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SOIL DEGRADATION RISK AND HUMAN SECURITY IMPLICATIONS OF LAND USE IN SAMARINDA'S STEEP SLOPES

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ABSTRACT

Soil erosion represents a critical environmental issue that threatens both ecological stability and human security in rapidly developing urban areas of Indonesia. This study aims to assess the soil erosion potential in Air Hitam Subdistrict, Samarinda Ulu, East Kalimantan, through field observation and environmental analysis. The study area is characterized by steep slopes, open-pit mining activities, limited vegetation cover, and high rainfall intensity, which collectively accelerate surface erosion processes and increase landslide potential. The soil type was identified with clay-dominated texture and low permeability, leading to significant surface runoff. Observations revealed clear signs of slope instability, sediment displacement, and exposed subsoil layers, confirming high erosion susceptibility. The degradation of vegetation and soil structure not only increases the likelihood of slope failure but also poses direct risks to surrounding communities, infrastructures, and water systems. To mitigate these impacts, integrated land conservation strategies are recommended, including slope stabilization, drainage improvement, and revegetation using local pioneer species such as Vetiver grass and leguminous cover crops.

Keywords: Soil erosion; Environmental security; Human security; Land conservation; Samarinda

A. INTRODUCTION

Soil degradation in Indonesia's urban slope environments presents a critical challenge to sustainable development, exacerbated by rapid urbanization and inadequate land management practices (Istiqomah et al. 2024). Land degradation processes, including erosion and slope instability, are intensified by deforestation, intensive land use, and climate-driven heavy rainfall, leading to loss of topsoil, reduced productivity, and heightened disaster risks in hilly watersheds (Ambarwulan et al. 2021).

Ecological stability is closely intertwined with human security, as deteriorating land quality undermines ecosystem services essential for food security, health, and economic resilience (Indrawati and Fatchurohman 2023; Khusna et al. 2022). In tropical urban settings, ecological risks from mining and land conversion threaten national security by disrupting social-economic growth and increasing vulnerability to disasters like landslides and floods (Adhi, Dewi, and Turisno 2022; Kedhaton and Krismondo 2024; Kedhaton and Hastuti 2023). Studies emphasize that comprehensive ecological security assessments, integrating spatial and biological approaches, are vital for mitigating these threats in mining-impacted regions (Indrawati and Fatchurohman 2023; Khusna et al. 2022).

Samarinda, the capital of East Kalimantan, exemplifies urban pressure on steep slopes, where coal mining occupies up to 70% of municipal land, driving rapid land cover changes (Indra, Amalia, and Damayanti 2021; Jamin et al. 2023). Secondary forests have declined by over 26 km² from 1990–2020, while mining expanded by 13.7 km² in watersheds like Karangmumus, elevating soil conservation curve numbers and peak discharges (Widyasasi et al. 2024). In Samarinda Ulu's Air Hitam area, characterized by slopes exceeding 40% and low vegetation cover, slope instability is rampant due to the city's low elevation (<50 MASL) and high daily rainfall (7.24–7.29 mm³/day) (Indra, Amalia, and Damayanti 2021; Istiqomah et al. 2024).

Key triggers include open-pit coal mining, which causes topsoil erosion, hydrological disruptions, and stability loss (Jamin et al. 2023; Sukri et al. 2023). Deforestation and vegetation removal, amplifying runoff (Sartohadi, Rahma, and Nugraha 2024; Widyasasi et al. 2024) and intense rainfall exacerbating landslides on exposed slopes (Sari et al. 2023; Sejati, Karim, and Tanjung 2020). Between 2014–2018, mining expansion in Samarinda worsened landslides and flooding, claiming lives and costing millions (Jamin et al. 2023).

These dynamics pose severe consequences for local communities and infrastructure, including habitat loss, sedimentation, floods, and infrastructure damage in vulnerable urban fringes (Restele et al. 2022; Kedhaton and Krismondo 2024). In Samarinda, mining expansion between 2014 and 2018 worsened landslides and flooding, with associated mining hazards claiming 115 lives in East Kalimantan's former coal mining regions and damages costing about $9 million according to Mining Advocacy Network and WWF research (Jamin et al. 2023).

Broader socio-economic impacts from land degradation persist in similar Indonesian contexts (Adhi, Dewi, and Turisno 2022).

This study aims to analyze soil erosion potential in Samarinda's steep slopes using Universal Soil Loss Equation Models, to assess human security implications of land degradation, focusing on ecological risks and community vulnerability, and to propose land conservation strategies, including revegetation, spatial planning, and sustainable mining reclamation. The research contributes to sustainable urban land management by prioritizing restoration in high-degradation zones, informing environmental policy for ex-mining reclamation in Kalimantan, and advancing disaster risk reduction through erosion hazard indexing and zoning. Ultimately, it supports regional spatial planning for resilient human security amid urbanization.

