J. MANUSIA DAN LINGKUNGAN, Vol. 20, No. 3, November 2013, 294-302

SOIL PROPERTIES OF EIGHT FOREST STANDS RESULTED FROM REHABILITATION OF DEGRADED LAND ON THE TROPICAL AREA FOR ALMOST A HALF CENTURY

(Sifat-sifat Tanah Delapan Tegakan Hutan Hasil Rehabilitasi Lahan Terdegradasi pada Daerah Tropika Selama Hampir Setengah Abad)

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Abstract

Physical, chemical and biological properties of soil are influenced by vegetation types which grow above it. Different tree species of stands will produce difference litter quantity, litter quality and also plants' root system. Therefore quantifying physical and chemical soil properties in several stands after rehabilitation of degraded land will increase the understanding of forest soil characteristics. The research was conducted in 8 forest stands in Wanagama I, Gunungkidul, Yogyakarta. Collection of soil samples was done at the depth of 0-10, 10-30 and 30-50 cm by making soil profile. The result showed that the textural classes were from sandy clay loam to clay. The content of clay increased with increasing soil depth. Bulk density did not differ much among the profiles and soil depth, ranging from 0.90 to 1.28 g/cm^3, and so were particle density ranged from 2.19 to 2.55 g/cm^3 and pore space ranged from 47.89 to 58.08 %. pH H_2O ranging from 5.81 to 7.49 (slightly acid to neutral), meanwhile pH KCl ranging from 4.44 to 6.37. C-organic content varied widely among the vegetations and soil depth ranged between 0.11 and 5.17 %. Available P and total P varied widely from 1 to 104 ppm and from 20 to 390 ppm, respectively. CEC were not much different among the profiles and soil depths, ranging from 19.80 to 38.06 cmol (+)/kg and base saturation in all samples were very high i.e. > 100 %.

Keywords: Soil properties, forest stand, degraded land, rehabilitation

Abstrak

Sifat-sifat fisik, kimia dan biologi tanah dipengaruhi oleh tipe vegetasi yang tumbuh di atasnya. Perbedaan spesies pohon suatu tegakan akan menghasilkan perbedaan jumlah seresah, kualitas seresah dan juga sistem perakaran. Kuantifikasi sifat-sifat fisik dan kimia tanah pada beberapa tegakan hutan pada lahan terdegradasi setelah direhabilitasi akan meningkatkan pemahaman mengenai sifat-sifat tanah hutan. Penelitian dilakukan pada 8 jenis tegakan hutan di Hutan Pendidikan Wanagama I, Gunungkidul, Yogyakarta. Pengambilan sampel tanah dilakukan pada kedalaman 0-10, 10-30 dan 30-50 cm dengan cara membuat profil tanah. Hasil penelitian menunjukkan bahwa kelas tekstur mulai dari geluh lempung pasiran sampai lempung. Kandungan lempung meningkat dengan semakin dalamnya tanah. Berat volume tidak banyak berbeda antar profil dan kedalaman tanah, berkisar antara 0,90 - 1,28 g/cm^3, dan kerapatan partikel berkisar antara 2,19 – 2,55 g/ cm^3, dan ruang pori tanah berkisar antara 47,89 – 58,08 %. pH H_2O berkisar antara 5,81 – 7,49 (agak asam sampai netral), pH KCl berkisar dari 4,44 – 6,37. Kandungan C-organik sangat bervariasi antar jenis vegetasi dan kedalaman tanah mulai 0,11 – 5,17 %. Kandungan P tersedia dan P total sangat bervariasi, secara berturut–turut dari 1 – 104 ppm dan 20 – 370 ppm. Nilai KPK tidak banyak berbeda antar profil dan kedalaman tanah berkisar antara 19,80 – 38,06 cmol (+)/ kg dan kejenuhan basa untuk semua sampel mempunyai nilai sangat tinggi > 100 %.

Kata kunci: Sifat-sifat tanah, tegakan hutan, lahan terdegradasi, rehabilitasi

INTRODUCTION

Background

Soil, as climate, plays a very important role in the process of forest development. Soils which are formed from different parent material, climate, organisms (vegetation), time and relief, will have different properties in providing water and nutrients, thus affecting forest composition and growth (Fisher and Binkley, 2000).

