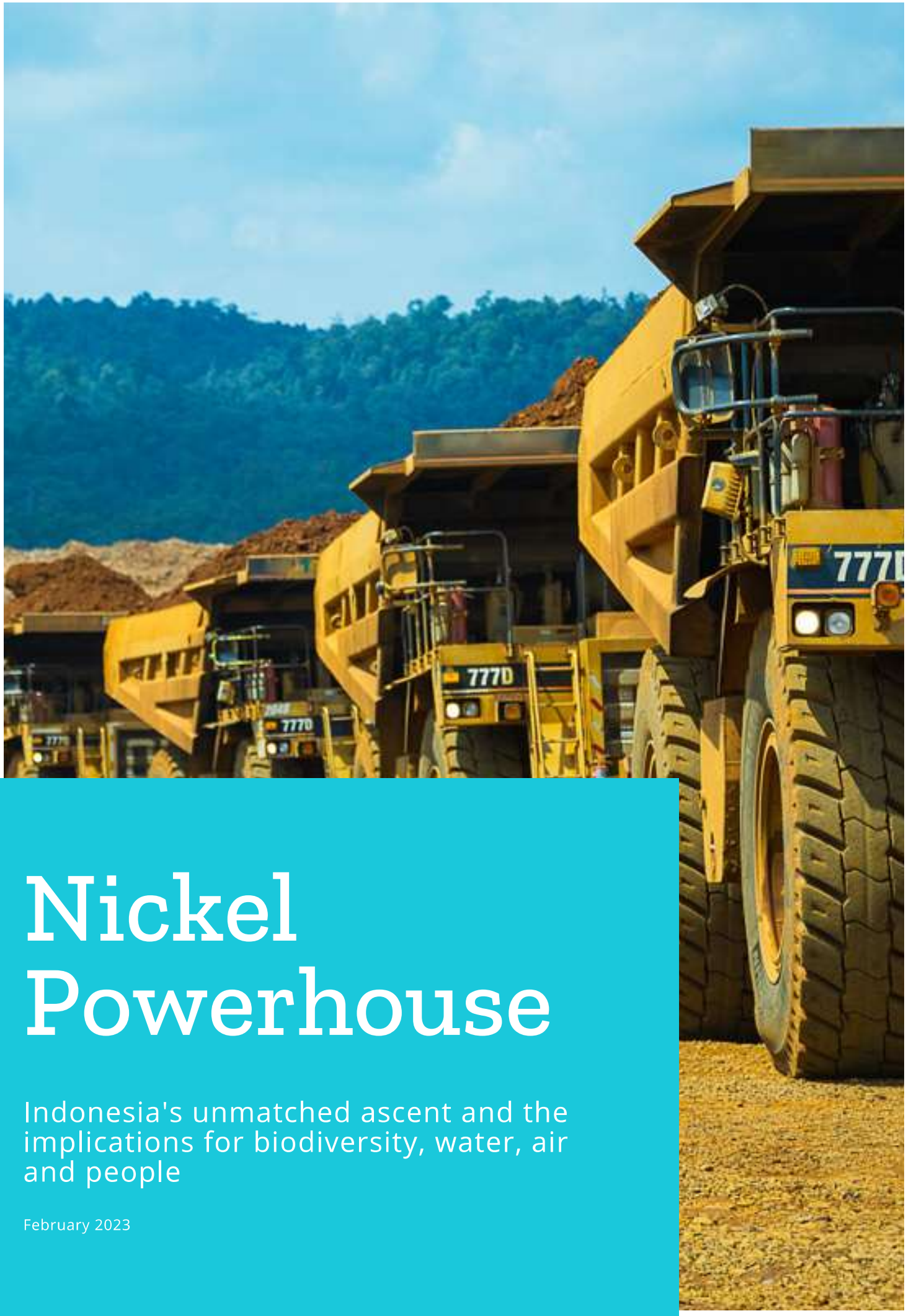

Nickel Powerhouse

Indonesia's unmatched ascent and the implications for biodiversity, water, air and people

February 2023

Within the next five years, Indonesia will have 4.5 million tonnes of nickel production capacity.

Current world demand is only 3 million tonnes.

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Introduction

As the world races to decarbonize, we now face the hard reality that we must produce significantly more metal to enable the transition to an electrified future. Nickel has emerged as one of the key metals for energy storage and electric vehicles.

Today's society expects greater sustainability assurances than ever before. To be successful, electric vehicle makers must demonstrate how they respond to expectations of their environmental and social performance, including in metals sourcing.

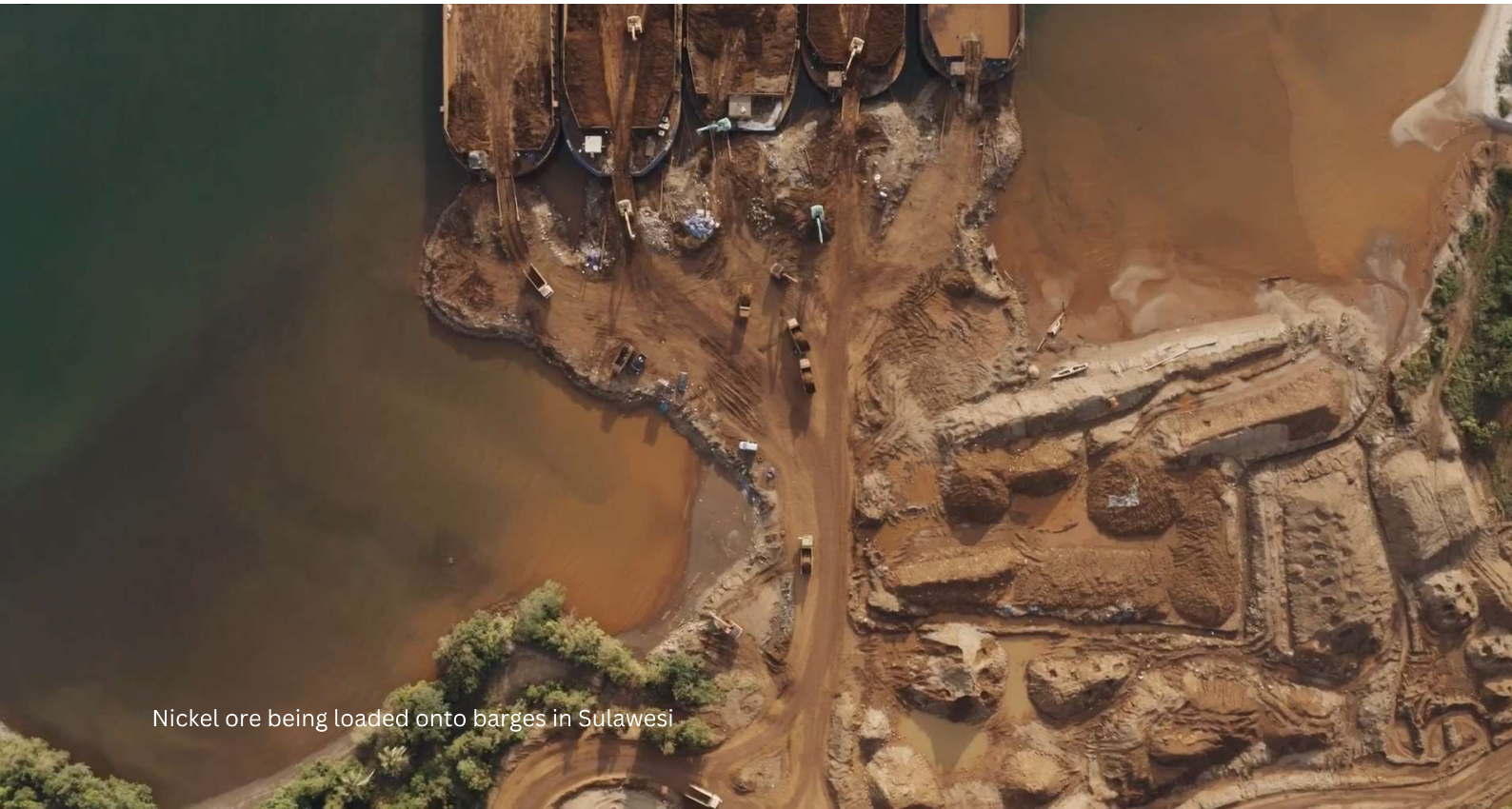
Indonesia has become the world's biggest source of nickel, and is the only region that has seen any growth in nickel supply in recent years. Yet, there is a generally poor understanding of how Indonesian nickel is mined and processed, and what impact this has on the environment and local communities.

This paper aims to capture the current status of our understanding of Indonesian nickel supply and its impact on the environment and society. It also aims to document knowledge gaps in our understanding.

In doing so, it is hoped that actors in the nickel supply chain will be better equipped to fill knowledge gaps and improve the sustainability of nickel sourcing.

