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China's Belt and Road Initiative in Indonesia

MAPPING AND MITIGATING ENVIRONMENTAL AND SOCIAL RISKS

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ABSTRACT

Inbound investment from China (including Hong Kong) in Indonesia has grown dramatically in recent years, particularly after the Belt and Road Initiative (BRI) was launched. In addition to its scale, Chinese foreign direct investment (FDI) is unique in two ways. First, it is concentrated in the environmentally sensitive sectors of metals industry and infrastructure. Second, the environmental and social oversight of these projects is left solely in the hands of the Indonesian government, due to China's "country systems" approach. Thus, Chinese investment makes a useful example to explore the management of inbound investment waves in a highly biologically and culturally diverse setting.

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We assess on-ground changes in vegetation cover occurring within 14 clusters of Chinese FDI projects across Indonesia associated with the BRI and the implications of development for nearby forests, threatened species, important carbon sinks and air quality. Additionally, we compare the relative environmental risks between FDI projects and identify Indigenous communities that may be impacted by these multiple risks.

Of the 14 clusters, three industrial complexes present the greatest risks to multiple environmental attributes: the Obi Industrial Area, SDIC Papua Cement Indonesia and Morowali Industrial Park. These projects are adjacent to primary forests, in areas with high carbon density, and they exhibit some of the highest rates of vegetation loss since 2010. In each case, nearby Indigenous communities face health risks due to air and water contamination, as well as the loss of vital ecological services through deforestation and the loss of key species.

Other sectors also saw commonalities. For example, the hydropower plants studied here display a tendency to be placed adjacent to primary forests and in areas with high carbon density, dampening their value for climate change mitigation. Three of these projects present local Indigenous communities with the risk of displacement due to flooding of ancestral lands.

These results open new potential approaches for environmental and social management of sensitive investment. They suggest that effective oversight should entail sector-specific regulations as well as approval processes that center the wishes of affected communities, particularly Indigenous communities whose ancestral lands are often not formally delineated or protected.

Keywords: China, Indonesia, biodiversity, Indigenous, governance

INTRODUCTION

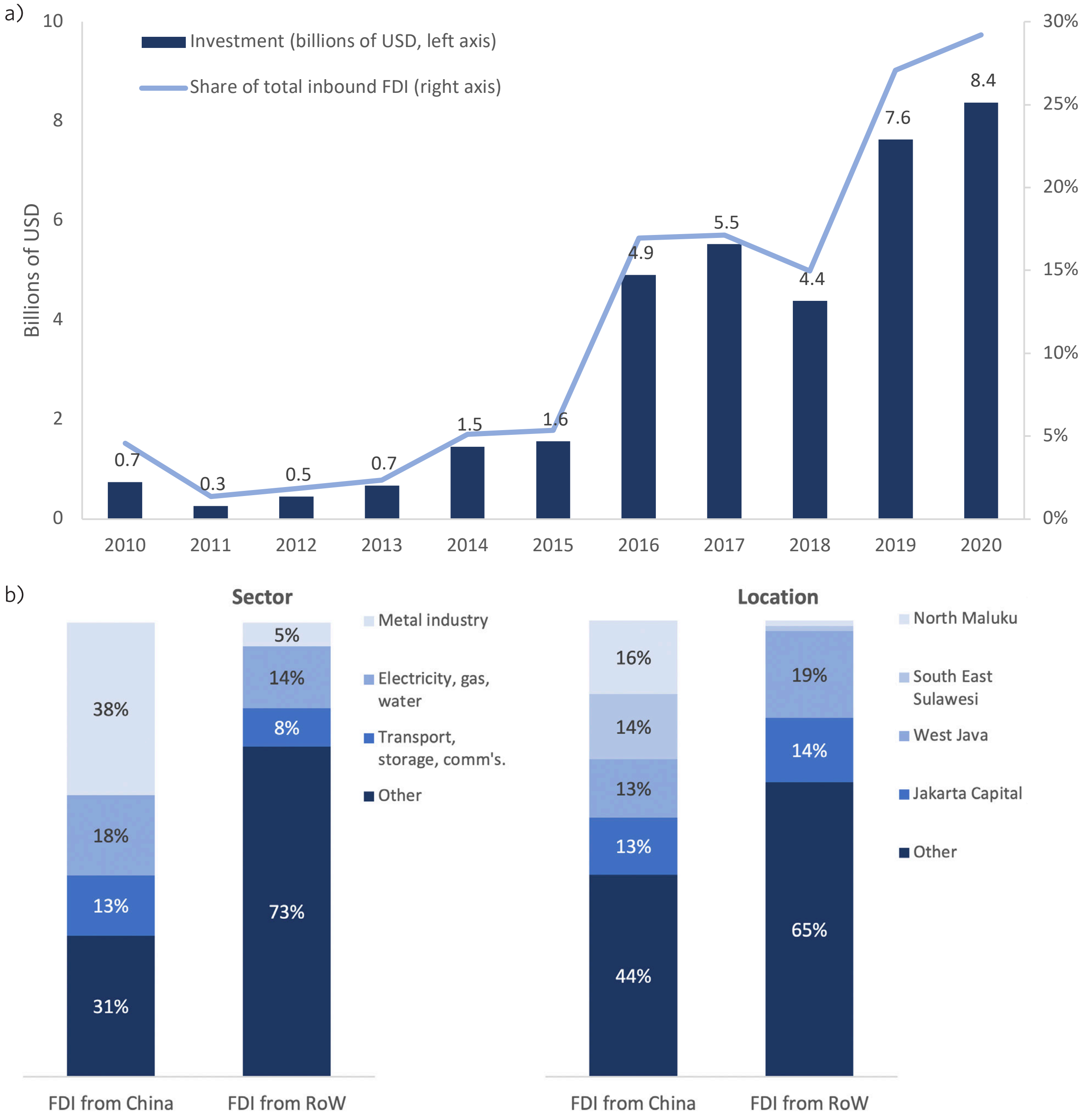
The Rise of Chinese Infrastructure Investment in Indonesia

Economic cooperation between Indonesia and China has intensified over the last decade through the emergence of a shared vision for economic prosperity. In 2011, former President Susilo Bambang Yudhoyono invited China to realize his vision of economic corridors throughout Indonesia by investing in the mining, infrastructure, industrial and agricultural sectors (Priyambodo 2011). The Chinese government gave its commitment to assist Indonesia when President Xi Jinping visited Indonesia through a comprehensive strategic partnership to share prosperity and security between the two countries (ASEAN-China Center 2013). This cooperation intensified in 2014 when President Joko Widodo took office and started implementation of China's international Belt and Road Initiative (BRI).

Inbound investment from China (including Hong Kong) has been growing steadily since 2010 (BKPM 2021a), particularly after the BRI was launched. In 2010, annual investment from China included 175 foreign direct investment (FDI) projects with a total investment of $740 million, rising to 5,816 projects with a total investment of $8.4 billion by 2020 (BKPM 2021a). From 2011 to 2020, total Chinese FDIs reached 12,831 projects, bringing in funds of more than $35 billion. At the same time, investments from other sources have declined, such that by 2020, China (including Hong Kong) was the second largest source of new FDI in Indonesia, representing 29 percent of total inbound investment (BKPM 2021b).

Chinese investment in Indonesia is markedly different from other inbound FDI in three ways. First, more than half is concentrated in just three sectors: metal industry (38 percent), electricity, gas and water (18 percent) and transportation, warehousing and telecommunication (13 percent) (BKPM 2021b). This profile is unusual among investors in Indonesia. Investment from the rest of the world has tended to be much more diversified, with important participation in other sectors including mining (12 percent) and real estate (10 percent). Chinese investment is also directed toward different regions of Indonesia, including North Maluku and Southeast Sulawesi, which account for 14 percent and 16 percent of Chinese investment over the last five years, respectively, but just 1 percent of other

Figure 1: Chinese Investments in Indonesia, 2010-2020 (a) Growth of China as a Source of Indonesia FDI, 2010-2020. (b) Sector Location Composition of Chinese and Other Investment



Source: Author calculations from BKPM 2021a, August 27, 2021.

Note: China includes Hong Kong.

FDI. For this reason, it is reasonable to expect a different environmental and social profile of this new and increasingly important source of investment, which this paper explores.

