PNAS
www.pnas.org

Supplementary Information for

Resource extraction and infrastructure threaten forest cover and community rights

Authors and affiliations:[1]

Anthony J. Bebbington
School of Geography, University of Melbourne, VIC 3010
Graduate School of Geography, Clark University, MA 01610
https://orcid.org/0000-0003-3342-7898

Denise Humphreys Bebbington
International Development, Community and Environment, Clark University, MA 01610

Laura Aileen Sauls
Graduate School of Geography, Clark University, MA 01610, USA
https://orcid.org/0000-0001-8868-7465

John Rogan

[1] The authors declare no conflict of interest.

www.pnas.org/cgi/doi/10.1073/pnas.1812505115

Graduate School of Geography, Clark University, MA 01610, USA

Sumali Agrawal
Yayasan Tambuhak Sinta, Kalimantan Tengah, Indonesia

César Gamboa
Derecho, Ambiente y Recursos Naturales, Lima, Peru

Aviva Imhof
European Climate Foundation, The Hague, The Netherlands

Kimberly Johnson
Graduate School of Geography, Clark University, MA 01610, USA

Herman Rosa
PRISMA, Programa Regional de Investigación sobre Desarrollo y Medio Ambiente, San Salvador, El Salvador

Antoinette Royo
The Samdhana Institute, Bogor, Indonesia

Tessa Toumbourou
School of Geography, University of Melbourne, Australia

Ricardo Verdum
Museo Nacional, Universidade Federal do Rio de Janeiro, Brazil

Corresponding author:

Anthony J. Bebbington

School of Geography, University of Melbourne, VIC 3010
Graduate School of Geography, Clark University, MA 01610
Email: Bebbington.a@unimelb.edu.au

This PDF file includes:

Supplementary text
Figs. S1 to S3
Tables S1 to S2
References for SI reference citations

Supplementary Information Text

Materials and Methods

Quantitative and cartographic data were collected to analyze the spatial relationships between resource extraction and loss of forest cover for the period 2000 to 2014 and 2016 in each of the three study regions: Amazonia, Mesoamerica and Indonesia (Table S1). Global datasets for roads, protected areas (PAs) and forest cover as well as national datasets on resource concessions and indigenous and traditional peoples lands (ITPL) were consulted: calculations of forest loss were based on the Global Land Analysis & Discovery Group global forest change data set (1). These datasets were overlaid and the rates of deforestation in different land use classes (concessions, PAs, ITPLs) over the time period of interest were calculated using a combination of Clark Labs TerrSet modules and Esri ArcGIS tools.

Not all countries or jurisdictions had equally available geospatial information, particularly for concessions extents. Due to their data availability and significant forested areas, we undertook national-level analyses of Brazil, Peru, Guatemala, Honduras, and Panama, as well as sub-regional analysis of Sumatra and West Papua. In each case, concession data was either downloaded or digitized based on static maps from national or NGO sources. Mining and hydrocarbon concessions constitute a claim on a forested area. While actual mine sites are a small part of a concession, and concessions do not imply deforestation, they show geographies of interest in mining. Research has also shown that the impacts of mining on forest degradation reach well beyond the mine site (2, 3), and for that reason concessions may be a better measure of the potential extent of forest loss and degradation than is the operating area of a mine or well.

Most qualitative research was conducted between August 2016 and November 2017, with additional interviews in 2015 and 2018. Interviews were conducted in each region with key informants from government, civil society and industry (110 total). Informants were interviewed in person, by telephone, electronically or by videoconference. They were selected on the basis of known expertise and also by snowballing (i.e. based on the recommendations made by other interviewees regarding people who we should interview). Interview-based information was complemented by: individual authors' on-going field research and engagement on these themes and many other informal conversations which served to triangulate and confirm data and claims. Documents on investments and legislation were drawn from ministries of economy and finance, parliamentary and sectoral ministries, and industry and consulting company websites.

For each region and for the categories of infrastructure, mining, oil and gas, deforestation drivers, and development finance and investment trends for these sectors, we reviewed academic and grey literature (primarily NGO and international organization documents, as well as consultancy reports). Searches for peer-reviewed and NGO-produced literature were primarily conducted in Google Scholar and Web of Science. Google searches for country-specific government and industry documents, including from ministries of economy and finance, conservation and forestry, energy and mining, and human rights or ombudspersons' offices, provided specific information regarding projects, partners, and key priorities in each region. These searches also produced slideshow decks, videos, press releases, and news coverage related to the sectors, key categories of interest, and regions, which we reviewed for content and context. The database produced for this project contains over 1000 unique files of the above types.

