# Andisols Derived from Acid Pyroclastic Liparite Tuff : Their Properties and Their Management Strategy for Agricultural Development

*Andisols Berasal dari Tuf Liparit Piroklastik Masam : Sifat-sifat dan Strategi Pengelolaannya bagi Pengembangan Pertanian*

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## ABSTRACT

The characterizations of Andisols from acid pyroclastic liparite tuff have been studied. Six soil profiles were made in the field, and 29 soil samples were taken for chemical, mineralogical and physical analyses in laboratory. Results indicate that sand mineral composition of Andisols was dominated by biotite, quartz, and sanidine, while the clay mineral was dominated by allophane. Soil bulk density is low (0.47-1.00 g cm$^{-3}$), while total porosity is high (53-80%). Soil reaction is slightly acid (pH 5.5-6.0) to very acid (pH< 4.5), poor of nutrients, have a high to very high of P retention (>80%), high (>3%) to very high organic carbon (>5%) and high potential K (>41 mg 100g$^{-1}$). The high value of organic carbon positively has relationship with N and soil cation exchange capacity, while the P retention positively has relationship with amorphous material in the form of $Al_o$+0.5 $Fe_o$. Andisols investigated were classified as Medial, amorphic, isothermic, Acrudoxic Hapludands (UG 444 and MD 121 ), Medial, amorphic, shallow, isothermic, Duric Hapludands (KR 227), and Medial, amorphic, shallow, isothermic, Acrudoxic Hapludands (KR 190, AI 1045 and KR 1188). The characterization of Andisols is very useful in the soil management planning on Andisols land. Planting some vegetation that tolerant with soil acidity and soil conservation to protect organic matter from erosion hazard should be become priority. Maintain land cover of Andisols is a good way to protect Andisols from erosion process.

*Keywords : Andisols, Liparite tuff, P retention*

## ABSTRAK

Karakterisasi Andisols dari tuf liparit piroklastik masam telah diteliti. Enam profil tanah dibuat di lapangan, dan 29 contoh tanah di ambil untuk analisis kimia, mineralogi dan fisika di laboratorium. Hasil penelitian menunjukkan bahwa komposisi mineral pasir dari Andisols didominasi oleh biotit, kuarsa, dan sanidin, sedangkan mineral liat didominasi oleh alofan. Bobot isi tanah rendah (0,47-1,00 g cm$^{-3}$), sedangkan porositas total tinggi (53-80%). Reaksi tanah agak masam (pH 5,5- 6,0) sampai sangat masam (pH< 4,5), miskin hara, retensi P tinggi sampai sangat tinggi (>80%), karbon organik tinggi (>3%) sampai sangat tinggi (>5%) dan K potensial tinggi (>41 mg 100g$^{-1}$). Tingginya nilai karbon organik secara positif berhubungan dengan N dan kapasitas tukar kation tanah, sedangkan retensi P berhubungan secara positif dengan bahan amorf dalam bentuk $Al_o$+0,5 $Fe_o$. Andisols yang diteliti diklasifikasikan sebagai Medial, amorphic, isothermic, Acrudoxic Hapludands (UG 444 dan MD 121 ), Medial, amorphic, shallow, isothermic, Duric Hapludands (KR 227), dan Medial, amorphic, shallow, isothermic, Acrudoxic Hapludands (KR 190, AI 1045 dan KR 1188). Karakterisasi Andisols sangat bermanfaat bagi perencanaan pengelolaan tanah pada lahan Andisols. Penanaman beberapa vegetasi yang toleran terhadap kemasaman tanah dan konservasi tanah untuk melindungi bahan organik dari bahaya erosi perlu mendapatkan prioritas. Mempertahankan penutupan lahan Andisols merupakan cara baik untuk melindungi Andisols dari proses erosi.

*Kata kunci : Andisols, Tuf liparit, Retensi P*

## INTRODUCTION

Andisols is young developed soil, derived from volcanic material, especially volcanic ash that rich of volcanic glass. In Indonesia, distribution of Andisols is about 5.4 million ha (Subagyo *et al*., 2004), mostly found in highland area. Andisols were characterized by some special properties, such as dark to black color of the top layer, andic horizon, low bulk density, high water retention, high P retention, and high amorphous materials (Shoji *et al*., 1993; Soil Survey Staff, 2010).

Studies of Indonesian Andisols mostly were deal with their morphology and chemical properties, like Andisols from Marapi and Talamau Mountains (Fiantis and van Ranst, 1997), Andisols from Dempo Mountain (Hikmatullah *et al*., 1994), Andisols from West Java (Hardjosoesastro *et al.*, 1983; Arifin and Hardjowigeno, 1997), Andisols from Flores Island (Sukarman and Subardja, 1997; Hikmatullah *et al.*, 1999) and Andisols from Tangkubanperahu Mountain (Yatno and Zauyah, 2005). Recently study about mineralogy of Andisols was carried out by van Ranst *et al.* (2008) from Dieng Mountain. Most of Indonesian Andisols studied were derived from

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andesite to andesite basalt (Prasetyo, 2005). The soils were generally characterized by high organic carbon, low bulk density, high CEC and high P retention. The sand fraction of the soils was composed by ferromagnesian minerals (hornblende, hypersthene, and augite), feldspar and opaque, while the clay fraction was dominated by allophane (Yatno and Zauyah, 2005).

Andisols from Toba highland is special phenomena in Indonesia as it was derived from acid pyroclastic liparite tuff. Studies of Andisols developed on liparite tuff were still limited. Mohr *et al.* (1972) reported that the sand fraction of soil derived from liparite tuff materials was dominated by quartz, zircon, and biotite, followed by volcanic glass and sanidine. Liparite tuff is the product of Toba eruption. The chemical analyses of Toba tuff show that it is dominated by $SiO_2$, followed by $Al_2O_3$, and this condition together with higher $K_2O$ content than MgO. This indicates that the Toba tuff is acid (Westerveld, 1947; Nincovich *et al*., 1978).

This paper aims to inform some properties of Andisols derived from acid pyroclastic liparite tuff in Indonesia and their management strategy for agricultural purposes.

## MATERIALS AND METHODS

The study area is located around the Toba Lake, North Sumatra Province, with elevation from 900 to 1,800 m above sea level. Geographically, the area is located in between 98b48ǫ51ǫǫ and 99b06ǫ11ǫǫ East Longitude, and 02b40ǫ34Ɛ to 02b48ǫ22Ɛ North Latitude. Mean annual rainfall in the study area is 2,587 mm. According to Schmidt and Ferguson (1951) the study area is classified as A rainfall type. This means that the area does not have a significantly dry month during the periods of the year. According to Oldeman (1975) this area is considered to have a C1-agroclimatic zone as characterized by 6 wet months (mean monthly rainfall > 200 mm) and no dry month (mean monthly rainfall < 100 mm).

Geology formation in the study area is from late Pleistocene age. This formation is product of Toba eruption, and mainly consists of liparite tuff and rhyolite tuff (Clarke *et al.,* 1982). The study area is located in the upper part of Toba Plateau and is composed of acid Toba tuff materials.

