The Impact of Bauxite Mining On The Semanduk Lake Environment: A Case Study In Tayan Hilir, Sanggau District, West Kalimantan Province, Indonesia Country

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Abstract

Background: Several mining activities, especially bauxite, have been carried out in several areas in West Kalimantan. The areas most widely carried out bauxite mining are Sanggau and Ketapang districts. Bauxite mining is included in the classification of surface mining or often referred to as open mining. This is characterized by the demolition of the upper layers of soil and taking the results of weathering rocks, namely granite rocks. The demolition of topsoil is done with the clearing of vegetation above. In this condition, the land still has the same morphology when clearing has not been done and the soil has not been much disturbed. But after mining there is a lot of clay, sandstone, topsoil materials, of course, this will have a negative impact on the environment.

Result: The results showed that the gradient of the slope has an important role in land conservation. The greater gradient of the slope will automatically increase the surface runoff, so the greater the energy of run-off. The soil depth is shallow on average and has poor deep soil drainage. Soil is easily eroded, so a lot of rocks and gravel are exposed on the surface, plants cannot develop properly. Floods often occur, in areas of alluvial plains with a range of more than 24 hours. The water availability capacity is also very low. Rainwater in the area mostly becomes runoff. The nutrient content in the ex-mining area is also low. Therefore it is necessary to improve efforts by means of reforestation of the former land so that in the future it can be used for certain uses, especially for agriculture, plantations, and forests.

Conclusion: Slopes have an important role in land conservation. Slope affects runoff, effective soil depth, erosion rate, plant growth, waterlogging. Nutrient content in ex- Bauxite mining areas is also low.

Introduction

West Kalimantan has very diverse natural resources. Mining potential includes iron, silver, copper, gold, antimony, Mo, lead, bauxite, and so on. The high potential of the mine is due to West Kalimantan is a metalogin track that contains a lot of metal mineral types. The metalogin track or often called metalogin province is an area that contains one or more types of metal mineral traps (Yuniarni R, 2014). The types of metal minerals are widely distributed in various regions in West Kalimantan. Bauxite which is a superior mining resource in West Kalimantan is located in Mempawah, Bengkayang, Sanggau, Landak, Ketapang, Sekadau, Kuburaya, and North Kayong districts.

The large potential of mining materials spread across West Kalimantan has an impact on investment direction. The direction of investment that was initially focused or dominant in the plantation sector has now shifted to the mining sector, especially bauxite refining. This was carried out until the end of 2016 as many as 640 companies had held mining licenses and 60 percent were engaged in bauxite mining (Jumiadatin, 2015). Mining activities could be beneficial to the economic growth of countries if managed properly. However, there is always a trade-off between economic growth and environmental sustainability, because of the excessive exploitation of natural resources (Awan, 2013; Bawua & Owusu, 2018).

Several mining activities, especially bauxite, have been carried out in several areas in West Kalimantan. The areas most widely carried out bauxite mining are Sanggau and Ketapang districts. Bauxite mining is included in the classification of surface mining or often referred to as open mining. This is characterized by the demolition

of the upper layers of soil and taking the results of weathering rocks, namely granite rocks. The demolition of topsoil is done with the clearing of vegetation above. In this condition, the land still has the same morphology when clearing has not been done and the soil has not been much disturbed. But after mining there is a lot of clay, sandstone, topsoil materials, of course, this will have a negative impact on the environment.

Mining impacts can be categorized into three aspects: 1) physical impacts due to mining to the land are of lots of open lands, land use change, deforestation, erosion, alteration of the soil profile (Haddaway et al., 2019; Sonter, Moran, Barrett, & Soares-Filho, 2014; Swenson, Carter, Domec, & Delgado, 2011) landslides, holes, and piles of mountain rock fragments, soil compaction due to the use of heavy equipment for excavation and transportation. Essentially a lot of damage is inflicted on the soil and the discovery of negative traits on the soil during repairs (Haigh, 2000; Miao & Marrs, 2000) 2) water quality impacts caused by mining. Impacts on water quality include contamination of local streams and (Haddaway et al., 2019; Sonter et al., 2014; Swenson et al., 2011); 3) ecological impacts such as habitat loss and species disturbance (Sengani & Zvarivadza, 2018).