Wanagama I forest was initially a degraded land, it was famous as land of "soily rock" which mean that on the surface, the rock appearance was dominant than the soil. The degraded land was caused by a shallow solum, thus the existing plants experienced water and nutrients shortage. By planting adaptive pioneer vegetations, the process of soil development then began. The soil development continued when several commercial tree species such as Ebony (*Diospyros celebica*), Eucalypt (*Eucaliptus pellita*), Mahogany (*Swietenia macrophylla*), Teak (*Tectona grandis*), Gamal (*Gliricidia sepium)*, Gmelina (*Gmelina arborea)*, Cajuput (*Mellaleuca cajuputi)* and Acacias (*Acacia mangium, A. auriculiformis*) etc. were also planted in the area. The processes of soil development were characterized by a deeper soil solum and increasing the accumulation of organic matter derived from litter, this then affected the adequacy of water and nutrients for plants (Supriyo, 2004).

Wanagama I was established in 1966 and now it has diversity in species composition and distribution patterns. This was because each site has a specific characteristic of environment such as differences in species and tree density of stand. Therefore each of site has resulted differences in litter biomass. Supriyo et al. (2009) stated that the highest litter biomass was in Acacia stand (13.36 ton/ha), followed by Ebony (7.44 ton/ha), then Mahogany (6.23 ton/ha), Teak (5.7 ton/ha), Eucalypt (5.6 ton/ha) Gmelina (4.12 ton/ha) and the lowest was in Gliricidea stand (2.98 ton/ha). Meanwhile,

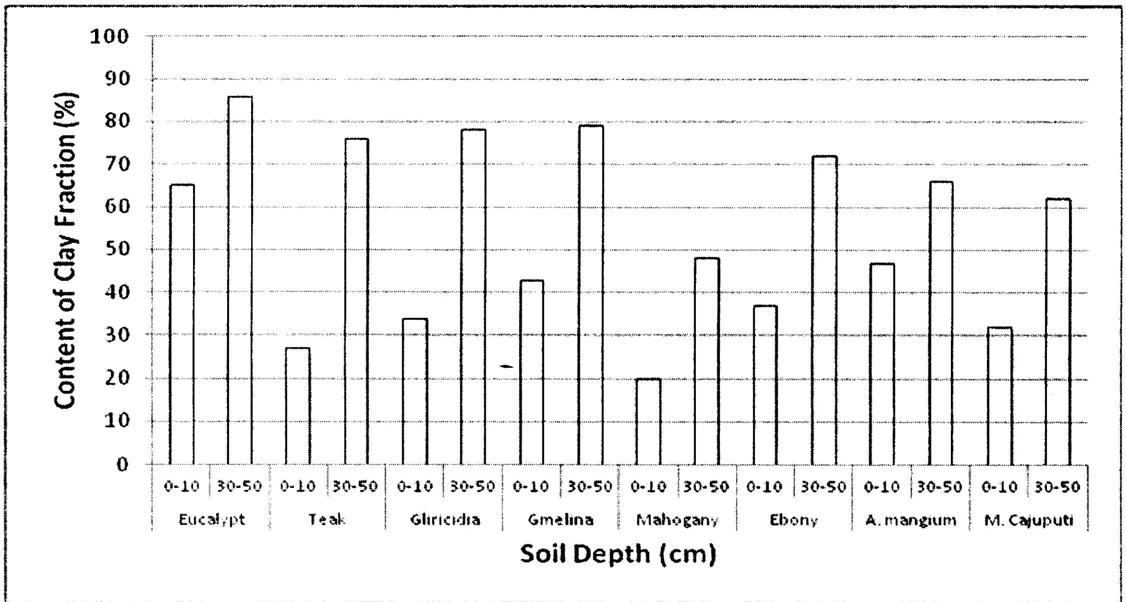

Figure 1. The content of clay fraction at various forests stands and soil depths

Table 1. Bulk density, particle density, porosity and soil color under 8 different forest stands.