After an initial phase of document review and interviews, and initial drafting of findings, the research team convened four workshops and led discussions in two others to solicit the views of civil society, forest peoples', research center, government and industry representatives on the trends in infrastructure and resource extraction and development and the implications for forests, economic development, and community rights. In all workshops, participants also commented on initial findings, validating, amending or questioning them. Workshops were held in San Salvador (El Salvador), Mexico City (Mexico), Jakarta (Indonesia), Brasilia (Brazil), Lima (Peru) and Oslo (Norway). Fundación PRISMA convened a workshop of 18 participants representing ten different NGOs, universities, indigenous/*campesino* groups and philanthropic bodies in San Salvador on March 13, 2017. The Mexico City workshop was convened in the offices of the Ford Foundation in Mexico City in collaboration with Clark University and with the support of Fundación PRISMA, on March 21, 2017. A total of 18 experts from 14 organizations (forest peoples' groups, human rights advocacy and legal institutes, and other foundations supporting initiatives around extraction and infrastructure) participated. The Jakarta workshop was convened by Samdhana Institute on March 7-8, 2017, and involved 28 participants from twenty different organizations, including research centers, indigenous peoples' organizations, civil society organizations, government bodies and foundations. The Lima workshop was convened by Derecho, Ambiente y Recursos and Clark University and held on November 10, 2017, with a total of 22 participants from university, non-government, indigenous peoples', and consultancy organizations as well as former ministerial officials. The Brasilia workshop involved a team presentation within a broader workshop on environment and development in the Amazon convened by the Climate and Land Use Alliance and held on July 11, 2017, with around 25 representatives of social movements and forest users' organizations, research centers, NGOs and philanthropic organizations. The workshop in Oslo, held on April 20, 2017, involved approximately 20 people from philanthropic organizations and government agencies in a series of three roundtables to discuss and critique draft findings.

Additional Results: Background data on current and projected patterns of forest loss, resource extraction and infrastructure

Amazon

Between 2001 and 2014, rates of deforestation, although still high, declined in the Amazon basin, with a mean annual loss of 238 km^2 between 2001 and 2007, and of 177 km^2 from 2008–2014. These reductions reflected a substantial decline in rates of forest loss in Brazil between 2004 and 2012, but an increase in other parts of the Amazon such that the non-Brazilian share of total Amazonian forest loss increased from 9.7% to 13.8% between the two periods (4). Furthermore, Brazilian deforestation rates have again trended upwards since 2012 (5) such that rates in 2016 and 2017 are substantially higher than they were in 2004 for both Brazil and the whole of Amazonia (Figure S1, Table S2). The expansion of large scale soy bean, livestock and oil palm cultivation accounts for much of this loss, though small scale forest clearing has become increasingly important (4, 6). New deforestation hotspots in Peru and Bolivia are associated with large-scale cultivation of oil palm and soy bean as well as infrastructure development and ASM (4, 7, 8).

As deforestation has progressed, governments in the Amazon basin have also extended concessions for resource extraction and infrastructure development. There are currently 327 oil or gas blocks available for bidding or under exploration in the Amazon Basin (covering some 1.08 million km^2). Mining concessions cover a further 1.6 million km^2, approximately 21% of the basin's total area (9). Nearly all protected areas and indigenous territories are threatened by hydro-power/waterway development, mining, oil and gas, and road investment. In Brazil, applications for, and approvals of, mining concessions have moved steadily westwards, and the state of Amazonas, the principal remaining area of primary forest in the Brazilian Amazon, is now ringed on three sides by mining concessions or requests for concessions. In neighboring Peru, the deforestation frontier is moving eastward, and gold mining is extending towards the frontier with Brazil.

While there are in general no clear spatial correlations between resource extraction activity and forest loss, there are important exceptions to this pattern. In Brazil, the "arc of deforestation" running from Northeast Para across Mato Grosso and Rondônia is characterized by the presence of exploration concessions and operating mines in Eastern Para and in Rondônia. The curvilinear area of deforestation in Southeast Peru is the consequence of extensive ASGM in alluvial deposits in Madre de Dios (10). Finally, 1.5 million ha of forest in the states of Pará and Maranhão, including in quilombola and indigenous communities, have been lost over three decades due to charcoal making to support the iron complex at Gran Carajás (11). Illegal loggers in search of wood have entered reserves and indigenous lands and threatened and murdered local residents that resist.

Brazil's expansion of export-oriented agroindustry is directly dependent on building bulk transport systems that can lower costs. Figure 3, based on a map that was presented by the Brazilian Minister of Agriculture in 2016, shows the current and planned network of roads, railways, and waterways for the Brazilian Amazon. Thirty waterway terminals were planned in the Northern Region for the period 2015-18, with 20 already under construction or completed. Such infrastructure is conceived in synergy with agricultural expansion and resource extraction. While the Southern Interoceanic Highway linking the Brazilian Atlantic to the Peruvian Pacific has not served as a major transport corridor for agricultural products, it has facilitated migration, typically of resource-poor migrants, into forest areas.

While infrastructural investment has a long history in the Brazilian Amazon, current government plans are distinctive for their sheer scale and the multimodal and multi-country nature of planned investments. These investments in access infrastructure have been accompanied by commitments to energy infrastructure, especially large-scale hydropower projects. Brazil's Energy Expansion Plan 2023 anticipated 23 new or expanded hydroelectric installations in the Legal Amazon, 17 of which would affect indigenous populations and territories. The country's planned dams would have flooded 12,000 km^2, an area roughly the extent of the state of Connecticut (12). Projections suggest that over 123,000 km^2 of forest could be affected by the proposed Tapajós Hydroelectric Complex, a package of seven dams to be constructed in the mid-Tapajós River Basin. Current plans outline new dams being built on the major Andean tributaries of the Amazon River: the Marañon basin will have some 104 dams, the Ucayali, 47 dams, and the Napo, 21 dams. Hydropower projects are associated with 39% of protected area downsizing, downgrading and degazetting events in the Amazon (13). In 2018 the government of Brazil announced a halt to hydroelectric dam building, so it is unclear if these plans will now apply.

