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3 **Mining threatens isolated indigenous peoples in the Brazilian Amazon**

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19 ABSTRACT

20 The largest concentration of isolated indigenous peoples in the world is in the indigenous lands
21 of the Brazilian Legal Amazon. However, the right to self-isolation and the survival of these
22 societies are at risk because powerful interests want to exploit the natural assets of their
23 relatively untouched areas. These ambitions are reflected in a recent bill (PL191/2020), which
24 proposes opening up indigenous lands to mining. We assess the threat imposed by mining to
25 isolated peoples and the indigenous territories they occupy. Specifically, we cross data on
26 mining requests received by the National Mining Agency with information on the distribution
27 of isolated indigenous groups recorded by the Socio-Environmental Institute, in order to
28 evaluate the number and aerial extent of requests for mineral prospecting and operation
29 registered in indigenous lands with isolated groups. We also analyze whether mining requests
30 are related to the presence of isolated groups, the state of knowledge about them, and the
31 current existence of illegal mining operations. Our results indicate that, even though mining is
32 not yet allowed in indigenous lands, mining companies are very active in the search for
33 exploitable areas in these territories. If bill PL191/2020 passes, mining operations would affect
34 more than 10 million hectares in 25 indigenous lands in the Legal Amazon region that are
35 home to 43 isolated groups. We found that the situation is especially worrisome for 21 isolated
36 groups whose lands concentrate 97% of all mining requests. Mineral-rich areas overlap remote
37 areas where more indigenous peoples persist in isolation, so that mining requests are
38 significantly related to the presence of isolated groups. Nonetheless, we show that companies
39 are hesitant to invest in lands with well-known isolated groups that could impede the licensing
40 process and pose reputational risks to the companies. Brazil's mechanisms for environmental
41 and indigenous protection have been dismantled by the current presidential administration
42 and offer no guarantees for a safe coexistence between extractive operations and isolated
43 peoples. Thus, the approval of bill PL191/2020 could lead to undesired contact and the
44 extinction of a large number of unique peoples, societies and cultures.

45

46 Keywords: Amazonia, extractive activities, policy, socio-environmental impact, sustainable
47 development, uncontacted indigenous groups.

48

49 INTRODUCTION

50 The Brazilian Amazon is home to more isolated indigenous societies than any other
51 region on the planet, with at least 120 groups that live isolated from the majority society
52 (Black 1992, Hemming 1978, 2003, Ricardo and Gongora 2019, Leal Filho 2020) and speak
53 approximately 50 native languages (Velden 2010). These indigenous groups lack permanent
54 relations with other societies, either indigenous or not. Many of them are aware of the
55 existence of other societies but have voluntarily chosen to exercise their right to self-isolation
56 as a survival strategy after suffering historical episodes of contact associated with violence or
57 epidemics (OACNUDH 2012, Amorim 2016, FUNAI 2021). Thus, their isolation constitutes
58 express manifestation of their autonomy and their will. Their rights of self-determination and
59 self-isolation are protected in Brazil by the oldest and one of the most robust sets of policies in
60 Latin America. These policies were established in 1987 after the tragic consequences of
61 practices whose paradigm was to contact isolated groups (Amorim 2016). The National Indian
62 Foundation (FUNAI) even has a specific department dedicated to the identification and
63 monitoring of isolated indigenous groups (FUNAI - General Coordination of Isolated and
64 Recently Contacted Indigenous Peoples). In spite of this, these peoples are poorly known: the
65 majority of records are just notifications by third parties, and only one-quarter of them have
66 been verified through overflights or other means by FUNAI (Ricardo and Gongora 2019).

67 The persistence of isolated societies is closely connected to protection of indigenous
68 lands, as three-quarters of the known uncontacted groups occur in these territories (90 of 120
69 groups; Ricardo and Gongora 2019). Indigenous lands were designed to defend the rights of
70 both isolated and non-isolated indigenous peoples and cover 23% of Brazil's Amazon forest
71 (ISA 2019a). Despite their effectiveness in providing protection, indigenous territories have
72 historically been under pressure from the exploitation of their natural resources (Albert 1992,
73 Finer et al. 2008, Zhouri 2010, Bolanos 2011, Ricardo and Gongora 2019). Land invasion for
74 ranching, logging and mining has resulted in undesired contact and the extinction of many
75 indigenous peoples in the past and continues threatening the groups that remain isolated
76 (Walker et al. 2015, 2016, Vaz 2013, CIMI 2018, Leal Filho 2020). One-third of the indigenous
77 lands in the Brazilian Amazon have a registered interest for mining, and the region is one of
78 the world's largest potential suppliers of minerals (Ferreira et al. 2014, Cordani and Juliani
79 2019). Mining in Brazilian indigenous lands is not officially permitted, in spite of which
80 numerous mining requests are continuously sent to Brazil's National Mining Agency (Villén-
81 Pérez et al. 2018, ANM 2021), suggesting that mining companies are confident of future
82 approval. The mining lobby has been pressing since 1996 to get regulating legislation passed,
83 so far without success.

84 In 2020 Brazil's far-right president Jair Bolsonaro submitted bill PL191/2020 to the
85 National Congress that would allow both mining and hydroelectric dams in indigenous lands.
86 The President promised to open up the Amazon for business and specified indigenous lands as
87 the main target (Abessa et al., 2019; Artaxo, 2019). Bolsonaro has repeatedly pledged not to
88 demarcate "a single centimeter" of new indigenous territory and to integrate the indigenous
89 peoples into the Brazilian society; both of these statements flout Brazil's Constitution of 1988
90 and legal obligations under international agreements on human rights to which the country is
91 signatory, including the Indigenous and Tribal Peoples Convention ILO 169 (ILO 1989). While
92 bill PL191/2020 is under discussion in the National Congress, the president is preparing a
93 decree to allow mining by international companies in 177 indigenous lands located near the
94 country's borders, and the USA has been specifically encouraged to invest in this exploitation
95 (Teodoro 2020). The Brazilian government is also supporting legislative proposals that seek to
96 paralyze the demarcation of new indigenous lands (Constitutional Amendment Proposal PEC
97 215) and to reduce already demarcated lands, opening the way for privatization and illegal
98 invasion (PL490/2007). Bill PL490/2007 even opens the door to contact without the consent of

99 isolated indigenous groups in case a given area is considered of *public utility*, a concept wide
100 enough to include any development project, such as mining operations.

101 The Bolsonaro presidential administration has also worked to make environmental
102 policy more permissive and to dismantle government agencies in charge of containing
103 deforestation, conserving biodiversity and protecting indigenous peoples (i.e., IBAMA, ICMBio
104 and FUNAI; ISA 2020, Barbosa et al. 2021). These institutions have been restructured, military
105 officers have been appointed to many of the key positions, and the personnel and budgets
106 have been reduced to the point that their activities have almost completely halted (Ferrante
107 and Fearnside 2020b). This directly threatens the isolated indigenous groups of the Brazilian
108 Amazon (ISA 2020). For instance, authorizations for FUNAI expeditions to indigenous lands
109 have been greatly bureaucratized, hindering *in situ* activities of the agency (INA 2019).
110 Moreover, a total of 35 groups were left unprotected when the official supervision of
111 indigenous lands with incomplete demarcation was cancelled (Biasetto 2019) and when the
112 monitoring bases in the Yanomami and Vale do Javari indigenous lands were shut down
113 (Angelo 2020). In addition, FUNAI has now opened the possibility of contacting isolated groups
114 even during the COVID-19 pandemic, violating their right to self-determination and
115 threatening their health (CIMI 2020). In addition, a former evangelical missionary was
116 appointed to head the FUNAI division for isolated Amazonian indigenous groups (Phillips
117 2020). His previous participation in an extremist sect that focused its activity on contacting
118 isolated indigenous groups makes him an obvious threat to the 120 indigenous groups that are
119 voluntarily isolated in the Brazilian Legal Amazon and could see their numbers decimated due
120 to epidemics derived from contact, whether intentional or not.

121 Mining can affect isolated indigenous peoples in multiple ways. First, extractive
122 operations drive deforestation, reducing the territory usable by isolated groups and boosting
123 the chances of undesired contact (Angelo 2020, Siqueira-Gay and Sánchez 2021, Quijano-
124 Vallejos et al. 2020). About 20% of Brazil's Amazon forest has already been lost (INPE 2020, da
125 Cruz et al. 2020), and approximately 9% of this is due to the direct or indirect consequences of
126 mining (Sonter et al. 2017). Areas surrounding mining operations typically undergo an
127 expansion of urbanization and transport infrastructure, and increased deforestation rates can
128 be perceived up to 70 km from the mining operations (Sonter et al. 2014, 2017). Moreover,
129 demographic changes associated with the arrival of the workforce contribute to the depletion
130 of food resources in the forests and rivers in the area, compromising the livelihoods of the
131 isolated communities (Hilson 2002, Ricardo and Gongora 2019). Mining can also affect isolated
132 peoples through environmental pollution (Fernández-Llamazares et al. 2019). As a result of
133 intensive gold mining, Amazonian people are among the most exposed to mercury in the world
134 and report severe health problems (Passos and Mergler 2008), and there is no reason to
135 expect that these health problems have not reached isolated peoples through polluted waters
136 and food resources. Finally, the invasion of indigenous territories by non-indigenous people
137 brings diseases that can decimate indigenous populations (Walker et al. 2015). Isolated
138 peoples do not have immunity to diseases that are common in the majority society, which
139 means that even a brief contact can provoke a demographic catastrophe, as has repeatedly
140 occurred in the past (Amorim 2016). For instance, the massive recent invasion of the
141 Yanomami Indigenous Land by goldminers has propagated COVID-19, provoking hundreds of
142 indigenous deaths (Ferrante and Fearnside 2020a, Santos et al. 2020, Palamim et al. 2020).
143 Mining could have also driven the infection of isolated groups close to mining operations
144 during the incursions of isolated members that have been reported in mining camps (Ricardo
145 and Gongora 2019, Fellows et al. 2021). Even in the absence of direct interaction, isolated
146 peoples may suffer from regional increases in malaria incidence driven by mining camps (Valle
147 and Tucker-Lima 2014). Thus, opening the door to mining in indigenous lands with isolated
148 groups is expected to result in a chronicle of a death foretold.