Mining impact also affects the community around the mine site. That impact, among others human health (Nakazawa et al., 2016; Stephens & Ahern, 2001), and living standards (Loayza & Rigolini, 2016), affect traditional practices of Indigenous peoples living in nearby communities (Gibson & Klinck, 2005; Haddaway et al., 2019), and conflicts in land use (Nakazawa et al., 2016; Zhang et al., 2012). Besides having a negative impact, mining also has a positive impact. In terms of positive impacts, mining is often a source of local employment and may contribute to local and regional economies (Fleming & Measham, 2014; Haddaway et al., 2019; Knobbloch & Pettersson, 2010).

Based on a number of mining impacts that might arise above, mitigation of former land mainly to the land, in this case, is the physical and chemical characteristics of the land so it is necessary to make an inventory of conditions that occur after mining. This effort was made so that the land former to bauxite mining does not experience more severe degradation. But land can be used sustainably for the survival of ecosystems in and around it. Though the benefits are known, its induced consequences are enormous (Adesipo, *et al*, 2020). Therefore, direct and indirect impacts can be identified that have caused them on the environment around the mine (Adesipo et al., 2020; Kim, Zerbe, & Kowarik, 2002)

Material And Method

Study Area

This research was conducted at the site of the former bauxite mining, located in Sejutang Village, Sanggau District, West Kalimantan Province, Indonesia. The area of study site is 93,628.7 Ha. Geographical this area is located between Longitude from 110°4'0" E to 110°5'0" E and Latitude 0°1'30" S to 0°20'30" S. For more details, the bauxite mining location can be seen in Fig. 1.

The method used in this research is the survey and laboratory analysis. The survey method is used to take soil samples and record the physical characteristics of former bauxite mining land, while laboratory analysis is used to determine the chemical nature of the land at the site of the former bauxite mine. The data used in this study are: 1) physical soil data consisting of surface slopes, soil texture, soil permeability, soil depth, soil

drainage, erosion hazard, erosion sensitivity, 2) chemical land data consisting of organic soil, Exchange Capacity Cation, pH, KCl, C, total N, N-NH₄, phosphorus, P₂O₅, K₂O, Na, K.

The Case Study

Administratively the research site is bordered by the village of Kawat in the west, Tebang Benua and Subah in the north, in the east by Subah and Lalang, in the south by Toba sub-district. The results of the author's survey (2020) have been known since PT Mahkota Karya Utama (MKU) engaged in bauxite mining conducted mining, the current condition of the lake experienced silting, the surrounding environment (forest) many were damaged and the community lives increasingly difficult. The source of income is getting smaller and even partially lost, since mining activities began, in 2011.

The results of the author's survey revealed that there had been environmental damage and siltation of the Semanduk lake due to bauxite mining. Land damage was identified characteristics: a lot of vegetation was lost, so that many land surfaces were exposed. Land clearing causes rough surface textures, reservoir water bodies to disappear. Land damage is seen in the image even extends to the border of the Kapuas river. There is even soil material which is partly flowing and settling in the Kapuas River. Kapuas river water looks turbid and somewhat brownish, this shows that there are materials that are carried by the flow of water into the river and are deposited on the riverbed.

Result

Physical Characteristic

The slope gradient of the study site ranges from 0–20% with flat to hilly topography. The soil texture at the study site is clay to sandy loam. The results of laboratory analysis show that the permeability of the ex-bauxite mine site ranges from 0.059 cm/hour (very slow in the classification of permeability) to 15,67 cm/hour (very fast) in the classification of permeability. The depth of the soil at the study site ranges 25 - > 90 cm. Based on the survey results it is known that the soil drainage of the study site is bad, poor, and good.

The soil drainage is very bad, shown by the soil in all layers until the soil surface is gray and the subsoil is gray or there are bluish spots, or there is water that has stagnated on the surface of the soil for a long time so that it inhibits plant growth. The drainage poor shown by the soil has good air circulation in the root area. There are no yellow, brown, or gray spots on the top layer and the top of the lower layer (up to about 60 cm and the soil surface). The soil drainage good shown by soil has good air circulation. The entire profile from top to bottom (soil depth 150 cm) is uniformly light-colored and there are no yellow, brown, or gray spots.

Erosion sensitivity (soil erodibility) in the study area ranges from 0.21 to 0.63 (in the erosion sensitivity include moderate until very high). The form of erosion that occurred at the study site showed the presence of gully erosion. These erosions have a depth of > 40 cm and a width of more than 30 cm.

