Potential hyperaccumulator plants for sustainable environment in tropical habitats

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Abstract. Hyperaccumulators are rare ability of plants to accumulate excessive concentration of elements on roots and shoot tissues without any evidence of physiological stress. However, less research has been conducted in different environmental habitats. Hence, this study was conducted in Mount Magdiwata and Peatland Forest of La Paz, Philippines. The objectives of this research were to identify hyperaccumulator plants as well as analyze soil and plant elemental accumulations. Sampling stations were designated in stratified habitats. Collected soil and plant specimens were analyzed in the laboratory and data were interpreted using SPSS software. Cratoxylum sumatranum (Jack) Blume, Syngramma alismifolia (C. Presl) J.Sm., Mitragyna speciosa Korth, Pneumatopteris laevis (Mett) Holtt and Pneumatopteris glabra (Cope) Holtt were species that shown hyperaccumulation criterion and had significant accumulation capacity in respective habitats. Manganese had accumulation capacity in the leaves of Mitragyna speciosa Korth above the thresholds level for heavy metal concentrations at 22393 mg/kg-1. Soil element Mg has higher accumulation in the leaves at 5257 mg/kg-1 and Fe at 4298 mg/kg-1 both major soil elements had shown significant results. The accumulation capability of this identified species were prospective sources of hyperaccumulator plants onwards to phytoremediation technology to cleanse environmental toxicity.

1. Introduction
Tropical habitats has a wider range of species diversity due to its geographical location and climatic conditions. This condition forms a sequence in forest dynamics and the association of soil and plants. But, in the advent of globalization human being had put pressure for development in the equilibrium state of the earth. The condition became unstable due to the increasing population that enable industrialization to compensate for the demand of food production. Population growth has a greater impact in the social, economic and environmental state of the earth.

The greater impact of development was in environmental condition that anthropogenic activities contribute significantly to environmental contamination. The usage and component of metals in industrialization had adverse effect in humans as well as in the environment. Heavy metals are among the contaminants in the environment. Beside the natural activities, almost all human activities have potential contribution to produce heavy metals as side effects. Migration of these contaminants into not contaminated areas as dust or leachates through the soil and spreading of heavy metals containing
sewages sludge area are few examples of events contributing towards contamination of the ecosystems [1].

Since, heavy metals are naturally occurring elements their association within the soils and plants in the environment enable to drive intertwining possibilities of using plants to reduce environmental contamination. This unique characteristics of plant is known as hyperaccumulators. Hyperaccumulators are a suite of plants with the rare ability to extract certain metals and metalloids, and to accumulate them in normally toxic shoots and root tissue concentrations without any evidence of physiological stress[2]. Hyperaccumulators that belong to the genus Buxus, Ariadne, Rinorea, Psychotria, Euphorbia and Phyllanthus from Cuba, New Caledonia, or parts of the Philippines and Indonesia [9] are predominantly occurring on substrates enriched in their hyperaccumulated elements. Host soils has elevated levels of heavy metals and supporting highly specialized floras [3]. Aside from understanding the unique ecophysiological adaptations of hyperaccumulators, previous studies of Reeves [9] and Boyd [4] revealed on some plants that contain unusual large amount of elements which play a role on plant defense and has potential application for rehabilitation, metal prospecting, phytoremediation and mine restoration [3], [4]. Where in, limited or no analytical work has been performed in tropical habitats and it is expected that hyperaccumulators related taxa or new plants species could be discovered in the Philippines or other part of the world. On this onset, research was conducted in the Province of Agusan del sur, Philippines which aimed to identify and determine potential hyperaccumulator plants and analyze the elements in soils and plants. This will compile also convening awareness on the association of elements in soil and plants that maybe a solutions for mitigation and adaptation in sustainable environment.

2. Methods

The research study was conducted in two environmental conditions. The first site was located in Mount Magdiwata, San Francisco, Agusan del Sur, Philippines with geographical coordinates of North 8.47793 and East 125.9833. The area was declared as a watershed forest reserve under Presidential Proclamation 282 dated October 23, 1993. The 1,658 hectares watershed forest reserves were previously affected by unabated timber poaching, hunting, quarrying, and illegal mining and exploration activities [5]. The second site was located in Osmena, La Paz, Agusan del Sur, Philippines with geographical coordinates of North 8.32615 and East 125.82230. A Peat land forest and a protected area covering more than 14,000 hectares in the heart of the 250 kilometer Agusan River.

