Other ILS*
2017	52.4	10.6	6.0	3.4	1.2
2018	85.6	15.1	8.8	5.0	1.3
2019	105.6	32.2	15.7	11.6	4.9
total	243.6	57.8	30.5	20.0	7.3

*Indigenous lands in which illegal mining was detected.

Table A3. The total area of deforestation increments (km^2) detected by PRODES monitoring in the Legal Amazon region and Indigenous Lands.

Year	Legal Amazon	Total ILS	Total ILS with mining*	Kayapó*	Munduruku*	Other ILs*
2017	7000	198.1	30.3	8.2	4.3	17.8
2018	7200	260.6	56.2	7.7	6.6	42.0
2019	10 300	429.9	169.1	20.0	18.3	130.7
total	24 500.0	888.5	255.6	35.9	29.2	190.5

*Indigenous lands in which illegal mining was detected.

ORCID iDs

Ana C Rorato https://orcid.org/0000-0002-1532-2016
Gilberto Camara https://orcid.org/0000-0002-3681-487X
Maria Isabel S Escada https://orcid.org/0000-0002-5822-8265
Michelle C A Picoli https://orcid.org/0000-0001-9855-2046
Judith A Verstegen https://orcid.org/0000-0002-9082-4323

References

Abessa D, Famá A and Buruaem L 2019 The systematic dismantling of Brazilian environmental laws risks losses on all fronts *Nat. Ecol. Evolution* **3** 510–11

Aência Câmara de Notícias 2020a Governo e garimpeiros defendem viabilidade ambiental de mineração na Amazônia (*in Portuguese*) https://www.camara.leg.br/noticias/586081-governo-e-garimpeiros-defendem-viabilidade-ambiental-de-mineracao-na-amazonia/ (Accessed 10 June 2020)

Aência Câmara de Notícias 2020b Maia diz a Raoni que não vai pautar projeto sobre mineração em terras indígenas (*in Portuguese*) https://www.camara.leg.br/noticias/590576-maia-diz-a-raoni-que-nao-vai-pautar-projeto-sobre-mineracao-em-terras-indigenas/ (Accessed 10 June 2020)

Alvarez-Berríos N L and Aide T M 2015 Global demand for gold is another threat for tropical forests *Environ. Res. Lett.* **10** 014006

Angelo M 2020 Como o lobby da mineração e do garimpo é recebido com prioridade dentro do Ministério de Minas e Energia (*in Portuguese*) https://observatoriodamineracao.com.br/como-o-lobby-da-mineracao-e-do-garimpo-e-recebido-com-prioridade-dentro-do-ministerio-de-minas-e-energia/ (Accessed 10 June 2020)

ANM 2020 Mining Geographic Information System–SIGMINE www.anm.gov.br/ assuntos/ao-minerador/sigmine (Accessed 17 February 2020)

Asner G P and Tupayachi R 2017 Accelerated losses of protected forests from gold mining in the Peruvian Amazon *Environ. Res. Lett.* **12** 094004

Assembly U G 2007 United Nations declaration on the rights of indigenous peoples (https://waubrafoundation.org.au/wp-content/uploads/2014/06/United-Nations-Declaration-on-the-Rights-of-Indigenous-Peoples.pdf)

Begotti R A and Peres C A 2019 Brazil's Indigenous Lands under Threat *Science* **363** 592–592

Begotti R A and Peres C A 2020 Rapidly escalating threats to the biodiversity and ethnocultural capital of Brazilian Indigenous Lands *Land Use Policy* **96** 104694

Brazilian Executive Power 1966 Law 5.173/1966 (www.planalto.gov.br/ccivil_03/leis/L5173.htm)

Brazilian Executive Power 2020 Bill 191/2020 (https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2236765)

Brazilian Mining Institute 2020 Setor Mineral primeiro trimestre (*in Portuguese*) http://portaldamineracao.com.br/wp-content/uploads/2020/04/PDF_DADOS_1oTRIM20_16ABR20_FINAL.pdf (Accessed 15 April 2020)

Camargos D 2019 In an offensive against indigenous people in Pará, illegal gold miners move billionaire market https://reporterbrasil.org.br/2019/11/em-ofensiva-contra-indigenas-no-para-garimpeiros-ilegais-movimentam-mercado-bilionario/ (Accessed 02 February 2020)

Chade J 2020 ONU e indígenas pressionam por veto a projeto de mineração de Bolsonaro https://noticias.uol.com.br/colunas/jamil-chade/2020/03/02/na-onu-indigenas-gainst Indigenous Peoples in tentam-frear-projeto-de-bolsonaro-de-mineracao-em-reserva.htm (Accessed 10 June 2020)

CIMI 2019 Violence against Indigenous Peoples in Brazil (data for 2018) https://cimi.org.br/observatorio-da-violencia/edicoes-anteriores/ (Accessed 20 January 2020)

Coelho M C, Wanderley L J and Costa R 2017 Garimpeiros de ouro e cooperativismo no século xxi. exemplos nos rios Tapajós, Juma e Madeira no sudoeste da amazônia brasileira *Confins. Revue franco-brésilienne de géographie/Revista franco-brasilera de geografia*

Diniz C G *et al* 2015 DETER-B: The New Amazon Near Real-Time Deforestation Detection System *IEEE J. Selected Topics in Applied Earth Observations and Remote Sensing* **8** 3619–28

