Mining Observatory

Cumulative Climate Risks for Transition Minerals in Brazil

April 2025

Brazil's government hopes to turn the country into a key supplier of transition minerals (TMs)[1] and is well-positioned to do so given rich untapped reserves and strong international interest. Its non-aligned geopolitical status means it could play an essential role in efforts to diversify TM supply chains, reducing concentration risks.

However, mining has already had severe negative impacts on Brazil's rich ecosystems and diverse communities. The adverse effects of climate change further exacerbate the social and environmental risks posed by the industry while increasing the chances of disrupted mineral production.

This report examines the impact of mining in four key states for the industry: Pará, Minas Gerais, Goiás and Bahia. All are also highly exposed to climate and social-grievance risks, underscoring the need for proactive risk management to adapt to climate impacts and strong policy frameworks to ensure standards are upheld as the industry enters a period of rapid expansion.

Contributions

Mining Observatory

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The Mining Observatory is an investigative journalism center and think tank focused on the extractive sector, created in 2015. It specializes in covering the role of mining in the climate crisis and energy transition, the role of multinational companies, and the socio-environmental impacts of mining and prospecting.

TMP

TMP is a consulting group dedicated to understanding and solving complex climate, environmental, social, and security problems. This report incorporates climate and social risk analyses conducted by TMP, providing data-based insights into four key mining states. TMP's contribution focuses on assessing climate and social risks to support an understanding of cumulative climate challenges in these regions.

Financial collaborators of the Mining Observatory:

Instituto Clima e Sociedade and Fundação Heinrich Böll - Brazil

1 Key materials for energy transition technologies, including lithium, copper, bauxite, rare earth elements (REEs), graphite, cobalt, nickel, manganese, and niobium.

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EXECUTIVE SUMMARY

- Managing the adverse impacts of mining in the context of rapid climate change will require a proactive approach to risk management from companies, strong policy frameworks, robust oversight by authorities, and better mechanisms to involve rights-holders in key decisions.
- Strict health and safety standards, thorough consultations with local communities, and comprehensive reparation for those adversely affected are essential measures. Free, prior and informed consent (FPIC) should also be a key pillar of decision-making.
- Pará, Minas Gerais, Goiás and Bahia are all exposed to considerable climate impacts in the near-term (up to 2030). Specifically, we expect radical changes in temperature and precipitation, both in their extremes and seasonality.
- Without effective adaptation efforts, climate impacts could damage vital ecosystems and exacerbate existing social grievances, potentially fueling disputes and violent conflict.
- Pará is the most-exposed of the four states to the majority of climate risks we assessed, making it a fitting host for COP30. Minas Gerais is highly-exposed to drought risk, while water scarcity is also a prominent risk factor for Goiás and Bahia.

INTRODUCTION

Key decision-makers still seem unprepared for the near-term impacts of climate change,[2] despite extreme weather events[3] surging globally amid record-high average temperatures in 2024.[4] Paradoxically, the risks that extreme weather poses to TM supply chains are often overlooked. Managing such risks will require substantial up-front investment but could bring significant benefits in the long-run, enhancing supply chain resilience while improving the local impact of the industry.

A proactive approach to climate risk is particularly important for Brazil as the government is supporting investment in its abundant TM resources, with the hope of turning the country into a key supplier amid growing global demand.[5] It is strategically well-positioned to do so and leverage efforts to diversify global mineral supply chains, given its non-aligned geopolitical status and stable diplomatic relations with the US and China.[6]

However, mining has already severely impacted Brazil's rich ecosystems and diverse traditional communities. The push to develop TM reserves raises numerous underappreciated risks that merit urgent attention. Besides threatening mining operations themselves, climate-related risks could exacerbate pre-existing challenges for the industry and local communities, such as water-related risks, social grievances, and resource competition.

