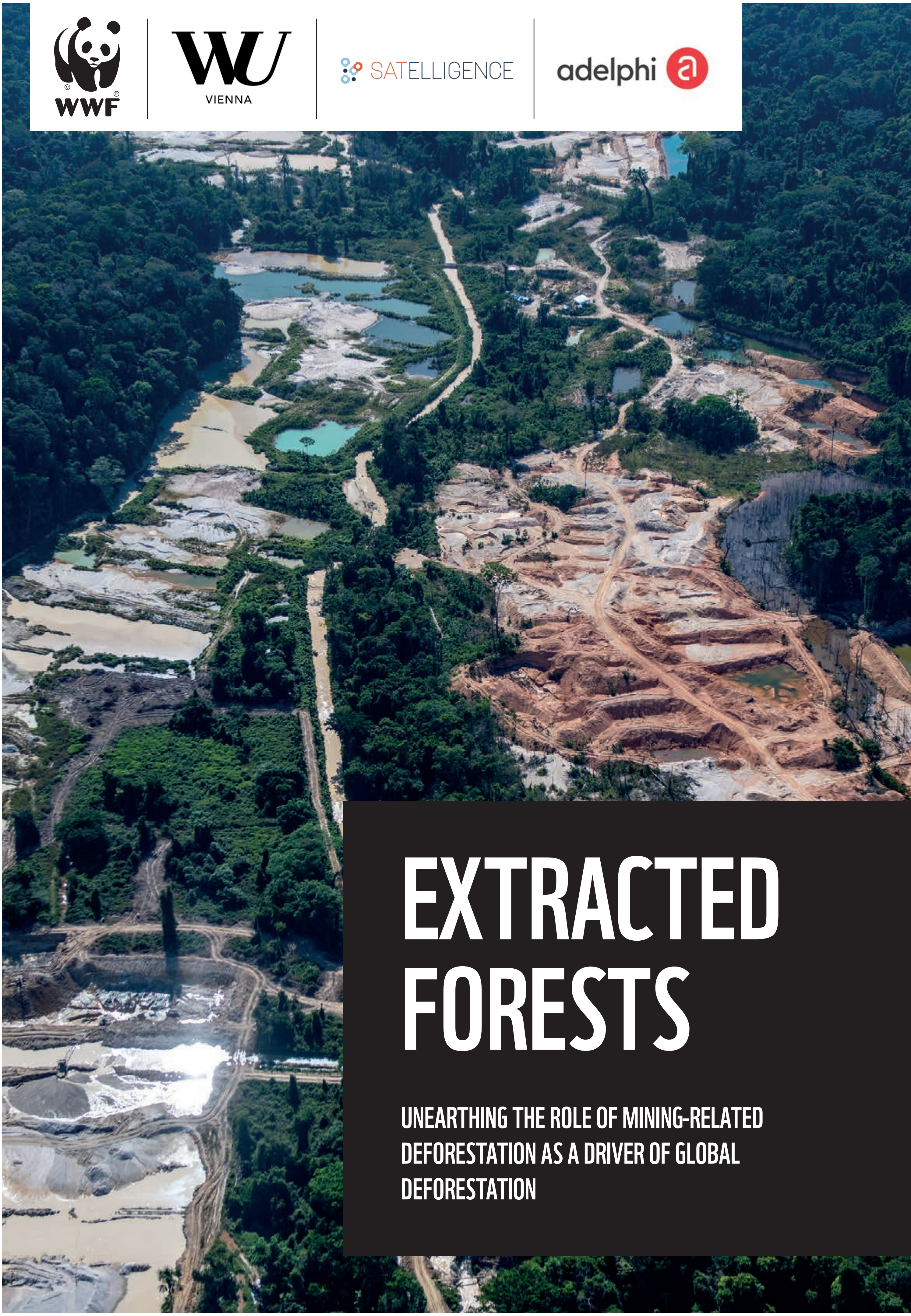

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EXTRACTED FORESTS

UNEARTHING THE ROLE OF MINING-RELATED DEFORESTATION AS A DRIVER OF GLOBAL DEFORESTATION

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FOREWORD

TOBIAS KIND-RIEPER,
GLOBAL LEAD MINING
& METALS

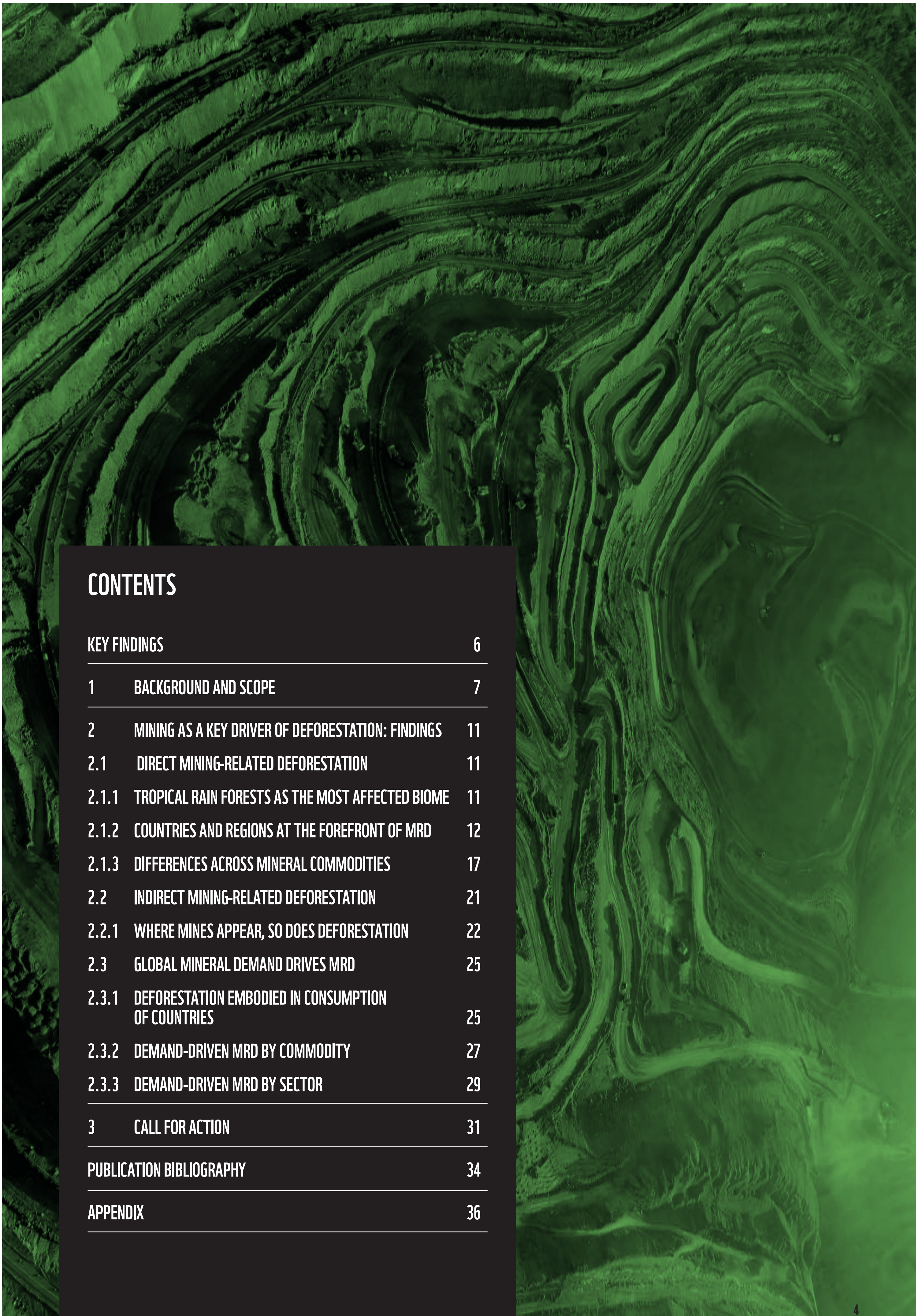
Metals are important for the development of human civilization and the life we live today. But the footprint left by the extraction of these commodities has a heavy toll on ecosystems

Mining is currently considered to be the fourth largest driver of deforestation. However, this statistic only considers the direct impacts of mining. Mining's role in deforestation increases significantly when indirect impacts are taken into account (such as mining related infrastructure, settlements, agriculture through settlement, water and soil contamination and illegal logging). Mining may already affect up to one third of the world's forest ecosystems, as forest loss and degradation can occur within a 70 km radius of the mining activity itself. In addition, mining affects biodiversity at multiple spatial scales (site, landscape, regional and global), and 77% of all mines exist within a 50 km radius of key biodiversity areas. Negative consequences for wildlife and ecosystems have already been recorded; the numbers of Indochinese tigers in the Greater Mekong region have seriously decreased due to habitat fragmentation from infrastructure development, and gold mining in the Amazon Basin has led to increased mercury levels in endangered species such as the Tucuxi river dolphin. As mining activities are set to increase in the coming years, mining and its associated infrastructure must be recognized as key causes of deforestation and biodiversity loss.

Equally important and certainly linked to this issue are the rights of indigenous communities. They are at risk in certain regions where mining expansion or processing of ores destroy ancestral territories, affecting and violating community interests. Negative social impacts and human rights violations are accompanied by bad mining practices and must be addressed. Even though this study focuses on the environmental impacts, human rights and environmental rights go hand in hand.

This report highlights the impacts of direct as well as indirect deforestation through mining. It presents for the first time ever the deforestation embodied in the consumption of products and showcases the extensive deforestation potential that artisanal and small-scale mining (ASM) can have on forest ecosystems. Governments are in an excellent position to exert influence on and broaden the scope to demand transparency in mineral supply chains, reduce the use of primary raw materials and increase the use of secondary raw materials. Using environmental impacts assessments that also take indirect impacts of mining as well as ASM into account, companies can begin to gain a more in-depth understanding of the challenges to be tackled on the ground. There is significant potential for positive improvement.

Tobias Kind-Rieper



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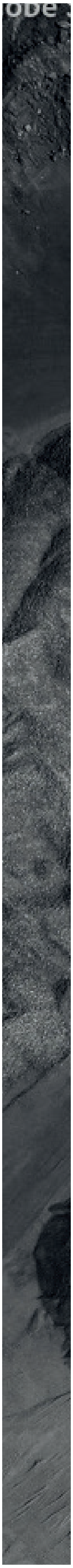

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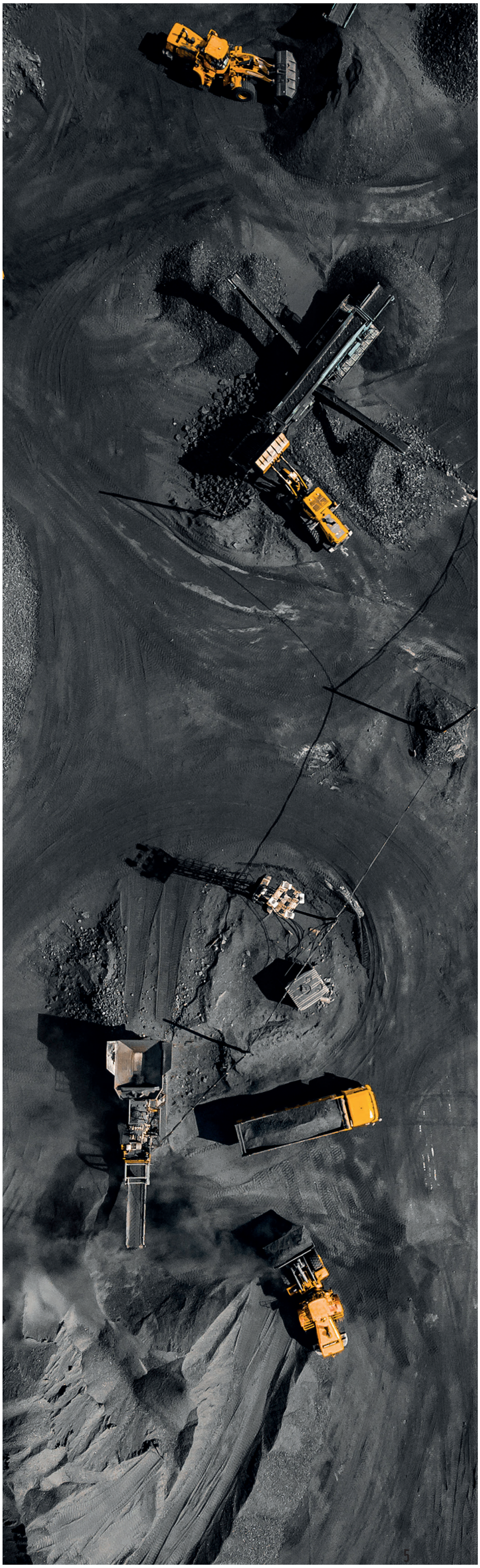
LIST OF ABBREVIATIONS

ASGM	Artisanal and small-scale gold mining
ASM	Artisanal and small-scale mining
CBD	Convention on Biological Diversity
DRC	Democratic Republic of Congo
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FPIC	Free, prior and informed consent
GHG	Greenhouse gas(es)
IFL	Intact forest landscape
IPLC	Indigenous peoples and local communities
IUCN	International Union for Conservation of Nature
LSM	Large-scale mining
MRD	Mining-related deforestation
PADDD	Protected Area Downgrading, Downsizing, and Degazettement
PCA	Protected and Conserved Areas
USA	United States of America
WU	Vienna University of Economics and Business
WWF	World Wide Fund for Nature Inc.



KEY FINDINGS

This report shows that:

- The **direct* deforestation impacts of mining in the past 20 years are highly concentrated**, with almost 84% of total direct mining-related deforestation (MRD) worldwide taking place in only 10 countries. The same holds true when looking at the most mined commodities: 71% of all global direct MRD can be traced back to coal and gold.
- The **indirect** deforestation impacts of mining can far exceed direct impacts**, but are rarely taken into account in planning and policy-making. These impacts are not yet given sufficient consideration in environmental impacts assessments and reporting, leaving them virtually invisible to policy-makers. Recent research has made the case that the indirect impacts of mining on forests are often not only greater than direct impacts, but can also be more extensive. Furthermore, the impact is often entangled with other deforestation causes such as agriculture, urbanisation and infrastructure, obscuring the role of mining as one of the key drivers behind these causes and threatening assessments of the role of mining behind deforestation.
- There are considerable **discrepancies in MRD between the national, regional and local levels**. In some countries, national MRD levels are relatively low, but a look into regional and local hotspots has revealed much higher impact levels than previously assumed.

84%

OF TOTAL DIRECT MINING-RELATED DEFORESTATION (MRD) WORLDWIDE TAKING PLACE IN ONLY 10 COUNTRIES.

71%

OF ALL GLOBAL DIRECT MRD CAN BE TRACED BACK TO COAL AND GOLD.