Forest Stand	Soil depth (cm)	BD (g/cm^3)	PD (g/cm^3)	Porosity (%)	Soil Color (dry)
Eucalyptus *(Eucaliptuss pellita)*	0 -10	1.06	2.52	58.08	7,5YR 3/4 (dark brown)
	10 – 30	1.15	2.55	55.01	7,5YR 4/4 (dark brown)
	30 – 50	1.12	2.52	55.63	7,5YR 5/4(brown); with some mottles 10YR 6/1 (reddish gray) and 10YR 4/6 (red)
Teak (*Tectona grandis*)	0 -10	1.28	2.46	47.89	5YR 3/4 (dark reddish brown)
	10 – 30	1.07	2.48	56.73	5YR4/4 (reddish brown)
	30 – 50	1.11	2.48	55.26	5YR 5/6 (reddish brown)
Gamal (Gliricidia sepium)	0 -10	1.13	2.43	53.61	7.5YR 3/4 (dark brown)
	10 – 30	1.04	2.48	58.08	7.5YR 4/4 (dark brown)
	30 – 50	1.08	2.47	56.23	7.5YR 5/4 (dark brown)
Gmelina (Gmelina arborea)	0 -10	1.19	2.51	52.66	5YR 3/4 (dark reddih brown)
	10 – 30	1.18	2.51	52.74	5YR 4/4 (dark brown)
	30 – 50	1.16	2.50	53.51	5YR 4/6 (yellowish red)
Mahogany *(Switenia macrophylla)*	0 -10	0.90	2.19	59.00	10YR 2/2 (very dark brown)
	10 – 30	1.02	2.32	56.04	10YR 3/3 (dark brown)
Ebony (Diospyros celebica)	0 -10	1.13	2.36	52.31	10YR 2/2 (very dark brown)
	10 – 30	1.10	2.40	54.32	10YR 3/2 (very dark grayish brown)
	30 – 50	1.06	2.39	58.08	10YR 3/3 (dark brown)
Acacia *(Acacia mangium)*	0 -10	1.16	2.49	53.46	10YR 3/4 (yellowish brown)
	10 – 30	1.19	2.50	52.25	10YR 4/4 (dark yellowish brown)
	30 – 50	1.13	2.47	54.35	10YR 6/4 (dark yellowish brown)
Cajuput *(Mellaleuca cajuput)*	0 -10	1.19	2.36	49.68	10YR 3/3 (dark brown)
	10 – 30	1.12	2.39	52.99	10YR 4/4 (dark brown)
	30 – 50	1.18	2.40	50.76	10YR 4/6 (dark yellowish brown)

Eucalypt stand in compartment number 17 of Wanagama I, had a litter biomass as much as 8.51 ton/ha (Supriyo et al., 2012).

Differences in litter biomass, litter quality and root system can lead to differentiate in soil properties, both physically and chemically. The diversity of soil properties naturally resulted of the factors and processes of soil formation, from parent material then developed into soil in various site conditions namely: climate, topography/ relief, organisms (vegetations), and time. High diversity of vegetation and different of soil developed in the area made information on physical and chemical properties of soil on eight stands of different species in Wanagama I were very important to be investigated. The data collected would be a data base which could be used by decision maker in further management.

Objectives

This research was conducted with the aim of understanding the physical (texture, color, bulk density, particle density and percent of pore space) and chemical properties (total C-organic, N and P; available P; exchangeable Ca, K, Mg, Na; base saturation, cation exchange capacity (CEC), actual and potential pH) of soil in eight stands of different species after 46 years of rehabilitation.

METHODS

Location of the Study Area

The study was conducted in June-November, 2011. The location of study was Wanagama I, Gunungkidul, Yogyakarta. Wanagama I was located in karst (limestone rocks) with an average rainfalls was about 1,500 mm/yr, the humidity was between 60-90%, dry months were more than 6 months, the temperature ranged from 23.2 to 32.4o C with an average temperature of 27.7 o C and the area had undulating topography. Soils formed in the area were Lithosol (Entisols), Grumusol (Vertisols) and Mediterranean soils (Alfisols) (Supriyo, 2004).

