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Chemical dynamics of a highly weathered soil under native tree species in Mt. Pangasugan, Leyte

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ABSTRACT

The study evaluated the changes of the chemical properties of a highly weathered soil planted to native tree species. Soil samples were gathered at monthly interval for 12 months and were analyzed for pH, OM, N, P, Ca and Mg. Decomposition of leaf litter of the dominant native tree species (*Parashorea malaanonan* and *Dipterocarpus warburgii*) in the site was determined using the litter bag method.

Results revealed significant temporal variations of pH in $CaCl_2$, OM, total N and available P, but not for pH in H_2O and exchangeable Ca and Mg. Significant differences between sites (spatial variation) were also observed for OM, total N and exchangeable Ca and Mg suggesting the important effects of vegetation type on these soil properties. Decomposition rates of 0.0331 kg/ha/week and 0.0231 kg/ha/week were obtained for *D. warburgii* and *P. malaanonan*, respectively. Both rates suggest fast litter decomposition.

Keywords: chemical soil dynamics, highly weathered soil, native tree species, Mt. Pangasugan, Leyte

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INTRODUCTION

Highly weathered soils of the humid tropics are characterized by high leaching and acidity (Hassett and Banwart, 1992). They also have high clay content and abundant stable secondary minerals like halloysite or kaolinite and thus are generally less productive and difficult to manage (Sanchez, 1976).

In Southeast Asia, more than 1/3 of the total area is covered by infertile highly weathered soils classified as Ultisols and Oxisols in the USDA Soil Taxonomy (Soil Survey Staff, 1996) or Acrisols and Ferralsols in the World Reference Base (WRB) (IUSS Working Group WRB, 2006). In the Philippines, about 58 % of the total land area has acidic soil conditions (Stark, 2000). In the mountainous areas of Leyte, many soils are highly weathered and can be classified as Ultisols (Asio, 1996; Asio *et al*., 1998). Studies indicated that nutrients are generally limited in these highly weathered ultisols (Jahn and Asio, 1998; Zikeli *et al*., 2000).

Trees generally influence the soil chemical properties with time by providing the soil with organic matter mainly in the form of leaf litter accumulated in the thin A and O horizons. Trees could survive for many years, thus contributing considerable amount of leaf fall to the soil surface. Upon decomposition, the chemical components of this litter are released back to the soil. This, in fact, is the major recognized avenue by which trees add organic matter to the soil (Altieri, 1987). Nutrient enrichment by some tree species enables highly weathered and infertile soil types to support vegetation growth. Individual tree species also affect the chemical properties of the soil in their vicinity. Properties such as stem flow and litter accumulation could be important in their effects on soil properties as processes associated with the different species (Riha *et al*., 1986).

While it is widely accepted that trees play a major role in nutrient enrichment of the soil underneath them, there is very little information available on the effects of the different tree species on the chemical properties of a highly weathered soil under a humid tropical island environment. For native tree species, the lack of published literature on their performance on reforestation could be one reason why they are not commonly used (Langenberger, 2000).

To achieve better understanding of the important role of trees in improving soil quality, it is important to understand how nutrient availability changes with time (Kelly and Mays, 1999). Although much research has been done on the characteristics of highly weathered soils, there is little available information on the changes of their chemical properties following a change in land use, particularly from Imperata grassland to plantation of indigenous tree species. In particular, very little data exist on the nature and rate of change of soil chemical properties under native tree species.

This study was conducted to evaluate the dynamics of some chemical properties of a highly weathered soil as influenced by native tree species.

MATERIALS AND METHODS

Study site

The study site is located at the GTZ Reforestation Site (Closed Canopy Project) on the lower western slope of Mt. Pangasugan at an elevation of approximately 100 m above sea level. Original vegetation was dipterocarp forest (Langenberger *et al*., 2005) which was replaced with *Imperata cylindrica* until the early 1990's as a result of shifting cultivation. In 1994, native tree species were planted which now cover the area. Table 1 summarizes the dominant tree species found at the two sites selected.

Collection and preparation of soil samples

Three sampling plots measuring 3m x 4m were established at two neighboring areas inside the reforestation project site. From each plot, six subsampling points were marked. Soil samples were collected around each point at 20 cm depth using a soil auger at monthly interval for 12 months. The subsamples were mixed thoroughly to obtain one composite sample for each plot. In the same manner, a composite sample was also collected from a nearby area covered with grasses (*P. conjugatum*) for comparison purposes. The area has been in existence for more than 10 years now.