- Particular attention should be paid to **areas with a high-incidence of artisanal and small-scale mining (ASM)**. Due to the dynamic nature of the activity and the absence of regulation, the impacts of ASM are rather extensive, i.e. causing more superficial impacts in wider areas and potentially making it more difficult to assess and monitor.
- **Mineral demand in foreign countries and sectors is an important driving force behind MRD**, but its contribution is not visible when assessing the impacts of mining on forests solely in the producing countries and regions. Almost half of the global mineral demand is driven by China, the EU and the US. Within the EU, Germany leads with the highest demand, 17% of which is due to its motor vehicle sector. Globally, the construction sector claims first place, causing 18% of all MRD through its sector-specific mineral demand.
- **Policy-makers and the private sector can play distinct, but crucial roles in implementing the mitigation hierarchy** for avoiding and minimising MRD, as well as restoring and compensating for MRD areas. Recommendations range from the mine pre-development, operation and post-closure phases, and include the investments in comprehensive assessments and forest recovery, the inclusion of affected populations as key stakeholders for forest protection, and the advancement of circular economy practices and a clean energy transition.

***direct impacts:** occurring within mining areas; or caused by the expansion of mining areas

**** indirect impacts:** occurring in the surroundings of mining areas due to e.g. construction of processing or transport infrastructure

1. BACKGROUND AND SCOPE

Forests are crucial for people and nature. Besides providing clean and fresh air, they offer a home for humans, animals and plants, as well as food, fuel and income. They are the habitat of many species that are essential for human life and environmental health, and the lifeline of 750 million people, including 60 million indigenous people (Beatty et al. 2022). Forests also regulate the climate and harbour life-giving natural resources such as water and biodiversity (see Box 1 for more on the importance of forests for people and nature).

However, the world's forests are under threat: Between 2011 and 2021, global tree cover has decreased by 11% (Global Forest Watch 2022). The loss of forest cover is driven by both natural and human factors, but human activities are the major driver of deforestation (Pacheco et al. 2021). With the increased availability of better socio-economic and environmental data and tools, our understanding of human-induced deforestation has been continuously improving (FAO 2022). While the relative importance of deforestation drivers varies over time and across locations – depending, for example, on global market and investment trends, as well as shifts in national political priorities and local political economies – agriculture is considered the most significant direct cause of deforestation worldwide (FAO 2022; Pacheco et al. 2021).

Although mining is only the fourth largest driver of deforestation behind agriculture, infrastructure and urban expansion (Hansen et al. 2013), its importance is growing rapidly as mining activities expand in size and increasingly move into environmentally sensitive areas (Luckeneder et al. 2021). Over the past decades, mining activities have expanded globally at an unprecedented rate, due to a surging global mineral demand for consumer products, infrastructure and energy transition technologies. Mineral extraction doubled between 2000 and today – a trend that is expected to continue in the coming decades (UNEP IRP 2019). **Almost 63% – approximately 8,600 km² – of deforestation caused by the expansion of global mining activities in the past 20 years took place after 2010 and only 37% in the period 2001 to 2010** (WU 2022). Tropical forests, which harbour 7% of all forest mine operations and also constitute the biome with the highest biodiversity and carbon values, are particularly affected by this trend (World Bank 2019b).

Mining not only directly causes deforestation through the expansion of its extractive activities, for example by clearing forest for mining pits, but also drives deforestation indirectly through activities that support mining, for example the development of transport or energy infrastructure. In addition, mining is often one key step in opening up areas of a country for other extractive and economic activities that in turn continue to drive deforestation. It often attracts migration, leading to the growth of settlements, and opens up agricultural land or logging areas, all of which contribute further to deforestation (Giljum et al. 2022). In addition, road networks can have an enormous impact on forests, often with high levels of deforestation and forest degradation being detected up to a distance of 2.5 km on both sides of the road (Hughes 2018). This indirect deforestation driven by mining is rarely measured or taken into account, and thus the actual extent of deforestation linked to mining is likely underestimated (Sonter et al. 2017). Hence, the contribution of mining to deforestation is in all probability much larger than previously assumed. At the same time, it is particularly challenging to assess indirect mining-related deforestation, given the difficulty of linking such parallel developments to mining activity.

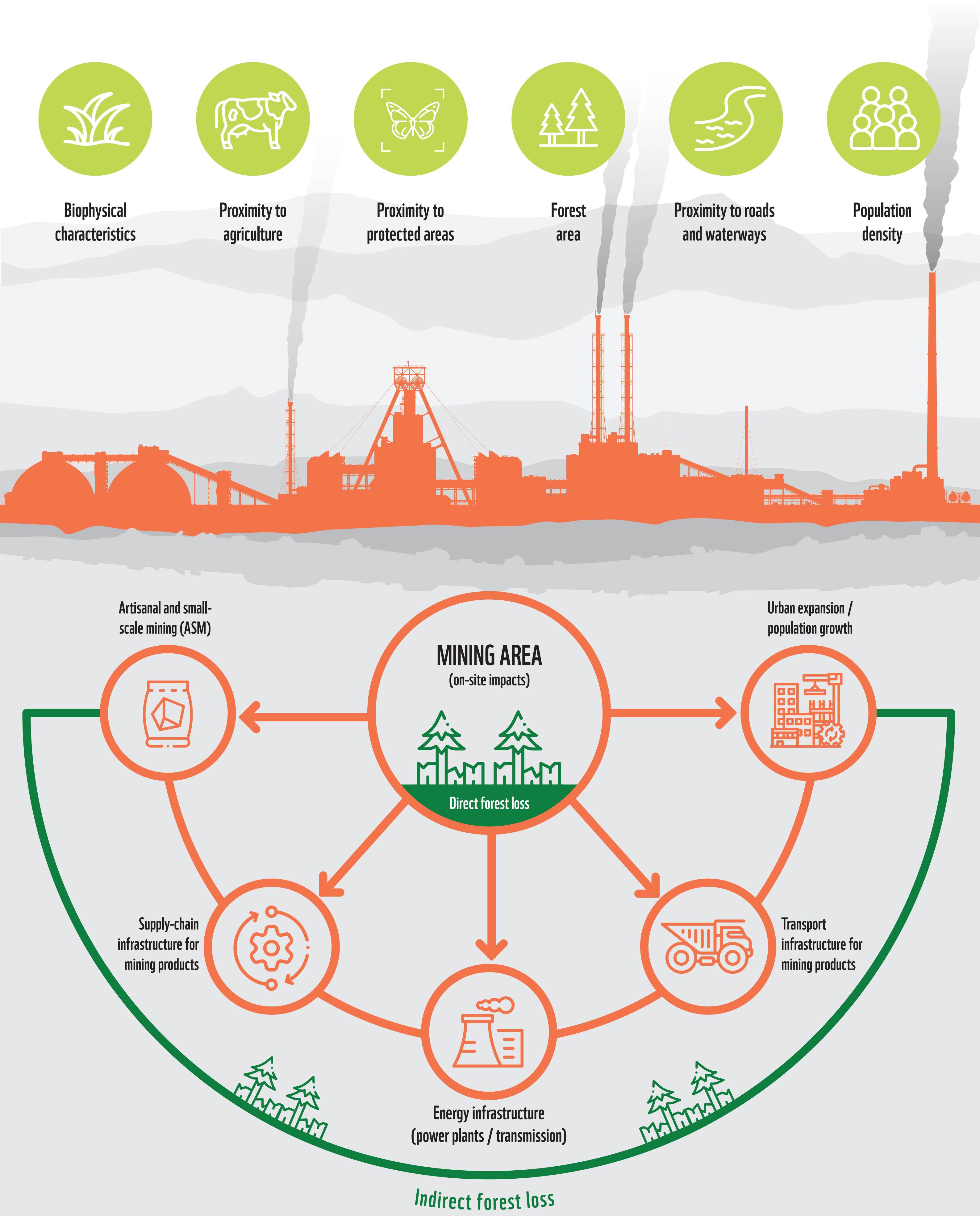
With that in mind, this report, based on different spatial datasets and analyses by WWF, Vienna University of Economics and Business (WU), Satelligence and adelphi, seeks to broaden understanding and awareness of the role that mining plays as a driver of deforestation, thus helping to fill the current data gaps around the indirect effects of mining on deforestation. This is the first comprehensive attempt to assess direct deforestation induced by the global mining sector and provide an estimate of indirect deforestation in mining regions. The report sets out to synthesise this data and identify patterns and trends by:

1 **Assessing direct mining-related deforestation (MRD):** Satellite data of mining areas worldwide between 2000 and 2020/2021 gives a consistent overview of forest loss directly associated with mining activity, as well as the degree to which mining activity has been expanding, and what ecosystems are predominantly affected. In addition, direct MRD linked to artisanal and small-scale mining (ASM) is highlighted through two case studies and the role of different mineral commodities driving deforestation is assessed.

2 **Assessing indirect MRD:** By assessing forest loss in buffer zones up to 50 km around mining areas, satellite data is used to shed light on the indirect impacts of mining activity. Although satellite data is not able to differentiate between forest loss associated with mining and that which is not associated with it, this approach can demonstrate the difference between regions with and without mining activity, as well as those before and after mining concessions have been granted. These differences can be used to estimate the influence of mining activity on deforestation trends. In addition, the example of the Carajás iron ore mine in Brazil serves to illustrate pathways of indirect deforestation caused by large-scale mining operations.

3 **Assessing MRD embodied in global trade and consumption:** It is important to look at the countries and sectors that demand mineral commodities to understand the drivers of MRD and find entry-points to address it. To this end, the same data used to assess commodity-specific direct deforestation was connected to a model of the global economy, which includes the bilateral trade relations between 164 countries and regions, allowing the calculation of consumption-based indicators (‘deforestation footprints’) that illustrate which final demand for products, as well as which sectors, induce the extraction of raw materials and related deforestation.

4 **Call for action:** Informing stakeholders in governments and the private sector of specific actions that can be taken to avoid, reduce, mitigate and reverse the impacts of mining on forests, especially in light of a growing demand for minerals due to the green energy transition.



Direct deforestation is quantified as forest loss within mining areas. Infrastructure, settlements and artisanal and small-scale mining (green circles) are conceptualised as effects causing indirect deforestation induced by mining activities in an area of 50 km surrounding industrial mines. Grey circles indicate control variables in the statistical assessment. Source: Giljum et al. 2022

BOX 1: IMPORTANCE OF FORESTS FOR PEOPLE AND NATURE

CLIMATE

Forests provide several critical ecosystem services in terms of climate and environmental regulation. It is widely known that forests are some of the world's key carbon sinks. Tropical forests alone capture 1.8 gigatonnes of carbon every year, and store seven times humanity's annual emissions (Pacheco et al. 2021). Besides this key function, forests also provide a habitat for pollinators upon which food systems depend, regulate water supply, and provide shade and windbreaks (FAO and UNEP 2020). Forest degradation therefore affects the capacity of forests to provide these services (Pacheco et al. 2021), leading to an increase in carbon emissions, a destruction of habitats and ecosystems and impacts local (as well as global) food systems (Pacheco et al. 2021).

HEALTH

Human health is also impacted by forests through other pathways. Forests are home to several species that can be carriers of pathogens, many of which are dangerous for humans. When forests are healthy, they serve as buffer zones and control the spread of potential diseases to human settlements. Deforestation and forest degradation can disrupt this important barrier (Pacheco et al. 2021), and a rise in diseases among rural populations can be observed in contexts where deforestation and forest degradation have taken place. It is estimated that deforestation was behind the emergence of several diseases that today constitute global level health problems, such as yellow fever, malaria and Lyme disease (FAO and UNEP 2020).

LIVELIHOOD

Humanity is fundamentally dependent on healthy forests on several fronts. People living in or around forests and whose sources of livelihood and income are tied to forest-related products and services are more directly dependent on forests. However, given the immense impact that forests have on global and regional food systems, biodiversity, climate and health, also people living farther away rely upon this valuable ecosystem. When forests are lost to deforestation and degradation, economic and livelihood losses rise for the people dependent on these resources (FAO and UNEP 2020).

CULTURAL SERVICES

Deforestation is leading to the loss of indigenous homes, culture and spiritual practices, obliterating important traditional knowledge, including the foraging and use of medicinal plants, which in turn affects said populations' health (FAO and UNEP 2020). Even in cases in which IPLCs are compensated for the loss of lands and livelihoods, depending on cash rather than on living from the land erodes traditional practices and increases social vulnerability (Miranda 2022). Furthermore, undermining indigenous populations, their lands and cultural practices poses a direct threat to the environment. Geospatial analysis of 50 countries containing 98.4% of the world's intact forest landscapes has demonstrated that their occurrence is almost twice as high within indigenous lands as it is in other lands (Fa et al. 2020). At the same time, in the Amazon forest, mining concessions and illegal mining overlap with 450,000 km² (more than 20%) of indigenous lands. When looking at the different countries in the Amazon forest region, deforestation rates are 1 to 3 times higher in indigenous lands with mining activity, than in indigenous lands without (Quijano Vallejos et al. 2020).

WATER

Forests and trees provide several ecosystem services that are crucial for regulating rainfall and water supply, and generally for the improvement of the water cycle. This includes reducing runoff, improving the replenishment of the water table, filtering water pollutants, regulating storm water and controlling both erosion and floods. Deforestation can reduce evapotranspiration and enhance surface temperatures, disrupt hydrological cycles, and impact the availability of clean water. As forested areas are cleared, natural barriers of water cumulation are disrupted, increasing the incidence of periodical and post-storm floods. With the loss of deep-rooted trees, the soil becomes less able to absorb and contain water that maintains the underground life systems of vegetation, thereby contributing to soil compaction, degradation and erosion (Ekhuemelo et al. 2016).

FOOD

Forests are important sources of food for indigenous peoples and local communities (IPLC), many of whom have low to very low income. About 252 million rural people living in the world's forests and savannahs earn less than USD 1.25 per day. Of these, 63% live in Africa, 34% in Asia and 3% in Latin America (FAO and UNEP 2020). Not only do forests provide fresh, free and nutritious nourishment for low-income populations (CIFOR 2022), they do so sustainably, as forest foods require little to no inputs (Vinceti et al. 2013). Studies show that access to forests and tree-based systems is linked to higher dietary diversity, as well as to more nutrient-dense diets (FAO and UNEP 2020).

BIODIVERSITY

The importance of the ecosystem services that forests provide as a habitat cannot be overstated: about 80% of the world's amphibian species, 75% of birdsand 68% of mammals, as well as 60% of all vascular plants, are found in tropical forests alone (FAO and UNEP 2020). Forests cover almost one third of the Earth's land surface and harbour 75% of its freshwater (Pacheco et al. 2021). The destruction of forests around the world is contributing to the mass extinction that we are currently living through (Almond et al. 2022). Additionally, over a billion people live in or around forests (Pacheco et al. 2021). Not only do they depend on the forest, but they also play an important role in its protection and management.

2. MINING AS A KEY DRIVER OF DEFORESTATION: FINDINGS

Mining is an important driver of deforestation. While its contribution to global deforestation is often overshadowed by other drivers, such as agriculture, a closer look at critical mining hotspots and into the indirect contribution of mining activity to developments associated with deforestation reveal a much larger contribution. In order to assess the role mining plays in deforestation worldwide, this chapter will look into three dimensions: direct MRD, indirect MRD, and demand-driven MRD.

