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# Floristic composition in Kinalablaban River delta interconnected with the nickel mines in Surigao, Philippines

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**Abstract**

In nickel mining, a considerable amount of topsoil and vegetation are removed to extract the ore, thus soil erosion during rainy season is inevitable. This causes the soil particles and associated minerals to eventually reach the freshwater and marine water bodies nearby. Reforestation is viewed to provide the buffering effect to soil erosion, so this study was done to determine local plant species with potential for use in mine rehabilitation to reforest the area. A total of 55 floral species belonging to 36 families was recorded growing in the alluvial plain of the Kinalablaban Delta. The predominant plant species found is *Pandanus tectorius* of the Family Pandanaceae which is a perennial species. Other typical beach forest plants found in the site were *Terminalia catappa, Calophyllum inophyllum, Ipomoea pes-caprae* and species of mangroves. *Xanthostemon verdugonianus* which is native to the Philippines is also a common plant in the site. The existence of diverse floral species in the delta indicates that the soil particles deposited from soil erosion can support biodiversity. The soil quality in the delta supports the survival of plant species despite the deficiency in nitrogen. These information are useful in mine rehabilitation because the interconnectivity between the soil quality in the mountain slopes and the deposited soil in the delta is critical in planning in the landscape approach.

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## Introduction

The Philippines is the top nickel producer in the world for the period 2014-2015. In 2015, the Philippines was the largest exporter of DSO in the world due to the ban in Indonesia (Bloomberg, 2015). The Philippines also holds 3.1 million tons in nickel reserves. The large scale nickel mining operations in the Philippines are generally located in Caraga Region. In 2014, MGB reported 20 of the 27 registered nickel mining companies are operating in the region. Mining investments has been steadily increasing due to the world demand for nickel, chromite and gold which are abundant in Caraga Region (MGB, 2013).

The mining operations in the region are viewed as the cause of environmental degradation. Strip mining is the common technique adopted in nickel mining. Using this method, a considerable amount of topsoil has to be removed through stripping to extract nickel ore thus disturbance to the soil and vegetation occurs. With the surface removal of soil and vegetation, soil erosion during rainy season is inevitable. This causes the soil particles and associated minerals to eventually reach the freshwater and marine water bodies nearby. The presence of iron and nickel in the soil makes the waters in the seas and river systems adjoining the mine areas silted. This is the scenario in the Carrascal-Claver area of Surigao Province, where most large-scale nickel mining occurs. Mining companies operating in the area have started to address this issue by managing the siltation through establishing settling ponds and dredging the siltation when the ponds are almost filled up. However, siltation of the river system cannot be completely controlled. The silt deposits eventually form sediments particularly in the delta of rivers. This is the case of Kinalablaban River in Claver, Surigao del Norte which is the main water body that passes through the nickel mining areas.

Nickel mine rehabilitation tries to address the impacts of mining through replanting of the mined-out areas towards rehabilitation of the ecosystem and minimize siltation and sedimentation. For a more holistic mine rehabilitation, the vegetation along the riparian zone of major water bodies and the river delta is regarded as critical components inasmuch as this will provide the last defense before the soil particles reach the freshwater and marine ecosystem. Thus this study was done to assess the floristic composition of Kinalablaban River particularly in the delta. The findings of the study can be used as inputs in the holistic planning for sustainable nickel mine rehabilitation.

## Methodology

Sampling was conducted at the alluvial plain where Kinalablaban River empties into Hinadkaban Bay in Cagdiano, Claver, Surigaodel Norte (Fig. 1). Another tributary joins the course of the river known as Tandawa creek which also goes toward the sea. The area is only saturated with water when flooding occurs or after heavy downpour such that most of the plants encountered were mesophytes and only few hydrophyticspecies.