This study was conducted on June to August 2007 and January 2008. Hapludands is dominant soil in the study area, its cover about 12,617.20 ha. Six soil profiles were made, and 29 soil samples were taken from each horizon in the profiles. Some ring samples were taken from the A and B horizons of profiles UG 444, MD 121 and KR 190. The soil samples were analyzed for their mineral composition, physical and chemical properties. The location of every profile measured by GPS was given in Table 1.

Total sand mineral fraction was analyzed using polarization microscope with line counting method, while clay mineral was analyzed by x-ray

**Table 1. Elevation and location of six profiles in the field measured by GPS**

*Tabel 1. Elevasi dan lokasi enam profil di lapangan yang diukur dengan GPS*

| Pedon | Elevation asl (m) | Regency | Coordinate E | Coordinate N |
|---|---|---|---|---|
| UG 444 | 1196 | Tobasamosir | 98°56ǫ10ƐE | 2°43ǫ54ƐN |
| KR 227 | 1483 | Tobasamosir | 99°08ǫ55ƐE | 2°11ǫ12ƐN |
| MD 121 | 1272 | Tobasamosir | 99°14ǫ37ƐE | 2°15ǫ27ƐN |
| KR 190 | 1410 | Tobasamosir | 99°09ǫ54ƐE | 2°16ǫ01ƐN |
| AI 1045 | 1546 | Humbang Hasundutan | 98°16ǫ26ƐE | 2°34ǫ24ƐN |
| KR 1188 | 1764 | Humbang Hasundutan | 98°29ǫ44ƐE | 2°34ǫ09ƐN |

diffractometry after sample was saturated by $Mg^{+}$. The samples were scanned from 3 to 32°2$\theta$ with CuK$\alpha_{1,2}$ radiations and a curved crystal monochromatic. The soil physical analyses were carried out including bulk density, total pore space and permeability.

Physical and chemical analyses included texture with pipette methods, pH ($H_2O$) with glass electrode (Soil Survey Laboratory Staff, 1992), organic-C (acid dichromate digestion), total N (Kjeldahl digestion), exchangeable bases and cation exchange capacity using $NH_4$O-Acetate pH 7,0, exchangeable acidity (1N KCl), $P_2O_5$ and $K_2O$ (HCl 25%), P retention (Blackmore *et al.,* 1981), and amorphous Fe, Al, and Si by ammonium oxalate extraction. The soil analyses were conducted following the standard procedures of the Soil Laboratory of the Indonesian Center for Agricultural Land Resources and Development, Bogor, Indonesia.

## RESULTS AND DISCUSSION

### Mineral composition

Sand mineral composition of Andisols investigated is qualitatively similar in all horizons. It is dominated by biotite, quartz and sanidine (Table 2). Association of biotite, quartz, and sanidine indicate that soil parent material is acid liparite tuff (Mohr *et al*., 1972). Other feldspar minerals such as oligoclase, andesine, and labradorite, and ferromagnesian minerals such as hornblende and hypersthenes are only found in small amount. This indicates that all the studied soils are developed from acid rock materials. The other mineral that proves if the parent material is coming from volcanic material is volcanic glass and opaque mineral (Dahlgren *et al*., 1993).

The presence of significant amount of weatherable primarily mineral such as biotite, sanidine, volcanic glass and hornblende indicates that materials are not completely weathered. Sand mineral composition of Andisols investigated is different with other Indonesian Andisols which are mostly developed from andesite-basaltic pyroclastic rock. Those Andisols was dominated by hypersthene, augite, amphibole, andesine and volcanic glass (Prasetyo, 2005).

Clay mineral composition is dominated by allophane. XRD pattern shows that the allophane is only showed by big and broad shoulder diffraction peak (Figure 1). The allophane is the first clay minerals formed in the Andisols as resulted of weathering of volcanic glass. Other minerals are gibbsite indicated by peak 4.85Å, and quartz indicated by peak 4.24Å and 3.33Å. Gibbsite commonly exists as the end product of advanced weathering, but gibbsite has been found in some Andisols in Japan (Wada and Aomine, 1966). The formation of gibbsite is a result of desilication of amorphous materials in which the drainage condition is good (Wada, 1989).

Previous study indicates that clay mineral composition of Indonesian Andisols developed from andesitic-basaltic pyroclastic rock mostly consisting of allophane, imogolite, halloysite, disorder kaolinite, gibbsite and ferrihydrite (Prasetyo, 2005). Allophane, imogolite and halloysite are more frequent in Indonesian Andisols, while disorder kaolinite was only founded in Eastern Indonesia that has drier climate (Sukarman and Subardja, 1997; Hikmatullah *et al.*, 1999). Recent study in mineral composition of Andisols by van Ranst *et al.* (2008) reports that perudic Andisols from Dieng Mountain consist of smectite, kaolinite, pyrophyllite, and allophane. Actually the clay mineral composition of Andisols is influenced by soil forming process, composition of volcanic material, soil pH, soil moisture regime and accumulation of organic matter (Mizota and van Reeuwijk, 1989).