MORE THAN

35%

OF ALL MRD ASSESSED FOR TROPICAL RAIN FORESTS IN THE PAST 20 YEARS HAS OCCURRED ONLY IN THE FINAL FIVE-YEAR PERIOD

2.1 DIRECT MINING-RELATED DEFORESTATION

2.1.1 TROPICAL RAIN FORESTS AS THE MOST AFFECTED BIOME

Tropical and subtropical moist broadleaf forest (better known as **rain forests**) harbour only 29% (almost 30,000 km^2) of the world's mining areas, but **accounted for 62% or approximately 8,533 km^2 of the total direct deforestation** occurring within mining areas between 2000 and 2020 globally. Other critical ecosystems are also significantly affected: **boreal** and **temperate forests account for 13% and 9% of the total direct MRD**, respectively (WU 2022).

Yet, tropical rain forests stand out as MRD hotspots. Deforestation trends suggest that the situation is worsening: more than 35% of all MRD assessed for tropical rain forests in the past 20 years has occurred only in the final five-year period (2016 to 2020) (Giljum et al. 2022). Given the importance of rain forests for many key life-sustaining natural cycles and processes (see chapter 1), this trend is particularly worrying for efforts towards biodiversity conservation and climate change mitigation.

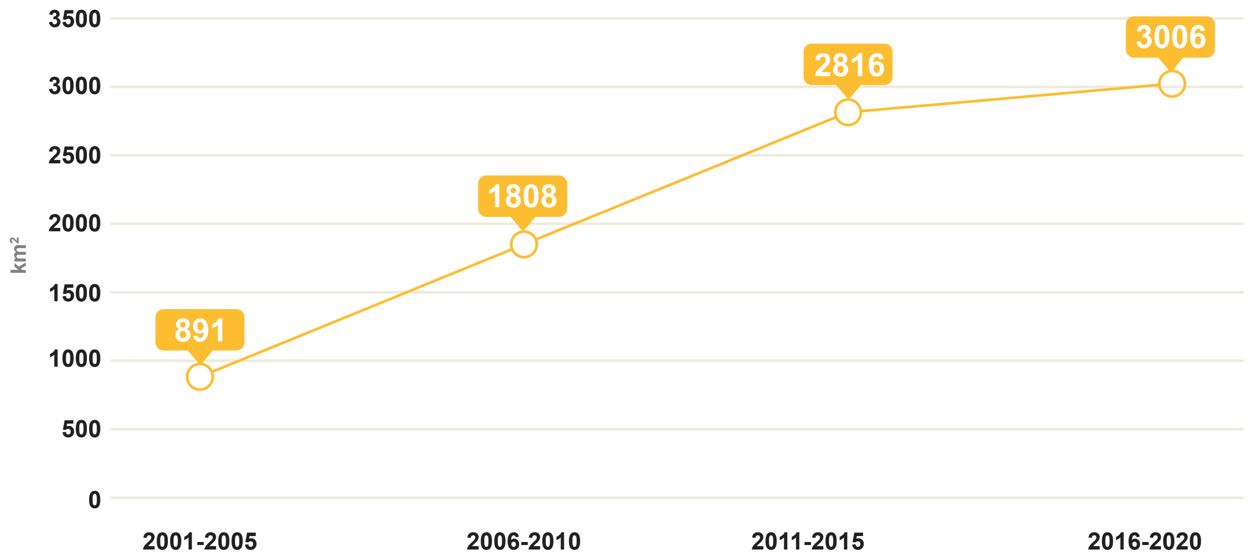


Figure 1: **Direct MRD in tropical rainforests from 2001 to 2020, by 5-year period**

2.1.2 COUNTRIES AND REGIONS AT THE FOREFRONT OF MRD

MRD can be observed in all the regions of the world. However, MRD trends are particularly pronounced in some countries. In fact, 84% of global direct MRD in the past 20 years occurred in just 10 countries.

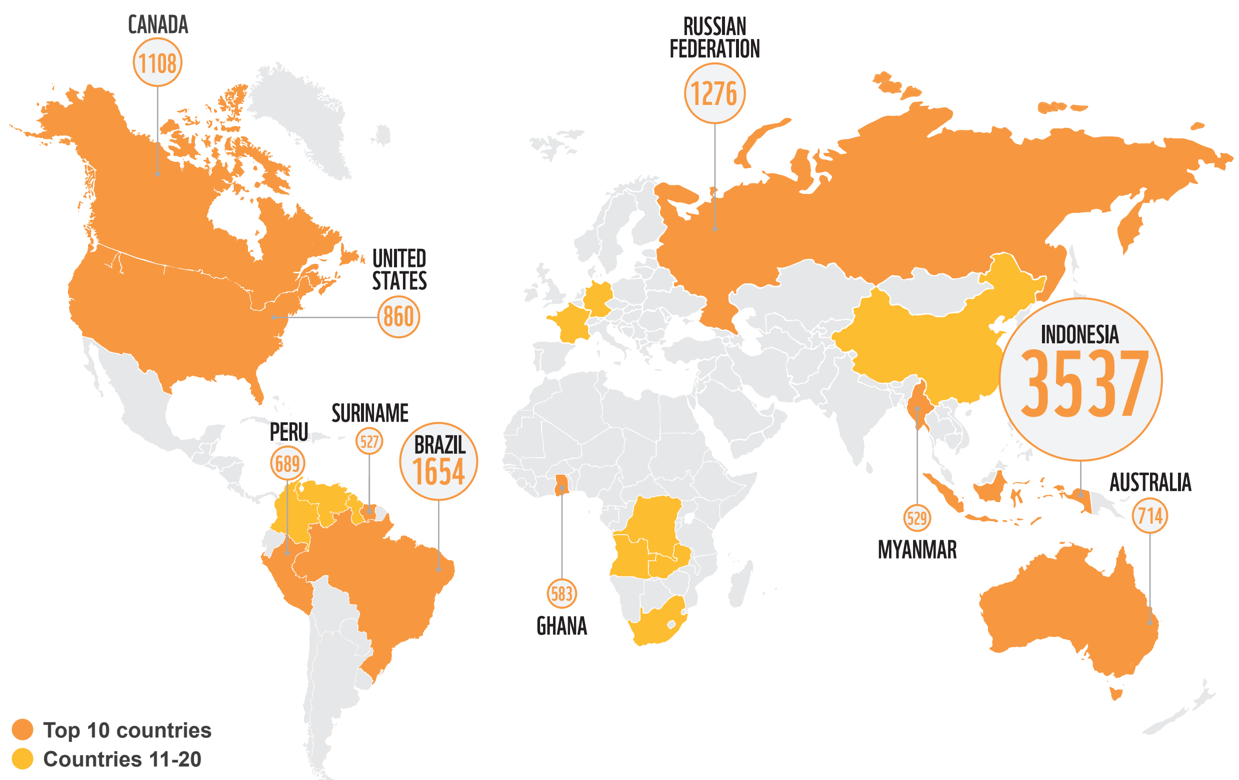


Figure 2: **Direct MRD in top 20 countries from 2001 to 2020 (in km²)**

Highest shares of global MRD

Responsible for over 25% of global MRD, or over 3,500 km², Indonesia leads as the country with the highest forest loss in mining areas worldwide. An accelerating trend can be observed, with 61.5% of the deforestation having occurred after 2010. From 2011 to 2015, accumulated deforestation levels were the highest: almost 38% of the total deforestation was observed in that 5-year period. Since 2018, deforestation rates within mining areas have been slowing (WU 2022).

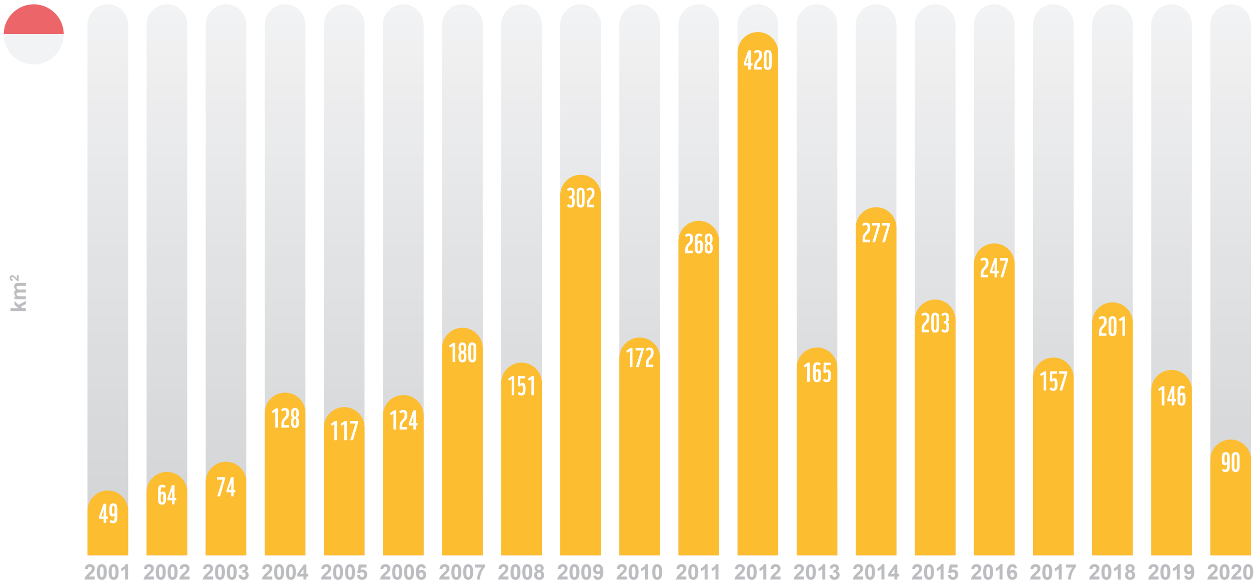


Figure 3: Direct MRD in Indonesia from 2001 to 2020

Brazil is in second place, responsible for 12% of global MRD and has also seen an accelerating trend in the past years. Much of this is due to expansion of ASM in the Amazon forest. Exponential growth on MRD rates can be observed across the 5-year periods: 10% in 2001 to 2005, 14% in 2006 to 2010, 25% in 2011 to 2015 and 50.2% in 2016 to 2020, with the highest peak in 2017 and significant high rates in 2016, 2018 and 2019 (WU 2022).

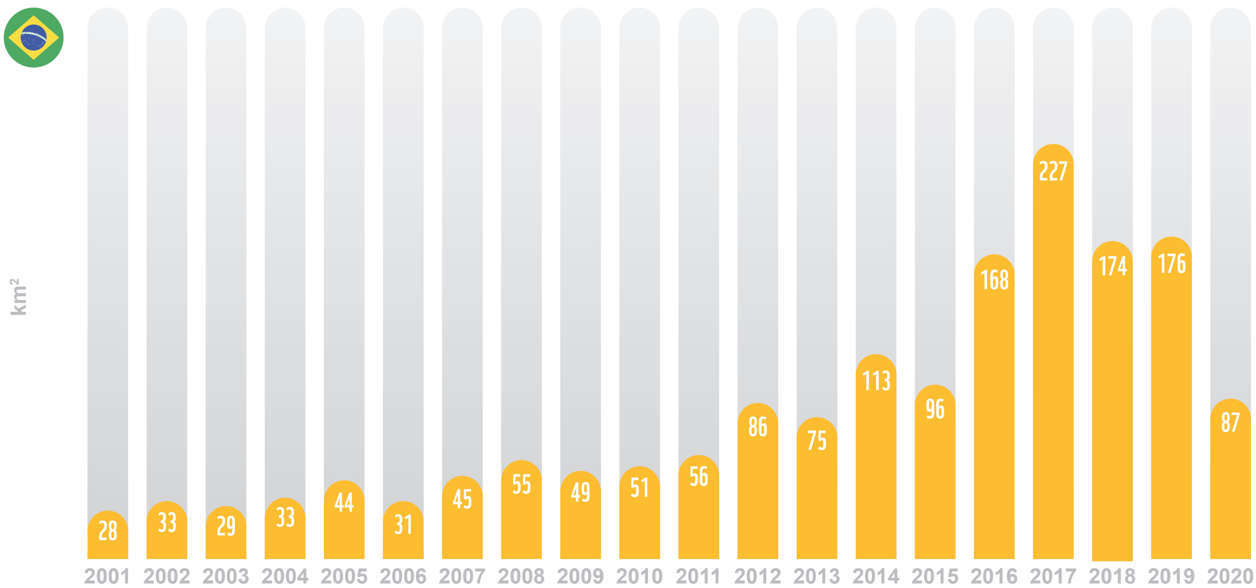


Figure 4: Direct MRD in Brazil from 2001 to 2020

Highest national MRD shares

Some countries stand out for the share of MRD in relation to other causes of deforestation within the country. In **Suriname**, 527 km² of forest was lost due to mine expansions, accounting for 28.5% of the total forest loss of 1,847 km² and representing the highest national share of MRD in the world. **Guyana** comes next with 2,056 km² of deforestation between 2001 and 2019, of which 428 km² (or 20.8%) can be allocated to the expansion of mining areas (WU 2022).

