Bundesanstalt für Geowissenschaften und Rohstoffe

Informationsblatt Entwicklungspolitische Perspektiven

Mining and Deforestation

Understanding mining-induced deforestation is important for development cooperation, given the importance of forests for biodiversity, carbon sequestration, and local livelihoods in partner countries. While agriculture remains the primary driver of deforestation, the mining sector's contribution is receiving increasing attention (Luckender et al., 2024). This information sheet seeks to provide people working in international and development cooperation with an overview of recent studies that examined the link between mining and deforestation on a global scale, their results and methodologies, with a particular focus on BMZ partner countries.

It addresses the following key questions:

- **How does mining compare to other sector-specific drivers of global deforestation?**
- **What is known about the direct and indirect deforestation associated with mining on a global scale, and where are "deforestation hotspots"?**
- **What are implications for development cooperation?**

Sector-specific drivers of global deforestation

How does mining compare to other sectors in terms of deforestation drivers on a global scale? Mining is often cited as the fourth largest driver of deforestation, contributing approximately 7 %, following agriculture (73 %), infrastructure (10 %), and urbanization (10 %). These figures are derived from the study by Hosonuma et al. (2012), which estimates the relative importance of deforestation drivers in (sub)-tropical forests from 2000–2010, based on data reported in documents such as REDD+ readiness reports and CIFOR country profiles, that is, they do not refer to impacted land area in terms of measured area size but are derived qualitatively and semi-quantitatively from the frequency and ranking of reported deforestation drivers.

Definitions: Forest, deforestation, forest degradation, and tree cover loss

The FAO (2024) defines a **forest** as "land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds *in situ*". This definition excludes land primarily used for agriculture or urban purposes (FAO 2024). **Deforestation** refers to the permanent conversion of forests to other uses, whether through human activity or natural processes. **Forest degradation** is characterized as the long-term reduction in the overall supply of forest benefits, including wood, biodiversity, and other ecosystem products and services.

Another commonly used concept is **"tree cover"** and **"tree cover loss"**, based on the definition by Hansen et al. (2013) and used by the Global Forest Review (GFR) and Global Forest Watch (GFW). **Tree cover** refers to woody vegetation at least 5 meters tall with a canopy density of at least 30 % at a 30-meter resolution (Landsat spatial resolution). It includes natural forests, plantations, and tree crops, which may not meet standard forest definitions. **Tree cover loss** is defined as a "stand replacement disturbance"—the complete removal of tree canopy within a Landsat pixel (i. e., reducing tree cover from over 30 % to nearly 0 %), caused by either human activity or natural events. Unlike deforestation, which implies permanent forest removal, tree cover loss can be either permanent or temporary. In analyses focused on primary forests, the terms tree cover loss, forest loss, and deforestation are often used interchangeably.

Analyses of deforestation and forest degradation typically distinguish between boreal, temperate, and (sub)-tropical forests. They also differentiate between primary forests, meaning those largely undisturbed by human activity—and secondary forests, which have regrown following clearance or degradation.

More recent studies on drivers of deforestation on a global scale focus on the impacted area sizes, often calculated with the help of satellite-based data (see Table 1). These studies tend not to assess mining separately but instead group it within broader categories. For instance, Curtis et al. (2018) classified global deforestation drivers into "commodity production," "shifting cultivation", "forestry", "wildfires", and "urbanization." Mining is included under "commodity production", alongside activities like oil palm cultivation and agriculture, but it´s impact is not calculated separately in comparison to other drivers. This classification approach is also used by the Global Forest Review (GFR), which is connected to platforms such as Global Forest Watch (GFW) and Global Forest Change (GFC). These platforms provide up-to-date analyses of deforestation and often serve as key data sources in studies on global deforestation drivers. According to the GFR, humid tropical primary forests lost approximately 7 % of their total area between 2001 and 2022. Of this loss, about 56 % was attributed to "commodity production" and 40 % to shifting cultivation. Similarly to Curtis et al. (2028), mining forms part of the "commodity production" category without accounting its impact separately.