![Figure 1. Map of the Study Area](image)
2.1. Data collection and sampling
Stratified sampling plot per habitat type based on forest composition has been used in this study. Habitat type based on forest composition has been identified in Mount Magdiwata and La Paz, Peatland Forest respectively. A sample plots (quadrats) has been established to provide quantitative and qualitative descriptions of the plant species present per forest composition. Sampling of soil and plant species were done in accessible location per habitat type. The three sampling sites were selected within different forest composition which were established in agro-forest area, lower dipterocarp forest and mid-montane dipterocarp forest. Another site is in peatland forest, wherein three peatland habitat types were identified for selected sampling, namely; Sago, Mixed Forest and Terminalia. In each sampling site, we established three sampling plots with size 20m x 20m (400 m² equivalent to 0.04 ha) and established replicate plots with 50m interval per quadrat [6]. In every sampling plots, collection of soil samples and plant specimens were undertaken.

2.2. Plant Screening and Sampling Lay-out
A quantitative sampling has been done per area based on sampling plots for nickel (Ni) accumulation was performed on washed plant material. Leaf, fragments were crushed on prepared filter paper, which were previously impregnated with 1% dimethylglyoxime dissolved in 95% ethanol. Formation of pink to red colour indicates a Ni concentration of 100 to > 1000 μg/g of dry plant matter. A total of seven plant species were collected that shown obligate hyperaccumulation, 3 species from Mount Magdiwata and 4 species from peatland forest, Osmena. Leaves, stems and roots were collected following the standard protocol for plant collection [7].

Soil sampling was established in a plot of 20 x 20 meters. Soil physical sampling were undertaken using a soil auger with diameter of 2 cm, 10 probes which were collected of the 0-30 cm soil depth following a regular zig-zag pattern covering the whole surface of the established plot per area and habitat type. Collected soil samples per plot were sealed in zip lock cellophane weighing more or less 200 grams per samples. A total of 18 soil samples were collected, 9 samples per area. Soil and plant specimens were dried and then analyzed on the contain of elements at Czech University of Life Sciences, Prague, Czech Republic.

2.3. Laboratory Analysis
2.3.1. Soil Analysis
Soil samples were further dried in an oven for 48 hours in the soil laboratory of the Faculty of Agrobiology, Food Nutrition and Natural Resources, Prague, Czech Republic. Sieving were done in a 2mm fraction in all the soil samples for further filtering and dilution process. Soil pH were also obtain to determine the acidity and soil alkalinity in water and potassium hydrochloride protocol.

Analysis of soil samples was performed using aquaregia extraction were (Nitric Acid and Hydrochloric Acid) a solvent designed to digest all metals in a soil sample giving the “pseudo total” content in a soil sample. In a screw cap teflon tube, 1 g of soil was added and to this 1 ml of deionized water was added to obtain a slurry. Then, 7 ml of 35% HCl was added followed by 2.334 ml of 65% HNO₃. The mixture was gently heat on a hot plate for several hours. After that, we did filtering of the slurry. About 1 ml of this mixture was then transferred by pipette to a clean 50 ml tube and make up to the mark with deionized water. Dilution were further done with 1 ml mixture added with 9 ml of 0.055 concentration of deionized water with the use of pipette and mixed in the test tube for further heavy metal analysis using Inductively Coupled Plasma (ICP) – Optical Emission Spectroscopy (OES)[8].

2.3.2. Soil pH analysis
10 g of soil was weight per sampling habitat and added with 20 ml deionized water. The soil and water was mixed for 5 minutes using a glass stick and further diluted in a shaking machine for an hour. The pH value were measured by the pH – meter in various habitat sampling location [8]. In contrast, a 2M solution of KCl was prepared (dissolved in 14.91 g of KCL in 1 liter of D.I water).
Further mixing was done in a 1:5 soil: liquid ratio (v:w) e.g. 2 g of soil to 10ml of KCl. The solutions were put in a shaker machine for an hour and diluted solution were further measured with pH level in pH-meter at various habitat respectively [8].