**Table 2. Sand mineral composition of Andisols derived from liparite tuff**

*Tabel 2. Komposisi mineral pasir Andisols berasal dari tuf liparit*

| Profile/ horizon | Opaque | Zircon | Quartz | Weathered mineral | Rock fragment | Volcanic glass | Oligoclase | Andesine | Labradorite | Sanidine | Biotite | Hornblende | Hypersthene | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ƕƕƕƕƕƕƕƕƕƕƕƕƕƕƕ.. % ƕƕƕƕƕƕƕƕƕƕƕƕƕƕƕ.. | | | | | | | | | | | | | |
| UG 444 | | | | | | | | | | | | | | |
| A | 6 | 1 | 33 | 5 | 1 | 3 | 1 | 1 | 1 | 24 | 13 | 10 | 1 | 100 |
| Bw1 | 11 | Sp | 20 | 3 | 1 | 2 | 1 | 1 | Sp | 17 | 35 | 8 | 1 | 100 |
| Bw2 | 4 | 1 | 21 | 4 | 1 | 1 | Sp | Sp | Sp | 13 | 49 | 6 | Sp | 100 |
| BC | 3 | Sp | 16 | 5 | Sp | Sp | Sp | - | Sp | 12 | 61 | 3 | Sp | 100 |
| C | 2 | Sp | 10 | 7 | Sp | Sp | - | Sp | Sp | 11 | 66 | 4 | Sp | 100 |
| KR 227 | | | | | | | | | | | | | | |
| A | 4 | Sp | 46 | 5 | 2 | 8 | 1 | 3 | 1 | 24 | 3 | 2 | 1 | 100 |
| Bw1 | 3 | 1 | 44 | 8 | 1 | 6 | 2 | 1 | Sp | 24 | 5 | 4 | 1 | 100 |
| Bw2 | 1 | Sp | 45 | 6 | 2 | 3 | Sp | 1 | Sp | 27 | 11 | 4 | Sp | 100 |
| BC | 2 | 1 | 45 | 9 | 1 | 9 | 1 | 2 | - | 20 | 9 | 1 | Sp | 100 |
| C | 1 | Sp | 18 | 6 | 2 | 5 | 1 | 2 | - | 12 | 52 | 1 | Sp | 100 |
| MD 121 | | | | | | | | | | | | | | |
| A | 2 | Sp | 31 | 10 | 1 | 7 | 3 | 1 | - | 21 | 20 | 3 | 1 | 100 |
| Bw1 | 6 | Sp | 40 | 13 | 3 | 6 | 1 | 1 | - | 19 | 9 | 2 | Sp | 100 |
| Bw2 | 5 | 1 | 35 | 12 | 2 | 5 | Sp | 3 | - | 15 | 16 | 6 | Sp | 100 |
| Bw3 | 4 | 1 | 34 | 13 | 3 | 6 | 1 | Sp | Sp | 13 | 22 | 3 | Sp | 100 |
| Bw4 | 4 | Sp | 39 | 7 | 1 | 5 | 1 | 2 | Sp | 20 | 18 | 3 | Sp | 100 |
| KR 190 | | | | | | | | | | | | | | |
| A | 3 | Sp | 50 | 2 | 1 | 7 | 2 | 1 | Sp | 24 | 6 | 3 | 1 | 100 |
| Bw1 | 2 | 1 | 32 | 3 | 1 | 5 | 1 | 1 | 1 | 13 | 36 | 3 | 1 | 100 |
| Bw2 | 2 | Sp | 26 | 3 | 3 | 5 | Sp | 2 | Sp | 14 | 41 | 3 | 1 | 100 |
| BC | 3 | 1 | 24 | 3 | 1 | 6 | Sp | 1 | Sp | 12 | 46 | 3 | Sp | 100 |
| C | 3 | Sp | 24 | 4 | 2 | 4 | 1 | 3 | 1 | 8 | 47 | 2 | 1 | 100 |
| AI 1045 | | | | | | | | | | | | | | |
| A | 4 | Sp | 17 | 2 | 1 | 2 | Sp | 1 | 2 | 3 | 59 | 8 | 1 | 100 |
| Bw1 | 4 | Sp | 43 | 1 | Sp | 6 | 1 | 2 | 3 | 6 | 21 | 12 | 1 | 100 |
| Bw2 | 2 | Sp | 20 | Sp | 1 | 2 | 1 | 1 | 1 | 2 | 61 | 8 | 1 | 100 |
| C | 3 | Sp | 16 | 2 | Sp | 1 | Sp | Sp | 2 | 2 | 66 | 7 | 1 | 100 |
| KR 1188 | | | | | | | | | | | | | | |
| A | 3 | 2 | 29 | 1 | 1 | 9 | 1 | Sp | Sp | 12 | 41 | 1 | Sp | 100 |
| Bw1 | 4 | 1 | 30 | 1 | Sp | 8 | 1 | 1 | Sp | 11 | 40 | 3 | Sp | 100 |
| Bw2 | 5 | Sp | 36 | Sp | Sp | 9 | 1 | 2 | Sp | 9 | 27 | 9 | 2 | 100 |
| BC | 10 | 1 | 17 | 1 | 1 | 3 | 1 | 1 | Sp | 8 | 42 | 11 | 3 | 100 |
| C | 9 | Sp | 15 | Sp | Sp | Sp | Sp | Sp | Sp | 10 | 48 | 13 | 3 | 100 |

Note : Sp = sporadic

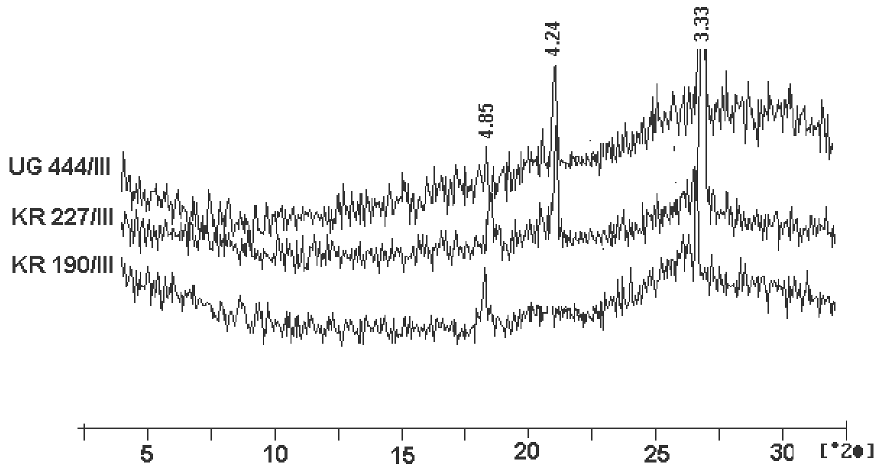


**Figure 1. X-ray diffraction pattern of UG 444/III, KR 227/III, and KR 190/III, Mg saturated**

*Gambar 1. Pola difraksi sinar X profil UG 444/III, KR 227/III, dan KR 190/III, penjenuhan Mg*

**Physical properties**

Bulk density of representative Andisols is in the range of 0.47 to 1.00 g $cm^{-3}$ (Table 3). It indicates that the bulk densities are fit with the Andisols criteria. The low of bulk density is generally caused by high content of organic matter and high total pores. Total pore ranges between 52.7 and 80.1% volume, and there was a trend that high total pore was founded in soil with low value of bulk density. The low soil bulk density and the high total porosity are related to the presence of non-crystalline or amorphous materials. Nanzyo *et al*. (1993) reported that allophane is one of the most important non-crystalline materials contributing to the low bulk density of Andisols through the development of porous soil structure.

The value of soil permeability ranges from low (1.11-2.68 cm $hour^{-1}$) to moderate (7.00-12.34 cm $hour^{-1}$). The soil permeability is related to the soil bulk density and total porosity. The soil permeability tends to increase with increasing total porosity and decreasing bulk density. The ability of the soil studied in flowing water to the deeper soil depth may also be related to the presence of organic matter and amorphous clay minerals. Those materials could absorb the water due to their high surface properties. Thus, they contribute to the fluctuation of the soil permeability.

Clay and silt fractions could not be separated in the laboratory, thus the particle size distribution was only separated into (clay + silt) and total sand. The Andisols generally show coarse loamy particle size class, mainly caused by the domination of quartz mineral in the sand fraction. The difficult clay dispersion was related to the presence of amorphous clay minerals such as allophane and imogolite. These minerals have high specific surface areas due to very small particle size (Harsh *et al*., 2002). The high surface areas may result in the high reactivity of the surface minerals which promote the strong formation of clay-organic complexes. The formation of amorphous clay-organic matter complexes may contribute to the stable and porous soil structure.