What's more, global supply chains for numerous TMs are heavily concentrated in Brazil, particularly for niobium—the country produces more than 90% of the world's supply, with ~88% coming from just two

2 *Climate Change 2023*, Intergovernmental Panel on Climate Change, Mar 2023
3 We define extreme weather events as unusual weather triggered by significant changes in one or more climate indicators including temperature and precipitation
4 *State of the Global Climate 2024*, World Meteorological Organization, Mar 2025
5 Durao, *Brazil Offers $815 Million to Back Strategic Minerals Projects*, Bloomberg, Jan 2025
6 Barreto Vieira do Prado and Moerenhout, *Brazil's Potential Role in Diversifying US Critical Mineral Supply*, Columbia University, Aug 2024

mines, in Minas Gerais (owned by Brazil's CBMM) and Goiás (owned by China Molybdenum).[7] Brazil also has the second-largest reserves of graphite and rare earth elements (REEs) globally, the third-largest reserves of nickel, and is the fourth-largest bauxite producer.[8]

Yet Brazil's key mining states, including those examined here, are increasingly exposed to climate hazards, which are compounded by longstanding socio-environmental issues. This underscores the urgent need to empower local communities and secure targeted international investment to strengthen climate resilience and maintain stable mineral supplies for the energy transition.

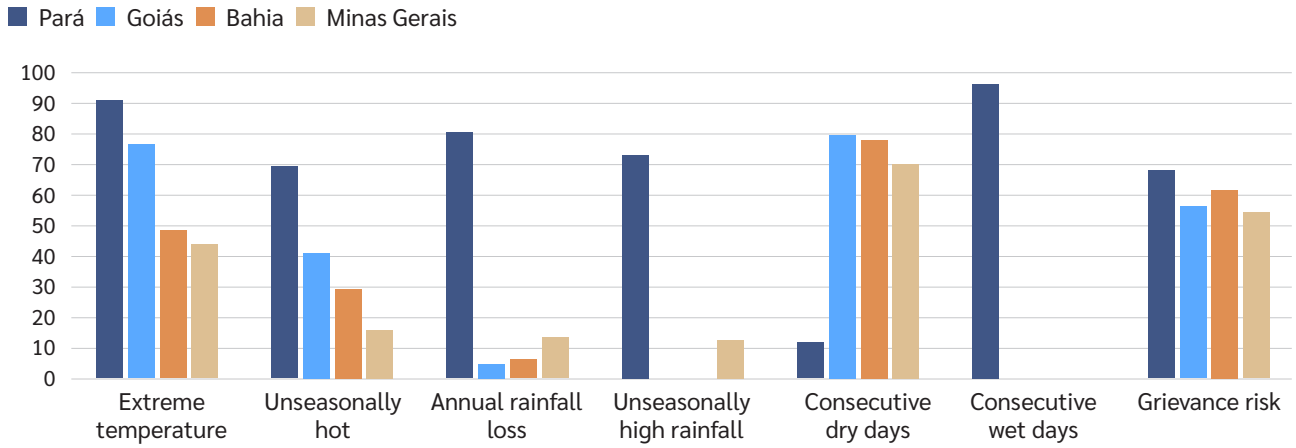
Should policymakers and businesses fail to adapt physical and human infrastructure to avoid the worst climate impacts, we can expect severe supply chain disruptions that will result in larger investments to resolve, or even stranded assets. This could create a vicious cycle in which lack of adaptation delays mitigation efforts, in turn leading to worse climate impacts and increasing instability.

This report combines on-the-ground insights from leading local NGO, The Mining Observatory (TMO), with cutting-edge climate data and analytical expertise from sustainability consultancy, TMP. We aim to improve understanding of shared risks, while empowering urgent and scalable actions, helping governments, companies and communities best allocate the substantial resources required to tackle the global climate challenge.

Climate Risk Assessment: High Risk Exposure

This analysis considered eight climate variables,[9] unique social risk data,[10] and several hydrological risk datasets[11] to assess cumulative climate risk in Pará, Minas Gerais, Goiás and Bahia. All four states are exposed to considerable shifts in climate patterns in the period up to 2030. Specifically, we expect radical changes in temperature and precipitation, both in their extremes and seasonality.

