the metals company

Summary Report

Nickel and Cobalt Mining Impact on Terrestrial Carbon Sinks in Sulawesi, Indonesia and Katanga, DRC

With total carbon impact comparison of producing nickel and cobalt from land vs. the NORI-D Polymetallic Nodule Project

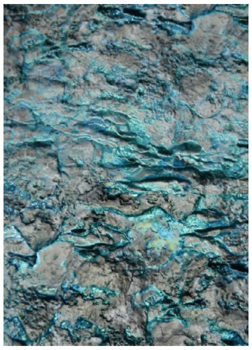
October 2023

Summary

In 2022, 75% of the world's cobalt production came from the Democratic Republic of Congo (DRC) and 50% of the world's nickel production came from Indonesia.[1] Both DRC and Indonesia are "megadiverse" countries[2] – conservation hotspots with high levels of endemism. The study commissioned by The Metals Company (TMC) and conducted by Benchmark Mineral Intelligence (Benchmark) sought to understand the impact of mining in these countries on terrestrial carbon sinks.

The carbon model developed by Benchmark quantified the magnitude of carbon and sequestration services loss due to the mining of cobalt in the Katanga region of the DRC and nickel in Sulawesi, Indonesia, as shown in Figure 1. The extraction of these metals destroys forest/woodland carbon sinks, and increases loss of carbon sequestration services over time as mining area expands.

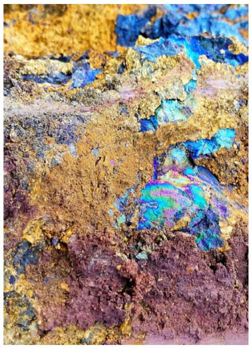
Varying results for the carbon impact per unit of metal produced relate to the distinct forest species mapped in each region, which represent different carbon stocks, as well as differences in metal grades. At an average DRC cobalt mine grading 0.35% cobalt, 317 tonnes of ore are removed for every tonne of cobalt extracted (1:317 metal-to-ore ratio), while at an average Indonesian nickel mine grading 1.5% nickel, 78 tonnes of ore are required to produce 1 tonne of nickel (1:78 metal-to-ore ratio).



Cobalt

Carbon stock reduction:
~3.6 kg CO_2e per kg of Co mined per year

Carbon sequestration loss:
~9.3 g CO_2e per kg of Co mined per year



Nickel

Carbon stock reduction:
~7.0 kg and ~9.4 kg of CO_2e per kg of Ni mined from saprolite and limonite, respectively

Carbon sequestration loss:
~4.8 g and ~6.5 g of CO_2e per kg of Ni mined from saprolite and limonite, respectively

Saprolite is processed via RKEFs and limonite is processed via HPALs

Figure 1

Background

The global energy transition is metal intensive and requires an unprecedented ramp-up of the primary production of critical minerals. Where and how these critical minerals are sourced can make a material difference in the environmental cost of the energy transition itself.

The carbon impacts of mining is an important issue, with awareness around the direct carbon emission profiles of various mining and processing routes increasing. Most lifecycle assessments quantify the greenhouse gas (GHG) emissions derived from the lifecycle of producing metals but do not quantify the impact that land-use changes have on carbon sinks as a result of mining operations.

From a planetary systems perspective, effective action to mitigate climate change depends not only on low-carbon energy sources and technologies but also the protection and restoration of carbon sinks.

Forests are seen as the most critical terrestrial ecosystem in terms of their ability to capture and lock up carbon from the atmosphere.[3] At the 2022 United Nations Climate Conference, Brazil, the DRC and Indonesia announced their intention to form a “rainforest OPEC,” highlighting the importance of protecting their forests and securing associated economic benefits.