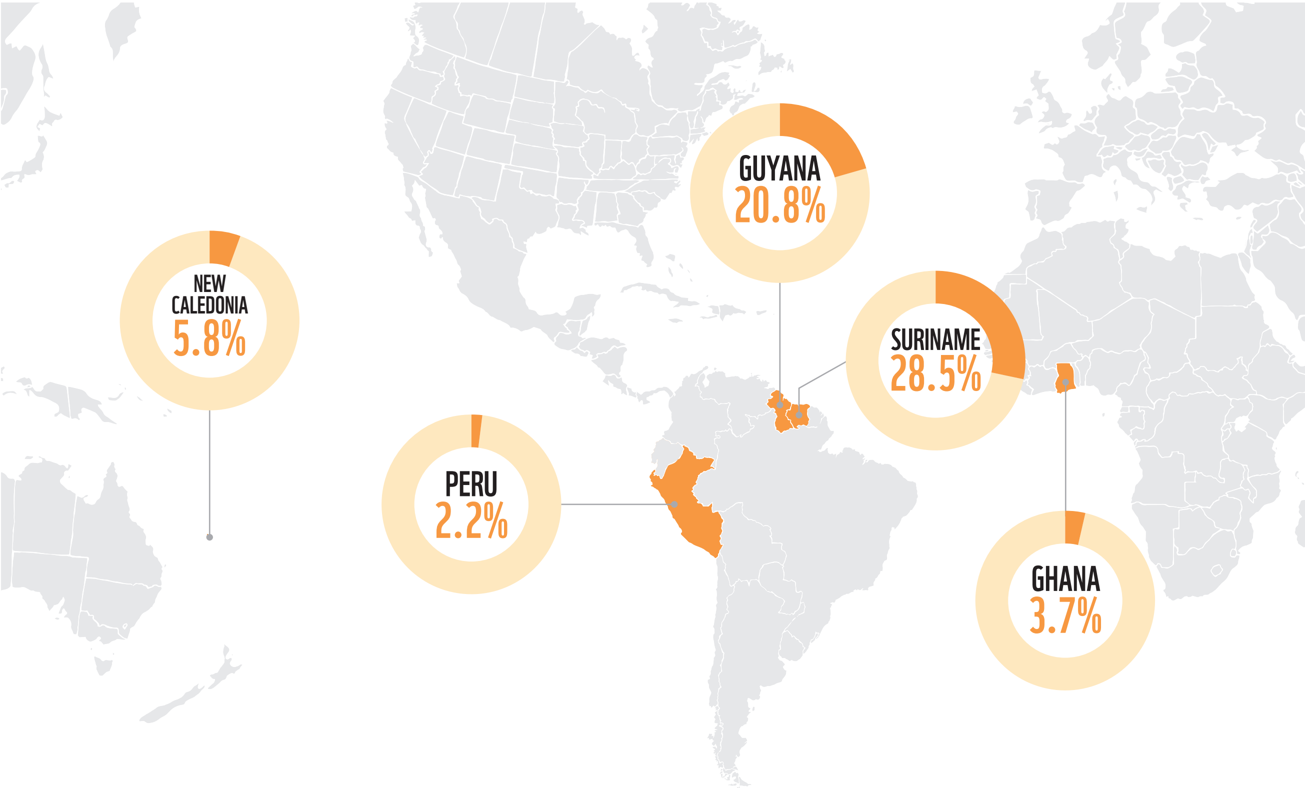


Figure 5: Top 5 countries with highest national MRD shares from 2001 to 2020

BOX 2: ARTISANAL AND SMALL-SCALE MINING AT THE LOCAL LEVEL

© André Bärtschi / WWF

Large-scale mining (LSM) and ASM differ greatly in terms of their direct and indirect deforestation impact. LSM is defined as a formal and regulated activity using modern industrial-scale extraction and processing technologies and involving a wide range of commodities (World Bank 2019b). Its impact on forest loss can be understood as being extensive in terms of time, scale and space. However, the sheer scale of the LSM sector means that it is more often obliged to comply with environmental and social standards. The ASM sector, on the other hand, is often informal by nature and less regulated, which means it often uses more environmentally harmful extraction methods with few rehabilitation measures in place, albeit more at surface level and over shorter time periods (World Bank 2019a). ASM is also an important source of income for local populations. In the Democratic Republic of the Congo (DRC) for example, it is estimated that more than 2 million people directly engage in ASM and that 10 million are indirectly dependent on ASM for their livelihoods (WEF 2020). Across the Global South, these figures are estimated at more than 40 million people working in ASM and up to 150 million people indirectly dependent on ASM income (IGF 2017). At the same time, the informality of the ASM sector makes it vulnerable to exploitation, often involving child labour and working conditions amounting to slavery (World Bank 2019a).

Distinguishing between the deforestation impacts of LSM and ASM and the linkages between them is crucial to understand MRD's impacts in a given area and the entry points for addressing it. Therefore, as global data on ASM is not fully available, local spatial data was analysed for Suriname and Ghana to highlight, on the one hand, the contribution of ASM to MRD and, on the other hand, to show the localised impacts of ASM on deforestation. The cases of Suriname and Ghana clearly show that ASM plays an important role in MRD in certain countries. Furthermore, they demonstrate that assessments looking solely at the impact of large-scale operations do not capture the full breadth of the impacts on forests associated with mining. While Suriname and Ghana greatly differ in terms of their national MRD shares, with 28.5% and 3.7% respectively, a zoom in to the local level reveals similar MRD patterns, with much clearer direct impacts.

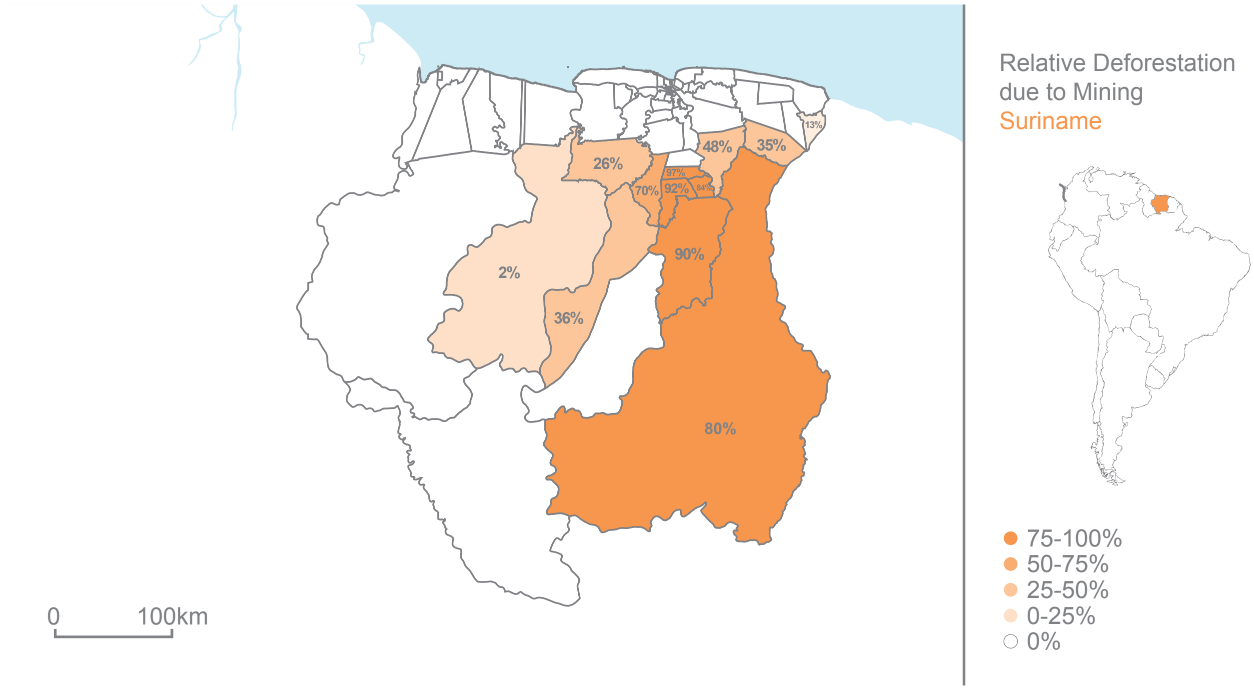


Figure 6: **Map of Suriname highlighting MRD hotspots**

Suriname is predominantly covered by tropical forest and is rich in gold reserves, making it a hotspot for mining, particularly artisanal small-scale mining. Of the 527 km² of forest lost due to mine expansions, 480 km² were due to gold mining. It is the country with the highest national share of MRD (WU 2022). A high share of this deforestation can be traced back to ASM activity in the country's eastern districts of Tapanahony, Sarakreek, Brownsweg, Brokopondo Centrum and Klaaskreek. Using the granular Satelligence dataset, we find that ASM led to 27.2 km² of forest loss in these five districts (based on Satelligence calculations).

Ghana, on the other hand, has a relatively low share of national MRD (3.7%). This is despite it being responsible for 15% of all bauxite-related MRD, being only beaten by Brazil, and featuring in the top 10 countries with the highest gold-related MRD rates (WU 2022). Yet, a closer look at the southern districts of Atiwa and Wassa West reveals that ASM accounts for 67.2 km², approximately one third, of the overall deforestation in these regions (based on Satelligence calculations).

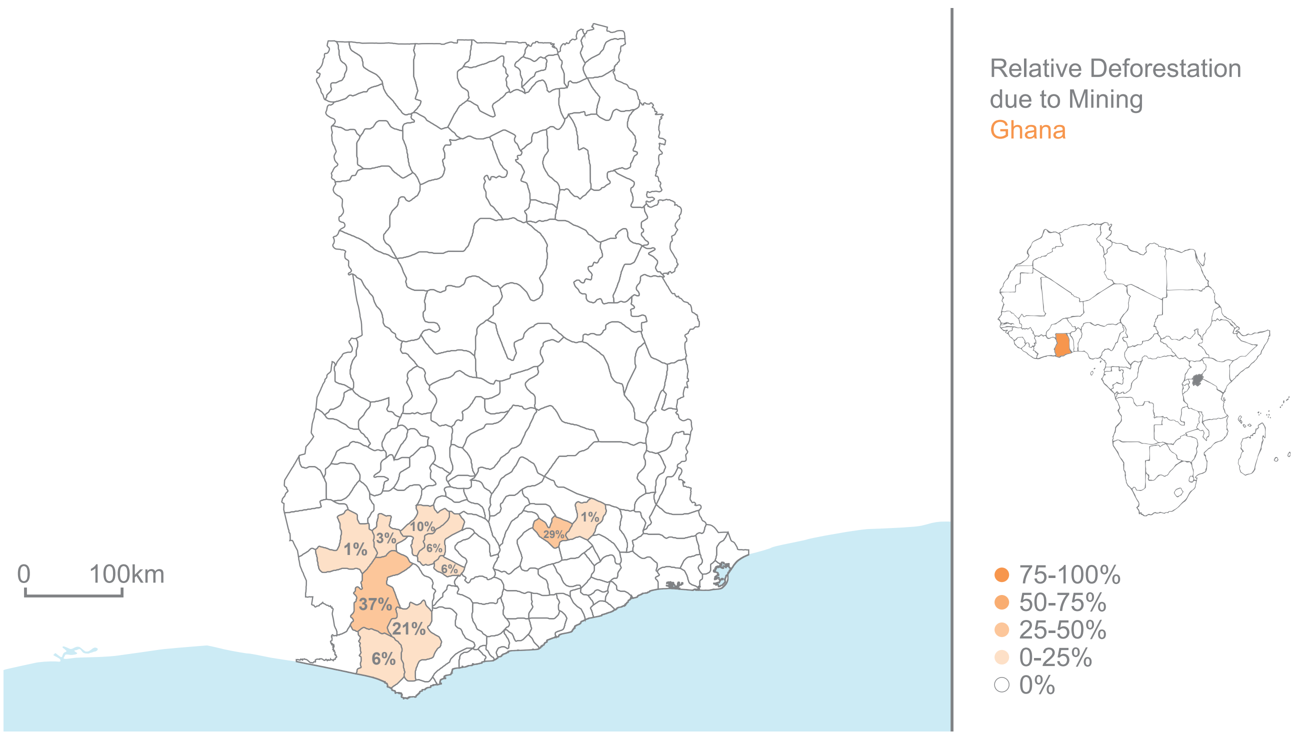


Figure 7: **Map of Ghana highlighting MRD hotspots**

2.1.3 DIFFERENCES ACROSS MINERAL COMMODITIES

Over 71% of direct mining-related deforestation at global level can be traced back to only two commodities: gold and coal. While coal is mostly extracted as a single commodity, gold is usually mined in combination with several other metals, such as copper. This is a challenge when trying to allocate deforestation to single commodities (see Appendix). Assuming that high value commodities are the main driver of mining activities, this leads to higher shares being allocated to valuable raw materials, such as gold.

Figure 3 gives an overview of more than 18 commodities and their contribution to MRD from 2001 to 2019.

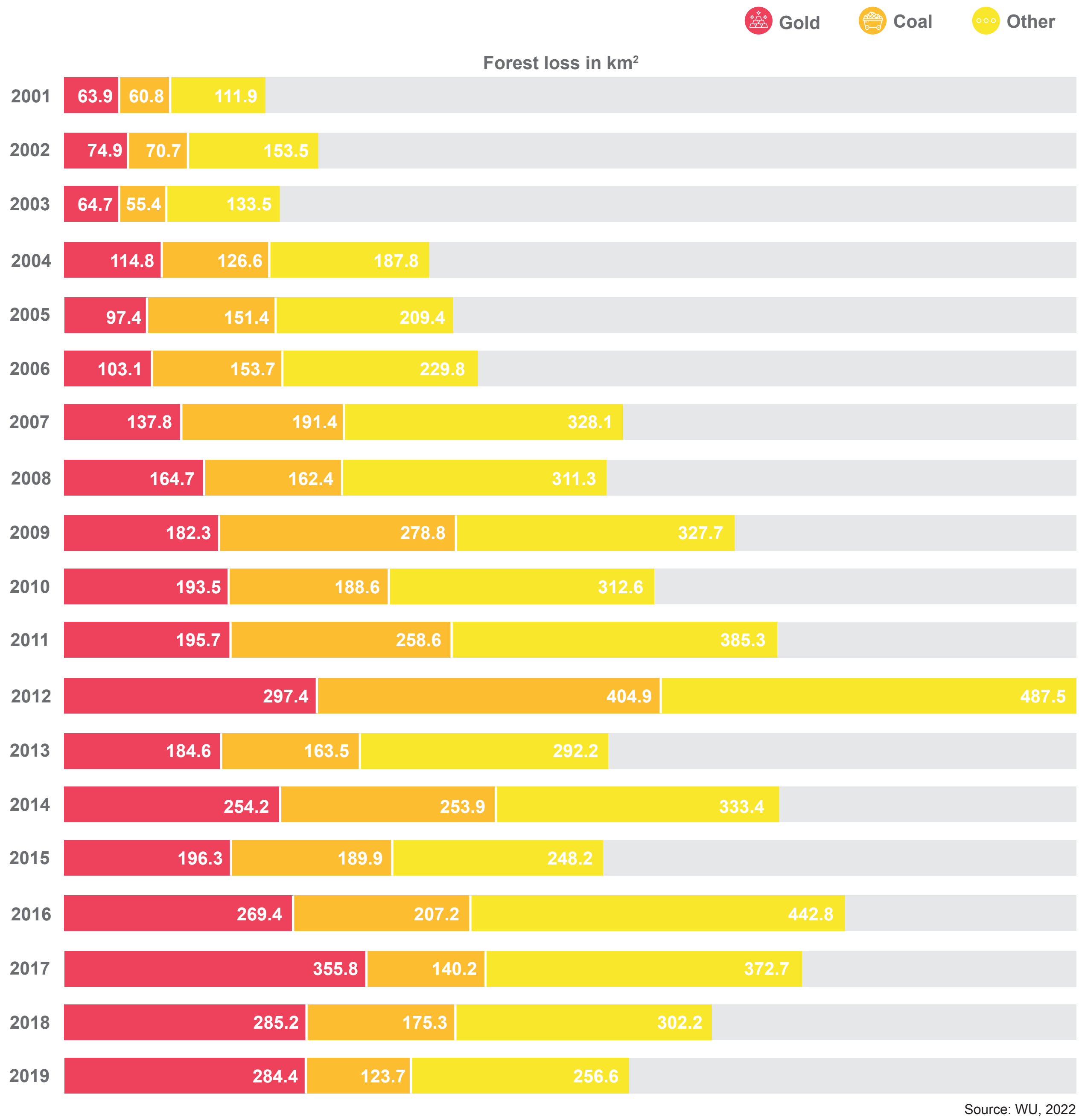


Figure 8: Mining-related forest loss by commodity, 2001 to 2019

Gold

With 3,520 km² of deforested area, gold was the commodity that caused the highest direct deforestation through the expansion of mining areas between 2000 and 2019. This data includes both large and small-scale mining activity and the area accounts for 36% of the total mining-induced direct deforestation area that could be allocated to specific commodities. Almost 60% of all gold-related deforestation occurred in four countries: Peru (632 km² or 18% of gold-related total), Suriname (480 km² or 14%), Russia (471 km² or 13%) and Brazil (463 km² or 13%). Forest loss induced by gold mining has been increasing in the past 20 years, with peaks in 2012 and 2017 (WU 2022). The peak in 2012 coincides with a peak in average annual global gold prices of approximately USD 1,669, although the average price in 2017 was lower at USD 1,260[1].