Select climate and social risk factors[12]



Source: TMP Public

7 Siqueira-Gay, Sánchez, *Keep the Amazon Niobium in the Ground*, Environmental Science & Policy, Sep 2020

8 *Mineral Commodity Summaries 2025*, USGS, Mar 2025

9 TMP's algorithms assess change in eight climate indicators at 1.5°C of warming (~2029) compared to 1°C (~2017). Indicators are: Extreme temperature (days when temperatures exceed the 95th percentile of the temperature range at 1°C); unseasonably high temperatures; annual rainfall loss; annual dry days; unseasonally high and unseasonally low rainfall; consecutive dry days and consecutive dry days.

10 Our model is based on TMP's Landscope tool, drawing on 14 environmental, social and governance indicators of grievance risk between local communities and companies.

11 Including WRI's Aquaduct 4.0 and a Global River Widths (GRWL) remote-sensing database which measures changes in river extents between the late 20th and early 21st centuries.

12 Risk exposure is provided on a scale of 0-100. Readings above 80 indicate "extremely exposed"; 60-80 "very exposed"; 40-60 "unusually exposed"; 20-40 "exposed"; and below 40 "slightly exposed."

Elevated conflict: Climate impacts could exacerbate existing disputes.[13] Multi-stakeholder collaboration is key to improve relationships between miners and communities, combined with strong protection for biodiversity, watersheds and traditional livelihoods.

Pará highly-exposed: This makes adaptation efforts particularly urgent. The state also has one of Brazil's largest mining industries, which will further increase resource requirements.

Extreme temperature: This was the highest risk factor for all four states along with consecutive wet or dry days. All four also have elevated grievance-risk exposure, which reflect challenging operating environments for mine operators and greater chance of dispute with local communities.

Water stress: The extent of rivers has already declined in much of Minas Gerais, Goiás and Bahia, pointing to reduced water availability and increased resource competition.

Erratic precipitation, flooding: Heavy rainfall can disrupt mine production, causing floods and hampering dewatering. Heavy rainfall has disrupted numerous mining operations in Brazil, including Vale S.A.'s Mariana complex, Vallourec's Pau Branco,[14] and Lundin's Chapanda mine.[15]

REGIONAL FOCUS

PARÁ STATE

HIGHEST CLIMATE RISK

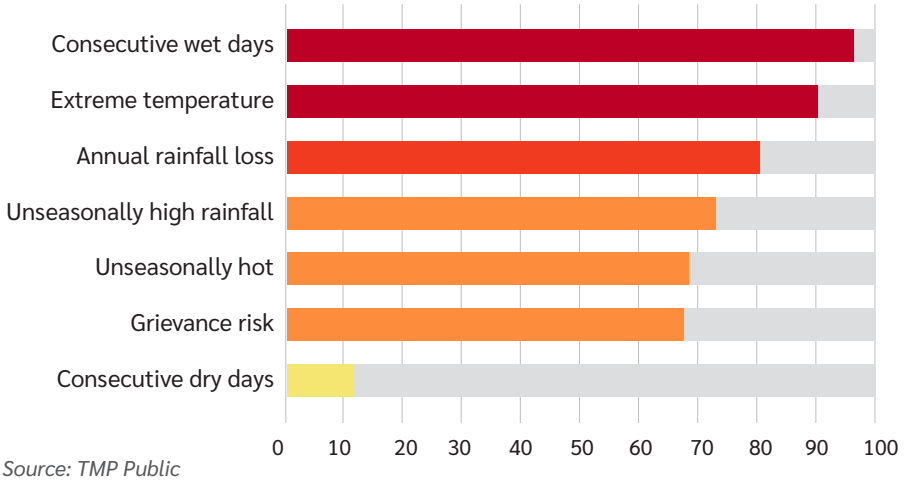
Pará is the most-exposed state in our study to the majority of climate risks, and has the highest grievance risk. It's Brazil's second-largest mineral producer, accounting for ~90% of aluminum output, as well as producing copper, manganese, nickel and gold.[16]

High Multi-hazard Risk

Pará has the highest exposure to extreme temperatures; unseasonably high temperatures and rainfall; increased consecutive wet days; and a loss in annual rainfall.

