Lithologic discontinuity in Andisols on tea plantation area in West Java, Indonesia

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Abstract. Tea plantation areas are normally found on Andisols developed from volcanic eruptions. Volcanic eruptions can occur within several periods, resulting in a sequence of soil layers that can differ in every period and produce lithologic discontinuity in the soil profile. Lithologic discontinuities were investigated in Andisols on Ciater Tea Plantation in Ciater, West Java, Indonesia. Andisols in this area developed from the eruption of Mt. Tangkuban Parahu, Mt. Dano and Mt. Tampomas derived from two geological formation, the Qyd (Middle Holocene) and Qyt (Early Holocene). The objective of this research was to investigate the lithologic discontinuity of Andisols in Ciater Tea Plantation through macromorphological observations from four profiles in this location. The results showed that there were lithologic discontinuities in all profiles, indicated by unusual changing color detected by Munsell Soil Color Chart and increasing organic carbon content in certain depth. Some A buried horizons (Ab) were found, indicated that the underlying soils had developed from the parent material of the earlier eruption period than the overlying horizons. Detailed analyses of mineralogical and element in sand and silt fraction were needed to have the more accurate information of lithology discontinuities. Instruments like X-Ray Fluorescence Spectrometry and Visible Near-Infrared Diffuse Reflectance Spectroscopy can be explored to investigate the lithologic discontinuity.

1. Introduction

Lithologic discontinuities are the meaningful changes in various things in one soil profile like color, texture, coarse fragment content, organic C, or other physicochemical parameters [1, 2]. This is the physical manifestation of either a break in sedimentation such as change from deposition of sands by running water to deposition of silts by wind, or an erosion surface. It presents if there are two or more parent materials differ vertically within a profile due to previous distinction in past depositional or geological processes, causing variations in the soil forming processes. The understanding of lithologic discontinuity provides important information related to the processes occur in the soil, precede the process of soil formation, also the information of past geologic and sedimentologic processes [3].

Lithologic discontinuities are common feature found in soils derived from the ash of volcanic eruption. During the eruption, the volcanoes emit fine materials such as ash, pumice and cinder. These materials are the parent materials for the formation of volcanic soils, which can be classified as Andisols if fulfilled the prerequisite of andic soil properties [4]. Volcanic eruption can occur in several periods. In one period of
eruption, it contributed the parent materials to the earth followed by the development of soil processes resulted in complete horizon layers in the soil. If the next eruption happened, probably after a long period of geological time, the processes of soil development will occur, resulted in different layers with previous one. It will yield specific and unique morphology such as the presence of lithologic discontinuity in their profiles [5].

Some common features in the lithologic discontinuities in Andisols are the darker color underlying the lighter color horizons named as A buried horizon, coarser texture in A buried horizon, different mineral content and different carbon dating age [6]. However, other physicochemical parameter can be a marked as the phenomenon of lithologic discontinuity. This paper discusses lithology discontinuities in Andisols found in tea Ciatet Tea Plantation in West Java, Indonesia.

2. Materials and Methods

The research was done in Andisols located in Ciatet Tea Plantation (CTP) area. These Andisols developed from the eruption of Mt. Tangkuban Parahu, located at 1250 m above sea level (asl) derived from two geological formation, the Qyd and Qyt [7, 8]. The Qyd formation consisted of sandy tufa nests, containing rough hornblende crystals and weathered reddish from the eruption of Mt. Dano and Mt. Tangkuban Parahu in the Middle Holocene [7, 8]. The profiles in this area were symbolized as CTP A-1 and CTP A-2. The Qyt formation [8] consisted of rocky tuffs, containing tuffaceous sand, lapilli, bombs, lava and pieces of andesite-basalt with many lumps and pumice fragments as the result of the eruption of Mt. Tangkuban Perahu and Mt Tampornas in the Early Holocene. The profiles in this area were symbolized as CTP B-1 and CTP B-2.

The map used in this study was the Soil Map of Subang Regency scale 1: 100 000 (Regional Planning Agency, 2008a), Agroclimatic Zone Map scale 1:250,000, Land Use Map scale 1: 125,000 (Regional Planning Agency, 2008b), Topographical Map scale 1: 125,000 [9].

Field equipment used was GPS (Global Position System), Munsell Soil Color Chart, clinometer, auger, ring sampler, description paper, plastic bag, knife, meter and labels. Field observations in the profile included the depth of the solum, boundaries and thickness of the horizon, color, texture, structure, consistency, pore, pH, rooting, guided by the Field Book for Soil Describing and Sampling Soils [10].

