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The multi-risk vulnerability of global coal regions in the context of mine closure

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Abstract

Coal mining industries face real challenges to meet legal demands on a low carbon future. The history of coal in industrial transitions seems to come to a rapid end, accompanied by widespread boom of closing active coal mining projects. This change can result in negative ramifications for coal mining regions, involving a complex interplay of multiple risks. In this paper, we aim to analyse the complexity of environmental, social, and governance factors that can cause significant difficulties in closure of coal mining operations. We identify multi-factor risk profiles for operating mines by applying spatially explicit indicators within a proposed multi-risk framework. The indicators have not been captured by conventional market, as they tend to be more long-term oriented in the context of strategy and performance. We map eight risk categories: stability, water and climate, biodiversity, vulnerability of land uses, indigenous people, social fragility, political fragility, and regulatory environment, and analyse their effect on a global dataset of active open pit coal mines. The spatial analysis reveals that a significant proportion of the projects face accumulation of multiple risk factors. A total of 552 projects out of 916 show medium to very high-risk occurrence. In this paper, we present global risk vulnerability across the coal mining projects by indicating extent to which operators of the mines face multiple risk factors when planning for closure.

Keywords: *coal phase-out, ESG, multi-factor risk, rehabilitation*

1 Introduction

Coal industries have been challenged by a movement targeting a reduction in global emissions. Over one hundred major financial institutions have issued restrictions on investments in coal (Buckley 2019). The European Parliament has called for the European Union to exit coal by 2030 (European Environmental Bureau 2019). This year, for the first time in history, an Australian judge ruled against a new coal mine development citing community concerns about climate change (McGowan & Cox 2019). These and other actions forecast changes in the coal mining industry with ramifications for the energy sector worldwide. In some jurisdictions, a rapid and widespread closure of coal mining projects is expected in order to meet legal demands on a low carbon future. All this can result in negative consequences for coal mining regions, involving a broad range of complex risks. To achieve long-term sustainability and social gain in these regions, closure approaches should consider co-occurrence of multiple risks.

Coal mining has specific characteristics that warrant particular attention (Salmon 2018). When open pit coal mines operate, millions of tons of rock need to be moved, resulting in distinct landscape changes. Key features of this change are spoil piles, rejects and tailings depositories, and final voids where mining occurred immediately prior to closure. These human-made environments, and their interplay, are more sensitive to various factors and their interplay than natural ecosystems. They can create a complex set of long-term environmental and social issues and challenges for post-mining land use and rehabilitation as previously shown by, for example, Lechner et al. (2017). Therefore, a broad range of environmental considerations are present in investor decision-making in mine closure planning. In the open pit, large-scale coal mining, environmental risks primarily include stability of waste storage facilities and final voids, and water and biodiversity impacts (Hendrychová & Kabrna 2016; Walters 2016). The social risks of coal mining refer to the nature of multi-faceted relationships between the company, the local community, and host society (Bainton & Holcombe 2018), to the vulnerability of the environment caused by cumulative human disturbances (Venter et al. 2016), and to the dynamics associated with cultural heritage, and indigenous and tribal lands (O'Faircheallaigh 2017). The governance risks highlight the link between institutional frameworks and the achievement of Sustainable Development Goals (United Nations Development Programme 2015). These risks include the legal and regulatory systems, processes and mechanisms that control corporate decisions and actions, corporate disclosure and transparency, corruption, taxation regime, trade barriers, and other political factors (Organisation for Economic Co-operation and Development 2017).

In this paper, we use the framework of environmental, social, and governance (ESG) risks in global mining industry environment as previously developed by Valenta et al. (2019). Recent research about large-scale mining has highlighted the complexity of factors that need to be considered by companies, communities, and governments in designing, developing, operating, and closing large-scale extractive projects (Ranängen & Lindman 2017). Addressing ESG issues has therefore become a critical part of business strategy. The ESG framework presented in this paper explores important risk domains that have not been captured by conventional market indicators. These risk domains tend to be long-term oriented in the context of strategy and performance.

The aim of the study is to analyse the complexity of ESG factors that can cause significant difficulties in closure of coal mining operations. Using the ESG framework presented in Section 2.1, we applied spatially explicit indicators to map multi-factor risk profiles of active coal mine projects on a global scale.