**Chemical properties**

Andisols investigated have acid (pH 4.5-5.5) to very acid (pH < 4.5) soil reaction. The difference between $pH_{KCl}$ and $pH_{H2O}$ in some horizon ranges from -1.3 to -0.1. This indicates that some soils

**Table 3. Soil physical properties of Andisols from liparite tuff**

*Tabel 3. Sifat-sifat fisika tanah Andisols dari tuf liparit*

| Profile | Horizon | Bulk density | Total porosity | Permeability | Clay and silt | Sand |
|---|---|---|---|---|---|---|
| | | g $cm^{-3}$ | % volume | cm $hour^{-1}$ | ...... % ...... | |
| UG 444 | A | 0,80 | 72,60 | 7,00 | 45 | 55 |
| | Bw1 | | | | 50 | 50 |
| | Bw2 | 0,70 | 71,10 | 9,64 | 46 | 54 |
| | BC | | | | 37 | 63 |
| | C | | | | 22 | 78 |
| MD 121 | A | 1,00 | 62,00 | 1,65 | 18 | 82 |
| | Bw1 | | | | 38 | 62 |
| | Bw2 | 0,89 | 52,70 | 1,44 | 33 | 67 |
| | Bw3 | | | | 38 | 62 |
| | Bw4 | 0,84 | 68,20 | 2,68 | 27 | 73 |
| KR 190 | A | 0,47 | 80,10 | 10,99 | 41 | 59 |
| | Bw1 | | | | 52 | 48 |
| | Bw2 | 0,53 | 74,00 | 12,34 | 52 | 48 |
| | BC | | | | 42 | 58 |
| | C | 0,74 | 67,50 | 1,11 | 13 | 87 |

almost do not have negative charge, but other soils still have much negative charge (Table 4).

Organic carbon is very high (>5%) in A and upper part of B horizons, and very low (<1%) in BC, C, and lower part of B horizons. Nitrogen content is in the range of moderate to high and the N is positively related with organic-C (Figure 2). The contribution of organic- C to N reaches 88%.

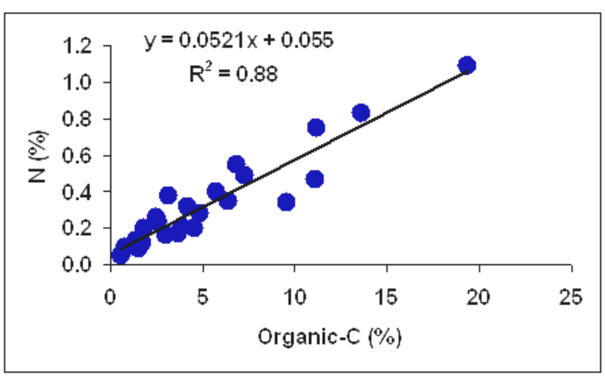


**Figure 2. Relationships between organic-C and N of Andisols from liparite tuff**

*Gambar 2. Hubungan antara C-organik dan N Andisols dari tuf liparit*

Exchangeable bases of Andisols investigated were very low (Table 5). The low content of exchangeable bases can be caused by two reasons. First, the weathering processes of primary minerals were in the early stage, and second, the product of minerals weathering were leach soon due to relatively coarse texture and moderate permeability. The exchangeable bases have positive relationships with Organic-C indicating that most of exchangeable bases were contribute by organic-C (Figure 3). The contribution of organic-C in exchangeable bases is in the range between 75 to 99%.

Soil cation exchange capacities (CEC) range from low (< 16 $cmol_c$ $kg^{-1}$) to high (> 24 $cmol_c$ $kg^{-1}$). Effective CEC (ECEC) is also very low in all soils investigated, generally less than 2 $cmol_c$ $kg^{-1}$. Consider that the clay mineral of the soil dominated by amorphous clay mineral that do not have contribution in the soil CEC, the high value of soil CEC have to influenced by organic matter. There are positive relationships between organic-C and cation exchange capacity (Figure 4). The contribution of organic-C on the CEC is in the range of 58-95%.

**Table 4. Soil reaction, organic-C, and N of Andisols from liparite**

*Tabel 4. Reaksi tanah, C-organik, dan N Andisols dari tuf liparit*

| Horizon | Depth | pH $H_2O$ | pH KCl | Delta pH | Organic-C | N | C/N |
|---|---|---|---|---|---|---|---|
| | cm | | | | ƕƕƕ.. % ƕƕƕ.. | | |
| UG 444 | | | | | | | |
| A | 0-17 | 3.4 | 3.1 | -0.3 | 12.03 | 0.18 | 65.75 |
| Bw1 | 17-38 | 4.1 | 4.0 | -0.1 | 3.90 | 0.21 | 18.30 |
| Bw2 | 38-58 | 4.4 | 4.1 | -0.3 | 2.47 | 0.26 | 9.66 |
| BC | 58-80 | 4.6 | 4.2 | -0.4 | 1.71 | 0.13 | 13.56 |
| C | 80-100 | 4.7 | 4.3 | -0.4 | 0.78 | 0.10 | 7.83 |
| KR 227 | | | | | | | |
| A | 0-13 | 5.3 | 4.0 | -1.3 | 11.16 | 0.75 | 14.98 |
| Bw1 | 13-29 | 5.1 | 4.7 | -0.4 | 5.72 | 0.40 | 14.34 |
| Bw2 | 29-38 | 5.7 | 5.4 | -0.3 | 2.60 | 0.24 | 11.06 |
| BC | 38-48 | 5.9 | 5.6 | -0.4 | 1.82 | 0.20 | 8.97 |
| C | 48-60 | 6.1 | 5.6 | -0.5 | 1.71 | 0.11 | 15.13 |
| MD 121 | | | | | | | |
| A | 0-14 | 5.2 | 4.9 | -0.3 | 7.30 | 0.49 | 14.99 |
| Bw1 | 14-51 | 4.8 | 4.3 | -0.4 | 6.82 | 0.55 | 12.36 |
| Bw2 | 51-76 | 5.0 | 4.8 | -0.2 | 5.37 | 0.59 | 9.12 |
| Bw3 | 76-95 | 4.6 | 4.4 | -0.2 | 5.83 | 0.66 | 8.87 |
| Bw4 | 95-150 | 4.6 | 4.2 | -0.4 | 3.13 | 0.38 | 8.19 |
| KR 190 | | | | | | | |
| A | 0-11 | 5.1 | 5.0 | -0.1 | 13.63 | 0.83 | 16.4 |
| Bw1 | 11-24 | 5.4 | 5.1 | -0.2 | 4.84 | 0.28 | 17.41 |
| Bw2 | 24-36 | 5.5 | 5.1 | -0.4 | 4.17 | 0.32 | 13.03 |
| BC | 36-52 | 5.8 | 5.1 | -0.6 | 1.41 | 0.13 | 10.76 |
| C | 52-80 | 6.0 | 5.8 | -0.2 | 0.62 | 0.05 | 12.92 |
| AI 1045 | | | | | | | |
| A | 0-15 | 5.2 | 4.6 | -0.5 | 9.56 | 0.34 | 27.88 |
| Bw1 | 15-28 | 5.5 | 5.2 | -0.3 | 4.55 | 0.20 | 23.11 |
| Bw2 | 28-52 | 5.4 | 5.1 | -0.3 | 3.65 | 0.17 | 21.59 |
| C | 52-70 | 6.0 | 5.6 | -0.4 | 1.52 | 0.09 | 16.56 |
| KR 1188 | | | | | | | |
| A | 0-14 | 4.7 | 4.4 | -0.3 | 19.31 | 1.09 | 17.75 |
| Bw1 | 14-33 | 4.8 | 4.6 | -0.2 | 15.89 | 0.58 | 27.21 |
| Bw2 | 33-54 | 5.0 | 4.5 | -0.4 | 11.11 | 0.47 | 23.80 |
| BC | 54-72 | 4.9 | 4.7 | -0.2 | 6.37 | 0.35 | 18.40 |
| C | 72-88 | 4.8 | 4.4 | -0.4 | 3.03 | 0.16 | 19.04 |

