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The Paradox of Nickel Investment in Indonesia

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ABSTRAK

Indonesia, home to the world's largest nickel reserves, plays a vital role in the global electric vehicle supply chain. However, large-scale nickel exploitation has caused serious ecological and social issues, especially in Sulawesi and Maluku. This study examines the socio-ecological impacts of nickel mining and explores pathways for sustainable management. Conducted from February to November 2024 in Central Sulawesi, Southeast Sulawesi, and North Maluku, the research used qualitative methods, including interviews, observations, and document analysis. Findings show that while nickel exploitation has spurred economic growth through investment and industrialization, it has also led to environmental degradation, pollution, and loss of local livelihoods. The unequal distribution of economic benefits, weak environmental regulation, and limited community involvement have worsened local conditions. Stakeholders express differing views on the industry's impact, revealing the need for inclusive, collaborative, and justice-based management approaches that balance economic gains with ecological and social sustainability.

Keywords: economic growth; environmental degradation; investment; nickel exploitation; socio-ecological impact

INTRODUCTION

As the world's largest holder of nickel reserves, Indonesia plays a pivotal role in meeting the growing global demand for nickel, particularly in the electric vehicle (EV) industry. According to the Ministry of Energy and Mineral Resources (2020), Indonesia possesses 72 million tons of nickel reserves, including limonite, accounting for 52% of global nickel reserves. This substantial reserve positions Indonesia alongside Australia (15%), Brazil (8%), and Russia (5%) as a leading global nickel producer. The same report indicates that Indonesia's nickel reserves are projected to last until 2047.

Indonesia's strategic position aligns with the increasing global demand for nickel, driven by the expansion of the EV industry. The EV sector is expected to grow significantly, in line with the global energy transition aimed at reducing greenhouse gas emissions as a climate change mitigation strategy (Nassef et al., 2025). A report by the Fan et al. (2025) highlights a sharp increase in global EV sales from 0.2% in 2013 to 13% in 2022. In 2022, China led EV sales with 6.181 million units, followed by Europe with 2.683 million units, North America with 1.108 million units, and other regions with 551 thousand units.

The rapid growth of EV production presents a positive opportunity for Indonesia, as EVs utilize nickel-based batteries, positioning the country as a central hub in this sector (Meirizal et al., 2023). The widespread adoption of EVs is driven by the perception that they are a crucial solution for mitigating climate change by reducing carbon emissions from fossil fuel-powered vehicles (A. D. Santoso et al., 2024). This aligns with global commitments post-Paris Agreement to enhance greenhouse gas emission reduction targets (Su et al., 2025).

However, the surge in EV production and global nickel demand has led to intensified nickel exploitation in Indonesia, particularly in Sulawesi and Maluku (Warburton, 2024). These regions

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are known as the primary nickel reserves in Indonesia (Schodde & Guj, 2025). The Ministry of Energy and Mineral Resources (2020) notes that Indonesia has issued 292 Mining Business Licenses (IUPs), with 154 in Southeast Sulawesi, 85 in Central Sulawesi, 44 in North Maluku, 34 in South Sulawesi, 2 in Maluku, and 4 in Papua; 11 smelters, and 4 work contracts as the forefront of nickel mining and production. However, the increased mining activities raise concerns, as the majority of IUPs (93.49%) are located in Sulawesi, a region within the Wallacea biodiversity hotspot with high levels of endemic flora and fauna.

Research by Haryadi et al. (2024) indicates that nickel exploitation in Morowali, Central Sulawesi, has led to significant environmental degradation, including extensive deforestation and ecosystem damage. Similarly, Muthalib & Nuryadi (2023) found that nickel mining activities in South Konawe, Southeast Sulawesi, resulted in soil fertility decline and reduced irrigation quality, causing losses for rice farmers amounting to IDR 3,102,476 per hectare. Zainuddin Rela et al. (2021) reported that nickel mining in Kolaka, Southeast Sulawesi, has led to issues in licensing processes, land clearing, and production, continuously degrading environmental quality. These studies highlight the high dynamics of nickel mining, often lacking the application of good mining practices and neglecting environmental sustainability principles. Nancy (2022) revealed that many mining practices overlook environmental and social management aspects, exacerbating the negative impacts.

In line with this, most nickel mining companies in Indonesia are Foreign Direct Investment (FDI) entities '(Qaseem, 2023). Sarkodie & Strezov (2019) suggests that foreign companies sometimes lack a sense of ownership over the environment and local communities, leading to suboptimal environmental management. Kartiko et al. (2023) emphasizes that legal policies facilitating foreign investments have negative impacts by marginalizing domestic funding and resource potentials. This situation triggers social disharmony, particularly prolonged tensions and conflicts. Hyldmo et al. (2025) explain that social conflicts often arise during land acquisition, land clearing processes, labor recruitment, and production activities, leading to disputes between local and foreign workers. 'Karsadi & Aso (2023) reveal that these social conflicts often result in prolonged tensions and even fatalities. For instance, Kadek & Pradnya (2025) reported in various print and online media about clashes between local communities and company personnel, causing physical and psychological harm to surrounding communities in several mining projects in Sulawesi and Maluku.

Beyond significant social impacts, nickel exploitation also poses environmental risks, particularly in the Wallacea region, known for its exceptionally high biodiversity levels Prematuri et al. (2020). 'Slavenko et al. (2023) explains that this area serves as a biogeographical transition zone with extraordinary levels of flora and fauna endemism, making it one of the most biodiverse regions globally. Skeels et al. (2023) mentions that the Wallacea region possesses unique natural characteristics with diverse flora and fauna, distinct from other parts of Indonesia and the world, rendering it a natural laboratory for global scale research. However, poorly managed nickel mining threatens to degrade the environment and contribute to the extinction of endemic species found only in this region (Adidharma et al., 2023; Brown et al., 2024; Nasution et al., 2024).

The negative impacts of nickel exploitation are not limited to environmental and social damage but also extend to economic disparities (Fazaalloh, 2024). According to a report by Myllyvirta et al. (2024), although the mining sector significantly contributes to Indonesia's GDP, many nickel-producing regions, such as those in Sulawesi and Maluku, do not experience substantial benefits from these activities. Nurlaela et al. (2020) state that the income generated from nickel exploitation is often enjoyed primarily by large corporations and foreign investors, while local communities continue to struggle with limited access to decent employment, adequate public facilities, and improved quality of life.

This study offers a novel interdisciplinary approach by integrating environmental, social, and economic dimension to assess the real impacts of nickel exploitation in Wallace's biodiversity hotspot an area rarely analyzed holistically, thus filling the gap in sustainability governance in Indonesia's strategic resource regions. Therefore, this study aims to further explore the implications of nickel exploitation on environmental conditions in Indonesia, particularly in the three main nickel-producing regions: Central Sulawesi, Southeast Sulawesi, and North Maluku. The research examines how nickel exploitation affects the social and ecological conditions in these areas. Innovation and breakthroughs are urgently needed in managing natural resources especially nickel by applying the principles of sustainability and ensuring a balance between social, economic, and ecological aspects to achieve more sustainable development in Indonesia.

RESEARCH METHODS

This study employed a qualitative research approach to gain a comprehensive and holistic understanding of the impacts of nickel exploitation in Indonesia. The qualitative method was chosen for its strength in capturing contextual realities, local perspectives, and complex interactions among ecological, social, and economic dimensions in the study areas.

The research was conducted from February to November 2024, focusing on the main nickel-producing regions in Indonesia: Central Sulawesi, Southeast Sulawesi, and North Maluku. These areas were chosen because they are the largest contributors to Indonesia's nickel output and represent the regions most affected by mining activities in terms of social, economic, and environmental dimensions. Direct field observations were carried out to examine ecological landscape changes, community dynamics, and economic activities associated with the mining industry.

The population of this study includes all individuals who are directly or indirectly involved in or affected by nickel mining activities in the study areas. To gain rich and context-specific insights, a qualitative method with purposive sampling was employed to select informants based on their relevance to mining-related issues and capacity to provide in-depth information. A total of 45 key informants were interviewed in-depth, consisting of: (a) Local community members: 15 individuals, including farmers, fishers, and indigenous leaders living near mining sites; (b) Mine workers: 15 individuals from both formal and informal sectors; (c) Company representatives: 9 individuals from various managerial and operational levels; and (d) Government officials: 6 individuals from relevant agencies such as the Environmental Office, Industry Department, and Mining Department.

Semi-structured interviews were used to explore experiences, perceptions, and expectations related to mining impacts and regulatory responses. To analyze the qualitative data, this research employed an exploratory descriptive approach, allowing a deep and nuanced understanding of the socio-ecological implications of nickel investment in the study sites. This method allowed for the thorough exploration of primary data such as interviews with affected communities, field observations, and documentation along with secondary data, including official reports, academic studies, and relevant statistical records.