2 Methods and data collection

2.1 ESG Framework

In developing the ESG framework, we considered eight risk categories that can contribute to risk vulnerability of mining projects and entire regions, if being in high or medium importance: stability, water and climate, biodiversity (environmental risks); vulnerability of land uses, indigenous people, social fragility (social risks); political fragility, and regulatory environment (governance risks). The scheme of the framework is presented in Figure 1. Risk categories and risk factors (input datasets) are described in Appendix 1.

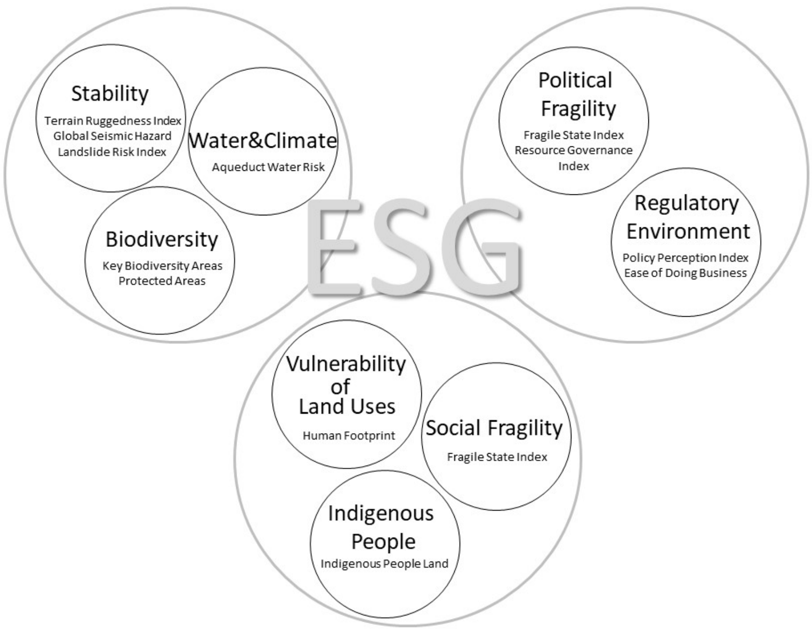

Figure 1 The ESG framework

Every risk category compiles from various risk factors developed by previous research. The factors represent measures of particular risks or their aspects. Recognising diversity in completeness, content, and representativeness of the factors, different combinations of global risk factors were compiled for each risk category. Each of these factors, through their interactions with the mining project, are considered as having the potential to generate risks that can cause difficulties in mine closure planning.

2.2 Data collection and spatial analyses

The global dataset of active coal mines was extracted from the S&P Global Market Intelligence database (S&P Dataset) (S&P 2019) as an Excel table with latitude and longitude coordinates and other characteristics such as projected closure year, mining method, activity stage, owner's name, and operator's name. The S&P database is a commercial database where data are collected from publicly-released information provided by owners of mining properties. Although it is one of the largest, most comprehensive and up-to-date sources (Valenta et al. 2019), the data are limited by the extent of corporate self-reporting. For instance, artisanal and small-scale mining or some state-owned projects and other unreported mining activities are not covered by the database.

From the global dataset, we selected all projects where coal was a primary commodity and where an extractive method was open pit mining. To narrow the responsibility for the risk management toward the operating companies, we further reduced our sample to the mining projects that are active, under care and maintenance, on hold, or under litigation. As a result, we selected a set of 916 coal mining projects. Approximately 92% of these entries are projects in their active phase and the remaining 8% are under care and maintenance, on hold, or under litigation. Only 107 of the active projects (13%) has reported a closure year (Figure 2).