Finally, Chinese investment is distinguished from other sources of FDI in its environmental governance. A growing body of interdisciplinary research has studied China's traditional "country systems" approach to the social and environmental management of overseas projects (see for example Chin and Gallagher 2019; Gallagher and Yuan 2017; Pramano et al 2021). Based in China's "Five Principles of Harmonious Coexistence," this approach acknowledges the sole authority of host country governments to set the terms for inbound investment (see for example Wen 2004). Thus, environmental management of Chinese investment depends on the political will and institutional capacity of host country central governments. Given the disproportionate concentration of Chinese investment in Indonesia in heavy industry and infrastructure, as well as its reliance on the Indonesian government's oversight, it is important to examine the environmental and social aspects of this new and important investment portfolio, with the goal of developing evidence-based policy recommendations.

Growing Concerns over Social and Environmental Impacts

Due to its scale and "country systems" governance approach, the global expansion of Chinese investments has raised concerns over the environmental and social risks of rapid development, especially in countries with weak governmental or institutional capacity for sufficient project oversight (Compagnon & Alejandro 2013). A growing literature base has evolved on the environmental and social impacts of Chinese FDI, including those under the BRI scheme. For example, Ascensão et al. (2018) predict "a high toll for the environment" created by BRI development projects and Teo et al. (2019) highlight concerns emerging from the chain of effects of infrastructure development projects. However, most studies tend to focus on a single theme. Hughes (2019) and Ng et al. (2020), for example, investigated the impacts of BRI investments on biodiversity, including key biodiversity areas (KBAs). A third stream of a more interdisciplinary focus broadens this scope in two ways, by taking into account both the social impacts of environmental changes and the governance challenges that arise from this interconnected web of social and environmental costs and benefits. Authors in this stream explore how ecological impacts become social impacts, with special consideration for Indigenous peoples due to their frequently insecure land tenure (which leave them more vulnerable to uses and contamination of nearby natural resources) and their historic dependence on the ecological services provided by those resources. They often include case studies to allow for both qualitative and quantitative analysis, to examine the mechanisms of interplay between community, national and international actors. For example, this approach is frequently followed in regional studies, including Ray et al. (2017) in Latin America; Foggin et al. (2021) in Central Asia, Coenan, Newig and Meyfroidt (2022) in Eastern Europe; Hughes et al. (2020) in Eurasia and Africa; as well as in global studies (Yang et al., 2021).

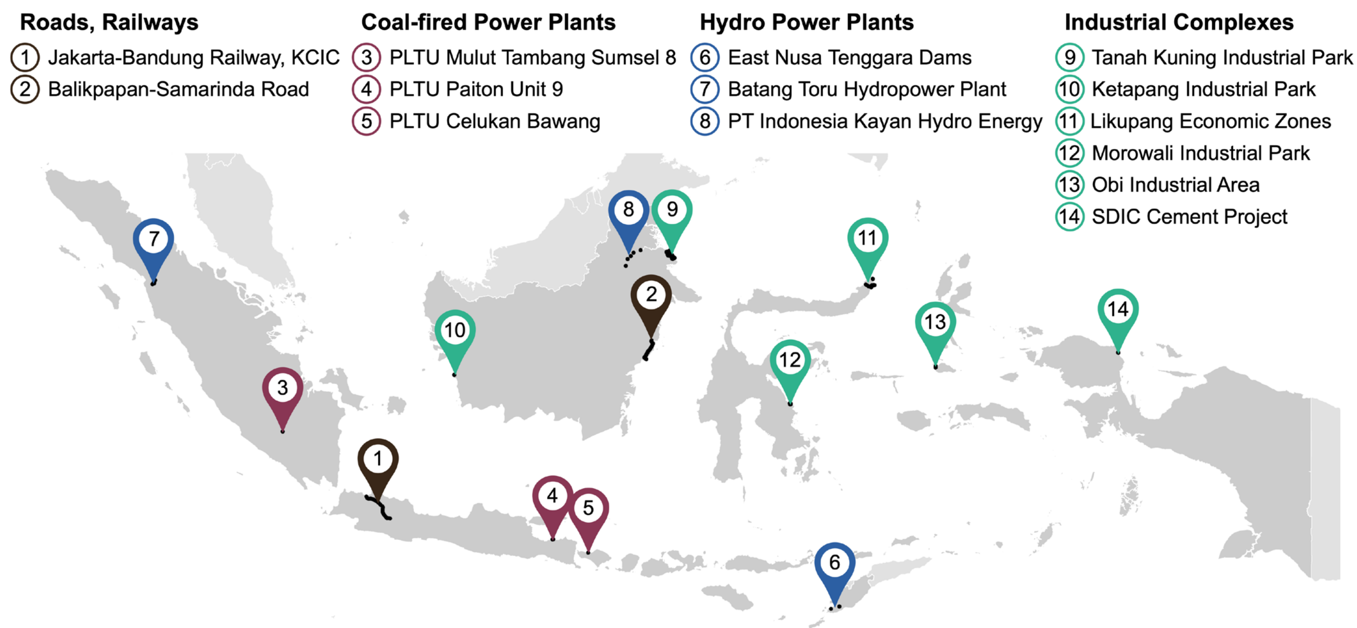
This study contributes to the growing literature on environmental and social risks of BRI projects, using Indonesia as an exemplar case study of a BRI member country that has received significant Chinese investment and must balance these priorities with the conservation and management of its substantial biological and cultural diversity. We assess on-ground changes in vegetation cover occurring within 14 clusters of Chinese FDI projects across Indonesia associated with the BRI and the implications of development for nearby forests, threatened species, important carbon sinks and air quality. We track potential impacts to affected Indigenous communities through direct health impacts from air and water contamination, loss of ecological services that support community diets and livelihoods and displacement due to flooding or construction. Additionally, we compare the relative environmental risks between FDI projects and draw recommendations for ongoing environmental policy and investment regulation discussions in Indonesia.

METHODOLOGY

Study Area and Chinese FDI Projects

We mapped the locations of 14 clusters of Chinese FDI projects related to the BRI across Indonesia previously identified by Pramono et al. (2021), including the regions of disproportionate Chinese investment mentioned above (Figure 1). These projects represent four major infrastructure types: (1) roads and railways, (2) coal-fired power plants, (3) dams for hydro power plants and irrigation and (4) industrial complexes, which include industrial parks, other large facilities and mixed-infrastructure projects, such as the Likupang Economic Zone which includes several facilities and an associated road. Eight of these projects are listed as Indonesia's national strategic projects as stipulated in Presidential Regulation No. 109 Year 2020 (on the Third Amendment of the Acceleration of the Implementation of National Strategic Projects).

Figure 2: Locations and Names of the 14 Project Clusters Investigated in This Study Across Indonesia. Precise Locations are in Black, with Borders Thickened to Enhance Visibility



Source: Authors' elaboration.

Environmental Assessments

We include five environmental parameters to investigate multiple dimensions of environmental risk most relevant to development activities (Gupta et al., 2006; Momirović et al., 2019; Rahman et al., 2014; Sun et al., 2013; Zhan et al., 2005; Zhang et al., 2021): vegetation cover, carbon density, primary forest, threatened species density and air pollution.

VEGETATION COVER

Using the method proposed by Rouse et al. (1974), we calculated the Normalized Difference Vegetation Index (NDVI) within the boundaries of each project by combining surface reflectance of red and Near-Infrared Band of the Landsat series data. We adapted the proposed method of NDVI time-series harmonization developed by Nguyen et al. (2020) based on combined data from several

Table 1: Project Clusters Studied

Project sites	Core business	NSPa	Project status	Supporting facilities	External inputs
1. Jakarta-Bandung High Speed Railway	High speed train	Yes	Under construction		
2. Samarinda-Balikpapan Toll Road	Toll road	Yes	Operational		
3. PLTU Mulut Tambang Sumsel-8	Coal-fired power plant	Yes	Under construction		
4. PLTU Paiton Unit 9	Coal-fired power plant	No	Operational		Coal
5. PLTU Celukan Bawang	Coal-fired power plant	No	Operational		Coal
6. East Nusa Tenggara Dams:		No			
6a. Raknamo Dam	Water reservoir	No	Operational		
6b. Kolhua Dam	Water reservoir	No	Under preparation		
6c. Mbay/Lambo Dam	Water reservoir	Yes	Under construction		
7. Batang Toru Hydropower Plant	Diversion- type hydropower plant	No	Under construction		
8. Kayan River Cascade Hydro-power Project	Series of 5 Impondment-type hydropower plants	No	Under construction		
9. Tanah Kuning Industrial Park	Ferronickel production	Yes	Under preparation		Hydropower from Kayan plant
10. Ketapang Industrial Park	Bauxite smelters	Yes	Operational	Coal-fired power plant	Bauxite, coal
11. Likupang & Bitung Economic Zones	Tourism, fisheries industries	Yes	Under construction	Coal-fired power plant	Coal
12. Morowali Industrial Park	Nickel smelters; producers of stainless steel, car batteries	Yes	Operational	3 coal-fired power plants	Nickel ore, coal
13. Obi Industrial Park	Nickel smelters; stainless steel, car battery production	Yes	Operational	Coal-fired power plant	Nickel ore, coal
14. SDIC Papua Cement Indonesia	Cement production	No	Operational		

Source: Authors' elaboration.
Note: NSP: National Strategic Project

multispectral sensors—namely Landsat 7, Landsat 8 and Sentinel 2—using the Google Earth Engine cloud platform (Gorelick et al., 2017).

