



Waqf-based rehabilitation of former mining land: Cash waqf linked to infrastructure fund (CWL-FRA) and phytomining models for sustainable economic growth

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ABSTRACT

Background: Abandoned mining lands in Indonesia suffer severe environmental degradation from heavy metal contamination, limiting their agricultural and productive potential. Rehabilitation therefore requires an approach that simultaneously addresses environmental pollution, economic recovery, and social development. This study aims to develop a cash waqf-based rehabilitation model integrating Islamic social finance with phytomining technology for sustainable post-mining land recovery. **Methods:** This study employed a literature review to identify relevant concepts and to develop an integrated operational model that combines a Cash Waqf Linked to Infrastructure Fund (CWL-FRA) with phytomining technology. The model was developed by synthesizing literature on cash waqf, sustainable financing, phytoremediation, phytomining, post-mining land rehabilitation, and socio-economic development. **Findings:** The proposed model allocates cash waqf through an infrastructure fund to finance land rehabilitation and employs phytomining to extract heavy metals from contaminated soil. The model proposes that the resulting biomass could be processed into bio-ore and subsequently converted into nickel salt for industrial commercialization. Revenue generated from these activities is reinvested to sustain rehabilitation operations and support Islamic socio-economic programs, including pesantren and micro, small, and medium enterprises (MSMEs). The model demonstrates potential to transform degraded mining land into a productive asset while generating ecological, economic, and social benefits. **Conclusion:** The integration of CWL-FRA and phytomining provides a potentially sustainable framework for post-mining land rehabilitation by linking environmental restoration with productive financing and socio-economic development. **Novelty/Originality of this article:** The novelty lies in integrating cash waqf as an Islamic social finance instrument with phytomining as a green technology within a single commercially oriented rehabilitation model, thereby extending the role of waqf from conventional social financing toward productive environmental restoration and sustainable economic development.

KEYWORDS: cash waqf linked dinfra; mining rehabilitation; phytomining; sustainable economic growth.

1. Introduction

One important pillar of Indonesia's economy is the mining industry. According to data from the Ministry of Energy and Mineral Resources (ESDM/*Energi dan Sumber Daya*

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Mineral), mining-related GDP in Indonesia rose from IDR 231,300 billion in the first quarter of 2025 to IDR 233,800 billion in the second. From 2010 to 2025, Indonesia's mining contribution to GDP/Gross Domestic Product averaged IDR 201,909.20 billion; it peaked at IDR 249,881.10 billion in the fourth quarter of 2024 and fell to IDR 171,254.70 billion in the first quarter of 2010. At the macro scale, mining accounts for roughly 6–12% of Indonesia's GDP, 10% of GDP in 2017, and 33% of the country's export value (Tui & Adachi, 2021; Soelistijo et al., 2015; Tui & Adachi, 2020). Additionally, through multiplier effects, the industry boosts household incomes in mining regions and promotes growth in other industries like manufacturing and construction (Sulista & Rosyid, 2022; Sujarwadi, 2021).

However, major environmental problems, especially post-mining land degradation, pose a threat to this profit. An important problem in environmental management, particularly in Indonesia, is former mining land. Mining operations frequently cause environmental damage, such as water pollution, soil degradation, and biodiversity loss, even tho they have positive economic effects (Hidayati, 2022; Yudhiman et al., 2023). The physical and chemical contamination of abandoned lands, where soil frequently contains acids and heavy metals and has reduced fertility, is one of the effects (Bella et al., 2021; Jafar et al., 2022). Reclamation efforts to restore land functionality for agriculture or natural ecosystems are severely hampered by this contaminated soil quality. Additionally, the mining process produces acid mine drainage, which can contaminate nearby water sources and have an impact on local flora and fauna as well as human health (Yudhiman et al., 2023; Jafar et al., 2022). Mismatches between post-mining land use and local community needs can also lead to social tensions (Nursaputra et al., 2021). In order to restore biodiversity in these degraded areas, a reclamation strategy must incorporate biophysical and ecological elements (Nimasari et al., 2023).

Thus, reclamation strategies are crucial. Restoring the physical and chemical characteristics of the soil, as well as the land's ability to be used for forestry or agriculture, are all included in these activities. According to previous studies, using fast-growing plants in vegetative approaches may significantly improve soil quality (Ririmase & Makaruku, 2023; Irwanto et al., 2022) and support the removal of current pollutants (Suwardi & Randrikasari, 2023). Restoring ecological function, productivity, and sustainability to mining-damaged land entails addressing physical degradation (altered topography, soil structure), chemical degradation (low pH, heavy metals), and biological degradation (loss of soil microbes and fauna) (Lefi et al., 2023). Revegetation and phytoremediation, a slow process that depends on plant species (Farraji et al., 2020), are important techniques. Phytoremediation is an affordable, sustainable technique that uses metal-absorbing plants (Rahayu & Agustianto, 2020; Meena et al., 2023).