Soil Sampling and Analyses

Soil sampling was done by making soil profiles in each stand with depth up to the parent material. Solum depth, profile picture and root conditions were observed. Soils were taken at the depth of 0-10, 10-30 and 30-50 cm with 3 replications. Soil samples were then air dried at the room temperature, ground and sieved with a sieve of 2 mm, for soil analyses.

Samples then were analyzed for total N content and C-Organic. Analysis of total C- organic was performed by Walkley and Black method (Walkley and Black, 1934), carbon extracted was measured by spectrometry. P available was analyzed with Olsen method as soil pH tended from neutral to alkaline, whereas to get the total P, samples were first extracted with 25% HCl and then measured with a spectrophotometer (Hesse, 1971). The content of exchangeable Ca, Mg, K and Na was extracted with NH4OAC (Ammonium acetate) 1 M at pH 7, the extracted alkaline metals then were measured by AAS (Atomic Absorption Spectroscopy).

To get the bulk density (BD) of soil, samples of undisturbed soil were taken with rings, then dried in the oven at the temperature of 100-110 oC until a constant weight had been reached. Particle density (PD) was measured with a picnometer or measuring cup. Percent of the pore was calculated as: percent pore = 100 % - (BD/ PD) x 100% (Millar et al., 1965). Soil color was determined using the Munsell Soil Color Charts.

RESULTS AND DISCUSSIONS

Physical Properties

Textures

Soil texture at the study area were mostly clay, some were clay loam. There was only sandy clay loam in the mahogany stand at a depth of 0-10 cm; the sand content of this soil was 55% (Figure 1). Soil textures were mostly clay as the soil was developed from limestone which had a fine particle size.

In all soil profiles, clay contents of upper layers were smaller then the lower layers and vice versa for the sand content. This was suggested that the much smaller clay fraction (diameter < 2 μm) which had a lighter weight had been eroded by the rain into primary grains and carried away by surface run off during the rainy season and sedimentation was occurred in the most distance.

In Wanagama I, although annual rainfall was not so high, the rain intensity was high. The soil cultivation by farmer for their crops or fodder for cattle in the end of dry season or just before the rainy season were damaging the soil structure and causing the fine fractions were easy to be eroded.

Bulk Density (BD)

Soil BD in Wanagama I, ranged from 0.90 to 1.28 g/cm3 (Table 1), this was because the soil generally has a fine texture, dominated by the clay fraction, a BD of a soil was affected by texture, structure and soil organic matter content. As noted by Millar et al. (1965), a soil which had a fine texture had a BD ranges from 1.0 to 1.3 g/cm3, while coarse-texture had BD ranges from 1.3 to 1.8 g/cm3 and heavy organic soil had BD between 0.2 and 0.6 g/cm3. The value of BD 0.9 was only found in Mahogany stand at 0-10 cm layer, this was because on the high organic material found in that layer which was as much as 5.17% (Figure 2).

Particle Density (PD)

Particle densities were not so different among forest stands, which ranged from 2.19 to 2.55 g/cm3, as PD takes into amount only the solid particles divided by the soil volume without soil pores. The difference was only due to the organic matter content and mineral composition, especially in silt and sand fractions and mineral soil generally had a particle density of about 2.65 g/cm3 (Miller, et al., 1965).

Soil Color

Soil color can be used to expect soil organic matter content, drainage, soil aeration condition, etc. In general, the soil aeration and drainage were relatively good, indicated by reddish in color, except for ebony stand which had not so good aeration and drainage, indicated by grayish color and also in eucalypt stand, which had mottles at soil depth of 30-50 cm (Table 1) (Miller et al., 1965)

Solum (Soil Depth)

Information of solum or soil depth was very important since tree growth was highly dependent on soil depth. Soil physical fertilities (solum, structure etc) were more important than chemical fertility (pH, nutrients status). In general, Wanagama I soil had moderate soil depth (50-90 cm), except in mahogany stand which had a shallow solum (as deep as 20 cm) (Arsyad, 2006).

Soil Chemical Properties

Soil Organic-Carbon

Soil organic-carbon at a depth of 0-10 cm varied between forest stands, ranging from 1.31% (eucalypt) up to 5.17% (mahogany). There were a drastic decreased of soil organic matter at a depth of 30-50 cm. The smallest was in eucalypts (0.11%) and the highest was in teak (0.97%) (Figure 2). Total soil organic carbon was strongly influenced by the vegetation type, density, age and type of clay content and also climate (Brady, 1985).