Right after sampling, the collected samples were air-dried, freed of large plant residues and rock fragments, and then ground using a wooden mallet and allowed to pass through a 2-mm wire mesh. This fine-earth fraction was the sample used for most analyses. For organic matter (OM) analysis, enough amount of fine-earth fraction was taken and then ground again until all particles passed through a 0.0425 mm sieved. The samples were then stored in plastic containers ready for analysis.

Table 1. Dominant native tree species found in the two adjacent sampling sites in Mt. Pangasugan, Leyte

Site	Common Name	Scientific Name
1 (lower slope)	Bagtikan*	*Parashorea malaanonan*
	Mayapis	*Shorea palosapis*
	Dao	*Dracontomelon dao*
	Almaciga	*Agathis philippinensis*
2 (upper slope)	Hagakhak*	*Dipterocarpus warburgii*
	White lauan	*Shorea pentacme*
	Yakal-saplungan	*Hopea plagata*
	Almaciga	*Agathis philippinensis*
	Antipolo	*Artocarpus blancoi*

* Most common

Analysis of soil chemical properties

Soil pH was measured potentiometrically in water and in 0.01 M CaC_{l2} at a soil-solution ratio of 1:2.5 (ISRIC, 1995). OM was determined following the Walkey-Black method (ISRIC, 1995). Total N was determined by the modified Kjeldahl method of ISRIC (1995). Available P was extracted using the Bray No. 2 method of Jackson (1958), by the method of Murphy and Riley (1962) for color development, and by spectrophotometry for quantification. Exchangeable Ca and Mg were determined by titration with EDTA using $NaNO_3$ as extractant (PCARR, 1980).

Rate of litter decomposition

Native tree species and associated vegetation in the two sites were identified with the assistance of a vegetation specialist. The leaf litter of two dominant tree species at each site, *Parashorea malaanonan* Brandis (bagtikan) and *Dipterocarpus warburgii* (hagakhak), were then used for the decomposition study. Litter decomposition was studied using the litter bag method (Verhoef, 1995).

Fresh leaf litter of the above-mentioned tree species were collected, washed, and oven-dried at 40°C until a constant weight was obtained. Two grams of leaf litter was weighed, cut into small pieces and placed in separate 7 x 10 cm litterbags made from 1 mm nylon mesh. Thirty samples (bags) were used for each tree species. The bags were placed randomly on the soil surface and covered lightly with leaf litter. Collection of litterbags was done after 3 weeks and at 3-weeks interval thereafter, with five samples taken from each site. The litter remaining inside each litterbag was air-dried, brushed lightly to remove adhering soil particles, and then oven-dried again at 40°C until constant weight was reached. The final weights were used to compute for the percentage loss of weight as index of decomposition. The actual rates of decomposition were computed using the equation derived from the Weigart and Evans' equation (Cuevas and Sajise, 1978) for the instantaneous rate of decay, as follows:

$$r = \frac{\Sigma t2}{\Sigma Yt}$$

where: $Y = 1\text{ n } Wo/\ Wt$
Wo = initial dry weight of litter (2g)
Wt = dry weight after a period of time
t = time in weeks

Analysis of data

All data for chemical soil properties were analyzed using standard ANOVA to determine significant variations with time and with site.

RESULTS AND DISCUSSION

General characteristics of the soil

Early pedological studies conducted in the study site (Asio, 1996) showed that the soil was developed from late Pleistocene to Miocene andesitic pyroclastic rocks. The typical soil color ranges from dark brown (7.5 YR 3/3) on the surface to yellowish red (5YR 4/6) in the lower horizons. The general horizon sequence is Ah - BA - Bt - BC. The soil is friable when moist due to very good aggregation but exhibits plasticity and stickiness when wet. The soil is relatively acidic with a pH value of less than 5.00, an effective CEC of 7.84 to 9.17 cmol (+) / kg, base saturation of less than 30 percent, and a very low available P due to a high phosphate retention capacity of more than 96 percent.

The highly weathered nature of the soil is also shown by the dominance of 1:1 clay minerals such as halloysites and kaolinites, and iron oxides like goethite and hematite (Jahn and Asio, 1995). The soil is classified as a Haplic Alfisol (FAO, 1988) or a Hapliudult in the USDA Soil Taxonomy (Soil Survey Staff, 1992).