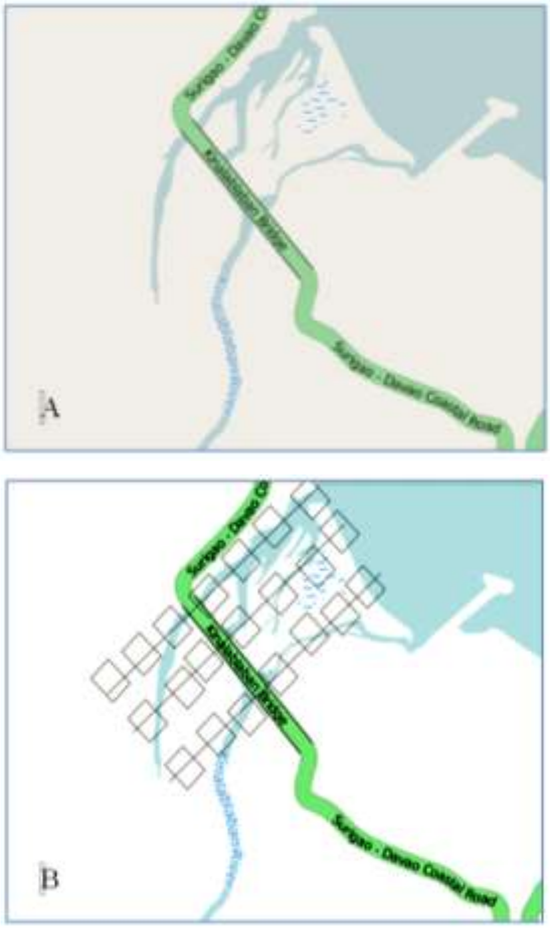


**Fig. 1.** Map showing the A) riparian floral assessment study site and B) the layout of transect lines for the floral diversity assessment.

*Floral diversity assessment*

Three transect lines were established perpendicular to the coastline (Fig. 1). Establishment of 10 x 10 m quadrats was employed in a systematic sampling strategy with 20 m interval from one quadrat to another. Plants that were within the quadrat were identified and listed. Plant samples were gathered for species that cannot be determined on site, pictures were also taken. Since the assessment was quantitative, frequency, density and cover of different plant species were the parameters measured in the field. Data were organized and calculated and Shannon-Weiner Index was used to calculate the diversity of floral species in the area.

*Floral species identification*

The plant samples were identified on site by a botanist. Samples and pictures of plant species that were not identified on site were taken for identification by a specialist. The details of the plant samples (eg. microhabitat description, associated plants) were likewise recorded. Samples of plant species found in the transect lines established in the river delta were recorded.

*Soil sampling and analysis*

Soil samples were collected from the study site. Standard procedures in soil sampling were followed to minimize errors. These were analyzed in the Soils Laboratory of the Department of Agriculture, Caraga Region. The laboratory analyses were then analyzed and mapped out to show distribution of soils based on soil characteristics.

## Results and discussion

*Floristic composition in the river delta interconnected with nickel mine*

Table 1 indicated 55 floral species belonging to 36 families growing in the alluvial plain of the Kinalablaban Delta. The predominant plant species found is *Pandanus tectorius* of the Family Pandanaceae which is a perennial species. During the survey, traces of harvested dried leaves were found littered on the ground floor and hung indicating that leaves of this plant are used for weaving products such as mats and hats.

Leaves of *P. tectorius* are utilized by local people for making indigenous products as source of additional income especially during off season of the mining operation. There were plots where *P. tectorius* was dominant which is due to the extensive growth of its sucker shoots and left to grow in the area with little or no disturbance. Presence of prickles along its leaf margins hampers the intrusion of humans in *Pandanus*-dominated area though there are cuttings of its trunk that were observed all throughout the delta.

*Casuarina equisitofolia* is another plant species found in the delta and was more prominent in areas closer to the coast. This plant is commonly used for rehabilitation of mined out areas since it is prolific and grows very fast even in very disturbed sites. Notably this plant can occur in open coastal habitats with sandy beaches in tropical regions. Other typical beach forest plants found in the site were *Terminalia catappa, Calophyllum inophyllum, Ipomoea pes-caprae* and species of mangroves. *Xanthostemon verdugonianus* is native to the Philippines and a common plant in the site.