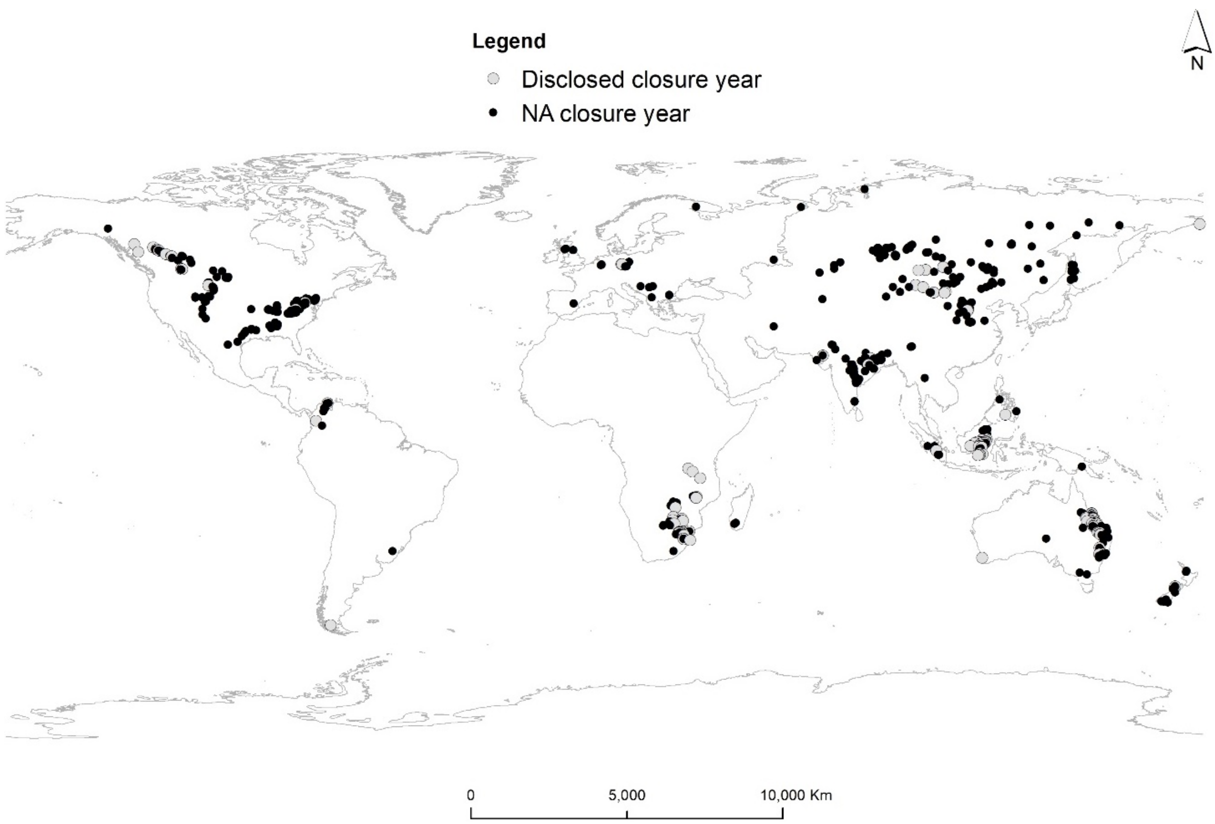

Figure 2 Coal mines selected for the study considering criteria such as active, open pit mining method, coal as a primary commodity. Only 13% of the projects have disclosed closure year

The input datasets for the ESG risk factors were downloaded from the sources listed in Appendix 1 as spatially referenced Geographic Information System data represented by rasters or vectors.

All spatial analyses were conducted using ArcGIS 10.6 system software. The coordinates of coal mines were transferred to spatially explicit vector points. To identify multi-factor risk profiles of coal mine projects, we conducted overlay analyses Spatial Join (Analyses toolset) and Extract Multi-Values to Points (Spatial Analyst toolset) using the mines as a target layer and the ESG risk factors as join layers (Environmental Systems Research Institute 2018).

As a result of these analyses, every mining project received a level of risk for each ESG factor, based on risk calculation and normalisation presented in Table 1. For every mine, medium and high-risk factors were indicated as '1' and low level risks as '0'. The ESG risk category was considered as severe when any of its input risk factors received a value of '1'. For instance, the stability ESG risk category was recognised as severe when any from Global Seismic Hazard, Terrain Ruggedness Index, or Landslide Risk Index were showing high or medium risk (value '1'). In the presented ESG framework, we considered all ESG risk categories as equivalent in terms of their impact on mine closure. Based on the risk profiles, all mines were divided into three categories:

1. Low-risk projects (zero to three ESG risks presented).
2. Medium-risk projects (four to six ESG risks).
3. High-risk projects (seven to eight ESG risks).