Dynamics of soil chemical properties

Significant monthly changes were observed on soil pH in 0.01 M $CaCl_2$ but not on the pH in water (Table 2). However, no significant difference in the values of both pH measurements between the sites was found. Results also showed irregular trend for pH in water (Figure 1a) and a slightly increasing trend for pH in 0.01 M $CaCl_2$ (Fig. 1b). Soil pH in water ranged from 4.77 to 5.17 while in $CaCl_2$ it ranged from 4.30 to 4.90 indicating higher pH values of the former than the latter method (Asio *et al*., 1992). A slightly increasing trend of pH in 0.01 M $CaCl_2$ could be attributed to the possible effect of Ca and Mg from mineral weathering in the upper slope of the area and probably to the release of nutrients from leaf litter decomposition.

Bache (1988) found that pH in 0.01 M $CaCl_2$ is more stable than pH in water primarily because the former limits suspension and stirring effects. The use of 0.01 M $CaCl_2$ can also effectively mask small differences in salt concentration. Schlichting *et al*. (1995) also pointed out that Ca and K ions are able to replace weakly adsorbed H- and Al-ions which is not possible in the case of water. This could partly explain why significant results were obtained for pH in 0.01 M $CaCl_2$ but not for pH in water and consequently a higher CV for pH in water than in 0.01 M $CaCl_2$ (Table 2).

Irregular fluctuations in pH values could be explained by the fact that soil pH is a very changeable soil property. It is strongly affected by processes such as organic matter decomposition, pedoturbation, weathering, leaching and decomposition. At any given time, H+ inputs to the soil could vary. In general, pH dynamics in the soil reflects the interaction of vegetation, organisms, and various other processes (Magdoff *et al*., 1987).

Changes in OM content are significant both with time (months) and between sites (Table 2). The variations were irregular and appeared to have no clear trend (Fig. 2a). The figure also shows that the upper slope had slightly higher OM content than the lower slope while the grassland area had the lowest. The lower OM levels in the grassland soil is probably the result of

Table 2. Summary of the ANOVA results for the dynamics of some soil chemical properties

Variation	Soil Chemical Properties						
	pH H_2O	pH 0.01 M $CaCl_2$	OM	Total N	Avail. P	Exch. Ca	Exch. Mg
1. Temporal (between months)	ns	**	**	*	**	ns	ns
2. Spatial (between sites)	ns	ns	**	**	ns	*	**
C. V. %	7.49	1.37	8.79	7.88	35.85	6.16	8.73

ns = not significant
* = significant
** = highly significant

lower litter production and better mineralization relative to soils under trees or plants. It should be pointed out, however, that this grassland studied is dominated by a single grass species (*P. conjugatum*).

Generally, OM dynamics in the soil is a function of the addition and losses of organic material in the soil (Sanchez, 1976). The amount of OM accumulated in the soil depends on the litterfall contributed by trees as the primary vegetation in the area and the consequent decomposition of these materials. The higher amount of OM for site 2 could probably be due to greater litterfall since this site has larger trees and thicker canopy.

Stevenson (1982) emphasized that for forest soils, differences in the profile distribution of OM and similarly N, occur by virtue of the manner in which leaf litter becomes mixed with mineral matter. The irregular fluctuations in OM values through time could be attributed to the complex effects of the time of the year, soil and crop management practices (McGill *et al*., 1986) rainfall, temperature and soil texture (Parton *et al*., 1987) as well as the amount of C incorporated into the soil (Rasmussen and Collins, 1991) which is much a function of the organic residues returned to the soil as litterfall.

Results also showed significant monthly changes in the total N content of the soil. Variations between sites were also significant (Table 2). Since about 95 percent of the soil N is present in organic matter (Pagel *et al*., 1982), the trend for total N is closely similar to that of OM. Figure 2b shows short-term fluctuations of the total N content of the soil. These fluctuations could be

