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Catchment-based approach and formalisation of artisanal and small-scale mining for sustainable mining management in the Philippines

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1. Introduction

The impacts of climate change have created an urgent need to reduce fossil fuel consumption and increase the use of renewable energy. This global clean energy transition is highly dependent on raw materials, with an estimated minimum of 30 energy transition minerals and metals (ETMs) needed [1]. Their demand is projected to increase 500% by 2050 to meet the requirements for clean energy technologies needed to limit global warming to below 2 °C [2]. Mineral-rich developing countries will play a crucial role in meeting the growing demand for ETMs. Yet, these countries also possess some of the world's richest biodiversity [3]; potentially at risk from unsustainable extraction and processing practices.

Governance, including policy and regulation, will be crucial in promoting climate action, particularly in the carbon-intensive [4] metals and mining sector, which is associated with considerable environmental and social impacts. To ensure that the climate change-driven clean energy transition brings tangible benefits to communities directly impacted by mineral extraction, the international community has developed and advocated sustainable mining approaches. These efforts align with the United Nations Sustainable Development Goals (SDGs), aiming to prevent environmental and social harm from unsustainable extraction and processing practices. Programmes such as the Climate-Smart Mining Initiative of the World Bank aim to support mineral-rich developing countries to sustainably extracting and processing minerals and metals, thereby providing a steady supply of clean energy technologies is provided whilst minimising their climate and material footprints [2]. In parallel, the International Council on Mining & Metals (ICMM) advocates a catchment[8]-based approach to manage water resources in the mining sector, aiming to mitigate shared risks and address collective impacts at the river catchment level [5].

Despite these global initiatives, mining governance ultimately depends on national laws and regulatory frameworks, making it essential for each country to develop and implement their own sustainable management practices. The overarching goal remains clear: to balance mineral development and extraction with environmental conservation and social acceptance. In this Perspective, we explore the potential of a catchment-based approach to managing mining-affected areas and propose mechanisms for promoting the formalisation of artisanal and small-scale mining (ASM) in the Philippines. We examine the existing institutional frameworks and suggest practical strategies for prioritising environmental protection and

[8] The word 'catchment' is sometimes used interchangeably with 'river basin', 'drainage basin', or 'watershed'.

integrating community stakeholder participation to address sustainability challenges in the mining sector.

2. Overview of the mining sector in the Philippines

Among developing economies, the Philippines stands out with one of the highest mineral rents per unit of land area, estimated at USD 20 000 per km^2 [3]. The country has been a significant producer of ETMs such as nickel and copper throughout the 20th and 21st centuries, contributing 10%–20% of the global nickel supply between 2011 and 2022 [3]. As the transition to clean energy accelerates, the Philippines is well-placed to harness mining as a driver for socio-economic development, provided it ensures environmental protection and the well-being of affected communities.

To regulate the mining sector, the Philippine government enacted two landmark laws in 1991 and 1995: the People's Small-scale Mining Act and the Philippine Mining Act, with revised implementing rules and regulations, as well as several other pertinent laws that protect local populations and the environment [3]. Additionally, the country committed to participating in the Extractive Industries Transparency Initiative (EITI) in 2013 to enhance transparency, accountability, and synergies between stakeholders in the mining sector. In 2017, the largest mining companies in the Philippines also subscribed to the Towards Sustainable Mining (TSM) initiative [6], making the Philippines one of the 13 countries, and the only Asian country, to implement this global environmental, social, and governance performance measurement standard [7]. Within the Philippine Mining Act, the Social Development and Management Plan (SDMP) requires the extractive industries to allocate 1.5% of their annual operating costs, in addition to taxes and royalties paid to the government, for the development of host and neighbouring communities (75%), advancing mining technology and geosciences (10%), and information, education and communication for public awareness (15%). As a policy instrument unique to the Philippine mining sector, the SDMP has the potential to become a catalyst for change. Significant improvements in the quality of life for host and neighbouring communities have been spurred by SDMP-funded infrastructure projects, enhanced access to basic social services such as healthcare and education, improved transportation, and expanded livelihood opportunities [8]. On the other hand, a nationwide audit of large-scale mining operations in the country from 2018 to 2020 revealed significant opportunities for improving environmental and social performance, including optimising SDMP implementation to achieve broader and more sustainable long-term impacts [9]. Additionally, the 2021 Philippine EITI report highlighted the need for greater public awareness and education on mining technology and geosciences, as well as enhanced engagement and collaboration with various stakeholders. This includes actively involving community representatives in decision-making processes on key social, cultural, environmental, and economic issues [8].