The impact of infrastructure on Amazonian deforestation has long been recognized (14). Estimates are that 95% of all forest loss occurs within 50 km of a road, or 80% within 20 km of a road (15, 5). Roads facilitate agricultural colonization and expansion, and render resource extraction possible. The Tapajós river hosts 20,000 ASGM miners, many of whom followed Highway BR 163 into protected forests. ASGM miners have followed the Interoceanic Road into Madre de Dios in southeastern Peru. It is estimated that 500,000 artisanal gold miners are active throughout the Amazon basin (16). The same synergies apply for large-scale mining. The US $14.3 billion S11D Mineral Complex is being built inside national forest in Southeast Para, with ore removed on conveyors and a dedicated railway that crosses 100 indigenous and quilombola (traditional afro-descendent) communities and 28 conservation units, in addition to 86 quilombola communities directly affected by the mine itself (17).

The multiple planned infrastructure investments across Amazonia signal governments' and elites' intent for future development in the basin. Specifically, synergies between access infrastructure, agroindustry and resource extraction suggests that the waterways and rail lines planned in the so-far relatively deforestation-free state of Amazonas could trigger agricultural expansion and enhance the economic viability of mining concessions in the east and north-west of the state, as well as potentially in Venezuela and Colombia (Figures 2 and 3). Although data on informal road building is mostly anecdotal, it is sufficiently consistent to assert that the phenomenon is widespread and designed to ease small-scale miner, logger, and colonist access to forest. The future impact of resource extraction on forest loss and community rights will increase significantly because of such synergies with large- and small-scale infrastructure. In 2017, more people defending these rights were killed in Brazil than in any other country (18).

Indonesia

Humid tropical forest in Indonesia is concentrated in the islands of Borneo (Kalimantan), Papua and Sumatra. Rates of forest loss have been significant since 2000, especially in Sumatra where over 8.5 million ha were lost from 2000 to 2014 (19, 20). Primary drivers of forest loss include the expansion of oil palm plantations (21, 22) , and of the fiber and logging sectors (19, 23, 24), though authors disagree on the relative weight of these drivers. The significance of oil palm may be declining, with plantation expansion concentrating increasingly in already deforested areas (25).

Between 2000 and 2014 in Sumatra, 71.8% of deforestation occurred within an industrial natural resource concession (including oil palm, logging, coal, and tree plantations) (20, 24). Much forest targeted for investment is inhabited by and claimed by indigenous and local communities – the government recognizes only 0.025% of these land claims (26). Only 2% of this forest loss occurred within coal mining concessions (Figure 4), though rates of deforestation within coal concessions are similar to those within other types of concession. Where coal concessions overlap with other concessions due to lack of planning or corruption, 40% of concession areas show deforestation, while oil palm concessions that overlap with other concession types show 34% of forest loss (20).

Coal mining is a clear actual and potential driver of deforestation. Currently active coal mining affects 1.74 million ha of forest land according to Indonesian NGO Auriga, and future permits could threaten 8.6 million ha, around 9% of Indonesia's remaining total forest cover (27). Over 1.1 million ha of designated "conservation" and "protection" forest is currently allocated to coal mining permits, in spite of laws that prohibit mining in conservation forests and limit mining in protection forests to underground mining (most coal mining in Indonesia is open pit). Around 49,000 hectares of conservation or protected forest have already been affected by coal mining operations according to Auriga's analysis.

Approximately 3.9 million ha of all coal mining permits are located in Papuan forests (Figure S2). The majority of the remaining areas affected by mining concessions are located in the interior of Kalimantan, with a smaller amount in Sumatra. Some 3.45 million ha of Kalimantan's forests were designated as coal mining concessions in 2011 (28). Around 14 percent of all South Kalimantan forests lie in coal concessions, over 45% of East and South Kalimantan has been allocated for mining, mostly for coal, and between 2009 and 2011, one-quarter of all deforestation in Kalimantan was due to the clearance of forest within coal mining concessions (28). The IndoMet coal mining concession in the province of Central Kalimantan spans an area of 350,000 ha, including 75,000 ha of primary forest, more than twice the size of Greater London. It is estimated to contain ~1.2 billion tons of coal. Should rates of forest loss within coal concessions in Kalimantan become similar to those that have occurred in Sumatra (22%, without overlaps), then the risk to forest cover in Kalimantan is significant.

The impact of mining on forest loss can be aggravated by the effect of price on stripping ratios of large coal mining operators. When coal prices are low, miners extract only shallower seams, leaving deeper coal underground because of cost (29). This practice blocks future access to seams by placing overburden on top of them, and increases forest loss as mines expand horizontally to mine shallow seams, rather than vertically to mine deeper seams.

Though not on the same scale as coal mining, ASGM is a growing threat to Indonesia's forests, with approximately one million ASGM miners across the archipelago, many in forested lands (30). Their impact on forest is not captured by work assessing the relationships between types of natural resource concession and forest loss, as ASGM frequently occurs without any prior license, and in cases where miners establish themselves illegally within other types of concession, ASGM may itself be a driver of the forest loss recorded in those units. ASGM is more likely to occupy protection forest and conservation areas known to have gold deposits (31), because operating in such areas is difficult for formal, legal, and larger scale companies. Even when ASGM miners have formal licenses, these have often been given by local authorities through patronage or corrupt relations, and many such licenses overlap with administratively prohibited areas of land. The mobility of gold dredging operations means that impacts on forests are more widespread than from hard-rock mining. ASGM miners are often driven into the activity by poverty and a lack of other livelihood opportunities.