This plant can be found in an ultramafic area which is the characteristic of the study site and because of the inherent hardness of its wood it has been harvested at a faster rate. According to WCMC (1998) it is now categorized as a vulnerable plant species and with its current status, additional conservation measures should be adapted by the government. More so in Caraga Region since the habitat of *X. verdugonianus* has already been widely disturbed by large scale mining. *Saccharum spontaneum* is another common species found in the Kinalablaban River delta.

It is one of the dominant grass species found in the area since this plant can grow very well in floodplains and in a wide range of soil type. The extensive rooting system of many species under Poaceae makes it an effective binder/trap to soil particles hence presence of *S. spontaneum* in the area is an advantage as it may lessen the occurrence of siltation in nearby surface waters especially during the rainy months.

Another species found in the area belonging to Poaceae was *Imperata cylindrica* which basically grows everywhere even in very acidic soil.

Hydrophytes such as the mangrove *Rhizophora* sp. were also encountered but most of the *Rhizophora* population was planted manually in the delta as part of the mitigating measures and rehabilitation efforts of the mining company. *Rhizophora* sp. and other hydrophytes are effective in trapping silts and sediments which then lessen the occurrence of siltation in nearby coastal area. Waterways with emergent vegetation were observed to have a significant effect on transport of sediment. Results of some studies show high sediment deposition rates because of direct trapping of sediments on stems and leaves of emergent plants (Saiers *et al.*, 2003; Palmer *et al.*, 2004; Huang *et al.*, 2008; Kothyari *et al.*, 2009).

The study of Tue *et al.*, (2012) stipulated that higher fractions of clay and silt in the mangrove sediments indicated that fine grained sediments were transported further up into the mangrove forest zone. Roots of *S. alba* were observed to be crooked which could indicate that roots of this species are undergoing stress from root burial due to sediments. The ability to cope with this kind of stress varies between species such as extending its pneumatophores and developing a secondary thickening on the top of its buttress (Ellison, 1998). When sediment burial occurs, mangroves can be adversely affected by becoming unhealthy, prone to pest and disease, or die. Since the area is always affected by sedimentation, a more suitable mangrove could be planted to tolerate rapid sediment accretion.

**Table 1.** List of floral species found in Kinalablaban River delta adjacent to Platinum Group Metals Corporation, Claver, Surigao del Norte.

| Family | Scientific name | Common Name |
|---|---|---|
| Adiantaceae | *Adiantum capillus-veneris* | Maidenhair fern |
| Anacardiaceae | *Buchanania arborescens* | Sparrow mango |
| Araliaceae | *Polycios nodosa* | Malapapaya |
| Araceae | *Pothos longipes* | Aligwai or barung-uai |
| Aspleniaceae | *Asplenium scolopendium americanum* | Harts tongue fern |
| Asparagaceae | *Liriope spicata* | Creeping Lily turf |
| Boranginaceae | *Cordial dichotomia* | Balingasai/anonang |
| Casuarinaceae | *Casuarina equisetifolia* | Agoho |
| Clusiaceae | *Calophyllum inophyllum* | Bitaog |
| Convolvulaceae | *Ipomea pes-caprae* | Goats foot vine |
| Combretaceae | *Lumnitzera racemosa* | Kulasi |
| Combretaceae | *Terminalia catappa* | Talisay |
| Combretaceae | *Lumnitzera littorea* | TeruntumMerah |
| Dipterocarpaceae | *Hopea acumonata* | lahi-lahi |
| Ebenaceae | *Dios pyrus pilosanthera blanco* | bolong-eta |
| Euphorbiaceae | *Homalanthus populifolius* | Bleeding-heart tree |
| Fabaceae | *Acacia aurecoliformis* | Aure |
| Fabaceae | *Acacia mangium* | Mangium |
| Fabaceae | *Paraserianthes falcataria* | Falcata |
| Fabaceae | *Colophospermum mopane* | Mopani or kaba-kaba |
| Fabaceae | *Leucena leucocephala* | Ipil-ipil |
| Fabaceae | *Mimosa pudica* | Makahiya |
| Gleichnaceae | *Dicranopteris linearis* | Agsam |
| Lamiacea | *Gmelina arborea* | Gemelina |
| Liliaceae | *Liriope muscari* | giant lily turf |
| Lythraceae | *Sonneratia alba* | Pagatpat |
| Meliaceae | *Sandoricum koetjape* | Santol |
| Moraceae | *Artocarpus altilis* | Antipolo |
| Moraceae | *Ficus heteropleura* | Kalapat or Is-is |
| Moraceae | *Ficus benjamina* | Balete |
| Moraceae | *Ficus pseudopalma* | |
| Mrytaceae | *Xanthostemon verdugonianus* | Magkono |
| Mrytaceae | *Psidium guajava* | Bayabas |
| Oleaceae | *Ligustrum vulgare* | Philippine privet |
| Pandanaceae | *Pandanus tectorius* | Pandan |
| Poaceae | *Impera tacylindrical* | Cogon |
| Poaceae | *Paspalum conjugatum* | Laua-laua or carabao grass |