Soil samples were taken from every horizon for soil physical and chemical analyses. Observation of soil macro-morphology as well as profile description and soil sampling were done by making four profiles. Two profiles were made at the area with older age of parent materials (Middle Holocene) and two profiles were made at the area in the young age parent materials (Early Holocene). Observation of lithology discontinuities were based on the macromorphological observation in the profiles together with physical and chemical analysis.

3. Results and Discussions

The four profiles were investigated their andic soil properties to ensure that the soils were Andisols based on the requirements stated by Soil Survey Staff [4]. The results of the analysis for andic soil properties for each profile are presented in Table 1. The value of soil characteristics to a depth of 60 cm must indicate that C-organic is less or equal to 25%; fill weight is smaller or equal to 0.9 g cm-3, Alo + ½ Feo is greater or equal to 2%; and P retention greater or equal to 85%. Data in Table 1 and Table 2 show that these criteria are met for all depths, not only to 60 cm depth. Soil on all profiles on both slopes can thus be classified as Andisols.

Data in Table 1 informed that all profiles (CTP-A1, CTP A-2, CTP B-1 and CTP B-2) met the criteria of Andic Soil Properties, where the whole organic carbon content were lower than 20%, the bulk density were lower than 0.9 g cm², P-retention were higher than 85% and Al + ½ Fe (with ammonium oxalate) were higher than 2%. All the criteria required by Soil Survey Staff [4] for Andic Soil Properties were found on
those profiles, for the soils were classified as Andisols. The macromorphological characteristics of the four profiles can be seen in Table 2, covered color, texture and coarse fragment.

### Table 1. Investigation of Andic Soil Properties data to the Profiles in Ciater Tea Plantation

| Horison | Depth (cm) | Organic Carbon (%) | Bulk Density (g cm$^{-3}$) | P-retention (%) | Al+½Fe (ammonium oxalate) |
|---------|------------|---------------------|-----------------------------|-----------------|---------------------------|
| **CTP A-1** | | | | | |
| Ap | 0-12 | 14.42 | 0.53 | 92.2 | 4.38 |
| Bw | 12-26 | 10.05 | 0.53 | 96.7 | 5.42 |
| 2Ab | 26-37 | 10.42 | 0.22 | 98.5 | 8.39 |
| 2Bwb | 37-50 | 8.16 | 0.38 | 98.4 | 9.08 |
| 2BCb | 50-75 | 3.52 | 0.81 | 98.2 | 9.02 |
| 3Ab | 75-90 | 8.54 | 0.31 | 97.2 | 10.84 |
| 3BCb | 90-110 | 9.30 | 0.58 | 98.9 | 9.43 |
| 4 Ab | 110-142/150 | 10.59 | 0.29 | 98.9 | 9.45 |
| **CTP A-2** | | | | | |
| Ap | 0-12/15 | 8.22 | 0.63 | 92.0 | 3.77 |
| Bw | 12/25-25 | 6.24 | 0.49 | 95.8 | 6.20 |
| BC | 25-33/40 | 5.57 | 0.23 | 97.3 | 7.09 |
| 2Ab | 33/40-49/58 | 9.62 | 0.40 | 97.3 | 8.86 |
| 2BCb | 49/58-73 | 3.39 | 0.49 | 98.9 | 9.12 |
| 3Ab | 73-88 | 7.68 | 0.32 | 97.8 | 9.32 |
| 3Bwb | 88-103 | 8.00 | 0.32 | 98.6 | 11.11 |
| 3BCb | 103-116/123 | 6.26 | 0.41 | 98.4 | 10.63 |
| 4Ab | 116/123-140 | 8.85 | 0.33 | 99.0 | 8.71 |
| **CTP B-1** | | | | | |
| Ap | 0-20 | 10.00 | 0.31 | 96.5 | 12.38 |
| Bwl | 20-30 | 3.96 | 0.26 | 98.8 | 7.33 |
| Bw2 | 30-42 | 5.82 | 0.32 | 98.5 | 9.71 |
| BC | 42-54 | 4.48 | 0.51 | 97.2 | 7.57 |
| 2Ab | 54-70 | 3.98 | 0.30 | 99.3 | 9.90 |
| 2BCb | 70-85 | 5.34 | 0.36 | 98.8 | 9.41 |
| 2Ab | 85-113 | 6.07 | 0.27 | 99.1 | 13.04 |
| 2A'bl | 113-140 | 8.07 | 0.20 | 99.3 | 10.46 |
| 2Ab | 140-155 | 5.80 | 0.40 | 98.6 | 10.92 |
| **CTP-B-2** | | | | | |
| Ap | 0-11 | 8.52 | 0.35 | 96.7 | 6.45 |
| Bwl | 11-36 | 6.25 | 0.48 | 98.5 | 11.04 |
| Bw2 | 36-58 | 5.73 | 0.28 | 98.9 | 9.88 |
| BC | 58-70 | 5.78 | 0.32 | 98.5 | 9.03 |
| 2Ab | 70-85 | 4.85 | 0.42 | 98.4 | 7.05 |
| 2BCb | 85-98 | 2.82 | 0.54 | 98.8 | 7.31 |
| 2Ab | 98-112 | 10.14 | 0.34 | 98.5 | 11.20 |
| 2Ab | 112-123 | 8.99 | 0.20 | 98.6 | 7.93 |
| 2BCb | 123-142 | 5.76 | 0.43 | 98.7 | 7.23 |
Taking into account the horizonation in the left-hand-side content in Table 1, it can be seen that there were information of some lithologic discontinuities, marked by the arabic number of 2, 3 and even 4. The buried horizon of 2Ab, found in CTP B-1 and CTP-B2 profiles. Meanwhile, the buried horizon of 2Ab,