The viability of coal concessions and ASGM activity will depend on access infrastructure, mineral prices and predictability of demand. The Indomet coal concession, for instance, requires a 425km long railway to link the concession to ports. A tender for this railway has been won, but construction is currently on hold because of cost, financing and regulations. If new railway infrastructure proceeds in Kalimantan, the Government of Indonesia has estimated it would allow a seven-fold increase in coal production, much on forest lands. The infrastructure would also facilitate forest clearance by other land users. Infrastructure's impact on forest loss is indirect and occurs through the land extensive, natural resource based extraction it makes viable. This impact is significant: the strategic environmental assessment of the Government of Indonesia's 2011-2025 development strategy, one based on infrastructure and natural resource extraction, concluded that the strategy could put US $490 billion of natural capital at risk annually though actual impacts were deemed likely to be lower than this (32).

Killings of environmental defenders have been far fewer in Indonesia. Interviews, however, suggest this danger is increasing and that some active forest defenders are scaling back their activity for fear of violence. At the same time, interests linked to expanded investment in mining and infrastructure are directly present within national and subnational governments lobbying for expanded investment.

Mesoamerica

Central America's "asymmetric forest transition" (33) combines on-going loss of humid tropical forest in lowland areas with patches of forest resurgence in mostly upland areas of high out-migration (34). Guatemala and Nicaragua are amongst the top 20 countries globally in terms of rates of tree cover loss in the period 2000-2014. Mexico is the 15th largest gross tree cover loser globally (1, 35). Forest loss is primarily driven by small- and large-scale agricultural colonization, timber extraction, and increasingly activities related to illegal narcotics trafficking (36).

Substantial areas of Guatemala, Honduras, Mexico, Nicaragua, and Panama are affected by mineral and hydrocarbon concessions. In recent years, the governments of Honduras, Nicaragua, and Mexico have passed legislation highly favorable to resource extraction investment. The participation of mining and quarrying in Panama's economy was expected to increase tenfold from 1% in 2013 to about 10% in 2018 (37). Conversely, the governments of Costa Rica, El Salvador, and Guatemala have passed partial or permanent moratoria on mining, although ongoing operations continue in the former and rule-making to implement the moratorium in the latter remains contentious. The impacts of resource extraction on forest loss are, however, less clear (Figure 5; Figure S3). Across Honduras, Guatemala and El Salvador, only 0.96% of forest loss during 2016 occurred in concessions with operating mines. There are exceptions to this pattern. The Cobre Panama concession consists of four zones totaling 13,600 ha in an area currently covered by dense rainforest (38). With full mining operations expected to begin in 2018, the project's impacts will include: the clearing of 5,500 ha of tropical forest, with 2,800 ha. lost permanently after reforestation; additional forest loss due to development induced by access roads (39); emissions from a two-unit, coal-fired power plant in Punta Rincón built to power the mine; and overall an 8% increase in Panama's national greenhouse gas emissions (40). Mining concessions and mining reserves in Nicaragua covered 10.5% of national territory by 2015, with substantial overlaps with protected area forests near the border with Honduras, including in the Bosawas Biosphere reserve (41).

Infrastructure has had clearer impacts on forest loss, especially through synergies with resource extraction and agro-industrial expansion. In the humid forest region of the Petén, Guatemala, road expansion has correlated directly to forest clearing over at least three decades (42, 43). Some of this road building was directly related to oil extraction in the Petén. The road building–forest clearing–resource extraction nexus is evident in the Laguna del Tigre and Sierra del Lacandón National Parks, where forest loss increased significantly in the mid-1990s in areas around a road entering the park from the south and built to provide access to the Xan oil field and other potential sites. In interviews, local leaders attribute loss in forest cover in this zone to rapid and uncontrolled settlement made possible by this road. A proposed natural gas pipeline connecting US and Mexican gas supplies with Guatemala, Honduras, and El Salvador would cross communal lands and areas already concessioned for mining in the western portion of Guatemala, pointing to other possible future synergies between infrastructure, resource extraction and forest loss (44).

Forests around the Mexico-Guatemala border in Petén are especially vulnerable because the Mesoamerican Integration and Development Project (MIDP, formerly Plan Puebla-Panama), is promoting cross border integration (45). Currently, the area between Calakmul National Park in Quintana Roo, Mexico, Belize, and Guatemala has a dense network of paved roads and shows extensive tree cover loss. While deforestation slows at the Guatemalan border, the pressure to build the roads into more remote areas of Guatemala is mounting, especially as the government continues to promote hydrocarbons concessions and tourism as economic development drivers (46). The majority of the area in Northern Guatemala that has not yet experienced deforestation is currently managed by community based forest management groups, organized as the Association of Forestry

Communities of Petén (ACOFOP). Further road building and agricultural colonization on the southern, eastern and western borders of the ACOFOP forest concession, coupled with the fact that the Guatemalan government has not yet renewed ACOFOP's concessions beyond 2020, places this forest at risk.

