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# Nickel Content in Plants and Soil: The Case of Mine Tailing Sites in Bato-Bato Narra Palawan, Philippines

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***Abstract***

*Forests once deforested through mining losses its rich biodiversity. The re-opening of open-pit mining corporation in 2011, in the small village of Bato-Bato, Narra, Palawan had caused deforestation, floods, and low rice harvest. This study determined the nickel content in topsoil and native dominant plants in mine-tailings. Field data collection and laboratory analysis methods were used in this study. Nickel content in topsoil (2 kg replication$^{-1}$ site$^{-1}$) was analyzed using X-ray Flourescence (XRF). Inductively Coupled-plasma–Optical Emission Spectrometry (ICP-OES) determine nickel in dominant plants (200 g replication$^{-1}$ site$^{-1}$). Normality of data was determined by Pearson coefficient of skewness test. Significant difference on the nickel content in plant tissues was analyzed using Kruskal Wallis test, analysis of variance, and Tukey post hoc test for nickel in soil. Native dominants are National Seed Industry Council Rice cultivar 218, Philippine Seed Board Rice cultivar 18, and carabao grass. The nickel content in native dominant plants is higher in comparison with the average nickel content in plant tissues and the nickel content in topsoil is high in comparison with the average nickel content a topsoil should contain. Prevention of leaching of nickel during flood is recommended.*

*Keywords*: *nickel, mining, soil, Palawan*

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## Introduction

Forest serves as shelter to many organisms and reservoir of mineral deposits. Once a forest is already open for mining, deforestation follows, thereby destroying the ecosystem. Thonfield et al. (2020) stated that forest land cover loss, is primarily cause by mining activities in tropical regions. Deforestation of tropical rainforest related to mining destroys carbon storage which is an implication of climate stability.

Mines from our natural resources serves as raw materials for commodities that we use. Industrialization requires extraction of our mineral resources, which is detrimental to our environment. Too much extraction of our mineral resources is coupled with environmental phenomena such as deforestation, floods, rise of water levels, El Nino and La Nina phenomena and low crop yield. Cui et al. (2018) expressed that too much extraction of mines contaminates the soil from the mine tailings and discharge wastewaters from the mining sites. Improper waste disposal, accumulation, thereby creating heavy metal pollution has a long-term effect. Its effect is irreversible and posed serious environmental threats.

Nickel is an element that can be extracted through mining. It is a raw material of steel where most of its products are used in our homes (kitchen utensils) and offices. Genchi et al. (2020) stated that one of the transition elements in the earth is nickel. It can be found in the environment, air, water, and soil.

Wood (2015) disclosed that nickel in plants concentration is found mostly in the leaves and normally ranges from about 0.1 to 5 parts per million (ppm) dry weight. If beyond 10 ppm in plant tissues, it is already toxic. According to Liu et al. (2022), nickel concentration in soil ranges from 5–500 mg kg$^{-1}$ and 50 mg kg$^{-1}$ as an average or 0.005%. Among the many long-term effects in the environment includes reduction in the quality of soil, water, and crops. The study of Hassan et al. (2019) revealed that higher levels of nickel in soil reduces germination of seed, growth of root and shoot is also reduced, and low final production or yield.

Prematuri et al. (2020) reported that open-cast mining affects soil fertility. Post-mining soil resulted in lower growth of fast-growing tropical tree species *Falcataria moluccana* with a common name falcata and *Samanea saman* with a common name raintree or monkey pod. The study of Wei et al. (2020) showed that plants with well-developed diffuse roots and large biomass thrive well in mining sites and tolerate the high metal concentrations. The soil with heavy metal accumulation in mining sites can be restored and remedied through sustaining the growth of native dominant plants with well-developed diffuse roots.

Philippines is an archipelagic country composed of 7,107 islands located in the Southeast Asia (Figure 1). As of 2020 its forest cover is 7,226,394 ha, compose of 2,221,73 ha as closed forest, open forest is 4,693,821 ha, and mangrove

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forest is 311,400 ha (DENR-FMB, 2021).