B. METHOD

This study was conducted in the Air Hitam Subdistrict, Samarinda Ulu District, East Kalimantan Province, Indonesia, at coordinates 0°27'04.53" S; 117°08'11.30" E. Field observations documented slope stability, vegetation density, bare soil exposure, and surface drainage patterns in mining and residential zones. Topographic mapping utilized Google Earth Pro imagery to delineate mining extents. Semi-structured interviews with local residents provided qualitative insights into perceived erosion risks, seasonal flooding, and human security impacts. Erosion potential was estimated qualitatively and descriptively using the Universal Soil Loss Equation (USLE) parameters: rainfall erosivity (R), soil erodibility (K), slope length/steepness, cover-management (C), and support practices (P). Human security implications were assessed by overlaying vulnerability indices from interviews with erosion hazard zones to identify high-risk communities.

C. RESULT

C.1. Soil Erosion Potential in Air Hitam Subdistrict, Samarinda

The Air Hitam subdistrict in Samarinda Ulu features steep slopes exceeding 40%, active sand mining, and sparse vegetation cover, fostering high soil erosion vulnerability under a tropical rainforest climate with annual rainfall surpassing 2,000 mm (Abedini, Said, and Ahmad 2025). High rainfall intensity drives erosivity, amplifying runoff on disturbed mining lands compared to vegetated residential zones (Widyasasi et al. 2024). Field observations confirm sediment displacement and exposed subsoils in mining pits, indicating severe degradation.

The observed soil, based on field texture and color, appears to be clay loam subsoil commonly found in Samarinda's hilly areas, regionally classified as Ultisol according to soil maps. This soil structure allows little water infiltration and tends to form compact layers. As a result, rainfall quickly becomes surface runoff, accelerating erosion on unprotected slopes (Widyasasi et al. 2024). Observations at several sites show visible signs of crusting and fine particle detachment, confirming that the soil in this area is highly susceptible to erosion under heavy rain (Figure 1). Mining activities disturb the natural soil profile and destroy the thin organic layer that stabilizes aggregates, increasing the risk of sediment displacement even under moderate rainfall intensity (Zulkarnain et al. 2023; Istiqomah et al. 2024).

Figure 1. Erosion Area in Air Hitam, Samarinda Ulu

Vegetation cover in the study area is generally sparse, especially on the southern slopes where active sand excavation occurs. Only a few patches of grass and small shrubs remain, offering minimal protection against splash and sheet erosion. The absence of deep-rooted vegetation in mined zones contributes to slope instability and exposes the subsoil layer to direct rainfall impact. Consequently, eroded materials are frequently transported downslope, accumulating near drainage channels and along roadside embankments, which in turn increases sedimentation and reduces drainage efficiency (Zulkarnain et al. 2023; Saksono, Indrawan, and Wilopo 2022).

Figure 2. Sediments Resulting from Erosion on The Slope Area

The combination of steep slopes exceeding 40%, low infiltration capacity of Ultisols, and inadequate drainage systems exacerbates soil degradation in Air Hitam Subdistrict. Field sketches and photographs taken along the Ringroad area reveal visible rill formation and shallow gully erosion resulting from uncontrolled surface runoff. In several locations, mining excavations have produced near-vertical slope faces devoid of terraces or retaining structures, rendering them highly susceptible to collapse during intense tropical storms (Simangunsong, Prassetyo, and Pinem 2024; Pambudi et al. 2023). The close proximity of these degraded slopes to residential areas elevates risks to human life and infrastructure, as sediment-laden runoff infiltrates roads and drainage ditches (Figure 2), inducing localized flooding and muddy debris flows. Such physical evidence illustrates that unmanaged land use and excavation practices on steep terrains directly precipitate land degradation.

C.2. Implications of Erosion on Human Security

Soil erosion in Air Hitam from stone mining destabilizes steep slopes, heightening landslide risks to nearby settlements, infrastructure, and lives in stone mining-adjacent urban fringes. Exposed quarries and bare slopes amplify vulnerability, with informal communities facing property damage and service disruptions (MacAfee, Löhr, and de Jong 2024; Pambudi et al. 2023). Dust and instability from stone mining operations compound health and safety threats for residents (Zapico et al. 2020).

Landslides from erosion damage roads, buildings, and utilities, isolating low-income households in high-risk zones (Choirunnisa, Purwaningsih, and Prasetyani 2022; Momon et al.

2021). In East Kalimantan mines, proximity of concessions to settlements elevates human exposure to failures (Werner et al. 2023). Regulatory lapses in permits exacerbate risks, linking land clearing to heightened instability (Saksono, Indrawan, and Wilopo 2022). Local interviews reveal perceived threats to daily mobility and economic access.