Large increases in small-scale road building in the Honduran Muskitia and in the North and South Caribbean Autonomous Regions (RACCN and RACCS) of Nicaragua threaten the forested coastal zone. While road expansion and accompanying electrification and connectivity may open up new economic opportunities for people in these more remote regions, they also impact traditional livelihoods and territorial claims by fostering in-migration into previously forested regions. Informal road building, often linked to the drug economy, aggravates these pressures and also exists in synergy with expanded ASGM, for instance in the Nicaraguan Muskitia. Non-fossil energy projects, such as hydropower, also affects forested areas and exacerbate tensions over environmental degradation and land rights, as the violence surrounding the Aguas Zarcas conflict demonstrated in 2016. A regionally-led energy integration project to connect the South American and Central American grids across Panama, could also lead to deforestation in the region by opening up previously remote zones.

Conflict around mining and infrastructure development is constant in the region. Even in relatively stable Costa Rica, which allows no major metals mining, hydroelectric power expansion plans have led to conflict (47). Environmental defenders contesting the impacts of these investments on community rights have been subject to violence, and Honduras and Nicaragua are on a per capita basis, the most dangerous countries in the world in which to be an environmental activist (18). In our interviews and workshops, organizations working on community based rights protection and litigation reported increasing sense of insecurity and harassment, and organizations go out of their way to hide the nature of their work from view, or simply avoid the most violent disputes over forest cover and land rights.

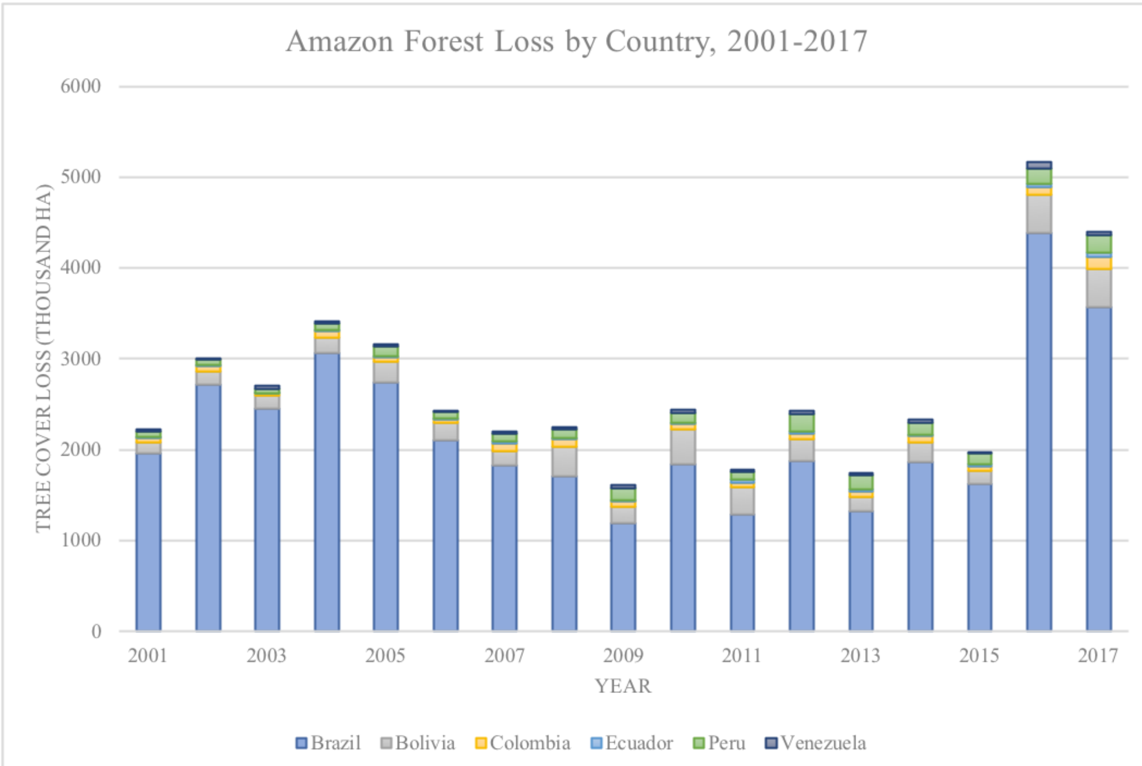

Fig. S1. Amount of deforestation in selected Amazon countries (in thousands of ha), 2000-2017.

(Note: Figure S1 shows deforestation in thousands of ha., aggregated by those sub-national jurisdictions that include parts of the Amazon Basin. Table S2 aggregates that same data by country over the entire time period. Date from Global Forest Watch, 2018.)