For each project, we calculated the mean NDVI within the project boundaries (30 m resolution) for all time periods where data was available between January 1987 and February 2022. We used locally weighted smoothing (LOESS) to identify trends in vegetation cover over time within each site. Additionally, we compared the mean NDVI for 2009-2011 with the mean NDVI for 2020-2022 to estimate changes in vegetation cover before and after expected construction of all the FDI projects. We use 2009-2011 as an estimate for 2010 (before) and 2020-2022 as an estimate for 2021 (after) to account for data limitations or stochastic events affecting the NDVI in a single year or season (e.g. changes due to El Niño-Southern Oscillation events, wildfires or cloud cover).

CARBON DENSITY

To estimate carbon density within each site prior to construction, we obtained data from the Global Aboveground and Belowground Biomass Carbon Density Maps for the Year 2010 (Spawn et al., 2020), accessible through Google Earth Engine. For each project, we calculated the mean carbon density within the site's boundaries (300 m resolution), measured in MgC per hectare as of 2010.

PRIMARY FOREST

To estimate the potential indirect impact of development activities on forest loss outside the boundaries of the FDI projects (Barber et al. 2014), we calculated the minimum, maximum and mean Euclidean distance from each FDI project to the nearest primary forest. Here, we adopt the definitions used by the Indonesian Ministry of Environment and Forestry (KLHK, 2021), in which primary forests represent undisturbed natural forests, including "natural forest cover in the forms of primary dryland forests, secondary dryland forests, primary swamp forest, secondary swamp forests, primary mangrove forests and secondary mangrove forests" (p. 6). We obtained maps of primary dryland forests, primary swamp forests and primary mangrove forests from the most recent land cover map of Indonesia published by the Ministry of Environment and Forestry (Indonesia Geospatial Agency, 2022).

THREATENED SPECIES DENSITY

To identify additional risks to biodiversity, we focus on select threatened species representing surrogates of the intactness of ecosystems across Indonesia. We selected several threatened species, representative of the ecosystem where each FDI cluster occurs, including, where possible, keystone species essential to each ecosystem. For instance, the threatened hornbill distributes fig tree species, an indispensable building block of the tropical rainforest. Threat categories and species-specific assignments follow the IUCN Red List (IUCN Standards and Petitions Committee, 2019). The IUCN Red List classifies threatened species into nine groups based on a set of standardized criteria: population size, area of geographic distribution, rate of population decline and degree of population and distribution fragmentation. Only species categorized as "Critically Endangered", "Endangered" and "Vulnerable" were considered for each cluster. The selection sampled diversity of taxonomic groups and habitats. The terrestrial habitats included primary and secondary forests, both lowland and highland. The marine habitats included coral reef, sea grass and open sea clear water. Where information was available, we complemented the information on selected threatened species with considerations of the autecology of the species by way of literature reference, using SCOPUS and Web of Science. The final selection of species is in Table 2.

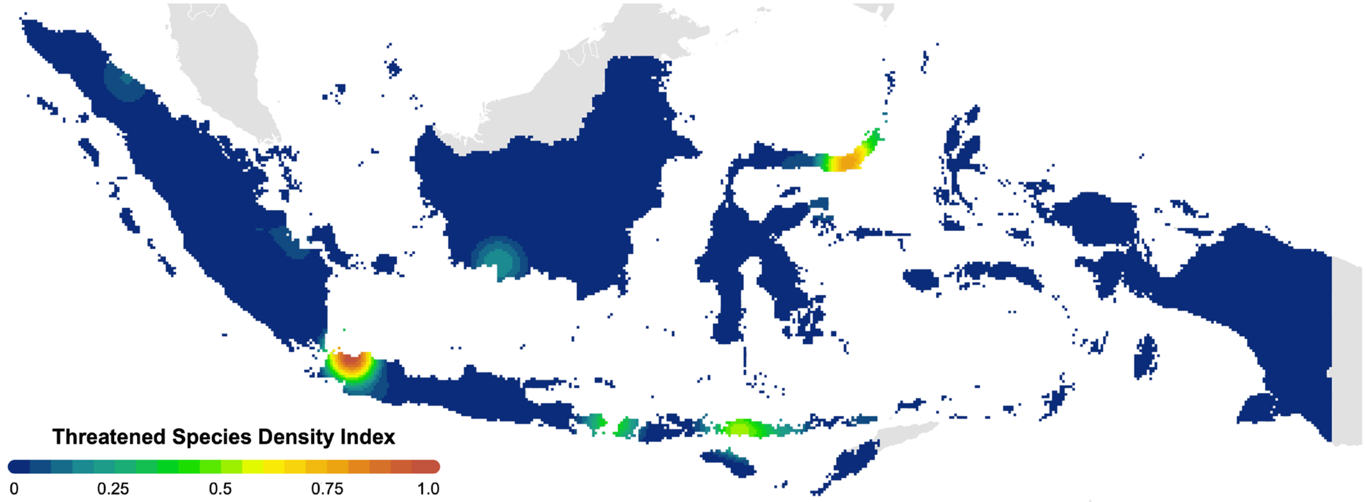
To measure the range of recorded species on a given island, we used a nonparametric kernel density estimator (Forte et al. 2018) given its wide range of applications, which does not require an understanding of the complex process behind it (Fleming and Calabrese, 2017). We utilized species presence-only data and predicted the distribution or niche of the selected threatened species and calculated species density at a 10 km resolution. We classified recorded species based on the IUCN Red List status (Table 2) and scored it as weighted distance (Figure 3).

Table 2: Selected Threatened Species

Species	Number of occurrences (point data)	Status	Geographical distribution
Panthera tigris sumatrae	6	Critically Endangered	Sumatra, Indonesia
Pongo tapanuliensis	1	Critically Endangered	Batang Toru ecosystem, North Sumatra, Indonesia
Hylobates moloch	62	Endangered	Western Java, Indonesia
Rhincodon typus	6	Endangered	Migrant, with an Atlantic subpopulation (from Maine and the Azores to South Africa) and an Indo-Pacific subpopulation (containing close to 75 percent of the population)
Mycteria cinerea	270	Endangered	Predominantly in coastal mangroves, a native to parts of Cambodia, Vietnam, Malaysia and Indonesia.
Hippocampus kuda	127	Vulnerable	Neritic and inter-tidal living species, from the Persian Gulf to Southeast Asia, Australia and Japan, some Pacific Islands including Hawaii, eastern coast of Africa (Tanzania to South Africa).
Nisaetus floris	151	Critically Endangered	Endemic to the Lesser Sunda Islands, Indonesia
Hylobates muelleri	3	Endangered	Southeast Kalimantan, south of the Mahakam River and east of the Barito River, Indonesia
Nasalis larvatus	82	Endangered	Borneo, mostly in mangrove forests and coastal areas
Eusideroxylon zwageri	95	Vulnerable	Sumatra, Borneo, Bangka, Belitung, Sulu Archipelago and Philippines (Palawan)
Rhinoplax vigil	5	Critically Endangered	Malay Peninsula, Sumatra, Borneo, Thailand and Myanmar
Hippocampus histrix	156	Vulnerable	Widespread, Indo-Pacific
Macrocephalon maleo	232	Endangered	Sulawesi and Buton islands, Indonesia
Zaglossus bruijnii	2	Critically Endangered	Bird's Head Peninsula and Foja Mountains of West Papua and Papua provinces, Indonesia
Ornithoptera aesacus	0	Vulnerable	Obi Island (the Maluccas), Indonesia

Source: Authors' elaboration.

Figure 3. Map of the Distance-Weighted Threatened Species Density Index, Showing Hotspots of Selected Keystone Species



Source: Authors' elaboration.