Studies on global deforestation consistently highlight significant regional and local variability in its drivers. For example, Seymour and Harris (2019) report that deforestation in the Brazilian Amazon is primarily driven by extensive cattle ranching, in the Congo Basin by subsistence farming and small-scale commercial agriculture, and in Indonesia by selective logging and forest conversion to industrial oil palm and pulp

Table 1: Examples of studies on global deforestation drivers

Literature	Period	Data	Geography	Biggest drivers in % of total
Hosonuma et al. 2012	2000–2010	Redd+ documents CIFOR country reports; UNFCCC documents; literature	46 tropical and sub-tropical countries	Agriculture 73 % (commercial 40 %, subsistance 33 %) Infrastructure 10 % Urbanisation 10 % Mining 7 %
Potapov et al. 2017	2000–2013	Tree canopy cover data set (with a 20 % tree canopy cover threshold) Landsat satellite imagery	65 countries with Intact Forest Landscapes (IFL)	Timber harvesting (37.0 % of global IFL area reduction) Agricultural expansion (27.7 %) Wildfire spread from infrastructure and logging sites (21.2 %) Roads for mining and oil/gas extraction, pipe- lines, and power lines (12.1 %) Expansion of the transportation road network (2.0 %) * Mining and mineral exploration (mostly for gold) played a significant role in Australia (64 % of the total IFL reduction) and tropical South America (9 %)
Curtis et al. 2018	2001–2015	High-resolution Google Earth imagery	Global (tropical, subtropical, temperate, and boreal)	Commodity-driven (oil palm, agriculture, mining etc), 27 ± 5 %) Shifting agriculture (26 ± 4 %) Wildfire (23 ± 4 %) Urbanization (0.6 ± 0.3 %)
FAO Remote Sensing Survey 2020	2000–2010 & 2010–2018	Landsat imagery Sentinel imagery Open Forest Collect Earth Online	Global (tropical, subtropical, temperate, and boreal)	Cropland expansion, including palm oil (50 %) Livestock grazing (38 %) Urban and infrastructure development (6 %) Other drivers (4 %) Dam construction and change in water courses (1.8 %)

plantations. These regional and local differences underscore the need to consider specific contexts when analyzing the mining sector's role in deforestation – an important consideration for development cooperation as well.

Mining and deforestation

Studies on mining-related deforestation often focus on specific countries such as Indonesia, Ghana, Peru, and the Democratic Republic of Congo, while relatively few address the issue on a global scale. Generally, research on mining and deforestation distinguishes between direct and indirect deforestation related to mining.

Direct Deforestation
Direct deforestation refers to forest clearings directly linked to mining activities. This includes the mining areas themselves, as well as associated infrastructure such as overburden and waste dumps, processing plants, and transport roads, often accounted within concession areas. Direct deforestation tends to calculate the impact of industrial mining operations within their concessions. Areas affected by artisanal and small-scale mining (ASM) are less frequently included in analyses due to challenges in identifying ASM areas as such due to limited systematic data on ASM locations and the dynamic nature of ASM activities which impede their quantitative impact assessments (Ladewig et al. 2024).

One of the first global studies on mining and deforestation was the 2019 "Forest-Smart Mining" report by the World Bank. While this study did not analyze the area size of deforestation, it assessed the number of industrial mines operating in forested areas (MFAs), based on Hansen's forest cover data and the Raw Materials database (later the S&P database). It identified 1,539 industrial mines active in forests and an additional 1,826 mines classified as "in development" or "temporarily closed" (see Table 2).

Another prominent global study, Giljum et al. (2022), analyzed direct deforestation caused by industrial mining in pantropical countries between 2000 and 2019. It found that global direct deforestation amounted to 3,264 km², with 80 % of this loss occurring in Indonesia, Brazil, Ghana, and Suriname. The WWF (2023) study on mining and deforestation expanded upon this methodology by including operational and inactive mining projects across all forest types and partially accounting for ASM. According to the WWF study, direct deforestation from mining between 2001 and 2020 totaled 13,732 km², of which 8,533 km² occurred in tropical and subtropical forests. The higher deforestation area reported by WWF, compared to Giljum et al. (2022), is likely due to differences in data sources and scope. Giljum et al. (2022) used the first version of the Maus et al. dataset (2020), which focused on industrial mining, whereas WWF relied on the second version (Maus et al., 2022), which also includes ASM.

Differences in methodologies, datasets, definitions, the inclusion or exclusion of ASM, which forest types, and whether only specific raw materials are included contribute to discrepancies in reported deforestation figures on global scale and country-level comparisons, which can result in differing estimates for the same periods (see Table 3). Despite these variations, global studies consistently identify Indonesia, Brazil, the Democratic Republic of Congo, and Ghana among the countries with the highest direct deforestation from mining, all of which are commonly among development partner countries. Additionally, both Giljum et al. (2022) and the WWF (2023) highlight Suriname and Guyana as countries where mining accounts for the highest proportion of total deforestation, albeit with differing magnitudes (see Table 3).