14x

increase in Indonesian nickel production over last 8 years



Nickel ore being loaded onto barges in Sulawesi

Indonesia's significance

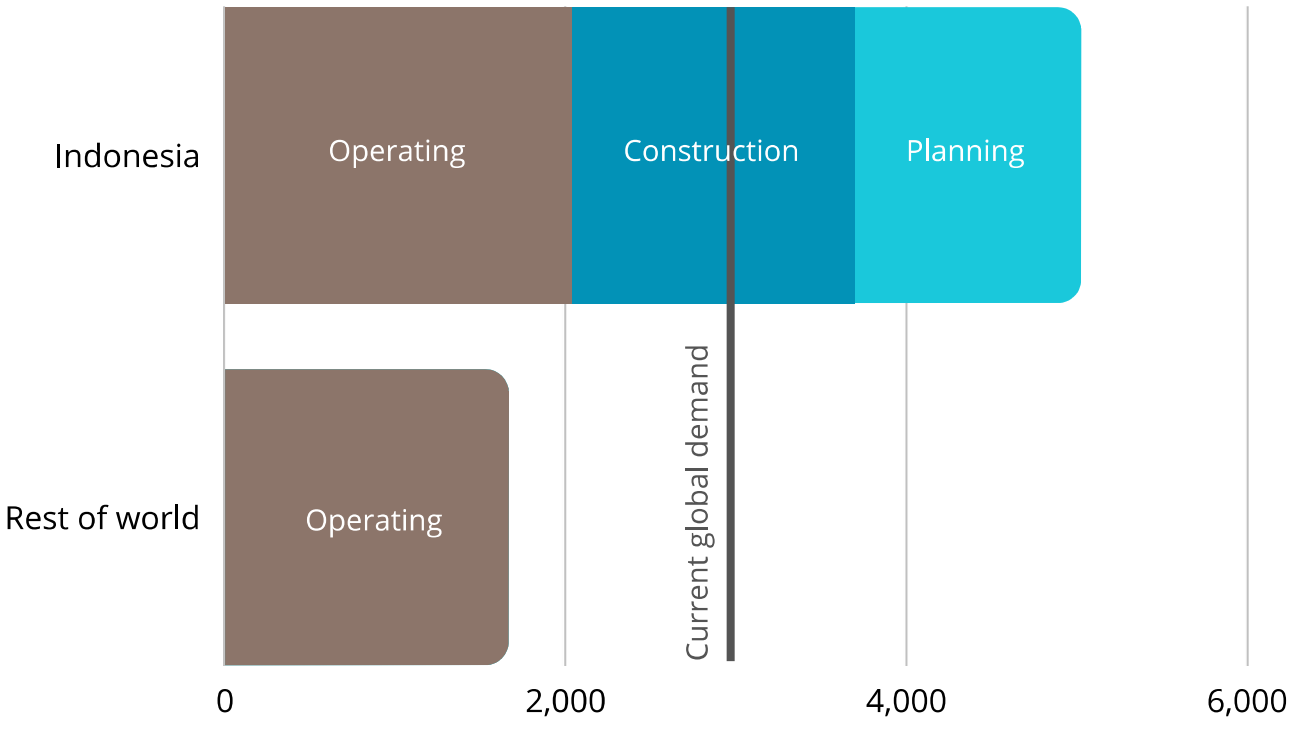
Indonesia has always been a significant source of nickel, but it is only in the last five years that it has become such a titan of metal production. In 2014, Indonesia had two nickel smelters, producing 100,000 t Ni per year. In 2022, Indonesia produced 1,400,000 t Ni, which was 50% of world supply.

There are credible plans in place to grow production capacity to over 5 million tonnes Ni per year within the next 3-5 years. This is an incredible feat, considering that total nickel demand today is only 3 million tonnes. New projects are being announced regularly, and development timelines are a fraction of those seen elsewhere around the world, meaning there could be even more than the 5 million tonnes capacity over this period.

Other nickel producing regions such as Canada, Russia and Australia are struggling to invest enough just to maintain their production levels.

Nickel production capacity

'000 t Ni per year



Source: Macquarie, December 2022

Rudimentary jetties are used to take ore from mines to the processing hubs

Typically, Indonesian ore production exceeds demand, with excess ore stockpiled at processing hubs. In 2021, Indonesia mined a record 100 million tonnes of nickel ore.

Incredibly, in 2022, Indonesia beat that record by an additional 50%, producing around 150 million tonnes.

The pace of growth has left mining companies struggling to maintain good mining practices. Environmental and social performance has suffered. With a shortage of mining equipment, there has been a tendency among some mining companies to prioritize production over rehabilitation.

Mine planning has also suffered. Many locations have been mined without any water runoff controls, and some access roads have been constructed without due care to avoid sensitive habitats.

While regulator processes are in place to prevent such issues, the large number of mining companies applying for permits has placed an unsustainable strain on government resources. Consequently, the enforcement of regulation has been sporadic and under-resourced.

150

million tonnes of ore mined in 2022

Compliance and enforcement

The enforcement of regulations in the Indonesian nickel mining industry faces several challenges, which can limit the effectiveness of the regulatory framework in promoting sustainable and responsible mining practices. The key challenge is the limited resources and capacity, with a severe shortage of trained personnel to carry out inspections and investigations. This limitation stems from the unprecedented growth of the industry, which has placed enormous strain on the public sector.

In 2022, the Indonesian government announced that it had revoked 2,065 permits covering more than 3.1 million hectares, due to non-compliance or because they had not been used.

In December 2022, a court ordered a local environmental agency in Sulawesi to publish the licensing documents of two nickel mining companies that were accused of contaminating a river with sediment. In a response the environmental agency said it was unable to comply because some of the licenses were still being processed at the environment ministry in Jakarta, while others would have to be requested directly from the ministry instead of the agency.

The Ministry of Environment and Forestry undertakes compliance audits through its PROPER program. Some of the larger nickel companies, such as Vale, Antam, and Hengjaya, are included in the audits, and have achieved a “green” rating, meaning they’ve gone beyond compliance. However, the majority of the Indonesian nickel operations are not included in the program, meaning that their compliance status is unknown.

> The pace of growth has placed unprecedented strain on government agencies

Knowledge summary

Indonesian nickel production

What we know

- Indonesia is currently the world's only source of growth in nickel production.
- Indonesian nickel is mined and then transported to processing hubs within Indonesia.
- Majority of mining companies are Indonesian private- and state-owned companies, while processing hubs are foreign-owned, mostly by Chinese entities.
- Production data for processing hubs is well understood.
- Estimated carbon emissions from processing hubs is available.
- Local environmental impact assessments are not publicly available and typically do not adequately address key issues.

What we don't know

- Production data for individual mines.
- Footprint of key mining locations.
- Traceability of nickel back to individual mine sites.
- Company disclosures (very few companies produce public reports or even have websites).

4%

of Indonesian nickel operators prepare public reports

The Sulawesi Hornbill is endemic to Sulawesi. It is a highly social species, living in communities of about 20 individuals, where only the dominant pair breeds. The female seals herself inside a tree hole to lay her eggs, while the male and helpers provide food for the female and the young.

Listed as vulnerable on the IUCN Red List of Threatened Species, the species is under threat from habitat loss and fragmentation.

Environmental setting

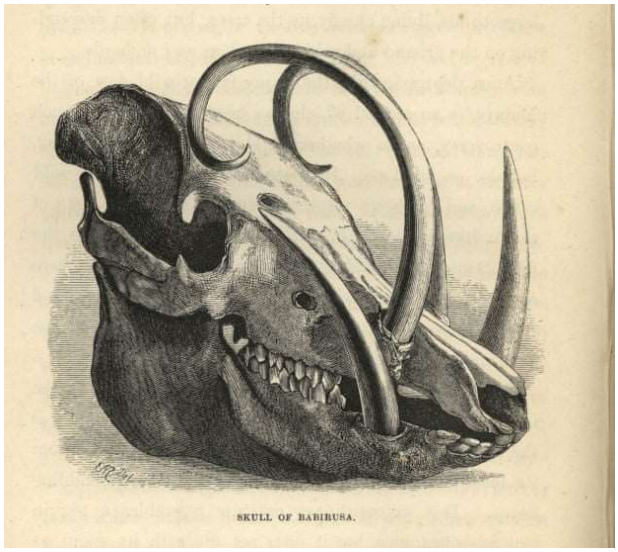
Indonesian nickel mining activities occur in Sulawesi and the Maluku Islands, in a region known as Wallacea.

Wallacea is named after famed naturalist, Alfred Russel Wallace, who travelled through the region for a period of eight years, starting in 1854.

Wallacea has been described as a living laboratory of evolution. Millions of years of relative geographical isolation have allowed fascinating and highly unique fauna to evolve.

Although the flora of Wallacea is not well known, it is estimated that there are about 10,000 species of vascular plants. Roughly 1,500 of those species are endemic (found nowhere else).

Sulawesi is the largest island in Wallacea and is the world's main source of nickel. It has the highest number of mammals in Wallacea, of which an incredible 90 % are endemic. It holds important flagship species such as the anoa and the babirusa.



Babirusa skull, as illustrated by Wallace in 1876

The **anoa** is the smallest of the wild cattle species. It is listed as endangered, considered to be facing a very high risk of extinction in the wild, and is on the IUCN Red List of Threatened Species.

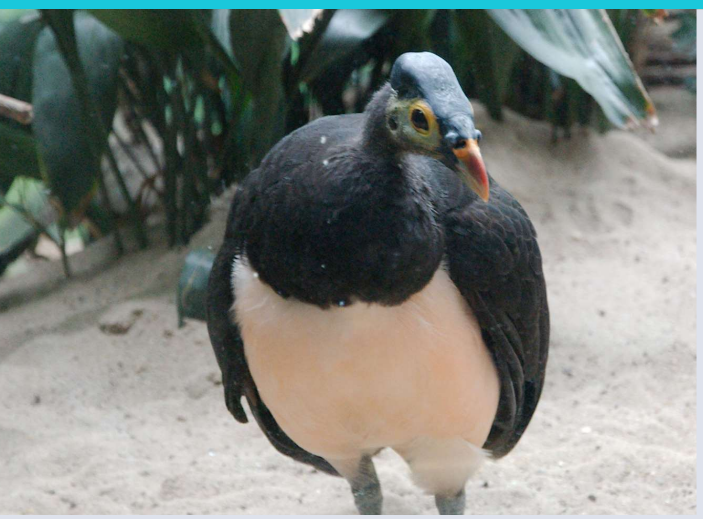
The **babirusa** ("pig deer" in Indonesian), is an unusual pig with long upper tusks that penetrate through the skin of the upper lip. The population in their native habitat is estimated to be less than 10,000, and is listed as Vulnerable on the IUCN Red List of Threatened Species.

Despite its importance, there are still significant knowledge gaps about the region's ecology and culture. For example, there is a lack of data on the distribution and abundance of many species, as well as a lack of understanding of the complex relationships between different species and their environment. Additionally, there is limited information about the traditional ecological knowledge and resource management practices of the indigenous peoples of the region. This lack of information makes it difficult to effectively conserve and manage the unique and valuable resources of the Wallacea region.