To address these challenges, mining policy in the Philippines would benefit from incorporating a catchment-based management approach for mining areas and from a more rapid action towards fully formalising and more strongly regulating the ASM subsector. These frameworks are essential for effectively monitoring and evaluating sustainable mining practices. They rely heavily on geoscientific data and stakeholder engagement, as explored in the following sections.

3. Catchment-based approach in managing mining-affected areas

From a geoscience perspective, the concept of river catchments is central to the management of mining-affected areas. Within a river catchment, water, sediments, and contaminants from various terrestrial sources, at differing volumes and concentrations, flow into the river due to natural factors such as topography and weathering, as well as anthropogenic factors such as land use. River corridors, including main river channels and floodplains, are the environments most significantly affected, with sediment-associated contaminants being transported, stored and accumulated for tens to thousands of years [10]. In tropical areas with strong climate seasonality, such as the Philippines, contaminated sediment stored in floodplains can be remobilised during storm events, acting as secondary sources of contamination [3]. The projected increase in extreme hydrometeorological events due to climate change could further heighten the exposure of downstream communities and ecosystems to metal contamination. Therefore, adopting a catchment-based approach for mining activities will help in understanding a river's present and future functionality, identifying the location and concentration of contamination sources, and planning remedial and preventive actions.

In the Philippines, mining areas are managed administratively at the national, regional, and provincial levels. However, since mineralised catchments span administrative boundaries and communities, adopting a catchment-based management approach is more appropriate. This approach holistically examines activities and issues across the entire catchment, brings stakeholders together to identify appropriate environmental standards and response measures,

and establishes collaborative mechanisms to implement these actions [5]. A catchment-based approach is already promoted by industry partners, international agencies, and non-governmental organisations beyond the mining sector [11]. While its application would be novel with respect to managing mining areas, a precedent already exists in water resource management in the Philippines. The National Water Regulatory Board regulates surface and groundwater extraction based on water availability and water quality conditions within river catchments. At the same time, the River Basin Control Office (RBCO) oversees the integrated planning, management, rehabilitation, and development of catchments at the national level. By aligning with ICMM guidance [5] and with oversight from these government agencies, management of mining areas at the catchment level is feasible, but would require extensive collaboration among stakeholders. A catchment mining regulatory board, akin to the provincial/city mining regulatory boards (PMRB) outlined in law [3] but with representatives from the RBCO and other relevant agencies, could serve as a practical governance mechanism for operationalising this approach. Such a multi-stakeholder platform will be crucial to encourage cooperation and coordinate across institutional levels [11].

To understand and manage river catchments comprehensively, policies and management strategies for legacy and contemporary mining areas can and should be informed by catchment-specific geological, water chemistry, and geomorphological data that will provide the context for decision-making. The reason for this is that the natural or environmental background is often different between catchments. Given that the Philippines is geologically diverse, natural river water chemistry and background metal concentrations vary considerably across the river catchments of its 7641 islands [3]. Therefore, catchment-specific environmental guidelines should be tailored to the unique geologic setting and land cover. Currently, a national-level classification for water bodies guides water management and environmental impact assessments (EIAs). However, critical data, such as the location and concentration of contaminated sediment, bioavailability, potential ecotoxicity, and geomorphic stability, are not incorporated into EIAs, despite being essential for comprehensive assessments. Furthermore, international sediment quality guidelines are used in the absence of national guidelines [12]. Then again, using such generic guidelines may not always be appropriate when considering the high geological variability, especially in mineralised catchments where background metal concentrations could be orders of magnitude greater than international threshold values [12]. Increasing funding allocation for the development of mining technology and geosciences (DMTGs) component of the SDMP (table 1) could support essential water and soil quality baselining and monitoring programs. As DMTG encompasses the enhancement of environmental protection and mining safety [9], strengthening this component will improve impact assessments and monitoring for mining areas, build stakeholder capacity, and ultimately support the implementation of the recently enacted Philippine Ecosystem and Natural Capital Accounting System law [13].