Bonye (2018) reported that Philippines ranked 5th as the world's most mineralized country. The untapped copper, gold, nickel, zinc, and silver are estimated at USD1 trillion. In 2017 the Philippines Mines and Geoscience Bureau (PMGB) reported only 50 operating mines in the country.

Palawan is an island province of the Philippines (Figure 1). It is home for 17 key biodiversity areas, watersheds, endemic flora and fauna, indigenous tribes, and two United Nations' Educational, Scientific, and Cultural Organization (UNESCO) world heritage sites. The province is declared as the Philippines last ecological frontier and having rich mineral deposits. The expansive metal ores (nickel and chromite) in the province lay underneath the old growth forests. In 2011 PGMB approved mining operations all over the province and pauses a major threat specifically its extensive remaining forest cover and biodiversity (Zambales, 2021). The small village of Bato-Bato in the municipality of Narra Palawan, Philippines (Figure 1) is the locale of this study. Figure 2 posited the water and land use-map of the municipality, and the small village of Bato-Bato is in forest area within the national area integrated protected areas system (NIPAS). The visible environmental impacts of the mining corporation are loss of wildlife and agro-diversity due to deforestation, food insecurity due to low crop harvest, landscape aesthetic degradation, noise pollution, soil contamination, overflow of mine wastes, pollution of surface water, ground water depletion, decrease water quality (physico-chemical and biological). The potential environmental impacts are soil erosion, floods, and air pollution (Environmental Justice Atlas, 2015).

Palawan experienced strong typhoons and flooding on November 6, 2021. Flooding due to deforestation in mining sites and low-pressure area happened last March 29, 2022, and another flooding on October 31, 2023 (Palawan News, 2023). Heavy rains and floods are the major factors of nickel leaching from mining sites and siltation ponds. Calleja (2012) reported that on November 25, 2012, the mining corporation failed to control the silt-laden water spilled from its silt pond. The water from the pond overflowed into the "Pinagduguan" river and irrigation canals, affecting 70 rice farms and fishponds. Notice of violation was issued by the Department of Environment and Natural Resources. The mining management constructed Gabions at the gullies and additional silt traps to restrict surface water run-off.

Fabro (2020) interviewed a farmer whose farm is near the mining corporation in Narra, Palawan. The rice farmer revealed that his rice harvest decreased from 5,000 kg $ha^{-1}$ to 2,250 kg $ha^{-1}$ since the opening of open-pit mining corporation in the area.

Environmentalists are now taking consideration how unfertile soil in mine- tailing areas can be remedied. Since the re-opening of open-pit mining in Bato-Bato Narra, Palawan Philippines no study on determining the nickel content in soil and in plants in mine-tailing sites is conducted. Thus, this study will serve as baseline information for local environmental planners regarding the nickel content in the soil as well as in native dominant plants that thrive in mine-tailings areas. The results of this study will help environmental planners to come up with programs/projects that will prevent environmental degradation. The study's objective includes, determine the nickel content in native dominant plants in mine-tailing sites, determine the significant difference on the nickel content in native dominant plants in the sampling sites in mine-tailing sites, determine the nickel content in the topsoil in mine-tailing sites. Compute the difference on the nickel content in the topsoil in sampling sites in mine-tailing areas. It also describes the native dominant plants that thrive in the sampling sites, its common and scientific name, and agronomic characteristics.

## Methods

**Site description** Sampling sites were identified by the licensed agriculturist from the Municipal Agriculture Office and assisted by the licensed environmental planners from the Municipal Planning and Development Office. Global positioning system (GPS) map camera mobile application was used in determination of the three sampling sites. The coordinates for the first sampling site are 9.187470 latitude and 118.262792 longitude (Figure 3). For the second sampling site, latitude is 9.183515 and longitude of 118.273770 (Figure 3). Third sampling site coordinates are


Figure 1 Location of Bato-Bato, Narra, Palawan, Philippines (PhilAtlas [n.d.]).