In addition to collecting primary

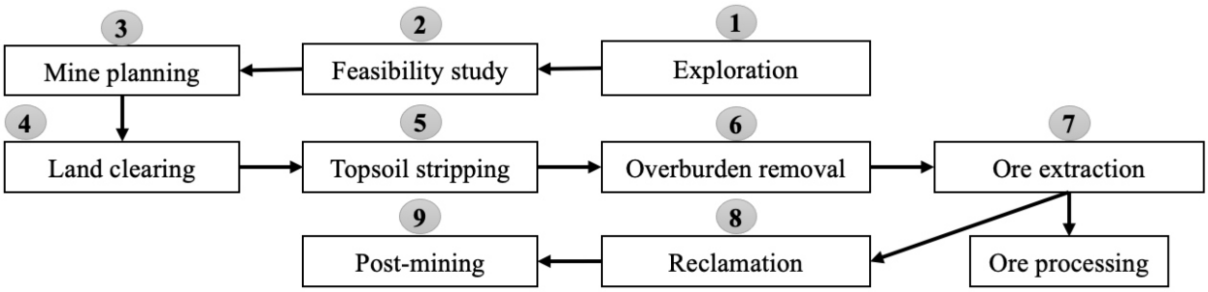
data through field observations and in-depth interviews, this study also incorporated an extensive literature review of various secondary sources. The literature review was conducted systematically to support and triangulate the findings derived from the field. Key secondary sources included peer-reviewed articles from internationally recognized journals, policy reports, and research publications from reputable international organizations. These sources provided broader insights into the global context of nickel investment and its associated environmental and socio-economic impacts, enabling the study to position Indonesia's case within a comparative and theoretical framework. The integration of both primary and secondary data enhanced the robustness of the analysis by combining localized, grounded perspectives with global discourses and empirical evidence. This approach enabled a holistic and critical examination of the paradoxes surrounding nickel investment, especially the tension between economic development and environmental-social sustainability without shifting from the qualitative paradigm. Through this lens, patterns and relationships between nickel extraction and local transformations were uncovered, including perceptions, local responses, conflicts, and adaptive strategies within affected communities.

RESULTS AND DISCUSSION

Nickel Mining and Processing Activities

Nickel mining in Indonesia has become one of the key sectors supporting the national economy, as the country is the world's largest producer of nickel. According to the Ministry of Energy and Mineral Resources of the Republic of Indonesia (Ministry of Energy and Mineral Resources, 2020), there are two main types of nickel ore found in the country: laterite and limonite. Each type has distinct characteristics and requires specific processing methods. According to Zhang et al. (2020), laterite nickel ore is formed through the chemical weatheringof ultramafic rocks containing nickel. In Indonesia, as noted by Patadungan et al. (2024), laterite nickel is commonly found in tropical regions, particularly on the islands of Sulawesi, Maluku, and parts of Papua. Farrokhpay et al. (2019) explain that laterite ores generally have lower nickel content compared to sulfide ores, but because they are typically located near the surface, they are easier to extract.

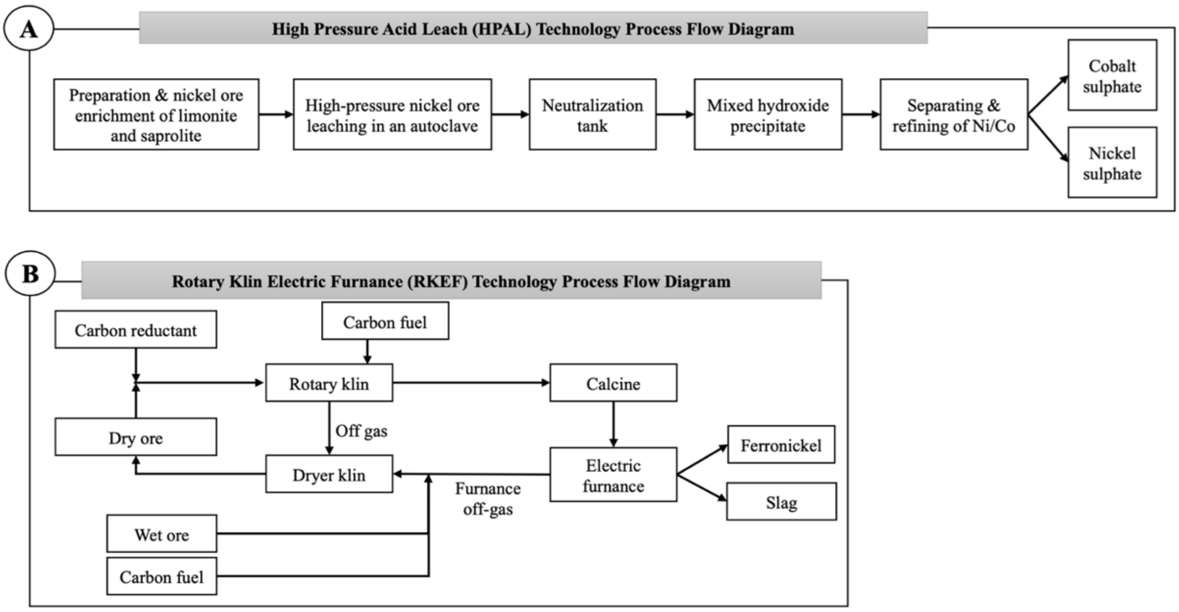
Limonite, on the other hand, is a type of mineral found within the laterite layer and is an iron oxide that contains nickel, as described by Astuti et al. (2024). Research by Xue et al. (2022) found that limonite has a relatively lower nickel content compared to other types of laterite, but it is widely available in Indonesia. Like laterite, limonite is often located near the surface and is extracted using open-pit mining methods, as stated by Abdul et al. (2020). Fundamentally, the mining process for both types of nickel ore follows the same basic stages, as illustrated in Figure 1.



Source: Cao et al. (2025

Figure 1

Nickel Mining Process (Pre-operation, Operation, and Post-Mining)



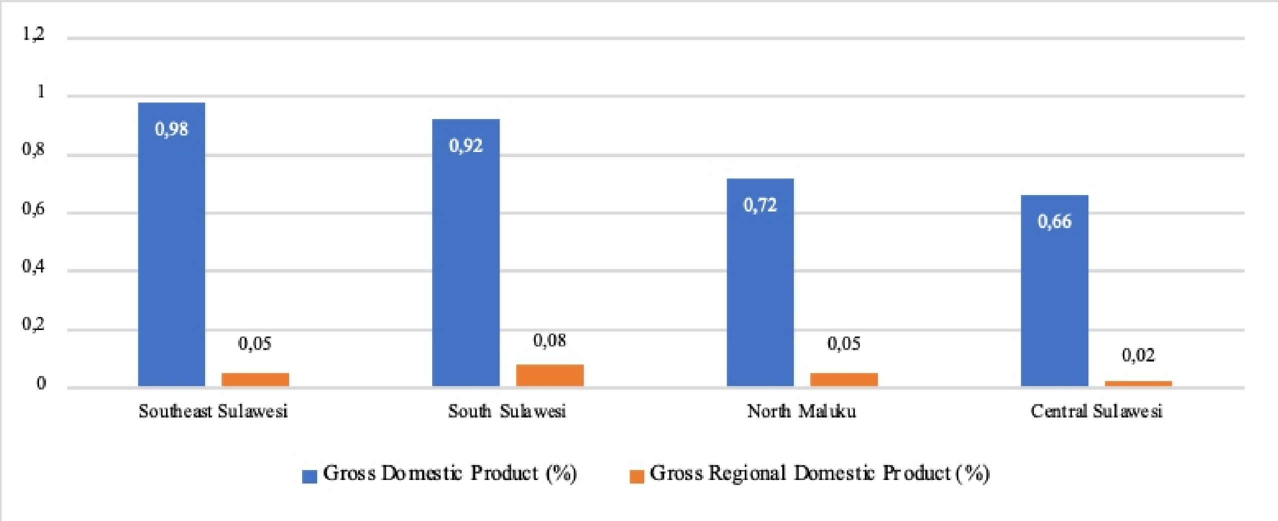
Source: Çoban & Baş (2022) and Satritama et al. (2024)

Figure 2

Nickel Ore Processing, (A). HPAL Technology and (B). RKEF Technology

Figure 1 shows that the first step is exploration. According to Motta & Faria (2016), this process is conducted to determine the quantity and quality of nickel reserves, field conditions, and geological structure. Next, the results of the exploration are assessed for feasibility '(Sabaruddin et al., 2023). If deemed viable, the process moves on to mining planning, followed by land clearing to remove various types of vegetation in order to facilitate the stripping process (König, 2021; Stopic & Friedrich, 2016; Zhang et al., 2020). Stripping the overburden is the stage of accessing the nickel ore, where the soil is excavated to a certain depth where nickel reserves are found (Heijlen & Duhayon, 2024). The excavated soil is then moved to a safe location, referred to as a top-soil bank (Acero, 2023). Afterward, the nickel ore is extracted using heavy equipment such as excavators and transport trucks (Razika, 2022). At this stage, the nickel ore obtained is still in raw form and must undergo further processing to produce pure nickel (Putzolu et al., 2019). The next process involves refining the ore through pyrometallurgical or hydrometallurgical methods (Liang et al., 2022; Stopic & Friedrich, 2016) depending on the type of ore found (Figure 2). In some cases, hazardous chemicals are used during the refining stage, such as sulfuric acid, cyanide, or mercury (Martin et al., 2019). The residues from these chemicals have the potential to contaminate the environment if not properly managed.