Forest ecosystems are removed and/or degraded as a result of a number of land-use changes. Terrestrial mining is one such activity requiring significant land use, land which may or may not be remediated after extraction.[4] Peer-reviewed research shows that once the requisite infrastructure (e.g., roads, railways and ports) is built to access a mine, it acts as an enabler for further deforestation by other extractive industries such as agriculture and palm oil production. Degradation of these forests results in a reduction in carbon accumulation and removal through both the loss of carbon sequestration services as well as the release of CO_2 held in these carbon stocks.[5]

To quantify carbon impacts of cobalt and nickel mining operations, TMC engaged Benchmark to conduct an independent analysis.

Scope

The study is focused on the impact of land-use change on forest carbon sinks in the key cobalt and nickel mining regions of Katanga, DRC, and Sulawesi, Indonesia, as they are good examples of mining operations in these two world’s top-producing countries. Benchmark sought to establish a clear picture of changes in carbon sinks as a result of local mining.

Quantification of carbon impacts of cobalt and nickel mining requires building up a clear picture of rates of carbon accumulation and loss, which enables an understanding of how a carbon stock can change over time. This requires data on two issues:

A. Estimation of carbon stocks (quantity of carbon stored in the forest ecosystems) before mining disturbance and the estimation of loss of carbon stock after the start of mining, and;

B. Changes to carbon sequestration services (i.e., estimated changes to an impacted ecosystem’s capacity to remove CO_2 from the atmosphere).

Benchmark conducted an independent carbon sinks assessment of the impact of cobalt and nickel mining on carbon sinks in the two top-producing nations of the DRC and Indonesia.

Energy transition is not possible without a ramp-up in mining, a carbon-emissions-intensive industry. While incorporating low-carbon energy sources into the mining sector itself will be helpful, it is also important to understand the impact of land-mining on land use and associated carbon sinks – a topic attracting a growing international attention.

Cobalt

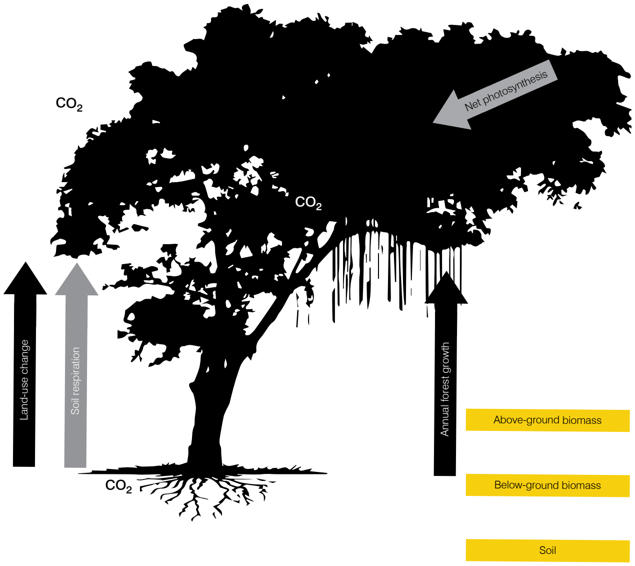
Cobalt produced in the DRC currently accounts for 75% of global production. Russia, Australia, the Philippines, Cuba, Madagascar, Papua New Guinea and Canada are also producers.

Nickel

Nickel produced in Indonesia currently accounts for 50% of the global production. The Philippines, Russia, New Caledonia, Australia, China, Brazil, United States and Canada are also producers.

Methodology

Calculating carbon changes due to mining requires understanding changes in land use and the different ways the carbon cycle is impacted, as shown below.



This study measured:

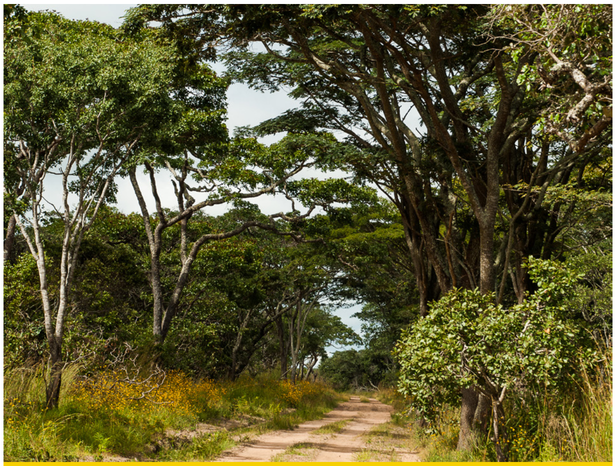
Total ecosystem carbon stock (tonnes/hectare) = above-ground biomass, below-ground biomass, soil