149 Given the extended mining interests in indigenous lands, it is obvious that mining
150 poses a threat to the 90 isolated groups that occupy indigenous territories in the Brazilian
151 Legal Amazon (Ricardo and Gongora 2019). However, the exact magnitude of the threat has
152 never been assessed before. This will depend on the spatial coincidence between mining
153 requests and isolated groups, and our hypothesis is that lands occupied by isolated peoples are
154 not necessarily the most attractive for mining companies for various reasons. First, mining can
155 be expected to be more profitable in more-developed regions with better operational and
156 transport infrastructures (e.g., Duffy 2012). These developed regions are less likely to maintain
157 large numbers of isolated groups, given that indigenous peoples have predominantly remained
158 isolated in remote areas (Kesler and Walker 2015). Second, the establishment of mining
159 operations in regions occupied by isolated indigenous groups has the risk to negatively affect
160 the reputation of the company. As a consequence, companies may avert planning mining
161 operations close to isolated groups. Moreover, given the controversy around regulating mining
162 activities in lands with recognized isolated peoples, mining companies may prefer to invest in
163 areas without isolated peoples or where these are poorly known. The controversy started
164 when FUNAI recommended prohibiting mining operations in indigenous lands with isolated
165 groups; a recommendation that was disregarded in bill PL191/2020 (Prazeres 2020). The bill
166 excludes operations only within the perimeter frequented by the isolated groups (PL191/2020,
167 Art. 1 § 2º). The text specifies that FUNAI will be in charge of delimiting this perimeter, but this
168 is very difficult given that only very scant information exists for 60 of the 90 isolated groups
169 identified in the indigenous lands of the Brazilian Legal Amazon to date, and this information
170 does not include any quantification of the territory they occupy (Ricardo and Gongora 2019).
171 In a scenario of policy uncertainty in which bill PL191/2020 is under discussion, mining
172 companies may anticipate greater trouble in obtaining operating licenses in indigenous lands
173 with well-known isolated peoples, which may reduce their interest in these areas.

174 Legal and illegal gold mining play a central role among the mineral commodities
175 exploited in the Amazon (Sonter et al. 2017) and have provoked social and environmental
176 impacts in successive gold-rush periods (Malm 1998, Asner et al. 2013, Kahhat et al. 2019). In
177 2021 the price of gold has reached unprecedented values after increasing by ca. 800% in 20
178 years of successive world crises (Goldprice 2021). The international demand for gold is
179 increasing the pressure on relatively unexploited areas such as the Brazilian indigenous
180 territories (Álvarez-Berríos et al. 2015) and has turned Brazil into one of the top ten producers
181 of gold in the world (Reuters 2020, World Gold Council 2020). Most mining requests in
182 Amazonian indigenous lands are for gold mining (Barros et al. 2016, Rorato et al. 2020), and
183 these territories are currently experiencing an explosion of illegal gold-mining activity (MAAP
184 2020, Nascimento and Faleiros 2020, Yeung 2020). In a scenario of a new gold-rush, the
185 interests of illegal and official mining are expected to coincide, so that illegal gold-mining in
186 indigenous lands should mirror official mining companies' requests. Mining companies could
187 even study the location of illegal activities to identify potentially profitable spots. If this is the
188 case, the approval of PL191/2020 would affect indigenous groups that are currently in a
189 vulnerable situation due to illegal activities.

190 Many researchers have documented the impact that mining and other development projects
191 have historically had on contacted and isolated indigenous peoples of the Amazon (e.g., de
192 Carvalho 1982, Fearnside 1989, Passos and Mergler 2008, Fearnside 2018, Quijano-Vallejos et
193 al. 2020, Ricardo and Gongora 2019, Walker et al. 2015), and have called attention on the
194 pervasive consequences of weakening environmental protection and regulating mining
195 activities in Brazilian indigenous lands (Villén-Pérez et al. 2018, Ferrante and Fearnside 2019,
196 Siqueira-Gay et al. 2020, Villén-Pérez et al. 2020). However, none has analyzed the near-future
197 consequences of these policy changes for isolated indigenous peoples.

198 Here we present the first quantification of the risk that the remaining isolated groups in the
 199 Brazilian Legal Amazon will confront in the near future if mining is legalized in indigenous
 200 lands. We also perform a novel analysis to understand whether the presence of isolated
 201 groups or the level of knowledge about them influences the preference of mining companies
 202 for an indigenous territory. We combine spatially explicit databases on mining requests (from
 203 the National Mining Agency), isolated indigenous groups (from the Socio-Environmental
 204 Institute), and indigenous lands (from FUNAI), to analyze the number and geographical extent
 205 of mining requests on indigenous lands where isolated indigenous peoples have and have not
 206 been reported. First, we test whether the presence of isolated groups is significantly related to
 207 the number of mining requests across all indigenous lands in the Brazilian Legal Amazon. We
 208 then focus on the subset of indigenous lands with isolated groups to assess the relative impact
 209 suffered by each land and to test whether the number of mining requests is related to the
 210 number of isolated groups, to the level of knowledge about these groups and to the previous
 211 presence of illegal mining activities. These results are essential for discussions of bill
 212 PL191/2020 and for developing strategies to mitigate the potential impact of future mining
 213 operations on isolated peoples.

214

215 METHODS

216 *Indigenous lands and isolated indigenous groups*

217 We compiled information on 90 isolated indigenous groups registered in the Brazilian
 218 Legal Amazon's indigenous lands, according to a study by the Socio-environmental Institute
 219 (ISA) (Ricardo and Gongora 2019) that includes all FUNAI records and some derived from ISA's
 220 independent research. The resulting database included: (1) the name of the isolated group; (2)
 221 the indigenous land or lands in which the group is found; and (3) whether there is any reported
 222 impact of illegal wildcat mines (in Portuguese, *garimpos*) affecting the area. Also included was
 223 a classification of isolated groups into three categories based on the level of knowledge about
 224 them: *i) "under information"* records are those that have been registered by FUNAI's General
 225 Coordination of Isolated and Recently-Contacted Indigenous Peoples (CGIIRC/FUNAI) but lack
 226 any further study; *ii) "under study"* records are those registered by FUNAI that have stronger
 227 evidence of truthfulness but still lack a systematic study; and *iii) "confirmed"* records are those
 228 verified by FUNAI through overflights, field expeditions or other means (Ricardo and Gongora
 229 2019, FUNAI 2021). We excluded from this study 32 isolated indigenous groups whose
 230 territories are in the Brazilian Legal Amazon but outside of the boundaries of official
 231 indigenous lands and are located either in conservation units (27 records) or outside of any
 232 protected area (5 records). Finally, we considered that an indigenous land has illegal mining
 233 activity if Ricardo and Gongora (2019) reported that the activity affects any of the isolated
 234 indigenous groups recorded in the indigenous land in question.

235 We combined this database with a spatialized database of all Brazilian Indigenous
 236 Lands obtained from FUNAI (see Suppl. Mat. Figure S-1). This database includes information on
 237 the Regional Coordination of FUNAI in charge of each indigenous land and on the stage of the
 238 demarcation process of the indigenous land (i.e., "under study", "delimited", "declared",
 239 "homologated" or "regularized"). The 90 records of isolated indigenous groups include four
 240 records that correspond to two groups where the same group was reported in two different
 241 indigenous lands. These were considered as independent groups for all analyses performed at
 242 the level of the indigenous land.

243 *Mining requests*

244 We obtained spatialized information on mining requests reported to the National
 245 Mining Agency (ANM 2021) by 28 August 2020. We therefore obtained additional information

246 on those mining operations that are not yet active but are in a planning phase (see Villén-Pérez
 247 et al. [2018] for an interpretation of the different phases of the Brazilian licensing system). We
 248 made a distinction between (1) “research” (mineral prospecting) requests, which seek
 249 permission to investigate the mining interest of an area; and (2) operating requests, which are
 250 asking for permission for operation. These phases are consecutive, so an enterprise is expected
 251 to first investigate the potential of the area and then ask for an operating license. It has been
 252 shown that, upon licensing in Brazilian protected areas, most mining enterprises start their
 253 operations within eight years (Villén-Pérez et al. 2018). These mining requests can therefore
 254 be considered to represent mining planned for the near future.

255 Mining requests located outside indigenous lands were discarded, as were mining-
 256 request polygons located inside indigenous lands but smaller than 1 ha. When a mining
 257 request affected several indigenous lands, it was considered as a separate request in each
 258 land. We found spatial overlapping among mining requests, as well as between mining
 259 requests and mining projects that are already operative (see Villén-Pérez et al. 2018). Overlaps
 260 were corrected in order to avoid overestimating the extent of the affected area. First, the area
 261 of research requests that overlap areas with operative mining was discarded, assuming that
 262 new requests will not progress in locations that are already being exploited. Second, when two
 263 mining requests overlapped, the one in the earlier licensing phase was eliminated (i.e.,
 264 operating requests prevailed over research requests) or either of the two in cases where both
 265 requests were in the same phase. Overlap correction affected only estimates of aerial extent
 266 of mining requests; no correction was applied in assessing the number of requests.

267 *Analysis*

268 We studied 55 indigenous lands in Brazil’s Legal Amazon region in which one or more
 269 isolated indigenous groups had been identified. For each indigenous land, we obtained the
 270 number of mining requests in the research and operating licensing phases and the area that
 271 would be occupied by these activities. We also calculated the size of each indigenous land. The
 272 boundaries of the polygons representing the mining requests delimit the area in which the
 273 mining operation is intended to be established. This area does not include any associated
 274 development such as transportation, urbanization or mineral processing infrastructure. The
 275 number of requests in an indigenous land is highly correlated with their total area of impact
 276 (see results below) so, for the sake of simplicity, we focused on the results for the number of
 277 requests.