Phytomining is an example of a phytoremediation application. Phytomining focuses on extracting valuable metals from plant biomass and turning it into bio-ore, whereas phytoremediation uses hyperaccumulator plants to remove harmful heavy metals from soil (Tomar et al., 2020; Nascimento et al., 2024). By converting mining waste into a resource, this dual-purpose strategy supports sustainable development principles and provides both land restoration and revenue (Sharma et al., 2023). The selection of suitable hyperaccumulator species that are fast-growing, metal-tolerant, and have a high accumulation capacity is essential to its success (Rachmadíartí, Sholikah, & Linggawati et al., 2022). Long harvest times, fluctuating metal prices, and the need for further studies on large-scale efficiency are some of this method's limitations despite its advantages.

Financing such resilient rehabilitation projects requires innovative models. Here, Islamic social finance, particularly cash waqf (CW), presents a strong solution. Cash waqf is an innovation that allows cash funds to be endowed and managed productively. Unlike traditional waqf, which involves fixed assets, cash waqf offers greater flexibility and faster fund mobilization for social or environmental projects (Sari, 2023). One form of cash waqf is Cash Waqf Linked Sukuk (CWL-FRA), a model linking waqf funds with infrastructure sukuk, serving not only as a financial instrument but also supporting development, community empowerment, and project sustainability (Baiti & Syufa'at, 2021). This instrument, free from usury (*riba*), uncertainty (*gharar*), and gambling (*maysir*), holds

ethical legitimacy and modern relevance. The integration of such social finance with green technology represents a new paradigm in sustainable development, where Islamic financial instruments provide funding, and green technologies offer implementation mechanisms (Yusuf et al., 2022; Baiti & Syufa'at, 2021). This synergy is crucial in the post-COVID-19 recovery era, enhancing community resilience and accelerating progress toward Sustainable Development Goals (SDGs), based on the theory of sustainable economic growth emphasizing the triple bottom line: profit, people, and planet (Rahayu & Agustianto, 2020).

There is still a research gap in spite of this potential. The majority of cash waqf literature concentrates on cash waqf linked deposits and cash waqf linked sukuk. Research on cash waqf specifically for the rehabilitation of former mining land, let alone its integration with phytomining technology, is noticeably lacking. Although there is currently little evidence to support this commercial aspect, phytomining aims to maximize the economic value of extracted nickel as bio-ore in addition to ecological recovery (Fatoni, 2021; Wijaya, 2023). This gap highlights this manuscript's uniqueness and cutting edge. By suggesting an integration of Cash Waqf Linked Infrastructure Investment Fund (CWL-FRA), this model aims to finance phytomining initiatives for post-mining land rehabilitation—it goes beyond well-known CW applications. This integration fills the gap by offering a financially viable, Shariah-compliant model that uses green technology to generate socioeconomic and environmental value, showcasing the potential of cash waqf as a cutting-edge instrument for local economic growth and environmental recovery (Priambodo, 2022; Ghazali et al., 2021). Therefore, this study is driven by the following research problems: (1) How can a financing model for a Cash Waqf Linked Infrastructure Investment Fund (CWL-FRA) be designed in accordance with Shariah principles to rehabilitate former mining land? (2) How can phytomining technology be integrated into the CWL-FRA financing scheme to reduce heavy metal content, restore soil fertility, and generate economically valuable bio-ore products? (3) What is the operational mechanism and income distribution model for the integrated CWL-FRA and phytomining scheme to ensure financial sustainability and fund Sharia-based socio-economic programs aligned with the SDGs?

This research aims to design and propose a sustainable financing model based on Cash Waqf, integrated with phytomining technology, for the rehabilitation of former mining land. It contribute not only to the theoretical development of cash waqf but also to offer practical guidance on its effective application, thereby presenting a sustainable model to mitigate the negative impacts of extractive industries while creating positive economic and social outcomes.

1.1 Cash waqf

The integration of Cash Waqf with phytomining rehabilitation represents an idea for addressing the persistent financial and environmental challenges of post-mining land restoration. Cash waqf, as a perpetual financial endowment overseen by nazhir (trustees or fund managers) under Shariah-compliant contracts, offers a sustainable funding mechanism that preserves the principal while generating continuous returns for social welfare and development (Kuswanto et al., 2024; Qadri et al., 2024; Riani et al., 2022). This perpetual nature aligns with the long-term horizons required for phytomining rehabilitation, which typically demands 3–10 years for biomass establishment, metal accumulation, and harvest cycles (Sari, 2023; Wang et al., 2021). Unlike conventional financing that seeks short-term returns, Cash Waqf provides patient capital that can sustain ecological restoration efforts over decades, while the harvested metals from hyperaccumulator plants offer potential revenue streams to replenish the waqf fund and generate ongoing social benefits (Akinbile & Mbohwa, 2025; Hamdan et al., 2021; Minuț et al., 2024). The dual-purpose nature of phytomining, which is rehabilitating degraded lands and recovering valuable metals from mine tailings and low-grade ores, creates a compelling value proposition for waqf donors who seek both environmental and social returns on their charitable endowments (Peco et al., 2021; Rabbani et al., 2025; Wang et al., 2021).