| Family | Scientific name | Common Name |
|---|---|---|
| Poaceae | *Muhlenbergia lindheimeri* | Big muhly grass |
| Poaceae | *Bambusaa lbifolia* | Hedge bamboo or la-agngakawayan |
| Poaceae | *Saccharum spontaneum* | Talahib or bugang |
| Poaceae | *Stipa capillata* | needle grass |
| Podocarpaceae | *Podocarpus imbricatus* | |
| Primulaceae | *Ardisia elliptica* | Mata ayam |
| Phyllanthaceae | *Phyllanthus* sp. | Haiti |
| Rubiaceae | *Morinda citifolia* | Noni |
| Sapotaceae | *Palaquium luzoniense* | Red nato |
| Sapotaceae | *Pouteria sapota* | Sapota |
| Smilacaceae | *Smilax aspera* | Smilax |
| Thymelaceae | *Wikstroemia indica* | Salago |
| Ulmaceae | *Sponia amboinensis* | Hanagdong |
| Urticaceae | *Leucosyke capitellata* | Alagasi |
| Verbenaceae | *Premna odoratablanco* | Alagaw |
| Verbenaceae | *Lantana camara* | Otot-otot |
| Verbenaceae | *Stachytarpheta jamaicensis* | Elepante |
| Zingerberaceae | *Alipinia rufa* | |

*Screening for potential hyperaccumulator of nickel*

Of the 55 floral species encountered in the river delta, only 3 species tested positive to have a potential as nickel hyper accumulator.

These floral species were *Ardisia elliptica, Phyllantus* sp. and *P. odorata*. The existence of these species even in the delta suggests that there is interconnectivity between the soil quality in the mountain slopes and the deposited soil in the delta.

The delta is a landform that is a result of the build-up of sediments coming from the mountain slopes due to erosion. Thus in planning for mine rehabilitation, these plant species can be considered for planting even in the foot slopes and near the river system and the sea. These species can be propagated and planted all throughout the delta to accumulate nickel since results of nickel concentration in the area was found to be high.

*Spatial distribution of selected chemical parameters of sediments deposited in Kinalablaban Delta*

Levels of pH in Kinalablaban Delta range from 6.45-8.89, indicating that soil deposits in the delta are slightly alkaline to moderately alkaline (Fig 2). These pH values are relatively consistent with the pH values derived from the mined-out and rehabilitated areas in TMC.

The soil in TMC is basically the same type of soil and parent material with PGMC, which are both adjacent to Kinalablaban Delta. Nickel concentration is also high since values range from 2,281 to 10,810 mg/kg. It can also be observed that sampling points with higher nickel concentration are those in closer proximity to the mine site but tends to become lower as it approaches closer to the shore.