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latitude is 9.183299 and longitude is 118.273962 (Figure 3). Descriptive method was used to determine the native dominant plants from three sampling sites in, Bato-Bato, Narra, Palawan. It also includes the classification (common and scientific names and agronomic characteristics) of native dominant plants from three sampling sites in Sitio San-Isidro, Bato-Bato, Narra, Palawan.

**Experimental design** Field data collection involved gathering of native dominant plants and topsoil from three sampling sites (replicated thrice per sampling site) in mine-tailing areas in Bato-Bato, Narra, Palawan. Quadrat method was used (Prematuri et al., 2020). In each site, three plots (2 m × 2 m) were randomly selected. For nickel analysis, 200 g of native dominant plants per replication per sampling site were gathered, packed in polyethylene labelled ziplocked bags, and sent to the laboratory.

**Materials used** Shovel was used to collect soil samples. At each replication and sampling site, 2 kg of soil samples were gathered. Impurities such as stones, roots and litter were removed, and packed in polyethylene and labelled ziplocked bags. The soil samples were sent to the laboratory as well. Nickel content in soil samples was analyzed using x-ray flourescence (XRF) method. According to Hou et al. (2021), XRF determined many elements in a variety of sample matrices. Wulandari et al. (2022) explained that XRF is an important analysis method for environmental analysis, research and development of materials and products, since it entails simple sample preparation, and the analysis accuracy is high. ICP-OES is the method used in nickel analysis in plant samples.

**Statistical analysis** Normality of data collected was determined using Pearson coefficient of skewness (PCS) for both nickel content in native dominant plants and nickel in topsoil per replicate/sampling site. Kruskal Wallis test in IBM SPSS version 2.0, was used since non normality of data was revealed in PCS of data obtained on the nickel content in native dominant plants. PCS of data on nickel content in topsoil was also computed and revealed normal data thus analysis of variance (ANOVA) was done in Microsoft Excel 2019. Significant difference among paired means in ANOVA was computed using Tukey's honestly significant difference (THSD) test.

## Results and Discussion

**Nickel content (mg kg$^{-1}$) in native dominant plants in mine-tailing sites** Nickel content (mg kg$^{-1}$) in native dominant plants in mine-tailing sites is shown in Table 2. The highest mean nickel content ($M$ = 65.695, $SD$ = 11.26) is found in sampling site 3 where carabao grasses are found. Rice straws in sampling site 2 ($M$ = 54.79, $SD$ = 14.30) followed and lowest mean nickel content in three sampling sites was found in sampling site 1 ($M$ = 45.415, $SD$ = 18.65). Yan et al. (2020) revealed that phytoremediation is a promising technique to remove heavy metals in polluted soil. According to Liu et al. (2022), plant tissues have an average nickel content of 10 mg kg$^{-1}$. Nickel content in two sampling sites (1 and 2) is beyond the average nickel content in mg kg$^{-1}$ that should be present in plant tissues (10 mg kg$^{-1}$), an indication that nickel in mine tailings sites was already present in the native dominant plants in the sampling sites. In the case of high nickel content on site 3 (carabao grass dominated site) there are several studies revealing the potential of carabao grass as heavy metal accumulator. Plants that can thrive in mining areas characterized by high metal contents are those plants that have well developed roots. The presence of these plants can restore soil fertility (Wei et al., 2020). Carabao grass can be considered as moderately sensitive plant since it can tolerate 50 mg kg$^{-1}$ of nickel (Liu et al., 2022). Omangpang et al. (2017) reported that the carabao grass, significantly decreased the heavy metals in soil. Delos Angeles and Cuevas (2018) found out that carabao grass was able to colonize mine tailing ponds with low pH and with high concentration of copper. It indicates phyto-stabilizing