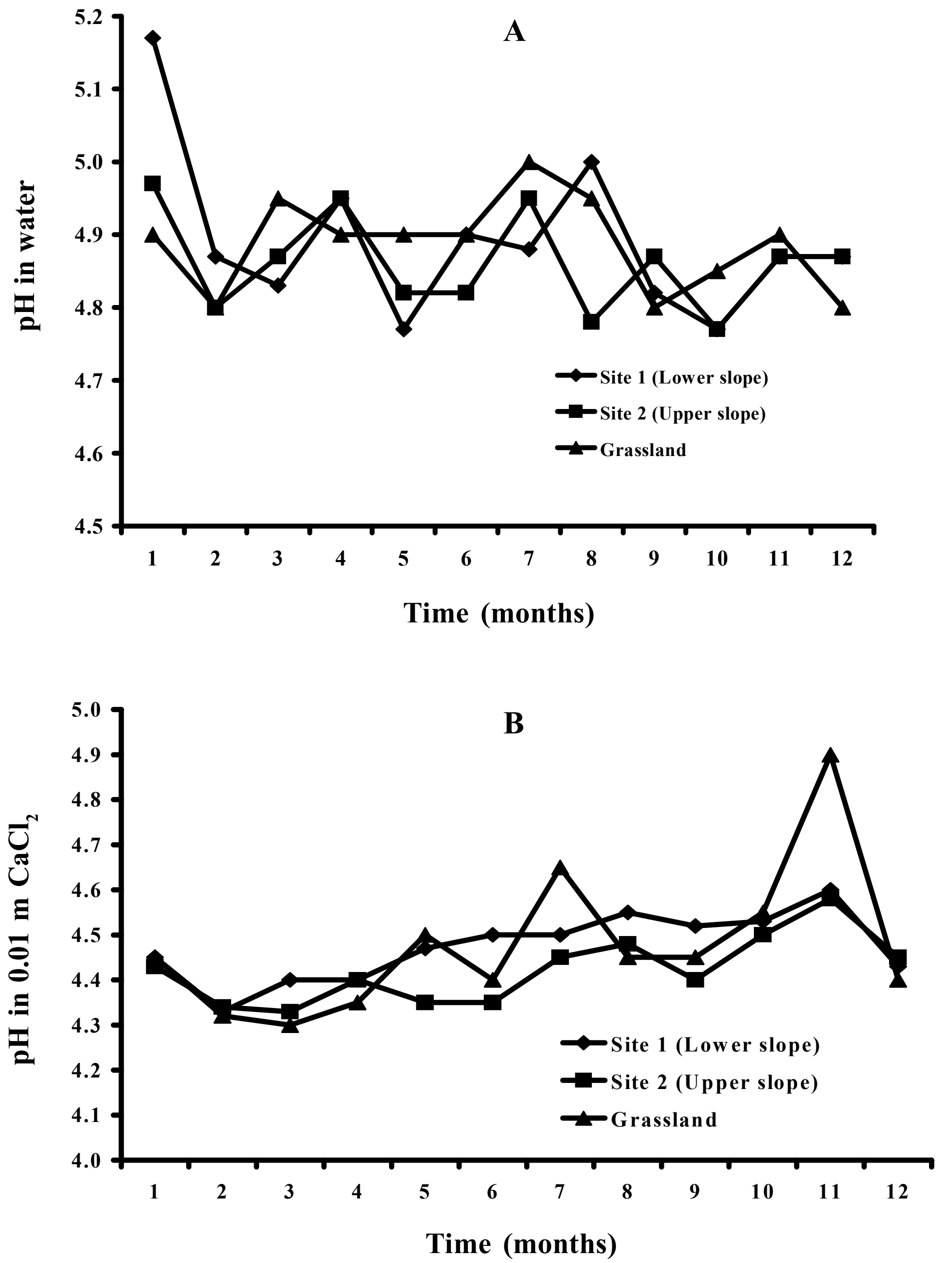


Figure 1. Dynamics of pH in water (a) and pH in $CaCl_2$ of a highly weathered soil under native tree species in Mt. Pangasugan, Leyte (November 2001-October 2002)