Extreme temperatures may further exacerbate grievance risks. Higher temperatures correlate with increased conflict at national and regional levels,[17] and can also disrupt mining activity due to labor laws and health and safety concerns.

Risk profile



Source: TMP Public

13 Levy, Sidel and Patz, *Climate Change and Collective Violence*, Annual Review of Public Health, Jan 2017
14 Gabriel Araujo, Ana Mano, *Vale, Other Brazil Miners Ramp Up Production as Rains Subside*; Reuters, Jan 2022
15 Miners' Profits Face An Unusual Foe: Extreme Weather, Reuters, Jul 2022
16 Pêna, *Boletim da Mineração 2023*, Agência Para, Sep 2023
17 Kim, Kim et al, *Positive Association of Aggression with Ambient Temperature*, Yale Journal of Biology & Medicine, Jun 2023

Erratic precipitation: Notably, Pará is exposed to a decline in annual rainfall as well as increased consecutive wet days and unseasonably high rainfall. This combination points to more erratic rainfall and increased flood risk.

Higher maintenance: Erratic rainfall can cause tailing storage failure, instability of mine slopes, and dewatering issues. Tailings waste poses contamination risks to surrounding areas, making robust community engagement key to maintaining social license to operate.

On the Ground: Mining Majors Test Regulations

Vale S.A. operates numerous mines in the Carajás region, including the world's largest iron ore mine, Salobo (copper), and Onça-Puma (nickel). A railroad servicing these operations has caused severe socio-environmental impacts, including accidental deaths, noise pollution, and structural damage to buildings. The company has drawn criticism for lack of transparency[18] and undermining collective bargaining with divide-and-conquer strategies.[19] Despite withdrawing applications for new mines in Indigenous territories in 2021 (largely in response to international pressure[20]), the company has continued to expand operations around protected areas and pushed to reclassify land so operations can continue.[21]

MRN (Brazil), controlled by Swiss trader Glencore,[22] is Brazil's largest bauxite producer. Local quilombola[23] and riverine communities have reported water contamination from the extensive network of tailings dams at its Oriximiná mine, and that the company neglects to monitor its impact on the Saracá-Taquera National Forest. Investigations by TMO moreover have found numerous unreported changes to the risk classification and potential associated damage of the company's dams in the ANM database.[24] This lack of transparency raises questions about the reliability of the classification process along with the integrity of the company's reporting and consultation processes.

Norsk Hydro (Norway): Tailings waste from the Paragominas bauxite mine has contaminated local waterways, leading to high levels of harmful substances in the local population, including lead, arsenic and radioactive substances.[25]

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MINAS GERAIS

HISTORY OF MINING DISASTERS

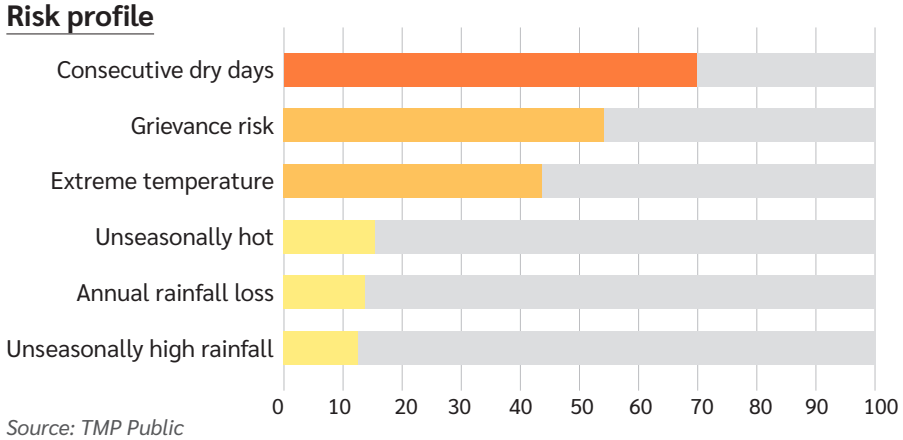
Minas Gerais has Brazil's largest mining industry and has seen some of its worst socio-environmental disasters, including two recent tailings dam failures (see below). The state contains 80% of national lithium reserves and is also rich in gold, bauxite, graphite, manganese, niobium, zinc, tantalum and lead.