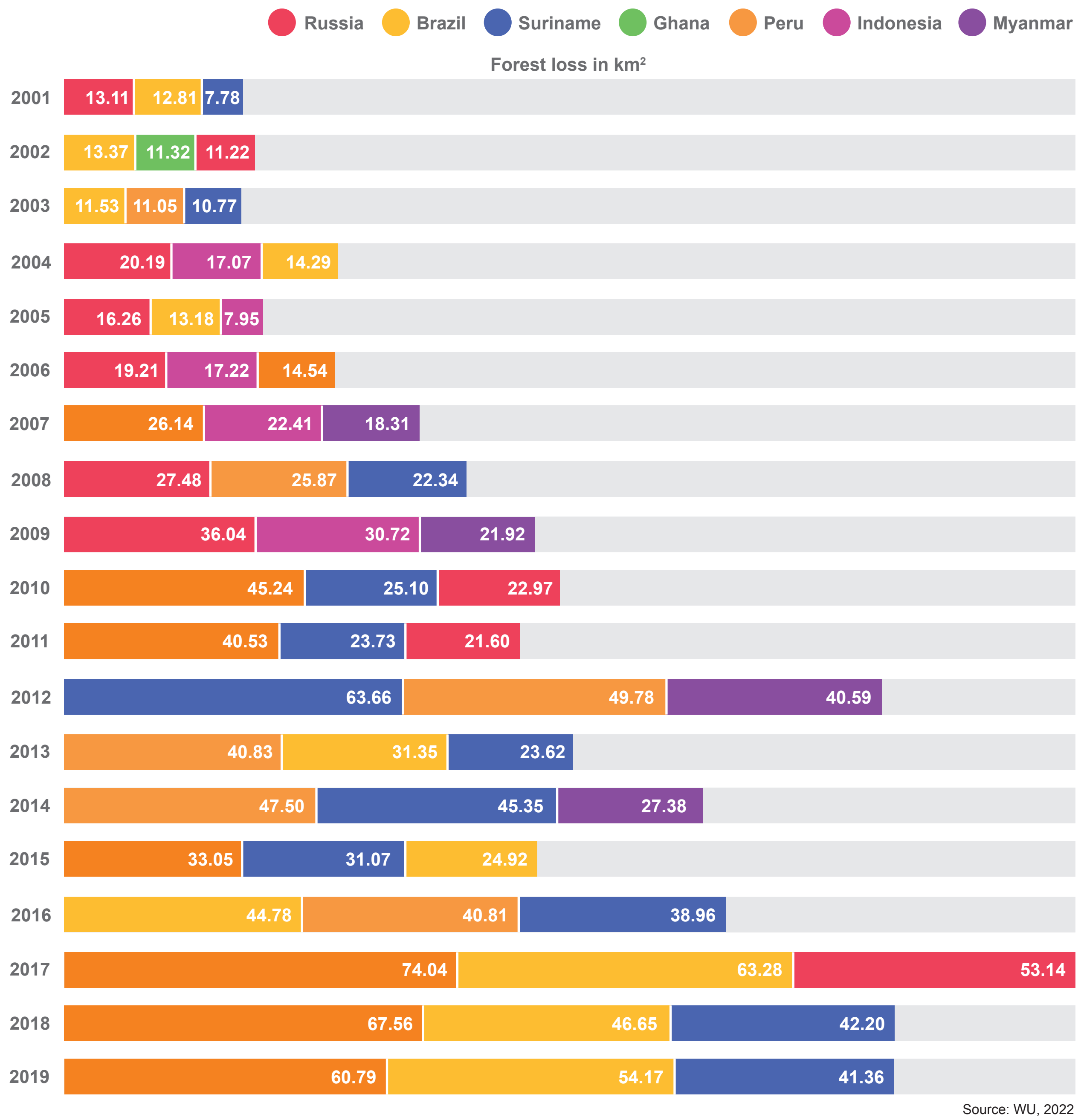


Figure 9: Forest loss induced by gold mining, 2001 to 2019

1. For an explanation of why and how this method was applied, see Appendix

Coal

In second place is coal with 3,357 km² of deforested area, equalling 34% of the total mining-induced direct deforestation area that could be allocated to specific commodities. In contrast to gold, where deforestation induced by extraction is divided among several countries, coal-related deforestation predominantly occurred in one country, Indonesia, which accounts for 1,924 km² of forest lost due to coal mining between 2000 and 2019. This means that 57% of the total global forest area lost due to the expansion of coal mining happened in Indonesia alone, which is also the country with the highest share of global MRD. The USA follows in second place, with 20% of global coal-related deforestation, or an area of 662 km², followed by the Russian Federation with 8% (268 km²), Australia with 5% (163 km²) and Canada with 3% (107 km²) (WU 2022).

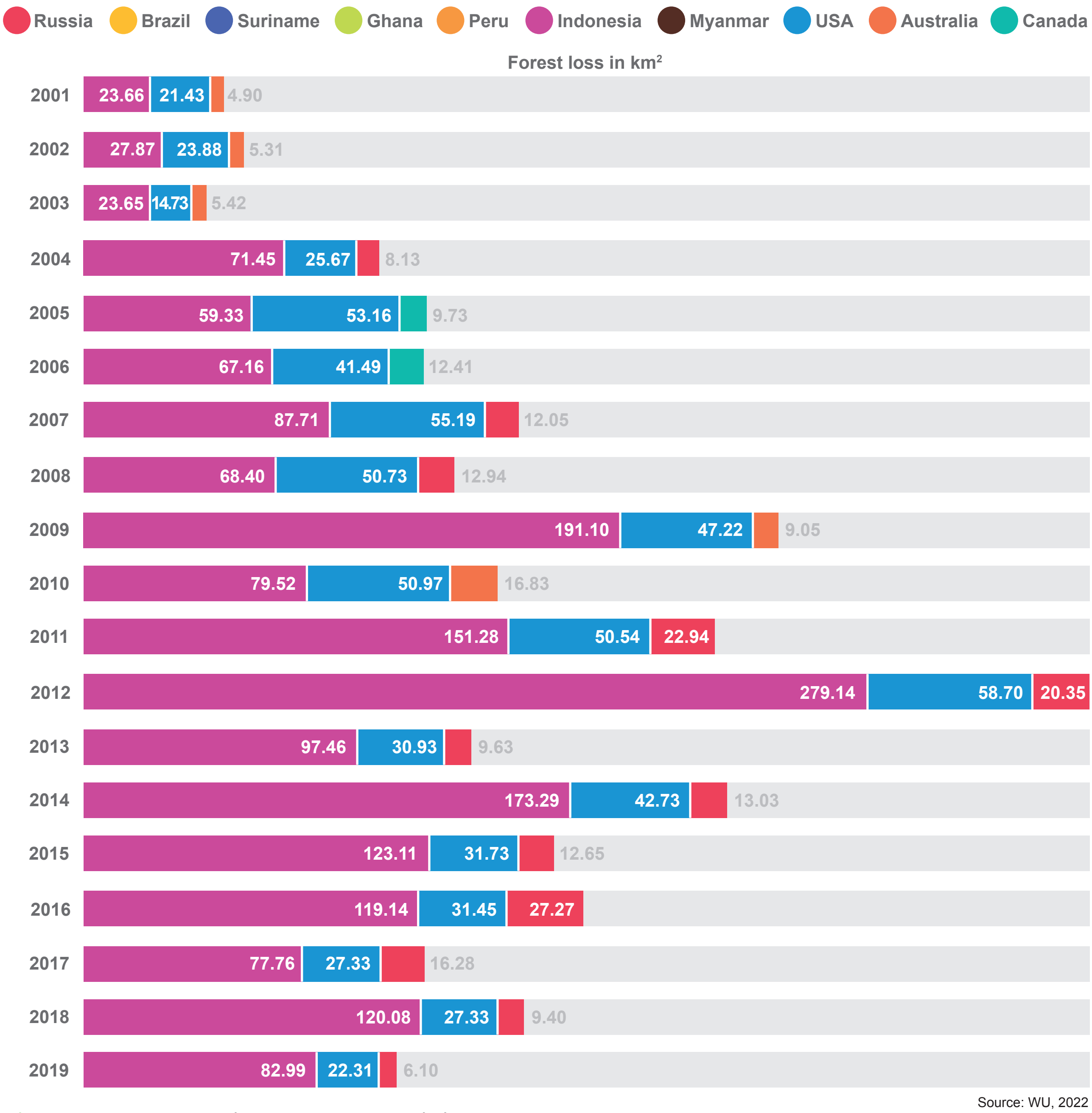


Figure 10: **Forest loss induced by coal mining, 2001 to 2019**

A peak in forest loss induced by coal mining is seen in 2012, with much of the growth coming from Indonesia. During the period of 2009 to 2013, coal production nearly doubled in Indonesia, from 254 Mtonnes to 474 Mtonnes. This was partially driven by increased demand from China and India, as well as a change in permitting regulations in 2009 that gave regional governments more authority to issue permits. Subsequently, the Indonesian government revoked the rights of local authorities to issue mining permits, shifting them to the provincial level in 2014 (Atteridge et al. 2018). Since passing the Mining Law Amendment in 2020, the licensing of mineral and coal mining businesses has shifted fully to the central government's jurisdiction (Soemadipradja et al. 2022).

Bauxite, Iron, Copper and further mineral commodities

Bauxite-linked deforestation accounts for 8% of direct MRD. It occurs almost entirely in 4 countries: Australia (50%), Brazil (16%), Ghana (15%) and Indonesia (14%). Iron ore and copper account for 7% and 4% of direct MRD, respectively. All other commodities, manganese, nickel, zinc, silver, platinum, cobalt, palladium, lead, U308 and molybdenyum, contribute to 11% of direct MRD in aggregate (WU 2022).

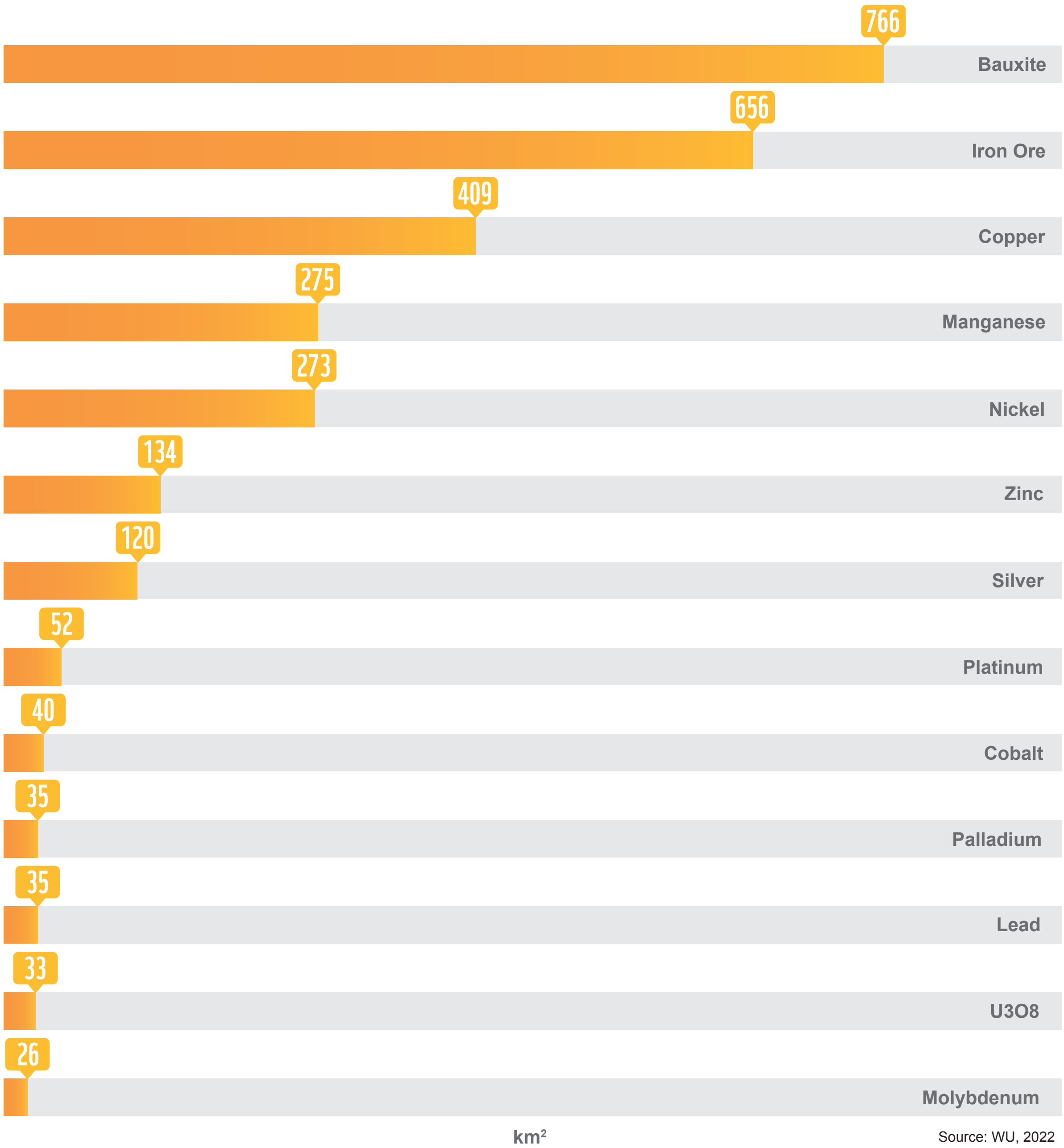


Figure 11: MRD for 13 commodities, excluding gold and coal, 2001 to 2019

2.2 INDIRECT MINING-RELATED DEFORESTATION

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MRD that is caused indirectly is difficult to quantify. Often, deforestation drivers fall under the categories of agriculture, infrastructure expansion and urbanisation – the main causes of deforestation ahead of mining (NYDF Assessment Partners 2020). Nonetheless, in many cases, the driver behind these deforestation causes is mining. In order for mining activity to be feasible, it requires energy, processing, storage and transportation infrastructure. A consistent workforce is also an inherent element of a mine site. In-migration and expansion of human settlements, including the related expansion of agricultural and pastoral lands, are therefore also associated with deforestation, in particular in remote and less developed areas (Giljum et al. 2022). Mining activities interact with and exacerbate these other drivers of deforestation. Hence, the contribution of mining to deforestation is likely much larger than previously assumed (Sonter et al. 2017). Studies have identified that higher and faster rates of deforestation occur with the appearance and expansion of mining sites than in forest areas without mining sites (Ranjan 2019; González-González et al. 2021). Likewise, the number of deforestation incidents rise as the proximity to mining sites increases (Sonter et al. 2017; Giljum et al. 2022). Between 10 and 33% of the world's forests may be affected by the indirect and cumulative impacts of mining (Bradley 2020).