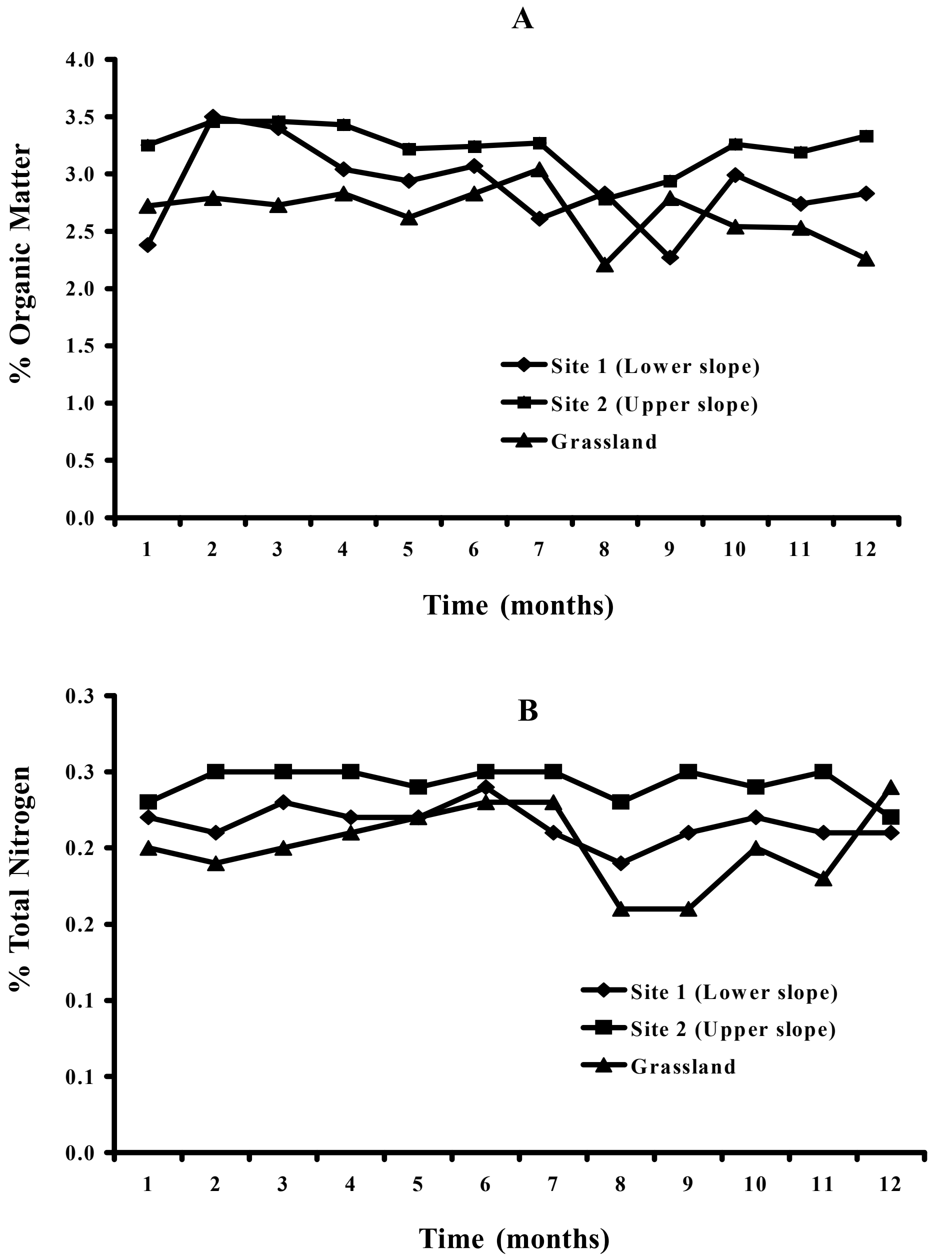


Figure 2. Dynamics of organic matter (a) and total nitrogen (b) of a highly weathered soil under native tree species in Mt. Pangasugan, Leyte (November 2001-October 2002)

attributed to the extent of the mineralization and immobilization processes in the soil. These two processes ultimately control the amount of N in the soil. Roth (1996) pointed out that N dynamics in the soil is complex since it is affected by and interacts with a spectrum of processes ranging from the mineral composition and chemical milieu of the soil to the flow of water and the dynamics of microorganisms and plant roots.

Concerning P, significant monthly changes in its available amount in the soil within plots were observed but not between sites (Table 2). Figure 3 shows these significant short-term fluctuations. The decrease can be due to uptake by plants while the increases can be due to enhanced decomposition and weathering or improved soil pH although the values are still considered deficient (Landon, 1991).

Despite the low levels of P, however, native trees could still survive in the area. Primarily because of outside sources of P coming from rainfall (Zikeli *et al.*, 2002), the roots ability to produce weak organic acids that enhance weathering of rocks or mineral fragments, and other adaptive mechanisms inherent to these species, they have an advantage over exotic species.