Carbon (C) contents of the high-organic soil were found in mahogany and ebony stand (3.30%), because the clay type was dominated by smectite which capable of fixing humus in the interlayer space. While in the other stands, clay dominated by 1:1 type of kaolinite which cannot swell and shrink, therefore incapable of fixing humus in its interlayer space (Dixon and Weed, 1989; Supriyo, 2004).

Soil Reaction (Soil pH)

The actual soil pH was measured with distilled water (H_2O) ranged from a slightly acid (6) to neutral to slightly alkaline (7.49) (Figure 3). The relatively high pH value was caused by soil parent materials which developed from limestone rocks ($CaCO_3$) which was rich in alkaline metal of Ca and a relatively low rainfall in the area (1,500 mm/yr) (Supriyo, 2004). It can also be seen from the high content of Ca exchanged (17.98 to 49.12 me/100 g) and base saturations were more than 100% (Figure 3).

Potential soil pH was measured with KCl solution, the K+ ions will exchange H+ ions which are located in the colloidal complex then will add H+ ions in the solution so that the soil pH becomes smaller. The greater the difference between pH H2O with pH KCl, suggested that H+ ion in the absorption complex were larger. The other possibility was Al3+ ion was exchanged by H+ ion in the

complex absorption, potential pH ranged from 4.44 to 6.29 (Figure 3) (Supriyo, 2004).

P Content

Available P was varies, ranging from 1 to 104 ppm (Figure 4). The upper layers (0-10) were always had a greater available P content than the layers below, except in the cajuput stand. The high available P content was likely derived from organic-P in the form of phospholipids, nucleic acids, phosphorous-protein, phosphate sugar etc. or it could also come from fertilization which were applied by

