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Research article

Global direct pressures on biodiversity by large-scale metal mining: Spatial distribution and implications for conservation

Diego I. Murguía [a, b, *], Stefan Bringezu [a, b], Rüdiger Schaldach [b]

[a] *Wuppertal Institute for Climate, Environment and Energy GmbH, Döppersberg 19, 42103 Wuppertal, Germany*
[b] *Center for Environmental Systems Research (CESR), Wilhelmshöher Allee 47, 34119 Kassel, Germany*

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ABSTRACT

Biodiversity loss is widely recognized as a serious global environmental change process. While large-scale metal mining activities do not belong to the top drivers of such change, these operations exert or may intensify pressures on biodiversity by adversely changing habitats, directly and indirectly, at local and regional scales. So far, analyses of global spatial dynamics of mining and its burden on biodiversity focused on the overlap between mines and protected areas or areas of high value for conservation. However, it is less clear how operating metal mines are globally exerting pressure on zones of different biodiversity richness; a similar gap exists for unmined but known mineral deposits. By using vascular plants' diversity as a proxy to quantify overall biodiversity, this study provides a first examination of the global spatial distribution of mines and deposits for five key metals across different biodiversity zones. The results indicate that mines and deposits are not randomly distributed, but concentrated within intermediate and high diversity zones, especially bauxite and silver. In contrast, iron, gold, and copper mines and deposits are closer to a more proportional distribution while showing a high concentration in the intermediate biodiversity zone. Considering the five metals together, 63% and 61% of available mines and deposits, respectively, are located in intermediate diversity zones, comprising 52% of the global land terrestrial surface. 23% of mines and 20% of ore deposits are located in areas of high plant diversity, covering 17% of the land. 13% of mines and 19% of deposits are in areas of low plant diversity, comprising 31% of the land surface. Thus, there seems to be potential for opening new mines in areas of low biodiversity in the future.

1. Introduction

Ever since the endorsement of the Convention on Biological Diversity (CBD) in 1992 and its strengthening in the Rio + 20 Conference in 2012, the issue of biodiversity and its global decline have become one of the most pressing contemporary environmental issues (Pereira et al., 2012). Despite numerous global responses, there is an ongoing biodiversity crisis (Cardinale et al., 2012; Kupfer and Malanson, 2004) and an overall reduction of biodiversity loss rates has not yet occurred (Butchart et al., 2010). Loss rates yet exceed critical boundaries (Steffen et al., 2015) and future prospects show only slight chances of improvement by 2020 if current trajectories continue (Tittensor et al., 2014). The greatest threats to biodiversity remain human-induced habitat loss and degradation, overexploitation, invasive alien species, and pollution (Armenteras and Finlayson, 2012). Metal mining activities do not literally figure among these top threats but are relevant forces at local and regional level as they cause direct and indirect pressures on biodiversity (Brummit and Bachman, 2010).

Despite positive effects in socio-economic dimensions and some positive impacts in the protection of biodiversity (e.g. via "net gain" compensation mechanisms or by the creation of deforestation buffers) (Sonter et al., 2013), large metal mining activities often have negative impacts on the environment. They adversely alter ecosystems (Simmons et al., 2008), contribute to the fragmentation of habitats, create pollution problems such as acid mine drainage (Naicker et al., 2003) or submarine tailings disposal in high biodiversity areas (Cardiff et al., 2012; Moran et al., 2009), may open the way for poaching, illegal logging or artisanal and small-scale mining (e.g. in the Brazilian tropical rainforest) (Laurance et al., 2009,

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* Corresponding author. Wuppertal Institute for Climate, Environment and Energy GmbH, Döppersberg 19, 42103 Wuppertal, Germany.
E-mail addresses: diegomurguia@yahoo.com.ar (D.I. Murguía), stefan.bringezu@wupperinst.org (S. Bringezu), schaldach@usf.uni-kassel.de (R. Schaldach).

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2002) or may create mining-induced human migration, bush meat hunting and wildlife trade in the face of weak governance (e.g. in the Congo rainforest, a conservation priority zone in Central Africa) (Edwards et al., 2014).

With the expected increase in absolute global mining of several metals at least during the next decade (Halada et al., 2008; Northey et al., 2014; Sverdrup et al., 2014, 2012), metal mining activities could intensify their overall pressures on biodiversity. This will depend on the richness of biodiversity in a respective region. To date, only few global spatial analyses have been conducted assessing how pressures on biodiversity are distributed between operating mines and protected areas (Durán et al., 2013) or with intact areas of high value for conservation (Miranda et al., 2003). However, it remains unclear how pressures are spatially distributed across the planet's terrestrial surface and across different biodiversity zones. Likewise, a knowledge gap remains on the spatial distribution of presently known mineral deposits and the resulting implications for future mine developments.