The nickel processing process, as shown in Figure 2, involves the use of hazardous chemicals such as sulfuric acid, which can potentially pollute the environment if not properly managed (Moyo et al., 2024; Salehi et al., 2023). Chemical waste from the refining and flotation processes can degrade the quality of soil, water, and air, as well as threaten surrounding ecosystems. This condition aligns with the findings of Kowasch (2018), who highlighted that waste from the mineral mining industry can cause significant environmental degradation, especially when waste management systems are inadequate. Additionally, Heijlen & Duhayon (2024) revealed that open-pit mining activities, often accompanied by deforestation and land degradation, also lead to widespread ecological and social impacts, such as the loss of biodiversity and disruption of local communities. This reinforces the argument made by Chen et al. (2024), who emphasize the importance of sustainable



Source: Taufikurahman et al. (2023), processed

Figure 3

Contribution of a 1% increase in investment and operations to GDP and GDRP (%)

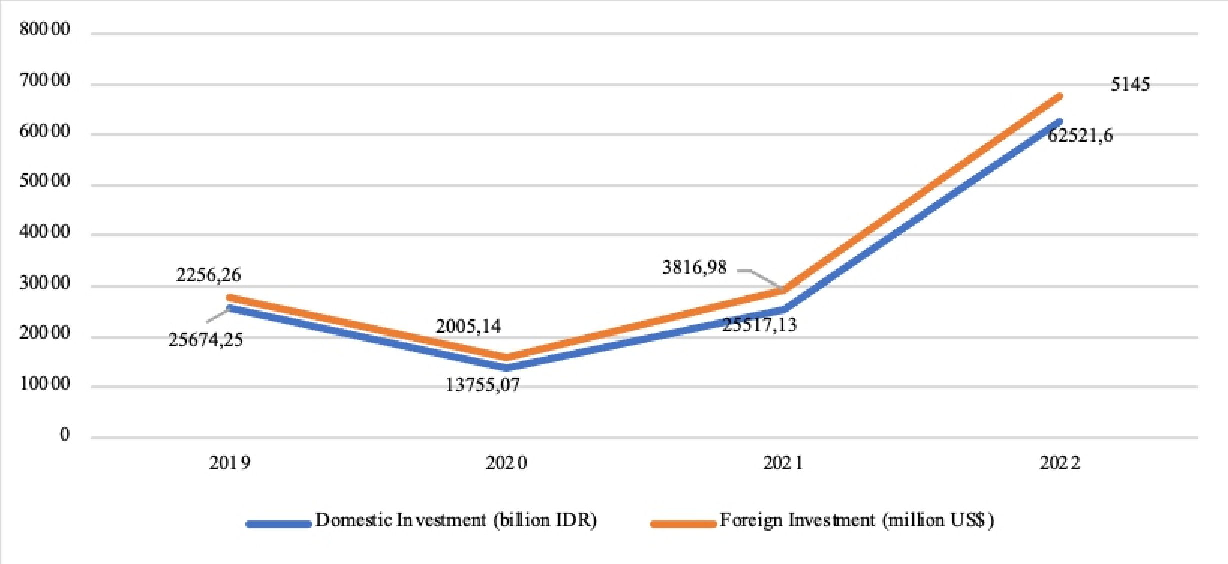
approaches in the mining sector, including through active involvement of local communities and comprehensive environmental impact assessments. Therefore, nickel processing is not only a technical issue but also demands serious attention to environmental and social aspects.

In this context, Severiano et al. (2025) stress that the balance between resource exploitation and environmental preservation is a central issue that cannot be ignored. Similarly, Kowasch (2018) reported that the socio-ecological challenges of mining activities continue to emerge, while on the other hand, the sector remains a strong magnet for investment, especially due to its significant economic value potential. Thus, it is important to examine how investments in the nickel industry contribute to national and regional economic growth, and how such investments can be directed to align with sustainable development principles.

Nickel Industry Investment

Nickel mining in Indonesia indeed provides a significant economic contribution, but Warburton (2024) warns that the challenges of environmental management and sustainability require serious attention in order to minimize negative impacts on the socio-ecological aspects. According to Taufikurahman et al. (2023), it must be acknowledged that investment in the nickel industry, both mining and processing, has led to improvements in national and regional economic value, but social and environmental aspects still need serious attention. Figure 3 displays a graph showing the contribution of nickel investment to the regional economy.

The research by Taufikurahman et al. (2023) reveals that investment and mining operations in Sulawesi have made a significant contribution to regional economic growth through increased GRDP and employment absorption, particularly in Southeast Sulawesi and South Sulawesi. However, their findings also highlight an imbalance in the distribution of economic benefits across regions, with areas such as Central Sulawesi and North Maluku receiving much smaller benefits despite also being mining production areas. This disparity reinforces the research by Nurlaela et al. (2020), which discusses how extractive industries often exacerbate structural inequities and marginalize local communities that are most affected socially and ecologically. Additionally, Syahputra (2024) explains that although job creation has increased, the number of jobs has not been proportional to the environmental and social impacts caused. Therefore, its crucial for nickel investment and downstream policies to focus not only



Source: Central Bureau of Statistic, (2023), processed

Figure 4

Development of Mining Sector Investment Achievements form 2019-2022

on economic growth but also on ensuring the equitable distribution of benefits and the protection of local communities and ecosystems.

This study further confirms those findings by revealing that many mining operations in Central Sulawesi and North Maluku are dominated by foreign-owned companies, which tend it repatriate profits rather than reinvest locally. A a result, the economic multiplier effect in these regions is relatively weak. Informants reported that although mining activities have intensified, public infrastructure such as roads, healthcare, and schools remain underdeveloped. Moreover, job opportunities are often limited to low-skilled labor, with managerial and technical positions occupied by workers from outside the region. This creates a dual economy structure where local communities remain economically marginalized despite living in resource-rich environments. The unequal benefit sharing not only deepens socio-economic disparities but also fuels social tension and erodes public trust in both corporations and government institutions.

However, the field data suggests that the benefits of downstream policies are not yet felt equally across regions. While Southeast Sulawesi has seen a rise in supporting industries and related job opportunities due to the presence of smelters, Central Sulawesi and North Maluku remain predominantly as raw material suppliers, lacking adequate downstream facilities. This structural gap not only limits their development potential but also exacerbates the environmental burden without corresponding economic compensation. Thus, for downstream policy to truly support sustainable and inclusive development, it must be accompanied by regional industrial planning, local workforce capacity-building, and benefit-sharing mechanism that prioritize communities in extraction zones.

The positive growth in the economy and increased employment absorption indicate that investment in the extractive industry sector can serve as a driver for regional and national economic growth. As explained by Farawansa & Ratnawati (2024), nickel down-streaming in Indonesia is a strategic policy aimed at adding value to natural resources through further processing before export. This policy was promoted with the issuance of Peraturan Pemerintah Republik Indonesia Nomor 1 Tahun 2024 Tentang Harmonisasi Kebijakan Fiskal, which regulates the ban on the export of nickel in raw ore form, with the aim of encouraging the development of domestic processing industries. This down-streaming policy has successfully stimulated positive growth for mining investment in Indonesia (Figure 4).

The findings in Figure 4 indicate an increase in investment in the mining sector, including the development of nickel smelters. In line with this, ""'Santoso et al. (2024) states that the downstream policy is designed to optimize the added value of natural resources and attract foreign investment. The increase in the number of smelters to more than 40 units over the past three years reflects the initial success of the mining industrialization strategy in boosting economic independence and creating jobs. However, this data also underscores concerns reported by Myllyvirta et al. (2024) that the development of the extractive industry without attention to social and environmental aspects can exacerbate social inequalities and cause ecological degradation. Thus, while these findings support the argument for the effectiveness of downstream policies in driving economic growth, Myllyvirta et al. (2024) also demonstrate that economic benefits need to be balanced with comprehensive sustainability policies to avoid long-term impacts on society and the environment.