A mechanism for operationalizing this integrated model is the Cash Waqf Linked Sukuk (CWLS), which specifically integrates cash waqf with state Sharia securities (SBSN) or government debt instruments, enabling a blended finance approach where waqf proceeds are invested in sovereign sukuk and the returns are channeled through nazhir to fund social programs, MSME development, education, health initiatives, and as proposed here environmental rehabilitation (Ashfahany & Lestari, 2023; Maesarach et al., 2022; Qadri et al., 2024). The Indonesian CWLS Retail variant exemplifies this mechanism, featuring a two-year term with a minimum contribution of IDR 1 million, allowing retail investors to access cash waqf while preserving safety and predictability through government-backed securities (Maesarach et al., 2022). For phytomining rehabilitation, the Cash Waqf structure could be adapted to fund large-scale planting, soil engineering with organic amendments and biochar, electrokinetic-assisted phytoextraction systems, and biomass processing infrastructure, with the government-backed nature of waqf providing credit enhancement that attracts risk-averse waqf donors (Ascarya, 2021; Dian et al., 2024; Medina-Díaz et al., 2024; Sarathchandra et al., 2023). The integration of Cash waqf with phytomining thus creates a virtuous cycle: waqf funds are preserved through investment in secure funds, the returns finance rehabilitation activities, metal recovery generates additional revenues, and these proceeds can be reinvested into the waqf fund or distributed to beneficiaries (*mauquf alaih*), thereby ensuring long-term sustainability (Ashfahany & Lestari, 2023; Maesarach et al., 2022; Qadri et al., 2024).

Effective governance is the core of successful Cash waqf deployment, with the nazhir playing a central role in managing proceeds, distributing returns to beneficiaries, and implementing productive activities such as MSME financing, community development, and phytomining rehabilitation programs (Ascarya & Masrifah, 2022; Ashfahany & Lestari, 2023). The nazhir take responsibility for fund distribution clarity, accountability, and transparent management (*amanah*), requiring professional capacity, Shariah-compliant governance structures, and robust monitoring systems to sustain trust and performance (Ascarya & Masrifah, 2022; Maesarach et al., 2022; Ula et al., 2023). To control fund flows and guarantee effective deployment, the Waqf Board, Ministry of Finance, regulators, and program implementers must coordinate closely, creating a cohesive ecosystem that ensures waqf funds are used as intended for infrastructure and SDG-aligned outcomes (Maesarach et al., 2022; Qadri et al., 2024). For the phytomining rehabilitation context, this governance framework would require a multi-stakeholder body comprising nazhir representatives, environmental scientists, mining regulators, community members, and technical experts to oversee fund allocation, monitor ecological outcomes, manage financial risks, and ensure that rehabilitation milestones are achieved (Peco et al., 2021; Sarathchandra et al., 2023; Włodarczyk et al., 2025). The Indonesian experience demonstrates that a coordinated ecosystem among waqf authorities, regulators, and fiscal authorities is essential for operational success, providing a template that can be adapted for environmental rehabilitation programs (Maesarach et al., 2022; Qadri et al., 2024).

Beyond Indonesia, the global Islamic finance literature offers valuable comparative insights for scaling Cash Waqf-linked rehabilitation models. A "global cash waqf model" has been proposed to mobilize cross-border funds for poverty alleviation through collective fund management and SPV-like structures, though adaptation requires careful attention to different legal regimes and financial markets (Saiti et al., 2021). Malaysia provides a particularly instructive regional governance reference, where waqf management operates under State Islamic Religious Councils (SIRCs) with a formalized ecosystem of related bodies e.g., Department of Waqf, Zakat and Hajj/*Jabatan Wakaf, Zakat dan Haji* (JAWHAR), Malaysia Waqf Foundation/*Yayasan Waqaf Malaysia* (YWM), illustrating how institutionalization and governance architecture shape the macro-level success of cash waqf-driven development programs (Rosli et al., 2020). Waqf-based microfinance for women's empowerment in contexts such as Egypt further illustrates the importance of legal clarity, governance structures, and community awareness, demonstrating that the effectiveness of waqf instruments depends heavily on the enabling environment and institutional capacity (Irhoumah et al., 2023). The comparative evidence explains that while

Cash Waqf Linked Infrastructure Financing is a universal concept, its effectiveness is contingent on country-specific regulatory and institutional ecosystems that support transparent management, reporting, and collaboration with public authorities (Rosli et al., 2020; Sari, 2023). For Indonesia and similar contexts, this implies the need to strengthen legal frameworks, enhance nazhir professional capacity, and ensure transparent reporting to donors and beneficiaries, drawing on best practices from Malaysia and other Islamic finance jurisdictions (Ashfahany & Lestari, 2023; Qadri et al., 2024; Rosli et al., 2020).