Brazil has fostered its lithium industry since scrapping export restrictions in July 2022.[26] Three of the four projects operating are in Minas Gerais, mainly in Vale do Jequitinhonha. With seven more projects in the pipeline, lithium production is expected to increase fivefold by 2028 and attract USD 6 billion of investment in the next decade.[27]

18 Angelo, *Alongside The Railroad Of The Biggest Iron Ore Mine In The World: Poverty, Pollution, Deaths and Human Rights Violations*, TMO, Jul 2022
19 Angelo and Sax, *Divided By Mining: Indigenous People In Pará Fight To Maintain Their Identity Against The Railroad That Feeds The Global Steel Industry*, Aug 2023
20 Angelo, *O Que Está Por Trás Da Desistência Temporária Da Vale De Minerar Em Terras Indígenas*, TMO, Sep 2023
21 Angelo, *Após Anunciar Desistência, Vale Agora Quer Minerar No Entorno Da Terra Indígena Xikrin No Pará*, TMO, Nov 2021
22 Angelo, *Among Corruption And Human Rights Violations, Swiss Trader Glencor, Becomes Main Owner Of Brazilian Aluminum*; TMO, Mar 2024
23 Descendants of Afro-Brazilian slaves
24 Angelo, *Revealed: Records Show Dozens Of Changes In Mineração Rio Do Norte (MRN) Tailings Dams In Pará And Communities Fear Disasters, TMO*, Feb 2025
25 Neto, *Barcarena, Uma Chernobyl Na Amazônia*, Amazonia Real, Dec 2021
26 Duchiade, *'Lithium Valley': Brazil's Latest Mining Hotspot Stirs Local Concerns*, Dialogue Earth, Jul 2024
27 Barbosa and Carvalho, *Lithium Leap: Brazil Makes Journey To Become A Leading Supplier*, S&P Global, Aug 2024

Risk Exposure: Water Scarcity

The highest risk factor for Minas Gerais is an increase in consecutive dry days. Additionally, 32% of sub-basins in the state have seen river extent decline to a level considered 'high risk' (i.e. a decline of more than 10%).



Source: TMP Public

Mining is water-intensive and resource competition with locals and commercial users like agriculture and energy could exacerbate water scarcity and feed existing grievance risks. Brazil is heavily reliant on hydropower so increased dry days could severely restrict electricity supplies.[28] The country has come close to rationing electricity in the past.[29] Two of its largest hydropower plants were switched off in August 2024,[30] while production from two other major plants was severely restricted in September.[31]

On the Ground: Lithium Mining Brings New Risks

Mariana (2015): Operated by Samarco, a joint venture between Vale and BHP Billiton, the Fundão dam collapse contaminated 600km of waterways including the Rio Doce river,[32] killing 19 people and 14 tons of fish. Rehabilitation efforts still have a long way to go.[33]

Brumadinho (2019): A tailings dam collapse at Vale's Córrego do Feijão iron ore mine polluted the Paraopeba River and took 272 lives, making it the deadliest labor disaster in Brazilian history. Courts have been criticized for prioritizing commercial interests over reparation and recovery efforts, favoring Vale in 75% of legal challenges between 2019 and 2023. TMO also found that the company covered up structural issues at the dam,[34] while the deadline to resolve the problems has been extended to 2035, exacerbating ongoing risks.[35]