**Table 5. Exchangeable bases, cation exchange capacity, effective CEC, P retention, potential P and K of Andisols from liparite tuff**

*Tabel 5. Basa-basa dapat tukar, kapasitas tukar kation, KTK efektif, retensi P, P dan K potensial Andisols dari tuf liparit*

| Horizon | NH4OAc 1N, pH 7 | | | | | Soil CEC | Effective CEC | P retention | HCl 25 % | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $K^+$ | $Na^+$ | $Ca^{++}$ | $Mg^{++}$ | Sum | | | | $P_2O_5$ | $K_2O$ |
| | ƕƕƕƕƕ..ƕƕƕƕƕƕ $cmol_c$ $kg^{-1}$ ƕƕƕƕƕƕƕƕƕ..ƕƕ | | | | | | | % | ƕ. mg $100g^{-1}$ ƕ. | |
| UG 444 | | | | | | | | | | |
| A | 0.22 | 0.05 | 0.44 | 0.20 | 0.91 | 29.7 | 3.69 | 96.11 | 13.09 | 57.53 |
| Bw1 | 0.10 | 0.04 | 0.11 | 0.06 | 0.31 | 19.3 | 0.31 | 79.65 | 13.74 | 92.82 |
| Bw2 | 0.13 | 0.04 | 0.12 | 0.04 | 0.32 | 16.9 | 0.32 | 97.14 | 8.37 | 184.75 |
| BC | 0.17 | 0.06 | 0.20 | 0.05 | 0.48 | 16.1 | 0.48 | 97.21 | 6.63 | 258.60 |
| C | 0.17 | 0.03 | 0.13 | 0.05 | 0.38 | 6.8 | 0.38 | 94.23 | 4.22 | 292.64 |
| KR 227 | | | | | | | | | | |
| A | 0.22 | 0.05 | 0.08 | 0.11 | 0.46 | 22.7 | 3.54 | 92.57 | 41.20 | 39.89 |
| Bw1 | 0.06 | 0.03 | 0.03 | 0.02 | 0.14 | 14.9 | 0.14 | 91.44 | 36.31 | 35.28 |
| Bw2 | 0.05 | 0.04 | 0.03 | 0.04 | 0.15 | 10.4 | 0.15 | 97.46 | 8.92 | 51.54 |
| BC | 0.05 | 0.04 | 0.03 | 0.02 | 0.13 | 16.5 | 0.13 | 97.38 | 7.96 | 49.21 |
| C | 0.11 | 0.04 | 0.03 | 0.01 | 0.18 | 11.6 | 0.18 | 97.84 | 8.08 | 178.81 |
| MD 121 | | | | | | | | | | |
| A | 0.17 | 0.07 | 3.05 | 0.42 | 3.72 | 9.8 | 3.96 | 52.00 | 32.21 | 77.97 |
| Bw1 | 0.17 | 0.06 | 1.11 | 0.23 | 1.57 | 20.1 | 3.21 | 65.54 | 17.22 | 66.76 |
| Bw2 | 0.18 | 0.06 | 0.87 | 0.18 | 1.29 | 15.3 | 1.49 | 68.15 | 14.78 | 84.14 |
| Bw3 | 0.17 | 0.07 | 0.32 | 0.10 | 0.65 | 18.3 | 0.86 | 74.59 | 16.70 | 87.43 |
| Bw4 | 0.13 | 0.06 | 0.17 | 0.05 | 0.40 | 11.1 | 0.40 | 72.27 | 12.72 | 70.79 |
| KR 190 | | | | | | | | | | |
| A | 0.69 | 0.09 | 1.07 | 0.56 | 2.41 | 33.5 | 4.99 | 92.65 | 22.38 | 52.03 |
| Bw1 | 0.35 | 0.07 | 0.12 | 0.09 | 0.62 | 21.3 | 0.62 | 95.15 | 15.61 | 78.29 |
| Bw2 | 0.33 | 0.04 | 0.05 | 0.06 | 0.47 | 21.9 | 0.47 | 96.10 | 12.41 | 125.82 |
| BC | 0.12 | 0.05 | 0.05 | 0.01 | 0.23 | 15.8 | 0.23 | 86.49 | 8.86 | 267.42 |
| C | 0.06 | 0.04 | 0.03 | 0.01 | 0.13 | 7.6 | 0.13 | 81.96 | 7.32 | 387.39 |
| AI 1045 | | | | | | | | | | |
| A | 0.10 | 0.07 | 0.17 | 0.05 | 0.38 | 15.6 | 0.38 | 84.08 | 12.31 | 106.64 |
| Bw1 | 0.02 | 0.05 | 0.04 | 0.01 | 0.12 | 6.3 | 0.12 | 89.78 | 8.03 | 64.81 |
| Bw2 | 0.02 | 0.09 | 0.08 | 0.01 | 0.21 | 9.8 | 0.21 | 84.39 | 10.07 | 170.69 |
| C | 0.01 | 0.05 | 0.05 | 0.01 | 0.12 | 9.2 | 0.12 | 85.53 | 8.68 | 387.55 |
| KR 1188 | | | | | | | | | | |
| A | 0.55 | 0.05 | 0.07 | 0.73 | 2.37 | 38.1 | 5.47 | 77.75 | 32.81 | 64.67 |
| Bw1 | 0.14 | 0.06 | 0.09 | 0.08 | 0.37 | 42.6 | 2.62 | 94.32 | 20.83 | 42.12 |
| Bw2 | 0.13 | 0.06 | 0.12 | 0.07 | 0.38 | 28.9 | 0.63 | 89.14 | 18.33 | 58.31 |
| BC | 0.09 | 0.04 | 0.08 | 0.03 | 0.24 | 23.9 | 0.24 | 90.90 | 18.69 | 239.59 |
| C | 0.04 | 0.05 | 0.06 | 0.01 | 0.16 | 15.9 | 0.16 | 90.08 | 24.50 | 509.37 |