AIR POLLUTION

To investigate air pollution surrounding FDI projects, we obtained tropospheric NO2 column concentration data produced by a TROPOMI instrument on a Sentinel-5P (Copernicus, 2022), which uses spectral bands from the ultraviolet, visible and near-infrared wavelength range to measure NO2 concentrations from July 2018 to July 2021. We created a single map of the three-year mean tropospheric NO2 concentration (in 1015 molec. per cm2) across Indonesia at an approximate 1 km resolution of the source data. Because it is impossible to attribute causality between FDI projects and local NO2 pollution, we compared the mean NO2 concentration within the boundaries of the FDI projects and at incremental distances outside their boundaries. We created buffers around each project at distances of 500 m, 1 km and further at 1 km intervals up to 20 km from the project. For each distance range, we calculated the mean NO2 concentration to identify any trends in air quality with increasing distance from the project location.

COMPARATIVE ENVIRONMENTAL ASSESSMENT

To facilitate relative comparisons of the extent to which each FDI project introduces environmental risk across the multiple dimensions included in this study, we transformed each of the five environmental indicators into standardized indices of relative threat, with 1 representing the greatest threat and 0 the lowest threat for all projects. For carbon density, threatened species density and air pollution, scores were standardized such that the project(s) with the greatest estimate received a score

Table 3: Spatial Datasets Used in the Environmental Assessment Analysis

Data	Description	Resolution/ scale	Source
Google Earth	High-resolution imagery	30 cm	Maxar
Land Cover map	Indonesia land cover map	1:50.000	Indonesia Geospatial Agency
Landsat series: 5, 7, 8	NDVI	30 m	United States Geological Survey
Sentinel 2	NDVI	10 m	European Space Agency
Sentinel 5P	Air quality: NO2	0.01 arc degrees	European Space Agency
IUCN Red List of Threatened Species	Threatened Species		IUCN
Global Biodiversity Information Facility (GBIF)	Biodiversity data		GBIF gbif.org
iNaturalist	Biodiversity data		iNaturalist (https://www.inaturalist.org/)
Indigenous lands: BRWA	Indigenous lands	1 : 14,000	Badan Registrasi Wilayah Adat (https://www.brwa.or.id)
Indigenous lands: Dayak	Dayak community distribution		Institut Dayakologi
Indigenous lands: AMAN	Additional Indigenous village locations		Aliansi Masyarakat Adat Nusantara
Mineral concessions	Bauxite and nickel concession's locations near Indigenous communities		Ministry of Energy and Mineral Resources

Source: Authors' elaboration.

of 1 and the project(s) with the lowest estimate received a score of 0. The converse was applied to the mean distance to primary forest, where the minimum estimate (i.e., nearest to primary forest) received a standardized score of 1, and the maximum estimate (i.e., furthest from primary forest) received a score of 0. For vegetation change, scores were standardized such that the project(s) with the greatest percent decline in NDVI received a score of 1 and a score of 0 was assigned to any project in which no change or an increase in NDVI was observed within the site. We compared each FDI project according to the frequency with which it presented relatively greater threats (score > 0.5) across multiple dimensions of environmental risk.

Affected Indigenous Communities

The geolocation of the affected Indigenous communities was carried out in two ways. Firstly, the team extracted available maps of Indigenous lands posted on the website of Badan Registrasi Wilayah Adat (BRWA, a civil society initiative in collecting and verifying maps of Indigenous lands). The main weakness of using the maps of Indigenous lands is that the maps tend to be scattered, as they were made based on the requests of the particular Indigenous communities. For West Kalimantan, we used a map of Dayak group distribution produced by Institut Dayakologi, which covers most of the province continuously. After obtaining consent from the respective organizations, the team overlayed the maps of Indigenous lands in 14 clusters with the maps of infrastructures developed by BRI projects and concession areas feeding the processing plants of bauxite and nickel in the clusters. Maps of concession areas were extracted from the geoportal of the Ministry of Energy and Mineral Resources (ESDM, 2021), particularly on its minerals and coal section. Secondly, as not all Indigenous communities have maps of their territories, we requested lists of community members of Aliansi Masyarakat Adat Nusantara (AMAN, the Alliance of Indigenous Peoples of the Archipelago), the largest Indigenous Peoples organization in Indonesia with a membership of 2,359 communities throughout Indonesia (as of January 2021). We extracted names of villages where the communities are located and checked against the villages affected by BRI projects and related concession areas obtained from the textual information posted on ESDM geoportal.

Table 4: Spatial Datasets Used in The Social Assessment Analysis

Data	Description	Resolution/ scale	Source
Indigenous lands: BRWA	Indigenous lands	1 : 14,000	Badan Registrasi Wilayah Adat (https://www.brwa.or.id)
Indigenous lands: Dayak	Dayak community distribution		Institut Dayakologi
Indigenous lands: AMAN	Additional Indigenous village locations		Aliansi Masyarakat Adat Nusantara
Mineral concessions	Bauxite and nickel concession's locations near Indigenous communities		Ministry of Energy and Mineral Resources

Source: Authors' elaboration.

Environmental risks facing identified Indigenous communities are recorded across three categories: health, ecological services and displacement. Health risks include the impacts of air and water contamination. Ecological service loss may include the loss of forests, key species or livelihoods based on these resources. Community displacement may result from encroachment of new construction on ancestral lands or from flooding for reservoirs. These risks are tracked categorically rather than quantitatively to allow for the intrinsically subjective nature of possible harms. For example, the relative intensity of loss from ecological services and from flooding will necessarily depend on the extent to which each community's economy depends on these resources as well as the intangible value placed on them in myriad cultural and traditional knowledge contexts.