Carbon emissions due to land-use change = net photosynthesis to create biomass (the rate of biomass acquisition changes over time)

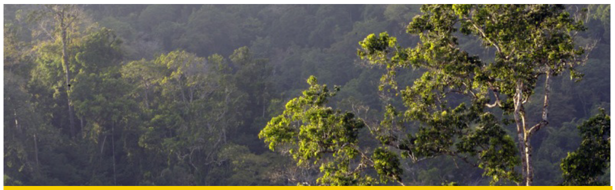
Carbon sequestration = soil respiration and decomposition (tonnes of carbon/per hectare/year)

The study drew on Geographical Information System (GIS) analysis to measure the land-use change within contracted mining areas. There were six main stages to the process:

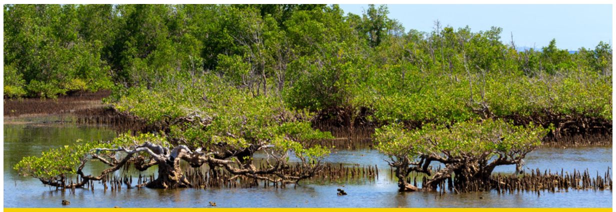
1. Benchmark data was used to identify Katanga, DRC, and Sulawesi, Indonesia, as the largest producers for cobalt and nickel, respectively. Five of the largest mines in each region were used as case study mines (CSMs).
2. CSMs were mapped using a combination of Landsat and Sentinel 2 GIS. The size and extent of each CSM was determined by examining mining licensing maps, where available. Habitat types in the DRC were defined by the Land Cover Classification System (LCCS) and, in Indonesia, by two natural ecosystems – rainforests and mangroves – and by various agricultural practices. To track land-use change over time, three time points were mapped: 2008, 2014 and 2022. The area (in hectares) of all the CSMs is the “pre-mine” time point. It was assumed that this is undisturbed Miombo woodland for the DRC and undisturbed rainforest and mangroves for Indonesia.
3. Biomass data was sourced from peer-reviewed literature for Miombo woodland and Sulawesi rainforest and mangroves.
4. Selected appropriate biomass equations for habitat type and data availability were used to create biomass estimates.
5. Carbon stock and carbon flow in the regions and carbon flows due to land-use change observed in the study area were then modeled.
6. Ore grades and volume estimates come from Benchmark’s database also used on Benchmark’s comparative LCA of TMC NORI-D project.



Miombo woodland



Tropical rainforest



Mangroves

Key findings

The extraction of metal ores through open pit mines requires complete removal of overlying ecosystems and contained carbon sinks. The removal of carbon sinks also eliminates the carbon sequestration services that these ecosystems provide.