| Horison | Depth (cm) | Color   | Texture      | Coarse fragment (2) |
|---------|------------|---------|--------------|---------------------|
| **CTP A-1** |            |         |              |                     |
| Ap      | 0-12       | 10YR 3/4-3/3 | Loam        | -                   |
| Bw      | 12-26      | 7.5YR 5/6-4/6 | Clay        | -                   |
| 2Ab     | 26-37      | 10YR 3/6    | Clay        | few, big            |
| 2Bwb    | 37-50      | 10YR 4/6    | Clay        | -                   |
| 2BCb    | 50-75      | 10YR 5/6-7/4 | Loam       | -                   |
| 3Ab     | 75-90      | 10YR 3/4   | silty clay loam | -                 |
| 3BCb    | 90-110     | 10YR 3/6    | Loam        | very much, small, soft |
| 4 Ab    | 110-142/150| 10YR 2/2   | silty loam  | few, small, very hard |
| **CTP A-2** |            |         |              |                     |
| Ap      | 0-12/15    | 10YR 3/3    | Clay        | -                   |
| Bw      | 12/25-25   | 7.5YR 4/6-5/6 | clay loam | few, small, hard |
| BC      | 25-33/40   | 7.5YR 4/4    | silty loam  | few, small, hard |
| 2Ab     | 33/40-49/58| 10YR 3/4   | silty loam  | few, small, soft   |
| 2BCb    | 49/58-73   | 7.5YR 5/6    | Clay        | -                   |
| 3Ab     | 73-88      | 10YR 3/6    | silty loam  | few, soft           |
| 3Bwb    | 88-103     | 10YR 3/4-3/6 | silty clay loam | few, soft |
| 3BCb    | 103-116/123| 10YR 5/6-5/8 | clay loam  | -                   |
| 4 Ab    | 116/123-140| 10YR 2/1-2/2 | Clay       | few, small, very hard |
| **CTP B-1** |            |         |              |                     |
| Ap      | 0-20       | 5YR 3/3    | silty loam  | -                   |
| Bw1     | 20-30      | 10YR 3/6    | silty loam  | -                   |
| Bw2     | 30-42      | 10YR 316    | silty loam  | -                   |
| BC      | 42-54      | 10YR 4/6    | loam        | -                   |
| 2Ab     | 54-70      | 10YR 3/6    | silty clay loam | -             |
| 2BCb    | 70-85      | 10YR 3/6    | silty loam  | -                   |
| 2A'bl   | 85-113     | 10YR 2/1    | silty clay loam | -             |
| 2A'bl2  | 113-140    | 10YR 2/1    | Clay        | -                   |
| 2BC'b  | 140-155    | 10YR 3/4    | silty loam  | -                   |
| **CTR-B-2** |          |         |              |                     |
| Ap      | 0-11       | 10YR 3/4    | silty loam  | -                   |
| Bw1     | 11-36      | 10YR 3/6    | silty loam  | -                   |
| Bw2     | 36-58      | 10YR 3/6    | clay loam   | -                   |
| BC      | 58-70      | 10YR 4/6    | silty loam  | -                   |
| 2Ab     | 70-85      | 10YR 3/6    | silty clay loam | few, small |
| 2BCb    | 85-98      | 10YR 3/4    | silty loam  | few, small           |
| 2A'bl1  | 98-112     | 10YR 2/2    | silty loam  | -                   |
| 2A'bl2  | 112-123    | 5YR 3/2-3/3 | Silt       | -                   |
| 2BC'b  | 123-142    | 10YR 416    | silty clay loam | few, big, hard |