Jequitinhonha Valley: While companies involved (including Sigma Lithium (Canada), Atlas Lithium (US),and Latin Resources (Australia) have promised economic benefits to local communities, lack of meaningful consultation has fueled concerns over water contamination, deforestation and displacement risks. The area already suffers from extreme poverty and drought.
Weak consultation, deregulation: Regulations introduced in September 2024 leave the consultation process in the hands of mining companies rather than an independent third-party, marking a major step backwards for accountability.[36]

28 Slaymaker, *Brazil Cuts Hydro Use As Droughts Continue Impacting Global Hydro Generation*, Power Technology, Aug 2024
29 *Climate Impacts On Latin American Hydropower*, International Energy Agency (IEA), 2021
30 Fucuchima, *Northern Brazil Cuts Hydro Power Use With Prolonged Drought*, Reuters, Aug 2024
31 Campos Jr, *Com Seca, Belo Monte Gera Menos De 3% Da Energia Projetada*, Poder 360, Sep 2024
32 *O Desastre Samarco*, Ministério Público Federal (MPF), 2015
33 Lynch and Smith, *Progress On Monitoring And Rehabilitation Of The Rio Doce Catchment*, The SETAC Globe, Jan 2024
34 Angelo, *Vale É Processada Nos Eua Por Mentir Sobre A Segurança De Suas Barragens Antes De Brumadinho*, TMO, Apr 2024
35 *CVM Trial Of Vale Executives Over Brumadinho Dam Collapse Brings New Momentum*, Both Ends, Oct 2024
36 Passarini, *Governo Zema É Denunciado Por Decreto Que Compromete Consulta Prévia A Comunidades Tradicionais E Favorece Mineradoras Em Mg*, TMO, Sep 2024

REGIONAL FOCUS

GOIÁS

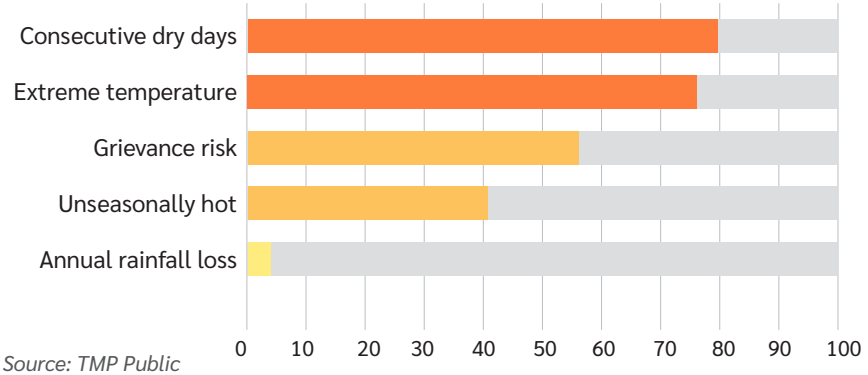
EXTREME TEMPERATURES, WATER SCARCITY

Goiás has the fourth-largest mineral output in Brazil behind Minas Gerais, Pará and Bahia. Mining contributes a growing share of state GDP and local authorities hope to leverage its geological diversity to build it into a key TM supplier.[37] It is the leading national producer of phosphate, nickel and vermiculite, and produces copper, gold, bauxite and niobium. The state is also home to one of Brazil's largest REE projects, Mineração Serra Verde, which started commercial production in 2023.

Risk Exposure: Extreme Temperatures, Dry Days

Goiás is most exposed to a combination of very hot days and an increase in consecutive dry days. In addition, 37% of sub-basins in Goiás have seen a decline in river extent to a level considered 'high risk' (i.e. a decrease of more than 10%). This shift towards hotter and drier climate conditions suggests water scarcity could become a growing concern for mining operations, which are heavy water consumers and compete for this resource with local communities and other industries.