While a distinction between deforestation causes alone is not adequate for identifying indirect MRD, a closer look into shifting temporal and spatial dynamics in specific contexts can help to make indirect MRD more visible. With this in mind, this chapter looks at satellite data from areas surrounding mining sites to identify deforestation that occurs beyond the mines, but which is nonetheless likely associated with mining activity. This approach provides a better overview of the actual impact that mining has on forests by capturing effects that can only be seen beyond the mining sites.

2.2.1 WHERE THERE ARE MINES, THERE IS ALSO DEFORESTATION

All over the world and throughout time, patterns of increasing deforestation rates can be observed within and surrounding mining areas. These patterns are driven by rapidly rising global demand for natural resources and are therefore consistent throughout the world. Coincidence can therefore be ruled out and a clear link to mining activity can be established. A global sample looking into the buffer zones of 21,000 mining spots between 2001 and 2021, covering 17 million km² (around 11.5% of the Earth's terrestrial surface), shows that 755,861 km², or 4.45%, of that area had been deforested by causes indirectly related to mining activities alongside other deforestation drivers (based on data from WWF). This is equivalent to 106 million soccer fields.

The fact that mining has an indirect deforestation effect beyond the actual mining sites was recently illustrated by a study that investigated mining-induced deforestation in 26 tropical countries. The study revealed that in two thirds of these countries, deforestation rates increase as distance to the mines decrease, showing a higher level of deforestation in the proximity of mines, even after checking for other deforestation drivers (Giljum et al. 2022).

If we look at buffer zones around mining sites in these 26 countries with tropical forests (the biome that is most affected by MRD, see chapter 3.1.1), we find that the 2000 to 2019 accumulated forest loss around mines relative to the forest cover in 2000 is very different across the investigated countries. Values range from around 30-35% for countries such as Malaysia, Sierra Leone and Indonesia, to less than 3% for countries such as India, Guyana and Mexico.

Some countries, such as Indonesia, show a pattern of higher indirect deforestation closer to mines and a fading trend when moving away from mines. This suggests that the distance to a mine plays a certain role in determining indirect deforestation. In countries such as Gabon, Angola or Guyana, the pattern is very pronounced, suggesting that the distance to the nearest mine has a substantial effect on deforestation.

In other countries, however, such a pattern cannot be observed. For example, in Brazil, indirect deforestation still increases when moving further away from mines, indicating that other drivers than the presence of a mine also have a significant effect on deforestation.

Another way to visualize the impacts of indirect MRD is by comparing deforestation rates between mining and non-mining areas within countries. Values range significantly, in Zimbabwe, for example, 86% of the total deforestation occurs within a 50 km radius of the mining areas. In the mining hotspots Ghana and Suriname, 41% and 62% of the countries' total deforestation occurs within 50 km of the nearest mine, respectively. Even if a direct causal link between deforestation and mining activity cannot be empirically established, the much higher incidence of deforestation within mining areas is a strong indication that a significant share of deforestation in these countries is indirectly associated with mining.

11.5%

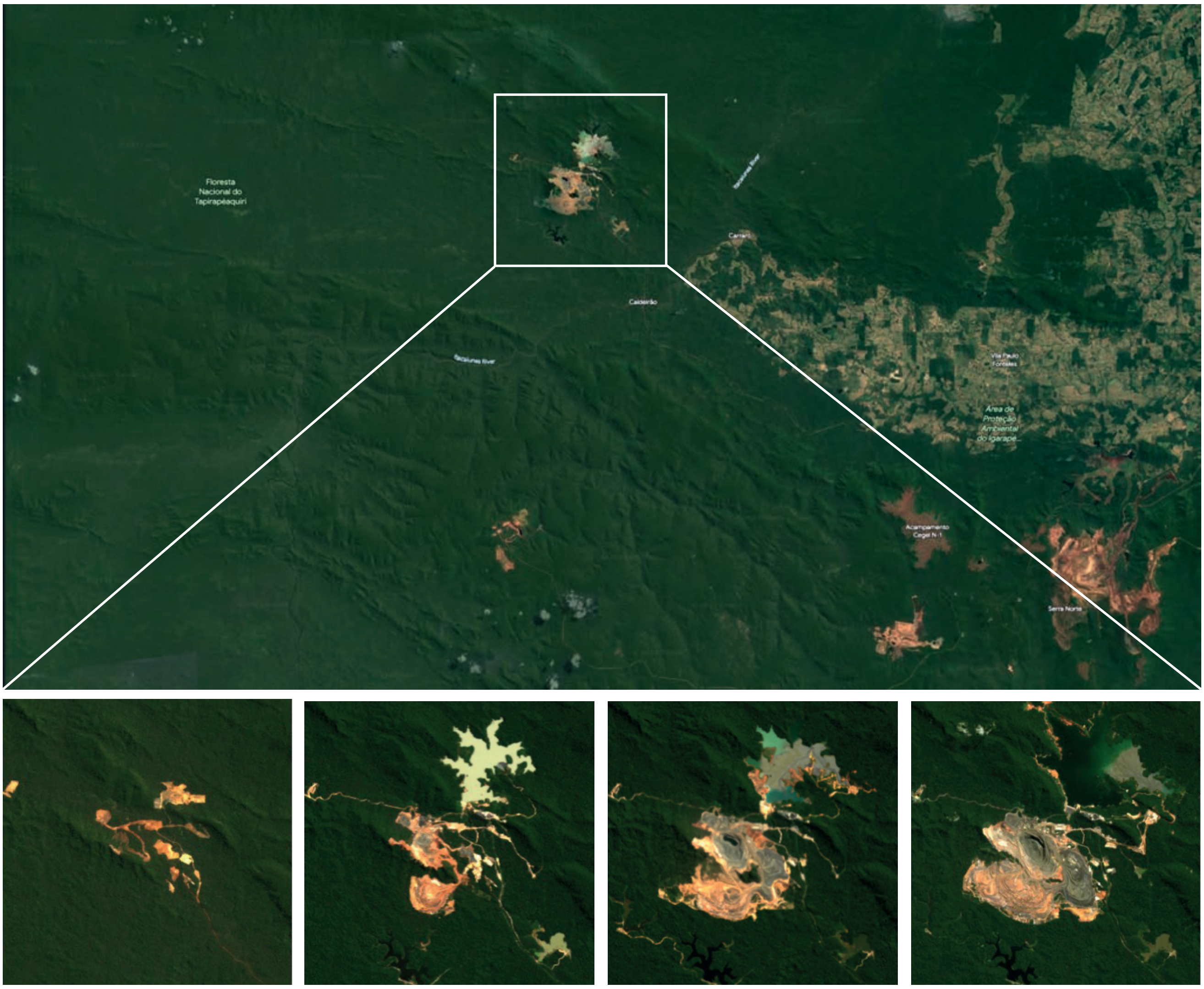
OF THE EARTHS TERRESTRIAL SURFACE MIGHT BE ALREADY AFFECTED BY MINING.

Case study on mining related infrastructure in the Tapirapéaquiri National Forest, Brazil

Mining related infrastructure is a stellar example of the indirect impacts of mining on forest ecosystems. The following case study corresponds to a satellite imagery interpretive and Machine Learning analysis of a region with a mining complex that extracts iron ore. It was possible to observe the structures associated with this operation, such as roads, buildings or dams, as well as their progression throughout the years in proportion to the neighboring forest areas, and the resulting deforestation.

This complex is located in the Carajás region of the Brazilian state of Pará, and the city of Parauapebas is the largest urban grouping in the region. The study site specifically is located in the Tapirapéaquiri National Forest

According to the following images (Figures 12), the mining operations appears to have started in the year 2008 and continues to expand until the present day resulting in an accumulated deforestation area of over 25 km² in 2022.



Area of study in the year 2008

Area of study in the year 2012

Area of study in the year 2017

Area of study in the year 2022

Figure 12: **Location of the analyzed mining area in Brazil**

BOX 3: PROTECTED AND CONSERVED AREAS

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Protected and Conserved Areas (PCAs) are the best instruments to ensure conservation outcomes while also serving a variety of conservation goals, from habitat and biodiversity preservation to climate mitigation and adaptation, increased water and food security, and local livelihood provision (Watson et al. 2014). They are a key focus of the Convention on Biological Diversity (CBD), which, through the Kunming-Montreal Global Biodiversity Framework Target 3 aims to ensure and enable that by 2030 at least 30% of terrestrial, inland water, and coastal and marine areas.

While new coverage of PCAs has grown in recent decades, the degree of equitable governance in protected areas varies considerably and protected status alone does not guarantee conservation (Watson et al. 2014). Further, a worrying trend of Protected Area Downgrading, Downsizing, and Degazettement (PADDD) has been on the rise, a process by which protected areas lose certain usage restrictions, area, or their entire protected legal status, respectively (Watson et al. 2014). Globally, PADDD has affected more than 130 million hectares in nearly 70 countries— roughly the size of Peru or South Africa (Conservation International).

A common driver of PADDD is economic pressure to allow mining in previously protected areas (Watson et al. 2014). Examples include: 1) the Selous Game Reserve in Tanzania, which was downsized to allow uranium mining (Watson et al. 2014) and 2) Brazil, where 219 PAs have some portion of their area overlapped by mining claims (WWF,2019).

2.3 GLOBAL MINERAL DEMAND DRIVES MRD

In the globalised economy we live in, the extraction of local resources and related environmental and social impacts are often driven by the demand of very distant consumers. Another question this study tries to address is therefore which countries and sectors are the primary drivers of MRD through their purchase and consumption of products that contain mineral resources and mining-related deforestation. This chapter looks at which countries, sectors and commodities are at the centre of global mineral demand by investigating international production, trade and consumption data.

2.3.1 CONSUMPTION BY COUNTRY AT THE ROOT OF DEFORESTATION.

The final consumption of China and the USA alone drives 30% of global MRD. Japan, India, Indonesia and Canada follow in the ranking, driving between 4 and 7%. Together, the top 6 countries are responsible for 51%, or 4,848 km², of all MRD. Indonesia and Brazil, which have the biggest national MRD shares worldwide (see chapter 3.1.2), simultaneously play an important role in driving the demand for mineral commodities: With 4%, Indonesia hass the 5th highest share of deforestation associated with mineral demand, and Brazil comes in 9th place with 3%.

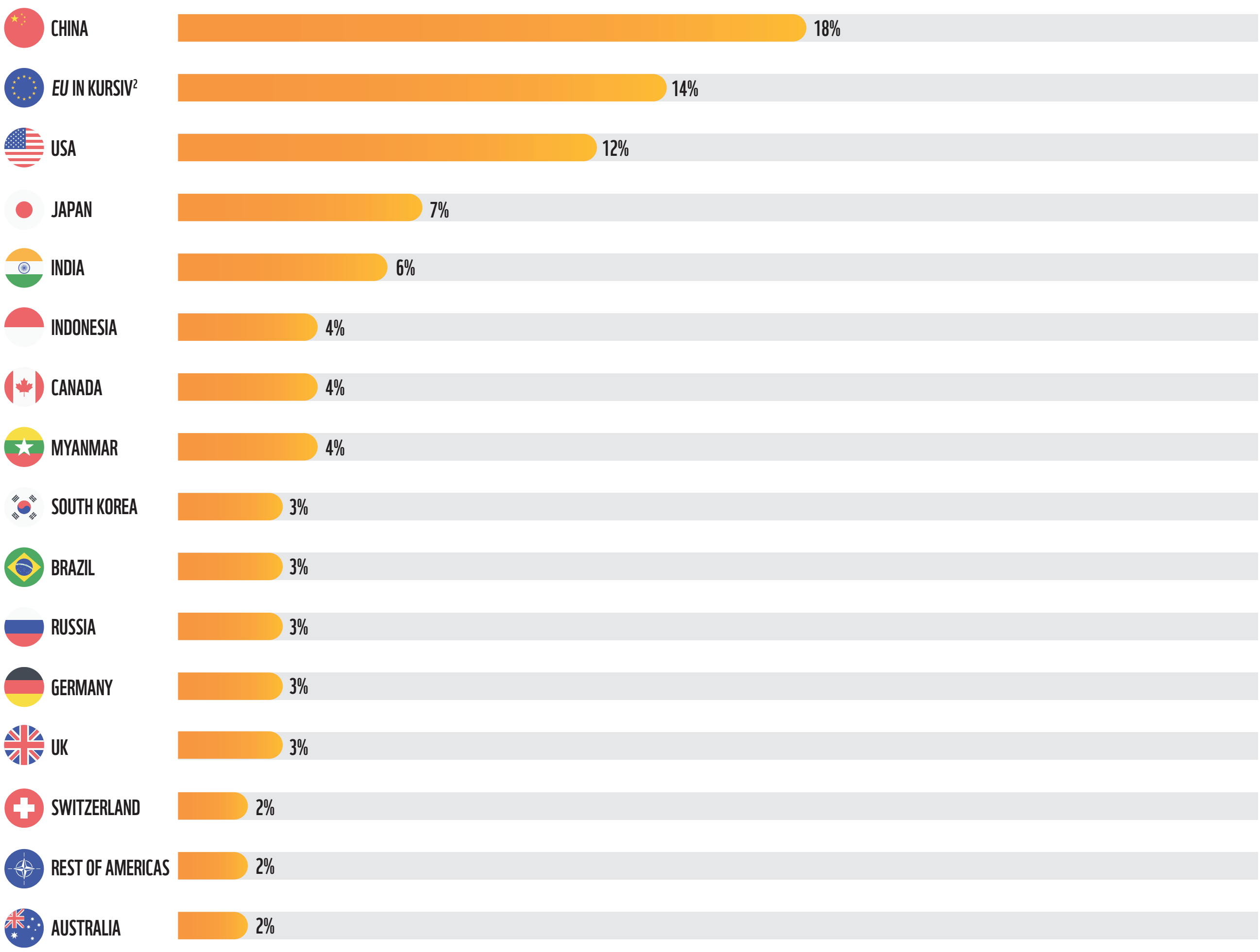

Figure 13: The 15 countries and regions driving 90% of global MRD with their demand, 2001 to 2019

2. United Kingdom is included in the list, as the analysis pertains to the period between 2001-2019, when it was still part of the EU.

BOX 2: THE APPETITE OF THE EUROPEAN UNION FOR MINERAL COMMODITIES

When aggregating the 28 EU countries' demand for minerals commodities, their share of global MRD driven by this demand takes them to second place behind China, with 14% of the global total, or 1,360 km². 85% of the deforestation footprint of the EU-28 was located outside of Europe. The most important countries of origin of EU's global mining deforestation footprint were Indonesia (20% of EU's footprint, mainly due to hard coal extraction), followed by Brazil (13%, due to gold, bauxite, copper and iron mining), and Russia (11%, gold and hard coal mining).