278 We tested the relationship between the number of mining requests in indigenous
 279 lands and the presence or absence of isolated indigenous peoples, controlling for the size of
 280 the indigenous land. The sample for this analysis was all of the 386 indigenous lands in the
 281 Brazilian Legal Amazon. The number of mining requests across all indigenous lands follows a
 282 negative binomial distribution, with mean = 12.31, variance = 5256 and theta parameter =
 283 0.098 (standard error = 0.010). We developed a generalized linear model (GLM) specifying the
 284 log link function. The covariance matrix of estimated coefficients was produced using a
 285 method that takes into account the effect of leverage points and the heteroscedasticity of
 286 residuals (Cribari-Neto and da Silva 2011); specifically, we used the *vcovHC* function in the
 287 *sandwich* package in R software, defining type “HC4m.” The generalized variance inflation
 288 factor (GVIF) value was 1.0004 for all predictor variables.

289 We also tested the relationship between the number of mining requests in indigenous
 290 lands and the number of isolated groups, the level of knowledge about isolated groups, and
 291 the presence of illegal mining activity, controlling for the size of the indigenous land. In this
 292 case the sample size was 55 indigenous lands in the Brazilian Legal Amazon with reported
 293 isolated indigenous groups. The level of knowledge of the isolated groups was an ordered
 294 factor with three levels, considering that Confirmed > Under Study > Under Information. The

295 level assigned to each indigenous land was the highest level of knowledge for the isolated
296 groups in that land. The number of mining requests across these indigenous lands follows a
297 negative binomial distribution, with mean = 66.3, variance = 32,569 and theta parameter =
298 0.169 (standard error = 0.040). We developed a generalized linear model and specified the log
299 link function. The covariance matrix of the coefficient estimates was produced using the same
300 method as in the analysis of presence or absence described earlier. GVIF values were 2.59,
301 1.29, 1.37 and 2.62 for the number of isolated groups, the level of knowledge of isolated
302 groups, the presence of illegal mining activity and the size of the indigenous land, respectively.
303 We used ArcGIS version 10.1 (ESRI, 2012) and R Software version 3.6.2 (R Core Team, 2019) for
304 database processing and analyses.

305 RESULTS

306 About half of the indigenous lands that contain isolated groups in the Brazilian Legal
307 Amazon (25 lands, 45%) have registered interest for mining. These lands contain ca. half of the
308 total number of isolated indigenous groups (43 groups, 48%; Figure 1). Eleven of these lands
309 (20% of the total) have more than 50 mining requests (Figure 2) and account for 96.7% of all
310 mining requests (i.e., 3526 requests). These highly threatened indigenous lands contain 21
311 isolated groups (24% of the total). Isolated groups are distributed in indigenous lands all across
312 the Brazilian Legal Amazon, although the indigenous lands with the highest numbers of
313 isolated groups are located in the western half of the region (Figure 3A, Suppl. Mat. Figure S-
314 2). Mining requests are concentrated in indigenous lands in the central and northern parts of
315 the region (Figure 3B).

316 Indigenous lands with isolated indigenous groups have a total of 3645 mining requests
317 occupying 10.6 million ha. Mining requests occupy a substantial portion of some indigenous
318 lands. Specifically, they affect more than 20% of the area of nine lands, occupying up to 82% of
319 a single land (Suppl. Mat. Figure S-3). Most requests (93.5%) are research requests (Suppl. Mat.
320 Figure S-4), and these occupy most of the affected land (95.5%). In each affected indigenous
321 land, the number of mining requests ranges from 1 to 1020 and the total area of impact ranges
322 from 11 ha to 3.3 million ha (Suppl. Mat. Figure S-5). The number of mining requests registered
323 in an indigenous land is highly correlated with the area they occupy regardless of the type of
324 request, considering all requests (Spearman correlation coefficient $\rho = 0.986$; Suppl. Mat.
325 Figure S-6A), only research requests ($\rho = 0.995$, Suppl. Mat. Figure S-5A) or only operating-
326 license requests ($\rho = 0.990$, Suppl. Mat. Figure S-6A).

327 The number of mining requests across all indigenous lands in the Brazilian Legal
328 Amazon is significantly and positively correlated with the presence of isolated indigenous
329 peoples, but not with the area of the indigenous land (Table 1, Figure 4A). This model is
330 globally significant (d.f. = 383, $\text{Chisq} = 58.57$, $p\text{-value} \ll 0.001$), and explains 21.6% of the
331 variation.

332 The number of mining requests in the indigenous lands that contained isolated
333 indigenous groups is significantly and negatively related to the level of knowledge about
334 isolated groups (Table 2, Figure 4B). This model was globally significant (d.f. = 49, $\text{Chisq} =$
335 23.88 , $p\text{-value} \ll 0.001$), and explained the 41.7% of the variation. Illegal mining reported by
336 Ricardo and Gongora (2019) affects 39 isolated groups (43% of the total) located in 21
337 indigenous lands (Figures 1 and 2), although this factor is not significantly related to the
338 number of mining requests in indigenous lands.

339 DISCUSSION

340 Mining companies have declared interest in ca. 10 million ha of indigenous land in the
341 Brazilian Legal Amazon, where 43 indigenous groups persist in isolation. The implementation

342 of these operations is pending approval of bill PL191/2020 that would open up indigenous
343 lands to mining. The situation is especially worrisome for 21 isolated groups whose lands
344 concentrate 97% of all mining requests, and the Yanomami land, which protects seven isolated
345 groups on the frontier with Venezuela, is the most affected in terms of both the number of
346 requests and potential area of impact (Figures 2 and S-5). Mining requests affect 15% of the
347 total extent of the indigenous lands that protect isolated groups in the Brazilian Legal Amazon,
348 a percentage similar to the effect for the complete set of indigenous lands (Rorato et al. 2020).
349 Remarkably, mining requests in some lands leave little space for the original purpose of
350 protecting indigenous rights. This is the case for medium-size lands, such as Xikrin do Rio
351 Catete or Baú, which have reported mining interests that cover ca. 80% of the area.
352 PL191/2020 does not specify any upper limit on occupation of indigenous lands by mining, so
353 these numbers could be achieved if the bill is approved by the National Congress.

354 Mineral-rich areas coincide with those where indigenous groups have persisted in
355 isolation, so that the number of mining requests is significantly correlated with the presence of
356 isolated indigenous groups (Table 1, Figure 4a). Mining requests are concentrated in two parts
357 of the region: one in Roraima state, and the far-northern portions of Amazonas and Pará states
358 and the other in southern Pará (Figure 3b). These areas correspond to the Guiana and Brazilian
359 shields, respectively, which are more mineral rich than the sedimentary areas either along the
360 Amazon River or in Acre and neighboring areas in Amazonas (Klein et al. 2018, Cordani and
361 Juliani 2019). The isolated indigenous peoples are mostly along Brazil's western and northern
362 borders, where there has been relatively little presence of non-indigenous Brazilians as
363 compared to the other parts of the region (Kirby et al. 2006). The areas that have long been
364 exposed to non-indigenous contact along the Amazon River and in the eastern part of the
365 region have few isolated peoples (Figure 3a). Where the concentration of isolated groups and
366 the concentration of minerals intersect, as in the Yanomami Indigenous Land in Roraima and in
367 the Munduruku areas in southern Pará, the result is disastrous. In addition to the shield areas
368 where igneous rocks derived from the cratons result in mineral concentrations, the
369 sedimentary areas are also threatened due to a different mineral attraction: oil and gas. The
370 "Solimões Sedimentary Basin" project now poses a threat to isolated indigenous peoples in the
371 western part of the state of Amazonas (Fearnside 2020a,b,c).

372 Notably, we found that mining companies are hesitant to invest in lands with a
373 confirmed presence of isolated groups (Table 2, Figure 4b). This is probably both because a
374 mining licensing could be more likely to be barred if the project affects well-known isolated
375 peoples and because of greater reputational risk to the companies. The current text of bill
376 PL191/2020 specifies that mining operations will not be allowed within the perimeter
377 frequented by isolated groups, but it does not specify any priority status to isolated groups
378 that are categorized as confirmed, in comparison with those under study or under information.
379 Nonetheless, mining companies may be aware that, at best, FUNAI will be able to provide
380 information about the perimeter used by groups categorized as confirmed, for which more
381 information is available (Ricardo and Gongora 2019, FUNAI 2021). As a consequence, they are
382 avoiding requesting mining licenses in lands with confirmed isolated groups but not in those
383 with groups under study or under information.

384 The behavior of corporations and other economic actors has been the subject of
385 considerable research and theory in the field of economics. One important factor in these
386 decisions is the degree of risk aversion of the different actors, and this is related to the type of
387 risk and the size of the company or other actor that is considering a venture. Larger actors
388 have consistently been found to be less willing to take major risks (e.g., Chen and Lin 1998).
389 This can be expected to be particularly important for reputational risks (Holzman 2020, RMF
390 2000). Damage to a large company's reputation can affect profits in a wide range of the
391 company's activities beyond the specific area of the venture in question. In terms of mining in

392 Amazonia, actors range from individual wildcat gold miners (*garimpeiros*) to large international
393 companies. Wildcat gold miners have little concern for their reputation, but actors applying for
394 prospecting and operational permits are generally corporations. Our finding that applications
395 are significantly less likely to be filed for indigenous areas with well-known isolated groups
396 than in areas either without isolated groups or that lack reliable information on these groups is
397 consistent with the expected effect of reputational risk aversion.

398 This novel result highlights the urgent need to study and confirm the existence of all
399 isolated groups for their protection, first to dissuade companies from investing in their lands
400 and then to be able to provide information about their location if bill PL191/2020 is approved.
401 Even in recent times, new isolated groups are recorded at a much faster rate than they are
402 studied: in the decade from 2006 to 2016, the number of groups under information or under
403 study increased by 36, while only 7 groups were confirmed (Amorim 2016). Only one more
404 group was confirmed by 2019 (Ricardo and Gongora 2019), and this type of FUNAI activity has
405 been almost completely paralyzed since Bolsonaro took office in January 2019 (Ferrante and
406 Fearnside 2020b). Here we empirically demonstrate that the activities of FUNAI's General
407 Coordination of Isolated and Recently Contacted Indigenous Peoples and non-governmental
408 organizations such as the Socio-Environmental Institute (ISA) are essential for the protection of
409 isolated indigenous groups. We therefore urge the government to provide the operational and
410 financial conditions to the National Indian Foundation to keep on studying the 91 unconfirmed
411 records of isolated indigenous groups in the Brazilian Legal Amazon.