RESULTS

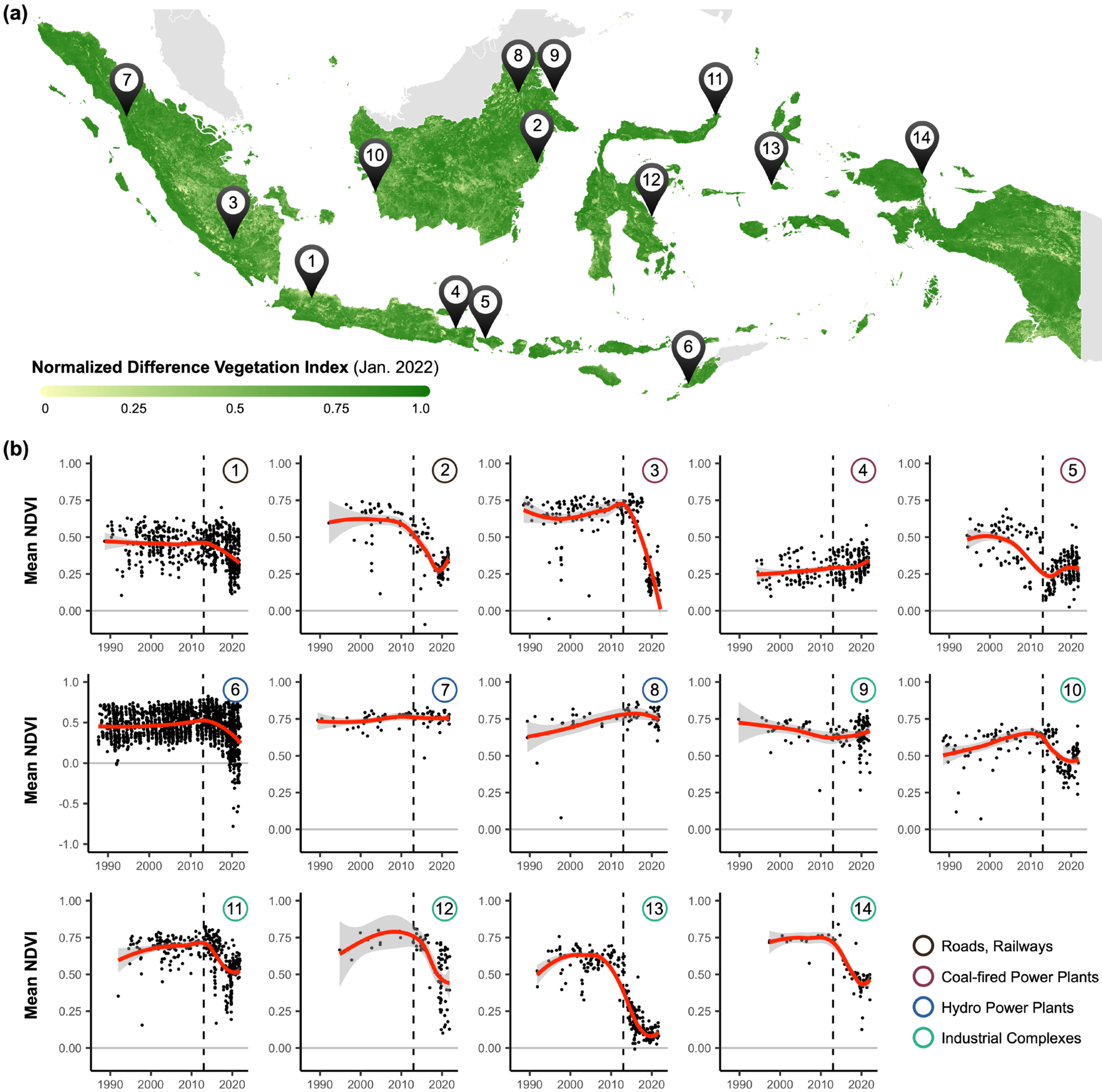
Environmental Assessment

CHANGES IN VEGETATION AND CARBON STOCK

Across all FDI projects, the mean NDVI has declined from 0.538 ± 0.155 (mean SD) in 2009-2011 to 0.388 ± 0.222 in 2020-2022, representing an average loss of 27.88 percent of vegetation overall. Trends in vegetation loss, however, are highly heterogenous between sites (Figure 4). In most sites, mean NDVI was stable or increased over time until 2013, or shortly thereafter, in which uncharacteristic declines began. Some of the most dramatic declines in mean NDVI after the launch of the BRI can be seen in the Obi Industrial Area, SDIC Cement Project, PLTU Mulut Tambang Sumsel 8 and along the Balikpapan-Samarinda Road (Figure 4b). For some projects, like the Batang Toru Hydropower Plant, PT Indonesia Kayan Hydro Energy, PLTU Paiton 9 and Tanah Kuning Industrial Park, changes in vegetation have been minimal, with some sites experiencing slight increases in NDVI since 2013. Some of these projects may have extensive vegetation loss when their construction is completed.

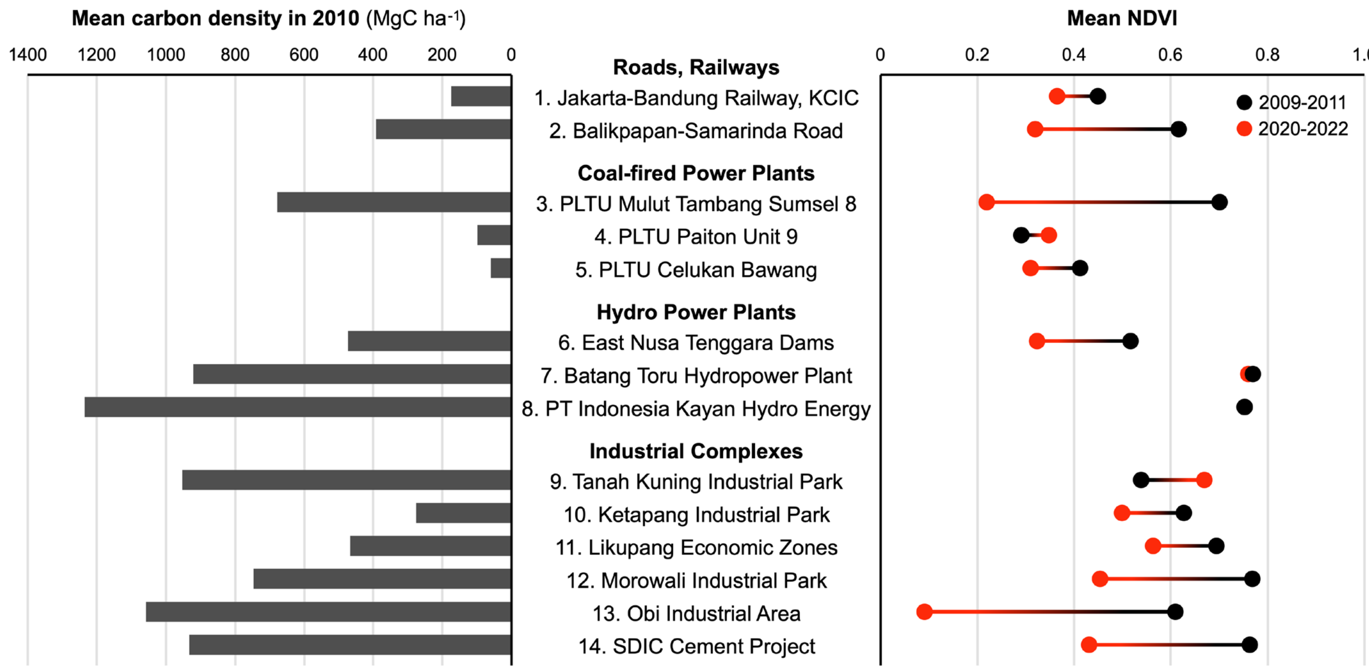
On average, the estimated aboveground biomass within the boundaries of all FDI projects amounted to 605 MgC/ha in 2010 prior to construction. As expected, all hydropower projects contained a high density of carbon in the adjacent forest (473-1236 MgC/ha) (Figure 5). Except for the East Nusa Tenggara dams, these hydro power projects have experienced minimal NDVI change since 2010. Notably, the landscape of the PLTU Mulut Tambang Sumsel 8 power plant and several industrial complexes (Morowali Industrial Park, Obi Industrial Area, SDIC Cement Project) were exceptionally carbon-dense prior to construction, yet these sites have experienced a 41-85 percent decline in NDVI since 2010 (Figure 5).

Figure 4: (a) Project Locations Relative to the Mean Normalized Difference Vegetation Index (NDVI) as of January 2022. (b) Change in Mean NDVI within the Boundaries of Each Project Over Time, with the 2013 Launch of the Belt And Road Initiative (Dashed Line) Highlighted for Reference. Trendlines (Red) and Confidence Intervals (Grey) are Fitted with Loess Smoothing



Source: Authors' elaboration.

Figure 5: Comparison of the Mean Carbon Density within the Boundaries of Each Project in 2010 and the Change in Mean Normalized Difference Vegetation Index (NDVI) from 2010 to 2021. Dates dor 2010 are averaged Across NDVI Estimates for 2009-2011 and Averaged across 2020-2022 for 2021, to Account for Seasonal and/or Annual Differences in Vegetation