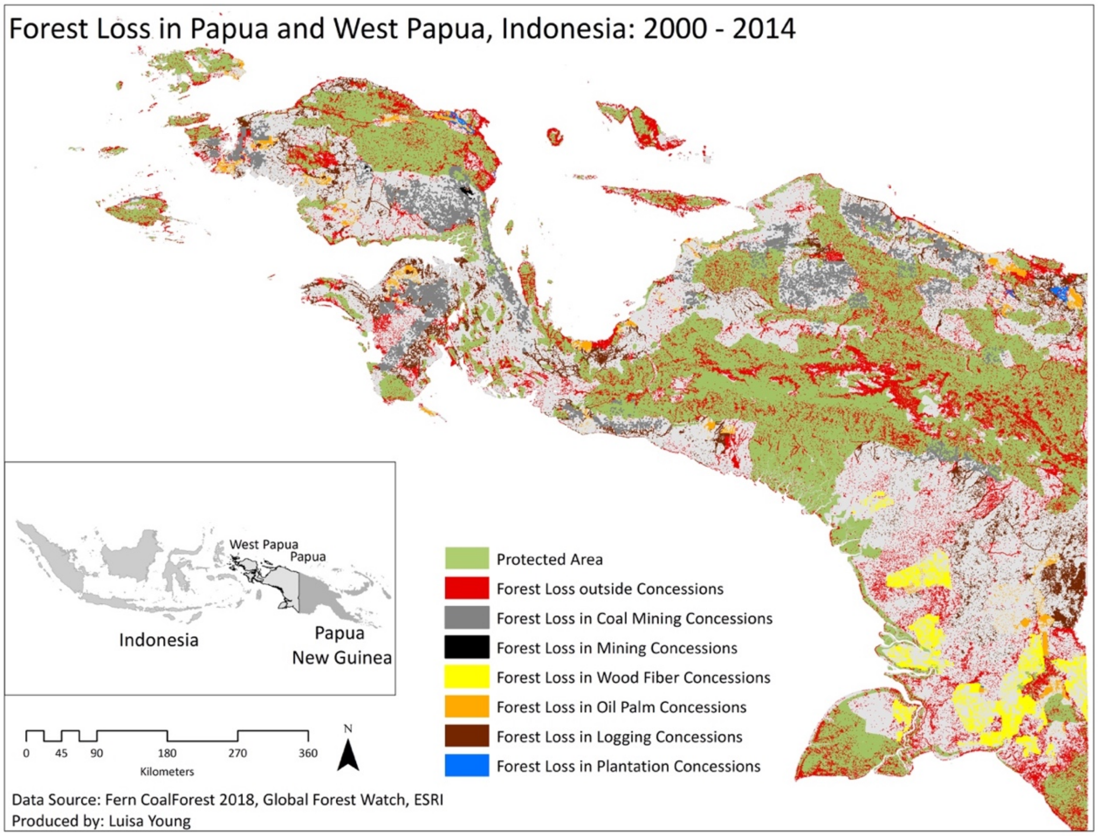

Fig. S2. Deforestation, extraction, and land use in Papua and West Papua, Indonesia.

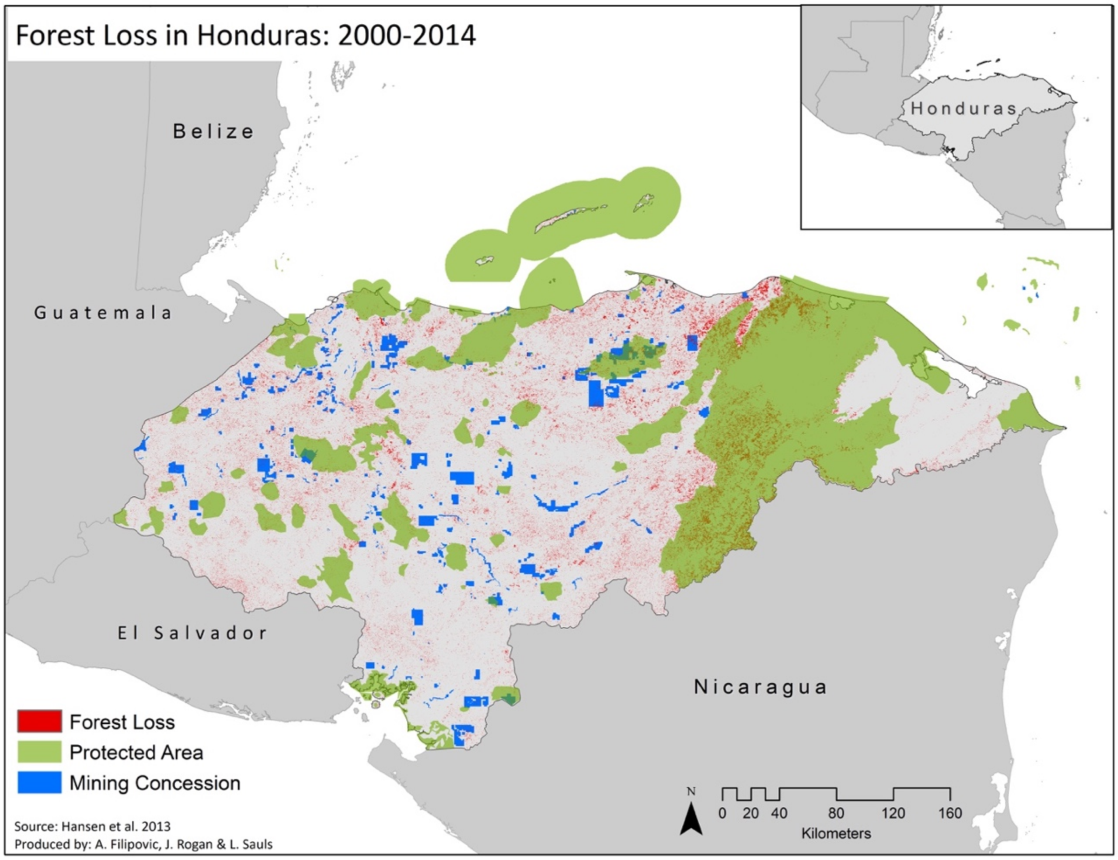

Fig. S3. Deforestation, extraction, and protected areas in Honduras.

Table S1. Countries and sub-national jurisdictions considered for each study region. Countries or jurisdictions with an asterisk were mapped as part of the geospatial analysis undertaken.