The high nickel concentration indicates sediment deposition in the entire delta which can possibly be coming from saprolitic soil from the upland. The study of Dzemua *et al*., (2011) revealed high concentration of nickel in different layers of saprolite in a lateritic soil profile which ranges from 2335 mg/kg in a serpentinitic rock to 6829 mg/kg in the upper saprolite.

High nickel concentration was reported by Bianchini *et al*., (2002) which even exceeded the Italian threshold limits designated for contaminated areas which is 120 mg/kg, from recent (post-Roman) overbank and deltaic deposits supplied by Po River. Since the study site is adjacent to a nickel mining industry, there is a tendency that a certain amount of nickel has accumulated in the delta. Wetlands absorb and bind heavy metals and make them slowly concentrate in sedimentary deposits (Sheoran and Sheoran, 2006). The study of Zabowski *et al*., (2000) found that soils and sediments surrounding the mining areas in one of the tributaries of Hei river have been contaminated by heavy metals.

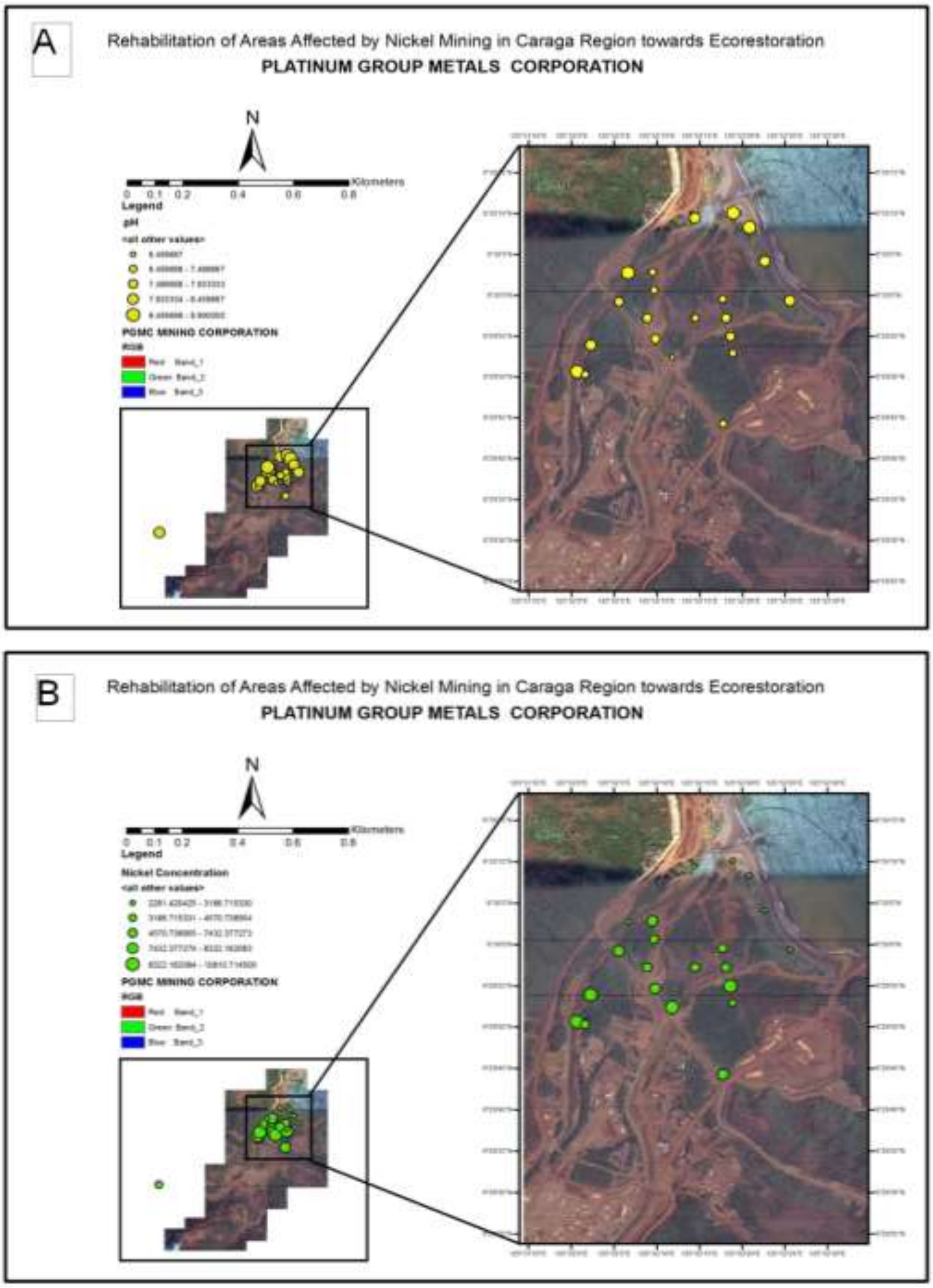


**Fig. 2.** Spatial distribution of pH (A) and nickel (B) in the alluvial plains of Kinalablaban River, Claver, Surigao del Norte.

Soil organic carbon ranges from 0.16 to 2.56 % (Fig. 3) indicating that some values are relatively low since the generally recognized value can range from 1.6 to 3.3 (Nelson and Sommers, 1982). Soil organic carbon is mostly derived from dynamic ecological processes such as photosynthesis, decomposition of organic materials, and soil organism activities.

The low values could be due to tidal flushing since there are areas in the delta that are affected when high tide occurs and low plant density because some sampling points has less vegetation than the others which have resulted in low organic matter accumulation. Flooding and heavy downpour can also take out the organic matter that may have started to accumulate.