Runoff carries sediments and mining contaminants into rivers, polluting water for drinking, sanitation, and irrigation (Cuevas et al. 2024). Sedimentation reduces watershed services, threatening food security via lowered agricultural yields. Communities reliant on polluted streams face compounded vulnerabilities in flood-prone lowlands (Restele et al. 2022; Widyasasi et al. 2024). The increased sediment load in waterways due to erosion can contaminate water sources, impacting public health and livelihoods.

Erosion undermines livelihoods, slashing topsoil fertility and agricultural productivity for slope farmers. Mining-dependent jobs falter amid unstable pits, with slope failures halting operations and causing losses (Barchia et al. 2023; Prasetyo, Dewi, and Adi 2023). Degraded lands diminish eco-services, affecting income from farming and informal mining. Socio-economic impacts persist, mirroring broader Indonesian mining contexts with $9 M damages (MacAfee, Löhr, and de Jong 2024; Jamin et al. 2023).

Holistic land management is imperative, incorporating slope stabilization, drainage upgrades, and revegetation with pioneers. Revegetation restores cover, curbing runoff and enhancing security via resilient ecosystems. Policy-driven reclamation, including zoning high-risk areas, bolsters community resilience (Khusna et al. 2022). These strategies mitigate disasters, safeguard water/food security, and sustain economies.

D. DISCUSSION

This study aimed to assess soil erosion potential and its human security implications in Samarinda’s steep slopes. The findings confirmed that sand mining and inadequate land cover are the primary drivers of surface degradation and slope instability. The degradation of slope environments directly threatens human security in the Air Hitam area. Unstable slopes and excessive sediment yield increase the likelihood of small-scale landslides, drainage blockage, and localized flooding that can endanger nearby settlements. Communities living around sand mining sites face reduced safety and environmental quality, particularly during heavy rainfall events.

Mitigation and soil conservation efforts are therefore essential to stabilize slopes and prevent further erosion (Zulkarnain et al. 2023; Novianti et al. 2021). Recommended measures include constructing terraces and drainage channels to control surface flow (Pambudi et al. 2023), as well as implementing revegetation using Vetiver grass and local leguminous cover crops to enhance root binding and infiltration (Sartohadi, Rahma, and Nugraha 2024). Returning topsoil to mined areas and contouring the slopes to gentler gradients can also improve soil stability (Pratiwi, Ramadani, and Tambunan 2023). In addition, increasing community awareness of the environmental and safety risks of uncontrolled sand mining is crucial (Werner et al. 2023). With proper conservation practices, it is possible to reduce erosion intensity and improve land resilience (Sujiman 2023), supporting sustainable land use and human security in the steep slopes of Samarinda's Air Hitam area.

From a policy perspective, integrating erosion hazard assessment into Samarinda's spatial planning framework is essential. Local authorities should enforce rehabilitation requirements for sand mining operations and strengthen community-based monitoring systems. Collaboration among government agencies, universities, and residents can support participatory land-use management that aligns with regional sustainability goals (Masruroh et al. 2023; Setiawan et al. 2021). Such strategies not only address land degradation but also reinforce environmental security as a component of human security in urban development planning

While field and spatial data were comprehensively analyzed, several limitations were encountered. Field observations were conducted during the dry season, which may not fully capture seasonal variations in erosion intensity. The limited number of soil sampling sites and reliance on self-reported data from interviews may also influence the precision of vulnerability mapping. Future research should include multi-seasonal monitoring and quantitative erosion rate validation.

E. CONCLUSION

The results of this study indicate that soil erosion in the steep slopes of Air Hitam Subdistrict, Samarinda Ulu, is primarily driven by sand mining activities, limited vegetation cover, and steep topography. Field observations revealed exposed subsoil, the formation of rills and small gullies, and loss of topsoil on slopes exceeding 40%, signifying active surface erosion and degradation. The removal of vegetation and disturbance of the upper soil layer have reduced infiltration and increased surface runoff during rainfall, intensifying slope instability. These conditions threaten nearby settlements and infrastructure through sedimentation, flooding, and minor landslides, linking environmental degradation directly to local human security concerns in urban hillside areas.

To address these challenges, slope stabilization and soil conservation practices are essential. Recommended measures include the construction of terraces and drainage channels to control runoff, along with revegetation using Vetiver grass and local leguminous cover crops to strengthen soil binding and enhance infiltration. Replacing topsoil and reshaping steep slopes into gentler gradients can further reduce erosion risk. In addition, community awareness and stricter regulation of sand mining activities are crucial to ensure responsible land management.

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