ESRI 2016 *Arcgis Desktop 10.4* (Redlands, CA: Environmental Systems Research Institute (ESRI)) https://www.esri.com/arcgis-blog/products/3d-gis/3d-gis/arcgis-10-4-is-here/

Ferreira J *et al* 2014 Brazil's environmental leadership at risk *Science* **346** 706–7

FUNAI 2019 Indigenous Lands / Indigenous Lands in Studies www.funai.gov.br/index.php/shape (Accessed 20 November 2019)

Garnett S T *et al* 2018 A spatial overview of the global importance of Indigenous lands for conservation *Nat. Sustainability* **1** 369–74

Global Witness 2020 DEFENDING TOMORROW: The climate crisis and threats against land and environmental defenders https://www.globalwitness.org/en/campaigns/environmental-activists/defending-tomorrow/ (Accessed 29 July 2020)

Hilson G 2002 An overview of land use conflicts in mining communities *Land Use Policy* **19** 65–73

Horowitz L S, Keeling A, Lévesque F, Rodon T, Schott S and Thériault S 2018 Indigenous peoples' relationships to large-scale mining in post/colonial contexts: Toward multidisciplinary comparative perspectives *Extractive Industries Soc.* **5** 404–14

ILO 1989 C169 – Indigenous and Tribal Peoples Convention *Convention concerning Indigenous and Tribal Peoples in Independent Countries* (Geneva: Int. Labour Organization)

INPE 2020a Amazon Deforestation Monitoring Project (PRODES) http://terrabrasilis.dpi.inpe.br/downloads/ (Accessed 30 April 2020)

INPE 2020b Near Real-Time Deforestation Detection System (DETER) http://terrabrasilis.dpi.inpe.br/downloads/ (Accessed 30 April 2020)

ISA 2020 O impacto da pandemia na Terra Indígena Yanomami (*in Portuguese) Technical report*, Instituto Socioambiental, São Paulo, Brazil

Le Tourneau F M 2015 The sustainability challenges of indigenous territories in Brazil's Amazonia *Curr. Opinion Environ Sustainability* **14** 213–20

Milanez B 2020 Mineração em Terras Indígenas: o que mostra a experiência internacional? https://diplomatique.org.br/mineracao-em-terras-indigenas-o-que-mostra-a-experiencia-internacional/ (Accessed 31 July 2020)

Ministry of the Environment 2020 Brazil geographic data http://mapas.mma.gov.br/i3geo/datadownload.htm (Accessed 17 February 2020)

Nepstad D *et al* 2006 Inhibition of Amazon deforestation and fire by parks and indigenous lands *Conservation Biol.* **20** 65–73

Oiveira V 2020 Brazil: Prospectors Murder 2 Yanomamis over Land www.hlrn.org/news.php?id=p3FraQ==.XySNnyhKjIU (Accessed 31 July 2020)

Pereira E J d A L, Ferreira P J S, de Santana Ribeiro L C, Carvalho T S and de Barros Pereira H B 2019 Policy in Brazil (2016–2019) threaten conservation of the Amazon rainforest *Environmen. Sci. Policy* **100** 8–12

Phillips D 2019 Amazon gold miners invade indigenous village in Brazil after its leader is killed https://www.theguardian.com/world/2019/jul/28/amazon-gold-miners-invade-indigenous-village-brazil-leader-killed (Accessed 31 July 2020)

Phillips D 2020 Like a bomb going off': why Brazil's largest reserve is facing destruction https://www.theguardian.com/environment/2020/jan/13/like-a-bomb-going-off-why-brazils-largest-reserve-is-facing-destruction-aoe (Accessed 02 February 2020)

R Core Team 2014 *R: A Language and Environment for Statistical Computing* (Vienna, Austria: R Foundation for Statistical Computing) www.R-project.org/

Siqueira-Gay J, Sonter L J and Sánchez L E 2020 Exploring potential impacts of mining on forest loss and fragmentation within a biodiverse region of Brazil's northeastern Amazon *Resources Policy* **67** 101662

Sonter L J, Herrera D, Barrett D J, Galford G L, Moran C J and Soares-Filho B S 2017 Mining drives extensive deforestation in the Brazilian Amazon *Nat. Commun.* **8** 1–7

United Nations 2018 Report of the special rapporteur on the rights of indigenous peoples: Attacks and criminalization of indigenous human rights defender *Report* A/HRC/39/17 *Technical report*, United Nations – Human Rights Council

Vega C M, Orellana J D Y, Oliveira M W, Hacon S S and Basta P C 2018 Human Mercury Exposure in Yanomami Indigenous Villages from the Brazilian Amazon *Int. J. Environ. Res. Public Health* **15** 1051

Villén-Peréz S, Mendes P, Nóbrega C, Cortes L G and Marco P D 2018 Mining code changes undermine biodiversity conservation in Brazil *Environ. Conservation* **45** 96–9

Villén-Pérez S, Moutinho P, Nóbrega C C and De Marco P 2020 Brazilian Amazon gold: indigenous land rights under risk *Elem. Sci. Anth.* **8** 1

Walker W *et al* 2014 Forest carbon in Amazonia: The unrecognized contribution of indigenous territories and protected natural areas *Carbon Management* **5** 479–85

World Gold Council 2020 Gold Price and Gold Market Data and Research https://www.gold.org/goldhub/data/gold-prices (Accessed 29 July 2020)