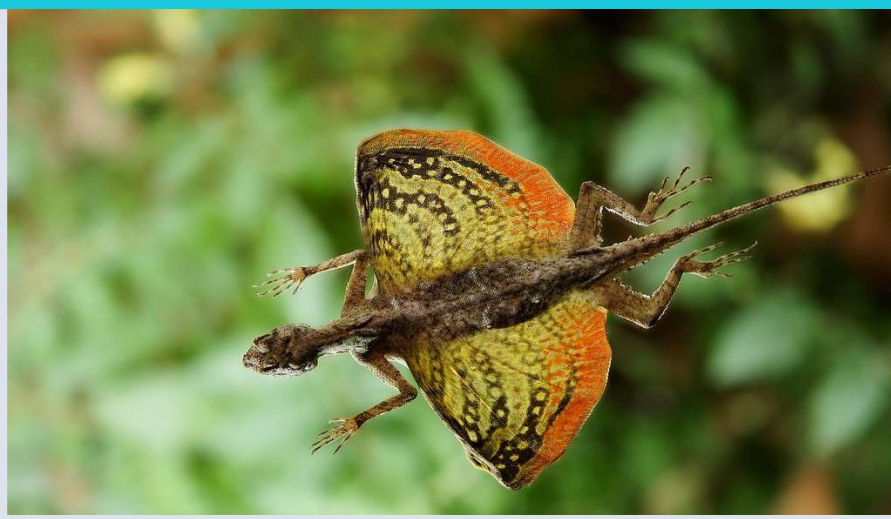
Wallacea

Located between the continental shelves of Asia and Australia, Wallacea is a region of immense ecological importance

Incredible Sulawesi



▲ The Maleo is a critically endangered bird that incubates its eggs using solar or geothermal heat



▲ The Sulawesi lined gliding lizard is endemic to Sulawesi and glides between trees using wing-like membranes

▲ The Sulawesi bear cuscus is the world's largest marsupial possum and is listed as vulnerable

▲ Sulawesi is home to some of the world's largest pythons, like this one that was killed by a villager just near IMIP

▲ The Tarsier is one of the world's smallest primates

▲ The Sulawesi Limnonectes is a giant frog with fang-like teeth. It is only known species of frog that gives live birth to tadpoles

▶ Camera-trap image of the Sulawesi Giant Civet: Sulawesi's extremely rare apex predator. The scientific community knows virtually nothing of its habits and ecology.

New sunbird species discovered near Sulawesi

In 2020, a research expedition found five new sunbird species and five new subspecies from a small island just off the Sulawesi mainland, all collected in a single 6-week expedition. This is remarkable, given that globally there are generally only about five or six new bird species discoveries per year. The research paper concluded that our "understanding of biogeographically complex regions such as Wallacea remains incomplete." [2]

Ultramafic rainforests

Wallacea is now a well-documented biodiversity hotspot. However, ecologists have largely overlooked Sulawesi in general, and especially where the mines are concentrated.

Despite being the largest island in Wallacea and recognized as a globally important conservation area across a range of evaluation criteria,[3] data collection rates in Sulawesi are among the lowest in Indonesia and taxonomic study has been limited.[4]

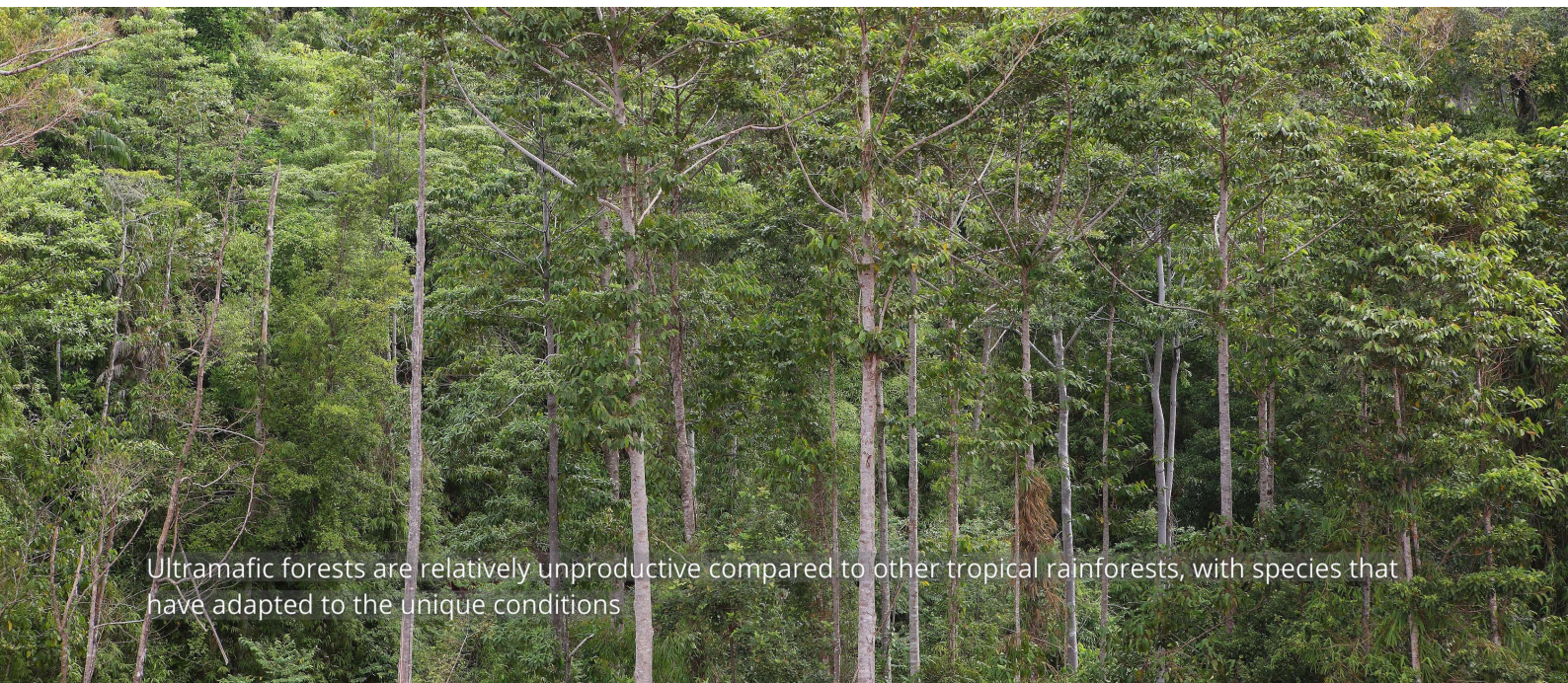
Within Sulawesi, there can be significant differences in ecosystems across the island. Sulawesi's unusual shape, with four narrow branches in the shape of the letter K, results in isolated peninsulas. Despite its large area (179,380 square kilometers), no location is more than 100 km from the coast.

All the mining activity is confined to a specific type of forest, known as ultramafic forests.

The ultramafic geology is the source of the nickel laterites that are targeted by mining companies. This geology contains high metals concentrations that inhibit plant growth, leading to exceptionally unique biodiversity where species have adapted to the unusual conditions.

With such high metals content, the ultramafic soils are generally unproductive and so are less preferred for agriculture. This means that the ultramafic forests have been largely ignored by local populations. The forests are somewhat uncharismatic, especially compared to other nearby alternatives that have garnered all the attention of research teams.

Sulawesi's ultramafic rainforests are highly unusual, yet remain largely unexplored by the scientific community



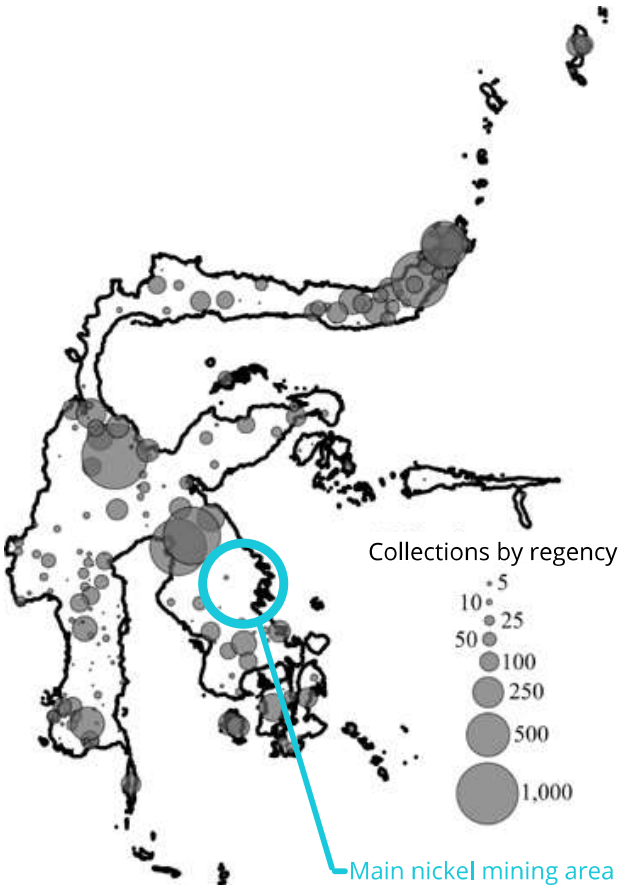
Ultramafic forests are relatively unproductive compared to other tropical rainforests, with species that have adapted to the unique conditions

Biodiversity of ultramafic forests

From the little research available, we know that these ultramafic forests are remarkably distinct. Yet, we have poor knowledge of species and abundance, due to the low numbers of collections undertaken, especially in the Morowali and Konawe mining regions that are the primary sources of nickel today. Most collections have occurred in the North Sulawesi arm and around the Malili Lakes.