Cobalt

Katanga Region, DRC

Miombo woodland

10.9 kg Co/m^2 mine area

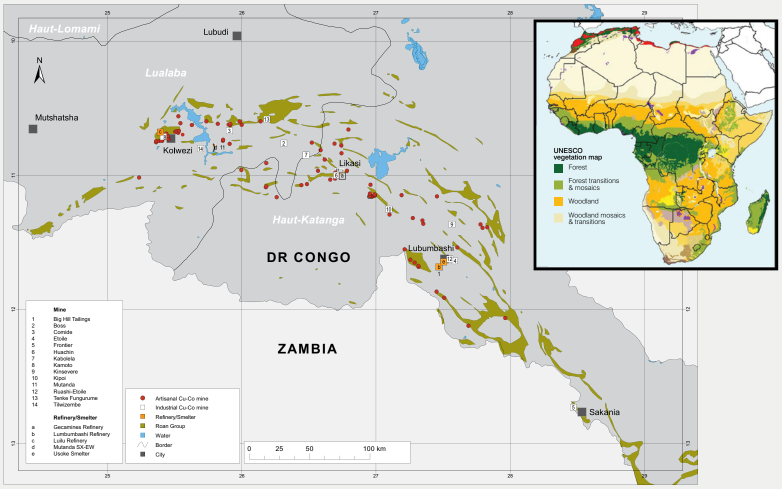


Figure 3: Map sourced from Bouvet et al. 2018 [9], p 158, showing the main habitat types in the DRC – woodland in this area is the Central Zambezian Miombo woodland

Figure 2: Map sourced from: Al Barazi et.al, 2017 [7] p.6 showing mines in Katanga region, DRC

The DRC is the largest producer of cobalt globally.[6] Located in central Africa with only 40 kilometers of Atlantic-facing coastline, DRC is essentially landlocked and is the largest sub-Saharan African country with a land area of ~2.345 square kilometers.[7] Most cobalt reserves are in the south of the DRC in the Katanga region.[8] Industrial mines are interspersed with artisanal mines (see Figure 2).

The five CSMs are all within the Katanga region and are all within the Central Zambezian Miombo woodland ecoregion, which is one of the DRC's major ecoregions.[9] The Congo basin to the north consists of tropical forests[10] (see Figure 3).

In the DRC, Miombo woodland covers an estimated 286,000 square kilometers; **more than 70% of the Miombo woodland in the DRC is in Katanga region.**[11]

This ecosystem has been managed for approximately 55,000 years by frequent dry-season fires, subsistence harvesting and cultivation.[12] Recently, however, there has been increased human activity including farming activity.[13]

In sub-Saharan Africa, there are five different Miombo ecoregions that extend across seven countries.[14] Broadly defined as dry or wet Miombo[15], the case study mines area within the wet Miombo receiving rainfall greater than 1,000 millimeters per annum. There is much variation throughout the region that is influenced by several factors including differences in soil, climate and biogeography.[16]

The Miombo and adjacent Mopane woodlands are dominated by Leguminosae, which includes over 19,500 species.[17] Plant diversity in the Miombo woodlands is high, with an estimated 8,500 tree, shrub, grass and herb species.[18] Miombo woodlands contain seven major soil groups,[19] and most of the soil organic matter (SOM) is concentrated in the top 30cm of soil.[20]

Nickel

Sulawesi, Indonesia
Tropical moist lowland rainforest
Two types of nickel ore are mined:
Limonite – 17.9 kg of Ni/m^2 mine area
Saprolite – 24.2 kg of Ni/m^2 mine area

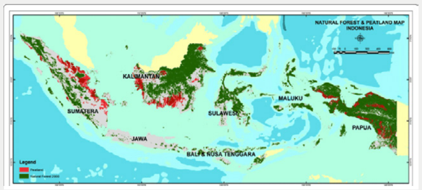


Figure 4: Map; BP-REDD+. (2015)[24] p23

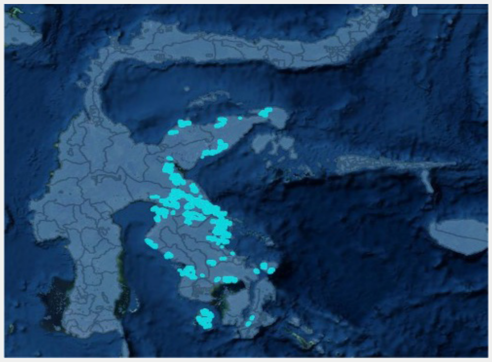


Figure 5: Map of nickel contracts in Sulawesi highlighted in blue ArcGIS Pro (2022)

Indonesia is the largest producer of nickel globally.[21] Located between the Indian Ocean and the Pacific Ocean in Southeast Asia, Indonesia is the largest archipelagic country in the world, with a land area of 1.91 million square kilometers, spread across 17,504 islands.[22] The five main islands include Sulawesi, which is the largest island in the Wallacean Island chain and is approximately 180,681 square kilometers[23,24] (see Figure 4). Sulawesi is the biggest region for nickel laterite mines as it includes some of the largest areas of ultramafic bedrock in the world.[24] These are mainly large industrial mines with concessions allocated adjacent to each other.[25,26]

The five CSMs of nickel laterite ores are all within Sulawesi's southeast arm. This is where most of the nickel mining concessions are located on the island (see Figure 5).