Tabel 2 Some macromorphological characteristics of the Profiles in Ciater Tea Plantation
3Ab and even 4Ab were found in CTP-A1 and CTP A-2 profiles. These informed that in the Ciater Tea Plantation the eruption happened several times and contributed the parent materials to the earth, resulted in several lithologic discontinuities with developed horizons A and B in each in the profiles.

Profiles in CTP A-1 and CTP A-2 showed 4 (four) A buried horizons (Ab). Those buried horizons indicated four times of lithologic discontinuities. Referred to profile CTP A-1, the first two layers consisted of Ap and Bw horizons. The moist colors of Ap (0-12cm) were 10YR 3/3 (dark brown) and 10YR 3/4 (dark yellowish brown). The underlying Bw horizon (12-26 cm) had lighter color of 7.5YR 4/6 - 7.5YR 4/6 (strong brown). The higher hue and chroma (3/3 and 3/ in Ap compared to 4/6 and 5/6 in Bw) informed the lighter color of Bw horizon. That was the common phenomenon where top soils (Ap) was darker than underlying horizon (Bw). The organic matter content in Ap (14.42%, Table 1) was higher than in Bw (10.05%, Table 1) contributed to the darker color in Ap horizon.

Normally, the lower the horizon, the lighter the color will be, due to the lower organic carbon content. The interesting occurrence then be found in this profile where the next underlying horizon (26-37 cm) symbolized with 2Ab, had the darker color (10YR 3/6, dark yellowish brown) than the overlying Bw horizon (7.5YR 4/6 and 5/6, strong brown). The lower value from 4 and 5 (Bw) to 3 (2Ab) supported that darker color. That darker color was promoted by the increasing of organic carbon content from 10.05% to 10.42% (Table 1).

The following underlying horizons (2Bwb, 37- 50 cm and 2BCb, 50 – 65/75 cm) had lighter color. Horizon 2Bwb was dark yellowish brown (10YR 4/6) and 2BCb was yellowish brown (10YR 5/6) and very pale brown (10YR 7/4). These data were supported by the lower organic carbon content (8.16 and 3.52%, Table 1). These were the common phenomena where the A horizon (2Ab) was darker with higher organic carbon content than the B horizon (2Bwb and 2BCb).

The next underlying layer 3Ab (65/75-90 cm), again showed the interesting case where the color was darker again (10YR 3/4, dark yellowish brown), with lower value and chroma than the overlying horizon. It was followed by the lighter color of 3BCb (90-110 cm), marked by the higher chroma (10YR 3/6), even though the color name was the same dark yellowish brown.

The last layer 4Ab (110 – 142/150 cm) which normally had the lightest color due to the least activity of microorganism and the lowest content of organic carbon, showed the darkest color (10YR 2/2, very dark brown). The organic carbon content was increase from 9,30 to 10.59%, instead of decreased.

The similar patterns were found in CTP A-2, CTP B-1 and CTP B-2 profiles. There were some deeper horizons that had higher organic C than the horizons above, like found in CTP A-1. Referred to CTP A-2 profile, 2Ab horizon (33/40-49/58 cm) had higher organic carbon (9.62%) than BC horizon (25-33/49 cm) that had 5.57% of organic C. The 3Ab horizon (73-88 cm) also had higher organic C (7.68%) than 2BCBb horizon (49/58-73 cm) that had only 3.59% of organic C. The same pattern was also found in 4Ab horizon (116/123-140 cm) which had higher organic C (8.85%) than the overlying 3BCb horizon (103-116/123 cm) which had 6.36% of organic C. This value even higher than the organic C in top soil Ap (0-12/15 cm) which only had 8.22% of organic C.

As the finding in CTP A-1 profile, the higher organic C in CTP A-2 profile were also marked by the lower hue and or chroma, resulted in darker color. The color of 2Ab profile was 10YR 3/4, had lower value than BC profile (7.5YR 4/4). The color of 3Ab profile was 10YR 3/6, had lower value and chroma than 2BCb profile (7.5YR 5/8). The color of 4Ab profile was 10YR 2/1-2/2, had much lower value and chroma of 3BCb profile (10YR 5/6-5/8).