4. Enhancing environmental and social stewardship through formalisation of ASM

Effective catchment-based management not only requires robust scientific data but also the active participation and responsible practices of local communities, including those involved in ASM. From a socio-environmental perspective, a key challenge for governments and the mining sector is ensuring the sustainability of ASM activities. In many parts of the world ASM provides the primary nonfarm rural income, driven by continued demand for minerals, domestic economic, environmental, and social drivers, including the impacts of climate change on farming and other nature-based livelihoods [14]. Although ASM can contribute to prosperity and poverty reduction, its current practices have significant negative environmental and social impacts [15]. Thus, formalising the ASM serves as a complementary pathway to enhance environmental and social development, aligning directly with core SDG themes [15].

In the Philippines, ASM remains relatively unregulated [16], unlike large-scale mining, which is subject to stringent regulations. Whilst ASM produces substantial amounts of gold, its economic benefits remain obscure due to smuggling and black market dominance [17]. Aside from non-compliance with taxes, ASM has longstanding issues of environmental and health and safety violations, including child labour and the use of mercury and cyanide in extracting gold [16, 17]. Therefore, ASM formalisation and regulation must be prioritised to promote a cleaner and more sustainable mineral supply. First, emphasis should be placed on the government's central role in regulating, monitoring, and fostering sector development, while also incentivising miners and authorities to adopt and uphold standards that follow governance frameworks and enhance mine performance [14]. Global initiatives adopted in the Philippines, such as the EITI and TSM, can be further supported by policy interventions that promote ASM formalisation and cooperation with large-scale

Table 1. Relevant laws to regulate the Philippine mining sector, including Republic Acts (RA), Executive Orders (EO), and DENR Administrative Orders (DAO).

Law and year enacted	Related mandates
RA No. 7076: People's Small-scale Mining Act (1991) **DENR AO No. 2022–03**: Revised Implementing Rules and Regulations of RA No. 7076 (2022)	Regulation of small-scale mining in the Philippines, including but not limited to he following: (i) Definition of small-scale mining (ii) Declaration of People's Small-scale Mining Areas (iii) Permitting arrangements (iv) Creation of a People's Small-scale Mining Protection Fund (v) Creation of a Provincial/City Mining Regulatory Board (PMRB), composed of the Mines and Geosciences Bureau Regional Director, Provincial Governor or City Mayor, one representative each from small-scale mining, large-scale mining, and environmental non-government organisation
RA 7942: Philippine Mining Act (1995) **DENR AO No. 96–40:** Revised Implementing Rules and Regulations of R.A. 7942 (1996) **DENR AO No. 2010–13:** Amendments to Section 16 (Ancestral Lands) and to Chapter XIV (Development of Mining Communities, Sciences and Mining Technology) of DENR AO No. 96–40, as amended, the Revised Implementing Rules and Regulations of RA NO. 7942, Otherwise Known as the Philippine Mining Act of 1995" (2010)	Regulation of large-scale mining in the Philippines, including but not limited to the following: (i) Mineral agreements (ii) Conduct of an Environmental Impact Assessment (iii) Preparation of an Environmental Protection and Enhancement Program (EPEP) and a Final Mine Rehabilitation and Decommissioning Plan (FMRDP) (iv) Implementation of a Social Development and Management Program (SDMP) (v) Requirement for a Free, Prior, and Informed Consent (FPIC) Annually, a minimum of 1.50% of the operating costs for the SDMP; provided that of this amount: • 1.125%, or 75% of the SDMP fund, shall be apportioned for the development of the host and neighbouring communities (DNHC) • 0.150%, or 10% of the SDMP fund, for the development of mining technology and geosciences (DMTG) • 0.225%, or 15% of the SDMP fund, for the implementation of Information, Education and Communication (IEC) Program
RA No. 8371: Indigenous People's Rights Act (1997)	Promotion and protection of the rights of indigenous communities, especially in consenting to activities that may affect their domain

(Continued.)