Risk profile



Source: TMP Public

On the Ground: Vital Ecosystem Services Under Pressure

Much of Goiás was formerly covered by the Cerrado tropical savannah biome, which plays a crucial role in the water cycle.[38] However, agribusiness, mining and urbanisation have already damaged much of this ecosystem. Further expansion of mining operations could exacerbate water scarcity and heighten climate risks, regionally and nationally.

Mosaic Fertilizantes, one of the world's largest phosphate producers, has extensive operations in Catalão and Ouvidor municipalities, including 12 high-risk tailings dams.[39] Local communities have reported land expropriation, environmental degradation, and health issues such as respiratory diseases and cancer.[40]

Maracá, a subsidiary of Lundin Mining (Canada), has contaminated the Formiga River with heavy metals from its Chapada copper-gold mine, causing widespread fish die-offs and chronic illnesses in local communities.[41] Similarly, CMOC's niobium mine near Catalão city has caused health issues from water contamination.[42]

37 *Mineração Em Goiás: Perspectivas De Investimentos*, Govierno de Goiás, Oct 2023

38 *Cerrado Cradle Of Waters*, Instituto Sociedade, População e Natureza

39 Angelo, *Uma Das Maiores Produtoras De Fosfato Do Mundo, Mosaic Fertilizantes Tem 12 Barragens De Alto Risco No Brasil*, TMO, Jul 2019

40 Angelo, *Gigante Americana Mosaic Fertilizantes Entra Em Conflito Com Agricultores Em Mg E Em Goiás Enquanto Expande Suas Atividades*, TMO, Sep 2021

41 Wolff, *Goiás Tem 18 Barragens De Risco Elevado E Um Rio Já Contaminado*, Jornal Opção, Aug 2022

42 Angelo, *Gigante Americana Mosaic Fertilizantes Entra Em Conflito Com Agricultores Em MG E Em Goiás Enquanto Expande Suas Atividades*, TMO, Sep 2021

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BAHIA

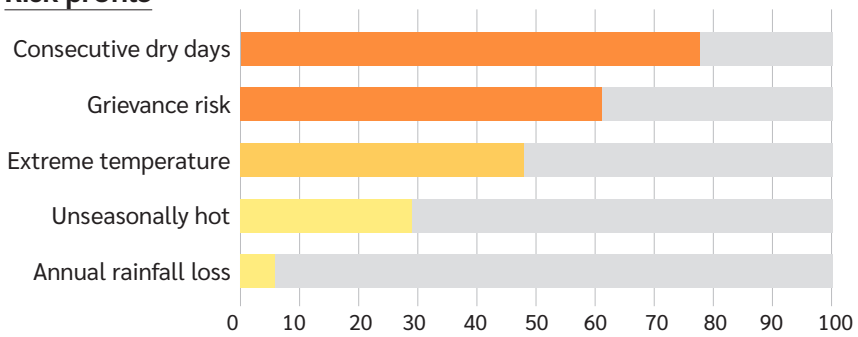
WATER SCARCITY RISK

Bahia has Brazil's third-largest mining industry and a major solid bulk port under construction (Porto Sul in Ilhéus) which will service the sector. It claims to have conducted the most extensive geological studies of any Brazilian state, with a focus on new TM deposits including copper, lithium, graphite, nickel, cobalt, REEs and platinum group metals (PGM).

Risk Exposure: Water Scarcity, Social Grievance

Bahia is exposed to an increase in consecutive dry days, while 39% of sub-basins within the state have seen a decline in river extent to a level considered 'high risk' (i.e. a decrease of more than 10%)—higher than any other state in our study. This suggests a growing risk of water scarcity.

Risk profile



Source: TMP Public

On the Ground: Atlantic Forest Under Threat

Southern Bahia, where mining is concentrated, is frequently affected by heavy rains, exacerbating the impact of the industry. The ongoing expansion of the sector also poses a threat to the vital Atlantic Forest ecosystem.