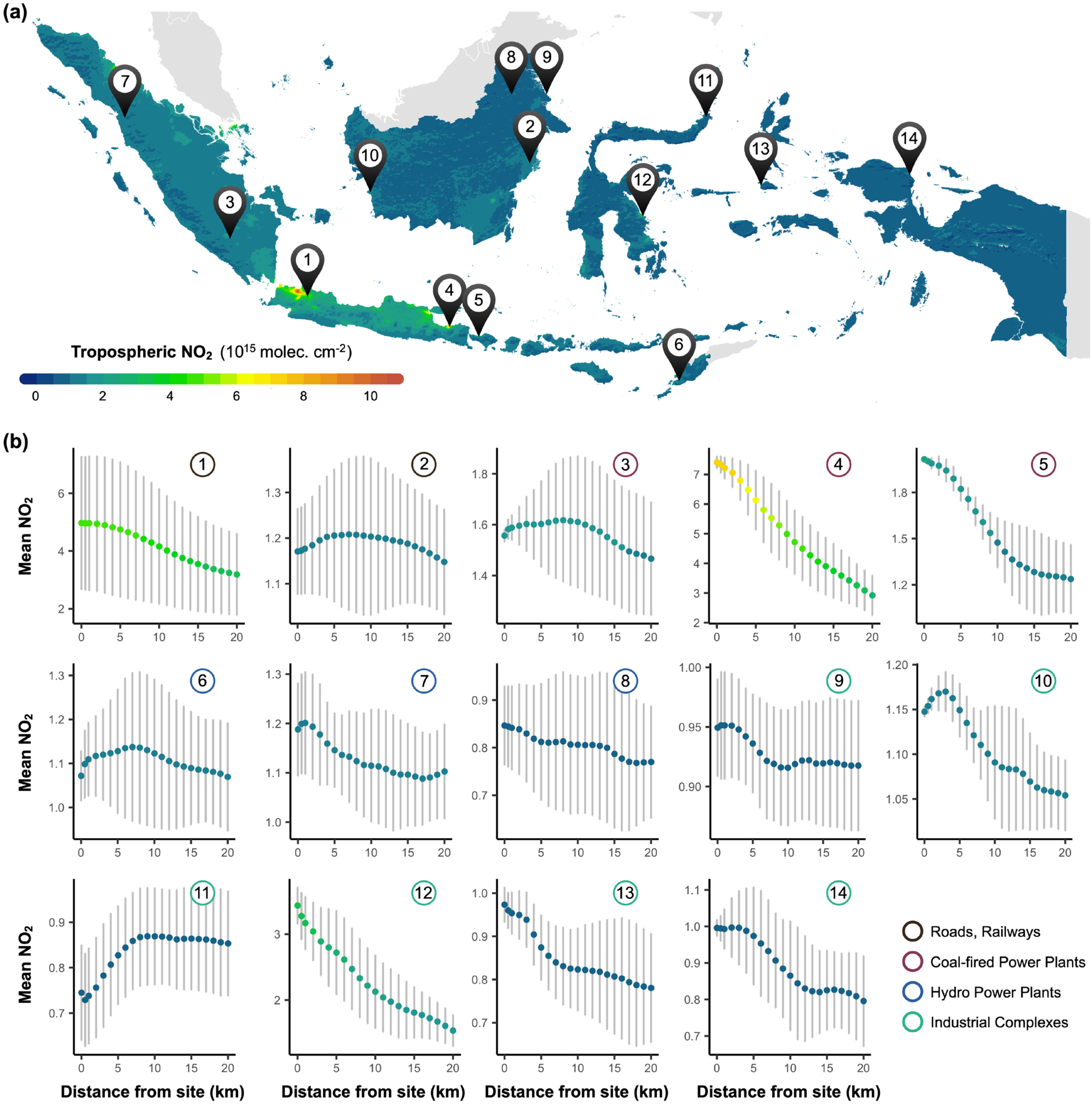


Source: Authors' elaboration.

AIR POLLUTION

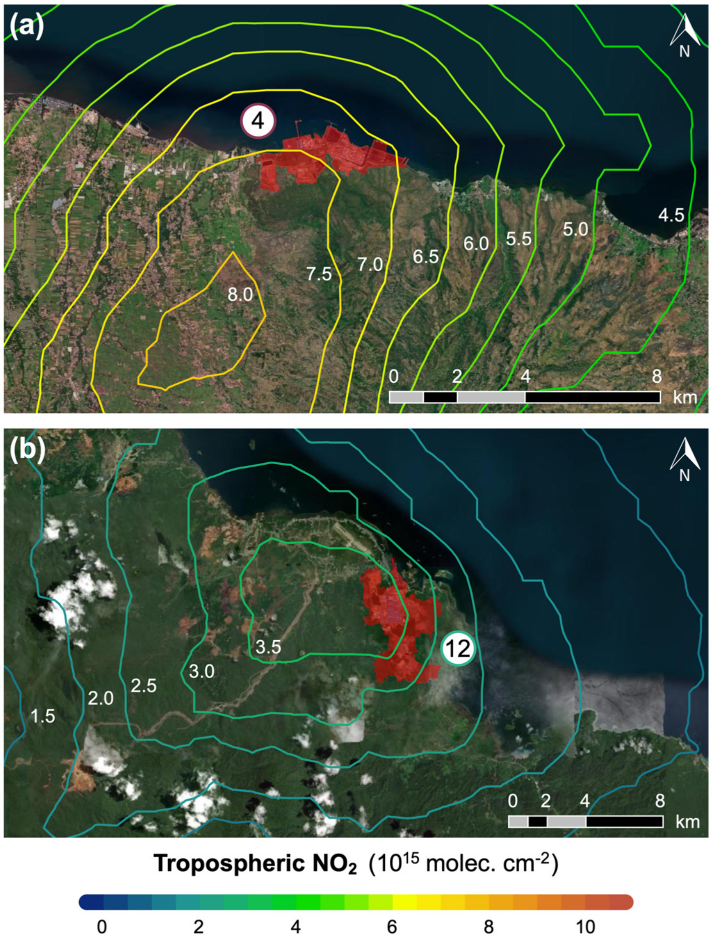
Mean tropospheric NO2 concentrations tend to be greatest within the boundaries of 10 FDI projects (71 percent) than in their immediate surroundings (Figure 6). However, the difference between NO2 concentrations within and outside project boundaries is relatively small for most projects, typically less than 0.5×1015 molec/cm2. Projects with the greatest declines in NO2 further from the project site are the PLTU Paiton Unit 9, Morowali Industrial Park and Jakarta-Bandung Railway. However, the magnitude of NO2 decline is smaller for the Jakarta-Bandung Railway, which is situated in the most polluted region of Java (Figure 6a). As the train tracks are under construction and electric train cars will be used, it is thus unclear just how much of this pollution is indicative of the railway rather than surrounding developments. In contrast, the PLTU Paiton Unit 9 power plant (mean NO2 concentration = 7.41×1015 molec/cm2) and Morowali Industrial Park (3.43×1015 molec NO2/cm2) overlap with unique hotspots of NO2 pollution in the region, where there is less outside development that might be contributing to these elevated NO2 concentrations (Figure 7).

Figure 6: (a) Project Locations Relative to the Mean Tropospheric NO2 Concentration between 2018 and 2021. (b) Change in Mean NO2 Concentration for Each Project With Increasing Distance from the Project Boundary. Distances Represent the Respective Buffer Zone Surrounding the Project, with a Distance of Zero Representing the Mean Concentration within the Project Boundaries. Error Bars Represent the Standard Deviation



Source: Authors' elaboration.

Figure 7: Isolines of the Mean Tropospheric NO2 Concentration between 2018 and 2021 Surrounding (a) PLTU Paiton Unit 9 (Project 4; Red) and (b) The Morowali Industrial Park (Project 12; red)



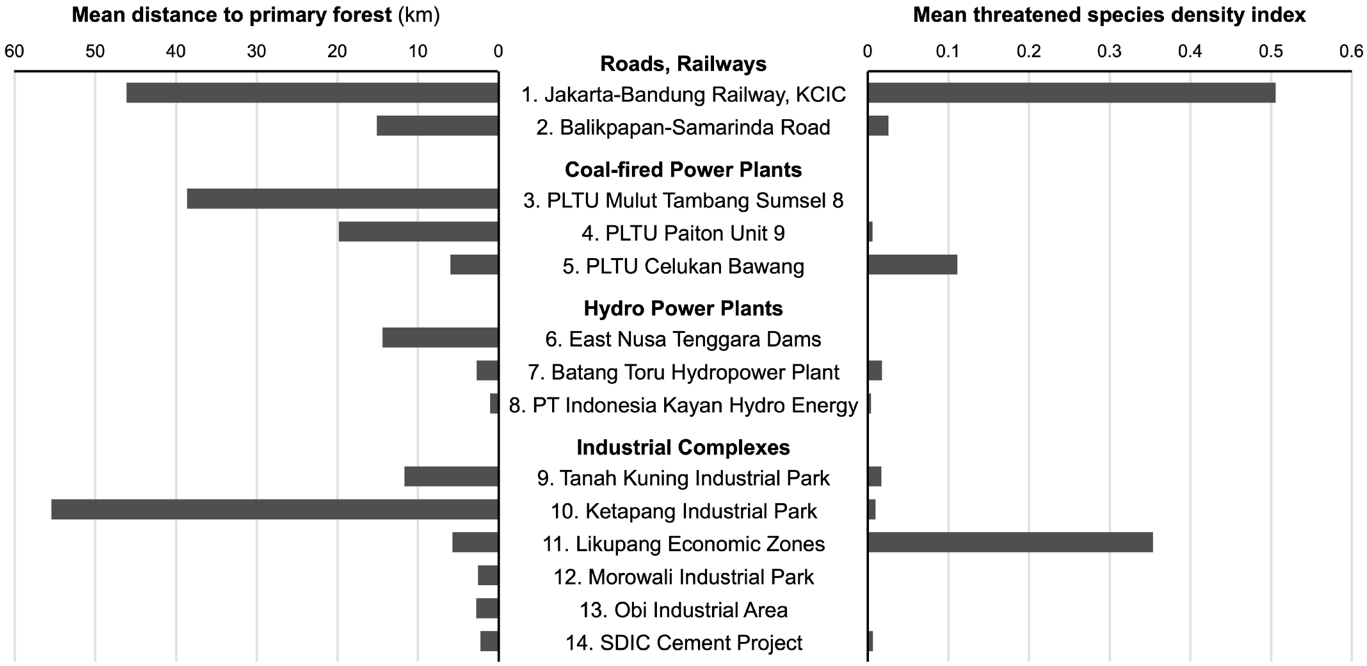
Source: Esri, Maxar, GeoEye, Earthstar Geographics, NES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community.