Sulawesi is mainly tropical, moist lowland rainforest and is considered a globally significant ecoregion.[27] It currently has approximately 95,000 square kilometers of forest area[28] and 14 different forest ecosystems. **This wide diversity of forest ecosystems is part of the reason for the island's high rate of endemism and biodiversity**.[29]

Sulawesi forests are globally important with high degrees of biodiversity and endemism due to a complex geology.[30] However, Sulawesi like much of Indonesia, has experienced high rates of deforestation and degradation due to several factors, including mining operations and plantations.[29,31] This has changed the island's forest composition and structure.

Coastal mangrove forests, once prominent around most of Sulawesi, are in decline because of mining, aquaculture and coastal tourism.[32,33] They are among the most carbon-rich forests in the tropics.[34]

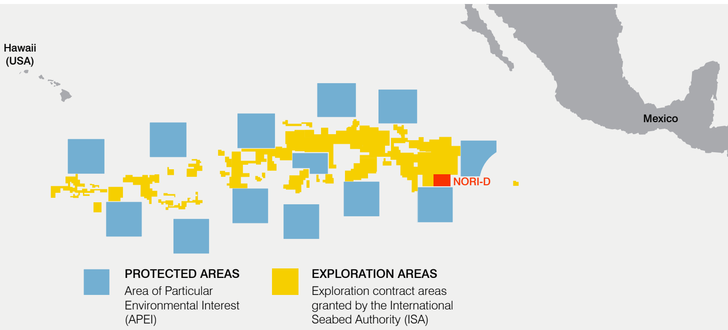
Despite being a conservation hotspot,[35] plant collection rates in Sulawesi have been some of the lowest in Indonesia.[36] **The distribution of known taxa, and the extent of diversity of taxa is poorly understood.**[37,38] In studies, primary dryland and secondary forest in Sulawesi are often classified as a single forest cover differentiated by elevation range.[39] There is a higher family diversity at submontane level compared to higher altitudes. The CSMs are mostly within lowland areas.

Mining impact on terrestrial carbon sinks

	Units	Cobalt	Nickel (limonite)	Nickel (saprolite)
Carbon stock loss per m^2	kg C/m^2	10.8	45.8	
Carbon sequestration loss per m^2	g C/m^2/per year	101.9	117.1	
Carbon stock loss per kg of metal	kg CO_2e/kg metal	3.6	9.4	7.0
Carbon sequestration loss per kg of metal	g CO_2e/kg metal/per year	9.3	6.5	4.8

Comparison to NORI-D nodules

For comparison, a peer-reviewed paper on the climate change impacts of deepsea nodules published in the Journal of Cleaner Production in December 2020 estimated that a deep-sea nodule collection project would result in a potential loss of carbon stocks up to 0.00011 kg CO_2e/kg Ni and 0.00014 kg CO_2e/kg Co.



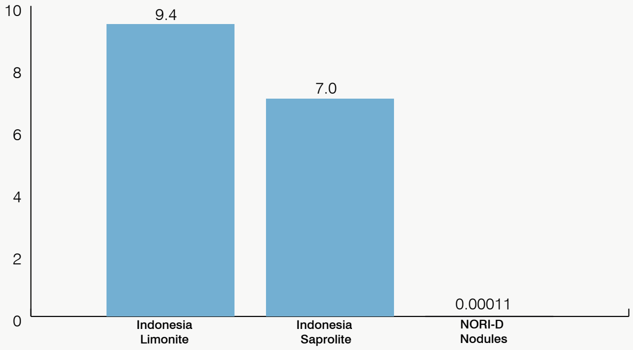
NORI-D

	Units	Cobalt	Nickel
Carbon contained in CCZ sediments potential release via riser water pipe	kg CO_2/kg of wet nodule	0.027	
Nodule moisture content	%	24	
Polymetallic nodule ore grade	%	0.14	1.39
Overall metal recovery rate (pyro+hydro+recycling loop)	%	77.2	94.6
Potential carbon released via riser water pipe*	kg CO_2e/kg metal	0.00014	0.00011