The operational integration of Cash Waqf with phytomining rehabilitation requires a staged technical framework that aligns with established phytoremediation and phytomining guidelines. First, site assessment and target metal characterization would identify tailings or contaminated soils with economically viable metal concentrations, with particular attention to nickel, rare earth elements (REEs), and noble metals that have demonstrated hyperaccumulator associations (Akinbile & Mbohwa, 2025; Balbin & Tabañag, 2024; Duddigan et al., 2023; Minuț et al., 2024). Second, plant selection would prioritize native or regionally adapted hyperaccumulator species such as those documented in Philippine studies showing 28 native species with tissue concentrations above hyperaccumulator thresholds, where nickel concentrates in aboveground tissues while copper and aluminum accumulate more in belowground parts to minimize ecological risks and maximize establishment success (Balbin & Tabañag, 2024; Boi et al., 2023; Duddigan et al., 2023; Solomou et al., 2022). Third, soil engineering with organic amendments, biochar, or lime would improve substrate properties and optimize metal uptake, with electrokinetic-assisted phytoextraction offering a pathway to enhance REE recovery by 57–68% under alternating current treatments (Medina-Díaz et al., 2024; Sarathchandra et al., 2023; Wang et al., 2021). Fourth, biomass harvesting and processing—through combustion, ash refining, or smelting—would recover bio-ores, with revenues recycled into the waqf fund to ensure long-term sustainability (Duddigan et al., 2023; Jones & Bismarck, 2024; Wang et al., 2021). This staged approach aligns with the CWLS disbursement mechanism, where funds are released progressively as rehabilitation milestones are achieved, ensuring accountability and measurable outcomes (Dian et al., 2024; Qadri et al., 2024).

Despite its promise, the integration of Cash Waqf with phytomining rehabilitation faces several challenges that must be addressed through targeted strategies. Key challenges include low cash waqf literacy among potential donors, regulatory complexity, limited operational capacity within nazhir institutions, and the technical uncertainties inherent in phytomining projects (Kuswanto et al., 2024; Muhammad et al., 2023; Uula et al., 2023). While studies show that waqf literacy can influence donation interest, knowledge alone does not always translate into higher participation, indicating a need for integrated education and outreach strategies that demonstrate the tangible environmental and social benefits of waqf-funded rehabilitation (Kuswanto et al., 2024; Muhammad et al., 2023). Sentiment analyses of social media discussions reveal positive public sentiment toward cash waqf, offering opportunities for targeted awareness campaigns that link waqf contributions to visible ecological restoration outcomes (Riani et al., 2022). Ecological risks associated with phytomining, including the potential introduction of invasive species, metal toxicity to local ecosystems, and the long-term bioavailability of residual contaminants, require careful risk assessment, adaptive management, and robust monitoring frameworks to prevent unintended consequences (Akinbile & Mbohwa, 2025; Boi et al., 2023; Rabbani et al., 2025; Włodarczyk et al., 2025). Financial risks, including metal price volatility, biomass yield variability, and processing cost uncertainty, necessitate risk-sharing mechanisms, contingency reserves, and diversified metal portfolios to protect the waqf corpus and ensure continuous returns for beneficiaries (Hamdan et al., 2021; Minuț et al., 2024; Wang et al., 2021). To scale similar blended finance schemes for environmental rehabilitation, policymakers should strengthen legal frameworks, enhance nazhir professional capacity through training and certification, ensure transparent reporting, and establish pilot programs that generate empirical evidence on performance and impact (Ashfahany & Lestari, 2023; Qadri et al., 2024; Sari, 2023).

For researchers, a pressing agenda includes empirical assessment of CWLS performance in environmental rehabilitation contexts, governance outcomes across different jurisdictions, comparative analysis of SPV-based blended-finance models versus crowdfunding cash waqf approaches, and comprehensive life-cycle evaluations of phytomining projects funded through waqf mechanisms (Al-Daihani et al., 2023; Ascarya, 2021; Qadri et al., 2024; Uula et al., 2023). Future research should focus on comparative cross-country case studies that examine how different regulatory frameworks influence the effectiveness of Cash Waqf-linked rehabilitation programs, empirical evaluation of cash waqf social and financial performance metrics, and the causal impact of waqf literacy on participation rates and donation behavior (Ascarya & Masrifah, 2022; Irhoumah et al., 2023; Saiti et al., 2021). Systematic analyses highlight research themes around nickel accumulation, heavy-metal uptake, serpentine soils, and agromining toward integrated resource-circular approaches, with growing interest in applying phytomining to REEs through microbial partnerships and bioaugmentation to increase phytoextraction efficiency (Jalali & Lebeau, 2021; Li et al., 2020). The convergence of evidence across the Cash Waqf, CWLS, and phytomining literatures demonstrates that an integrated model combining permanent endowment principles, blended-finance architecture, SPV-centered governance, CWLS instruments, and phytomining technology offers a replicable, Shariah-compliant, and ecologically sound financing solution for post-mining land rehabilitation (Al-Daihani et al., 2023; Ascarya, 2021; Dian et al., 2024; Qadri et al., 2024; Rosli et al., 2020; Sari, 2023). By aligning with circular economy principles, sustainable development imperatives, and Islamic social finance objectives, this model can unlock durable, ethical funding for environmental restoration while empowering communities, creating economic opportunities, and contributing to global climate and biodiversity goals (Akinbile & Mbohwa, 2025; Rabbani et al., 2025; Wang et al., 2021). Pilot implementations in Indonesia and other mining-impacted regions would provide the empirical foundation needed to refine the model, build donor trust, and demonstrate the transformative potential of integrating Islamic finance with ecological innovation.