RISKS TO FORESTS AND BIODIVERSITY

More than half of the FDI projects are within 5 km of primary forest. The Batang Toru and PT Indonesia Kayan Hydro Plants are adjacent to these important forests and several industrial complexes are within 3 km of these forests, on average (Figure 8). At their closest, the perimeters of the buffer zones along the Bitung-Likupang toll road near the Likupang Economic Zones and Morowali Industrial Park are just 300 meters from the nearest primary forest. Additionally, the Balikpapan-Samarinda Road tends to be, on average, 15 km from any primary forest, yet at its closest point it is within 5 km of nearby forest. Projects that likely pose the least risk to primary forests include the Ketapang Industrial Park, Jakarta-Bandung Railway and PLTU Mulut Tambang Sumsel 8 power plant.

Eleven FDI projects (79 percent) score relatively low on the threatened species density index (SDI < 0.10) (Figure 8). The three projects with the greatest mean SDI are the PLTU Celukan Bawang power plant (SDI = 0.111), Likupang Economic Zones (SDI = 0.354) and Jakarta-Bandung Railway (SDI = 0.505). Collectively, risks may be greatest surrounding the PLTU Celukan Bawang power plant and the Likupang Economic Zones given the presence of threatened keystone species and nearby

Figure 8: Comparison of the Mean Distance of Each Project from the Nearest Primary Forest and their Mean Score on the Threatened Species Density Index.



Source: Authors' elaboration.

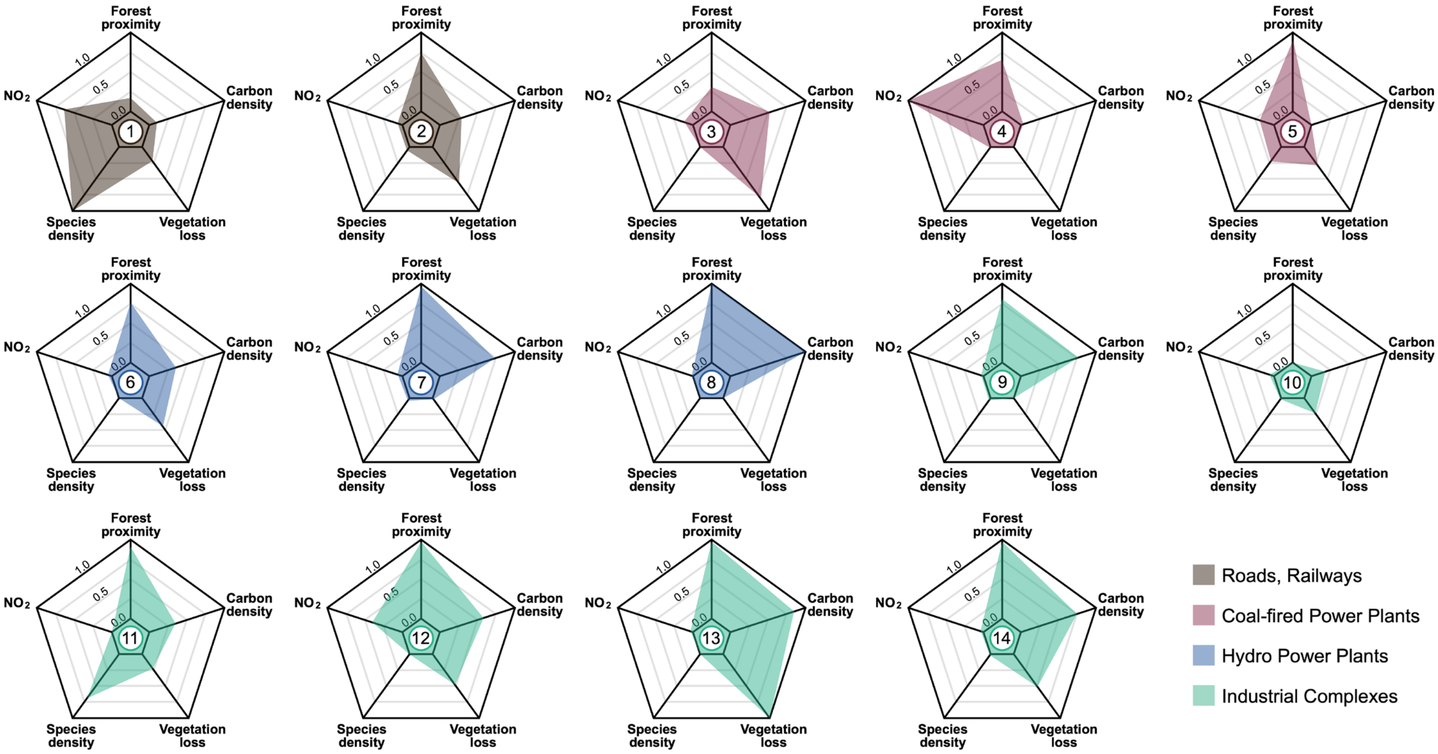
primary forests. However, if the extraction of external inputs is considered, the risks may be much higher, particularly in open pit mines.

COMPARATIVE ENVIRONMENTAL ASSESSMENT

Three industrial complexes present the greatest risks to multiple environmental attributes: the Obi Industrial Area, SDIC Papua Cement Indonesia and Morowali Industrial Park (Figure 9). These projects are all adjacent to primary forests, in areas with high carbon density and exhibit some of the highest rates of vegetation loss since 2010. Eight projects present relatively high risks to just two of the environmental attributes we considered, but there is little consistency in threats within similar types of projects. For example, the PLTU Mulut Tambang Sumsel 8 power plant presents high risks related to vegetation and carbon loss, while the PLTU Paiton Unit 9 presents greater risks to air quality and nearby primary forests. Additionally, while the Jakarta-Bandung Railway does not present the same level of threats to forests and vegetation loss to the Balikpapan-Samarinda Road, it poses the greatest risks to the threatened keystone species included in our analysis and may be contributing to NO2 pollution. Notably, some projects only present relatively high risks to one environmental attribute. For example, the PLTU Celukan Bawang power plant may primarily affect adjacent primary forests. Only one FDI project, the Ketapang Industrial Park, presents relatively low risks to every environmental attribute considered.

There does appear to be a trend for most hydro power plants. The Batang Toru and PT Indonesia Kayan hydro power plants are adjacent to primary forests and situated in areas with a high carbon density (though they are not yet experiencing much vegetation change as they are under preparation) and not in areas with high pollution. The East Nusa Tenggara Dams show higher vegetation loss. However, this is primarily observed in the Raknamo Dam; the Kolhua and Mbay/Lambo Dams are more similar to the other two hydro power projects.

Figure 9: Comparison of Each Project's Score on the Indices of Primary Forest Proximity, Carbon Density, Vegetation Loss, Threatened Species Density and Pollution (NO2). Projects Scoring Higher on an Index Present Greater Threats to the Respective Environmental Attribute



Source: Authors' elaboration.

Risks to Indigenous Communities

The BRI projects affect the Indigenous Peoples in 11 out of 14 clusters. The most affected groups are those whose territories overlap with mining concessions, i.e., in Ketapang district (West Kalimantan), Morowali district (Central Sulawesi) and Obi Island (South Halmahera district, North Maluku). In West Kalimantan, the bauxite concessions located in the western part of the province cover a large portion of areas where at least 46 Indigenous Dayak languages are spoken. This situation implies that a large number of Indigenous Dayak peoples are affected. In the Morowali district, the nickel concessions supplying the smelters in Morowali industrial park in the southeasternmost end of Central Sulawesi and close to Matano-Towuti lake complex overlap significantly with the 45,000-ha territory of Bahomotefe people. In Obi Island, AMAN registers the whole island as the territory of the Obi people. Since the island has several nickel concessions and nickel-based industrial complexes, Obi people face a high potential of environmental and social risks from the investments.