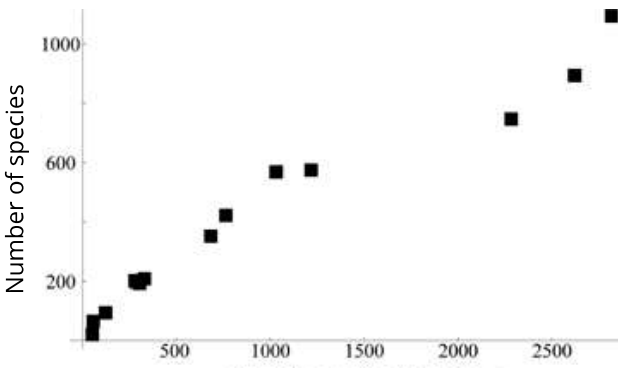
This geographic bias in collection history directly affects the observed species diversity measures, as collection density by biogeographic region has a linear relationship with number of unique species observed. Consequently, the mining activities around Morowali and Konawe could be impacting on countless numbers of unknown species.

Collection density map of Sulawesi



Source: Cannon, Summers, Harting, and Kessler,[4]

Correlation between number of collections and number of species



The area most impacted by nickel mining is also the area with the least known about its biodiversity

Freshwater ecosystems

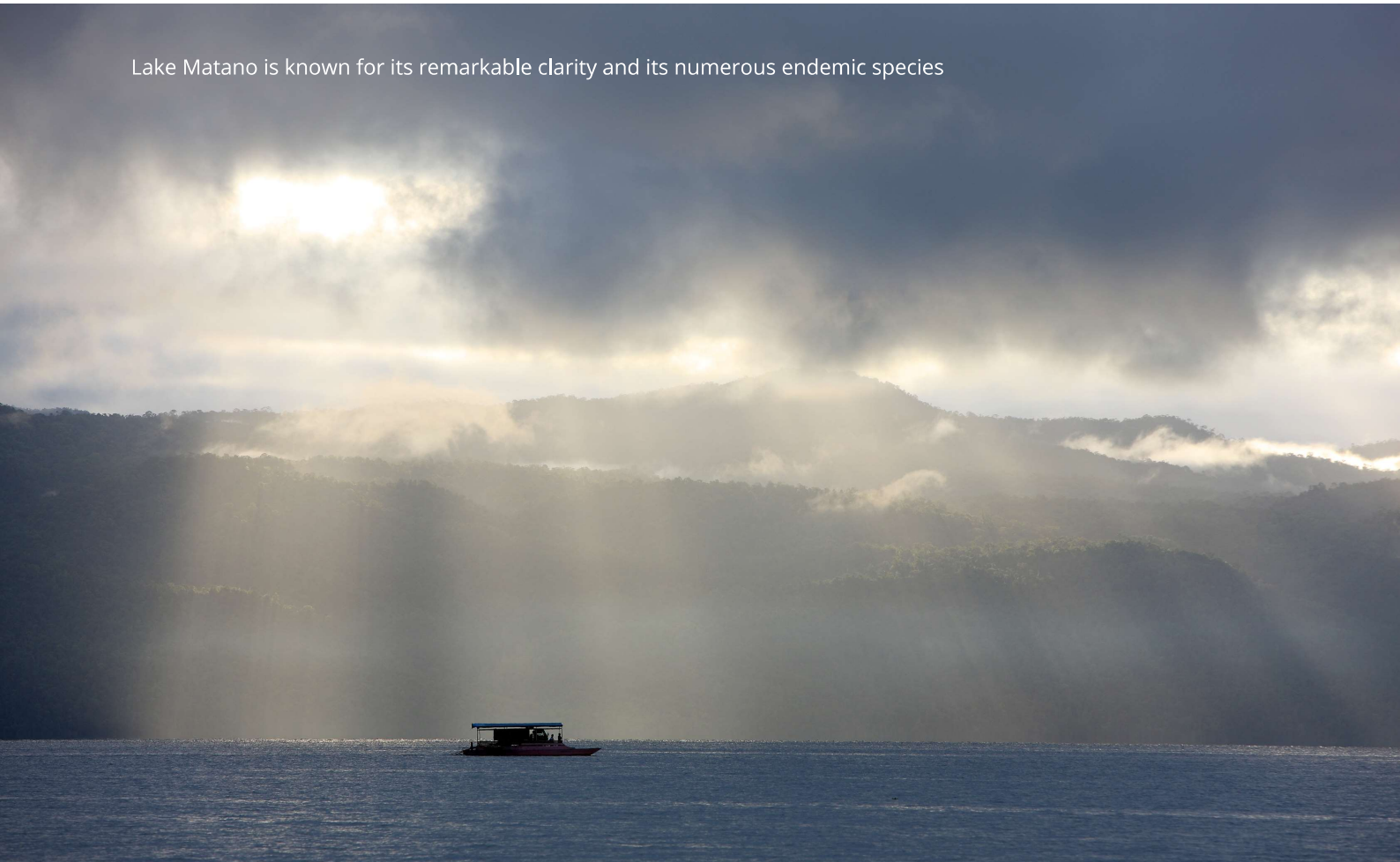
Freshwater biodiversity studies[5] in the Indonesian ultramafic forests have focused on the exploration of species diversity and evolutionary biology in Sulawesi. Endemic species include gastropods, crustaceans and fishes. Most of the research has focused on Sulawesi's lakes, especially the ancient lakes, which are some of the world's oldest lake environments.

The Malili Lakes system (adjacent to the Vale Sorowako nickel mine and smelter) is known for its endemic species flock of sailfin silversides (Telmatherinidae), and radiations of ricefishes (Oryzias) and gobies. The lakes are also known for their remarkable clarity.

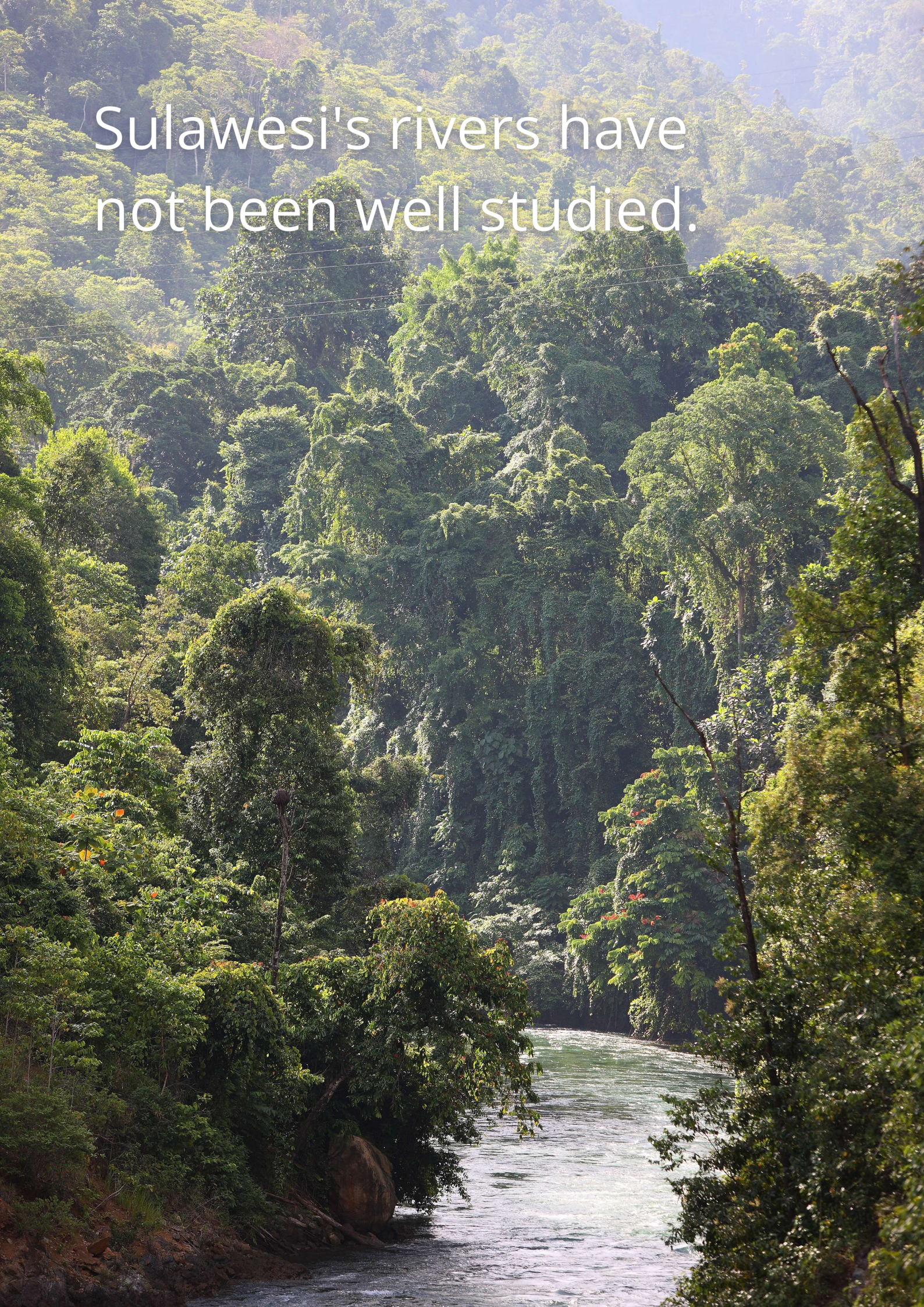
Lake Matano is one of the deepest lakes in the world, and yet it is only 34 kilometers from the coast. Its surface is at an elevation of 382 meters above sea level, while its deepest point is over 200 meters below sea level.

In contrast, little is known of the riverine environments in the Indonesian ultramafic forests. Unlike most other larger Indonesian islands, Sulawesi does not have many large, slow-flowing rivers. Instead, Sulawesi's riverine environments consist of small catchments with medium to high stream velocity.

One recent study found that riverine species in Sulawesi can be deeply divergent, even within a single river system.[6] This suggest that further studies of Sulawesi's rivers could reveal species richness similar to the lakes.



Lake Matano is known for its remarkable clarity and its numerous endemic species


Sulawesi's rivers have
not been well studied.