3 Results

A total of 102 mines (11%) out of 916 projects were identified as high-risk projects, 450 (50%) mines were assessed as medium-risk projects and the remaining 360 (39%) projects as low-risk. The average number of risks was 4.2 per project (Figure 3).

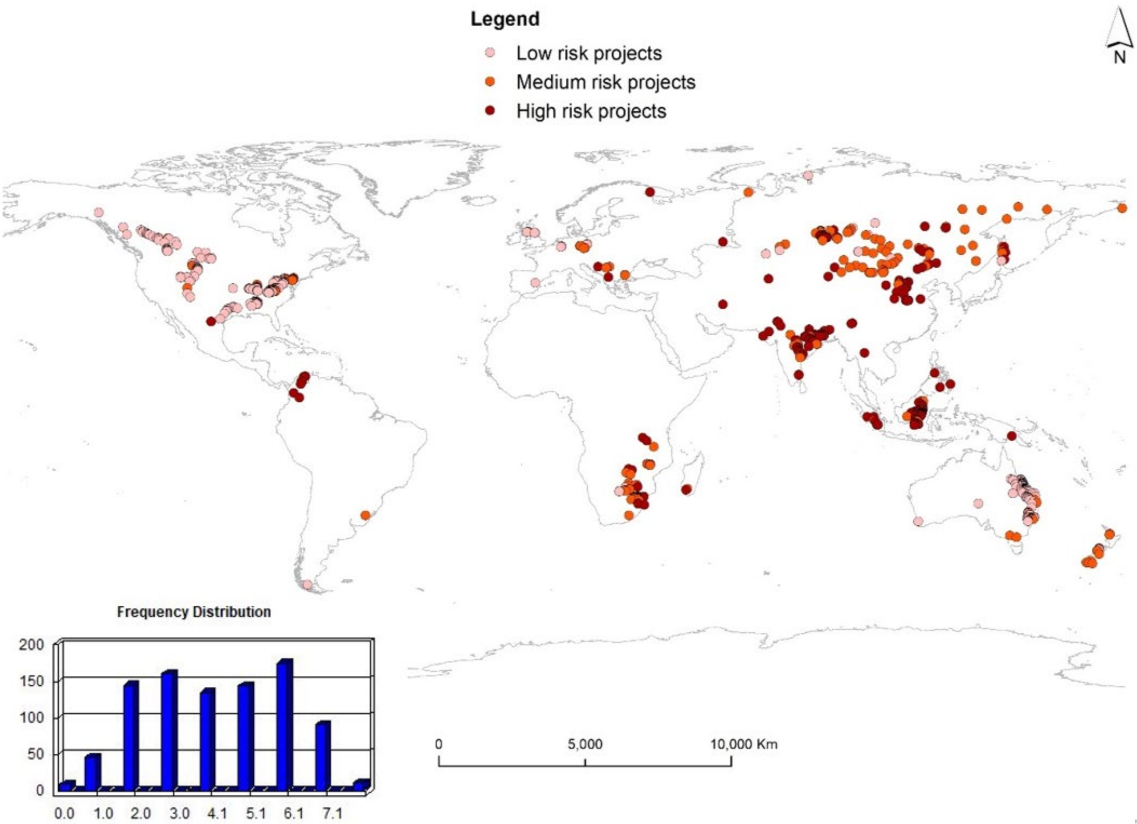

Figure 3 The global multi-factor risk profile of coal mining projects and the frequency distribution of multiple risks

A total of 11 coal mine projects showed an occurrence of all eight ESG risks, which indicates an extremely high-risk profile (Figure 4). All these mines are presently active with an operations commencement date between 1968 and 2009. According to the S&P Dataset, none of these projects have disclosed a closure year. Five of these projects are in India and run by four different companies. Five projects are in Indonesia operated by three various companies and one project is in Philippines.