Infrastructure development also presents serious potential impacts to Indigenous Peoples. The most significant is the development of dams in East Nusa Tenggara. If the dam is built at the planned location, the farms of Rendu people in Nagekeo district (Flores Island) will be inundated, affecting their livelihoods. Furthermore, the affected lands are of cultural significance to Rendu people where traditional houses and sacred sites are located. Finally, the activities of women in food provisioning and culturally important activities (such as weaving and medicinal plant collection) will be restricted. The Rendu people have not opposed the dam but have advocated for it to be relocated to reduce the impacts to them (de Rosary 2021). In August 2021 the Ministry of Public Works and Public Housing

Table 5: Known Indigenous Communities Overlapping with FDI Project Locations and the Anticipated Environmental and Social Risks from Development

Cluster	Known Indigenous Community	Health: pollution	Ecosystem svcs: lost resources/ livelihoods	Displacement
1. Jakarta-Bandung Railway	None			
2. Samarinda-Balikpapan Toll Road	Dayak communities (Balik)	Air		
3. PLTU Mulut Tambang Sumsel-8	None			
4. PLTU Paiton Unit 9	None			
5. PLTU Celukan Bawang	Celukan Bawang (a)	Air		
6. East Nusa Tenggara Dams				
6a. Raknamo Dam	Unknown			Flooding
6b. Kolhua Dam	Helong clan			Flooding
6c. Mbay/Lambo Dam	Rendu, Ndora and Labolewa (b)			Flooding
7. Batang Toru Hydropower Plant	Batak Angkola (c)		Critically endangered orangutan	
8. Kayan River Cascade Hydropower Project	Dayak Kenyah communities (d) (e)			Flooding
9. Tanah Kuning Industrial Park	Unknown			Involuntary resettlement
10. Ketapang Industrial Park	Dayak groups (f)	Air, water	Deforestation, livelihood loss	
11. Likupang & Bitung Economic Zones	Yes		Loss of valuable and vulnerable coral reef	
12. Morowali Industrial Park	Bahomotefe (g)	Air, water (tailing)	Deforestation, livelihood loss	Involuntary resettlement
13. Obi Industrial Park	Obi (h)	Air, water (tailing)	Deforestation, livelihood loss	Involuntary resettlement
14. SDIC Cement Project	Domberay group of Papuan peoples (i)	Air	Water loss, livelihood loss	

Source: Periyasa, 2021; b. Anonymous 2021.; c. Dalimunthe 2010; d. Pratama 2021; e. Zulkarnaen, 2020; f. Peta Keberagaman Bahasa Dayak di Kalimantan Barat (Map of Dayak Language Diversity in West Kalimantan), April 2008.; g. BRWA, 2021.; h. Membership list of AMAN (2021); i. Kementerian PPN/Bappenas, 2020.

selected a state-owned construction company to build the dam. Since then, the conflict has intensified as the contractor deployed its personnel and equipment with the assistance of security forces. The communities have continued to express their resistance, with women leading collective action.

DISCUSSION AND AREAS FOR FUTURE RESEARCH

These results open new avenues for considering and managing environmental and social risks associated with Chinese investment in Indonesia. They shed light on ongoing controversies surrounding the 14 clusters discussed here and allow for an evidence-based consideration of associated risks and potential risk management strategies.

Commonalities emerge among types of projects and associated ecological and social risks. As Figure 8 shows, the hydropower projects studied here are disproportionately likely to be in proximity to intact forests with high carbon density, blunting the value of these installations for climate change mitigation (see for example Hertwich 2013; Lu et al 2020). Table 5 shows that the hydropower dams also pose risk of displacement for Indigenous communities. Given these clustered risks, it is clear that Indonesia's renewable energy planning and development processes could benefit from greater emphasis on life-cycle emissions analysis, including from biogenic sources. Furthermore, greater care can be taken to ensure that investment benefits local communities rather than removing them from ancestral lands.

Industrial complexes have also been highly likely to be located near intact forests, in areas with high carbon density, resulting in vegetation loss. Their likely risks to local Indigenous communities include not only human health impacts through air and water contamination but also indirect impacts through diminished ecological services via deforestation and species loss. As with hydropower dams, the choice of location for industrial parks is a major factor in these impacts and both communities and the ecosystems that support them could benefit from greater consideration in project placement.

Among coal-fired power plants, air quality remains a significant concern. Substantial variation emerges between the NO2 emissions associated with Clusters 4 and 5 (the Paiton and Celukan Bawang plants, respectively), although they are both currently in operation. As Figures 6 and 8 show, the 4.7GW Paiton plant has NO2 levels many times higher than those near the much smaller Celukan Bawang. Moreover, as Figure 7 shows, these levels remain elevated over 20km from the source. Thus, for example, the town of Besuki (approximately 10km east of Paiton and with a population of approximately 34,000 people) faces NO2 levels higher than populations immediately adjacent to nearly any other investment cluster studied in this sample. Thus, it is important to consider a wider range of potentially affected communities when planning larger projects.

This study aims to contribute an evidence-based consideration of environmental and social risks from BRI projects in Indonesia. However, additional areas of future research remain to further inform enforcement and enhancement of environmental regulations for these projects. For example, another important contribution would be supply chain analysis, including materials supplied to the projects. This is particularly crucial for mining concessions of coal supplying coal-fired power plants, except for the Sumsel-8 MMCFPP which sources its coal from surrounding mines. For other plants, it is most likely that the coal is shipped from East Kalimantan and South Kalimantan where coal mining in Indonesia is concentrated. JATAM (2021) reports that many of these concessions carry significant social risks, including tenurial conflicts and abandoned mine pits and associated drowning deaths (particularly among children). Another key material of concern is cement for infrastructure development, considering the rich literature discussing the significant environmental and social impacts of the cement industry (see for example Ahmed et al 2021 and Putra et al 2020). The SDIC cluster in West Papua provides a good example as to how the industry affects society and environment. If and when the necessary information for supply chain analysis becomes public, it will be important to incorporate this aspect into environmental analysis.

CONCLUSIONS AND POLICY RECOMMENDATIONS

As a hotspot for both biological and cultural diversity, Indonesia should take special care to manage environmental and social risks from investment projects. Inadequate management of these risks may dampen the economic benefits brought by this activity, through lost traditional livelihoods and ecological services and the costs of remediation.

Fortunately, the Chinese government has shown a growing awareness of these risks. In 2021 the Chinese Ministry of Foreign Commerce and Ministry of Ecology and Environment issued joint "Green

Development Guidelines for Overseas Investment and Cooperation," urging investors to take a "whole lifecycle" approach to environmental management, incorporating upstream as well as downstream impacts (NDRC 2021). China has also committed to ending support for coal-fired power plants overseas and instead boost development of renewable energy generation (Xi 2021). However, as these results show, even renewable energy such as hydropower can have significant environmental and social impacts. Thus, it is crucial to ensure Indonesia's institutional will and capacity to manage risks and benefits of these important projects.

Unfortunately, BRI host countries impede effective environmental management, due to the inclination towards "investment friendly" policy. In Indonesia, the enactment of Job Creation Law (No. 11 of 2020) is expected to provide such an environment. As Pramono et al (2021) explain, the Job Creation Law reforms many social and environmental protections in the name of attracting investment and generating employment. However, as the results here make abundantly clear, it is important to consider the varied impacts of different sectors of projects. While it may be appropriate to simplify permitting processes for relatively low-impact sectors, the sweeping approach of the Omnibus Bill is mismatched in scope for the risk contours presented to Indonesia's ecosystems and the communities they support.

One element of the Omnibus Law that marks an important step forward is its treatment of social forestry and lands managed by Indigenous communities. As the results here show, Indonesia's Indigenous communities often lack even basic protections such as formal maps of their traditional lands and thus face substantial risks of environmental degradation of those lands or even displacement from them due to flooding and involuntary resettlement. However, the Omnibus Law also diminishes the community input necessary for environmental permit approval, potentially blunting this benefit. Furthermore, the Omnibus Bill expedites land appropriation for construction and weakens EIA processes, shrinking the time and attention paid to risks like those highlighted here. As of May 2022, the Supreme Court has ordered the bill's revision. As it is debated and potentially enacted, it is important to reinstate the obligatory function of EIA and ensure the immediately impacted communities maintain central decision-making powers.

Lastly, investors themselves can help fill this information gap through Nature-related financial disclosures. For example, the scarce data on threatened species provides an opportunity to establish monitoring sites. The latter will provide a good measure (including financially robust returns) for a company's Environmental and Social Governance ratings, especially when they are adequately calculated into the Task Force on Nature-related Financial Disclosure. The recommendations from Nature-related financial disclosure can help companies share information desired by investors, lenders and insurance underwriters to evaluate and price nature related risks and opportunities.

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