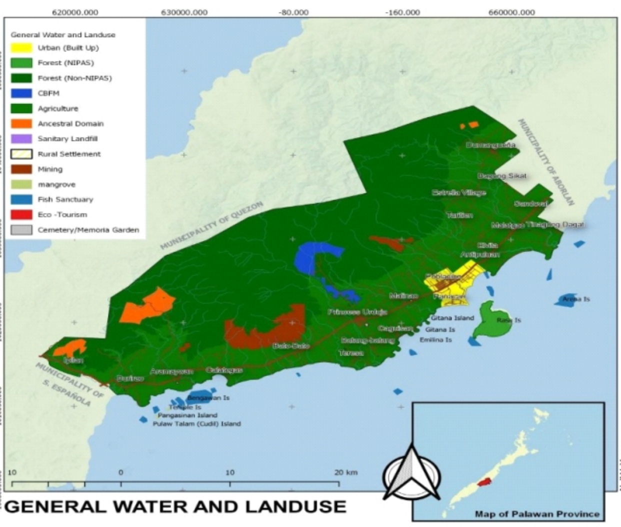


Figure 2 General water and landuse map of Narra, Palawan (MPDO, 2018).

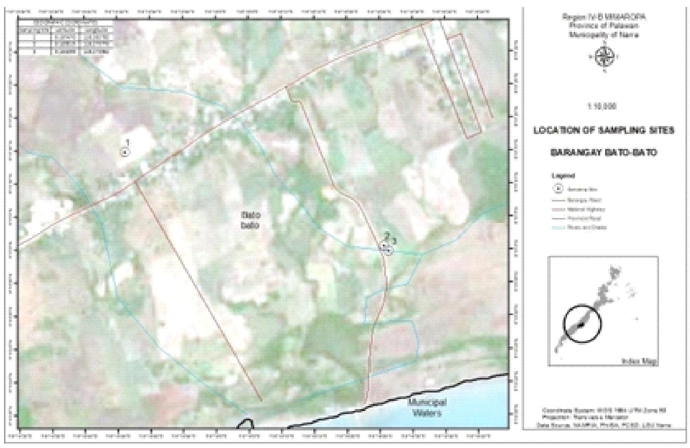


Figure 3 Geotagged map of sampling sites in Bato-Bato, Narra, Palawan.

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property of the *Paspalum conjugatum*. The study of Canillas et al. (2019), concluded that carabao grasses are accumulators of heavy metal like, copper. Carabao grass was also tested on lead accumulation. Other beneficial properties of carabao grass include limiting or controlling the growth of *Imperata cylindrical*, a weed that competes with plant nutrients in the soil (FAO, 2023). It improved soil fertility as bio fertilizer. Jumnau-as and Abug (2017) concluded in their study that *P. conjugatum* is more effective as bio-fertilizer than *Cynodon dactylon*. The lettuce plants had faster growth rate, with healthy leaves and stems and high survival rate. Carabao grass can be used as source of feed in pasture areas, thus increasing biodiversity. The pasture area not only for ruminants uses carabao grass and for raising of free-range native chicken (Prananghaya, 2017). The said studies imply that carabao grass as native dominant plants in site 3 along the mine tailing site can accumulate heavy metals like nickel which is detrimental to rice crops. The present of carabao grass can help restore the imbalance in the nutrient content, thereby improving soil fertility. The disturbed ecosystem brought about by denuded forest due to mining needs to be restored so that the organisms can still thrive in the natural forest. The growth of native dominant plants are efficient carbon dioxide fixers which is needed to lessen the effects of climate change.

In sampling sites 1 and 2 (dominated by rice plants) the nickel present in plants greatly affected the crop yield. Hassan et al. (2019) revealed that too much nickel affects crop productivity. Physiologic processes such as germination, growth of root and shoot, and plant yield. This affects photosynthesis and transpiration.