412 Our results indicate that, even though mining is not yet allowed in indigenous lands,
413 mining companies are very active in the search for exploitable areas (see proportion of
414 research requests in Suppl. Mat. Figures S-3 and S-4). It seems that these companies want to
415 be well-positioned for the opening of indigenous lands to mining (Angelo and Jordan 2020).
416 Even though the pressure on indigenous lands is lighter than is the case for conservation units
417 (protected areas for biodiversity) where mining activity is explicitly permitted (Villén-Pérez et
418 al. 2018), it seems that the costs of investing in indigenous lands are seen as financially
419 justified. Government policy positions and decisions are key to protecting isolated indigenous
420 groups. Illegal invasions and mining in indigenous lands increased greatly in 2019, 2020 and
421 2021, together with deforestation rates (HRW 2019, da Cruz et al. 2020, Angelo 2020, INPE
422 2020, MAAP 2020b). The increase stems from the general lack of supervision in the Amazon
423 together with the perverse discourse of Brazil's President and his Environmental Minister
424 (Ferrante and Fearnside 2019, Jornal Nacional 2020). Hundreds of indigenous leaders and
425 scientists have raised their voices against President Bolsonaro's policies, illegal mining and bill
426 PL191/2020, which they consider to be a project for genocide, ethnocide and ecocide (de
427 Almeida et al. 2019, Fórum de Lideranças Yanomami e Ye'kwana 2019, Forsetto 2020,
428 Hutukara Associação Yanomami 2020, INPE 2020, Raoni 2020, SBPC and INPA 2020, UNIVAJA
429 2020, <https://www.foragarimpoforacovid.org/>). Isolated indigenous peoples are even more
430 vulnerable to human-rights violations (ISA 2020, Phillips 2020) and to the consequences of
431 pandemics such as the COVID-19 (Ferrante and Fearnside 2020a, COIAB 2020, Wallace 2020).

432 We initially hypothesized that official mining requests would coincide with illegal
433 mining spots, increasing the pressure on areas that are already suffering the impact of illegal
434 activities, but our results show that this is not a generalizable pattern (Table 2). For instance,
435 the Vale do Javari Indigenous Land, which protects 16 isolated groups, has been repeatedly
436 invaded by illegal miners (UNIVAJA 2020) even though there are no official mining requests
437 registered for this territory. This decoupling may be explained because illegal mining focuses
438 on a smaller set of minerals than industrial mining run by companies and, as a consequence,
439 their distributions do not necessarily overlap (Quijano-Vallejos et al. 2020). Nonetheless,
440 special attention should be paid to the territories where mining requests do add to current
441 illegal mining. The most striking example is the Yanomami land, which has historically suffered

442 from illegal mining invasions. Mortality during a massive invasion of this land by wildcat
 443 goldminers, best known for the 1993 Haximu massacre, left a clear mark on the demographic
 444 structure of the surviving Yanomami (Nilsson and Fearnside 2017). In 2021 the Yanomami are
 445 facing a new large-scale invasion by illegal gold miners (Montel 2021). They have asked for
 446 help in their struggle against the invasion of miners and the associated risks of epidemics (ISA
 447 2019b; Fora Garimpo, Fora Covid 2021), but are “utterly abandoned” by Brazilian government
 448 authorities in facing this threat (Branford 2020). Isolated groups in the Yanomami Indigenous
 449 Land may be at high risk of contact, as airstrips for illegal mining and miners are reported to be
 450 only 5 km away from some of them (Ricardo and Gongora 2019, Palamim et al. 2020).

451 CONCLUSION

452 Here we show that, if bill PL191/2020 is passed, indigenous lands of the Brazilian Legal
 453 Amazon could be legally invaded for mining and other activities, even to the point of
 454 completely occupying many of these territories (Villén-Pérez et al. 2018). This would cause
 455 incalculable damage not only to indigenous peoples but also to the ecosystem services
 456 provided by these protected forests (Siqueira-Gay et al. 2020). For the first time, we have
 457 quantified the threat that mining imposes to isolated peoples in the Brazilian Amazon in the
 458 near future. Indigenous lands with isolated groups are threatened by more than 3600 mining
 459 requests to date, and the National Mining Agency of Brazil is working to attract even more
 460 investors (Angelo and Jordan 2020). Interest in Brazil’s indigenous lands is expected to peak if
 461 mining activity is officially allowed, as occurred in the Amazonian portions of neighboring
 462 countries (Quijano-Vallejos et al. 2020). Even though Brazil has robust policies aimed at
 463 protecting isolated indigenous peoples, governance difficulties in the Amazon have been
 464 aggravated in the current Brazilian political scenario, and there is no guarantee of a safe
 465 coexistence between mining operations and isolated indigenous peoples. Moreover, we have
 466 demonstrated that the paralysis of the activities of FUNAI put them at risk on the long-term,
 467 because the now-paralyzed study of isolated groups serves to protect them. Our results
 468 indicate that the government should invest in studying the locations and vulnerabilities of the
 469 isolated indigenous groups reported in the Brazilian Legal Amazon before permitting any
 470 increased development pressure that could result in undesired contact and consequent
 471 extinction of unique peoples, societies and cultures.

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- 744

745 **Table 1.** Results of the GLM model for the number of mining requests across all indigenous
746 lands in the Brazilian Legal Amazon. * = significant effect.

	<i>d.f.</i>	<i>Estimate</i>	<i>Std. Error</i>	<i>z value</i>	<i>Pr(> z)</i>
<i>Intercept</i>	383	3.014	0.316	6.189	$< 2 \cdot 10^{-16}$ *
<i>Isolated indigenous peoples (Presence Absence)</i>	383	-1.591	-6.102	-5.480	$< 2 \cdot 10^{-16}$ *
<i>Size of Indigenous Land (ha)</i>	383	$-8 \cdot 10^{-11}$	-0.936	1.587	0.349

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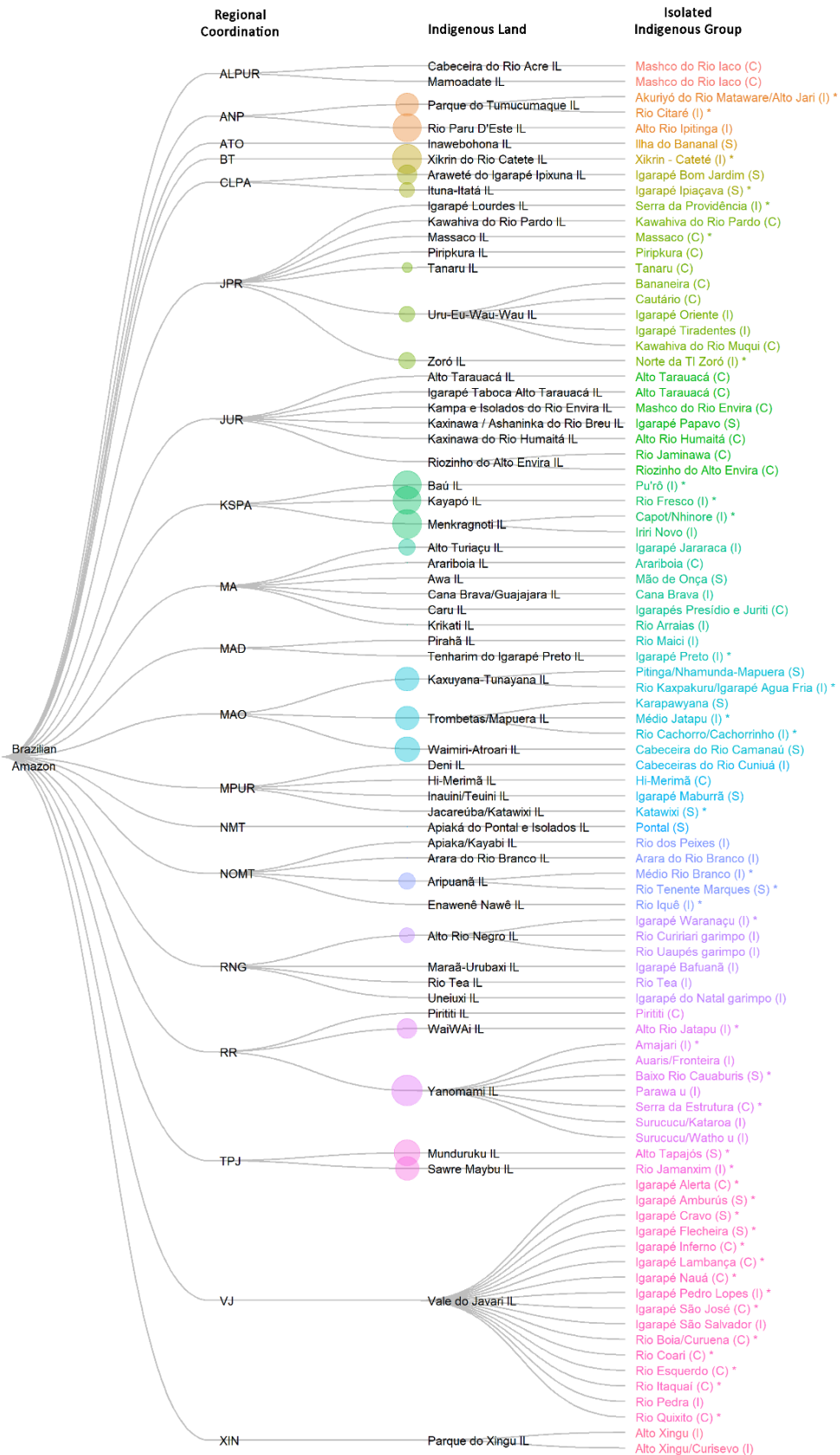
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750 **Table 2.** Results of the GLM model for the number of mining requests across indigenous lands
751 in the Brazilian Legal Amazon with isolated indigenous groups. * = significant effect.