Indirect Deforestation
Indirect deforestation refers to forest clearings caused by secondary effects of mining activities rather than by their operation processes. Examples include deforestation related to processing facilities and transport routes outside concession areas, as well as settlements established along these routes due to the population influx in mining regions. Measuring indirect deforestation is insofar complex, as it involves, on the one hand, determining the extent to which deforested areas can be causally connected to mining activities as well as, on the other hand, assessing the strength of this connection. For instance, if smallholder agriculturalists or industries like timber and palm oil expand into forested areas after transport roads have been built to access mining operations – would those areas have been deforested for such land-uses, had those roads not been built, and subsequently, would those areas count as mining-induced or not? Or, as Ladewig et al. (2024) put it "The identification of the true causal effect of mining on the surrounding forests requires the comparison of the same area with and without mining activities, which is a counterfactual and hence not observable".

To determine the extent to which deforestation can be considered an indirect effect of mining activities, studies have sought to employ various statistical methods, defining significance within their chosen methodology as an indicator that deforestation was mining-induced. An early attempt to investigate the relationship between deforestation and mining in Brazil was conducted by Sonter et al. (2017), who examined whether deforestation rates varied significantly with proximity to mines. Deforestation was measured within areas which included large operational mining leases and their surrounding buffer zones extending up to 100 km away, as well as in areas beyond 100 km from mining leases which served as "control group". If the difference in forest loss between areas with mining leases and their corresponding control groups was statistically significant, it indicated that forest loss could be attributed

Table 2: Examples of studies on deforestation and mining on a global level

	Gulijum et al. 2022	WWF 2023	Forest-Smart Mining LSM 2019
Data	Maus, et al., (2020). A global-scale data set of mining areas. Sci. Data 7, 289 Global Forest change	Maus et al., (2022) Global Forest Change Satelligence database	Hanson's 2015 forest cover data Raw Materials 2015 database
Period	2000–2019	2001–2020	2015
Geography	26 pantropical countries (tropical and subtropical)	Global & case studies for ASM (Suriname, Ghana) & industrial mining (Brazil)	Global & country-level studies
Mining type	Industrial	Industrial, but ASM partly included	Industrial
Forest type	Tropical & sub-tropical	all	all
Direct Deforestation	3,264 km²	Total: 13,763 km² Tropical-sub-tropical: 8,533 km²	1,539 operational (44 % of all operational mines) & 1,826 in development/nonoperational
Countries with the highest areas of direct deforestion	Indonesia, Brazil Ghana Suriname DR Congo Venezuela Zimbabwe * Peru not included, because no major industrial mining in forest areas	Indonesia Brazil *Russian Federation* *Canada* *USA* *Australia* Peru Ghana Myanmar Suriname	*China,* *Russian Federation,* *Canada,* *USA* Brazil DR Congo Zambia Ghana Zimbabwe * National Density of Mines, Contribution to the Economy, Level of Forest Cover, Significance of Forest in GHG
Mining as highest share of total deforestation	Suriname (11 %) Guyana (4 %)	Suriname (28.5 %) Guyana (20.8 %)	*n. a.*
Indirect deforesation	18 out of 26 countries studied have a significant correlation between the distance to the mine and deforestation.	Global sample: 755.861 km²	Within a 50 km radius, approximately 10 % of all forests are influenced by an operational industrial mining project, and nearly a third of the forests when currently non-operational or projects in development are included. These results are based on a 50 km radius.

to mining activities. Sonter et al. (2017) found that such significance and consequently mining-induced indirect deforestation extended up to 70 km from mining sites, with the strongest statistical significance observed within a 50 km radius. Consequently, the 50 km threshold is often cited as a benchmark in related studies.

Recognizing that deforestation scope and dynamics vary across countries, Giljum et al. (2022) used a regression analysis to see in which countries deforestation rates are significantly greater in areas near mining sites compared to locations more than 50 km away. The study found such significant correlation, and thus, indication for indirect deforestation, in 18 out of the 26 countries analyzed. While Giljum et al. (2022) focused on determining to what extent indirect deforestation could be established in a pantropical assessment, the WWF (2023) study aimed to quantify the magnitude of indirect deforestation in all forest types. Analyzing a global sample of 21,000 mining sites from 2001 to 2021, the WWF assumed all deforested areas within a 50 km radius of a mining-site to count as mining-induced. However, the WWF also cautions that to better understand the magnitude of indirect deforestation, further studies are needed that pay attention to local and regional variability in deforestation dynamics, as the 50 km radius cannot be applied automatically globally across all countries.