Coastal and marine biodiversity

Indonesia's nickel mining operations lie in the heart of the coral triangle - the epicenter of marine biodiversity, spread across six countries: Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands and Timor-Leste. It represents 30% of the world's coral reefs, despite occupying just 1.5% of the world's total ocean area.[7]

Over three quarters of the world's coral species are found here. Fifteen of the coral species are endemic to the region.

Little is known of the status of the coral reefs that fridge the nickel mining areas. Satellite imagery shows extensive coral reefs in all the key nickel mining regions in Indonesia. While some companies have undertaken marine baseline studies prior to commencement of operations, these have been rare exceptions rather than commonplace.

The Gag Nickel project site covers the entire area of Gag Island, located in Raja Ampat – a proposed UNESCO World Heritage site renowned for its marine biodiversity.

Only a tiny fraction of Indonesian nickel operations conduct proper baseline studies of the marine environment


The Lasolo Bay Nature Park is located directly offshore from one of Indonesia's major nickel mining regions

The coelacanth, known to local fishermen as “raja laut” (“king of the seas”)

Sulawesi's living fossil

The coelacanth was once believed to be extinct, with only fossils remaining from approximately 65 million years ago when the dinosaurs disappeared during the great extinction. However, in 1938, a living coelacanth was discovered off the coast of Africa, leading to the discovery of a community near the Comoros Islands between Madagascar and Mozambique.

The scientific community was once again stunned in 1998 when UC Berkeley researchers announced the discovery of a coelacanth in Sulawesi, Indonesia, located nearly 10,000 kilometers from the Comoros. Despite its resemblance to the Indian Ocean population, DNA analysis of tissue samples from the Indonesian specimens revealed genetic differentiation. Studies have suggested that the two populations have been separated for millions of years, leading to the description of the Indonesian form as a new species, *Latimeria menadoensis*, in April 1999.

Coelacanths can reach lengths of over six feet and weigh up to 200 pounds, covered in thick, scaly armor. They are estimated to live for 60 years or more. One striking feature of these fish is their four fleshy fins, which extend away from the body and move in an alternating pattern, resembling the movement of the forelegs and hind legs of a tetrapod walking on land.

Knowledge summary

Environmental setting

What we know

- Wallacea is one the most significant biodiversity hotspots in the world.
- Ultramafic forests are an important part of the Wallacea ecoregion.
- Ultramafic soils are unique, leading to highly adapted flora species.
- Limited research has been undertaken in ultramafic forests, but research studies can often yield many new species discoveries.
- Significant research has occurred in Sulawesi's ancient lakes, with numerous endemic species discovered.
- Riverine biodiversity varies significantly across the region, with significance species divergence possible within a single river.
- Coral reefs of global significance exist around the mining areas.

What we don't know

- Limited research has been undertaken on the biodiversity of ultramafic forests, especially in the most important mining areas around Morowali and Konawe.
- Freshwater biodiversity, especially in rivers, has not been well researched.
- The extent and status of coral reefs around the mining areas is largely unknown.
- The significance of the ultramafic forests, including the interconnectivity with the broader Wallacea ecoregion, is not understood.

The tarsier is a tiny primate found only in Wallacea

Environmental impacts

Given the importance of the environmental setting outlined above, understanding the impact of nickel production in Indonesia is crucial.

Lateritic nickel operations impact the environment in several ways. The physical footprint of the operations displaces and fragments habitats. This can be partially offset by mine rehabilitation activities where these are undertaken. Water runoff introduces chemical and physical stressors that can threaten ecosystem health in rivers and coastlines. Air emissions affect local air quality and contribute to climate change. Infrastructure can also provide access to areas that were previously isolated from human activities, leading to secondary impacts such as forest conversion for agriculture and poaching.

Impact assessments

EIA review meetings rarely yield meaningful change

All mining developments in Indonesia must have an environmental and social impact assessment (EIA) prior to commencement. If done well, the EIA will include a thorough baseline study of environmental conditions at the site, identify sensitive habitats and communities, quantify impacts, and determine appropriate impact management and monitoring plans.

The degree to which nickel mining EIAs achieve this coverage varies significantly. The EIAs are reviewed and approved by the government, but only the larger developments require central government review by the Ministry of Environment and Forestry. The vast majority are reviewed at the local level, where capacity to deal with the huge numbers of nickel mines is low.

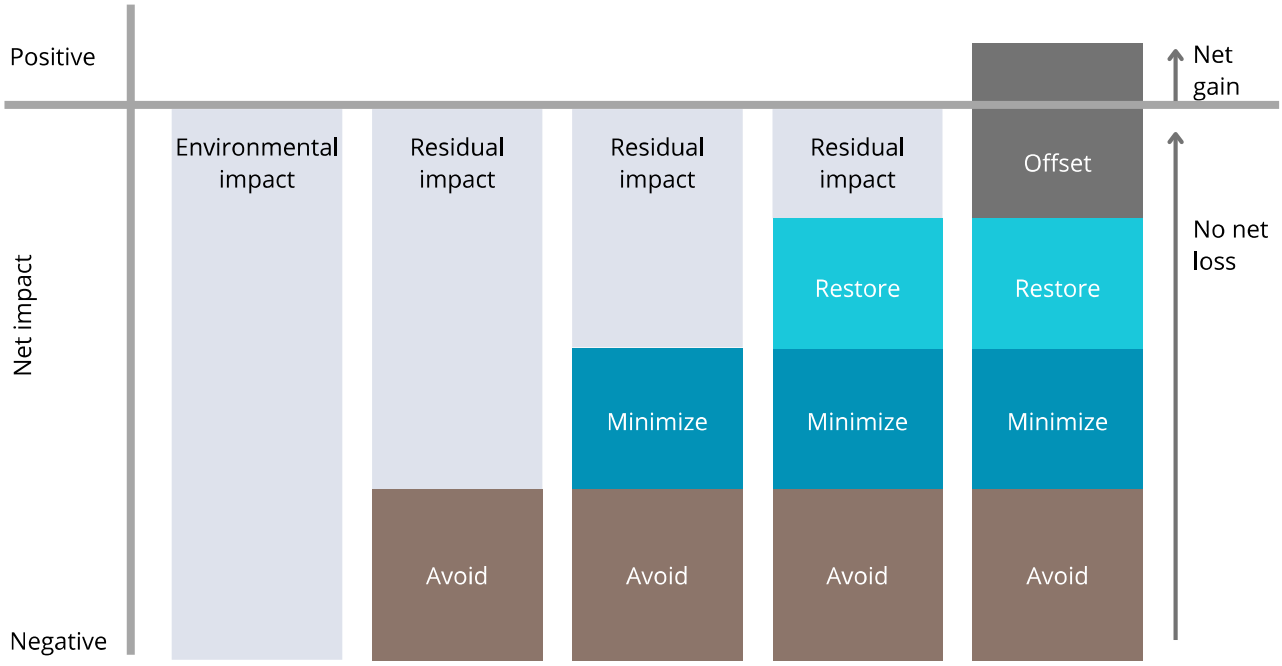
EIA review meetings are led by the Government, but include community and NGO representatives. The large review panels mean that there is not enough time to adequately discuss genuine project issues, and instead digress into debates over individual grievances, mostly around fair distribution of employment opportunities between the nearby villages.

Consequently, most EIAs fail to properly document baseline biodiversity and fail to quantify actual project impacts let alone determine appriate management plans.

Moreover, there is little genuine effort to consider cumulative impact of the combined mining activities in the region. Most EIAs define a study boundary around their individual mines, but there has been no consideration of the broader impacts to the ultramafic forests in which all the Indonesian nickel mines are located.

Given the scale of the nickel activities, with more than half the world production occurring in a concentrated environment, a landscape-scale assessment is warranted.

The site-by-site approach that is currently employed is not fit-for-purpose and risks missing the far-reaching and long-term impacts that may arise.



Mitigation hierarchy

In many jurisdictions, mining operators must mitigate environmental impacts by following a mitigation hierarchy. The mitigation hierarchy is a widely used requirement to limit the negative environmental impacts of mining projects.

The sequential steps in the hierarchy are to avoid and then minimize any negative impacts, and then restore sites no longer used by a project, before finally offsetting any residual impacts.

Many jurisdictions require “no net loss” or sometimes even “net gain” in biodiversity.

Indonesia does not require the use of this mitigation hierarchy, and does not have any requirement for “no net loss” or “net gain”. Instead, Indonesian mining operations are merely required to “minimize” significant negative impacts by implementing management plans. This is a significant difference in the requirements applied to mining activities in Indonesia compared to many other jurisdictions.

Other nickel-producing countries, such as Canada and Australia, require no net loss, except in specific circumstances where partial offsets are allowed.

Indonesia does not require use of the mitigation hierarchy and does not require "no net loss" of biodiversity

Mine footprint in ultramafic forests

Indonesia’s nickel operations are located exclusively within ultramafic forests.