**Significant difference on the nickel content (mg kg$^{-1}$) in dominant native plants in sampling sites** After laboratory analysis, data on nickel content (mg kg$^{-1}$) per replication per sampling site was determined. PCS was used to determine normality of data. PCS revealed a positive significant skewness (Table 2), which is a limitation for the use ANOVA. Kruskal Wallis test was used, and it revealed a non-significant result ($H$ = 0.276 >, $p$-value = 0.05) as shown in Table 3. It further explains that although the nickel content in the native dominant plants in three sampling sites varies, it did not differ significantly.

**Nickel content (mg kg$^{-1}$) in topsoil in mine-tailing sites** Table 4 posited the nickel content (mg kg$^{-1}$) in soils in mine-tailing sites. Sampling site 3 had the highest mean nickel content of 3,293 mg kg$^{-1}$ with a standard deviation of 3,295.80 mg kg$^{-1}$. Sampling site 1 ($M$ = 2,846.70, $SD$ = 112.39)

Table 1 Identified native dominant plant species and its common name and scientific name

| Sampling site | Common name | Scientific name | Specific variety (rice) |
|---|---|---|---|
| 1 | Rice | *Oryza sativa* | NSIC Rc 2018 |
| 2 | Rice | *Oryza sativa* | PSB Rc 18 |
| 3 | Carabao grass | *Paspalum conjugatum* | |

Table 2 Nickel content (mg kg$^{-1}$) in dominant native plants in mine-tailing sites

| Criteria | Nickel content (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | Control (Normal nickel in plant tissues [Wood, 2015]) | Sampling site 1 | Sampling site 2 | Sampling site 3 |
| Replication 1 | 10 | 59.56 | 40.57 | 34.62 |
| Replication 2 | 10 | 18.65 | 48.37 | 40.40 |
| Replication 3 | 10 | 12.62 | 20.64 | 56.37 |
| Total | 30 | 90.83 | 109.58 | 131.39 |
| Mean | 10 | 45.42 | 54.79 | 65.70 |
| Median | | 18.65 | 40.57 | 40.40 |
| Standard deviation | | 25.54 | 14.30 | 11.26 |
| Pearson coeffiecient of skewness | | 3.14 | 2.98 | 6.73 |

Legend: + = positively skewed (denotes the use of non-parametric test)

Table 3 Kruskal-Wallis test for determining significant difference on the nickel content in native dominant plants in sampling sites

| Null hypothesis | Test | Sig. or $p$-value | Decision |
|---|---|---|---|
| The distribution of nickel is the same across the groups (sampling sites) | Independent samples-Kruskal-Wallis test | 0.276$^{n.s}$ | Retain the null hypothesis |

Legend: n.s = not significant at 5% level of significance

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followed, and the lowest nickel content in soil in three sampling sites was found in sampling site 2 ($M$ = 2,330.70, $SD$ = 2,336.90). Geotagged map of the three sampling sites in Figure 3, showed that the sites is near the river that run along the rice farms. The third site (approximately 500 m) is much nearer the second sampling site (approximately 1 km) from the river. The first site is near the mining area (approximately 4 km). Nickel content in soil in the three sampling sites (1, 2, and 3) is beyond the normal average nickel content in mg kg$^{-1}$ that should be present in topsoil (50 mg kg$^{-1}$ [Liu et al., 2022]). This could be attributed to the flooding in the area which transported the mining sediments including nickel in the rice farms. Flooding due to deforestation in the mining site is apparent in the locality. Pascal's principle (water seeks its own level) prevails in the drainage canals, during floods, and leaching of mining sediments were channeled to the rice farms. Too much accumulation of nickel affected the rice physiologic processes and the harvest. Fabro (2020) interviewed a farmer in Bato- Bato, Narra Palawan and the farmer complained on the reduce rice harvest per cropping season. He stated, that when the open pit mining re-opened in 2011 his rice harvest decreased from 5,000 kg ha$^{-1}$ to 2,250 kg ha$^{-1}$. The nickel from mine which was leached to the rice farm had greatly affected the rice harvest. Hashem et al. (2020) stated that wastewater that is untreated carry substantial concentration of heavy metals and is a potential ecological risk to the environment, soil fertility, sustainable agriculture, and of course food quality and quantity. Prematuri et al. (2020) stated that opencast nickel mining seriously damaged the natural forest, the topsoil, vegetation, and decreased soil fertility.