Results showed no significant variations in exchangeable Ca and Mg with time (Table 2) indicating that the amount of losses due to leaching and nutrient uptake is probably balanced by the release from litter decomposition and mineral weathering. Variations in the amount of exchangeable Ca and Mg are shown in Figure 4. The fast litter decomposition probably helps maintain the relatively sufficient levels of Ca and Mg in the soil surface. This indicates a possible improvement of the nutrient status of the surface soil due to the nutrient cycling effect of the tree vegetation.

Litter decomposition

Through time, trees can transform the nature of the upper soil horizon through the thick deposition of litterfall (Huxley, 1999). In Mt. Pangasugan, a few centimeters thick of horizon composed of partly decomposed plant materials and fresh litter can be observed on the soil surface. Since litter decomposition greatly affects the chemical and nutrient dynamics of forest soils, a litter decomposition study was also done. Results revealed generally fast decomposition rates for the two indigenous species (*Parashorea malaanonan* and *Dipterocarpus warburgii*). Although the decomposition

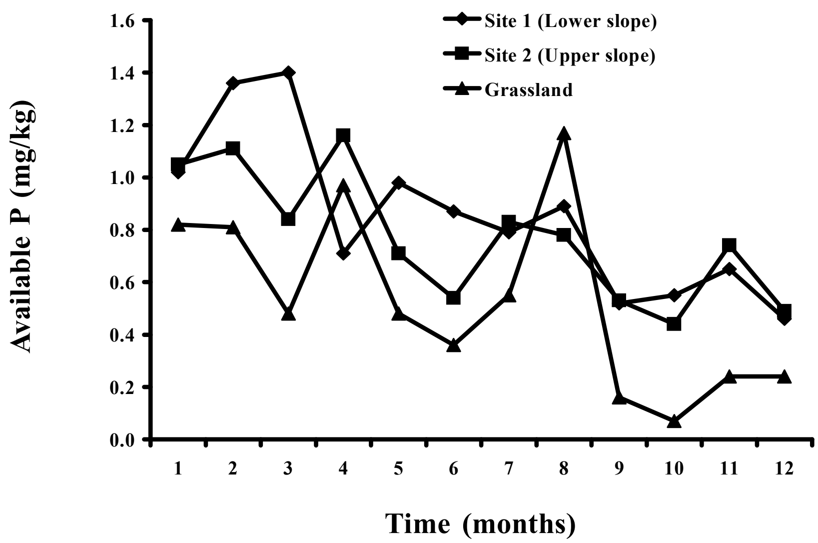
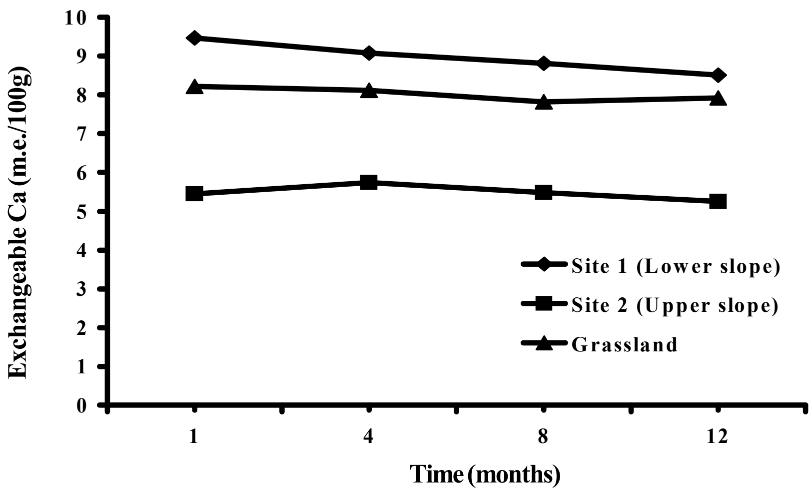


Figure 3. Dynamics of available P of a highly weathered soil under native tree species in Mt. Pangasugan, Leyte (November 2001- October 2002)