Although the development of the nickel downstream industry in Indonesia brings great hopes for national economic growth, increased investment, and job creation, the complexity of the social and ecological impacts it generates cannot be ignored. Structural transformation through down-streaming has reshaped the economic landscape in many nickel-producing regions; however, Karsadi & Aso (2023) remind us that industrialization without careful spatial and social planning often leads to land conflicts, the marginalization of indigenous communities, and heavy pressure on environmental carrying capacity.

Field interviews conducted in Central Sulawesi and North Maluku reveal that many smelter projects are established without proper community consultation and Environmental Impact Assessment (AMDAL). Communities in affected areas often feel excluded from decision-making processes and bear the environmental costs without receiving proportional economic benefits. For example, residents reported worsening air and water quality, loss of farmland, and increasing social tensions due to unequal access to jobs and infrastructure. These findings highlight the gap between national economic targets and local realities, emphasizing the need for inclusive planning and locally tailored sustainability safeguards.

In a global context, according to Ren et al. (2024), Indonesia's nickel industrialization is now inseparable from geopolitical dynamics and the clean energy transition agenda. As Michel (2024) notes, the drastically increased demand for nickel as a key component for electric vehicle (EV) batteries positions Indonesia strategically as a major supplier, but it also confronts the country with the dilemma of balancing global market demands with domestic environmental sustainability. Therefore, it is crucial to critically assess the socio-ecological implications of nickel industrialization, especially regarding the pressure on local ecosystems and communities, particularly in the context of the global energy transition era, which demands massive yet sustainable mineral supplies.

Implications of Nickel Industrialization on Socio-Ecological Aspects

The high global demand for nickel is driven by the energy transition towards net-zero emissions (NZE) as a commitment to the Paris Agreement and COP26, particularly through the development of electric vehicles (EVs), which heavily rely on nickel as a key component of batteries, as projected by the 'International Energy Agency (2021). This positions Indonesia, as the world's largest nickel exporter, in a strategic role to meet the surge in demand until 2050. These findings support Østergaard (2024) and

Table 1
Potential Negative Impacts of Nickel Mining

No	Activity	Primary negative Imp act	Secondary Negat ive Impact
1	Exploration	Disruption of natural habitat	Habitat fragmentation
		Potential contamination of water resources	Public health disturbance
		Potential introduction of invasive alien species (IAS)	Changes in community structur e and decline in biodiversity
2	Land clearing	Deforestation	Sedimentation, floodi ng, and decreased water quality
		Soil erosion	Potential increase in respiratory infections
		Decline in air quality	Public health disturbance
		Decline in water quality	Public health distu rbance
3	Mining or extraction	Water pollution	Death of aquatic organism, public health risks, and potential social conflicts
		Decline in soil quality	Reduced agricultural yields and the emergence of social inequality
		Air pollution	Increased risk of r espiratory infections and potential for social conflict

Source: Primary Data Processed, 2025

theSrinivasan et al. (2025), who emphasize the importance of nickel in global EV development, especially in countries like China and the United States. However, large-scale exploitation in regions like Sulawesi and North Maluku reveals a paradox, where the increase in upstream production often overlooks environmental carrying capacity, as evidenced by "Zainuddin Rela et al. (2021), who report ecosystem degradation, losses for farmers, and systemic damage due to uncontrolled land clearing. In this context, Randrikasari et al. (2025) emphasize that green technologies should be applied not only in the processing sector but also from the mining stage to minimize the widening environmental and social impacts.

Such efforts are important, but they are focused on the nickel processing industry, whereas the exploitation also occurs in mining activities, which often have a far greater environmental impact. It must be acknowledged that nickel mining in Sulawesi and North Maluku frequently causes fundamental issues that lead to the viral spread of cases such as deforestation, flooding, landslides, and water pollution. Table 1 presents data on the potential negative impacts of nickel mining in these two regions.

Table 1 illustrates the range of negative impacts that can occur throughout the stages of nickel exploitation, from exploration to active mining. Seemingly simple activities such as field surveys can actually have significant ecological consequences, including disruption of natural habitats, contamination of water sources, and the introduction of invasive alien species (IAS). Saul et al. (2017) note that surveys conducted without adequate mitigation often serve as the primary entry point for IAS, which subsequently disrupt local ecosystem stability. These impacts become more severe during the land clearing phase, which not only causes deforestation and soil erosion but also leads to a decline in air and water quality due to the destruction of vegetation cover. Research by Morel et al. (2025) De Frenne et al. (2021) and complement each other in showing that land clearing causes drastic microclimate changes, disrupting faunal communities and soil microorganisms, ultimately reducing long-term ecological carrying capacity. At the mining stage, environmental and social impacts become more permanent and cumulative. Intensive activities such as topsoil stripping, chemical use, and emissions from heavy machinery result in widespread air and water pollution as well as a significant decline in soil quality. Hirlekar et al. (2025) emphasize that these impacts often trigger social tensions due to the low absorption of local labor and the damage to communities' access to clean water and food sources. Reagen & Faha (2023) even found that natural resource exploitation encourages negative interactions between wildlife and human communities, increasing the risk of social conflict and systemic environmental degradation. These cumulative impacts have become apparent in various regions such as Southeast Sulawesi, Central Sulawesi, and North Maluku, where nickel exploitation has simultaneously led to ecological destruction and social inequality.

Therefore, comprehensive mapping of actual impacts is essential as a foundation for formulating policies that prioritize a balance between economic growth, environmental sustainability, and social justice. Several of the negative impacts listed in Table 1 have already occurred and are still ongoing in the field. In Southeast Sulawesi, Central Sulawesi, and North Maluku, nickel exploitation has drawn increasing attention from researchers and environmental observers due to the accumulating effects. Table 2 presents the actual negative impacts of nickel exploitation that have occurred and become matters of public concern.

Field interviews revealed that the negative impacts of nickel mining are not abstract risks but have been directly experienced by local communities in mining areas. In Morowali, Central Sulawesi, a local community explained: *"We never used to have floods here, but now every rainy season, the water rises. It's because the forests and hills have been cleared for mining.* This statement reflects growing concern over increased flooding and landslides, which locals associate with large-scale deforestation and land degradation.

In Bombana, Southeast Sulawesi, a traditional fisherman shared: *"It's hard to catch fish now. the seawater is murky, and many coral reefs are damaged. We used to fish just a few meters from the shore, but now we have gone to much farther out"*. This highlights the ecological impact of mining on marine ecosystems and the disruption of coastal livelihoods that depend heavily on health ocean conditions.

These firsthand accounts illustrate that environmental degradation from mining operations directly increases the socio-economic vulnerability of affected populations. In addition to the loss of livelihoods, communities reported reduced access to clean water, food sources, and safe living environments. Several respondents also expressed frustration over being excluded from decision-making process related to mining operations. As one respondent stated: *"The companies and government never asked us. We only find out when the machines arrive"*. These findings confirm that the nickel exploitation in the Wallacean regions is producing layered impacts on ecological, social, and economic that cannot be addressed by economic growth alone. The call for inclusive, locally informed, and sustainability-focused governance approaches.

Table 2 illustrates that nickel exploitation activities in North Maluku, Southeast Sulawesi, and Central Sulawesi, while contributing to economic growth and employment, also generate negative impacts such as environmental degradation, the loss of access to safe and nutritious food sources, the disappearance of primary livelihoods, and an increase in the frequency of natural disasters. These various environmental impacts indicate that nickel exploitation in these regions has not yet adhered to the principles of good mining practice and has failed to prioritize environmental considerations. Furthermore, the occurrence of flooding