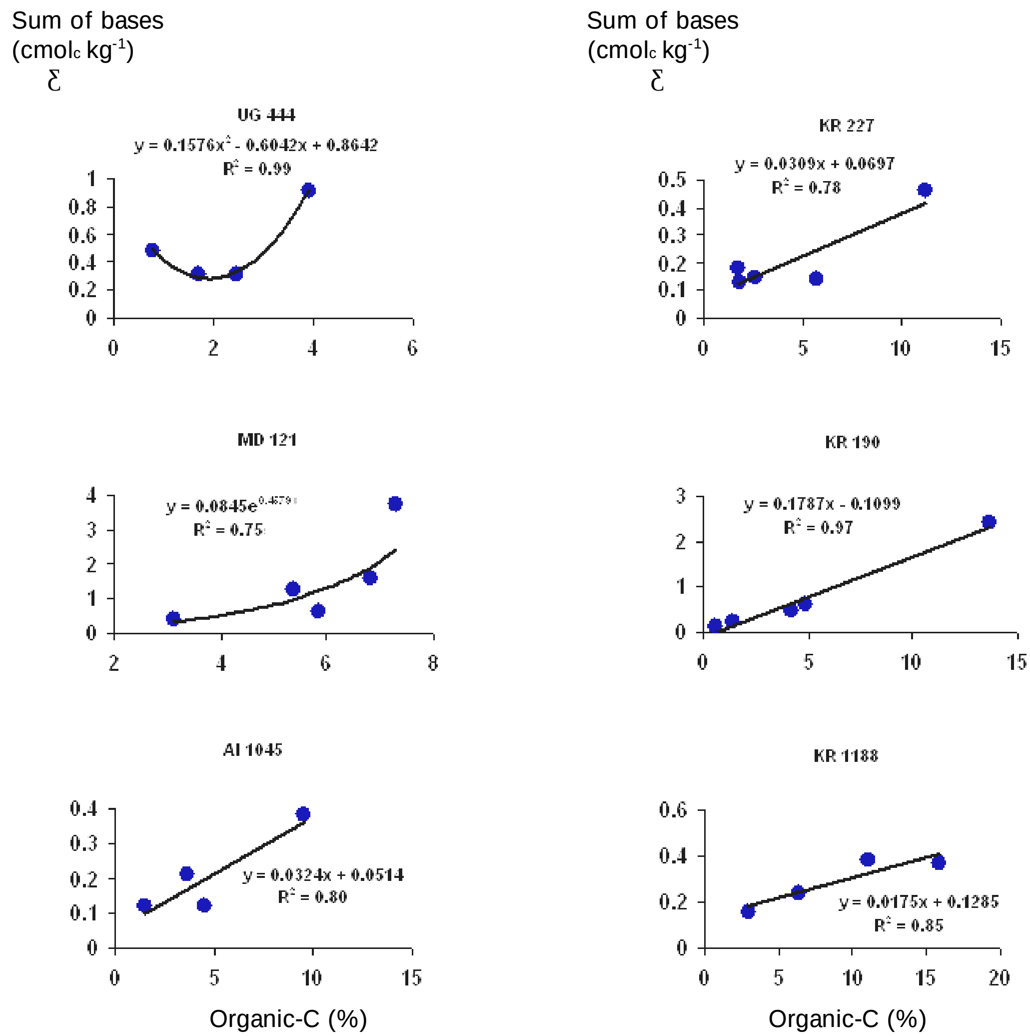


**Figure 3.** **Relationships between organic-C and sum of bases of Andisols investigated**

*Gambar 3. Hubungan antara C-organik dan jumlah basa-basa dari Andisols yang diteliti*

TP potential of Andisols is mostly classified as low (<20 mg 100g$^{-1}$), and the low content of P potential combine with very high of P retention make the available P become problem. The name of Andisols itself already indicates that the soils have problem with P retention (Soil Survey Staff, 2010). Nincovich *et al*. (1978) reported that the amount of $P_2O_5$ in the Toba tuff is very low (0.06%).

The Andisols investigated have high to very high K potential (>41 mg 100g$^{-1}$). The high content of K was caused by weathering of primarily minerals, biotite [$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$] and sanidine, that can be act as source of K in the soil. The K content tends to increase with soil depth. Even though K potential is high, the exchangeable K is very low. This situation indicates that K is still tie up in the mineral structure.

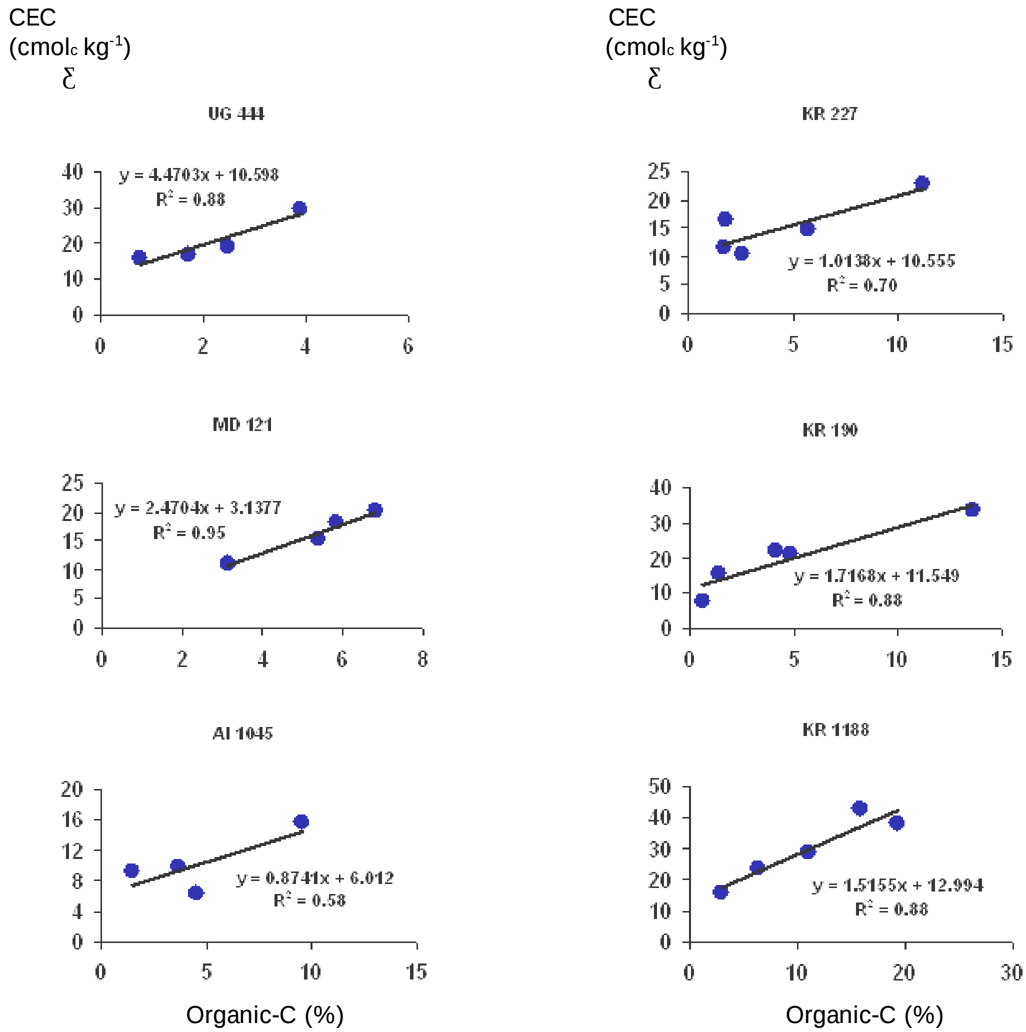


**Figure 4. Relationships between organic-C and CEC soil of Andisols investigated**

*Gambar 4. Hubungan antara C-organik dan KTK dari Andisols yang diteliti*

Al, Fe, and Si extracted by ammonium oxalate ($Al_o$, $Fe_o$, and $Si_o$) varies among the profiles investigated. In general, $Al_o + 0.5Fe_o$, defined as amorphous materials, increase with soil depth (Table 6). The amorphous materials are typically formed by weathering of pyroclastic materials. Aluminum, iron and silica were released by the rapid decomposition of primary minerals, and precipitate as amorphous gels. The increasing amorphous material with soil depth could be caused by weathering processes in the upper layer that leach some silica from the amorphous complex. The content of allophane can be calculated by formula : % allophane = % Si oxalate x 7.1 (Parfitt and Henmi, 1982).