1.2 Phytomining rehabilitation of post-mining land

Phytomining rehabilitation integrates plant-based remediation of contaminated mine lands with the recovery of valuable metals from biomass, yielding a dual payoff: environmental restoration and potential resource recovery. The literature consistently distinguishes between phytoremediation, which employs phytoextraction and phytostabilization to reduce contaminant mobility, and phytomining, the intentional use of hyperaccumulator plants to concentrate metals in aboveground tissues for subsequent metal recovery (Boi et al., 2023; Hamdan et al., 2021; Peco et al., 2021; Wang et al., 2021). The effectiveness of these mechanisms depends on plant physiology, soil chemistry, and amendments, with phytostabilization often prioritized in dryland or highly toxic tailings as a first step, while phytoextraction or phytomining is pursued when conditions permit (Sarathchandra et al., 2023; Włodarczyk et al., 2025). Plant selection is central, with Mediterranean natives, halophytes, and hyperaccumulators highlighted for their tolerance and metal-accumulation potential, though regional suitability and ecological risks must be carefully considered (Boi et al., 2023; Solomou et al., 2022). Amendments such as organic matter, biochar, and lime are frequently used to improve soil properties and support plant establishment, while soil reconstruction strategies further enhance rehabilitation outcomes (Peco et al., 2021; Sarathchandra et al., 2023). Harvested biomass can be processed via smelting or ash processing to recover metals, offering a bio-ore pathway that turns remediation biomass into a secondary feedstock, with non-hyperaccumulator biomass providing energy or other value streams (Hamdan et al., 2021; Jones & Bismarck, 2024; Wang et al., 2021).

Economic feasibility is case-specific and sensitive to metal prices, biomass yields, and post-harvest recovery efficiency, making site screening and pilot studies essential before scaling up (Akinbile & Mbohwa, 2025; Hamdan et al., 2021; Wang et al., 2021). Beyond metal

recovery, phytomining programs can deliver ecological and social co-benefits, including land restoration, biodiversity gains, carbon sequestration, and erosion control, which support regulatory and community acceptance (Jones & Bismarck, 2024; Wang et al., 2021). However, risks include ecological trade-offs from introducing non-native species, governance challenges, and the need for transparent management of remediation funds and metal recovery streams (Peco et al., 2021; Solomou et al., 2022; Wlodarczyk et al., 2025). Practical implementation follows a stepwise approach: site assessment and target metal identification, plant selection with native or well-adapted taxa, amendment and soil engineering tailored to tailing chemistry and climate, staging remediation versus production, developing post-harvest processing pathways, and establishing robust monitoring and governance frameworks (Akinbile & Mbohwa, 2025; Boi et al., 2023; Hamdan et al., 2021; Peco et al., 2021; Sarathchandra et al., 2023; Solomou et al., 2022; Wang et al., 2021; Wlodarczyk et al., 2025).

The synthesis underscores that phytomining rehabilitation offers an integrated framework to address land degradation from mining while also unlocking metal resources, contingent on site conditions, plant performance, and market dynamics (Hamdan et al., 2021; Peco et al., 2021; Sarathchandra et al., 2023; Solomou et al., 2022; Wang et al., 2021; Wlodarczyk et al., 2025). Policymakers and practitioners should coordinate soil remediation with metal-recovery pathways, environmental permits, and stakeholder engagement to maximize returns while mitigating risks, with structured pilot programs and adaptive management emphasized (Peco et al., 2021; Sarathchandra et al., 2023; Solomou et al., 2022; Wlodarczyk et al., 2025). Future research directions include comparative trials across climates, life-cycle assessments of remediation-plus-extraction chains, and innovative biotechnologies such as mycomining, all of which require careful ecological and economic evaluation (Jones & Bismarck, 2024).

2. Methods

2.1 Research design

This study uses a literature review methodology to address research issues related to the creation of a Cash Waqf Linked Infrastructure Investment Fund (CWL-FRA) model combined with phytomining technology for the rehabilitation of former mining lands. To ensure comprehensive coverage, the methodological approach applies systematic review principles.

The primary approach in the research design is literature review, which entails collecting, examining, and analyzing relevant scientific sources to better understand conceptual developments, trends, and findings related to cash waqf financing and phytomining technology. This method is especially useful for developing an integrated framework because it allows for the identification of innovations, challenges, and opportunities from previous research, as well as an understanding of how cash waqf concepts have evolved into modern financial instruments that support sustainable development and social inclusion (Jafar et al., 2025; Alshater et al., 2021). This study develops innovative models such as CWL-FRA, which integrate Islamic social funds with infrastructure financing, while emphasizing integration with emerging sectors such as phytomining to support green economy and sustainability goals (Wijaya, 2023; Jafar et al., 2025).

2.2 Study area and case study

The study focuses on former illegal gold mining sites (PETI) in Lamat Payang Hamlet, Tirta Kencana Village, Bengkayang Regency, which were chosen as a representative case study for post-mining lands across Indonesia. This location was chosen strategically because illegal mining activities in Bengkayang have been identified as major contributors

to environmental and geotechnical issues, such as slope instability and landslides caused by unsafe mining practices (Saputra et al., 2024).

The selection allows for a detailed analysis of soil characteristics, damage levels, and environmental hazards caused by illegal mining, as well as technical and policy recommendations for land improvement and reclamation. This case study approach is important for understanding local dynamics such as mining patterns, socioeconomic impacts, and law enforcement challenges, and the research findings can be applied to managing post-mining lands in other areas with similar characteristics (Saputra et al., 2024).