This research determined the global spatial overlap between terrestrial biodiversity zones (DZs) and mines and ore deposits of three base metals (iron (Fe), bauxite (Al), copper (Cu)) and two precious metals (gold (Au), silver (Ag)). The base metals were selected as they - besides coal and crude oil - are amongst the most massively extracted minerals worldwide and are mined predominantly in extensive surface operations demanding vegetation clearings. Furthermore, they are associated with inflicting substantial modifications of ecosystems (Cooke and Johnson, 2002). Gold and silver, often co-produced in the same mine, were chosen due to the high prevalence of gold (mostly open pit) and gold-silver-producing mines worldwide and the high economic value of silver and gold in global production (Ericsson and Hodge, 2012). In addition, the risk of pollution and other pressures on biodiversity by mining of these metals is high (e.g. Durand, 2012; Tutu et al., 2008). We analyse the spatial distribution of pressures on biodiversity by overlaying the spatial distribution of a global mines and deposits inventory with a global map of terrestrial biodiversity zones. The tested zero hypothesis argues that large-scale metal mines and deposits are randomly distributed across biodiversity zones. Finally, the question whether new mines could preferably be opened in low biodiversity zones is addressed, so that future mining activities could possibly lower their pressure on global biodiversity.

2. Materials and method

The methodology followed five steps. First, a global inventory of mines and deposits with geographic coordinates for each record (point location) was acquired, filtering the eligible records and preparing the digital data for the analysis. Second, different global mapping approaches for biodiversity were evaluated and a final one was chosen. Third, the spatial location of mines and deposits was overlaid with diversity zones and the observed frequency distribution was calculated. Fourth, a null model was created which allows computing the frequency distribution of mines and deposits randomly distributed across the diversity zones. Fifth, the frequency distributions of the actual (observed) data and the null model were analysed.

2.1. Data inventory of mines and deposits

The global inventory of mines and geological deposits was obtained from the database of the former Raw Materials Group (RMG), update April 2014, nowadays located within the SNL-Metals & Mining database, one of the world's most comprehensive commercial databases containing current and historical information on legal industrial mining entities (SNL Metals and Mining, 2015). Delimited by such inventory, all mines used in this study are large corporate affairs. Artisanal, small-scale or informal (illegal) mines are excluded from the analysis.

Only observations of mines with the status "operating", "closed", "suspended", or "under construction" were considered; observations without specified status or without geographic coordinates were excluded. The mines were not differentiated depending on their extraction method. In the case of mineral deposits, only observations with the status "project/no specification", "conceptual", "pre-feasibility", "feasibility", "abandoned", or "abandoned project" were considered; records for which no status was available were excluded.

Bauxite and iron ore records did not require any further allocation as these metals are predominantly extracted from mono-metallic mines. Copper, gold, and silver, however, are commonly produced in polymetallic mines. These observations were assigned depending on the nature of the main metal as stated in the "main metal" field in the database.

Most of the deposits in use are - despite some exceptions - in an advanced exploration status and known to contain an economically viable amount of ore. All deposits were included in the database if "published resources or reserves are available and this figure is greater than 50 kilotons of ore" (Raw Materials Group, 2004:55). In terms of status, deposits classified as "conceptual", "pre-feasibility", or "feasibility" host economically viable mines with the highest chances of becoming active soon, followed by "abandoned" ones with less chances. Amongst the "project/no specification" category the situation is more diverse and uncertain due to lack of information. However, most of the deposits in the dataset (with the exception of bauxite) are in the phase of becoming a project soon, i.e. they are situated under the "conceptual" or "pre-feasibility/feasibility" phase (Table 1). In order to simplify the analysis and provide a broad picture of trends, it was decided to include all deposits irrespective of their status.

The dataset provides the coordinates for mines and deposits by latitude and longitude with a six digit precision. An independent validation of these coordinates was conducted by sampling 70 randomly selected mine point locations (associated with Fe, Cu, Au, and Ag mines). The linear distance between the centre of the largest open mine pit or the largest mine building (for underground mines) as visible in Google Earth Pro (Google Earth Pro v. 7.1.4, 2015) and the location given in the SNL database was determined. For all mines in combination the mean distance was 2.59 km. These results are in line with previous studies which calculated a margin of error between 1 km and 3 km (Kobayashi et al., 2014). It was concluded that for a global assessment overlapping point locations with regional data the precision of the SNL points for mines and deposits is sufficiently accurate.

Besides allocating mines and deposits depending on the "main metal", the data preparation included the removal of double entries (e.g. a mine site for which two observations exist) as well as the relocation of data points outside a diversity zone (by applying the shortest linear distance to a diversity zone). A detailed description of all data preparation steps taken is given in the supplementary material. The final dataset comprised 2860 mines and 2055 deposits, 56% and 59.5% belonging to gold mines and deposits, respectively (Table 2).

2.2. Data used for mapping global biodiversity

Worldwide maps depicting the distribution of life on Earth and species-diversity have evolved following the expansion of databases, new mapping techniques, and scientific knowledge (i.e. inventories, taxonomic systems, or geospatial databases). Estimations