	<i>d.f.</i>	<i>Estimate</i>	<i>Std. Error</i>	<i>z value</i>	<i>Pr(> z)</i>
<i>Intercept</i>	49	1.460	1.030	1.417	0.156
<i>Number of isolated indigenous groups</i>	49	-0.155	1.008	-0.153	0.878
<i>Knowledge of isolated groups (Under study Confirmed)</i>	49	-2.761	0.661	-4.179	$< 2 \cdot 10^{-16}$ *
<i>Knowledge of isolated groups (Under information Under study)</i>	49	-0.158	0.484	-0.327	0.744
<i>Illegal mining (Presence Absence)</i>	49	-0.506	0.436	-1.159	0.246
<i>Size of Indigenous Land (ha)</i>	49	$8 \cdot 10^{-7}$	$4 \cdot 10^{-7}$	2.063	0.039

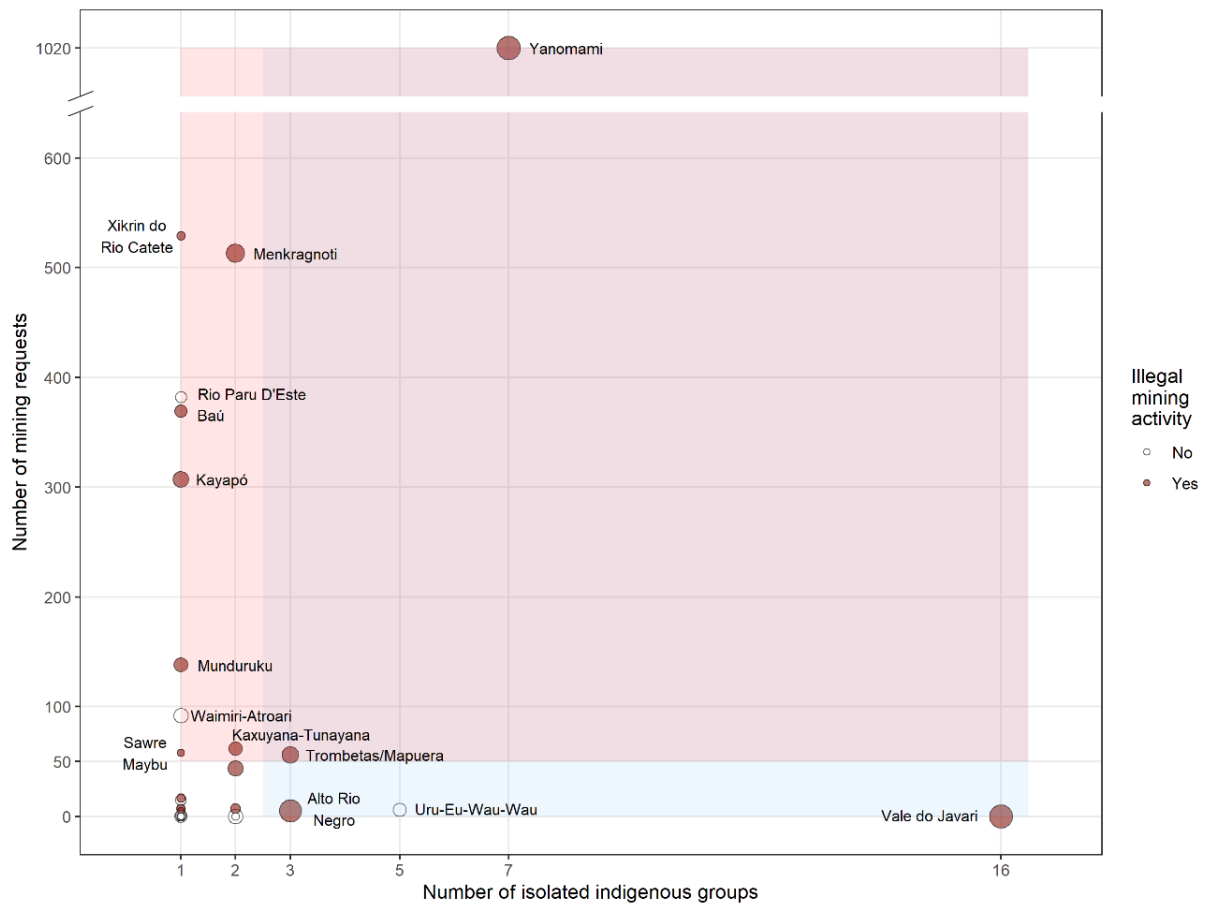
752



Number of mining requests 1 10 100 1000 1020

754 **Figure 1.** Number of mining requests in indigenous lands in the Brazilian Legal Amazon that
 755 contain isolated indigenous groups. Indigenous lands are grouped by the FUNAI Regional
 756 Coordination in charge (see complete names in Suppl. Mat. Figure S-1). Isolated groups are
 757 classified into three categories: “confirmed” (C), “under study” (S) and “under information” (I).
 758 Asterisks indicate whether illegal mining activity has been previously reported in the isolated
 759 group’s territory. Mining requests include both research and operating-license requests.

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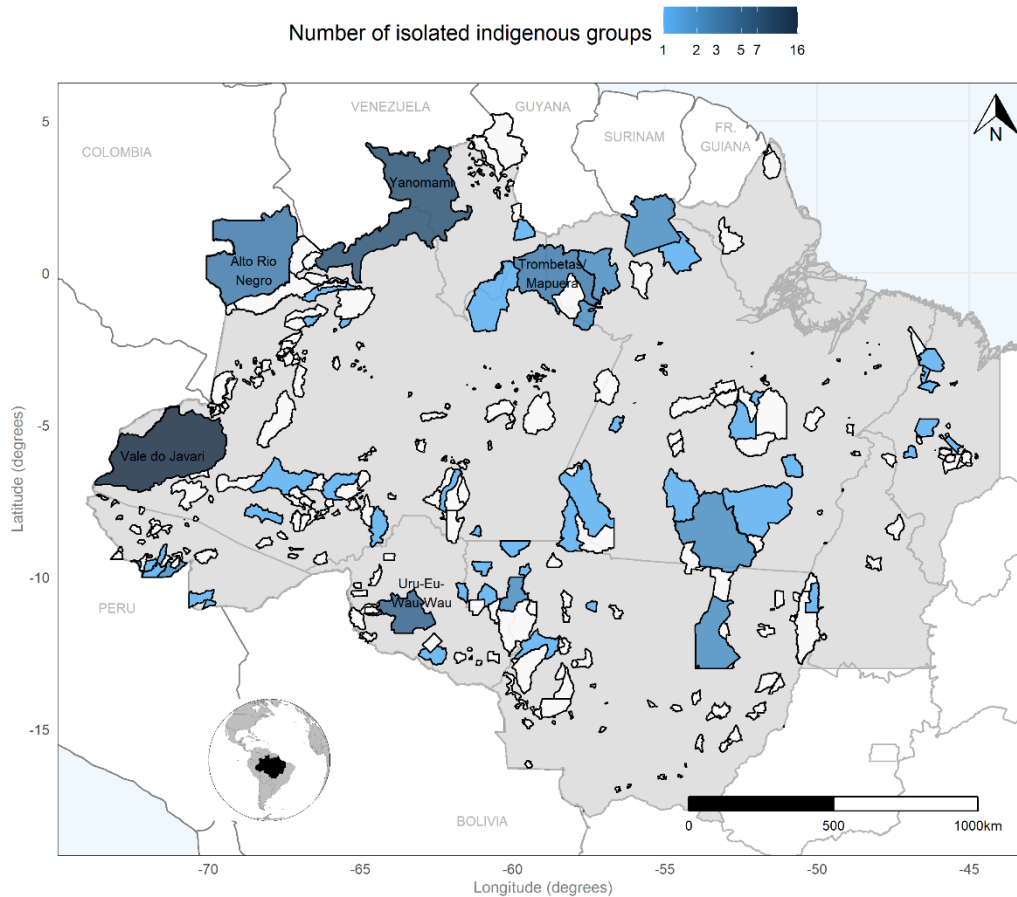


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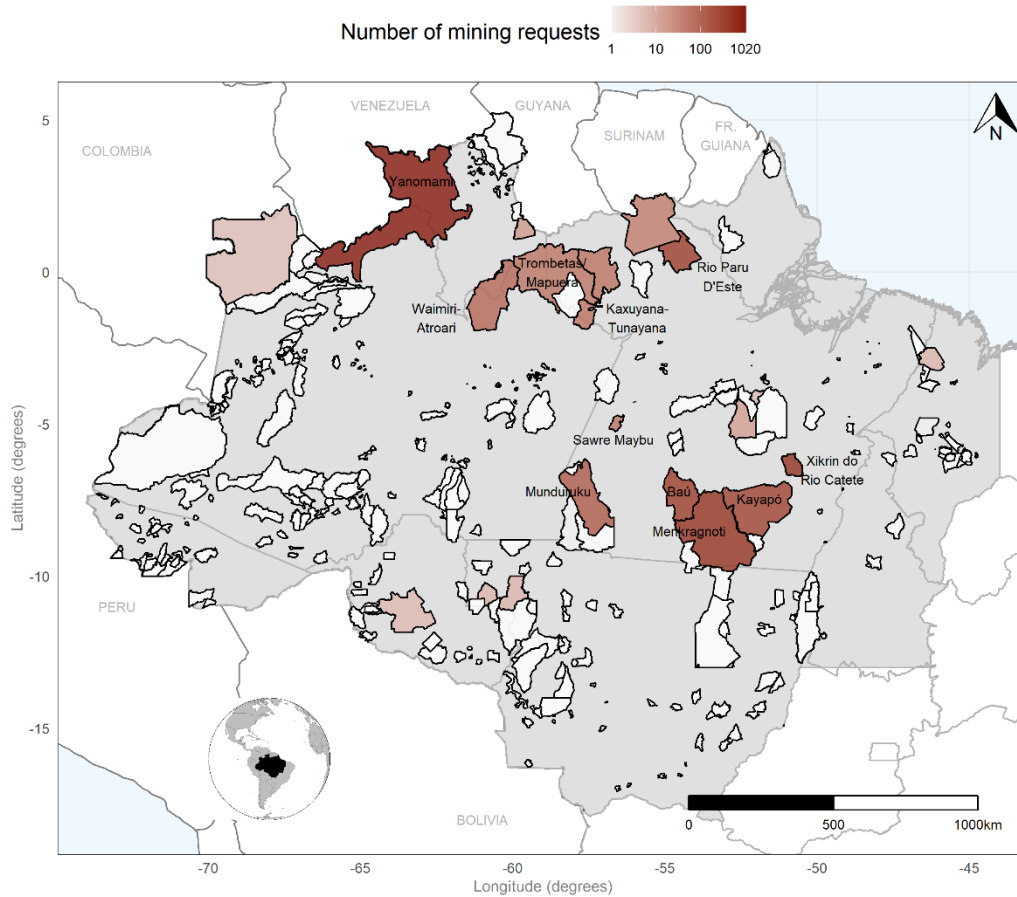
762 **Figure 2.** Relationship between the number of mining requests in indigenous lands and the
 763 number of isolated indigenous groups reported in these territories. Each point represents an
 764 indigenous land, and the size of the point is proportional to the area of the territory. Red
 765 points indicate indigenous lands where illegal mining activity has been reported. The red area
 766 highlights the region with over 50 mining requests; the blue area highlights the region with 3
 767 or more isolated groups; the purple area shows the region that met both conditions.
 768 Indigenous lands falling within the limits of any of these rectangles are labeled.