2.3 Data sources, selection criteria, and analytical framework

Scopus database was chosen as the primary data source for this study due to its comprehensive coverage of international journals, high-quality metadata, and advanced search and filter capabilities when compared to other databases (Ali & Tanveer, 2022; Valente et al., 2022). Scopus is used as the primary source because of its effectiveness in identifying relevant peer-reviewed literature, which improves the quality and credibility of the literature review (Ali & Tanveer, 2022; Valente et al., 2022). For references to specific samples such as post-illegal gold mining land in Lamat Payang, Bengkayang that are not available in Scopus, Google Scholar serves as a secondary source due to its broader coverage, which includes gray literature and local documents that are rarely indexed in Scopus (Martin et al., 2020; Haddaway et al., 2015). The inclusion criteria include publications indexed in Q1–Q4 journals and published within the past ten years.

The research strategy is consistent with best practices in systematic literature reviews, prioritizing high-reputation databases such as Scopus while also allowing for the use of Google Scholar, particularly for topics or locations underrepresented in international journals (Ali & Tanveer, 2022; Valente et al., 2022; Haddaway et al., 2015). This combined approach ensures that the collected literature is relevant, comprehensive, and scientifically sound. The analytical framework focuses on two primary components: Cash Waqf-Linked Infrastructure Investment Fund/*Dana Investasi Infrastruktur* (DINFRA) financing mechanisms and phytomining operational processes are examined to determine how they can be integrated into a unified scheme for sustainable post-mining land rehabilitation (Ratnasari et al., 2021; Ascarya et al., 2022; Aldeen et al., 2021).

3. Results and Discussion

3.1 CWL-FRA operational framework and implementation

The research developed an integrated Cash Waqf Linked Infrastructure Investment Fund (CWL-FRA) model for phytomining implementation in post-mining land rehabilitation. The operational framework begins with cash waqf collection from individual or institutional donors (*wakif*), which is then channeled to social financial institutions involved in waqf management. Within this CWL-FRA structure, waqf institutions must ensure that all donors understand the perpetual nature (*muabbad*) of the waqf contract, meaning waqf assets will be permanently managed by the institution. This finding aligns with existing research emphasizing the crucial importance of *nazhir* qualifications in managing cash waqf, particularly regarding accountability and transparency in waqf asset management (Aryana, 2022). The institutions must also adhere to principles established in Statement of Financial Accounting Standards/*Pernyataan Standar Akuntansi Keuangan* (PSAK) 112 to ensure proper waqf governance.

In the subsequent stages (second to fourth), waqf institutions invest the cash waqf into infrastructure assets through investment managers and custodian banks. A Special Purpose Company (SPC) provides revenue-generating infrastructure assets for Infrastructure Investment Fund/*Dana Investasi Infrastruktur* (DINFRA), specifically phytomining

infrastructure in this context. This multi-layered structure ensures professional management while maintaining Shariah compliance throughout the investment process.

The fifth stage focuses on the operational management of *Phyllanthus rufuschaneyi* from cultivation to bio-ore production. The process begins with seedling propagation in controlled greenhouse facilities, where high-quality seedlings are mass-produced to enhance survival rates and minimize the risk of harvest failure. Following seedling preparation, planting occurs on one-hectare land plots, supported by smart irrigation systems that use solar-powered pumps and water reservoirs, ensuring a consistent water supply through seasonal variations while reducing long-term operational costs.

Plants are maintained until harvest, with assumed productivity of 25 tons of dry biomass per hectare per cycle. Post-harvest, fresh biomass is collected and transferred to rapid-drying platforms (kilns or drying racks with controlled blowers) to maintain consistency in nickel content and prevent moisture-related degradation. The dried biomass is processed in pyrolysis facilities or low-emission controlled combustion systems, yielding nickel-rich bio-ore. Based on the assumed 2.5% nickel content, 25 tons of biomass yields approximately 625 kg of nickel per hectare per cycle.