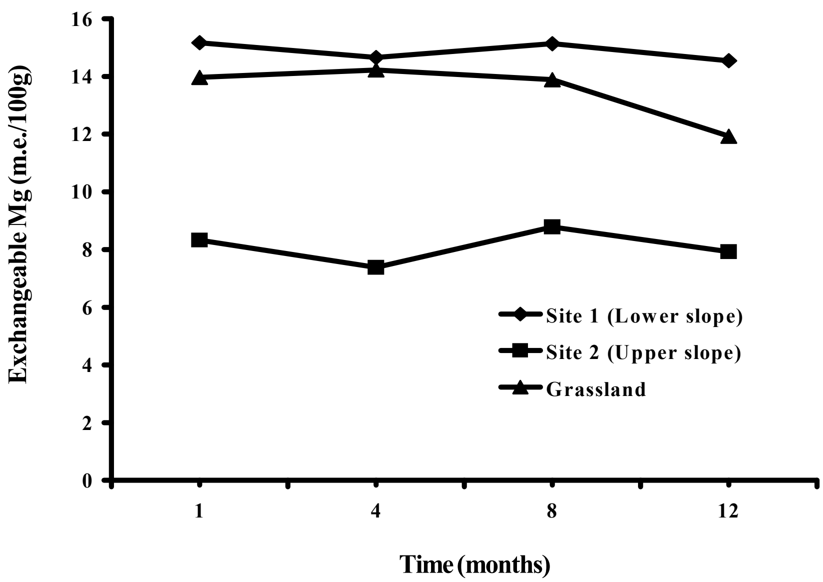


Figure 4. Dynamics of exchangeable Ca and Mg of a highly weathered soil under native tree species in Mt. Pangasugan, Leyte (November 2001-October 2002)

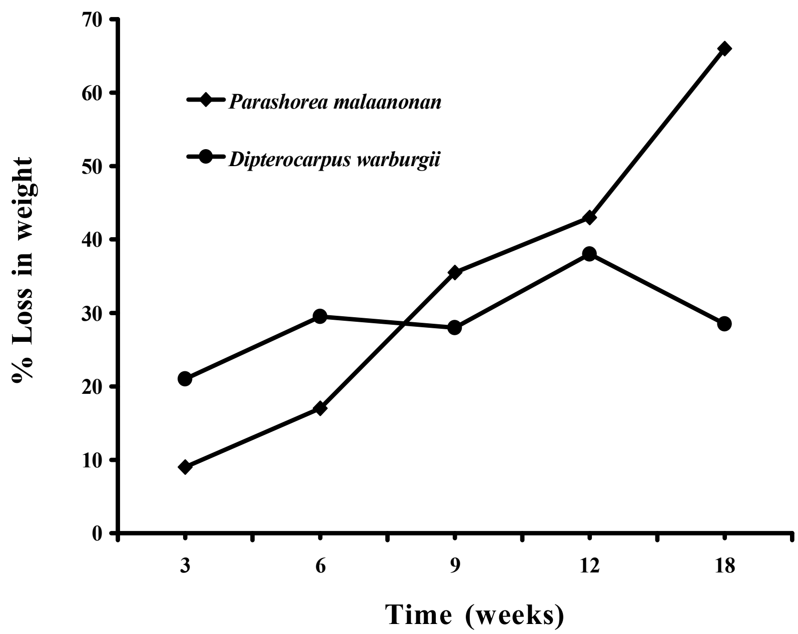


Figure 5. Percentage weight loss of *Parashorea malaanonan* and *Dipterocarpus warburgii* leaf litter after weeks of decomposition on the ground

behavior appeared to vary between the two (Figure 5). Using the equation of Weigart & Evans' the actual rates of decomposition (r) was 0.02311 kg/ha/week for *P. malaanonan* and 0.0331 kg/ha/week for *D. warburgii*. The result for *P. malaanonan* was confirmed by the study of Buenafe (2006). Cuevas and Sajise (1978) obtained an r value of 0.0342 kg/ha/week in Mt. Makiling using the equation but there was no mention of the specific species used. Manipula *et al*. (1999) evaluated the rate of litter decomposition in Davao del Norte and they observed that in the flatland, leaves totally decomposed after only about five months and for the hillyland, decomposition took a month more. Gapasin *et al*. (1993) as cited by Asio (1996), found an average of 52 percent decomposition after two months. Figure 5 shows an average weight loss of about 33.5 percent in about 9 weeks. The result of the study could only provide an estimation of the actual rate of decomposition since this could vary from one species to another, from one site to another, or due to the existing environmental conditions.

CONCLUSION

The highly weathered soil under native tree species showed significant monthly (temporal) variations in pH in 0.01 M $CaCl_2$, OM, total N and the spatial variations of OM, total N and exchangeable Ca and Mg. The native tree species in the site appear to help maintain the nutrient status of the inherently acidic and infertile highly weathered soil. The fast litter decomposition rate on the surface of the soil also appear to contribute to the improved nutrient status of the surface of the soil.

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