769

A

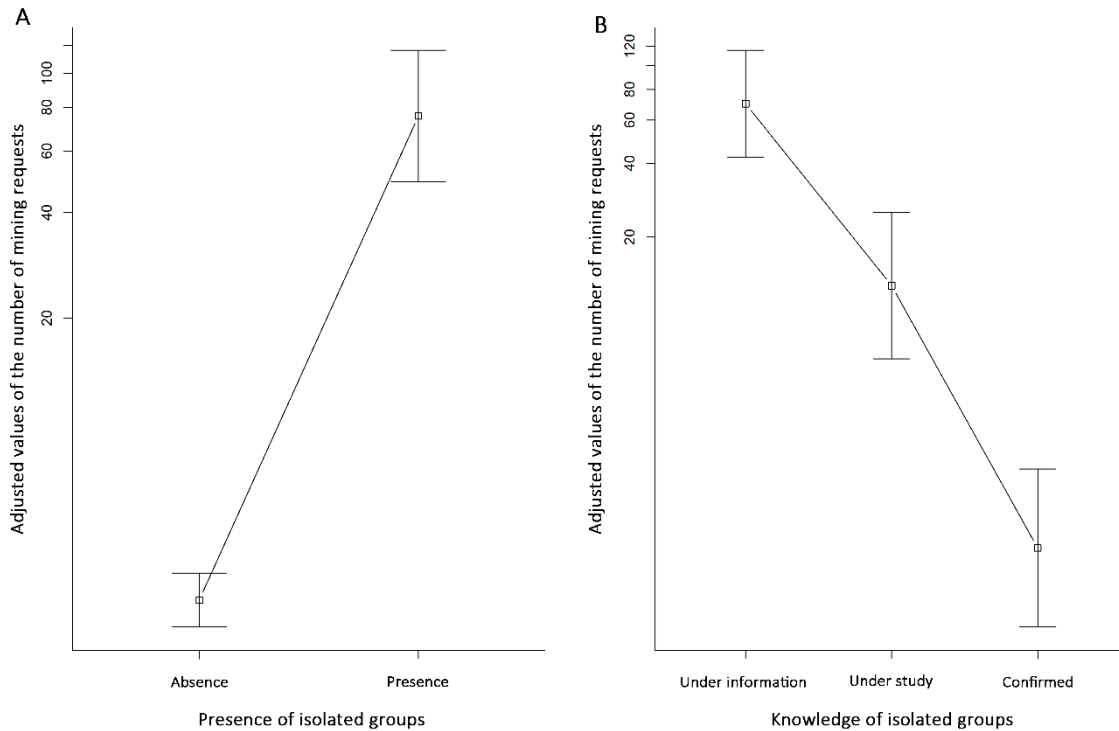


B



771 **Figure 3.** Geographical distribution of indigenous lands in the Brazilian Legal Amazon, the
 772 number of isolated indigenous groups (blue, top) and the number of mining requests (red,
 773 bottom). Indigenous lands with no isolated groups are in white in both maps. The Legal
 774 Amazon region is in gray. Indigenous lands with >3 isolated groups or >50 mining projects are
 775 labeled.

776



777

778 **Figure 4.** Partial effects of significant factors affecting the number of mining requests in all 386
 779 indigenous lands in the Brazilian Legal Amazon (A) and in 55 indigenous lands in the Brazilian
 780 Legal Amazon with reported isolated indigenous groups (B). A) Adjusted values for the
 781 presence or absence of isolated groups in the indigenous land. B) Adjusted values for the three
 782 levels of knowledge of indigenous isolated groups. Squares and intervals represent adjusted
 783 means and standard errors, respectively. The level of knowledge of the isolated group
 784 indicates the highest level of knowledge of the isolated groups in the indigenous land,
 785 considering that Confirmed > Under Study > Under Information.

786

Mining threatens isolated indigenous peoples in the Brazilian Amazon

SUPPLEMENTARY MATERIAL

SM Fig. S-1. Geographical distribution of indigenous lands with isolated indigenous groups and with no isolated groups.

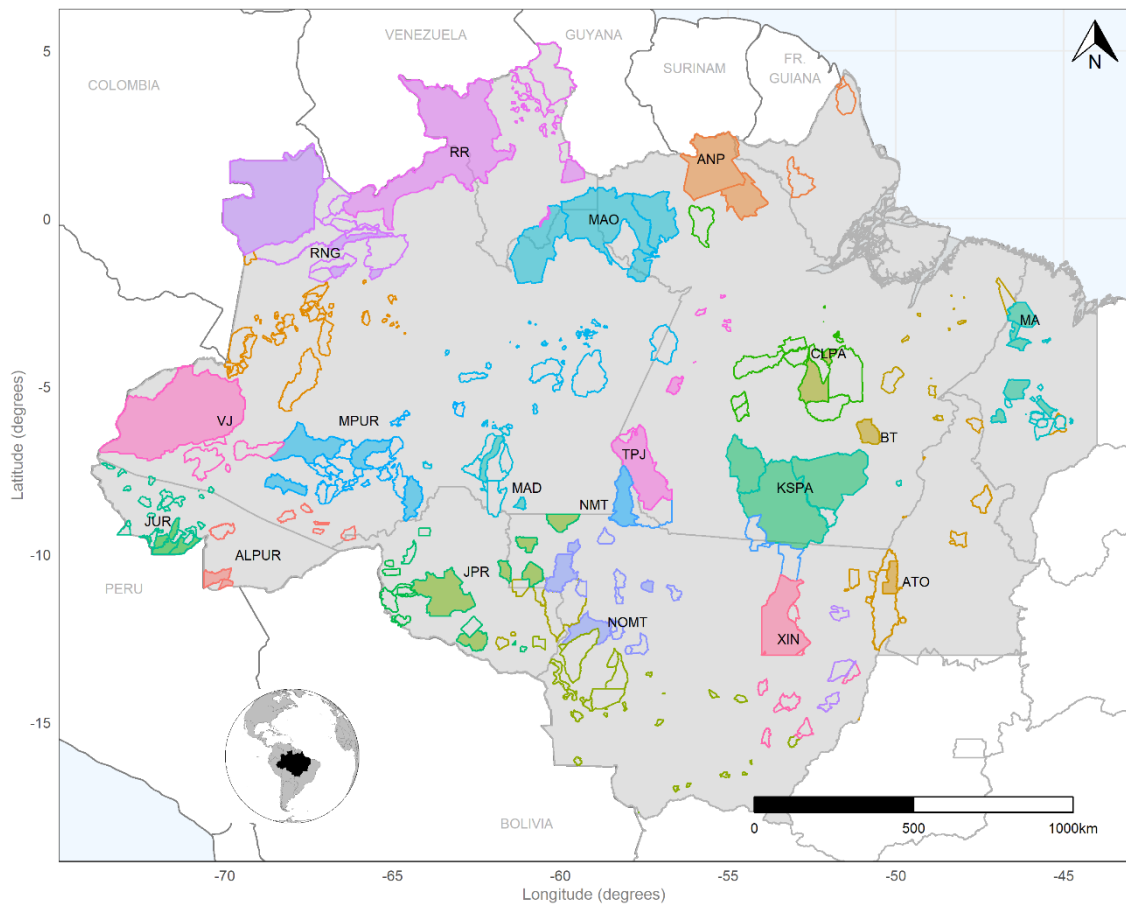
SM Fig. S-2. Geographical distribution of isolated indigenous groups under information, under study and confirmed within indigenous lands in the Brazilian Legal Amazon.

SM Fig. S-3. Percentage of the area of indigenous lands in the Brazilian Legal Amazon with reported isolated indigenous groups that is affected by mining requests.