Within the EU, Germany is the largest source of demand-driven MRD, with 265 km² or 19% of the EU total, and 3% of the global total. In Germany, the 'Motor vehicles' sector contributed most to the overall deforestation footprint (17% of total), followed by the machinery and equipment sector (11%) and brown coal extraction (9%). The latter is one of the main culprits behind the 15% of deforestation footprint of the EU-28 which was located within Europe.

85%

OF THE DEFORESTATION FOOTPRINT OF THE EU WAS LOCATED ABROAD.

2.3.2 DEMAND-DRIVEN MRD BY COMMODITY

As the mining of gold and coal is associated with the largest deforested areas (see chapter 3.1.3), the two commodities also have the highest share of demand in most countries. But some notable differences between countries can be observed. In China, gold contributes 33% and coal another 24% to the total demand-driven MRD. China also has the by-far largest bauxite deforestation footprint, in particular due to imports of bauxite and aluminium concentrates from Northern Australia. In the USA, a very high fraction is related to coal (at 57% of the total footprint). This is particularly related to coal extraction within the USA itself. In Germany, gold contributes 29% to the total country footprint. Again, it needs to be emphasised that this high number partly stems from applying a price allocation[3] in cases where gold is mined together with other commodities in LSM. Lignite (brown coal) also contributes significantly, at 15%, to Germany's footprint, the number relates to the extraction of lignite in Germany itself.

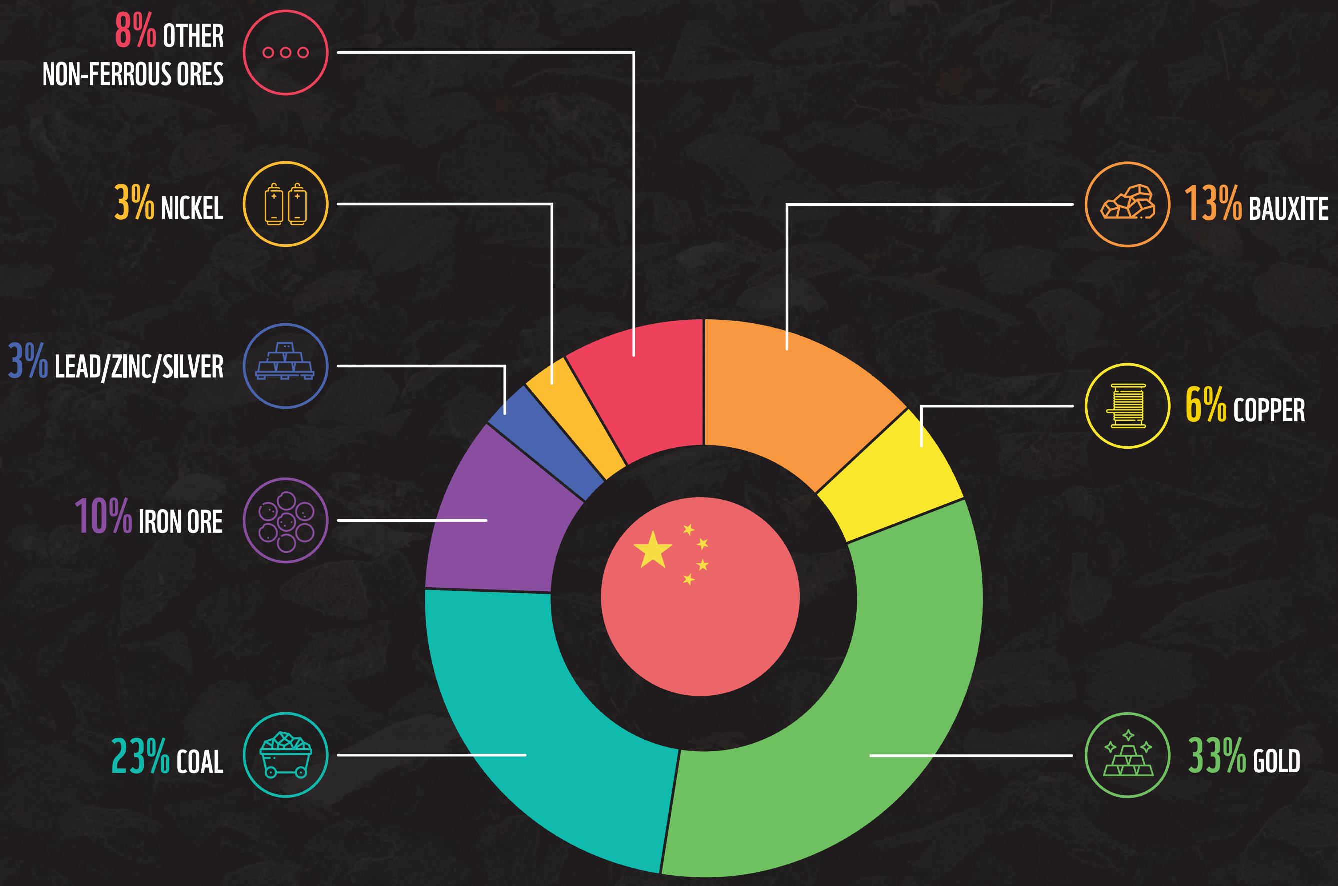

Figure 14: China's demand-driven MRD by commodity

3. See Appendix for an explanation on price allocation. For an overview of gold prices, see https://www.macrotrends.net/1333/historical-gold-prices-100-year-chart

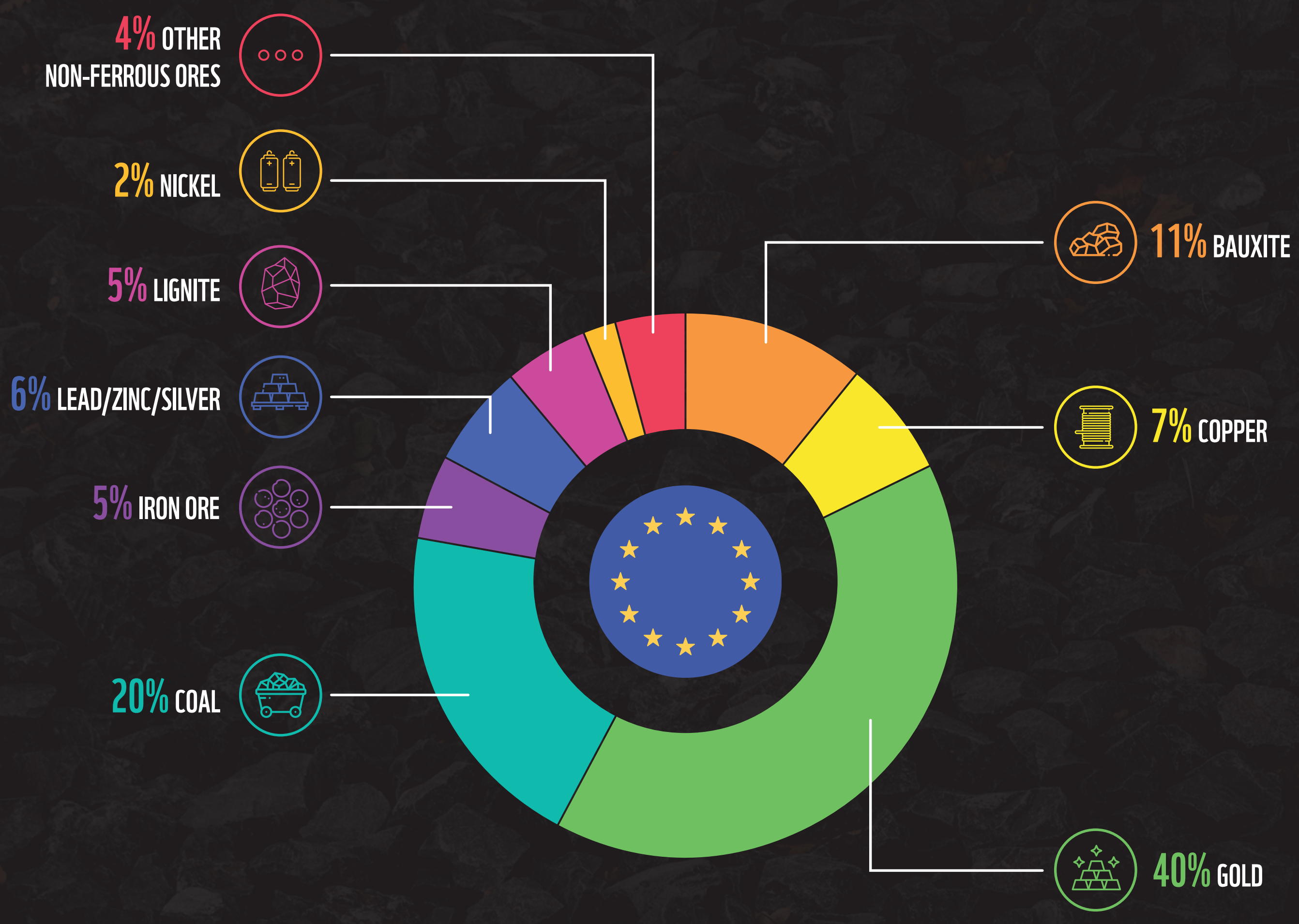

Figure 15: EU's demand-driven MRD by commodity

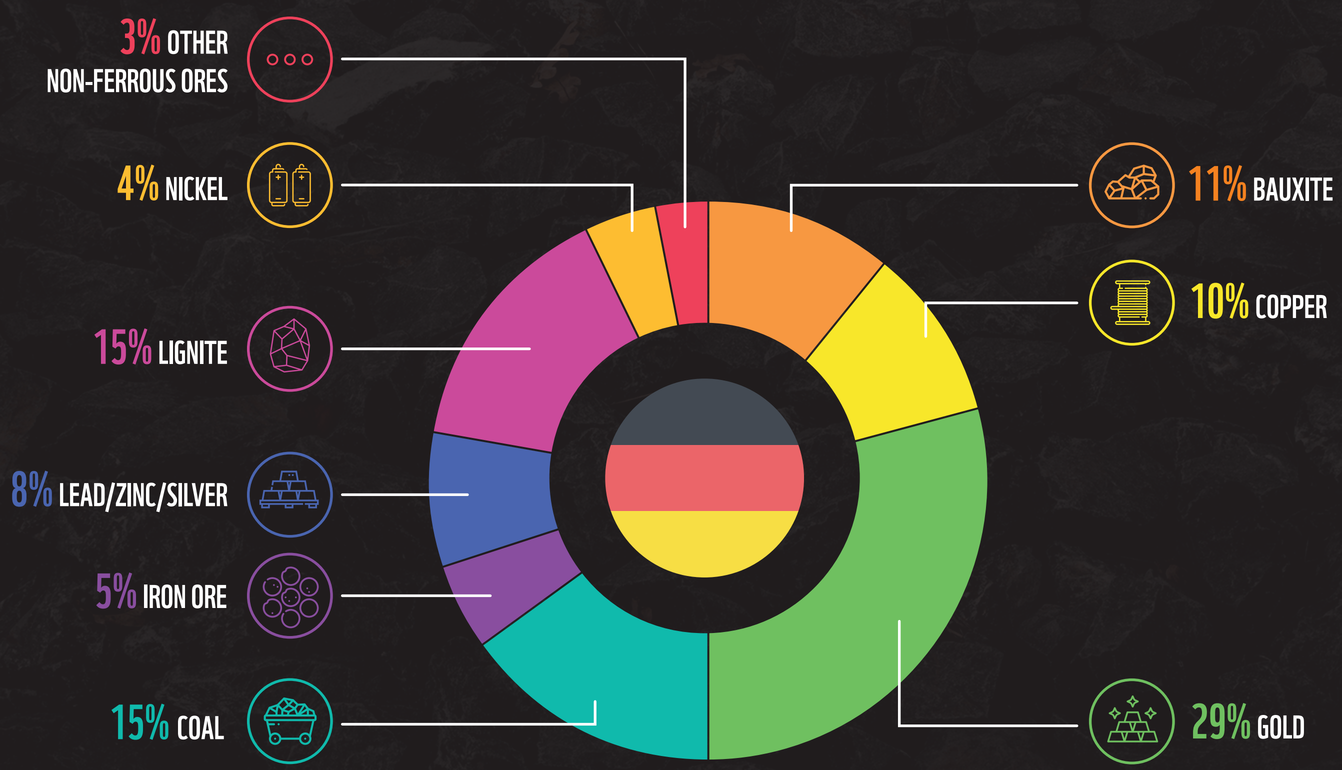

Figure 16: Germany's demand-driven MRD by commodity

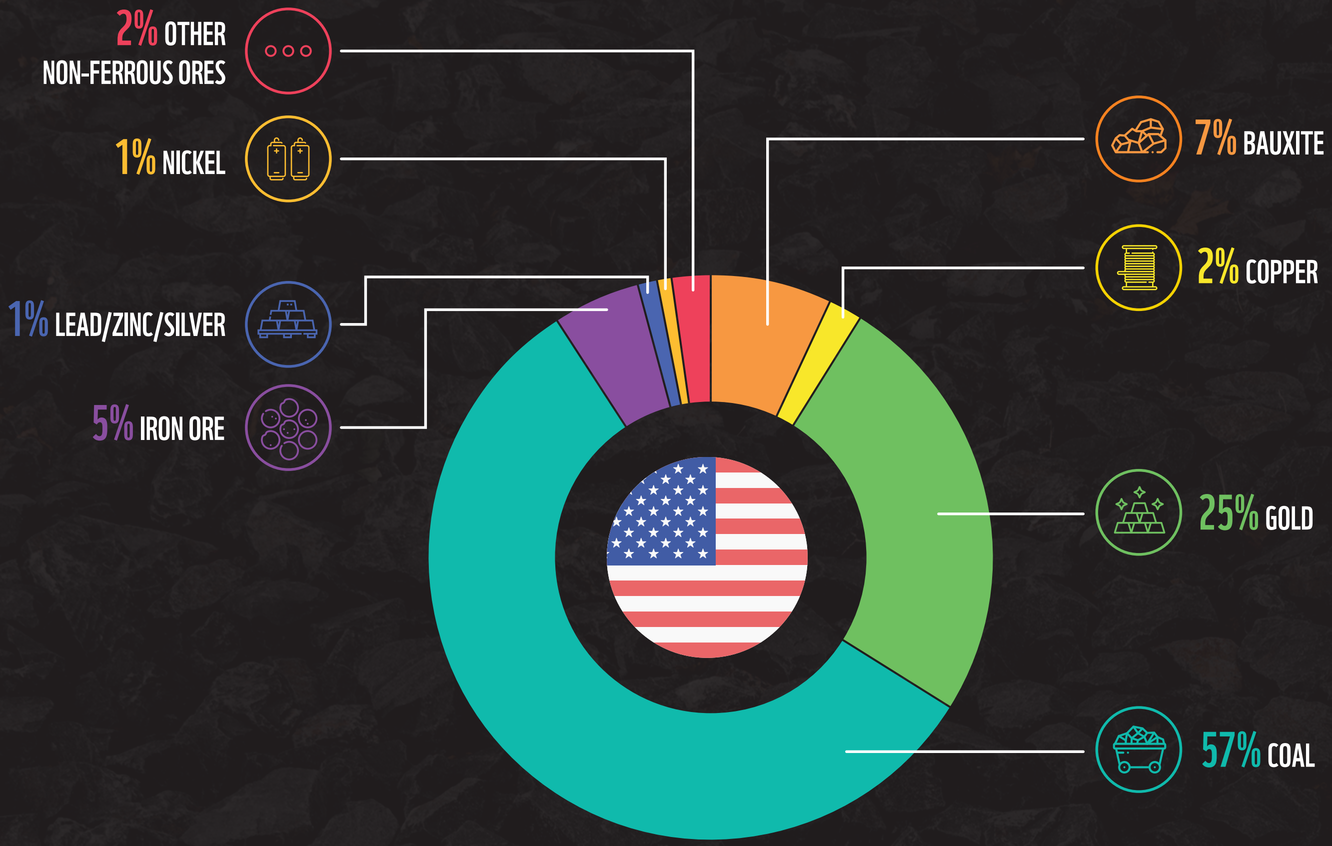

Figure 17: **USA's demand-driven MRD by commodity**

2.3.3 DEMAND-DRIVEN MRD BY SECTOR

When analysing the results by sector of final demand, i.e. the endpoint of global supply chains serving private consumption, public consumption and investments, the global 'Construction' sector has the highest MRD footprints of all economic sectors. Construction activities have driven 18% of all deforestation world-wide related to mining expansion between 2001 and 2019. Construction is followed by the 'Vehicles' sector, which contributed 8%, and the 'Machinery and equipment' sector at 7%. In addition, sectors mainly related to public final consumption contribute significant shares to the aggregated sector-specific footprints of the global economy: the sector 'Public administration, social security, defence' contributes 6% to the total global footprint, the 'Human health' sector 2%.