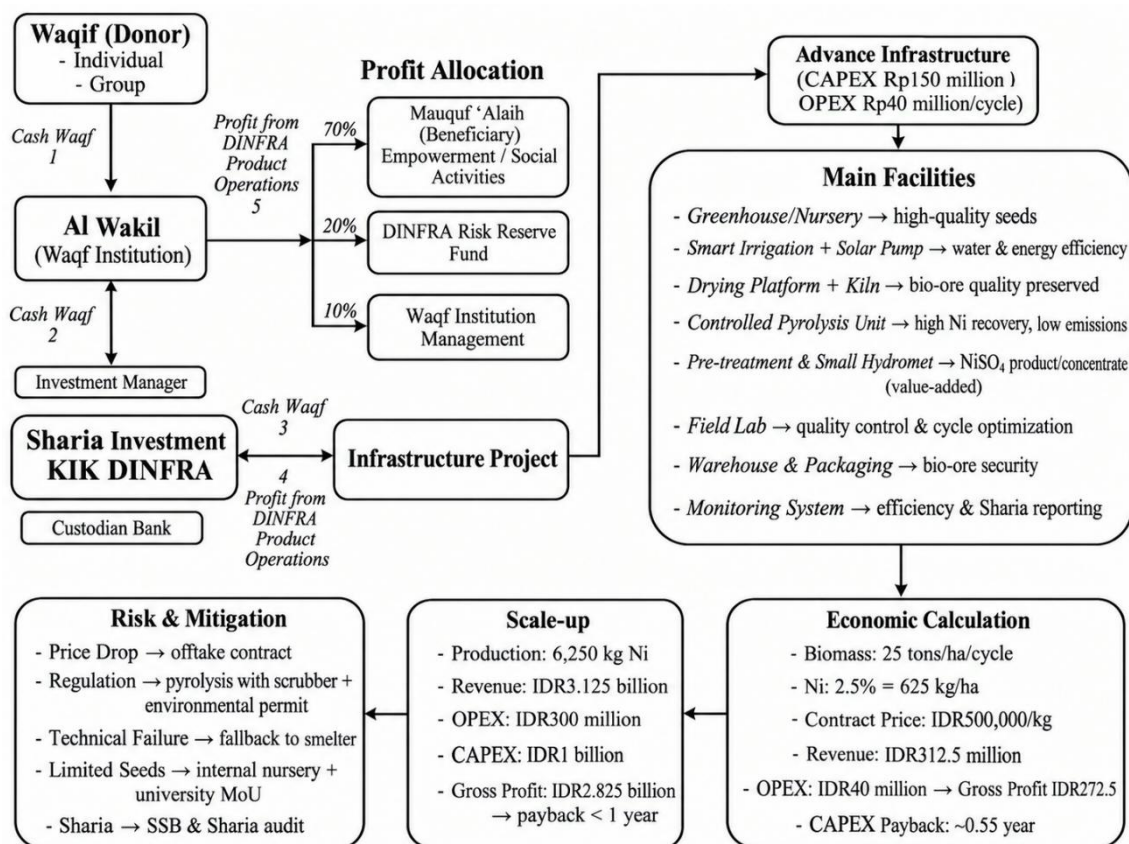


Fig. 1. CWL-FRA mechanism

When Infrastructure Investment Fund/Dana Investasi Infrastruktur (DINFRA) assets comprise bio-ore, waqf institutions generate revenue from users of bio-ore. The CWL-FRA approach implements a structured dividend distribution system: 70% for empowering *mauquf 'alaih* (waqf beneficiaries) and social activities, specifically directed toward healthcare workers and educators in the research area; 20% for Infrastructure Investment Fund/Dana Investasi Infrastruktur (DINFRA) risk reserve funds; and 10% for waqf institution operational management. This distribution mechanism ensures social sustainability while maintaining operational efficiency and risk mitigation. The allocation of dividends creates a clear linkage between income generated from productive waqf assets and the fulfillment of social objectives. The dedicated risk reserve also provides a financial buffer to absorb potential fluctuations in infrastructure-related returns without disrupting

beneficiary-oriented programs. Meanwhile, the operational allocation supports institutional continuity and ensures that the waqf management system can function effectively over the long term.

3.2 Socio-economic impacts and benefit distribution

The allocation of 70% of profits to *mauquf 'alaih* represents a strategic approach to addressing development challenges in the research area of Lamat Payang Hamlet, Tirta Kencana Village, Bengkayang Regency. The focus on teacher and doctor salaries shows the model's potential to improve educational and healthcare quality. Investment in teacher salaries proves crucial not only for enhancing welfare but also impacting education quality. Past studies confirm that adequate salaries significantly improve teacher motivation, satisfaction, and professionalism, leading to greater commitment and more effective teaching capabilities (Prashanti & Astawa, 2022; Widyantara, 2019; Krismawati & Manuaba, 2022). The research further supports existing literature indicating that sufficient compensation encourages teacher engagement in various educational activities, positively affecting student learning outcomes (Sazideh et al., 2020; Torimtubun et al., 2020; Li-mei et al., 2022). Therefore, this allocation strategy represents a vital intervention for improving education quality, where salary increases not only impact teacher welfare but also serve as strategic factors in enhancing student achievement and overall education quality (Faizi et al., 2024).

Similarly, investment in doctor salaries demonstrates comparable importance, affecting healthcare service quality. The research findings indicate that adequate remuneration improves job satisfaction, motivation, and physician performance, ultimately enhancing medical service quality in healthcare facilities (Pasinringi et al., 2019). This aligns with existing research affirming that proper compensation for medical personnel constitutes human capital investment with long-term impacts on healthcare system effectiveness (Aspa & Badollahi, 2024; Prabowo & Widarni, 2021). The established positive relationship between adequate remuneration and improved health outcomes further validates this approach (Kim et al., 2020; Jacques, 2025).

Moreover, the model extends benefits beyond immediate sectoral improvements. Countries investing in medical personnel welfare tend to have healthier, more productive populations capable of optimally contributing to economic growth (Raghupathi & Raghupathi, 2020; Yar, 2024). Thus, the profit allocation strategy is expected to strengthen public service quality while promoting sustainable economic growth in the target region. Improved welfare can also enhance the motivation, retention, and service capacity of healthcare personnel, thereby supporting the continuity and quality of essential public services. Over time, these improvements may contribute to better population health outcomes, increased labor productivity, and reduced socioeconomic vulnerabilities. In this way, the allocation of waqf-generated returns can function not only as a financing mechanism but also as a means of reinforcing the broader human-capital foundation of regional development.