2.3.3. Laboratory analysis for plant specimens
Elemental analyses were performed on the plant material using analyses developed at Massey University [9]. The plant dried materials were separated in leaves, stems and roots. About 25 mg was weighed per samples to 0.1 mg into borosilicate tubes for dry ashing in a muffle furnace. The temperature was raised to 200 °C for over an hour and then to 500 °C for the span of 4 hours. After cooling overnight the ash was dissolved in 5.00 mL of 2M HCl. The solutions per sampling specimens was analyzed for the heavy metal accumulation respectively with the aid of an ICP-OES Spectroscopy.

2.4. Statistical Analysis
Data were analyzed using analysis of variance (ANOVA) and interpreted with the aid of Statistical Package for Social Sciences software.

3. Results
3.1 Accumulation of trace elements in soil and plant tissues
The accumulation of elements in soil and plant tissues has varied level of cumulative absorption capacity in the 2 study sites. In Mount Magdiwata the Agroforest habitat type, Al has higher accumulation in the roots of *Cratoxylum sumatranum* (Jack) Blume at 8774 mg/kg and Fe has been accumulated at higher level in the soil at 5300 mg/kg. The Fe element has been traced both in highest accumulation in the roots of *Syngramma alismifolia* (C. Presl) J.Sm. in the Lower Dipterocarp Forest at 599 mg/kg-1 and 2509 mg/kg in the soil. While, in the Mid montane Dipterocarp Forest Mg has highest accumulation in the leaves of *Pneumatopteris laevis* (Mett) Holtta at 6375 mg/kg-1 and Fe accumulation in the soil is 2889 mg/kg.

In Peatland Forest, Sago habitat type has two hyperaccumulator species being identified. *Mitragyna speciosa Korth* has Mg accumulation in the leaves at 22394 mg/kg and Fe in the soil at 2206 mg/kg. The other hyperaccumulator species is *Pneumatopteris laevis* (Mett) Holtta with Fe highest accumulation both in the leaves at 609 mg/kg and soil at 10067 mg/kg. In the Mixed Forest two elements has higher accumulation level being traced in the roots of *Pneumatopteris glabra* (Cope) Holt. Al has accumulation of 8528 mg/kg and Fe at 9271 mg/kg. While, in Terminalia Forest Mg has highest accumulation in the leaves of *Cratoxylum sumatranum* (Jack) Blume at 9838 mg/kg-1 and Fe at 4724 mg/kg.

| Habitat Type       | Hyper accumulator Plants | Plant Tissue and Soil | Trace Elements (mg/kg) | Al  | Cd  | Co  | Cr  | Cu  | Fe  | Mg  | Mn  | Ni  | Pb  | Zn  |
|--------------------|--------------------------|-----------------------|------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Agroforest         | *Cratoxylum sumatranum* (Jack) Blume. | Leaves               | Al  | 442.5 | 0.13 | 2.65 | 31.6 | 270.37 | 447.75 | 3,934.55 | 173.74 | 8.22 | 1.77 | 314.11 |
|                    |                          | Stem                  | Al  | 86.55 | 0.05 | 0.45 | 1.17 | 150.47 | 81.66 | 3,625.21 | 52.8 | 1.86 | 1.55 | 255.59 |
|                    |                          | Roots                 | Al  | 8,773.87 | 0.32 | 0.45 | 5.63 | 58.51 | 2,110.40 | 1,210.51 | 359.28 | 7.53 | 0.38 | 148.26 |
|                    |                          | Soil                  | Al  | 3,042.13 | 0.28 | 4.47 | 5.75 | 7.32 | 5,300.64 | 147.57 | 90.65 | 11.94 | 0.58 | 2,245.94 |
| Lower Dipterocarp  | *Syngramma alismifolia* (C. Presl) J.Sm | Leaves               | Al  | 243.77 | 0.36 | 0.45 | 1.18 | 43.48 | 94.33 | 3,765.04 | 79.06 | 2.46 | 0.94 | 70.91 |
| Forest             |                          | Stem                  | Al  | 131.32 | 0.05 | 0.45 | 0.62 | 74.47 | 64.61 | 3,651.23 | 25.3 | 2 | 0.84 | 83.39 |
|                    |                          | Roots                 | Al  | 2,908.55 | 0.05 | 0.45 | 1.26 | 54.78 | 598.89 | 2,619.76 | 111.16 | 2.85 | 0.38 | 62.11 |
|                    |                          | Soil                  | Al  | 2,192.09 | 0.11 | 0.45 | 1.7 | 2.26 | 2,509.41 | 291.66 | 20.43 | 0.4 | 0.88 | 400.73 |
| Mid Mountain       | *Pneumatopteris laevis* (Mett) Holtta | Leaves               | Al  | 252.22 | 0.05 | 0.45 | 1.69 | 64.88 | 166.07 | 6,374.77 | 171.7 | 3.96 | 2.37 | 105.31 |
| Dipterocarp        |                          | Stem                  | Al  | 142.48 | 0.05 | 0.45 | 1.31 | 66.43 | 93.98 | 3,418.85 | 74.41 | 10.29 | 1.41 | 61.68 |
Forest Roots 8,679.67 0.24 0.45 3.26 40.23 1,364.66 2,516.82 592.06 6.57 2.64 47.51
Soil 2,631.31 0.09 0.45 2.78 4.47 2,889.14 317.39 46.00 46 0.38 8.14