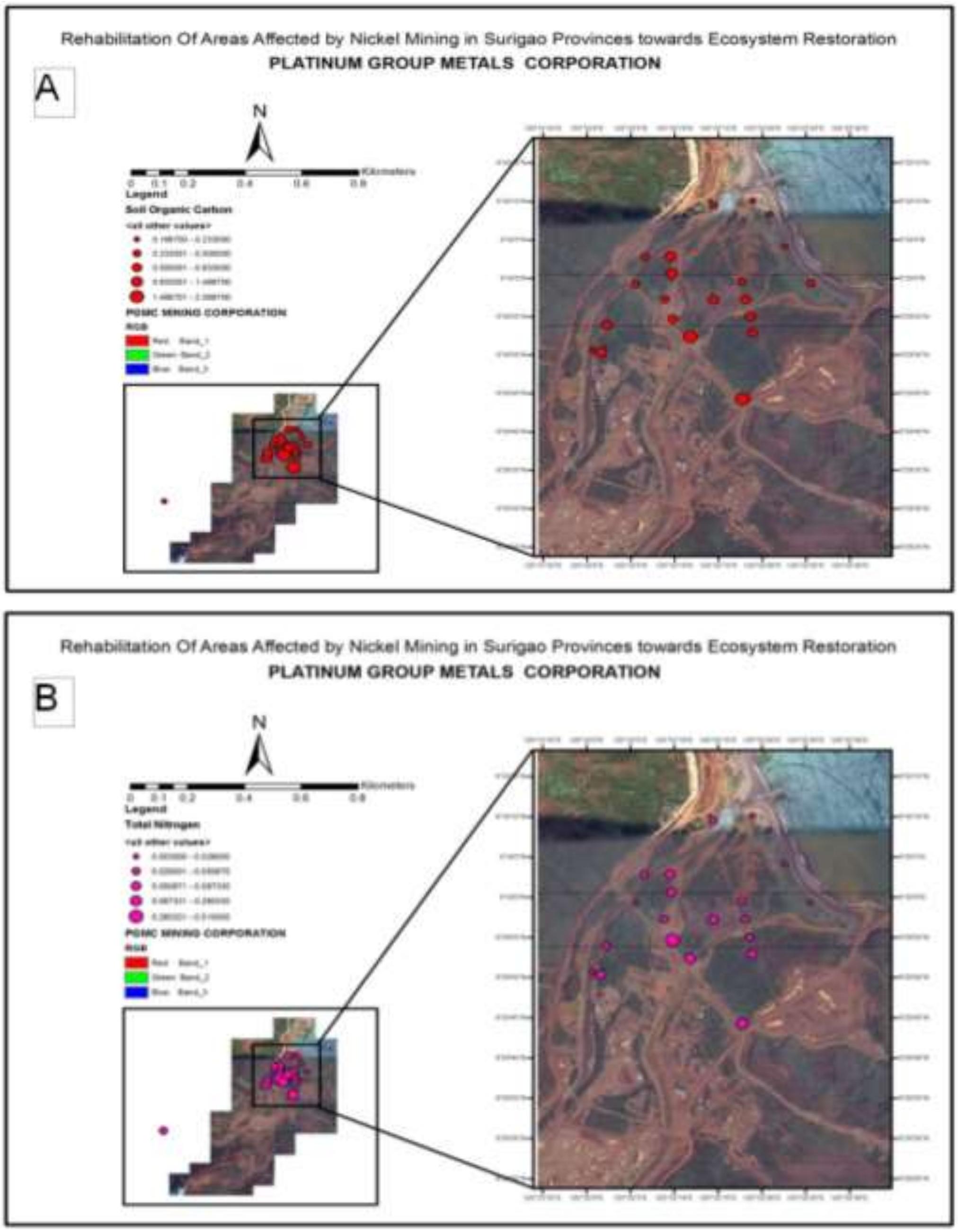


**Fig. 3.** Spatial distribution of soil organic carbon (A) and total nitrogen (B) in the alluvial plains of Kinalablaban River, Claver, Surigao del Norte.

Total nitrogen in the entire area was relatively low (Fig. 4). This is in reference to the values of total Nitrogen which do not exceed the critical value of 0.2 % (Landon, 1991). This suggests that the supply of N in the soil is deficient and could be limiting for plants that needs higher amounts of nitrogen. However, it was observed that nitrogen fixing plants exist in the delta and their presence could contribute in increasing nitrogen in the soil through fixation of nitrogen gas from the atmosphere.

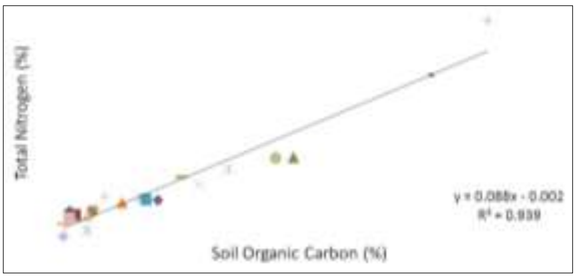


**Fig. 4.** Linear regression of the soil organic carbon (%) and total nitrogen (%) of surface sediments in the alluvial plains of Kinalablan River, Claver, Surigao del Norte.

There was a significant positive correlation between soil organic carbon and total nitrogen ($R^2$=0.939, $p < 0.01$) indicating that soil organic carbon contributes and influences the concentration of total nitrogen in the soil. Organic residues are sources of nitrogen because it is incorporated into the soil and after these are decomposed and are converted into inorganic compounds, these are available for plant uptake. The observation implies that the Kinalablaban River delta is no longer a very young soil since deposition of organic matter is already evident.

## Conclusion

The existence of diverse floral species in the delta indicates that the soil particles deposited from soil erosion can support biodiversity. This is useful information for mine rehabilitation because the interconnectivity between the soil quality in the mountain slopes and the deposited soil in the delta is critical in planning the landscape approach. The floral species in the riparian areas along Kinalablaban River and the delta can also be mass propagated in the nursery to be used as components in establishing the forest strips for mine rehabilitation. The presence of nickel hyperaccumulators is also essential for the nickel mine rehabilitation program inasmuch as these can reduce the movement of nickel particles into the water bodies.

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