Rocks and gravels are coarse material that has a diameter of 2.5 cm if they are round, the elongated axis has a size of 15–40 cm if they are flat. Rocks that are included in the gravel category have a diameter of more than 12 – 7.5 cm if they are round in shape, an axis that extends 15 cm if they are flat. These coarse materials are scattered in the topsoil layer or above the soil surface. A sampling of surface rock or gravel content is done by

taking the unit area, which is 25 square meters. Based on the results of the field survey, it is known that the content of these rocks and gravel ranges from 0.01–90%.

The threat of flooding or inundation is caused by deep drainage and poor surface drainage. The infiltration and percolation processes are hampered by the presence of soil texture or the size of the soft soil grains, while the drying of the surface is also hampered by the flat to gentle slope. Based on the research results, it is known that inundation conditions or the threat of flooding only occur in fluvial landforms. This landform is in danger of flooding for one month of the year, the land is always inundated by floods for more than 24 hours.

Bauxite mining also affects the water availability capacity of the study site. The results showed that the water availability capacity in the study area ranged from 7.5 to 22.5 cm. The lack of water availability capacity will greatly affect the function and roots in the total volume of soil. These effects are low water density, low soil strength, very low pH values, other chemical and physical properties that can limit root growth and root distribution in soil mass (Sinclair Jr & Dobos, 2006; Staff, 1999). The physical characteristics mentioned above can be briefly seen in Table 1.

Table 1
Land Characteristic and Land Quality of Each Land Unit

Code	(l)	(b)	(t)	(P)	(WAC)	(k)	(d)	(e)	(KE)	(L)	(O)
(%)	(%)		(cm/hr)	(cm)	(cm)		(%)				
D1	14–20	15–90	clay	0,5–2	>7.5–15	50–25	poor	25–75	0.11–0.20	light	never
D2	8–13	15–90	sandy loam	< 9,20	> 15 - < 22.5	< 25	good	25–75	0.33–0.43	light	never
D3	3–7	0,01	loam	< 0,5	> 22.5	90–50	bad	none	0.00–0.10	no landslide	sometime
D4	3–7	0,01	clay	< 0,5	> 22.5	> 90	good	none	0.00–0.10	no landslide	sometime
F2	0–2	0,01	loam	0,5–2	> 22.5	> 90	poor	none	0.00–0.10	no landslide	during one month flood > 24 hours

Source: Primary data, 2020

Explanation:

Land characteristics

(l) the surface slope (%)	(d) soil drainage
(b) gravel/rock (%)	(e) erosion hazard (%)
(t) soil texture	(KE) Erodibility
(p) permeability(cm/hr)	(L) landslide threat
(WAC) water availability capacity (cm)	(o) flood threat
(k) depth of soil (cm)	

Chemis characteristic

The chemical elements in this study included soil organic, CEC, pH, KCl, C, total N, N-NH₄, P, P₂O₅, K₂O, Na, K and salinity. These chemical properties, namely:

a. Nutrient Retention (nr)

This nutrient retention consists of soil cation exchange capacity (CEC), base saturation (KB), pH and organic C. The cation exchange capacity is between 2.01 and 4.23 cmol. Base saturation (N-NH₄) shows the ratio of the number of base cations that are exchanged for the cation exchange capacity is between 11 and 98 ppm. There are two methods in determining pH, electrometrically, using H₂O and KCl. The addition of H₂O serves to determine the active acidity, while the addition of KCl serves to determine the potential acidity. The pH of H₂O is between 5.26 and 5.54, while the pH of KCl is between 4.38 and 6.78. This indicates that the pH of the soil in the study location is acidic because it is still below 7. The organic matter content in this form of soil is between 1.69 and 5.17%. Dredging the topsoil for mining activities, a lot of soil organic remains on the surface are lost and it allows a reduction in the soil organic matter content.

b. Availability of Nutrients (na)

Most of the nutrients present in the soil needed by plants are in the bonded form as a compound for organic matter, so that not all nutrients are available in the soil in the form of cations or anions. These elements and compounds are macronutrients and are mostly taken up by plants. Nutrient availability includes total N, P, K available, and P₂O₅ available. The total Nitrogen (N) content in the soil is between 0.01% and 0.07%, the phosphorus content (P) in this soil form is 57 ppm. Potassium (K available) content is 5 ppm, and P₂O₅ content is available 10 mg/ 100g. The K₂O content is 5 mg/ 100g.

c.Toxicity (xc)

Toxicity is determined by the salt/salinity content in the soil. The soil toxicity at the study sites had values between 10.89 and 40.20 mmosh/cm. Salinity is a form of poison to plants. If seen, the salinity of the research location is quite high, so that the plants will not be able to grow and even die quickly.

d. Alkalinity (xn)

Alkalinity is determined by the sodium (Na) content. Alkalinity describes the amount of base contained in water. The Na content in the soil is between 0.24 and 0.36 cmol. Alkalinity or exchangeable Na content in this soil form is very low.