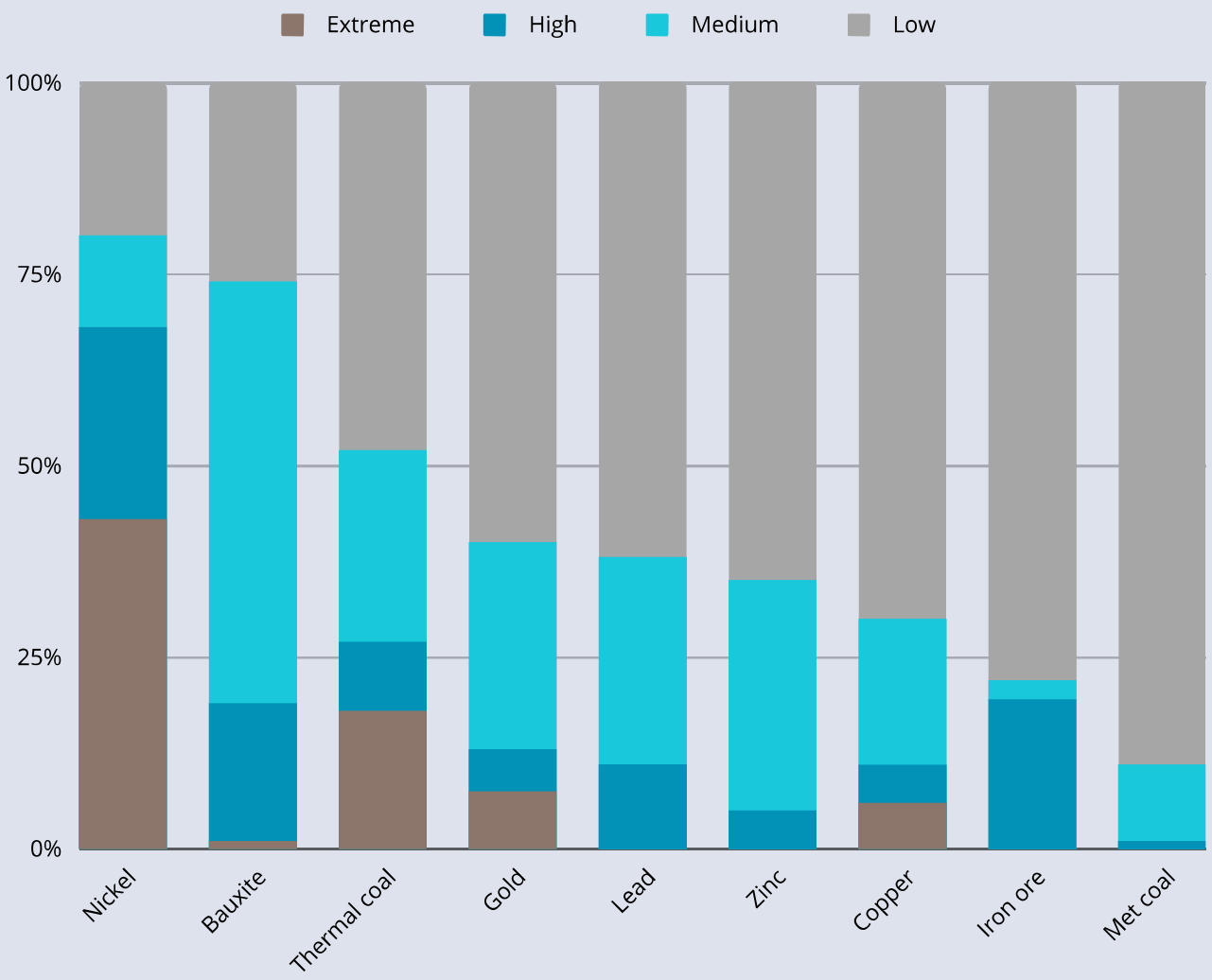
There are 313 nickel mining exploration and production licenses in Indonesia, covering a total of 825,000 ha. This represents a significant percentage of Indonesian ultramafic forest land. The area of ultramafic forest in Sulawesi is estimated to be about 1,500,000 ha, of which 36% is covered by nickel mining licenses.

Only a fraction of the license areas are actively mined at any one time. As mining progresses, companies are supposed to rehabilitate mined out areas before new areas are accessed. However, no data exists on the amount of exposed mining area over time. The local authorities do not cap total land exposure, although some of the larger mines have site-based caps imposed.

36%

of Sulawesi's ultramafic forest is covered by nickel mining licenses

Globally, nickel has a higher proportion of production in extreme and high risk areas for biodiversity



Source: Maplecroft , 2021

A recent study by Maplecroft found that nickel is the mined commodity most exposed to biodiversity risks, mainly because of huge nickel operations in biodiverse areas such as Indonesia, New Caledonia and the Philippines. The report also found that Indonesia had the highest risk of all major commodity producers.

Appropriate buffer zones

Indonesia has mandatory buffer zones around specific landforms, which limits how close mining activities can be carried out. For example, mining activities in coastal areas cannot be carried out within 100 meters of the high tide mark. Similar limitations exist for rivers and lakes.

Unfortunately, the definitions for rivers and lakes are unclear, leading to confusion about buffer zones around smaller water bodies and streams.

There is little information available about the effectiveness of these buffer zones in nickel mining regions. Some individual mine EIA documents have used empirical calculations to set distances between mines and receptors, but there are no requirements for post-approval monitoring to determine the effectiveness of these buffers.

Furthermore, the enforcement of these buffer zone rules is sporadic. While some companies incorporate the buffer zone requirements into their mine plans, a large number of other companies are either unaware of, or disregard, the requirements.

Buffer zone requirements are often ignored

Many nickel mines operate without applying any buffer zone between mine and coastline

Indirect deforestation

Historically, Indonesia's ultramafic forests remained relatively untouched from agricultural conversion. This was because of the low productivity of ultramafic soils, small populations in these areas and lack of infrastructure.

With the rapid expansion of nickel mining activities, the ultramafic forests have now come under significant pressure, with large areas being converted for agriculture since 2010.

The nickel mining infrastructure, including jetties, roads and bridges, have opened up previously inaccessible forest land. Population growth, caused by the mining activities, has also incentivized forest conversion.

No data is available on the rate of deforestation in the ultramafic forests. Further work is needed to understand how the mining activities directly and indirectly contribute to deforestation.

The cumulative effects of the indirect deforestation and the nickel production activities have also not been assessed.

Satellite image showing how mine infrastructure enables conversion of forest to agricultural land. In this case, an area allocated as a buffer zone has been converted to plantations.


Mine infrastructure provides access
to inland forests, leading to poaching
and increased deforestation

Effectiveness of rehabilitation

Lateritic nickel mines are shallow and can be rehabilitated to secondary forest without a major change in landform. Almost all Indonesian nickel mines are located in areas that are zoned as forest zones, meaning that by law they must be rehabilitated to restore forest cover.

Re-establishing tree coverage is challenging due to the poor soil conditions. If topsoil is not preserved prior to mining, it can be difficult to re-establish any vegetation cover. However, with adequate will and effort, tree cover can be re-established.

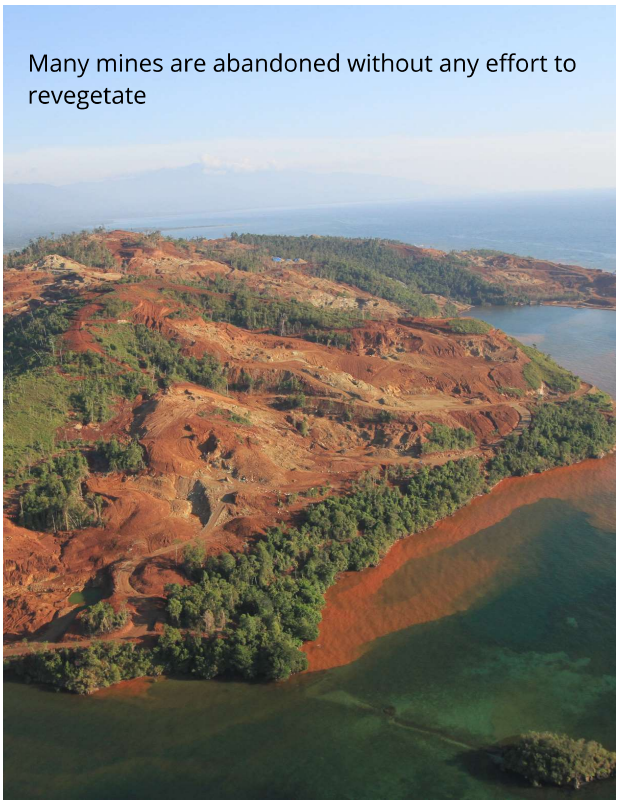
Many, but not all, mining companies do a good job of revegetating the mined-out pits. On those mines that undertake rehabilitation, a mix of local and introduced plant species are used. With adequate care, trees can be properly established within three years of mining.

Rehabilitated mines use a mix of native and introduced plant species

Mining companies must monitor tree growth and success rates to the government, but are not required to monitor broader biodiversity indicators.

Consequently, there are no data available to indicate if the rehabilitation practices are leading to a return of biodiversity to the post-mining landscape. The use of both native and introduced plant species in rehabilitation has not been assessed in terms of its long term effect on biodiversity. A recent study in Europe found that rehabilitation using non-native species had negative consequences for biodiversity.[9]

Satellite imagery also suggests that many companies do not undertake any mine site rehabilitation. Many nickel mines have been left open for many years without any effort to restore vegetation cover. No studies have been undertaken to measure rehabilitation efforts across the industry.



Many mines are abandoned without any effort to revegetate

Significant further work is needed to determine the effectiveness of current rehabilitation requirements and enforcement mechanisms. With advancements in the use of drone technology, it should be possible for the processing hubs to regularly monitor their ore suppliers to ensure that adequate rehabilitation is being undertaken. This could easily be incorporated as a requirement for all ore suppliers.

Water quality impacts

The main source of impact from lateritic nickel operations on freshwater quality is runoff from mining areas. In the wet tropics, it is not possible to retain runoff from operational areas for recycling or evaporation. Consequently, there is generally a continuous discharge of runoff water to the nearby streams and rivers.

This runoff water contains potentially harmful stressors, including sediments and metals. Responsible operators use sediment ponds to reduce the sediment loads prior to discharge, and may also use some chemical treatment for specific metals. These methods have been successful in meeting local regulatory requirements. However, enforcement of these requirements remains weak.

Indonesian regulations require monthly samples to be measured for sediment and metals content. Monthly sampling is not sufficient to adequately monitor the high variability of sediment and metals concentrations in tropical laterite mines. Typically, the monthly samples are collected in dry conditions, which correlate to the lowest concentrations. This means that monitoring data does not account for peak sediment and metals concentrations.

The Indonesian regulatory limits for sediment and metals require further scrutiny. Indonesia water standards have been adopted from European and North American requirements, and adjusted to take into consideration the cost of compliance. European and North American water quality standards have been developed based on toxicity studies in these areas. The toxicity of metals in tropical Southeast Asia may be different to that in colder climates.