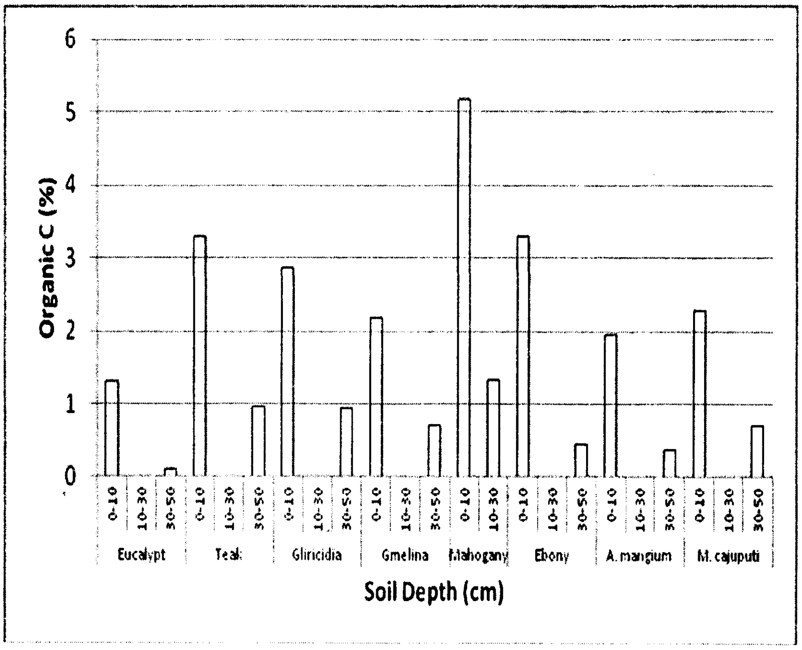

Figure 2. Organic-C in a variety of forest stands and soil depths

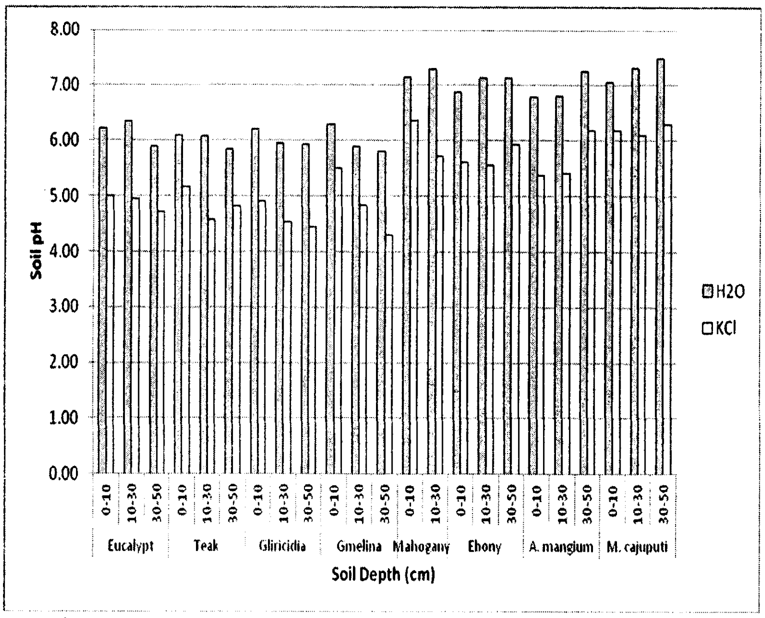

Figure 3. The actual (H_2O) and potential pH (KCl) at various stands and soil depths

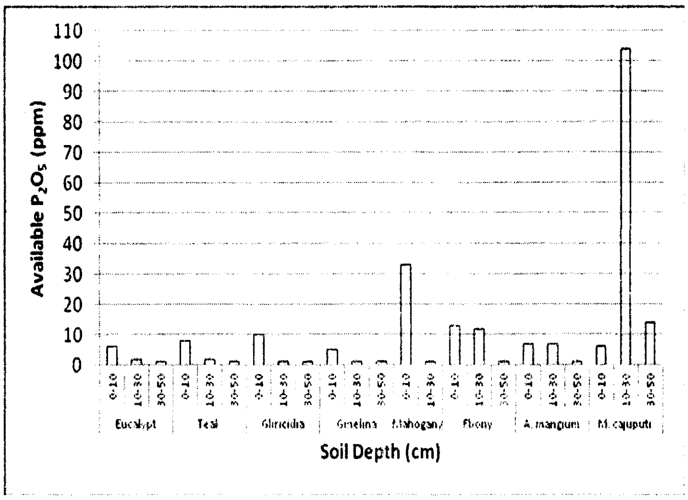

Figure 4. Available P in a variety of forest stands and soil depths

farmers on their crops. Those fertilizers **were relatively** easy to be absorbed by **plants such** as superphosphates (TSP, **DSP, ESP/** $Ca(H_2PO_4)_2$ (Foth and Ellis, **1988).**

The total P ranged from 2 to 37 **mg/100 g** (20 – 370 ppm), upper layers were **higher** than lower layer. Beside **from some** parent materials of such **apatite** minerals: (Ca10F2(PO4)6, **(Ca10Cl2(PO4)6,** (Ca10OH2(PO4)6 and **(Ca10CO3(PO4)6,** P was also derived **from organic** matter (Foth and Ellis, **1988).** As organic matter content at **upper** soil layer were much higher than **the lower** layers, the total P content in **the upper** layers were also greater than **those of** the lower layers.

Exchangeable Alkaline Metals

Ca, Mg, K and Na are categorized as **soil alkaline** metals. If the soil contains a **lot of these** metals, the metals will produce **hydroxyl** ions (OH-), more the alkaline **metals, more** OH- ions are formed, thus it **will reduce** soil acidity or increase the soil **pH. In** Wanagama I the dominant alkali **metal** was dominated by Ca2+ ions (Figure 5), because the soil was developed from limestone (CaCO3) and the rainfall of the area was relatively low, therefore only a small amount of the Ca2+ ions was leached out of the soil system (Supriyo, 2004).