Discussion

The slope of gradient has an important role in land conservation and land suitability. The composition of the developed soil, structure, biomass, density of the plant community is strongly influenced by the slope (Albaba, 2014). Large slopes are a serious threat to land degradation (Andrian, Supriadi, & Marpaung, 2014) when linked to land conservation. The greater the slope of the slope will automatically increase the surface runoff, so the greater the energy of the surface water (run-off) (Martono, 2004), as a result, a lot of soil grains are carried away by these currents. This condition clearly disturbs the plants above it, thus affecting plant growth and productivity (Nadal-Romero, Petrlc, Verachtert, Bochet, & Poesen, 2014).

The ideal depth of soil effectiveness in the field is difficult to find because of the influence of dredging on the surface soil by bauxite mining activities, however, in some, places it can still be found and can be measured in several places. For adjacent soil drainage with water drainage both in and in the soil, the drainage in (internal) is influenced by the size of the grain (texture). The bigger the grain or coarser the texture of the soil, the better the deep drainage. External drainage is influenced by the slope of the slope, the more sloping the slope the better the outer drainage.

Soils that have poor drainage are marked with the surface layer and the soil at the bottom layer has a gray color with spots due to water stagnation on the surface of the soil (Abd-Elmabod et al., 2017). Poor drainage affects the reduction of nitrogen (N), which is needed by plants (Stout & Schnabel, 1994). Soil that is moderately well drained is characterized by the absence of yellow, brown, or gray spots on the top and bottom layers. Soil that has good drainage is marked from the top layer to the bottom layer and has a bright color and does not have yellow, brown, or gray spots.

Soil sensitivity to erosion (soil erodibility) in the study area ranges from 0.21 to 0.63 (in terms of erosion sensitivity is moderate to very high). Soil erosion sensitivity (soil erodibility) is only one of several components/factors that influence erosion. Other factors are climate, slope length and slope, land cover (land cropping), and land management. Soil erodibility variations were significantly influenced by the thickness of the biological layer, soil mass density, organic matter content, plant litter density, and root mass density (Wang, Liu, & Zhang, 2011). Based on the results of the field survey, it is known that the rock and gravel content ranges from 0.01–90%. Rocks and gravel have an influence on land capability, namely inhibiting plant growth. Plants do not develop properly because of the distribution of rocks and gravel in the soil layer and on the land surface.

For the threat of flooding to occur during one month of the year, the land is always inundated by floods for more than 24 hours. The threat of flooding or inundation is caused by deep drainage and poor surface drainage. The infiltration and percolation processes are hampered due to the presence of soil texture or the size of the soft soil grains, meanwhile, the surface grinding is also hampered due to the flat to gentle slope.

Water availability capacity has a very important role. High water availability capacity is very beneficial for soil density, soil permeability, and soil strength and structure. High soil density, high soil strength, low permeability,

massive non-granular soil structures, and blocks reduce water capacity thereby limiting plant roots (Uhland, 1951) and root distribution over the entire soil mass. The ability of soil to provide water is needed by plants. In general, in a lot of open land conditions in ex-mining areas, the ability of the soil to store water is greatly reduced. However, an assessment of the capacity of water availability is necessary to determine the capacity of the land.

In areas where it rains frequently and supplying the land with more water, available water capacity is not very important. However, the condition of the former mining area which is wide open where the falling water becomes runoff and with high heat causes high evaporation, the falling rain is not sufficient to supply groundwater. However, in areas where crops emit more water than the amount provided by rainfall, the amount of available water that the soil can provide is very important. Water is needed to support the needs of plants.