Mitragyna speciosa Korth. Leaves 2,664.35 0.23 0.45 10.99 96.99 1,002.56 18,792 22,393.50 23.35 3.72 134.84
Stem 1,295.70 0.73 13.24 6.61 260.73 561.85 20,414.02 17,160.64 31.02 3.57 365.33
Roots 9,924.05 1.53 0.45 34.32 93.41 7,352.23 11,066.86 10,810 33.83 2.48 143.55
Soil 3,256.69 0.09 0.45 8.78 16.84 2,205.75 384.62 17.31 6.7 0.38 11.07

Sago Forest Leaves 948.08 0.12 0.45 3.58 46.77 608.76 6,701.92 1,053.05 19.04 1.61 57.9
Stem 86.56 0.05 4.59 1 34.45 92.24 2,172.45 300.70 9.46 0.38 60.05
Roots 8,983.52 0.72 5.29 24.97 90.3 10,066.9 3,684.20 4,144.71 45.3 1.75 85.03
Soil 2,997.6 0.08 0.45 9.19 42.3 2,135.62 338.40 19.91 6.04 0.38 21.71

Pneumatopteris leavis (Mett) Holt. Leaves 1,724.24 0.05 0.45 17.19 39.6 705.72 6,320 799.26 48.27 1.52 123.54
Stem 1,539.21 0.17 0.45 8.01 52.38 622.32 3,181.20 400.27 35.3 1.22 70.37
Roots 8,528.21 0.72 3.98 25.06 1,331.30 3,750.60 1.15 3.11 74.53 1.75 85.03
Soil 3,656.39 0.48 6.97 14.55 12.39 9,271.08 367.37 116.53 7.42 0.89 10.9

Terminalia Forest Leaves 342.81 0.52 0.45 2.3 86.96 282.01 4,447.27 290.78 57.51 0.92 222.66
Stem 241.25 2.48 0.45 2.02 112.73 207.05 9,837.54 330.5 156.2 9 328.61
Roots 2,029.19 4.01 0.45 11.52 78.1 1,235.96 2,670.80 485.62 343.8 1.84 209.68
Soil 3,375 0.23 0.74 13.58 18.22 4,724.42 646.73 31.84 9.04 0.38 970.17

3.2. Mean elements in the soil and pH level per sampling course
The result showed varied interactions of elements in the soil with respect to each habitat types. The elements of Al, Cd, Cu, Mg and Ni had significant results in Agroforest, Lower Dipterocarp Forest, Sago Forest and Mixed Forest. Significant mean difference in sample plots of elements Al and Cu within Mixed Forest, Agroforest and Terminalia Forest respectively. While, the other elements had no significant difference in varied sampling habitat.