To address this knowledge gap, NiPERA Inc (the Nickel Institute's independently-incorporated science division) has undertaken a large number of studies over the last decade to develop an approach that would allow interested parties (government authorities, companies, etc.) to assess risk of nickel exposure in tropical environments. However, this approach has not yet been used by Indonesian authorities to assess adequacy of current limits on nickel toxicity.

While the NiPERA approach is available to address nickel toxicity risk, there are no tools available for other metals that are present in laterite mine runoff. Chromium is of particular concern, given its presence in the laterite profile and known potential to oxidize to the highly toxic hexavalent chromium form. At least half of Indonesia's nickel mines generate hexavalent chromium at concentrations above the Indonesian regulatory limit. Some of the more advanced companies treat the hexavalent chromium, bringing it back within the allowed regulatory limit. However, no research has been undertaken to determine if this limit is appropriate in the tropical ultramafic environment.

To address these issues, it is necessary to systematically assess scales of risk of aquatic toxicity. It is likely that lateritic nickel mining causes impacts, but it is unclear if these impacts are restricted to the local scale or if they are more widespread.

2007, natural stream, prior to mining

2012, same location as above, after mining commenced upstream

Coastal impacts

Indonesia's laterite operations impact the coastal environment in four main ways:

- Sediment loads directly from coastal mines or transported via rivers and streams.
- Effluent discharge from HPAL plants.
- Cooling water intake and discharge from coal fired power plants.
- Reef and beach damage from jetty construction.

Sediment deposition along the coast is the most visually striking impact of Indonesia's nickel operations. First time visitors to major nickel hubs are often struck by the red color of the sea. These sediments smother the coral and seagrasses, and have drastic changes on the coastal ecosystems.

Indonesia's first HPAL plants began operating in 2021. Unlike the older NPI smelters, the HPAL plants use acid to leach the nickel from the ore, and produce a tailings slurry. The tailings can be dried and stacked or deposited into tailings dams. The remaining liquid effluent from the tailings is discharged to the sea via pipelines.

The effluent contains dissolved salts and metals, which can affect seawater quality. No toxicity studies have been undertaken to determine the acute and chronic toxicity of HPAL effluent in the tropical marine environment.

Indonesia's nickel processing hubs are almost entirely powered by coal fired power plants. These plants use "once-through" seawater cooling, where seawater is sucked in and cycles through the system to condense the steam, then is discharged back into the sea. This system is the cheapest cooling system to operate because it is more efficient than alternatives and does not require the additional infrastructure of cooling towers.

In tropical Indonesia, the seawater temperature is constantly high, meaning that very large quantities of cooling water are required. The discharged seawater can be significantly higher than the natural temperatures, which affects marine life. Studies in other regions have shown that this can negatively impact the fishing industry. No studies have been undertaken to determine impacts in the Indonesian nickel producing regions.

Most Indonesian nickel mines use crudely constructed jetties to transfer ore to barges to be taken to processing hubs. These jetties are often constructed directly onto the coral reefs. The in-fill construction method carries the risk of coastal erosion, reducing the resilience of natural beaches from storm surges and sea level rise. The perpendicular positioning of jetties to the shore disturbs naturally occurring longshore drift and causes down-drift erosion.

Indonesian port regulations are highly restrictive. To avoid onerous permitting requirements, most nickel mines operate their jetties under the simplest form of terminal permit. Unfortunately, this type of permit does not allow different companies to share the use of the jetty, meaning that each individual nickel operator has to construct its own jetty. This leads to a much larger scale of impact than necessary.

Overall, the cumulative coastal impacts of the Indonesian nickel industry are not well-understood. Much work is needed to understand how the impacts described above are affecting key marine receptors.

Jetty sharing is not permitted, so each mine must construct its own

Air emissions

Air quality is affected by dust from mining operations and air emissions from processing hubs. These emissions include carbon emissions, but also other pollutants, especially particulates and sulfur dioxide (SO2).

The carbon footprint of Indonesia's nickel operations have been estimated to be up to 60 tonnes of carbon dioxide equivalent per tonne of nickel produced (scope 1 and 2). This estimate applies to NPI and matte production using coal-fired power. For HPAL plants, the carbon emissions can be up to 20 tonnes of carbon dioxide equivalent per tonne of nickel produced. This is lower than NPI and matte emissions due to the much lower energy demand.

Combined, the carbon emissions from Indonesian NPI and matte in 2022 production would be in the order of 70 million tonnes of carbon dioxide equivalent.

With the global focus on climate change, the carbon emissions are relatively well understood. However, other emissions, such as particulates and SO2 are not well documented.

Nickel mining and especially nickel smelting operations produce significant amounts of particulates. This occurs from mines and haul roads, stack emissions and fugitive emissions. Indonesian smelters typically use electrostatic precipitators to reduce the particulate emissions from stacks. This is effective in meeting stack emission requirements.

SO2 emissions occur from the burning of sulfur-containing coal, and from the introduction of elemental sulfur to produce nickel matte. Many Indonesian plants do not use scrubbers to reduce SO2 emissions, and instead try to control emissions by selecting low-sulfur coal and by being more efficient in sulfur injection to the matte. Indonesia's new matte plants achieve low sulfur emissions, but Vale's older generation matte plant in Sorowako is one of the world's largest sources of SO2.

By comparison, companies such as Vale and Glencore have invested billions into SO2 emission controls in North America in recent years.

The overall impacts to air quality are not well understood. This is due to gaps in regulatory requirements. While stack emissions are well-regulated, the requirements for non-point sources such as mines and fugitive plant emissions are unclear and poorly implemented. Few operations, if any, mitigate and monitor non-stack emissions.

Although Indonesian stack emission requirements are clear, potential errors are introduced through the monitoring practices. Indonesian plants must use accredited laboratories to measure stack emissions against regulatory requirements. The accredited laboratory in Sulawesi (where the nickel operations are located) has had issues in properly measuring emissions, leading to under-reporting of emission concentrations. This has led to high emissions being reported as compliant, even though internal company measurements indicating that the emissions were actually above regulatory limits.

Modern laterite smelters use ESPs to capture particulate emissions from stacks. However, these smelters also have numerous fugitive emission sources, which are not well regulated at present.

Local laboratories often struggle with accurately measuring smelter emissions, resulting in under-estimating the SO2 emissions

There is also a significant gap in ambient air quality monitoring around the nickel operations. Only one site has a continuous ambient SO2 monitoring station. No other locations have continuous air quality monitoring.

Without continuous air quality monitoring stations, there is no useful information on the effects of the nickel industry on local air quality.

Knowledge summary

Environmental impacts

What we know

- Around 36% of Sulawesi's ultramafic forest is covered by nickel mining licenses.
- Mine infrastructure provides access to remote forests, leading to additional deforestation around mine sites.
- Mine water runoff contains potentially toxic pollutants, including hexavalent chromium.
- Indonesian nickel mines are only required to collect monthly water samples for sediment and metals concentrations.
- Fugitive emissions and other non-point air emission sources are not well regulated in Indonesia.

What we don't know

- Most impact assessments do not adequately assess impacts and mitigations.
- Net impacts are not quantified, as there is no requirement to achieve "no net loss".
- The adequacy of the buffer zone requirements has not been assessed.
- The ability of current rehabilitation practices to regenerate biodiversity loss is unknown.
- The toxicity of mine runoff in tropical environments is unknown.
- The impact of sediment runoff and HPAL effluent on coral reefs and the marine environment have not been assessed.
- Continuous air quality data is not available.

Social impacts

Indonesia's nickel industry delivers significant economic and social benefits to the nickel producing regions and the nation as a whole. Nickel exports (including stainless steel) were over $30 billion in 2022, representing 10.5% of total exports. In Sulawesi and Maluku, nickel mining alone accounts for between 23 and 41% of the regional GDP and represents close to 20% of all paying jobs. [10]

The rapid growth in nickel production also carries social and cultural risks. These include risks to:

- community health;
- indigenous peoples; and
- cultural heritage.

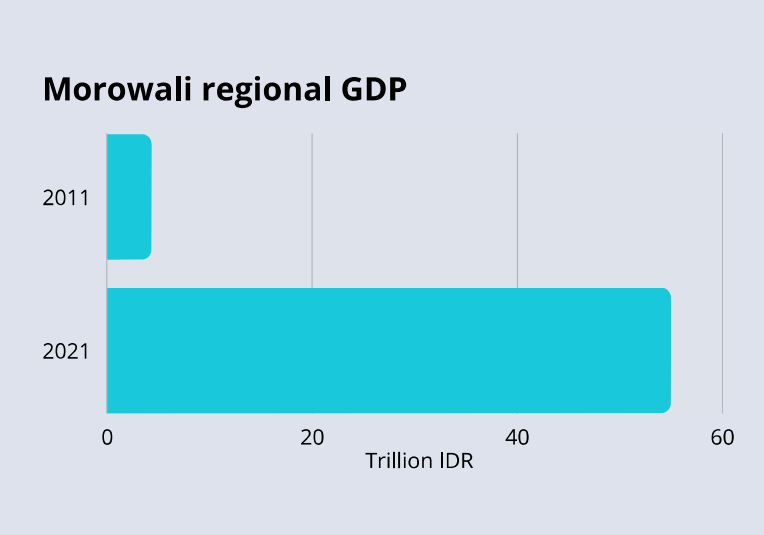
While this paper elaborates on each of these risks, this should not detract from the significant social and economic benefits of the industry. Even those community members who participate in demonstrations against nickel operations typically support the overall presence of companies, although they may disagree with specific issues (for example, recruitment processes).

2022 Ni export revenues

$30b

In focus: Morowali

Morowali is a regency in Sulawesi, and is Indonesia's largest producer of nickel. In the last 10 years, the regency has been transformed from a quiet undeveloped collection of fishing villages to a major driver of the Indonesian economy.