Table 2
Existing Negative Impacts of Nickel Exploitation Activities

Type	Impact	Location	Reference
Waste pollution and ecosystem structure disturbance	The structure of the gastropod community in the mangrove area affected by overburden waste showed a low diversity index value (H′ = 0.81), low species richness (R = 1.75), moderate evenness (E = 0.50), and dominance of certain species (C = 0.54).	Tambea Village, Pomala District, Southeast Sulawesi	(Purnama et al., 2024)
Deforestation	7,721 villages in Sulawesi showed that deforestation nearly doubled between 2011 and 2018.	Sulawesi Indonesia, 2011 and 2018	(Lo et al., 2024)
Deforestation and GHG emission	Approximately 5,331 ha of tropical forests have been cleared within the nickel mining concessions in Halmahera, resulting in the loss of about 2.04 metric tons of greenhouse gases previously stored there in the form of carbon.	Halmahera, North Maluku	(Nasution et al., 2024)
Air pollution	Another Air pollution from mining activities, which have operated 30 Smelters using Rotary Kiln Electric Furnace (RKEF) technology with a total production of 300,000 tons of nickel per year, is believed by the author to deteriorate air quality significantly.	Central Sulawesi and North Maluku	(Nasution et al., 2024)
Waste, shallowing, and flooding disasters	The increase in mining waste, sedimentation, and the silting of surface water bodies, along with the risk of flooding, are consequences of clean energy projects that exploit natural resources.	Sulawesi	(Nasution et al., 2024)
Marine waste pollution and loss of livelihood	The continuous failure of seaweed farming has led fishermen to change their profession. To survive, they have sold assets, depleted their savings, and gone into debt.	North Konawe	(Muthalib & Nuryadi, 2023)
Water resource pollution	The water quality of the Baula, Huko-huko, Pesouha, Sopura, and Oko-oko rivers is classified as lightly polluted, even though they serve as sources for irrigation, livestock, freshwater aquaculture, and water recreation.	Pomala District, Southeast Sulawesi	(Ilham et al., 2017)
Marine waste pollution	The concentration of Suspended Particulate Matter (SPM) exceeds the threshold set by the Ministry of Environment, which is <25 mg/L.	East Halmahera, North Maluku	(Sarianto et al., 2016)

Source: Secondary Data Processed, 2025

disasters highlights a weak commitment to spatial utilization zoning and the neglect of environmental carrying capacity and load capacity assessments.

This finding is supported by Hui (2015), who states that in the planning of natural resource utilization, one of the key considerations must be the carrying and load capacity of the environment (CLCE). The results of CLCE assessments serve as a critical guideline for spatial planning and the types of activities that may be carried out. Pahuluan et al. (2017) also emphasize that CLCE analysis results should be fully integrated into development planning and the management of activities and/or businesses within a region. Failure to comply with CLCE assessments may result in long-term environmental and social harm.

The various findings in Table 2 indicate that the negative impacts of nickel exploitation in regions such as Central Sulawesi, Southeast Sulawesi, and North Maluku are no longer latent issues, but have become visible and recurring realities. Myllyvirta et al. (2024) describe how water pollution, air degradation, coastal damage, and deforestation have eroded communities' basic rights to a healthy environment and access to sustainable natural resources. Ironically, despite regulations such as Environmental Impact Assessments (AMDAL) and mandatory environmental rehabilitation being legally required, implementation in the field is often weak and lacks effective oversight.

The desk study conducted across North Maluku, Southeast Sulawesi, and Central Sulawesi reveal that the ecological and social impacts of nickel exploitation are not merely theoretical concerns, but lived realities. Local residents consistently linked environmental degradation with declining quality of life. These phenomena underline that violations of environmental carrying capacity are not only measurable through scientific data but also tangibly experienced by communities. This experiential evidence highlights a critical failure to translate CLCE assessments into enforceable spatial planning, further supporting the conclusion that weak governance, rather mere technical shortcomings, is central to the crisis.

This reinforces the argument made by Nasution et al. (2024) that problems in the nickel industry are not solely technical or ecological in nature, but also reflect a broader failure in natural resource governance that does not yet align harmoniously with social and environmental ethics. Therefore, to fully understand the dynamics and complexity of this issue, it is crucial to explore how various stakeholders governments, companies, local communities, and academics interpret and respond to these conditions based on their respective perspectives and interests. Malik (2024) emphasizes that understanding stakeholder perceptions is key to formulating fair, inclusive, and context-specific policies. As such, the following subsection presents an analysis of stakeholder perceptions as a foundation for efforts to harmonize natural resource management in affected areas.

Stakeholder Perceptions as an Effort to Harmonize Nickel Resources Management

The various benefits and negative impacts of nickel investment in Indonesia are generally recognized by stakeholders. Hidayat & Hasan (2024) state that stakeholders perceive these issues based on their individual capacities and roles. Typically, the higher a person's level of education, the broader and deeper their perspective, resulting in a more holistic perception. However, according to Barroso et al. (2018), this condition may differ when individuals occupy specific positions or roles that are closely tied to their main duties and responsibilities. Werth (2019) emphasizes that a person's position or role can significantly influence their perception even when they have a higher level of education because they are often required to maintain the psychological stability of other related stakeholders. In this regard, Table 3 presents a verbatim matrix from in-depth interviews conducted with stakeholders at the research sites.

Stakeholders' perceptions of nickel investment in Indonesia, as presented in Table 3, reflect the complex dynamics between economic, social, and environmental interests, which often do not align. Local stakeholders particularly communities and workers express dissatisfaction with the unequal

Table 3
Verbatim Matrix of Stakeholder Perceptions on Nickel Investment

Identity	Informants Perception		
	Economic implications	Social implications	Environmental Implications
Local communities	Economic contributions have not been evenly distributed, with indications of control over rental properties and stores. Expectation: Businesses around the area can compete openly, without any monopolization of business sectors by parties with capital.	Labours recruitment is unfair, as only a small proportion of local workers (about 20% in the district) have been successfully hired. Expectation: It is necessary to prioritize and give preference to local workers (within the district) up to 75%.	Changes in environmental quality and a decline in its function, water quality, fish populations, fishermen's catch, air quality, and health infections. Expectation: The company is improving environmental management, and the government is tightening monitoring to ensure that waste meet quality standards.
Employees	Workers receive a sufficient salary to meet their needs, but the cost of living is very high and continues to rise. Expectation: There is an expectation that salary increases should at least match the percentage of annual economic inflation.	There is jealousy regarding the share of work and responsibilities between Indonesian and foreign workers, which has sometimes led to conflicts among workers and resulted in casualties. Expectation: The allocation of work and responsibilities should be fair according to the level and position, without discriminating between Indonesian workers and foreign workers.	Workers have carried out their duties in accordance with the Standard Operating Procedure (SOP) and under the guidance of their leaders. Expectation: Several cases have occurred that resulted in negative environmental impacts, and this should be taken into consideration for revising the SOP to make it better.
Company representatives	The company has provided workers' rights in accordance with the regulations and laws governing salaries/wages. The company is also not affiliated with or has any interests outside of its production activities. Expectation: The company will continue to be committed to fulfilling all its obligations to workers.	The company has established all labour recruitment procedures and the selection process is carried out objectively according to needs. However, at present, local workers are still unable to compete with national workers from other regions. Expectation: The company will continue to engage in community development and empowerment, includes skills training. Additionally, CSR initiatives will be provided to improve the living standards of the local community.	The company has implemented all Standard Operating Procedures (SOPs) and responsibilities as agreed upon in the Environmental Management Plan (RKL) and Environmental Monitoring Plan (RPL) documents. Expectation: The company is open to suggestions, feedback, and corrections from all parties concerned with the environmental impact caused, and if necessary, the SOPs will continue to be improved.

Source: primary research data, 2025

distribution of economic benefits, the low prioritization of local labor, and the deteriorating environmental quality, despite claims from companies and the government that applicable procedures and regulations have been followed. These findings support the study by "Muhammad et al. (2024), which suggests that public perceptions of extractive industry investments are shaped by unequal access to benefits and information, as well as limited involvement in decision-making processes.

Interestingly, even among highly educated stakeholders, their institutional roles and functions can constrain the open expression of critical views in order to maintain stability in stakeholder relations. This is consistent with the findings of 'García-Ortega et al. (2020)), who argue that the perceptions of policy actors are often shaped by institutional pressures and structural loyalties. Therefore, harmonizing natural resource management requires more inclusive deliberative mechanisms ones that allow all actors to express their aspirations and concerns transparently and ensure that these are followed up through policies grounded in ecological and social justice.

Given the often conflicting perceptions among stakeholders, Zembe & Barnes (2023) emphasize that harmonizing nickel resource management demands strategies that go beyond normative approaches. These strategies must be contextual and rooted in the social-ecological realities on the ground. According to research by Matikainen (2022), the imbalance between procedural claims made by companies and government entities and the substantive grievances voiced by communities and workers underscores the need for analysis that can objectively balance internal and external perspectives.

This pattern of dissatisfaction was clearly echoed in interviews with local community members. One respondent from Morowali, Central Sulawesi stated: "*We were promised jobs and development, but all we see is dust, noise, and our rivers becoming polluted*". Similarly, a respondent from North Maluku emphasized, "*The companies say they follow the rules, but we are the ones who suffer when floods come, and crops fail*". Another informant from Southeast Sulawesi noted, "*We're not against investment, but we want to be involved not just as spectators or cheap labor*". These quotes illustrate the depth of concern felt by those directly affected by nickel mining operations and provide qualitative evidence that supports the broader patterns of stakeholder perception described in this study. Including these direct voices not only reinforces the validity of the findings but also highlights the importance of integrating local perspectives in the formulation of fair and effective natural resource governance.