| Habitat Type                        | Trace Elements (mg/kg) |
|-------------------------------------|------------------------|
|                                     | Al         | Cd         | Co         | Cr         | Cu         | Fe         | Mg         | Mn         | Ni         | pb         | Zn         |
| Agroforest                          | 3814.63bc | 0.36bc     | 4.9b       | 9.01c      | 12.21abc   | 6759.52b   | 194.38a    | 133.26b    | 6.31b      | 4.3a       | 920.71a    |
| Lower Dipterocarp Forest            | 2091.99a  | 0.14a      | 0.62a      | 2.04a      | 4.39ab     | 2819.59a   | 361.99a    | 41.11a     | 0.45a      | 0.55a      | 149.31a    |
| Mid Mountain Dipterocarp Forest     | 2063.34a  | 0.11a      | 0.45a      | 2.23a      | 3.47a      | 2465.91a   | 249.47ab   | 36.69a     | 0.37a      | 0.61a      | 56.03a     |
| Sago Forest                         | 3021.94ab | 0.1a       | 0.45a      | 8.88b      | 22.82c     | 2248.19a   | 352.31ab   | 24.9a      | 6.35b      | 0.38a      | 13.64a     |
| Mixed Forest                        | 3337.59abc | 0.47c     | 0.45a      | 13.91c     | 19.9bc     | 9414.62c   | 381.88b    | 156.53b    | 7.95bc     | 0.55a      | 11.75a     |
| Terminalia Forest                   | 4394.79c  | 0.26c      | 0.93a      | 16.87c     | 17.82abc   | 5385.34b   | 726.96c    | 46.35a     | 10.77c     | 0.38a      | 337.27a    |

* mean of the same letter in the columns is not significant α = 0.05

The pH level signify the corresponding level of acidity per sampling habitat. The mean pH<sub>H2O</sub> in the Agroforest is moderately acidic and in the Lower Dipterocarp and Mid-Montane Forest is strongly acidic at pH level 5.69 and 5.26 respectively but has significant difference in the sampling habitat. The rest of the pH in succeeding habitat is very strongly acidic and has no significant difference at 0.05 probability level [10]. While, pH level in KCl solutions is extremely acidic and has no significant difference in all habitat types.
Table 3. Mean pH level per sampling course

| Habitat Type                  | Mean pH   |
|------------------------------|-----------|
|                             | pH2O      | pH KOH |
| Agroforest                  | 5.86c     | 4.47b  |
| Lower Dipterocarp Forest    | 5.69bc    | 4.31b  |
| Mid Mountain Dipterocarp    | 5.26ab    | 3.98a  |
| Forest                      |           |        |
| Sago Forest                 | 4.87a     | 3.98a  |
| Mixed Forest                | 4.98a     | 3.86a  |
| Terminalia Forest           | 5.11a     | 3.93a  |

*Mean of the same letter in the columns is not significant α = 0.05

3.3. Mean elements in hyperaccumulator plants per habitat

Successful phytoremediation requires recognition of suitable plant species to accumulate metal elements in toxic levels as well as creating high biomass [11], [12]. Hyperaccumulator plants require higher accumulation of biomass in the upper part of the plants most specially accumulation in the shoots. The results in this study revealed that element Cd had significant mean accumulation in the tissue of *C. sumatranum* (Jack) Blume, *S. alismifolia* (C. Presl) J.Sm., *M. speciosa* Korth, *P. laevis* (Mett) Holtta and *P. glabra* (Cope) Holtt in the Agroforest, Lower Dipterocarp, Sago and Mixed Forest respectively. While, elements Ni and Zn had significant mean accumulation in hyperaccumulator plants *M. speciosa* Korth, *P. laevis* (Mett) Holtta and *P. glabra* (Cope) Holtt at Sago and Mixed Forest. The Pb trace element had mean significant difference with hyperaccumulators, *C. sumatranum* (Jack) Blume, *P. laevis* (Mett) Holtta, *M. speciosa* Korth and *P. glabra* (Cope) Holtt in the four type of habitat namely; Agroforest, Mid-montane Dipterocarp, Sago and Mixed Forest.