Table 1. (Continued.)

Law and year enacted	Related mandates
EO No. 79: Institutionalizing and Implementing Reforms in the Philippine Mining Sector Providing Policies and Guidelines to Ensure Environmental Protection and Responsible Mining in the Utilization of Mineral Resources (2012)	(i) Establishment of Mining Industry Coordinating Council (MICC) (ii) Identification of 'no go zones', where exploration and mining cannot be done, which included protected areas and areas geographically close to mining (e.g. tourist areas, strategic agricultural lands, island ecosystems) (iii) Small-scale mining operations can only be done in Government-approved 'Minahang Bayan' (Communal Mining) areas (iv) Resource Accounting to value the natural resources (v) Membership of mining companies to the Extractive Industries Transparency Initiative
RA No. 10625: Philippine Statistical Act (2013)	Creation of the Philippine Statistics Authority to serve as the central statistical authority of the government on primary data collection Collection, compilation, analysis, and publication of statistical information relating to the country's economic, social, demographic, political affairs and general activities and condition of the people (including environmental accounts, statistics, and indicators)
DENR AO 2016-08: Water Quality Guidelines and General Effluent Standards (2016) **DENR AO 2021-19:** Updated Water Quality Guidelines and General Effluent Standards for Selected Parameters (2021)	Classification of water bodies in the country Determination of time trends and evaluation of stages of deterioration or enhancement of water quality Basis for taking positive actions in preventing, controlling, or abating water pollution
DENR AO No. 2022-03: Enhancing Biodiversity Conservation and Protection in Mining Operations (2022)	Integration of biodiversity measures into environmental management programmes, such as conducting economic valuation of ecosystem services
RA No. 11995: Philippine Ecosystem and Natural Capital Accounting System (PENCAS) Act (2024)	Development of a comprehensive information system and accounting framework that will take into consideration the role of our natural capital, consisting of both environmental and natural resources including ecosystem services, and its impact on the economy Compilation and progressive integration of natural capital accounts in macroeconomic indicators, strengthening and building on the Philippine Statistical Act

operators [15]. For instance, it is difficult for individual small-scale miners to comply with ASM permitting requirements [17]. To address this, the government could explore ways to simplify and streamline the process, ensuring easier compliance and oversight of ASM activities. Such licensing simplification, coupled with institutional support, has successfully expanded the ASM sub-sector in Tanzania [18]. Institutional reforms related to the decentralisation of ASM licensing have also been recognised as a priority action in other sub-Saharan African countries such as Sierra Leone [19].

An inclusive formalisation of ASM operations could enhance environmental accountability, particularly in the proper containment, treatment, and disposal of tailings. Additionally, instead of treating mining wastes as entirely hazardous end products, investments in understanding the potential for valorising mining wastes can create economic and environmental benefits. Such a formalisation would promote socio-economic equity by ensuring tax compliance, guaranteeing fair wages, and implementing stricter environmental standards. It would support potential institutionalised synergies between ASM and large-scale mining, such as the establishment of mining complexes where both sub-sectors operate as unified systems [20]. Since the law already mandates the inclusion of an ASM representative in PMRBs, integration of their participation alongside local and indigenous communities into existing and proposed governance systems that enhance not only ASM participation, but also decision-making and shared responsibility, would help bridge gaps in the implementation of mining laws.

5. Conclusion

The world's ongoing transition to net zero is expected to yield significant economic and environmental benefits, driven by the increased production of ETMs, higher cost-efficiency of clean technologies, and greater baseload renewable energy. Achieving these benefits sustainably requires robust management frameworks that integrate environmental stewardship and socio-economic development. Developing and implementing catchment-based approaches can guide management practices to preserve or improve the health of mining-affected river catchments. At the same time, advancing the formalisation of the ASM subsector is essential to align local practices with national environmental and social standards. Adopting these two complementary approaches, anchored in strengthened institutional governance, will not only enhance environmental protection but also provide a practical approach to sustainably address the challenges posed by legacy, current, and future mining activities.

Data availability statement

No new data were created or analysed in this study.

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