CONCLUSION

This study aimed to explore how nickel exploitation in Indonesia particularly in Central Sulawesi, Southeast Sulawesi, and North Maluku affects socio-ecological conditions and how stakeholders perceive and respond to these impacts. The findings reveal that while nickel investment has significantly boosted economic growth through industrial expansion and job creation, it has also resulted in serious environmental degradation (e.g., deforestation, pollution, and frequent natural disasters), the erosion of local livelihoods, and heightened social inequality due to the unequal distribution of benefits and weak community participation. Furthermore, stakeholder interviews exposed a deep sense of injustice among local communities and workers, who feel excluded from the decision-making processes and bear the brunt of ecological harm. Institutional actors, meanwhile, often operate under constraints that limit their ability to address these concerns effectively. Based on these findings, we suggest that future nickel resource management must prioritize three key actions: 1) Strengthen inclusive decision-making processes that ensure meaningful participation of local communities, 2) enforce environmental regulations grounded in ecological carrying capacity assessments, 3) promote fair distribution of benefits to reduce social tensions and enhance local well-being. Only by aligning economic goals with social and ecological justice can Indonesia realize truly sustainable nickel development.

REFERENCES

Abdul, F., Pintowantoro, S., & Purnamasari, A. (2020). Direct Reduction of Nickel Laterite Limonitic Ore Using a Coal-Dolomite Mixture Bed and Na2SO4 as a Selective Agent. *Journal of Chemical Technology and Metallurgy*, *55*(1), 103–109. https://www.semanticscholar.org/paper/DIRECT-REDUCTION-OF-NICKEL-LATERITE-LIMONITIC-ORE-A-Abdul-Pintowantoro/8dadced3900af6ceebf70f3293ba82dd69a41d59

Acero, L. H. (2023). Nickel Content in Plants and Soil: The Case of Mine Tailing Sites in Bato-Bato Narra Palawan, Philippines. *Jurnal Manajemen Hutan Tropika*, *29*(3), 200–207.https://doi.org/10.7226/jtfm.29.3.200

Adidharma, M. A., Supriatna, & Takarina, N. D. (2023). The impact of nickel mining on vegetation index in Molawe Sub-district, North Konawe District, Southeast Sulawesi, Indonesia. *Biodiversitas*, *24*(8), 4581–4588.https://doi.org/10.13057/biodiv/d240840

Barroso, D. B. R., Mimo, R. de A., Filho, F. de S. P., Sui-QUI, T., & Morais, F. R. de. (2018). Stakeholder Perception in the Organizational Environment Focusing on Behavior. *International Journal of Advanced Engineering Research and Science*, *5*(2), 44–54. https://doi.org/10.22161/ijaers.5.2.5

Brown, C. W., Goldfine, C. E., Allan-Blitz, L. T., & Erickson, T. B. (2024). Occupational, environmental, and toxicological health risks of mining metals for lithium-ion batteries: a narrative review of the Pubmed database. *Journal of Occupational Medicine and Toxicology*, *19*(1). https://doi.org/10.1186/s12995-024-00433-6

Cao, Z., Jin, C., Ma, B., Zhang, C., Chen, Y., & Wang, C. (2025). Preparation of high-purity iron phosphate from laterite pressure leaching residue and wastewater treatment: Kinetics and applications. *Process Safety and Environmental Protection*, *197*(December 2024), 106944. https://doi.org/10.1016/j.psep.2025.106944

Central Bureau of Statistic. (2023). Economic Indicators: Monthly Statistical Bulletin March 2023. In *Badan Pusat Statistik*. https://surakartakota.bps.go.id/publication/download.html?nrbvfeve=MmQyOGUyNTQ4MTJjNzIxODJiOTcxNTcw&xzmn=aHR0cHM6Ly9zdXJha2FydGFrb3RhLmJwcy5nby5pZC9wdWJsaWNhdGlvbi8yMDIyLzA4LzIzLzJkMjhlMjU0ODEyYzcyMTgyYjk3MTU3MC9pbmRpa2F0b3ItZWtvbm9taS1rb3RhLXN1cmFrYXJ0YS

Chen, W., Jiang, Y., & Liu, Z. (2024). Unveiling structural differentiation in the global nickel trade network: A product chain perspective. *Journal of Geographical Sciences*, *34*(4), 763–778. https://doi.org/10.1007/s11442-024-2226-y

Çoban, B., & Baş, A. D. (2022). HPAL of a lateritic nickel ore: An investigation on the relationship between nickel and cobalt extraction and acid consumption. *Department of Mining Engineering*, *218*(September), 1–15. https://doi.org/10.1016/j.mineng.2024.109014

De Frenne, P., Lenoir, J., Luoto, M., Scheffers, B. R., Zellweger, F., Aalto, J., Ashcroft, M. B., Christiansen, D. M., Decocq, G., De Pauw, K., Govaert, S., Greiser, C., Gril, E., Hampe, A., Jucker, T., Klinges, D. H., Koelemeijer, I. A., Lembrechts, J. J., Marrec, R., … Hylander, K. (2021). Forest microclimates and climate change: Importance, drivers and future research agenda. *Global Change Biology*, *27*(11), 2279–2297. https://doi.org/10.1111/gcb.15569

Fan, H., Li, Z., Duan, Y., & Wang, B. (2025). Incentive policy formulation for China's electric vehicle market: Navigating pathways to sustainable mobility with a green premium analytical model. *Energy Policy*, *202*(April 2024), 114610. https://doi.org/10.1016/j.enpol.2025.114610

Farawansa, S. M., & Ratnawati, E. (2024). Diagnosis Of Nickel Industry Downstreaming Policy In Export Restriction Towards Increasing Economic Added Value In Indonesia. *Jurnal Legalitas*, *17*(1), 1–16. https://doi.org/10.33756/jelta.v16i1.xxxx

Farrokhpay, S., Cathelineau, M., Blancher, S. B., Laugier, O., & Filippov, L. (2019). Characterization of Weda Bay nickel laterite ore from Indonesia. *Journal of Geochemical Exploration*, *196*(October 2018), 270–281. https://doi.org/10.1016/j.gexplo.2018.11.002

Fazaalloh, A. M. (2024). FDI and economic growth in Indonesia: a provincial and sectoral analysis. *Journal of Economic Structures*, *13*(1), 22. https://doi.org/10.1186/s40008-023-00323-w

García-Ortega, B., de-Miguel-Molina, B., & Chirivella-González, V. (2020). Stakeholder's perceptions of mining industry in Peru: Community involvement in decision-making and their causal conditions. *Journal Globalization, Competitiveness and Governability*, *14*(1), 48–61. https://doi.org/10.3232/GCG.2020.V14.N1.02

Haryadi, L., Hartiwiningsih, H., & Hermawan, S. (2024). Legal Protection for Communities Affected by Nickel Mine Exploitation Amidst Increased Exploration for Electric Battery Needs. *Advances in Social Science, Education, and Humanities Research*, *827*, 68–76. https://doi.org/10.2991/978-2-38476-218-7_12

Heijlen, W., & Duhayon, C. (2024). An empirical estimate of the land footprint of nickel from laterite mining in Indonesia. *Extractive Industries and Society*, *17*(February), 101421.https://doi.org/10.1016/j.exis.2024.101421

Hidayat, A. N., & Hasan, M. F. (2024). Stakeholder Dynamics in Downstreaming in Indonesia: A Case Study of Nickel Mining. *Public Policy: Jurnal Aplikasi Kebijakan Publik Dan Bisnis*, *5*(2), 973–989.

Hirlekar, O., Kolte, A., & Vasa, L. (2025). Transition in the mining industry with green energy: Economic dynamics in mining demand. *Resources Policy*, *100*(December 2024), 105409.https://doi.org/10.1016/j.resourpol.2024.105409

Hui, C. (2015). Carrying Capacity of the Environment. In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (Second Edi, Vol. 10). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.91002-X

Hyldmo, H. da S., Wardhani, I. S., Kurniawan, N. I., Cahayati, D. D., Rye, S. A., & Vela-Almeida, D. (2025). Urgent transition, urgent extraction? Global decarbonization, national governance, and local impacts in the Indonesian nickel industry. *Environmental Research Letters*, *20*(5), 1–12. https://doi.org/10.1088/1748-9326/adc31c

Ilham, Hartono, D. M., Suganda, E., & Nurdin, M. (2017). Metal distribution at river water of mining and nickel industrial area in Pomalaa Southeast Sulawesi Province, Indonesia. *Oriental Journal of Chemistry*, *33*(5), 2599–2607.https://doi.org/10.13005/ojc/330557

International Energy Agency. (2021). World Energy Outlook 2021. In *IEA Publications*. www.iea.org/weo

Kadek, N., & Pradnya, A. (2025). Juridical Analysis of the Effectiveness of Law Enforcement in Handling Nickel Mining Violations in North Maluku : Dispute Cases Between Companies and Affected Communities. *Indonesian Journal of Law and Justice*, *2*(3), 1–12.