CONSTRUCTION ACTIVITIES HAVE DRIVEN

18%

OF ALL DEFORESTATION WORLD-WIDE RELATED TO MINING EXPANSION BETWEEN 2001 AND 2019

Figure 18: Top-15 sectors' shares of demand-driven MRD

3 CALL FOR ACTION

Actions to curb the impacts of mining on the degradation and loss of forests, as well as of other critical ecosystems such as grasslands, wetlands and mangroves, can be undertaken on several fronts. Stakeholders with different functions and mandates will, of course, have distinct entry-points and pathways through which action can be taken.

POLICY-MAKERS

...are in the unique position to influence the policy landscape on different levels, including:

- accelerating efforts to **move towards a circular economy**. As the countries and regions with the highest levels of demand-driven MRD, China, the EU and USA must take concrete steps towards bringing down **overall demand for mineral products** and set targets for the reduction of primary mineral commodities across all economic policies and strategies.
- designing **targeted mitigation strategies** for the mineral supply chains of the most impactful sectors, in particular construction and the motor vehicles, and supporting the conduction of further assessments on sector-specific mineral footprint;
- aligning the increasing demand for mineral resources driven by the green transition with **global goals to halt climate change, deforestation and biodiversity loss**. As the mining sector is a major CO2 emitter and directly or indirectly responsible for high rates of deforestation, contributing to both climate change and biodiversity loss, it is crucial that the countries leading the green energy transition invest in clean and efficient technologies to avoid negative externalities stemming from renewable energy sources;
- funding research and development to conduct **comprehensive analyses** and take stock of the indirect impacts of MRD, in order to better inform policy-making. It is particularly crucial to conduct **granular, localised impact assessments** to detect subnational variations, and ASM hotspots;
- taking possible **indirect MRD impacts** into account when conducting **Environmental Impact Assessments** before a project can start to operate. While direct MRD is being addressed by some companies in the mining sector, indirect MRD is still a blind spot.
- working with local governments, organisations and civil society in places with a high-incidence of informal and illegal ASM **to address livelihood insecurity** among low-income populations. This includes opening pathways towards **alternative livelihoods**, but also increasing **financial and technical support** for conducting ASM more safely and with reduced environmental impact. Reducing informality and increasing support in the ASM sector also harbours the co-benefit of increasing security, as populations are then less likely to be compelled to work for illegal and armed groups, who often fund their activities through mineral exploitation;
- instrumentalising **existing policies** for addressing MRD. The benefit of expanding existing policies is that they often already include a myriad of instruments that would be necessary to drive action. For example, the new EU deforestation regulation[4] seeks to tackle deforestation stemming from the import of agricultural products and timber, but its scope can be extended to include minerals in the future. The regulation has introduced **due diligence** rules for companies to increase supply chain transparency. Such rules are crucial to mitigate the impacts of the mineral sector on deforestation;
- embeding the **role played by indigenous and local peoples in protecting forests** from MRD, in planning and policy-making. Several studies have shown that deforestation rates are lower in IPLC lands[5], and the same holds true for deforestation stemming from mining activity. As IPLCs are granted land rights and allocated protected areas, economic activities in said areas inherently slow down or stop altogether. Acknowledging the role played by IPLCs in protecting forests is an important step towards safeguarding not just forested areas in general, but some of the world's last remaining primary forests with priceless ecosystem value.

4. See https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7444
5. IPLC lands pertains to land areas which are protected with the intention of protecting the rights of IPLCs, giving these populations use and/or tenure rights

THE MINING INDUSTRY

...is at the centre of the issue, and must conduct decisive actions targeted towards reducing its impacts, such as:

- demonstrating that the consent of the indigenous people for new mining endeavours has been obtained through Free, Prior and Informed Consent (FPIC). If indigenous people do not consent to the mining activity, it should not proceed.
- **expanding on existing good practices**, such as avoiding mining activity on World Heritage areas listed by the International Union for Conservation of Nature (IUCN) and expand beyond these areas to include forests and important biodiversity areas;
- planning for the **urban expansion** that accompanies large mines, for example by placing settlements outside of highly sensitive areas, equipping these with renewable energy sources and local food production systems, in order to avoid encroachment of new populations into the forest for food and fuel;
- including **phasing-out strategies** for the post-closure period already in the mine's planning phase, including the cleaning and restoration of mine and infrastructure areas;
- **investing** in the recovery of forest areas impacted by mining and in the restoration of natural elements that support healthy forests, by cleaning water and soil pollution and boosting biodiversity.

THE PRIVATE SECTOR

...also has an important role to play, by:

- conducting **life-cycle analyses** for products in order to identify entry-points,increase efficiency and reduce the consumption and waste of minerals;
- adopting and mainstreaming the mitigation hierarchy **avoidance > minimisation > restoration > compensation**, including re-sourcing and recycling of scrap metals where possible and investing on the restoration of ecosystems;
- conducting **supply chain risk analyses** to gain traceability and knowledge of risks and impacts to forests throughout the supply chain, and taking actions to fulfil their due diligence obligations, minimise risks and implement measures along their mineral supply chains.

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APPENDIX

DEFINITIONS AND METHODOLOGY

The analysis of MRD is based on different spatial datasets. The following section defines the main concepts and methodological approaches used in this report.

FORESTS AND DEFORESTATION

In the datasets from WU[6] and WWF[7], a forest is defined as an area containing vegetation taller than 5 meters in height, while 'forest cover loss' is defined as a "stand-replacement disturbance, or a change from a forest to non-forest state" (Hansen et al. 2013). To determine where deforestation has taken place, analyses focus on detecting tree cover loss as an indicator of deforestation. The Hansen dataset is used as a proxy of deforestation for this study.

The forest baseline dataset from Satelligence[8], excludes perennial crops (e.g. cocoa, coffee, rubber, oil palm etc.), which explains differences in the Ghana and Suriname case study. Only changes in actual primary forests and disturbed forests – based on time-series analysis of 40 years of satellite data – are taken into account. The granular dataset enables detection of small regional changes and is therefore suitable to uncover deforestation induced by ASM.

DIRECT DEFORESTATION

Direct deforestation refers to deforestation occurring *within* mining areas. This includes extraction sites, tailing storage facilities, waste rock dumps, and on-site processing facilities and roads (Giljum et al. 2022). The assessment of direct deforestation utilises a global-scale dataset based on satellite images of mining sites across all land cover types. Satellite images were taken from the Sentinel-2 cloudless mosaic from 2019 (EOX IT, 2020) and the extent of a certain mining area was delineated by hand in the form of a polygon. The dataset covers 44,929 of these mining polygons and extends across 101,583 km² of land. Not only covering mines with an "active" status, but also "inactive" mines, as they often have ongoing mining activity, according to satellite images (Maus et al. 2022). Commodities covered by this mining-related land use database are mostly coal and metal ores, but they can also include a small share of other types of mineral commodities such as industrial minerals, sand and fertilizers.

The mining areas were overlaid with data from the Global Forest Change database[9], which assesses global-scale 'Tree Cover Loss' at a 30 meter spatial resolution during the period 2000 to 2021 (Hansen et al. 2013). The analysis assumes that deforestation occurring within mining sites can be attributed directly to mining activities.

Despite the global scale of the dataset, it does not cover all existing mining activities worldwide. Deforestation driven by ASM activities is only partly covered, as it is difficult to assess ASM as a driver of deforestation at global scale. Firstly, there is no database that would allow the locations and extent of ASM to be consistently considered in a spatial assessment with global scope. Secondly, the ASM sector is significantly more dynamic than the LSM sector, expanding and moving relatively rapidly. Therefore, ASM areas are often difficult to identify after they have been abandoned, as they are characterised by a mix of bare ground, pools of water, and remaining or new vegetation (Giljum et al. 2022).

6. Datasets on direct deforestation by biome, by country and by commodity, as well as indirect deforestation in 26 tropical countries.
7. Dataset on global indirect deforestation.
8. Datasets on ASM in Ghana and Suriname.
9. The datasets do not cover deforestation occurring in areas with vegetation below 5 meters height, as these do not fit the definition of forest as determined by the Global Forest Change database.

Nevertheless, to gain an in-depth insight into ASM, two country case studies, Suriname and Ghana, are considered. Detection of deforestation (tree cover change) in these case studies is achieved by combining optical satellite imagery (Landsat and Sentinel-2) and radar imagery (Sentinel-1). Time series of these satellite images are fed into an algorithm that is called “bayesian iterative updating” (Reiche et al., 2018) which determines for each pixel if change has occurred, and if so, on what date. The detection of deforestation is masked using the forest baseline[10]. This means that only changes within the forest baseline are considered. Furthermore, national deforestation definitions are followed, which means that for Suriname, only changes that are larger than 1 ha are classified as deforestation, while for Ghana this threshold was set at 0.5 ha. Smaller changes are generally classified as degradation and are not included in this analysis.

DIRECT DEFORESTATION LINKED TO SPECIFIC MINERAL COMMODITIES

Satellite images do not directly reveal the commodities linked to the deforestation in a specific mining area. We filled this information gap by integrating the commodities and production reported in the SNL Metals and Mining database in our analysis. In order to calculate the direct MRD by commodity, we grouped the mining polygons and associated deforestation to geographically near mining locations from SNL, creating regional clusters. This allows the forest cover loss within each mining area to be related to the reported commodities and production from the SNL dataset. If only a single commodity is mined in a cluster, this commodity received the total amount of deforestation within that cluster. In cases where several commodities were mined in a single cluster, *price allocation* was applied to distribute responsibility for deforestation impacts between different commodities. For this, production quantities were multiplied by world-market prices to calculate total revenue per commodity and deforestation was allocated according to the shares in total revenue. This method was chosen because high-price commodities generate higher revenues and thus provide greater economic incentives for mining activity and associated MRD. This partially explains why gold has a particularly high deforestation rate. In LSM, gold is usually mined together with other commodities, such as copper, and thus receives the highest share of the deforestation from a combined gold-copper mine. However, in ASM, gold is often mined as a single commodity (WU 2022).

INDIRECT DEFORESTATION

Indirect deforestation refers to deforestation taking place around mining areas due to activities such as infrastructure expansion, growth of settlements, and expansion of agricultural areas (see page 8). The assessment of indirect deforestation is complex, requiring a different approach to the assessment of direct MRD. Following other studies (e.g. Sonter et al. 2020), the approach chosen assumes that deforestation in buffer zones of up to 50 km around mining areas can be partially attributed to mining activities[11]. This assumption is based on the empirical observation that deforestation levels are higher in areas surrounding mines than in areas more than 50 km away, even after checking for other deforestation drivers (Giljum et al. 2022). However, it is difficult to assign indirect changes in land use to one single cause. The results show impacts of mining combined with those of other drivers, such as human settlements and the expansion of agriculture and infrastructure. Although many of these factors can themselves be attributed to mining activity, it is not possible to determine precisely to what extent this is the case, and so data on indirect deforestation must be interpreted with caution.

To showcase indirect MRD, two different samples of total deforestation occurring within a radius of 50 km around mines were assessed. The analysis looks into the 50 km buffer zone in steps of 10 km width, in order to determine the progression of deforestation in relation to its distance from the mines.

- A global sample assessed indirect MRD around 21,000 mining sites between 2001 and 2021, representing an area of 17 million km², or approximately 11.5% of the Earth’s terrestrial area.

10. Forest, as defined by the FAO is “land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.” Satelligence applies machine learning-based forest classification models to enable consistent application of these parameters. The Satelligence forest baseline distinguishes between primary and disturbed forest. For this purpose, the two forest types are grouped together.
11. This is a fairly conservative estimate, considering that other studies have found deforestation within buffers of up to 70 km from mining areas to be significantly greater than in areas further away from mines. See Sonter et al. 2017.

A second sample focused on 26 tropical mining countries in 2019 (WU 2022): Angola, Brazil, Colombia, Ivory Coast, Democratic Republic of Congo, Gabon, Ghana, Guatemala, Guinea, Guyana, Honduras, India, Indonesia, Liberia, Malaysia, Mexico, Mozambique, Nicaragua, Papua New Guinea, Philippines, Sierra Leone, Suriname, Tanzania, Thailand, Venezuela and Zimbabwe. The decision to focus on tropical mining countries stems from the results of a previous study, which indicated that tropical and subtropical moist broadleaf forests are among the biomes most affected by mining activity, while also harbouring the highest trends in mining expansion in recent years (Luckeneder et al. 2021). The 26 countries were chosen on the basis of three criteria: (a) the presence of a sufficient number of mining sites included in the set of mining polygons, (b) the location of the polygons in tropical forest areas, and (c) the importance of a country in terms of absolute forest loss observed since 2000.

DEMAND-DRIVEN DEFORESTATION

The deforestation data per commodity as described above were connected to a model of the global economy, which includes the bilateral trade relations between 164 countries and regions, and specifies 120 economic sectors for each country (GLORIA model, Lenzen et al., 2021). This allows the calculation of consumption-based or footprint-type indicators that illustrate which monetary supply chains and ultimately which final demand for products induce the extraction of raw materials and related environmental impacts, such as deforestation. The applied model of the global economy discerns the following ten mining sectors: bauxite/aluminium, copper, gold, coal, iron ore, lead/zinc/silver, lignite (brown coal), nickel, other non-ferrous ores and uranium. The results illustrate the amount of mining-induced deforestation embodied in products that are finally consumed in each country.

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