Region	Countries or Sub-national Jurisdictions of Focus
Amazonia	Brazilian Legal Amazon* Bolivia Colombia Ecuador Peru* Venezuela
Mesoamerica	Costa Rica El Salvador Guatemala* Honduras* Mexico Nicaragua Panama*
Indonesia	Kalimantan Papua* Sumatra*

Table S2 Tree cover loss in the Amazon basin, 2001-2016 based on 2000 tree cover.

Country	Percent Lost (2001-16, relative to 2000)	Mean Percent Loss Per Year 2001-2016
Bolivia	6.30	0.39
Brazil	8.90	0.56
Colombia	4.00	0.25
Ecuador	3.60	0.23
Peru	3.00	0.19
Venezuela	2.90	0.18
Average	*4.78*	*0.30*

References

1. Hansen MC, et al. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342(6160):850–853.
2. Schueler V, Kuemmerle T, Schröder H (2011) Impacts of surface gold mining on land use systems in Western Ghana. *Ambio* 40(5):528–539.
3. Sonter LJ, et al. (2017) Mining drives extensive deforestation in the Brazilian Amazon. *Nature Communications* 8(1). doi:10.1038/s41467-017-00557-w.
4. Kalamandeen M, et al. (2018) Pervasive Rise of Small-scale Deforestation in Amazonia. *Scientific Reports* 8(1):1600.
5. Fearnside PM (2017) Business as Usual: A Resurgence of Deforestation in the Brazilian Amazon. *Yale E360*. Available at: https://e360.yale.edu/features/business-as-usual-a-resurgence-of-deforestation-in-the-brazilian-amazon [Accessed May 18, 2018].
6. Hosonuma N, et al. (2012) An assessment of deforestation and forest degradation drivers in developing countries. *Environ Res Lett* 7(4):044009.
7. Dammert Bello JL (2015) *Hacía una Ecología Política de la Palma Aceitera en el Perú* (Oxfam, Lima, Perú) Available at: https://peru.oxfam.org/policy_paper/hacia-una-ecologia-politica-de-la-palma-aceitera-en-el-peru [Accessed December 30, 2016].
8. Killeen TJ (Forthcoming) *Ten Years After A Perfect Storm in the Amazon Wilderness: Success and failure in the race to save the largest tropical forest on Earth*.
9. RAISG (2012) *Amazonía Bajo Presión* Available at: https://raisg.socioambiental.org/system/files/AmazoniaBajoPresion_10_12_12.pdf [Accessed February 28, 2017].
10. Asner GP, Llactayo W, Tupayachi R, Luna ER (2013) Elevated rates of gold mining in the Amazon revealed through high-resolution monitoring. *PNAS* 110(46):18454–18459.
11. Killeen TJ (2007) A perfect storm in the Amazon wilderness. *Advances in Applied Biodiversity Science* 7:102.
12. Nobre CA, Sampaio G, Borma LS, Castilla-Rubio JC, Silva JS, and Cardoso M (2016) Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. *PNAS*:201605516.
13. Pack SM, et al. (2016) Protected area downgrading, downsizing, and degazettement (PADDD) in the Amazon. *Biological Conservation* 197:32–39.
14. Moran EF (1981) *Developing the Amazon* (Indiana University Press, Bloomington).
15. Barber CP, Cochrane MA, Souza CM, Laurance WF (2014) Roads, deforestation, and the mitigating effect of protected areas in the Amazon. *Biological Conservation* 177:203–209.
16. Cremers L, Kolen J, de Theije M eds. (2013) Small-scale mining in the Amazon. *Small-Scale Gold Mining in the Amazon: The Cases of Bolivia, Brazil, Colombia, Peru, and Suriname*, Cuadernos del CEDLA. (Centre for Latin American Studies and Documentation, Amsterdam, The Netherlands), pp 8–22.

17. Faustino C, Furtado F (2013) *Mineração e violações de direitos: o Projecto Ferro Carajás S11D, da VALE S.A.* (Relatório da Missão de Investigação e Incidência, Açailãndia, MA, Brasil).
18. Global Witness (2018) At What Cost? (Global Witness, London) Available at https://www.globalwitness.org/en/campaigns/environmental-activists/at-what-cost/. [Accessed November 7, 2018].
19. Margono BA, Potapov PV, Turubanova S, Stolle F, Hansen MC (2014) Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change* 4(8):730–735.
20. Johnson K (2017) Characterizing the Impacts of Coal Mining on Forest Loss and Protected Areas in Sumatra, Indonesia (2000-2014). MSc (Clark University, Worcester, MA).
21. Carlson KM, Curran L, Asner GP, McDonald Pittman A, Trigg SN, Adeney JM (2013) Carbon emissions from forest conversion by Kalimantan oil palm plantations. *Nature Climate Change* 3(3):283–287.
22. Harris NL, Goldman E, Gabris C, Nordling J, Minnemeyer S, Ansari S, Lippmann M, Bennett L, Raad M, Hansen M (2017) Using spatial statistics to identify emerging hot spots of forest loss. *Environ Res Lett* 12(2):024012.
23. Gaveau DLA, Sheil D, Husnayaen, Salim MA, Arjasakusuma S, Ancrenaz M, Pacheco P, Meijaard E (2016) Rapid conversions and avoided deforestation: examining four decades of industrial plantation expansion in Borneo. *Scientific Reports* 6:32017.
24. Abood SA, Lee JSH, Burivalova Z, Garcia-Ulloa J, Koh LP (2015) Relative Contributions of the Logging, Fiber, Oil Palm, and Mining Industries to Forest Loss in Indonesia: Deforestation among Indonesia's industries. *Conservation Letters* 8(1):58–67.
25. Austin KG, Mosnier A, Pirker J, McCallum I, Fritz S, Kasibhatla PS (2017) Shifting patterns of oil palm driven deforestation in Indonesia and implications for zero-deforestation commitments. *Land Use Policy* 69:41–48.
26. Rights and Resources Initiativ (2015) *Who Owns the World's Land? A global baseline of formally recognized indigenous and community land rights* (Rights and Resources Initiative, Washington, DC) Available at: https://rightsandresources.org/wp-content/uploads/GlobalBaseline_web.pdf [Accessed February 16, 2018].
27. FERN (2015) Indonesia's coal mines and forests. *CoalForest.org*. Available at: http://www.coalforest.org/maps.php?id=indonesia [Accessed February 26, 2018].
28. Greenpeace South East Asia-Indonesia (2014) *Coal mines polluting South Kalimantan's water* (Greenpeace, Jakarta); and https://news.mongabay.com/2014/10/indonesia-tries-to-clamp-down-on-coal-sectors-worst-excesses/) .
29. PwC (2016) *Supplying and Financing Coal- Fired Power Plants in the 35 GW Programme* (PwC Indonesia, Jakarta).
30. Krisnayanti BD (2018) ASGM status in West Nusa Tenggara Province, Indonesia. *Journal of Degraded and Mining Lands Management* 5(2):1077–1084.