Result from calculation indicates that the allophane content is very low in the top horizon, and tends to increase with soil depth. Allophane is often absent in surface horizons that are rich in organic matter in which aluminum humus complexes dominate (Mizota and Chapelle, 1988). The content of allophane ranges from 0.6 to 47.7%.

**Table 6. P retention, ammonium oxalate extractable Al, Fe, Si ($Al_o$, $Fe_o$, $Si_o$) of Andisols from liparite tuff**

*Tabel 6. Retensi P, Al, Fe, Si diekstrak dengan amonium oksalat ($Al_o$, $Fe_o$, $Si_o$) Andisols dari tuf liparit*

| Horizon | $NH_4$-oxalate | | | $Al_o$ + ½$Fe_o$ | $Si_o$ x 0.71 |
|---|---|---|---|---|---|
| | $Al_o$ | $Fe_o$ | $Si_o$ | | |
| | | | % | | |
| UG 444 | | | | | |
| A | 3.28 | 1.93 | 0.72 | 4.24 | 5.11 |
| Bw1 | 5.51 | 2.66 | 1.81 | 6.84 | 12.85 |
| Bw2 | 6.61 | 1.79 | 2.74 | 7.50 | 19.45 |
| BC | 6.78 | 1.22 | 2.87 | 7.39 | 20.38 |
| C | 5.14 | 1.17 | 2.47 | 5.73 | 17.54 |
| KR 227 | | | | | |
| A | 3.35 | 1.83 | 0.14 | 4.27 | 0.99 |
| Bw1 | 4.89 | 3.18 | 0.57 | 6.48 | 4.05 |
| Bw2 | 6.27 | 2.03 | 1.13 | 7.29 | 8.02 |
| BC | 6.25 | 3.31 | 1.22 | 7.9 | 8.66 |
| C | 8.07 | 2.46 | 2.53 | 9.3 | 17.96 |
| MD 121 | | | | | |
| A | 3.11 | 1.45 | 0.22 | 3.83 | 1.56 |
| Bw1 | 2.45 | 1.72 | 0.1 | 3.31 | 0.71 |
| Bw2 | 4.36 | 1.49 | 0.6 | 5.1 | 4.26 |
| Bw3 | 4.16 | 1.32 | 0.45 | 4.82 | 3.20 |
| Bw4 | 3.56 | 1.45 | 0.35 | 4.28 | 2.49 |
| KR 190 | | | | | |
| A | 4.3 | 2.87 | 0.09 | 5.74 | 0.64 |
| Bw1 | 9.18 | 3.18 | 2.29 | 10.77 | 16.26 |
| Bw2 | 10.47 | 2.08 | 3.64 | 11.51 | 25.84 |
| BC | 11.32 | 0.95 | 6.72 | 11.8 | 47.71 |
| C | 9.57 | 0.93 | 6.1 | 10.04 | 43.31 |
| AI 1045 | | | | | |
| A | 5.19 | 2.17 | 1.57 | 6.27 | 11.15 |
| Bw1 | 5.88 | 4.86 | 1.58 | 8.31 | 11.22 |
| Bw2 | 8.45 | 3.13 | 2.83 | 10.02 | 20.09 |
| C | 9.02 | 1.22 | 3.71 | 9.63 | 26.34 |
| KR 1188 | | | | | |
| A | 0.92 | 2.71 | 0.06 | 2.28 | 0.43 |
| Bw1 | 5.49 | 3.79 | 0.58 | 7.39 | 4.12 |
| Bw2 | 7.43 | 2.91 | 1.17 | 8.89 | 8.31 |
| BC | 9.52 | 2.69 | 2.22 | 10.86 | 15.76 |
| C | 11.13 | 0.88 | 3.52 | 11.57 | 24.99 |

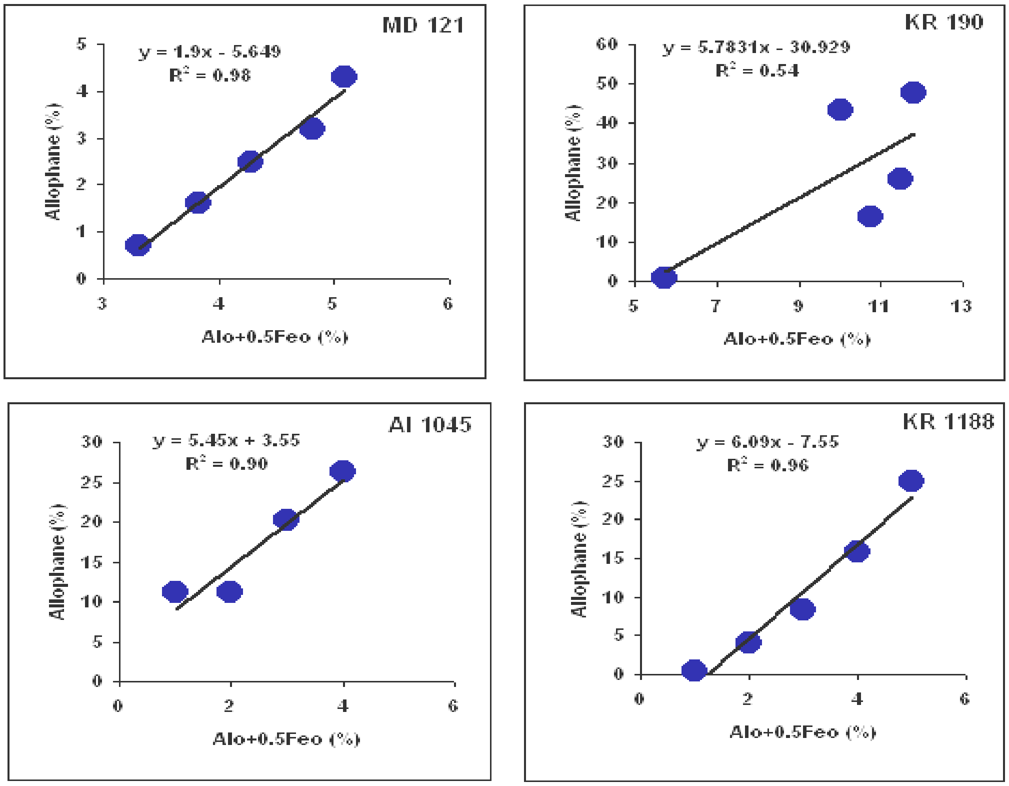


**Figure 5. Relationships between amorphous material ($Al_o + 0.5Fe_o$) and allophane in every soil profile**

*Gambar 5. Hubungan antara bahan amorf ($Al_o + 0.5Fe_o$) dan alofan pada setiap profil tanah*