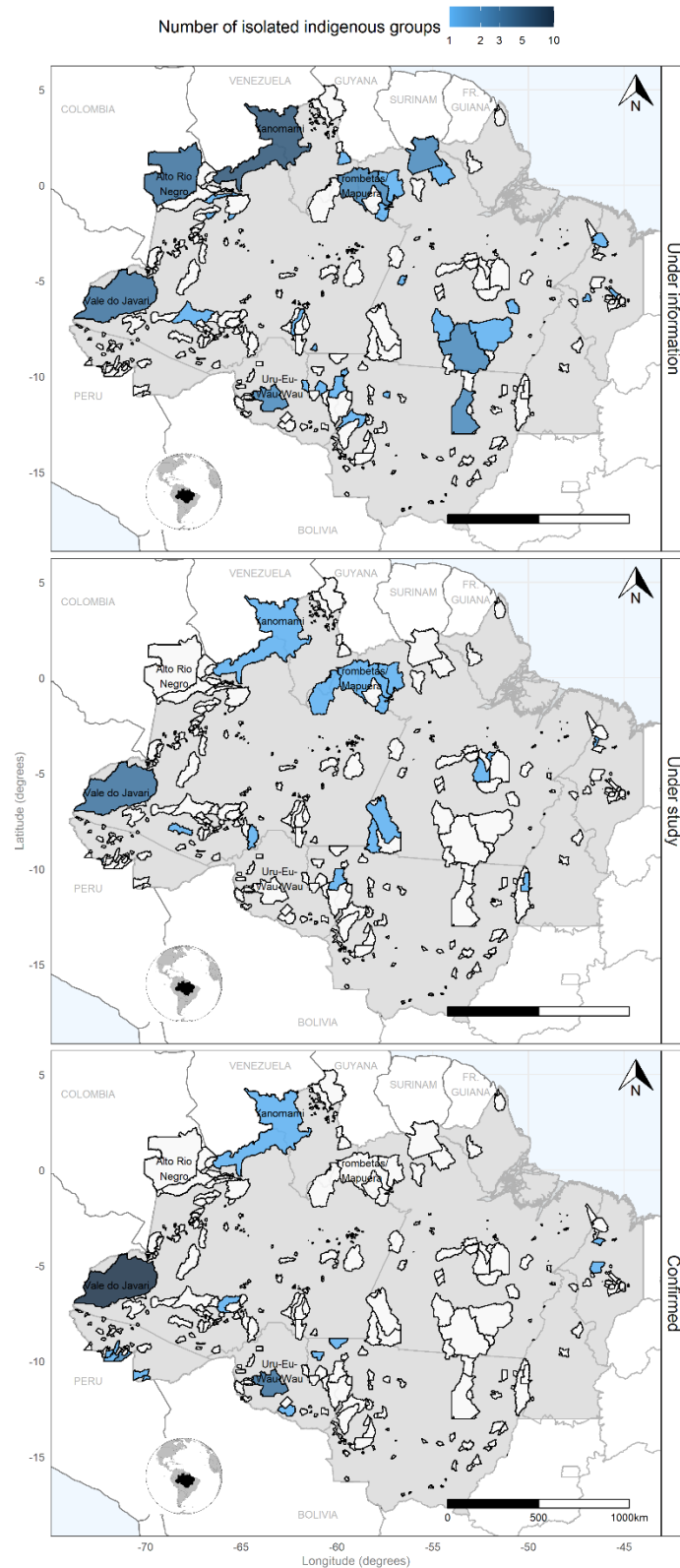
SM Fig. S-4. Number of research and operating-license requests in eleven indigenous lands that have more than 50 mining requests.

SM Fig. S-5. Number and area of mining research and operating-license requests in indigenous lands that have reported isolated indigenous groups.

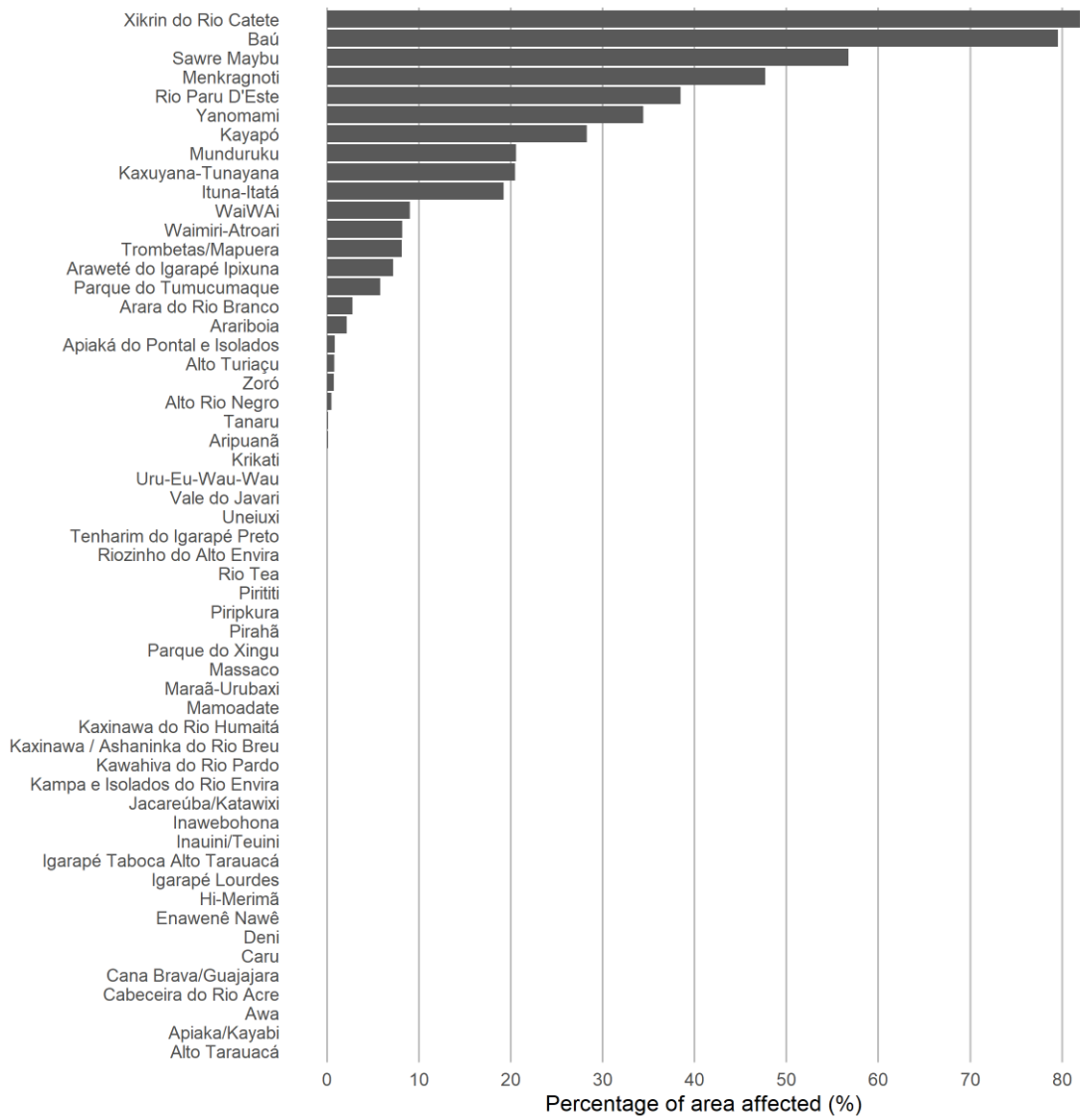
SM Fig. S-6. Correlation between the number of mining requests and their area of impact in indigenous lands that contain isolated groups.



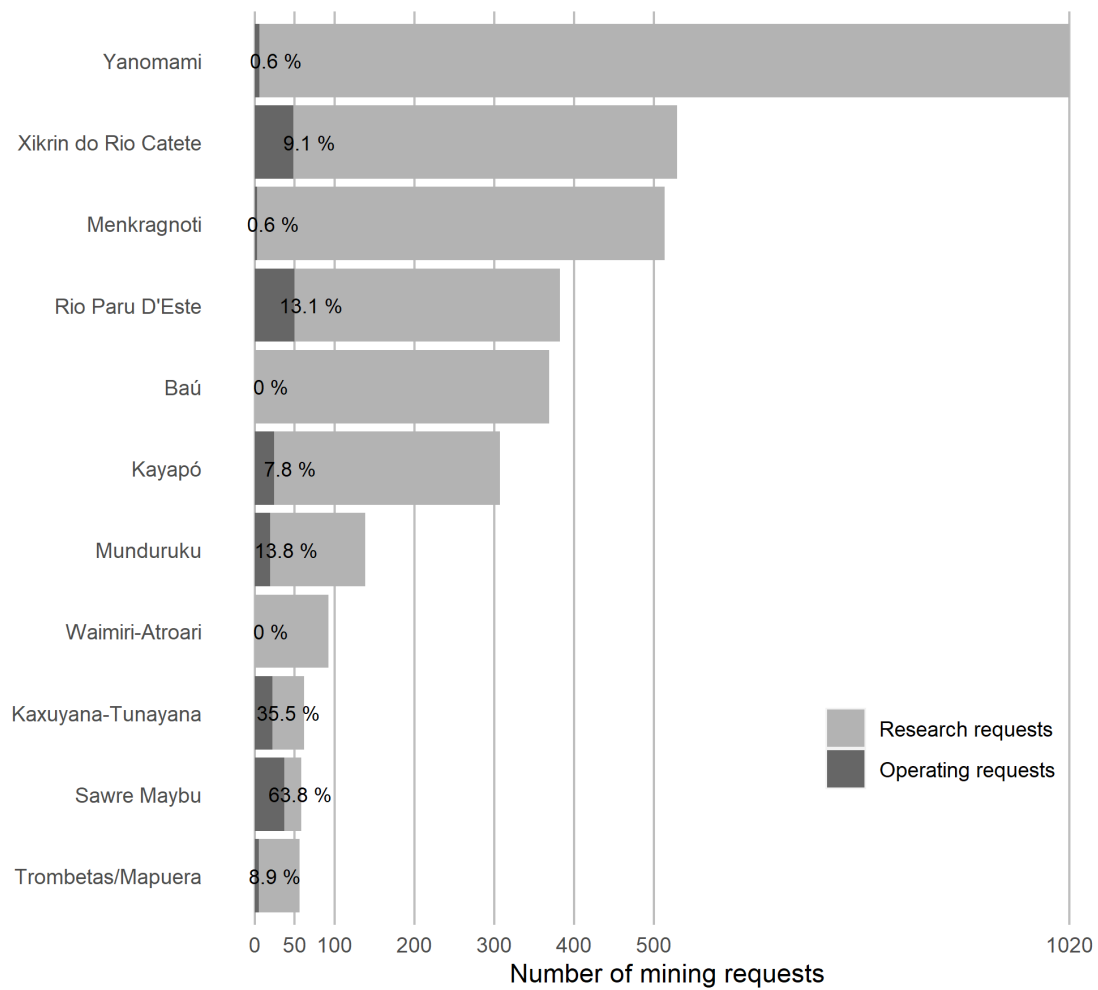
SM Fig. S-1. Geographical distribution of indigenous lands with isolated indigenous groups (filled) and with no isolated groups (open). All indigenous lands are colored in accord with the FUNAI Regional Coordination in charge of them, as in Figure 1 in the main text. The acronyms of Regional Coordinations with any record of isolated indigenous groups are indicated. The gray area represents the Legal Amazon. Brazilian state boundaries are indicated with light gray lines and international countries are represented with darker gray lines. ALPUR - Alto Purus; ANP - Amapá e Norte do Pará; ATO - Araguaia Tocantins; BT - Baixo Tocantins; CLPA - Centro-Leste do Pará; JPR - Ji-Paraná; JUR - Juruá; KSPA - Kayapó Sul do Pará; MA - Maranhão; MAD - Madeira; MAO - Manaus; MPUR - Médio Purus; NMT - Norte do Mato Grosso; NOMT - Noroeste do Mato Grosso; RNG - Rio Negro; RR - Roraima; TPJ - Tapajós; VJ - Vale do Javari; XIN - Xingu.