Karsadi, K., & Aso, L. (2023). Multidimensional Impacts of Nickel Mining Exploitation towards the Lives of the Local Community. *Jurnal Ilmu Sosial Dan Humaniora*, *12*(2), 222–227.https://doi.org/10.23887/jish.v12i2.58881

Kartiko, N. D., Soegiono, S. P., & Siswanto, C. A. (2023). The Paradox of Foreign Investment in Support Economic Sustainability After the Job Creation Law. *Legal Brief*, *12*(4), 426–433. https://doi.org/10.35335/legal.The

König, U. (2021). Nickel laterites—mineralogical monitoring for grade definition and process optimization. *Minerals*, *11*(11). https://doi.org/10.3390/min11111178

Kowasch, M. (2018). Nickel mining in northern New Caledonia - a path to sustainable development? *Journal of Geochemical Exploration*, *194*(July), 280–290.https://doi.org/10.1016/j.gexplo.2018.09.006

Liang, X., Tang, J., Li, L., Wu, Y., & Sun, Y. (2022). A review of metallurgical processes and purification techniques for recovering Mo, V, Ni, Co, Al from spent catalysts. *Journal of Cleaner Production*, *376*(September), 134108. https://doi.org/10.1016/j.jclepro.2022.134108

Lo, M. G. Y., Morgans, C. L., Santika, T., Mumbunan, S., Winarni, N., Supriatna, J., Voigt, M., Davies, Z. G., & Struebig, M. J. (2024). Nickel mining reduced forest cover in Indonesia but had mixed outcomes for well-being. *One Earth*, *7*(11), 2019–2033.https://doi.org/10.1016/j.oneear.2024.10.010

Malik, R. H. (2024). *Stakeholder views on the uptake of sustainable and responsible nickel mining and processing supply chains for electric vehicles in Indonesia*. Massachusetts Institute of Technology.

Martin, F., Aymonier, C., Einloft, S., Carême, C., Poirier, M., Claverie, M., Prado, M. A., Dias, G., Quilfen, C., Aubert, G., Micoud, P., Le Roux, C., Salvi, S., Dumas, A., & Féry-Forgues, S. (2019). A review of Ni and Co incorporation during talc synthesis: Applications to crystal chemistry, industrial compounds and natural Ni- and Co-rich ore. *Journal of Geochemical Exploration*, *200*(January), 27–36.https://doi.org/10.1016/j.gexplo.2019.02.002

Matikainen, L. S. (2022). Addressing Sustainability in the Mining Industry Through Stakeholder Engagement. *South Asian Journal of Business and Management Cases*, *11*(1), 35–48. https://doi.org/10.1177/22779779221078673

Meirizal, A., Juliana, C., Putri, D. J., & Mada, U. G. (2023). Power And Raw Materials : Indonesia Nickel Ban Policy Toward The EU. *Journal of World Trade Studies*, *7*(2), 1–13.

Michel, T. (2024). The Prospects of Indonesia's Nickel Boom Amidst a Systemic Challenge from Coal. In *Ifri Papers* (Issue May). The Frech Institute of International Relations. https://www.ifri.org/sites/default/files/atoms/files/ifri_michel_indonesia_nickel_boom_2024.pdf

Ministry of Energy and Mineral Resources. (2020). Peluang Investasi Nikel Indonesia. In *Kementerian Energi dan Sumber Daya Mineral Republik Indonesia* (pp. 1–40). Kementerian ESDM.

Morel, A., Vidal-Beaudet, L., Brialix, L., Lemesle, D., Bulot, A., & Herpin, S. (2025). Evolution of microclimate following small patch de-sealing and revegetation in urban context. *Urban Climate*, *61*(102371), 1–23. https://doi.org/10.1016/j.uclim.2025.102371

Motta, J. G., & Faria, I. R. (2016). A mineral potential mapping approach for supergene nickel deposits in southwestern São Francisco Craton, Brazil. *Brazilian Journal of Geology*, *46*(2),261–273.https://doi.org/10.1590/2317-4889201620160021

Moyo, A., Do Amaral Filho, J. R., Harrison, S. T. L., & Broadhurst, J. L. (2024). Acid mine drainage and metal(loid) risk potential of South African coal processing wastes. *Minerals Engineering*, *215*(July), 108825. https://doi.org/10.1016/j.mineng.2024.108825

Muhammad, S., Arifin, S., Syam, R., & Putra, B. A. (2024). On the brink of social resistance: local community perceptions of mining company operating permits in East Luwu, Indonesia. *Frontiers in Sociology*, *9*(October), 1–9. https://doi.org/10.3389/fsoc.2024.1373736

Muthalib, A. A., & Nuryadi, A. M. (2023). The economic adaptation pattern of seaweed cultivator community affected by nickel mine waste in North Konawe Regency, Indonesia. *AACL Bioflux*, *16*(1), 427–435.

Myllyvirta, L., Hasan, K., Kelly, J., Prapat, J., Adhinegara, B. Y., Rizqiana, A., Refani, F., Huda, N., Monica, L., Darmawan, J., & Utomo, W. T. (2024). Debunking The Value-Added Myth in Nickel Downstream Industry: Economic & Health Impact of Nickel Industry in Central Sulawesi, Southeast Sulawesi, and North Maluku. In *Center for Research on Energy and Clean Air and Center of Economic and Law Studies* (Issue February). http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Nancy, N. (2022). Potential Distortion of Sustainable Development in the Conflict of Interest of Nickel Mining and Indigenous Communities in. *Journal of Global Environmental Dynamics*, *3*(2), 11–20.

Nassef, A. M., Ghadbane, H. E., Sayed, E. T., & Rezk, H. (2025). Reducing hydrogen consumption in hybrid electric vehicles using Aquila optimiza - tion algorithm. *Global Journal of Environmental Science and Management*, *11*(2), 695–710. https://doi.org/10.22034/gjesm.2025.02.18

Nasution, M. J., Tugiyono, Bakri, S., Setiawan, A., Murhadi, Wulandari, C., & Wahono, E. P. (2024). The Impact of Increasing Nickel Production on Forest and Environment in Indonesia: A Review. *Jurnal Sylva Lestari*, *12*(3), 549–579. https://doi.org/10.23960/jsl.v12i3.847

Nurlaela, Roslan, S., Yusuf, B., & Masri, M. (2020). The Impact of Nickel Management on Community Socio-Economic Conditions in Morosi District Konawe Regency. *Indonesian Journal of Social and Environmental Issues (IJSEI)*, *1*(1), 1–4. https://doi.org/10.47540/ijsei.v1i1.4

Østergaard, P. A. (2024). Sustainable Energy Planning and Management with PV, Waste Heat, Positive Energy Districts and CO<inf>2</inf> Accounting. *International Journal of Sustainable Energy Planning and Management*, *41*. https://doi.org/10.54337/ijsepm.8513

Pahuluan, A., Soeprobowati, T. R., & Hadiyanto, H. (2017). Environmental carrying capacity based on land balance for evaluation planning of spatial and regional in Solok Regency, West Sumatra. *Journal of Ecological Engineering*, *18*(3), 22–30. https://doi.org/10.12911/22998993/69360

Patadungan, E., Azikin, B., & Pachri, H. (2024). Characteristics of Laterite Nickel Based on Geochemical Data and Electrical Resistivity Tomography (ERT) of Ultramafic Rocks in the. *Journal of Geology & Exploration*, *3*(2), 65–76.

Peraturan Pemerintah Republik Indonesia Nomor 1 Tahun 2024 Tentang Harmonisasi Kebijakan Fiskal, 1 (2024). [Government Regulation of the Republic of Indonesia Number 1 of 2024 concerning Fiscal Policy Harmonization]

Prematuri, R., Turjaman, M., Sato, T., & Tawaraya, K. (2020). The impact of nickel mining on soil properties and growth of two fast-growing tropical trees species. *International Journal of Forestry Research*, *8837590*(1), 1–9. https://doi.org/10.1155/2020/8837590

Purnama, M. F., Prayitno, S. B., Muskananfola, M. R., & Suryanti, S. (2024). Ecological Indices of Mangrove Gastropod Community in Nickel Mining Impacted Area of Pomalaa, Southeast Sulawesi. *Biotropia*, *31*(3), 359–371. https://doi.org/10.11598/btb.2024.31.3.2267

Putzolu, F., Boni, M., Mondillo, N., Maczurad, M., & Pirajno, F. (2019). Ni-Co enrichment and High-Tech metals geochemistry in the Wingellina Ni-Co oxide-type laterite deposit (Western Australia). *Journal of Geochemical Exploration*, *196*(November 2018), 282–296. https://doi.org/10.1016/j.gexplo.2018.11.004

Qaseem, F. I. (2023). The Analysis of Indonesia's Nickel Export Affecting the Dynamic of Foreign Direct Investment (FDI) inflows in Indonesia: Multiple Regression Analysis. *Cognizance Journal of Multidisciplinary Studies*, *3*(10), 240–252.https://doi.org/10.47760/cognizance.2023.v03i10.018

Randrikasari, O., Oktariani, P., & Islamiyah, N. (2025). Strengthening Indonesia's Nickel Downstream Industry through Green Energy-Based Smelter Technology. *Jurnal Pengelolaan Lingkungan Pertambangan*, *2*(1), 35–46.