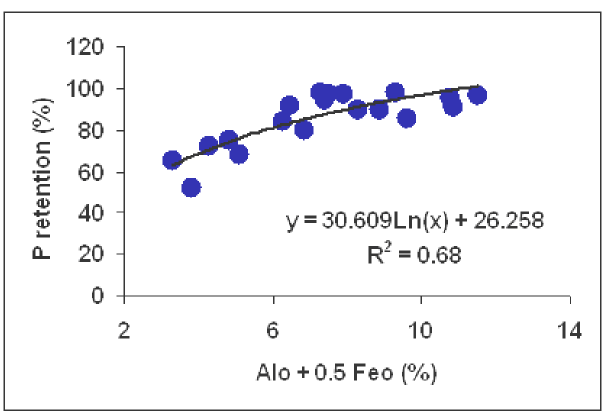


**Figure 6. Relationships between amorphous materials ($Al_o$ + 0.5 $Fe_o$) and P retention of Andisols derived from liparite tuff**

*Gambar 6. Hubungan antara bahan amorf ($Al_o + 0.5Fe_o$) dan retensi P Andisols dari tuf liparit*

Other researches in Indonesian Andisols showed that in Andisols from Marapi and Talamau mountains the content of allophane are in the range between 3% to 27% (Fiantis and van Ranst, 1997), in Andisols from Dempo mountain range from 10 to 32% (Hikmatullah *et al*., 1994). In every soil profile, the allophane was influenced by amorphous materials (Figure 5). The amorphous materials also positively influence on P retention (Figure 6). The higher the amorphous content, the higher the P retention will be. The positive relationships between P retention and $Al_o + 0.5Fe_o$ also have been reported in the previous research, by Suharta and Prasetyo (2009) in the Spodosols, and by Prasetyo and Suharta (2010) in the high land peat soils.

**Soil classification**

The Andisols investigated were classified following Soil Taxonomy system (Soil Survey Staff,

**Table 7. Soil classification according to Soil Taxonomy**

*Tabel 7. Klasifikasi tanah menurut Taksonomi Tanah*

| Pedon | Epipedon and other soil properties | Soil classification |
|---|---|---|
| UG 444 | Umbric, organic- C < 25%, *thixotropic*, have andic horizon, bulk density < 0,90 g $cm^{-3}$, P retention >85%, $Al_o$+0.5 $Fe_o$ > 2, ECEC < 2 $cmol_c$ $kg^{-1}$, | Medial, amorphic, isothermic, Acrudoxic Hapludands |
| KR 227 | Umbric, organic- C < 25%, *thixotropic*, have andic horizon, bulk density < 0,90 g $cm^{-3}$, P retention > 90%, $Al_o$+0.5 $Fe_o$ > 2, within 13-29 cm depth have > 20% cemented soil material. | Medial, amorphic, shallow, isothermic, Duric Hapludands |
| MD 121 | Umbric, organic-C <25%, *thixotropic*, have andic horizon, bulk density < 0,90 g $cm^{-3}$, P retention 52-74%, volcanic glass > 5%, $Al_o$+0.5 $Fe_o$ > 2, ECEC < 2 $cmol_c$ $kg^{-1}$. | Medial, amorphic, isothermic, Acrudoxic Hapludands |
| KR 190, AI 1045 and KR 1188 | Umbric, organic-C < 25%, *thixotropic*, have andic horizon, bulk density < 0,90 g $cm^{-3}$, P retention >85%, $Al_o$+0.5 $Fe_o$ > 2, ECEC < 2 $cmol_c$ $kg^{-1}$. | Medial, amorphic, shallow, isothermic, Acrudoxic Hapludands |

Source : Soil Survey Staff (2010)

2010). The soil classification was carried out based on the morphological characteristics of the soil and laboratory data. All profiles investigated have an andic horizon, which is especially characterized by the value of $Al_o$+0.5$Fe_o$ that higher than 2, bulk density smaller than 0.9 g $cm^{-3}$ and P retention higher than 80%.

From the soil classification, most of Andisols investigated were classified in the Subgroup Acrudoxic, indicates that the soils have very low effective cation exchange capacity (<2 $cmol_c$ $kg^{-1}$). The very low ECEC would influence the soil management, especially during fertilizing most fertilizer used will be loss. The other soil was classified in the Subgroup Duric as the soil has more than 20% cemented soil material within 13-29 cm depth.

### Soil management strategy

Andisols from liparite tuff have acid to very acid soil reaction, so that firstly should be considered planting some vegetation that tolerant with soil acidity. Liming to increase soil pH not always gives a benefit. In Andisols rich of humus-Al, liming caused organic matter decomposition and liberated Al that has consequences increasing P retention (Le Mare and Leon, 1989).

Based on relationships between amorphous materials with P retention, to decrease P retention the amorphous material should be reduced. Reducing amorphous material in the Andisols only occur by weathering process that leach some silica (*desilification)*. Soil developing from Andisols to Inceptisols also could change some amorphous minerals to crystalline mineral such as halloysite, kaolinite, and reduce P retention. Previous study indicates that the P retention was decrease from Acrudoxic Andisols-Andic Dystrudepts-Andic Kanhapludults-Andic Hapludox (Prasetyo, 2005).

Organic-C positively has relationships with N and CEC, so the high content of organic-C should be protected from erosion hazard. Organic material could block positive charge and increase negative charge of the soils. Consider that most Andisols have ECEC <2 $cmol_c$ $kg^{-1}$, fertilizing the soils should be done after increasing ECEC to avoid wasting fertilizer. Organic matter also has some important roles in the soil properties, it could increase soil aggregate, aeration, percolation, and soil structure.

Maintain land cover of Andisols is a good way to protect Andisols from erosion process. Clearing of vegetation cover could make dry the surface layer of Andisols, increasing permeability and decreasing cohesive capacity of Andisols, so that the soil has properties like loose sand and easy to erode by rain water.

## CONCLUSIONS

1. Andisols derived from acid pyroclastic liparite are dominated by biotite, quartz, and sanidine in their sand fraction and allophane in their clay fraction. P retention is very high and positively related with amorphous material in the form of $Al_o + 0.5Fe_o$.
2. Organic-C in Andisols is very high and positively influences nitrogen and cation exchange capacity. All Andisols studied have very low ECEC, indicate that without good soil management planning, during fertilizing some fertilizer would be loss.
3. The acid soil parent materials cause acid to very acid soil reaction, while the parent material that also rich in silica or glass materials make the soil dominated by amorphous materials.
4. Utilizing these soils should be considered two main limiting factors, P retention and low ECEC that will disturb soil fertilizing.

## RECOMMENDATION

The characterization of Andisols is very useful in the soil management planning on Andisols land. Planting some vegetation that tolerant with soil acidity and soil conservation to protect organic matter from erosion hazard should be become priority. Maintain land cover of Andisols is a good way to protect Andisols from erosion process.

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