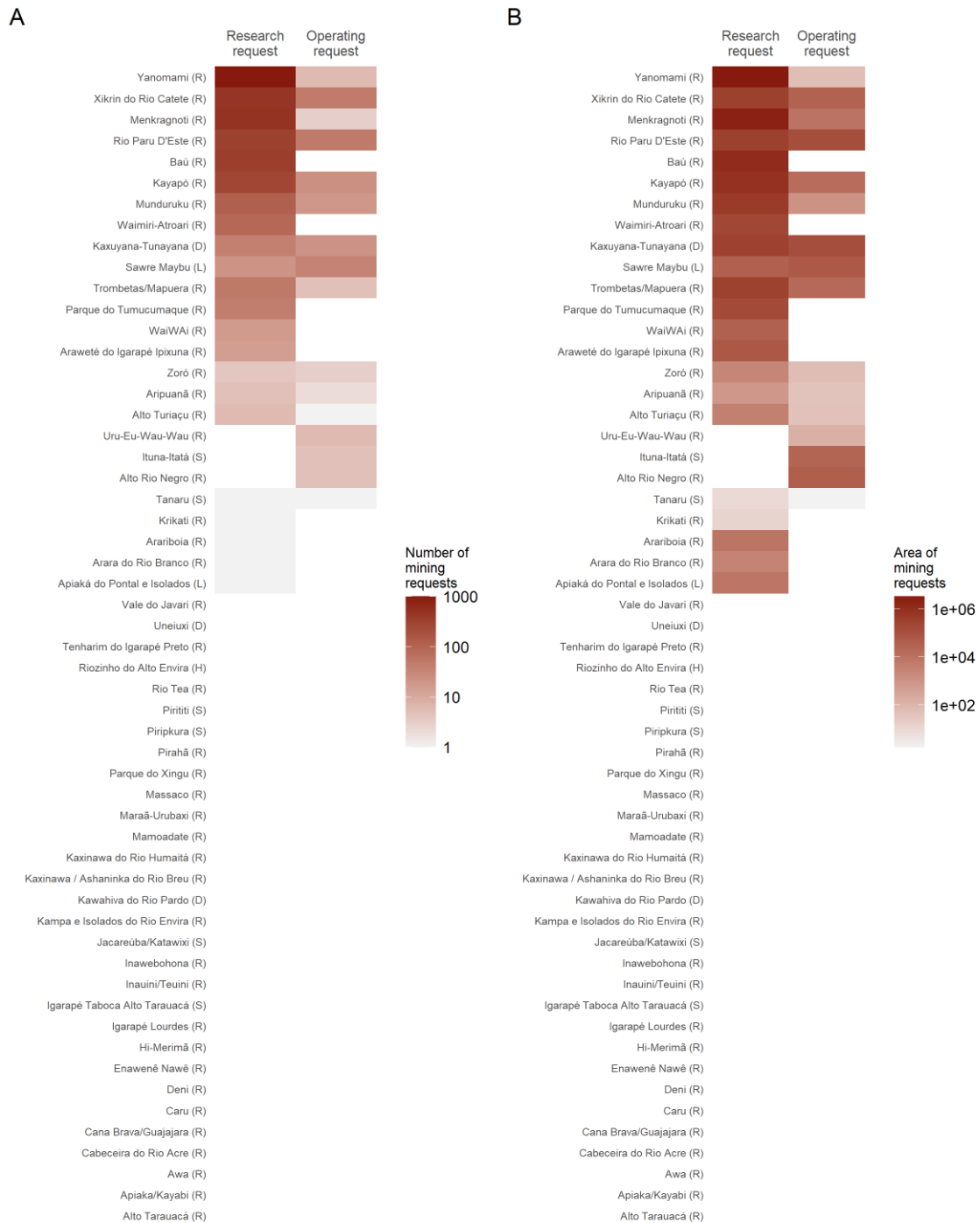
SM Fig. S-2. Geographical distribution of indigenous lands in the Brazilian Legal Amazon, and the number of isolated indigenous groups separated by level of knowledge. Indigenous lands with no isolated groups are in white in all maps. The Legal Amazon is in grey. Indigenous lands with a total of >3 isolated groups or >50 mining projects are labeled.



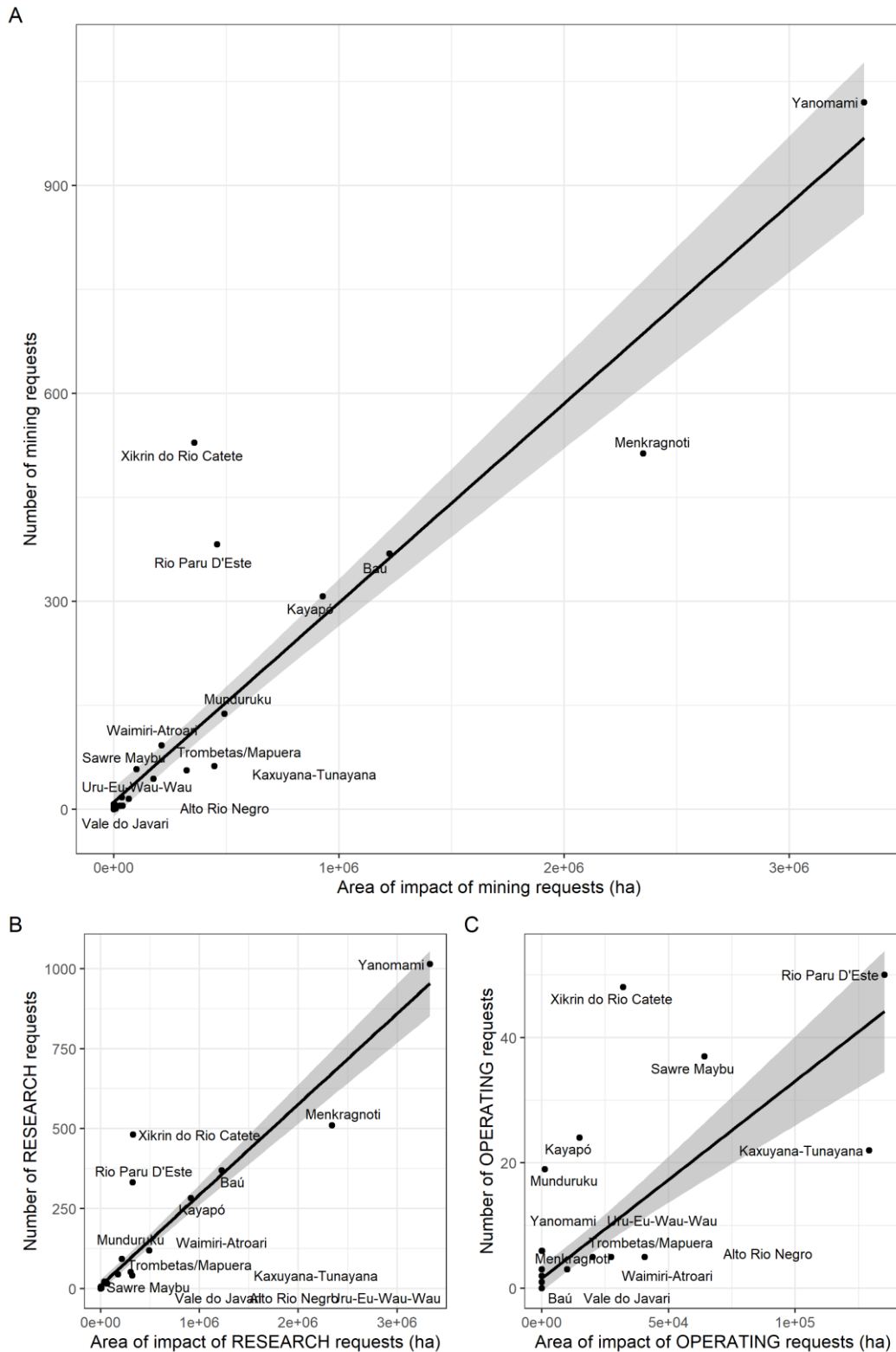
SM Fig. S-3. Percentage of the area of indigenous lands in the Brazilian Legal Amazon with reported isolated indigenous groups that is affected by mining requests.



SM Fig. S-4. Number of research and operating-license requests in eleven indigenous lands that have more than 50 mining requests. Percentages represent the operating-license requests (those more advanced in the licensing process) as percentages of the total.



SM Fig. S-5. Number (A) and area (B) of mining research and operating-license requests in indigenous lands that have reported isolated indigenous groups. Indigenous lands are ordered by the total number of mining requests in both graphs. Capital letters in parentheses indicate the stage of the demarcation process of the indigenous land: under study (S), delimited (L), declared (D), homologated (H) and regularized (R).



SM Fig. S-6. Correlation between the number of mining requests and their area of impact in indigenous lands that contain isolated groups, considering all requests (A), research requests (B) and operating-license requests (C) separately. Indigenous lands with >3 isolated groups and/or >50 mining requests are labeled. Shaded areas indicate the 95% confidence intervals of the linear regression model.