3.3 Comparative advantages and sustainability analysis

The infrastructure-based waqf investment scheme (DINFRA) for phytomining development using *Phyllanthus rufuschaneyi* demonstrates comprehensive advantages across fund collection, profit allocation, project implementation, and risk management dimensions. Compared to conventional rehabilitation approaches, this model offers superior sustainability through its integrated financial and environmental framework.

Regarding fund mobilization, active donor participation through managed cash waqf demonstrates waqf's evolution as a productive investment instrument in the real sector (Maisyarah & Hadi, 2024). The profit allocation mechanism reflects an optimal balance, prioritizing social sustainability (70% to beneficiaries) while maintaining operational stability (20% risk reserve) and institutional sustainability (10% operational costs),

consistent with best practices in social finance management (Majid, 2021). The implementation showcases advanced infrastructure integration, including nurseries, smart irrigation systems, and efficient pyrolysis units, enhancing productivity while maintaining environmental standards (Khosim & Busro, 2020). This represents significant advancement over traditional rehabilitation methods that often lack technology and economic viability.

The integrated risk management framework, incorporating offtake contracts, environmental compliance, and mitigation, ensures project continuity and addresses common mistakes in environmental rehabilitation projects (Fauzi & Jahidi, 2022). The project demonstrates viability with production capacity reaching 6,250 kg Ni annually and potential revenue of approximately IDR 2.825 billion, accompanied by a payback period under one year (Ascarya et al., 2022). Further economic analysis confirms the model's capacity to generate significant gross profit per hectare with capital expenditure recovery within 0.55 years, establishing both economic viability and social sustainability.

When compared to previous waqf models focused primarily on traditional sectors, this research demonstrates innovative application in environmental rehabilitation, creating new avenues for Islamic social finance contribution to sustainable development. The dual benefit approach mainly environmental remediation and socioeconomic improvement put this model as a comprehensive solution addressing Sustainable Development Goals. The CWL-FRA phytomining model thus represents a significant contribution to both Islamic finance and environmental management literature, offering a replicable framework for sustainable post-mining land rehabilitation while establishing new standards for social finance implementation in environmental projects.

3.4 Regulatory compability

The proposed CWL-FRA phytomining model operates within the existing legal framework of Indonesia's waqf and mining regulations, ensuring its feasibility and legitimacy. Under Law No. 41 of 2004 on Waqf and Government Regulation No. 42 of 2006, cash waqf is recognized as a valid form of waqf asset, provided that it is managed productively by a certified nazhir and its proceeds are directed toward permissible (halal) and socially beneficial purposes. The model's investment in phytomining infrastructure qualifies as a productive waqf activity, as it generates ongoing returns while serving environmental and social objectives. Meanwhile, the mining sector is governed by Law No. 3 of 2020 on Mineral and Coal Mining, which mandates that mining companies undertake reclamation and post-mining rehabilitation as part of their operational obligations. The integration of phytomining into post-mining land rehabilitation aligns with these statutory requirements, as it contributes to restoring land functionality and reducing environmental liabilities. Furthermore, the use of a Special Purpose Company (SPC) as an intermediary ensures that waqf funds are channeled through legally recognized corporate structures, facilitating compliance with both waqf governance standards and mining operational permits. This regulatory synergy underscores the model's viability within Indonesia's current legal landscape, providing a solid foundation for its implementation without requiring extensive regulatory reforms.

4. Conclusions

This study concludes that the integration of the Cash Waqf Linked DINFRA (CWL-DINFRA) model with *Phyllanthus rufuschaneyi* phytomining technology presents a solution for post-mining land rehabilitation. The research demonstrates that this integrated model successfully addresses the core aims of green development by combining economic productivity with ecological restoration. Its findings and contributions are threefold. First, it provides a mechanism for remediation by leveraging productive cash waqf as a sharia-compliant instrument for funding sustainable projects, thereby contributing to the literature on green economic growth and innovative financing. Second, the model generates layered value: it facilitates ecosystem recovery while at the same time creating economic

value through bio-ore nickel production, and aligns with the scope of sustainable resource management and eco-friendly innovation. Third, it integrates a social impact framework by channeling profits into community empowerment, education, and health, ensuring that economic gains translate into prosperity. The CWL-DINFRA scheme offers a replicable, policy-relevant case study in green development. It shows how modern waqf can be adopted to achieve sustainable development goals, providing insights for policymakers and financial institutions aiming to bridge economic development.

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Author Contribution

Conceptualization, B.A.S.; Methodology, B.A.S.; Software, A.S.M.; Validation, B.A.S.; Formal Analysis, A.R.A.; Investigation, A.R.A.; Resources, A.R.A.; Data Curation, A.S.M.; Writing – Original Draft Preparation, B.A.S.; Writing – Review & Editing, A.R.A.; Visualization, A.S.M.; Supervision, B.A.S.; and Project Administration, B.A.S.

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The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Scite AI to help synthesize the literature and Grammarly to improve the manuscript's grammar, clarity, and academic tone. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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