The sequence of uncommon changes color in this profile was quite prevalent in the profile with lithologic discontinuity. Lithologic discontinuity can be characterized by the changes in soil organic carbon, and its can be reflected in changing in color [1]. Actually, there were several indicator used in detecting lithologic discontinuities in soils as mentioned by several authors. Presence, absence, or change the content of a mineral [11], presence or absence the fossil [12], content of one or more resistant minerals in silt and
sand fraction [13], heavy minerals content [14], ratio of two or more element in silt and sand fraction [15] and some other indicators. There were also several ways to investigate the lithologic discontinuity like did by [16] who used X-ray Fluorescence Spectrometry and Visible Near-Infrared Diffuse Reflectance Spectroscopy for ensuring the lithologic discontinuity. However, features in the field (color) and laboratory (organic carbon) were the valuable clues for further investigation regarding lithologic discontinuity.

In location with older age of parent material from the Early Holocene (CTP B-1 and CTP B-2) the lithologic discontinuities were found in both profiles. There were two lithologic discontinuities in every profile, marked by 2Ab horizon in CTP B-1 (54-70 cm) and CTP B-2 (70-85 cm). The A burried horizons (2Ab) in these two profiles were marked by the lower color value from the overlying BC horizons (43-54 cm in CTPB-1 and 58-70 cm n CTP B-2). There was a coincidence that the color change in these two profiles were similar. The BC horizons in CTP B-1 and CTP B-2 were 10YR 4/6 and the 2Ab horizons in both profiles were 10YR 3/6.

The subtill difference color in 2Ab horizon compared to BC horizon in CTP B-1 (only different in one unit of chroma) continued with a bigger difference in the lower horizons. It can be seen that in 2BCb (70-85 cm), 2A'b1 (85-113 cm), 2A'b2 (113-140 cm), and 2BC'b (140-155 cm) horizons, the color was 10YR 3/6, 10YR 2/1, 10YR 2/1 and 10YR 3/4 respectively. It was followed by the increasing of organic carbon content sequentially as 3.98, 5.43, 6.07, 8.07 and 5.80%. Taking into account to the organic carbon content there were two big different layers in this profile. The first layer was from the top (0 cm) to 54 cm, and the second from 54 cm to 155 cm. It was indicated two different soil development that supported lithologic discontinuity in this soil.

The similar phenomenon was also found in CTP B-2 where the difference color of A burried horizon 2AB (70-85 cm, 10YR 3/6) was only 1 unit value to the overlying BC horizon (58-70 cm, 10YR 4/6). The similar phenomenon in CTP B-1 was also found in this profile where the deeper horizon showed continuously the decreasing of value and or chroma as can be seen in 2BCb (85-98 cm, 10YR 3/4), 2A'b1 (98-112 cm, 10YR 2/2) and 2A'b2 (112-123 cm, 5YR 3/2-3/3). The decreasing of value and or chroma were followed with the increasing of organic matter content in 2A'b1, 2A'b2 and 2BC'b horizons like 10.14, 8.99 and 5.76% respectively. As found in the CTP B-1, in CTP B-2 profile also consisted of two big different layers. The first layer was from the top (0 cm) to 70 cm, and the second from 70 cm to 142 cm. It was also indicated two different soil development that supported lithologic discontinuity in this soil.

Lithologic discontinuities in four profiles in Andisols on Ciater Tea Plantation can be identified through organic matter content and color. It however was still an initial stage in investigated the lithologic discontinuities which should be followed by other detailed analyzing like mineralogical analyses to have data of presence, absence, or change certain mineral content. It also have to be followed by detailed element in silt and sand fraction. The usage of X-Ray Fluorescence Spectrometry and Visible Near-Infrared Diffuse Reflectance Spectroscopy [13, 14, 15, 16].

4. Conclusion

Soils in Ciater Tea Plantation were Andisols due to complied andic soil properties. There were lithologic discontinuities in four profiles in Ciater Tea Plantation. The uncommon change of color and organic carbon content were the indication of lithologic discontinuity in this area. Detailed analyses of mineralogical and element in sand and silt fraction were needed to have the more accurate information of lithologic discontinuities. Instruments like X-Ray Fluorescence Spectrometry and Visible Near-Infrared Diffuse Reflectance Spectroscopy can be explored to investigate the lithologic discontinuity.

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