Razika, D. (2022). *Advanced study on the extraction of Nickel from its ores*. https://hal.science/hal-03637893

Reagen, D., & Faha, N. (2023). Revisiting natural resources-conflict nexus. *Resources Policy*, *70*(101903), 1–38.

Ren, H., Mu, D., Wang, C., Yue, X., Li, Z., Du, J., Zhao, L., & Lim, M. K. (2024). Vulnerability to geopolitical disruptions of the global electric vehicle lithium-ion battery supply chain network. *Computers and Industrial Engineering*, *188*(September 2023),109919.https://doi.org/10.1016/j.cie.2024.109919

Sabaruddin, R., Anas, A. V., Amalia, R., & Tui, R. N. S. (2023). Mine Design of Laterite Nickel Ore Based on Pit Limit Optimization with Floating Cone Method at Meranti Pit of PT Ang and Fang Brother. *Jurnal Geocelebes*, *7*(1), 64–76.https://doi.org/10.20956/geocelebes.v7i1.23065

Salehi, H., Maroufi, S., Mofarah, S. S., Nekouei, R. K., & Sahajwalla, V. (2023). Recovery of rare earth metals from Ni-MH batteries: A comprehensive review. *Renewable and Sustainable Energy Reviews*, *178*(January), 113248. https://doi.org/10.1016/j.rser.2023.113248

Santoso, A. D., Daulay, H., Priyanti, A., Silalahi, M., Yaumidin, U. K., Irawati, N., Sumartono, H., Astuti, P., Farandy, A. R., & Parikesit, A. (2024). Conversion of motorcycles to electric vehicles towards sustainable mobility. *Global Journal of Environmental Science and Management*, *10*(SI), 181–200. https://doi.org/10.22034/gjesm.2024.

Santoso, R. B., Dermawan, W., & Moenardy, D. F. (2024). Indonesia's rational choice in the nickel ore export ban policy. *Cogent Social Sciences*, *10*(1),1–19.https://doi.org/10.1080/23311886.2024.2400222

Sarianto, D., Simbolon, D., & Wiryawan, B. (2016). Impact of Nickel Mining on Fishing Ground in East Halmahera District Waters. *Jurnal Ilmu Pertanian Indonesia*, *21*(2), 104–113. https://doi.org/10.18343/jipi.21.2.104

Sarkodie, S. A., & Strezov, V. (2019). Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Science of the Total Environment*, *646*, 862–871.https://doi.org/10.1016/j.scitotenv.2018.07.365

Satritama, B., Zulhan, Z., Wulandari, W., Sasongko, D., Al Hakim, A. Y., & Hidayat, T. (2024). The Impacts of Temperature, Gas Composition and Reaction Time on the Reduction of Saprolite Nickel Ore Under Hydrogen–Argon Atmosphere. *Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science*, *55*(1), 396–408. https://doi.org/10.1007/s11663-023-02965-4

Saul, W. C., Roy, H. E., Booy, O., Carnevali, L., Chen, H. J., Genovesi, P., Harrower, C. A., Hulme, P. E., Pagad, S., Pergl, J., & Jeschke, J. M. (2017). Assessing patterns in introduction pathways of alien species by linking major invasion data bases. *Journal of Applied Ecology*, *54*(2), 657–669. https://doi.org/10.1111/1365-2664.12819

Schodde, R., & Guj, P. (2025). Nickel: A tale of two cities. *Geosystems and Geoenvironment*, *4*(1), 100356. --https://doi.org/10.1016/j.geogeo.2025.100356

Severiano, B. M., Northey, S. A., Hyman, J., & Giurco, D. (2025). Investigating the adoption of voluntary sustainability initiatives when mining for battery minerals: An iterative systems thinking approach. *Journal of Environmental Management*, *380*(November 2024), 124941. https://doi.org/10.1016/j.jenvman.2025.124941

Skeels, A., Boschman, L. M., McFadden, I. R., Joyce, E. M., Hagen, O., Robles, O. J., Bach, W., Boussange, V., Keggin, T., Jetz, W., & Pellissier, L. (2023). Paleoenvironments shaped the exchange of terrestrial vertebrates across Wallace's Line. *Science*, *381*(6653),86–92.https://doi.org/10.1126/science.adf7122

Slavenko, A., Allison, A., Austin, C. C., Bauer, A. M., Brown, R. M., Fisher, R. N., Ineich, I., Iova, B., Karin, B. R., Kraus, F., Mecke, S., Meiri, S., Morrison, C., Oliver, P. M., Shea, M. O., Richmond, J. Q., Shea, G. M., Tallowin, O. J. S., & Chapple, D. G. (2023). Skinks of Oceania, New Guinea, and Eastern Wallacea: an underexplored biodiversity hotspot. *Pacific Conservation Biology*, *29*(6), 526–543.https://doi.org/10.1071/PC22034

Srinivasan, S., Shanthakumar, S., & Ashok, B. (2025). Sustainable lithium-ion battery recycling: A review on technologies, regulatory approaches and future trends. *Energy Reports*, *13*(December 2024), 789–812. https://doi.org/10.1016/j.egyr.2024.12.043

Stopic, S., & Friedrich, B. (2016). Hydrometallurgical processing of nickel lateritic ores. *Vojnotehnicki Glasnik*, *64*(4), 1033–1047. https://doi.org/10.5937/vojtehg64-10592

Su, C., Geng, Y., van Ewijk, S., Borrion, A., & Zhang, C. (2025). Uncovering the evolution of the global Nickel cycle and trade networks. *Resources, Conservation and Recycling*, *215*(February), 108164. https://doi.org/10.1016/j.resconrec.2025.108164

Syahputra, A. (2024). Social and Economic Impact of Industrialization Nickel Mining on The Community (Study of Wonuamorome Village, Konawe Regency). *PJHP : Papsel Journal of*

Humanities and Policy, *01*(01), 01–09. https://journal.papsel.org/index.php/JHP/

Taufikurahman, M. R., Firdaus, A. H., Ahmad, T., Febriani, D. A., & Permana, A. S. (2023). The Impact Of Mining Sector Investment On National And Regional Economic Performance. *INDEF Policy Brief*, *07*(Desember), 1–9.

Warburton, E. (2024). Nationalist enclaves: Industrialising the critical mineral boom in Indonesia. *Extractive Industries and Society*, *20*(August), 101564.https://doi.org/10.1016/j.exis.2024.101564

Werth, H. (2019). *Stakeholder Perceptions of Organisational Response to Crisis: A Case Study* (Issue December). Stellenbosch University.

Xue, Y., Zhu, D., Pan, J., Guo, Z., Tian, H., Wang, D., & Pan, L. (2022). Distinct Difference in High-temperature Characteristics between Limonitic Nickel Laterite and Ordinary Limonite. *ISIJ International*, *62*(1), 29–37.https://doi.org/10.2355/isijinternational.ISIJINT-2021-307

Zainuddin Rela, I., Firihu, M. Z., Awang, A. H., Iswandi, M., Malek, J. A., Nikoyan, A., Nalepo, L., Batoa, H., & Salahuddin, S. (2021). Formation of farming community resilience models for sustainable agricultural development at the mining neighborhood in Southeast Sulawesi Indonesia. *Sustainability (Switzerland)*, *13*(2), 1–17. https://doi.org/10.3390/su13020878

Zembe, S., & Barnes, N. (2023). Exploring community engagement challenges in the mining sector of South Africa. *Indonesian Journal of Community Engagement*, *9*(1), 53. https://doi.org/10.22146/jpkm.72217

Zhang, Y., Qie, J., Wang, X. F., Cui, K., Fu, T., Wang, J., & Qi, Y. (2020). Mineralogical Characteristics of the Nickel Laterite, Southeast Ophiolite Belt, Sulawesi Island, Indonesia. *Mining, Metallurgy and Exploration*, *37*(1),79–91.https://doi.org/10.1007/s42461-019-00147-y