* While there are no known mechanisms for carbon contained in sediments at this depth to be released to the atmosphere, for the purpose of this comparison, the potential release of previously sequestered carbon arising from cold, pressurized seawater being pumped to the surface is included.

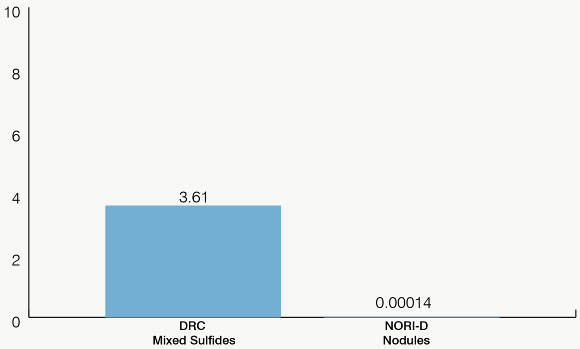
Nickel

Carbon stocks impact during mining
Kilogram of CO_2e emissions per kilogram of nickel



Cobalt

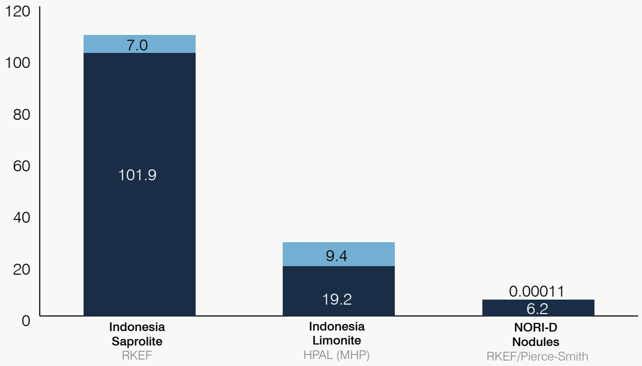
Carbon stocks impact during mining
Kilogram of CO_2e emissions per kilogram of cobalt



How material are impacts on carbon stocks and sequestration services in the mining phase in the context of overall lifecycle (mining+transport+processing+refining) carbon impacts of producing nickel and cobalt? We combine carbon impacts of land-use change during the mining phase with lifecycle global warming potential (GWP) estimates for producing cobalt and nickel sulfate used in the battery industry based on the comparative lifecycle assessment completed by Benchmark in March 2023.

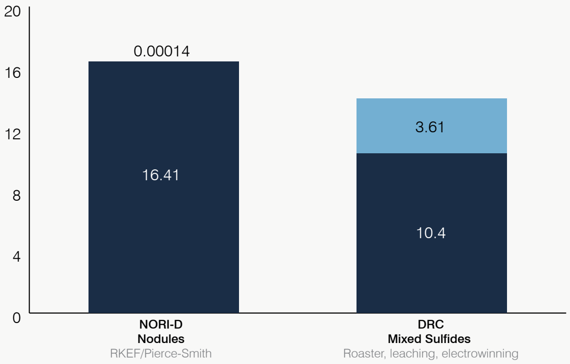
Nickel

Lifecycle GWP + *carbon stocks impact during mining*
Kilogram of CO_2e emissions per kilogram of nickel in nickel sulfate



Cobalt

Lifecycle GWP + *cobalt stocks impact during mining*
Kilogram of CO_2e emissions per kilogram of in cobalt sulfate




Benchmark carbon sinks report


Benchmark LCA report


JCP carbon impacts paper

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