Soil properties that affect water are soil texture and organic matter. Soil that has a fine soil texture has a high to very high water storage capacity and vice versa. Rock fragments reduce the capacity of available water in direct proportion to their volume unless the rock is porous. Soil that has a fine texture can bind more water. This is because soils with fine textures have a larger surface area than coarse-textured soils. Bulk density plays a role by controlling the pore spaces that hold the available water. In areas where it rains every day and supplies the soil with as much or more water than the plants remove, the available water capacity is not that important. However, the condition of the former mining area which is widely open, where the water that falls a lot becomes runoff and with high heat causing high evaporation, the rain that falls is not enough if it is only used as a supply factor for groundwater availability.

In areas where plants emit more water than the amount supplied by rainfall, the amount of available water that the soil can provide may be very important. This water is needed to sustain crops between rainfall events or irrigation periods. Soil effectively supports the root environment of the plant against periods of water deficit.

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Conclusion

The results showed that the slope of the gradient has an important role in land conservation and land suitability. The greater the slope of the slope will automatically increase the surface runoff, so the greater the energy of surface water (run-off), which will interfere with plant growth and productivity. The effective soil depth is shallow on average and has poor deep soil drainage. Soil is easily eroded, so a lot of rocks and gravel are exposed on the surface, plants cannot develop properly. Floods often occur, especially in areas located on alluvial plains with a range of more than 24 hours. The water availability capacity is also very low. Rainwater in the area mostly becomes runoff. The nutrient content in the ex-mining area is also low. Therefore it is necessary to improve efforts by means of reforestation of the former land so that in the future it can be used for certain uses, especially for agriculture, plantations, and forests.

Declarations

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Availability of data and materials

All data are included in the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors agreed and approved the manuscript for publication in

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Competing interests

The authors declare that they have no competing interests.

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References

1. Abd-Elmabod SK, Jordán A, Fleskens L, Phillips JD, Muñoz-Rojas M, van der Ploeg M, ... de la Rosa D (2017) Modeling agricultural suitability along soil transects under current conditions and improved scenario of soil factors. In *Soil mapping and process modeling for sustainable land use management* (pp. 193–219). Elsevier. <https://doi.org/10.1016/B978-0-12-805200-6.00007-4>
2. Adesipo AA, Akinbiola S, Awotoye OO, Salami AT, Freese D (2020) Impact of mining on the floristic association of gold mined sites in Southwest Nigeria. *BMC Ecol* 20(1):9. <https://doi.org/10.1186/s12898-020-00276-9>
3. Albaba I (2014) The effects of slope orientations on vegetation characteristics of Wadi Alquf forest reserve (WAFR) West Bank-Palestine. *International Journal of Agricultural Soil Science* 2(7):118–125
4. Andrian A, Supriadi S, Marpaung P (2014) Pengaruh ketinggian tempat dan kemiringan lereng terhadap produksi Karet (*Hevea brasiliensis* Muell. Arg.) di Kebun Hapesong PTPN III Tapanuli Selatan. *Jurnal Agroekoteknologi Universitas Sumatera Utara* 2(3):99357
5. Awan AG (2013) Relationship between environment and sustainable economic development: A theoretical approach to environmental problems. *International Journal of Asian Social Science* 3(3):741–761