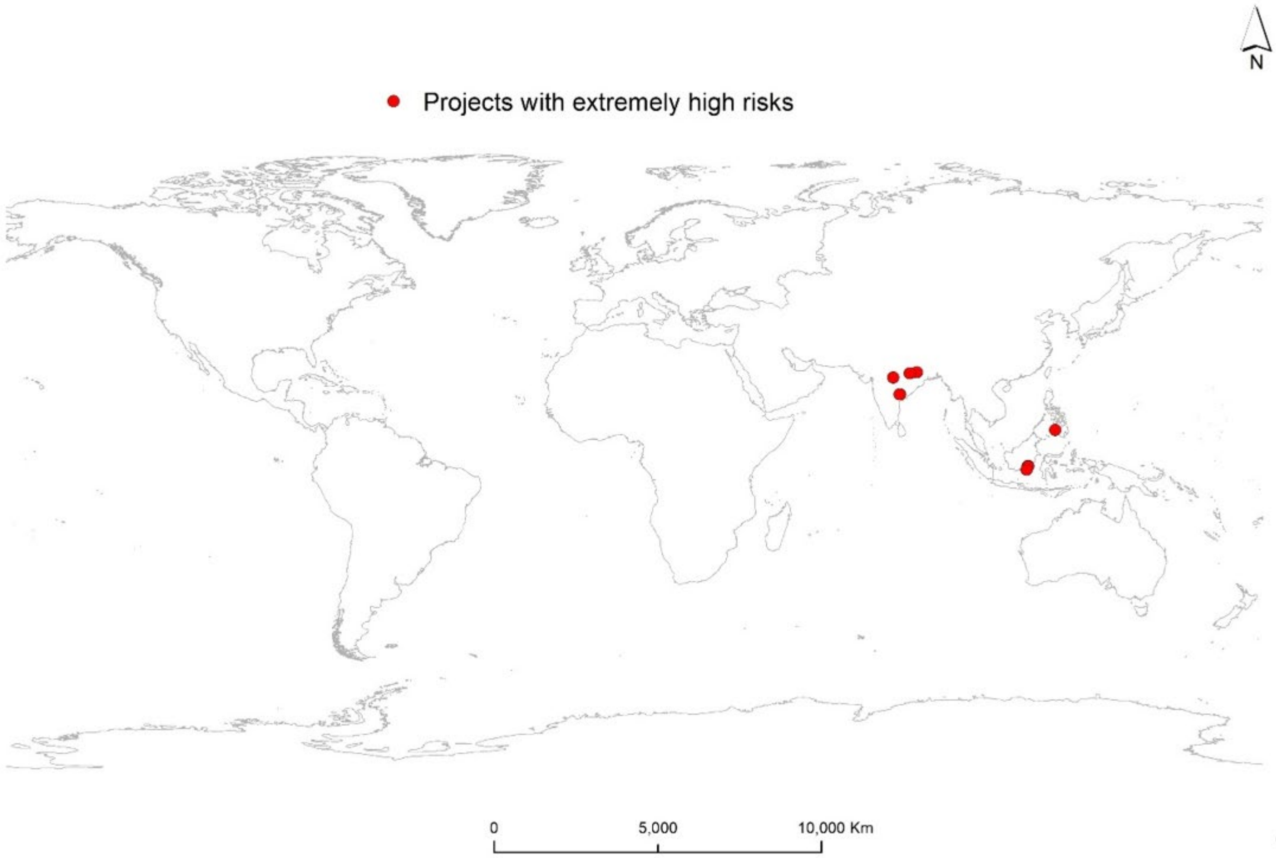

Figure 4 A set of 11 coal mining projects that show a complex co-occurrence of all risks across the ESG risk framework

The Adaro complex that includes the Wara, Tutupan and Paringin coal mines is one of the identified projects with extreme risk profile. They are located approximately 250 km north of Banjarmasin in South Kalimantan in Indonesia. The coal reserves amounting to 5.5 billion tonnes of coking coal are one of the largest coal reserves in the world. The annual production capacity of all three mines varies from 41 million tonnes (Tutupan) to 5 million tonnes (Wara) and 1 million (Paringin) tonnes of coal (Wood Mackenzie 2018). As shown in Figure 5, the project is in close proximity to the town Murung Pudak and surrounded by smaller villages.