The nickel industry has brought about major changes to the lives of the local community through significant investments in long-term improvements to the region. These include improvements in public infrastructure, education, recreational facilities, and cultural well-being.

Nickel companies have played a crucial role in supporting the local community during recent disasters. The companies have provided financial assistance and resources to help with recovery efforts and have worked closely with local government to provide aid such as food, shelter, and medical supplies.

Community health

The laterite nickel operations can impact community health through poor air quality and poor water quality. As outlined in the section on environmental impacts, the nickel operations can impact air quality through particulate and sulfur dioxide (SO2) emissions.

Particulates are inhalable particles that are small enough to penetrate the thoracic region of the respiratory system. The health effects of inhalable particulate matter are well documented. These include respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions, and also mortality from cardiovascular and respiratory diseases and from lung cancer.

The particle size and chemical composition of the particulate matter can influence the degree to which these health risks are presented. The specific risks relating to particulate matter found in the nickel producing regions of Indonesia have not been studied.

Sulfur dioxide also affects the respiratory system, particularly lung function, and can irritate the eyes. It can irritate the respiratory tract and increases the risk of tract infections. It causes coughing, mucus secretion and aggravates conditions such as asthma and chronic bronchitis. The elderly and children are more susceptible to these risks.

One study around the Sorowako operation found that "some health conditions typical of exposure to airborne particulates and nickel, such as asthma, rhinitis, and skin tumours, were more prevalent in areas closer to and downwind from nickel mining and smelting compared to Malili, a community located further away from the mines and smelter."[11]

Water quality impacts present an even bigger risk to human health. The risk of exposure to hexavalent chromium from mine runoff is a serious concern with potential for significant human health consequences.

Hexavalent chromium (Cr6+) is generated in the runoff from around half of Indonesia's nickel mines. It is a highly toxic chemical and carcinogen. Ingestion of Cr6+ through drinking water has been found to cause cancer in the oral cavity and small intestine. It rose to fame as the contaminant behind the Erin Brockovich case, which later went on to become a major cinema production starring Julia Roberts.

No risk assessments or studies have been undertaken to quantify Cr6+ exposure risks in Indonesian nickel operations.

Without reliable water quality monitoring data (see section on water quality impacts), it is not known how many people could be exposed to toxic levels of Cr6+.

Another potential heavy metals exposure pathway is via consumption of seafood. The coastal impacts of the nickel operations may lead to elevated metals concentrations in fish and other seafoods, which in turn can be consumed by the local people. No risk assessments have been undertaken to evaluate this potential exposure.

Indigenous peoples

A discussion on indigenous peoples around the nickel mining regions of Indonesia is complicated by the lack of official recognition of indigenous status for rural communities, which have been classed instead as “remote”, but given no recognition in terms of their ties to territory.

Currently there are four indigenous peoples groups that are acknowledged by the Indonesian government in nickel mining areas. These are located at Sorowako (near the Vale operation), Hukae Laea-Moronene (close to the Southeast Sulawesi mining areas), Bahomotefe (near the IMIP processing hub), and the Fritu people (close to the IWIP processing hub).

The nickel mining activities pose risks to indigenous populations by displacing them from traditional lands and by diluting the population. Local populations are insufficient to support the required workforce numbers. This has led to large numbers of Indonesian nationals internally migrating to these regions. This poses risks that indigenous beliefs and customs will be diluted and lost.

Little is known of the local population at Sorowako before mining activities began

Some of Indonesia’s earlier mining operations were developed decades ago, in an era when companies did not document indigenous people groups like they do today. Yet even today, many mining companies proceed with development with little thought to understanding indigenous peoples ties to the land in which the mines are located.

Ancestral land ties can be particularly difficult to notice in the nickel mining regions. As laterite soils are especially unproductive, the land can be left fallow for decades before families return to the area.

One of the major processing hubsis located close to lands thought to be part of the realm occupied by one of Indonesia’s last nomadic tribes – the Tobelo forest community. These people live in the rainforest without permanent settlements, and are mostly disconnected from the rest of Indonesian society. Although total numbers are hard to determine, knowledgeable sources estimate the nomadic community to be a total of 100 individuals.

A member of the nomadic Tobelo forest community, photographed in 2019

More broadly in the community, the influx of workers, both domestic and foreign, has led to significant cultural changes in the community. The impact on vulnerable segments of the population has not been assessed. In particular, there is a need to consider women's rights and health, given the influx of a largely male workforce.

In January 2023, a conflict between local and foreign workers broke out at a major processing hub, leading to the death of two workers.

Cultural heritage

There is little information available about cultural heritage in Indonesia's nickel mining areas. These areas have, until now, been sparsely populated and attracted little interest prior to the rush on nickel. Typical EIAs do not undertake proper cultural heritage assessments, especially among the smaller companies.

Many of the karst areas surrounding nickel mines have potential cultural heritage value. Some of these caves have harbored ancient artwork, while others have high tourism value.

Indonesian regulations have focused on physical artifacts, while intangible cultural heritage has often been overlooked.

Aside from some of the larger nickel developments at Weda Bay and the Sulawesi Cahaya Mineral site, very little work has been done to understand cultural heritage in the nickel mining areas.

Bokimoruru Cave, near a major nickel project, has cultural value potential

This painting of the endemic Anoa, discovered in a cave in Sulawesi, is believed to be one of the oldest surviving artworks in the world, dating back 44,000 years

Knowledge summary

Social impacts

What we know

- Indonesia's nickel industry provides significant economic and social benefits.
- Local communities are generally highly supportive of the nickel developments.
- Nickel mine runoff can contain hexavalent chromium, a known carcinogen.
- There are several known indigenous groups around the Indonesian nickel mining areas.

What we don't know

- The health effects of air emissions from laterite nickel mining and processing have not been well studied.
- The potential for serious health effects from hexavalent chromium in nickel mine runoff has not been assessed.
- Impacts of nickel activities on indigenous peoples have not been systematically assessed.
- Cultural heritage impacts have not been adequately evaluated at most mine sites.

Health effects on local communities have not been well studied

Governance

Although a full review of governance is beyond the scope of this paper, there are several known knowledge gaps in governance practices in Indonesia's nickel industry. The industry is characterized by low levels of transparency. Consequently, little is known of governance mechanisms outside the two main publicly listed companies, Vale and Antam.

Few Indonesian nickel operators provide any information about anti-corruption policies. The current Indonesian government has made major strides to reduce corruption. Still, corruption remains an area of concern, especially in the nickel sector where only a small number of publicly listed companies are active.

With the low levels of transparency, there remains significant barriers to achieving traceability of nickel back to individual mining operations. While blockchain has started to be used in other commodities to trace metal through the supply chain, it has not yet been used to trace Indonesian nickel.

To support responsible sourcing, electric vehicle producers are using supply chain due diligence tools such as the Initiative for Responsible Mining Assurance (IRMA) standard. The Indonesian nickel industry will face significant challenges in meeting the requirements of the IRMA standard.

For example, Indonesian nickel mines may not be able to demonstrate no net loss of biodiversity (requirement 4.6.4.1.), and may not be able to implement offsets in line with international best practice (requirement 4.6.4.3.). This is because Indonesian mining companies do not have sufficient baseline biodiversity data, and thus it would be impossible for them to demonstrate no net loss.

It may require several years for even the more advanced Indonesian producers to meet these requirements.

Even Indonesia's most responsible operators will require several years to comply with IRMA

Rehabilitation efforts focus on revegetation, but do not aim to achieve no net loss as required by IRMA

Recommendations

Organizations throughout the nickel supply chain should play a greater role in the stewardship of lateritic nickel.

As a general recommendation, it is important that other sources of nickel outside of Indonesia are developed. Diversity of supply is important to reduce dependence on one source, and to reduce potential environmental and social impacts. Consideration should be given to seabed polymetallic nodules, which could provide a viable source of nickel with potentially far lower impact to the environment and society.

This report highlights several noteworthy concerns, however, it should not be interpreted as a call to halt Indonesian nickel developments. The world needs Indonesian nickel, and there are potential solutions to all issues outlined in this report.

Recommendations for laterite mining companies

The most important step for mining companies is to implement a recognized global ESG framework, such as IRMA or TSM. These frameworks provide comprehensive tools that will address many of the key issues raised in this report. Additionally, mining companies should:

- Collaborate with customers to increase transparency and public knowledge sharing of the potential effects of laterite nickel mining.
- Openly and transparently share gathered environmental baseline data, EIA documents, monitoring data and company ESG performance.
- Engage with customers to develop workable due diligence frameworks for laterite nickel.
- Invest in capacity building to understand stakeholder expectations and best practice.

Recommendations for processing companies within Indonesia

- Recognize the challenge for small mining companies in meeting market expectations on ESG performance. Provide support to ore suppliers to build capacity.
- Provide clear expectations to suppliers on appropriate ESG standards, such as IRMA, TSM or the Joint Due Diligence Standard for Copper, Lead, Nickel and Zinc.
- Undertake appropriate supply chain due diligence, including monitoring and auditing of ore suppliers.
- Coordinate with other processing companies to align on standards to avoid duplication.
- Invest in training programs to share knowledge with ore suppliers.
- Engage with downstream customers and markets to develop appropriate supply chain requirements.
- Engage with the Indonesian Government to ensure appropriate requirements are regulated, and that tools, such as those provided by NiPERA, are utilized.

Recommendations for manufacturers and markets

- Communicate extensively with suppliers based in Indonesia to ensure they are familiar with manufacturers' and markets' expectations, values and priorities.
- Audit supply chains, and invest in appropriate remote sensing tools such as drones to monitor mine performance.
- Invest in appropriate studies to address knowledge gaps, including those identified in this paper.
- Review due diligence frameworks to identify appropriate frameworks for laterite nickel, understanding the constraints in place for smaller ore suppliers.

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Note: This report includes various assertions without accompanying references. These assertions are rooted in the author's professional experience within the nickel industry.

Never before has mining on this scale occurred in such a unique and rare environment

Author

Steven Brown
Responsible mining and metals specialist

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