**Significant difference on the nickel content (mg kg$^{-1}$) in topsoil in mine-tailing sites** PCS revealed a negative significant skewness of data (Table 4); thus, ANOVA was used significant difference ($F$ = 9.74098E-10 < $p$-value = 0.05) was obtained in the ANOVA (Table 5). To further determine which sampling site, differs with another sampling site, THSD test was done (Table 6). It revealed significant difference on the nickel content (in three sampling sites) where different superscripts (a, b, c, d) in each treatment mean denotes significant difference among each means. Heavy rains and floods are the major factors of nickel leaching from mining sites and siltation ponds. Irrigated agricultural lands serve as reservoir of the siltation from the mining sites. Somarin (2014) mentioned that

Table 4 Nickel content (mg kg$^{-1}$) in topsoil in mine-tailing sites

| Criteria | Nickel content (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | Control (normal nickel percentage in topsoil [Liu et al., 2022]) | Sampling Site 1 | Sampling Site 2 | Sampling Site 3 |
| Replication 1 | 50 | 2,820 | 2,330 | 3,470 |
| Replication 2 | 50 | 2,750 | 2,380 | 3,140 |
| Replication 3 | 50 | 2,970 | 2,300 | 3,269 |
| Total | 150 | 8,540 | 7,010 | 9,879 |
| Mean | 50$^{a}$ | 2,846.70$^{b}$ | 2,336.70$^{c}$ | 3,293$^{d}$ |
| Median | 50 | 2,820 | 2,330 | 3,269 |
| Standard deviation | | 112.39 | 2,336.90 | 3,295.80 |
| Pearson coefficient of skewness | | 0.7117$^{-}$ | 0.0085$^{-}$ | 0.0218$^{-}$ |

Table 5 Analysis of variance (ANOVA) on the nickel content in soil

| Source of variance | Sum of squares | Degrees of freedom | Mean of squares | $F$ | $p$-value | $F$ critical |
|---|---|---|---|---|---|---|
| Between groups | 18,705,843.58 | 3 | 6,235,281.00 | 594.92 | 9.74098E-10* | 4.066181 |
| Within groups | 83,847.34 | 8 | 10,480.92 | | | |
| Total | 18,789,690.92 | 11 | | | | |

Legend: * = significant at 0.05 level of significance

Table 6 Tukey honestly significant difference test on determining significant difference on the nickel content among paired treatment means

| Nickel content of paired means | Tukey HSD value | Tukey HSD interference | Interpretation |
|---|---|---|---|
| Control vs Sampling Site 1 | 0.0010053 | **p<0.01 | significant |
| Control vs Sampling Site 2 | 0.0010053 | **p<0.01 | significant |
| Control vs Sampling Site 3 | 0.0010053 | **p<0.01 | significant |
| Sampling site 1 vs Sampling Site 2 | 0.0013023 | **p<0.01 | significant |
| Sampling site 1 vs Sampling Site 3 | 0.0030806 | **p<0.01 | significant |
| Sampling site 2 vs Sampling Site 3 | 0.0010053 | **p<0.01 | significant |

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mining damages the landscape, contaminating bodies of water and land areas. It creates sediments containing heavy metals and remain in the surrounding soil which are carried by water and wind. Heavy metals from mining sites are non-biodegradable and contaminate the soil. Thus, the soil fertility in agricultural lands in Bato-Bato, Narra, Palawan is greatly affected, thereby lowering the harvest of rice farmers. Denuding the forest through mining created imbalances in the ecosystem, specifically the food chain.