31. UNITAR (2016) *Satellite Mapping of Artisanal and Small Scale Gold Mining in Central Kalimantan, Indonesia* (UNITAR, Geneva) Available at: http://www.unitar.org/unosat/map/2368 [Accessed March 7, 2018].
32. DHI Water & Environment (2014) *Strategic Environmental Assessment (SEA) for Indonesian Master Plan for Acceleration & Expansion of Economic Development (MP3EI): Evaluation of the MP3EI Policy, Final Report* (Bappenas, Jakarta).
33. Redo DJ, Grau HR, Aide TM, Clark ML (2012) Asymmetric forest transition driven by the interaction of socioeconomic development and environmental heterogeneity in Central America. *Proceedings of the National Academy of Sciences* 109(23):8839–8844.
34. Hecht SB (2014) Forests lost and found in tropical Latin America: the woodland 'green revolution.' *The Journal of Peasant Studies* 41(5):877–909.
35. World Resources Institute (2014) Country Profiles. *Global Forest Watch*. Available at: https://www.globalforestwatch.org/countries [Accessed May 18, 2018].
36. Sesnie SE, Tellman B, Wrathall D, McSweeney K, Nielsen E, Benessaiah K, Wang O, Rey L (2017) A spatio-temporal analysis of forest loss related to cocaine trafficking in Central America. *Environ Res Lett* 12(5):054015.
37. Wacaster S (2016) *The Mineral Industries of Central America: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama* (U.S. Geological Survey, Washington, DC).
38. First Quantum Minerals Ltd. (2017) Development Projects: Cobre Panama. *First Quantum Minerals Ltd*. Available at: https://www.first-quantum.com/Our-Business/Development-Projects/Cobre-Panama/default.aspx [Accessed May 7, 2018].
39. de Chassy AB, Chehab N, Cipollitti R (2016) *Year Three of the Long Term Mining Monitoring Project* (McGill University, Montreal) Available at: https://www.mcgill.ca/pfss/files/pfss/year_three_of_the_long_term_mining_monitoring_project_-_assessing_the_three_flows_of_information_on_water_quality_monitoring_in_donoso_panama.pdf.
40. End Coal | Global Coal Plant Tracker *End Coal*. Available at: https://endcoal.org/global-coal-plant-tracker/ [Accessed April 17, 2018].
41. IEEPP (2017) *La minería industrial en Nicaragua: una mirada desde la óptica fiscal* (Instituto de Estudios Estratégicos y Políticas Públicas & Centro Humboldt, Managua).
42. Sader SA, Sever T, Smoot JC, Richards M (1994) Forest change estimates for the northern Petén region of Guatemala — 1986–1990. *Hum Ecol* 22(3):317–332.
43. Sader SA, Hayes DJ, Hepinstall JA, Coan M, Soza C (2001) Forest change monitoring of a remote biosphere reserve. *International Journal of Remote Sensing* 22(10):1937–1950.
44. Dalmasso S (2016) Las cargas de Tecún Umán. *Plaza Pública*. Available at: https://www.plazapublica.com.gt/content/las-cargas-de-tecun-uman [Accessed April 16, 2018].
45. Grandia L (2013) Road mapping: megaprojects and land grabs in the northern Guatemalan lowlands. *Development and Change* 44(2):233–259.

46. Escalón S (2016) Guatemala y las petroleras: El socio tonto. *Plaza Pública*. Available at: https://www.plazapublica.com.gt/content/guatemala-y-las-petroleras-el-socio-tonto [Accessed April 9, 2018].
47. McPhaul J (2017) Costa Rica's Supreme Court Stops Hydroelectric Project for Failing to Consult Indigenous Peoples. *Cultura Survival*. Available at: https://www.culturalsurvival.org/news/costa-ricas-supreme-court-stops-hydroelectric-project-failing-consult-indigenous-peoples [Accessed March 27, 2018].