Table 4. Mean elements of hyperaccumulators plants

| Habitat Type | Hyperaccumulator Plants | Al   | Cd   | Co   | Cr   | Cu   | Fe   | Mg   | Mn   | Ni   | Pb   | Zn   |
|--------------|-------------------------|------|------|------|------|------|------|------|------|------|------|------|
| **Agroforest** | *Cratoxylum sumatranum* (Jack) Blume. | 3,100 | 0.17 | 1.18 | 1.1  | 12.  | 159. | 879.9| 2.92 | 195. | 5.87 | 1.23 |
|              | Syngramma alismifolia (C. Presl) J.Sm. | 1,094 | 0.15 | 0.45 | 1.0  | 57.  | 252. | 3,345.| 71.8 | 2.44 | 0.72 | 72.1 |
| **Lower Dipterocarp Forest** | *Pneumatopteris leavis* (Mett) Holta | 3,024 | 0.11 | 0.45 | 2.0  | 57.  | 541. | 4,103.| 279. | 6.94 | 2.14 | 71.5 |
|              | *Mitragyna speciosa* Korth. | 4,628 | 0.83 | 4.71 | 17.  | .38  | 2.25 | 167. | 88.0 | 29.4 | 3.26 | 211. |
| **Mid Mountain Dipterocarp Forest** | *Pneumatopteris leavis* (Mett) Holta | 3,339 | 0.55 | 3.44 | 9.8  | 57.  | 9.31 | 5,219.| 2.82 | 28.8 | 1.54 | 142. |
| Sago Forest | *Pneumatopteris glabra* (Cope) Holtt | 3,930 | 0.31 | 1.63 | 16.  | 55.  | 7.05 | 4,417.| 78.4 | 52.7 | 1.5a | 92.9 |
| **Mixed Forest** | *Cratoxylum sumatranum* (Jack) Blume. | 871.08 | 2.34 | 0.45 | 5.2  | 92.  | 575. | 5,651.| 368. | 185. | 1.29 | 253. |

*Mean of the same letter in the column is not significant α = 0.05
4. Discussion

4.1. Accumulation of elements in soils and plant tissues of hyperaccumulator species

Interest in phytoremediation has grown significantly following the identification of metal hyperaccumulator plant species. The success of phytoextraction, as an environmental cleanup technology, depends on several factors including the extent of soil contamination, metal availability for uptake into roots (bioavailability), and plant ability to intercept, absorb, and accumulate metals in shoots [13].

The result of this study revealed that in the 11 elements namely; Al, Cr, Cd, Cu, Co, Fe, Mn, Mg, Ni, Pb and Zn were hyperaccumulators for C. sumatranum (Jack) Blume, S. alismifolia (C. Presl) J.Sm., P. laevis (Mett) Holtt, M. speciosa Korth and P. glabra (Cope) Holt. 2 elements namely; Mg and Mn had the highest accumulation level in the shoots. Mg had an average accumulation of 5257 mg/kg\(^{-1}\) in the six habitat. While, Manganese had a highest accumulation of 22393 mg/kg\(^{-1}\) in the leaves at Sago Forest. The result correlates in the study of Ent var der et. al (2012) on element for hyperaccumulator species. Furthermore, Mn threshold had been widely exposed on varying concentrations (about 20–400 μg/g/ mg/kg), a 10,000-μg/g threshold was suggested by Baker and Brooks (1989). The result, signifies that Mn had higher accumulation in the leaves of M. speciosa Korth in the Sago Forest above the worldwide standard concentrations and thresholds level.

In all habitat, Fe had the highest accumulation in the soil with an average of 4298 mg/kg\(^{-1}\) in all sampling course and the level of concentration is above permissible level in the soil as set by WHO’s at 200 – 1000 mg/kg [14]. Accumulation level of Mg and Mn in the leaves is above permissible level on WHO’s set for phytotoxicity on plants at 200 – 2000 mg/kg [15] [16] [17].

4.2. Mean of elements in the soil and pH level per habitat

The soil pH reflects whether a soil is acidic, neutral, basic or alkaline. The acidity, neutrality or alkalinity of a soil is measured in terms of hydrogen ion activity of the soil, water system. The negative logarithm of the H ion activity is called pH and thus pH of a soil is a measure of the intensity of activity. The pH range normally found in soils varies from 3 to 9. The pH measure of soil in water and KCl systems provides information on the nature of charge discharge on soil colloids which will have a far recharging effect on nutrient measurement and reaction and this can also provide the toxicity present in the soil.