**Identified native dominant plant species and their common name and scientific name and its agronomic characteristics** Since the three sampling sites were within the rice farms, there are native dominant plant species that were identified is presented in Table 1 and displayed in Figures 4, Figure 5, and Figure 6. The two lowland rice varieties (*National Seed Industry Council Rice cultivar 218* [NSIC Rc 218] and *Philippine Seed Board Rice cultivar 18* (PSB Rc 18)] in sampling sites 1 and 2 are the hybrid varieties, recommended by PhilRice (2018) for rice farms in Region IV-A.

The characteristics of NSIC Rc 218 locally known as "*mabango* 3" was approved for commercial purposes in 2009. Its agronomic characteristics comprise its average yield 3.8 ton ha$^{-1}$ or 3,100 kg or 62 "cavans" (1 cavan is equivalent to 50 kg) ha$^{-1}$. However, it can also attain a maximum yield of 8 ton ha$^{-1}$ or 8,000 kg or 160 "cavans" ha$^{-1}$. Its maturity is 120 days or 4 months. The plant height is 1.06 m and the number of tillers is 14 (PhilRice, n.d.).

*Philippine Seed Board Rice cultivar 18* (PSB Rc 18) was approved for commercial use in 1994. Its agronomic characteristics are average yield ton ha$^{-1}$ is 5.1 or or 5,100 kg or 102 cavans ha$^{-1}$, and maximum yield is 8.1 ton ha$^{-1}$ or 8,100 kg or 162 cavans ha-$^{1}$. Its maturity is 123 days or 4.1 months. Its height is 1.2 m and number of tillers is 15 (PhilRice, n.d.).

Carabao grass (*P. conjugatum)* locally known as "*kaud kauaran*" is considered a weed but sometimes grown as coarse cover ground grass, as pasture grass and it is a monocot characterized by diffuse and shallow rooted roots. These plants can absorb nickel in topsoil. According to Gill and


Figure 4 Image of PSB Rc18 (PhilRice [n.d.]).


Figure 5 Image of NSIC Rc2018 (PhilRice [n.d.]).


Actual photo taken last February 27, 2023, in Bato-Bato, Narra, Palawan (Sampling site 3)

Figure 6 Image of *Paspalum conjugatum*.

Tuteja (2011) the most toxic effect of nickel is in the soil's upper layer at 3,100 ppm. It is also used as bio fertilizer, once it is plowed back into the soil as source of organic fertilizer. Jumau-as and Abug (2017) stated that *P. conjugatum* (carabao grass), can be used in organic farming for areas with less organic raw material to use for bio-fertilizers.

## Conclusion

The result of this study showed that high nickel content is present in the topsoil and native dominant plants along the rice farms in Bato-Bato, Narra, Palawan. The level of nickel in soil (mg $kg^{-1}$) is higher than the average nickel content in mg $kg^{-1}$ topsoil should contain. Once the nickel are leaches from deforested mining sites to mine tailing sites it is a factor that reduces crop productivity. The nickel content in carabao grasses is an indication that it can accumulate heavy metals, which can augment soil fertility for the growth of other plants. More plants can lessen the impact of climate change.

## Recommendation

The mining corporation should prioritize and implement environmental programs and projects, that will prevent the leaching of its mining sediments to agricultural lands specifically during heavy rains and floods. Government offices, (municipality's Agriculture Office, MENRO, MPDO), should strictly monitor the leaching of heavy metals (nickel in particular) from mining sites to agricultural lands. Recommend proper programs/projects to the mining corporation, such as massive reforestation in mining sites and projects that will prevent the leaching of mining sediments to the rice farms. Planting of carabao grass as nickel accumulator and source of organic fertilizer is also recommended to lessen the nickel accumulation in mine-tailings.

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