Porto Sul (BAMIN) is scheduled to commence operations in 2026. Its construction has caused springs to dry up and damaged the Atlantic Forest ecosystem.[43] The Atlantic Forest has already been impacted by industrial monocultures,[44] with extensive eucalyptus plantations in the area, many owned by Suzano, a leading global pulp and paper producer. Eucalyptus is an invasive species and these plantations threaten biodiversity, as well as putting additional pressure on infrastructure shared with locals and mining operations.

Brazil Iron, owned by a British holding company, has silted up springs and spread toxic dust in the coffee and sugarcane plantations of the Chapada Diamantina region. Locals allege that the company is unwilling to listen to their complaints.[45] In 2022, regulators halted activities at its Fazenda do Mocó Mine due to non-compliance with environmental regulations.

43 *População De Ilhéus Denuncia Fiol E Porto Sul Como Empreendimentos De Viabilidade Socioambiental Duvidosa*, Mapa de Conflictos
44 Wenzel, *Eucalyptus Threatens Biodiversity in the Atlantic Forest and Pampas*, Mongabay, Sep 2024
45 Martins, *Mineradora Inglesa Viola Direitos Quilombolas Na Chapada Diamantina Na Bahia*, TMO, Sep 2022

KEY RISKS

People, communities and the environment

- **Health and safety risks** from air pollution (e.g. dust, emissions), water contamination and land degradation, particularly from poorly-maintained tailings storage and mining infrastructure. Extreme weather events like drought, heat waves and flooding exacerbate these risks.
- **Loss of land access** due to resettlement, environmental degradation and biodiversity loss threatens traditional livelihoods and agriculture. Climate change can increase existing pressures on land by disrupting harvests or making areas inhabitable.

Investors and companies

- **Grievance risks** fueled by land grabs, forced displacement, and disregard for principles of FPIC can lead to local opposition and operational disruptions at mine sites. Climate impacts can compound existing social grievance risks, for example by impacting shared water resources, increasing regulatory headwinds, and eroding trust between stakeholders.
- **Extreme weather events** can disrupt mineral production and undermine investment returns in several ways. For example, floods can damage infrastructure, block site access and increase contamination risks from tailings waste. Droughts can limit water available for daily operations and disrupt hydropower supplies needed to power the industry.

RECOMMENDATIONS

Local actors

- Strengthen regulatory oversight and social and environmental standards, particularly adherence to principles of FPIC at all stages of project development.
- Ensure comprehensive reparations and fair economic benefits for communities affected by mining projects.
- Monitor local health impacts closely and improve access to transparent information about water, air and soil quality.
- Foster improved collaboration through regional platforms to coordinate monitoring efforts and knowledge transfers.
- Engage in local resilience programmes to prepare communities near mining operations for extreme weather impacts.

National actors

- Strengthen protection, conservation and restoration efforts in areas that provide vital ecosystem services, such as the Amazon and Cerrado.
- Promote Brazil as a leader in natural climate solutions by supporting practices that involve conserving, restoring, or managing ecosystems to build climate resilience.
- Strengthen land tenure rights for rural communities and complete the demarcation of indigenous and quilombola territories.
- Support economic diversification, protect traditional livelihoods and ensure operations have effective mine closure strategies to reduce dependency on extractive industries.
- Promote locally led climate resilience programmes that strengthen community capacity to prepare for climate impacts and implement effective, context-specific adaptation solutions.

International actors

- Fund collaborative research of environmental impacts and climate risks from TM extraction, and its effect on key biomes such as the Amazon and Atlantic Forest.
- Implement strict compliance with international human rights standards and thorough supply chain due diligence.
- Ensure that local voices are properly recognised in international forums to enable more effective dialogue and cooperation between stakeholder groups.
- Demonstrate the economic case for more effective risk management in the extractives sector for governments and businesses.
- Promote effective socio-environmental regulations and climate resilience strategies in exposed mining hotspots e.g. Jequitinhonha Valley in Minas Gerais (lithium), Carajás region in Pará (iron ore, copper, manganese), and Minaçu in Goiás (REEs).