This study determined that, in Lower Dipterocarp Forest and Mid Montane Forest the pH\(_{H_2O}\) was strongly acidic at mean of 5.69 and 5.26 but it has significant difference and the rest has no significant difference in all habitat type. While, the pH\(_{KCl}\) was extremely acidic at all habitat type ranges from pH\(_{KCl}\) 3.86 to 4.47 which has no significant difference. This study adheres to the analysis of Nazir et. al. (2015) in the accumulation of heavy metal in soil, water and plants. The result of the pH level in this study were all below permissible pH level set by WHO’s at pH 6.5 – 8.5 [17]. This implies that soil is detrimental and can cause adverse effect in the environment as well as in any life forms.

4.3 Mean of accumulated elements in hyperaccumulator species

Accumulating capability is the natural capacity of plants to accumulate metals in their above-ground parts (shoots). The typical concentrations of metals and metalloids in plants, and the worldwide standard reference, plant has elemental concentrations (μg/g/ mg/kg) of Ni (1.5), Zn (50), Cd (0.05), Pb (1), Cu (10), Co (0.2), Cr (1.5), Mn (200), Tl (0.02), As (0.1) and Se (0.02) [18], [19].

In this study, all the elements found in plant tissues were above the worldwide standard reference for elemental concentrations but below the thresholds set for heavy metal concentrations on the amounts greater than 100 mg kg\(^{-1}\) for Cd [20], 1000 mg kg\(^{-1}\) for Cu, Cr, Pb, and Co, 10 mg kg\(^{-1}\) for Hg [21] and 10000 mg kg\(^{-1}\) dry weight of shoots for Ni and Zn [22]. Elements Cd, Cu, Cr, Co, Pb, Mn, Ni and Zn has been considered as heavy metals and Al, Fe and Mg has been considered as major soil elements [23]. Relative to this, results signifies that Cd had significant mean accumulation in the tissue of C. sumatranum (Jack) Blume, S. alismifolia (C. Presl) J.Sm., M. speciosa Korth,
Pneumatopteris laevis (Mett) Holtt and P. glabra (Cope) Holtt in the Agroforest, Lower Dipterocarp, Sago and Mixed Forest respectively.

While, elements Ni and Zn had significant mean accumulation in hyperaccumulator plants M. speciosa Korth, Pneumatopteris laevis (Mett) Holtt and P. glabra (Cope) Holtt at Sago and Mixed Forest. The Pb trace element had mean significant difference with hyperaccumulators, C. sumatranum (Jack) Blume, P. laevis (Mett) Holtt, M. speciosa Korth and P. glabra (Cope) Holtt in the 4 types of habitat namely; Agroforest, Mid-montane Dipterocarp, Sago and Mixed Forest.

Conclusions
The use of potential hyperaccumulator for sustainable environment is one of the cost effective and friendly technologies to clean up soil from elemental contamination. The uptake and accumulation of pollutants vary from plant to plant and also from species to species within a genus. Proper selection of plant species for phytoremediation plays an important role in the development of remediation methods especially on polluted soils.

The identified species, Cratoxylum sumatranum (Jack) Blume, Syngramma alismifolia (C. Presl.) J.Sm., Mitragyna speciosa Korth, Pneumatopteris laevis (Mett) Holtt and Pneumatopteris glabra (Cope) Holtt. had significant accumulation capacity in respective habitats. The 11 elements analyzed had been classified into groups of heavy metals such as, Cd, Cu, Cr, Co, Pb, Mn, Ni and Zn. While, Al, Fe and Mg has been considered as major soil elements. All of the heavy metals being identified in the study were above the standard reference worldwide set for plants and Mn had shown highest accumulation capacity in the leaves above the thresholds level for heavy metal concentrations. While, elements Mg has higher plants accumulation in the leaves and Fe as major soil elements had shown significant results in all habitat.

Soil is a very specific component of the biosphere because it is not only a geochemical sink for contaminants, but also acts as a natural buffer controlling the transport of chemical elements and substances to the atmosphere, hydrosphere, and biota. Trace elements originating from various sources may finally reach the surface soil, and their further fate depends on soil chemical and physical properties. The lower the pH level denotes an active absorption of heavy metals on the accumulation capacity of hyperaccumulators.

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