6. Bawua SA, Owusu R (2018) Analyzing the effect of Akoben programme on the environmental performance of mining in Ghana: a case study of a gold mining company. *Journal of Sustainable Mining* 17(1):11–19. <https://doi.org/10.1016/j.jsm.2018.02.002>
7. Fleming DA, Measham TG (2014) Local job multipliers of mining. *Resour Policy* 41:9–15. <https://doi.org/10.1016/j.resourpol.2014.02.005>
8. Gibson G, Klinck J (2005) Canada's resilient north: The impact of mining on aboriginal communities. *Pimatisiwin* 3(1):116–139
9. Haddaway NR, Cooke SJ, Lesser P, Macura B, Nilsson AE, Taylor JJ, Raito K (2019) Evidence of the impacts of metal mining and the effectiveness of mining mitigation measures on social–ecological systems in Arctic and boreal regions: a systematic map protocol. *Environmental Evidence* 8(1):9. <https://doi.org/10.1186/s13750-019-0152-8>
10. Haigh MJ (2000) *Reclaimed land: erosion control, soils and ecology*, vol I. Taylor and Francis
11. Jumiadatin S (2015) *Pergeseran Minat Investasi di Kalbar*, (Online), <http://pontianak.tribunnews.com/2015/06/02/pergeseran-minat-investasi-di-kalbar>, accessed 13 september 2021
12. Kim YM, Zerbe S, Kowarik I (2002) Human impact on flora and habitats in Korean rural settlements
13. Knobbloch EA, Pettersson Ö (2010) Restructuring and risk-reduction in mining: employment implications for northern Sweden. *Fennia-International Journal of Geography* 188(1):61–75
14. Loayza N, Rigolini J (2016) The local impact of mining on poverty and inequality: evidence from the commodity boom in Peru. *World Dev* 84:219–234. <https://doi.org/10.1016/j.worlddev.2016.03.005>
15. Martono M (2004) Pengaruh Intensitas Hujan dan Kemiringan Lereng Terhadap Laju Kehilangan Tanah Pada Tanah Regosol Kelabu. Program Pascasarjana Universitas Diponegoro
16. Miao Z, Marrs R (2000) Ecological restoration and land reclamation in open-cast mines in Shanxi Province, China. *J Environ Manage* 59(3):205–215. <https://doi.org/10.1006/jema.2000.0353>
17. Nadal-Romero E, Petric K, Verachtert E, Bochet E, Poesen J (2014) Effects of slope angle and aspect on plant cover and species richness in a humid Mediterranean badland. *Earth Surf Proc Land* 39(13):1705–1716. <https://doi.org/10.1002/esp.3549>
18. Nakazawa K, Nagafuchi O, Kawakami T, Inoue T, Yokota K, Serikawa Y, ... Elvince R (2016) Human health risk assessment of mercury vapor around artisanal small-scale gold mining area, Palu city, Central Sulawesi, Indonesia. *Ecotoxicol Environ Saf* 124:155–162. <https://doi.org/10.1016/j.ecoenv.2015.09.042>
19. Sengani F, Zvarivadza T (2018) The Impact of Sand Mining on the Fluvial Environment: Case Study of Nzhelele River in Limpopo Province, South Africa. In *Symposium on Environmental Issues and Waste Management in Energy and Mineral Production* (pp. 67–80). Springer. https://doi.org/10.1007/978-3-319-99903-6_6
20. Sinclair HR Jr, Dobos RR (2006) Use of land capability classification system in the Surface Mining Control and Reclamation Act of 1977 (Public Law 95 – 87). *PUBLIC LAW* 95(87):1. <https://doi.org/10.21000/JASMR06022032>
21. Sonter LJ, Moran CJ, Barrett DJ, Soares-Filho BS (2014) Processes of land use change in mining regions. *J Clean Prod* 84:494–501. <https://doi.org/10.1016/j.jclepro.2014.03.084>

22. Staff S (1999) Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. *Agriculture Handbook*, 436
23. Stephens C, Ahern M (2001) Worker and community health impacts related to mining operations internationally: A rapid review of the literature. *London School of Hygiene & Tropical Medicine, London*
24. Stout WL, Schnabel RR (1994) Soil drainage influence on biomass and nitrogen accumulation by ryegrass. *Agron J* 86(1):111–116. <https://doi.org/10.2134/agronj1994.00021962008600010021x>
25. Swenson JJ, Carter CE, Domec J-C, Delgado CI (2011) Gold mining in the Peruvian Amazon: global prices, deforestation, and mercury imports. *PloS One* 6(4):e18875. <https://doi.org/10.1371/journal.pone.0018875>
26. Uhland RE (1951) *Soil permeability determinations for use in soil and water conservation* (Vol. 72). LWW. <https://doi.org/10.1097/00010694-195107000-00020>
27. Wang S, Liu C, Zhang H (2011) Suitability evaluation for land reclamation in mining area: A case study of Gaoqiao bauxite mine. *Transactions of Nonferrous Metals Society of China* 21:s506–s515. [https://doi.org/10.1016/S1003-6326\(12\)61633-1](https://doi.org/10.1016/S1003-6326(12)61633-1)
28. Zhang X, Yang L, Li Y, Li H, Wang W, Ye B (2012) Impacts of lead/zinc mining and smelting on the environment and human health in China. *Environ Monit Assess* 184(4):2261–2273. <https://doi.org/10.1007/s10661-011-2115-6>
29. Yuniarni R (2014) Jalur Metalogeni Indonesia. *Artikel Geologi Populer*, (On Line), <http://geomagz.geologi.esdm.go.id/jalur-metalogeni-indonesia/>, accessed March 15, 2021

Figures

Figure 1

Study Area

Figure 2

Gully Erosion