Cation Exchange Capacity (CEC) and Base Saturation (BS)

CEC value of a soil depends on the content of clay fraction, type of clay and organic matter (humus) content. Most of the clays in Wanagama I were reddish to brown in color, which was called Brown Grumusol. This suggests that some smectite clays that had a high CEC value had been turned into kaolinite which had a low CEC (Supriyo, 1992). CEC in Wanagama ranged between 19.80 and 38.06 me /100g (Figure 6). The higher CEC of some soil samples probably contained more smectite whereas smaller CEC dominated by kaolinite Almost all of base saturation values were more than 100 %, because the amounts of alkaline cations particularly Ca were higher than the CEC.

CONCLUSION

Soil profiles have a solum depth of 50-90 cm or more, except for the mahogany stand (20 cm), soil texture class were sandy clay loam to clay. Clay contents were higher in lower layers than those in upper layers. Soil pore space was about 50% (47.89 to 59.0 %), soil aeration generally has a moderate to fairly good (reddish color) and the slow drainage (poor) to slightly slow (there were mottles).

The actual pH was weak acid to neutral, C organic content of soil were very low to very high. Available P (Olsen) was very low to very high. P total were very low to very high. Exchanged Ca was high to very high. Exchanged Mg was moderate to high. Exchanged K was very low to low, Na was very low to low, and CEC was moderate to high. All soils have high base saturation.

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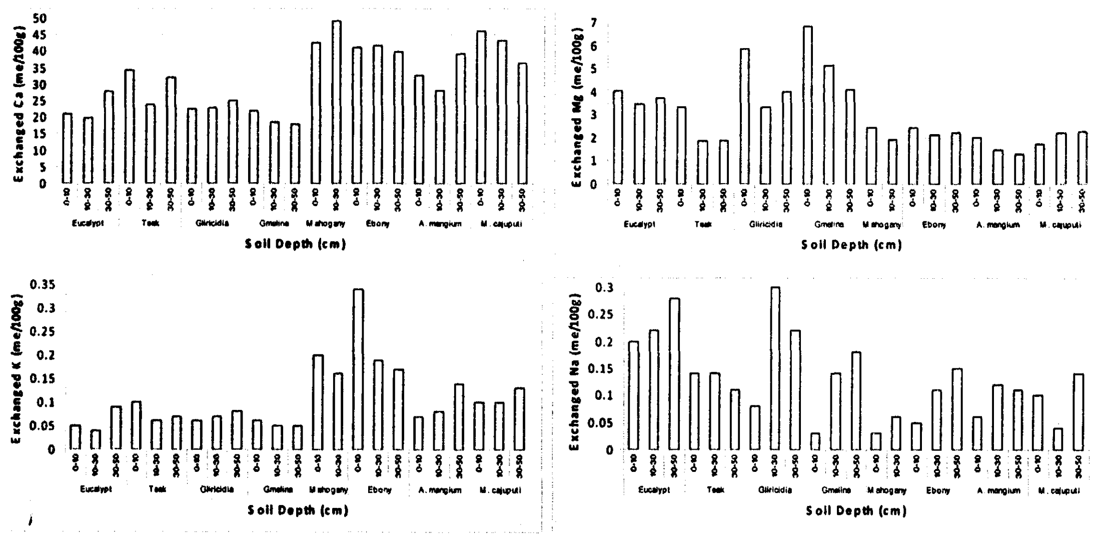

Figure 5. Exchangeable Ca, Mg, K and Na in various forest stands and soil depths.

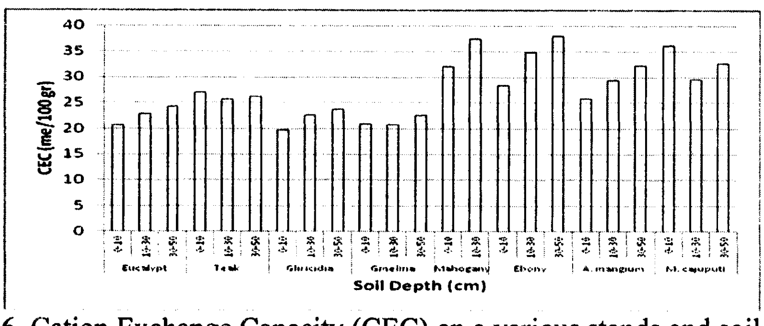

Figure 6. Cation Exchange Capacity (CEC) on a various stands and soil depths

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