Studies on mining-induced deforestation generally agree that indirect forest loss poses a much greater risk than direct deforestation. For instance, Sonter et al. (2017) found that indirect deforestation was 12 times higher than direct deforestation within mining concessions, and the Forest Smart Mining study acknowledges that secondary impacts far exceed direct impacts. Thus, impact assessments and mitigation plans should address both direct and indirect deforestation to ensure effective forest protection and conservation, which development cooperation should also take into account.

Implications for development cooperation

What can development cooperation in the mining sector do to contribute to the international goal to eliminate deforestation and degradation, and restore degraded forests? Evaluating which policies and measures have successfully addressed mining-induced deforestation and deriving empirically based recommendations for development cooperation is beyond the scope of this information sheet. Bager et al. (2021) have identified “Eighty-six EU policy options for

Table 3: Examples of studies on deforestation and mining in a country-comparison

	Period	Direct deforestation or within mining concession
Indonesia		
Guljium et al. 2022	2000–2019	1901 km²
WWF 2023	2001–2020	3537 km²
Austin et al. 2019	2001–2016	2200 km² * mining activities were responsible for an increasing share, over the study period
Brazil		
Guljium et al. 2022	2000–2019	327 km²
WWF 2023	2001–2020	1654 km²
Sonter et al. 2017	2005–2015	983 km²
Ghana		
Guljium et al. 2022	2000–2019	213 km²
WWF 2023	2001–2020	583 km²
Suriname		
Guljium et al. 2022	2000–2019	203 km²
WWF 2023	2001–2020	527 km²

reducing imported deforestation" alone, targeting different actors relevant for advancing forest protection, including producers' governments, supply-chain actors, consumers, importing governments, finance actors, multilateral institutions, and multi-stakeholder institutions.

However, such recommendations would be valuable. A structured approach to identifying effective recommendations for development cooperation could begin by systematizing progress assessments and monitoring reports from major global frameworks, such as *The New York Declaration on Forests*, *the UNFCCC Global Stocktake*, and *the Kunming-Montreal Global Biodiversity Framework*. For example, the *New York Forest Declaration Assessment* publishes annual peer-reviewed reports on the state of global forests, identifying gaps and proposing solutions to overcome economic and institutional barriers—which could help guide development cooperation.

Additionally, international development projects focusing generally on forest protection, which are also relevant in mining areas, as well as those explicitly addressing forest protection in the mining sector, could be systematically mapped and analyzed to determine what works, what doesn't, and why. An example of the former would be the German development programs for forest and climate protection. An example of the latter would be the technical development cooperation project by the Federal Institute for Geosciences and Natural Resources (BGR), which focuses on mine reclamation, forest protection, and participatory approaches to post-mining land use in Indonesia; or project components focusing on forest protection in the mining sector in the Democratic Republic of Congo (DRC) by the GIZ. Conducting a global analysis of similar projects would provide valuable insights for development cooperation on forest protection and restoration in the mining sector.

Until such a systematic analysis is available, general recommendations for development cooperation include:

- **Integrate forest protection into development planning and funding:** Ensure that mining and infrastructure projects align with climate and biodiversity commitments while critically assessing the best long-term development pathway. Evaluate who benefits from the project in the long run, who might not, and how risks can be avoided and mitigated.

- **Strengthen government oversight and regulatory frameworks:** Support regulatory and policy reforms, institutional capacity building, and enforcement mechanisms to effectively regulate mining-related deforestation

- **Address indirect and cumulative impacts:** Promote landscape-level planning that accounts for secondary and cumulative mining impacts. Ensure the implementation of effective mine closure plans with progressive rehabilitation and participatory post-mine land-use planning

- **Promote land tenure right, indigenous rights, and civil society participation:** Support a rights-based approach to forest conservation and restoration, including legal recognition of indigenous and community land rights. Promote forest management by communities in mining areas and the post-mining context to increase the link between local development and forest protection

- **Enhance transparency, traceability, and corporate accountability:** Promote transparency in forest commitments by mining companies and related industries. Support regulatory framework that mandates corporate disclosure and mitigation of deforestation risks

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