Figure 5 The Adaro complex: coal mines Wara, Tutupan, and Paringin in Indonesia. The risk profile of these mines contains multiple interplay of all ESG risks across the presented framework

4 Discussion and conclusion

Our findings provide a sense of the likely risk vulnerability across the coal mining projects, revealing the extent to which closure of these projects will encounter multiple risk factors. A total of 102 mines in the dataset show a high-risk profile with a co-occurrence of seven or eight out of the possible eight ESG risks. 11 projects out of these 102 show an extremely high-risk profile, including all evaluated risks. Recognising the average of 4.2 risks per project, we indicated that most open pit coal mine projects appear to be a subject to a complex interaction of multiple risks across the ESG framework.

Under the scenario of rapid and widespread closure of coal mining projects where nation states reconfigure their resource economies to meet a low carbon future, we confirmed that operating mining companies will face multiple types of concurrent risks in most of the mining regions around the world. Safe and sustainable closure of the projects will require operators to include a range of complex factors to their closure planning and management, particularly where projects are best with multiple medium and high risks. We argue that the presence of multiple risks contributes significantly to the design challenges of closure. Understanding the complexity of ESG risks and their effect on coal mining regions provides an opportunity to re-consider the future of research and innovation in global mining industry.

Considering future mine closure against a broad range of complex factors, we present an ESG risk-based approach that is applicable to any national mining context worldwide. Although this paper does not provide suggestions on how the impacts of the risks can be reduced, the presented framework can contribute to development of adaptive strategies in closure planning by recognizing bounding conditions and risk intensity. Moreover, using global data enable to focus on international difficulties of mine closure, giving a competitive advantage in a global marketplace.

Acknowledgement

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Appendix 1 The ESG risk factors, their coverage, description, and risk calculation procedure details

Risk factor	Reference *coverage	Data description	Risk calculation and normalisation
Global seismic hazard (GSH)	Giardini et al. (2003) *Global	The global seismic hazard map is the result of Global Seismic Hazard Assessment Program. The dataset depicts the seismic hazard as peak ground acceleration with 10% probability of exceedance in 50 years, corresponding to a return period of 475 years.	If GSH ≥ 0.8, medium to high-risk occurs
Landslide risk index (LRI)	Peduzzi et al. (2002) *Global	Estimate of the global risk induced by landslide hazard triggered by precipitations. This product was designed by United Nations Environment Programme (UNEP)/GRID-Europe for the Global Assessment Report on Risk Reduction.	If LRI ≥ 3=medium to high, risk occurs
Terrain ruggedness index (TRI)	Amatulli et al. (2018) *Global	Quantitative measure of topographic heterogeneity: The sum change in elevation between a grid cell and its eight neighbour grid cells.	If TRI ≥ 46, medium to high-risk occurs
Aqueduct water risk	Reig et al. (2013) *Global	The World Resources Institute designed the water risk dataset to assess the physical, regulatory, and reputational risks that water can pose to companies and their investors. The dataset calculates 12 indicators and aggregates them into one overall score. Weights for each indicator are customisable depending on their importance and relevance to the user. The 12 indicators are grouped into the physical risk category (quantity: baseline water stress, inter-annual variability, seasonal variability, flood occurrence, drought severity, upstream storage, groundwater stress; quality: return flow ratio and upstream protected land) and regulatory and reputational risk category (media coverage, access to water and threatened amphibians).	If the field 'OWR_cat' in the attributes of the water risk ≥ 0.6, medium to high-risk occurs
World Database on Key Biodiversity Areas	Birdlife International (2019) *Global	Key Biodiversity Areas (KBA) are sites contributing significantly to the global persistence of biodiversity, in terrestrial, freshwater and marine ecosystems. Sites qualify as global KBAs if they meet one or more of 11 criteria, clustered into five categories: threatened biodiversity; geographically restricted biodiversity; ecological integrity; biological processes, and irreplaceability (International Union for Conservation of Nature 2016).	If the project is located within 20 km distance from KBA, risk occurs
World Database on Protected Areas (WDPA)	United Nations Environment Programme (2018) *Global	The database is the most comprehensive global database on terrestrial and marine protected areas. It is a joint project between the UNEP and the International Union for Conservation of Nature (IUCN), managed by UNEP World Conservation Monitoring Centre.	If the project is located within 20 km distance from WDPA, risk occurs

Risk factor	**Reference *coverage**	**Data description**	**Risk calculation and normalisation**
Human footprint (HF)	Venter et al. (2016) *Global	The dataset represents a proxy for human disturbance of natural systems. It contains remotely-sensed and bottom-up survey information on eight different categories measuring the direct and indirect human pressures on the environment: built environments, population density, electric infrastructure, croplands, pasture lands, roads, railways, and navigable waterways. The dataset is from 2009. We used only four categories: built environments, population density, croplands, and pasture lands.	The highest value from those four was considered. Risk occurred in 'human dominated area', if HF=4–7, and 'High land pressure area,' if HF=8–10
Indigenous people land (IPL)	Garnett et al. (2018) *89 jurisdictions	The dataset maps lands that are managed or owned by Indigenous Peoples, i.e. areas where Indigenous peoples' influence on land management is either officially recognised or de facto substantial. The map was built out of information gathered from 127 data sources, all open access, and a majority of which is derived from scholarly publications. Sources include cadastral records, census data, and publicly accessible participatory mapping.	If the project is located within 20 km distance from IPL, risk occurs
Fragile state index (FSI)	Fund For Peace (2018) *178 countries	This dataset provides country-level scores for 12 indicators. The FSI sources data from three main streams that are triangulated: a content analysis that performs a systematic web search; quantitative public statistics from agencies such as the World Bank and the United Nations; qualitative social science research and validation by experts. We separated seven social components into social indicators for the social fragility and five datasets for the political fragility categories. Social Fragility: demographic pressures, refugees and internally displaced persons, human flight and brain drain, economic decline and poverty, uneven economic development, group grievance, security apparatus. Political Fragility: factionalised elites: state legitimacy, public services, human rights and rule of law, external intervention	If FSI ≥ 0.5, medium to high-risk occurs
Resource governance index (RGI)	Natural Resource Governance Institute (2017) *81 countries	The RGI dataset includes considerations on the political and institutional context of resource governance. The RGI score of a country is calculated through four main topics: the presence and quality of the country's laws, regulations and policies that are relevant to the extractive sector; the extent and quality of disclosure, e.g. the availability of information on processes such as licensing, or onsite-specific data such as ownership details; the presence of 'oversight', i.e. processes such as audits, or the appointment of	If RGI < 60, medium to high-risk occurs

Risk factor	Reference *coverage	Data description	Risk calculation and normalisation
		independent oversight bodies; and the quality of the enabling environment for resource governance, i.e. the practices and processes in the government, media and civil society that are likely to either enable or disable the effectiveness of resource policies and governance. Depending on their score, countries are characterised by a 'good' resource governance (RGI ≥75), or a 'satisfactory' (RGI 60-74), 'week' (RGI 45-59), 'poor' (RGI 30-44) or 'failing' one (RGI <30).	
Policy perception index (PPI)	Fraser Institute (2018) *91 jurisdictions in 55 countries	The PPI index is based on the results of informal opinion surveys obtained from mining professionals, and conducted by the Fraser Institute since 1997. How public policies may affect mining development in certain jurisdictions. 360 managers and executives; the results cover 91 different jurisdictions in 55 countries. The survey examines 15 different policy factors and how they influence company decisions on investments: regulatory uncertainty, environmental regulations, regulatory duplication, the legal system, taxation regime, uncertainty concerning protected areas and disputed land claims, infrastructure, socio-economic and community development conditions, trade barriers, political stability, labour regulations, quality of the geological database, security, and labour and skills availability.	If PPI < 70, medium to high-risk occurs (country scores ranking 27–99)
Ease of doing business (EODB)	World Bank (2018) *190 countries	The EODB measure evaluates the efficiency and quality of the business-related rules in a jurisdiction. It was built in 2002. It ranks countries according to the regulatory environment they provide for local entrepreneurs, focusing primarily on the domestic sector. The Doing Business methodology is survey based (expert surveys and internal expert evaluations), and is made of 41 indicators classified along 10 different topics: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, and resolving insolvency. Each topic has its own methodology and questionnaire. Approximately two-thirds of the data embedded are based on written laws and regulation, often provided as reference by the expert respondents. In 2018, the dataset draws inputs from around 13,800 professionals.	Normalised by the lowest rank 190 to receive 0 – 1 values. If EODB normalised value ≥ 0.40, medium to high-risk occurs

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