Characteristics and Classification of Soil Formed from Banda Recent Volcanic Ash on Various Topographic Positions

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Abstract : The Banda Islands consist of three main islands namely Banda Besar Island, Banda Naire Island, and Banda Api Island. Banda Api Mountain is an active volcano and based on history has erupted 20 times over the past 400 years. The eruption of volcanic ash has covered most of Banda Naire Island in the east and Banda Big Island in the east and south of Banda Api Mountain. This study aims to determine the characteristics and classification types of soil formed from parent material deposited in recent volcanic ash in different topographic positions. The method used was free survey method through toposequence approach by determining the profile point based on a straight line (transect) while soil classification refers to the Soil Taxonomy System. The results of the study showed that the profile of the soil at the position of the foothills on the island of Banda Naire and the Banda Besar morphologically had Andisols properties (Typic Hapludands), but in generally the physical and chemical characteristics of each soil profile did not match with the Andisols requirements so that they were classified into the Inceptisols (Vitrandic Eutrudepts and Vitrandic Dystrudepts) (in the slope and foothills), while at the top of the hill were classified as Entisols (Typic Udipsamments).

1. Introduction
Gunung Banda Api is an active volcano which appears amid the debris of an older volcano. History records that in 1856 to 1901 at least 19 times the eruptions have occurred, including two that have caused environmental damage and fatalities. The last eruption occurred in 1988 (period of eruption II) after 80 years of rest from the eruption in 1908 (eruption period I). Eruptions that occur emit volcanic ash up to 4 km from the center of the eruption, and at this distance found falling pyroclastic material < 2 cm in diameter [1, 2], it can be concluded that eruptions that repeatedly produce several times volcanic ash deposits which will differ in thickness in each topographic shape, thus affecting the depth of the soil solum.

Topography can affect water movements such as surface flow, infiltration and percolation so that in flat areas excessive water speeds will be much smaller than in sloping areas. Sloping topography increases erosion in the surface layer, if considerable erosion can prevent the possibility of deep soil formation. Based on [3, 4] explains that relief was a conditioning factor that controls the influence of climate factors and living organisms, and then controls the rate and direction of the process of soil formation.

Banda Islands, Central Maluku Regency, is one of the spice-producing regions since the Dutch era (VOC) and has been known by traders in Europe and the world. The existence of the European Nation is evidenced by the existence of Fort Belgica (1611), Fort Nassau (1617), and the old Church (1875) on
Banda Naire Island which is a legacy of Portuguese, Dutch, and English that once occupied the Banda islands between the 17th century and the century -19 [2]. This shows that since ancient times Banda had become the center of spices until now, meaning that the eruption had never destroyed the plants. As a region producing quality spices, it was inseparable from the carrying capacity of the land. The Banda Islands are one of the islands that are in the arc path in Banda volcanic [5]. These islands consist of a group of islands, some of which were classified as large islands, such as Banda Besar (Lonthor), Banda Neira and Banda Api Islands. Matahelumual [2] stated that in geology, Banda Besar Island, Banda Neira and Banda Api were interrelated in terms of the formation of the Gunung Banda Api Complex. Gunung Banda Api last erupted in 1988 spewing recent volcanic ash around it which was thought to have covered the land in the area. Therefore, the eruptions affect the characteristics and classification of existing soil which is thought to be able to be sourced from the deposit of recent volcanic ash.

The information currently available was a reviewed soil map (scale 1: 500,000) [6]. The Central Maluku still generally describes this soil as Ultisols which derived from lava, coral limestone, and volcanic breccias. Therefore, a more detailed study is needed to determine the characteristics and classification types of soil formed from volcanic ash deposits according to the Soil Taxonomy system USDA [7]. This study aims to characterize and classify of soil that formed from deposits of recent volcanic ash in different topographic positions in the Banda Islands region, Central Maluku Regency, Indonesia.

2. Material and Methods
Observations and profile descriptions and soil sampling were carried out on Banda Naire Island and Banda Besar Island, Central Maluku Regency, Maluku Province (Fig.1). Analysis of soil physical and chemical properties was carried out in the Soil Chemistry Laboratory, Department of Soil Science, Faculty of Agriculture, Hasanuddin University. The methodology of soil survey and soil analysis in the laboratory based on [8]. Soil mineralogy analysis was done at the Petrographic Laboratory, Department of Geology, Faculty of Engineering, Hasanuddin University.

Soil sampling was carried out based on free survey method through toposequence approach by determining profile points based on a straight line (transect). The determination of the location of the profile based on different topographic forms on the Banda Islands landscape. There were two transects that will represent the study location, so the number of observation profile points was 6 points on two islands (1 transect for 3 soil profiles). Soil classification refers to the Soil Taxonomy System [7]. For soil type mapping, it was using software ArcGIS 10.3 (licensed by ESRI Indonesia).
3. Results and Discussion

3.1. Characteristics Soil Morphology and Physical

The morphological properties of the soil from volcanic material in the study area were all pedons studied had a deep profile section (> 90 cm) with A horizon thickness varying from 10-20 cm and B horizon more than 70 cm (Table 1). The soil with highly permeable material has deep solum [9]. Horizon A was dark or black (10 YR 2/1) to dark reddish brown (5 YR 3/2), while the B horizon was slightly brighter, although there are several layers which have black color which are volcanic materials. A horizon color was darker because of the influence of higher organic matter content. The average pedon shows the soil in the initial stages of profile development because it has an A-Bw-C horizon arrangement. The texture of all pedons was dominated by high percentage of sand so that the textured class classified as clay, sandy clay, sandy clay, clay sand, and sand. The high levels of sand reflect low weathering levels of volcanic materials or in the initial stages [10, 11, 12]. Horizons A and B in all pedons generally have a weak to sufficient level of structural development, with granular and subangular blocky which break easily when pressed, and smooth to moderate sizes (Table 2). Based on [13] the surface horizon of volcanic soils generally has a granular structure, and the structure was angular blocky, or sometimes sub angular blocky. The consistency of soil was very loose (very friable) to friable (friable) in the humid conditions. The available moisture content was one of the causes of moist soil in each layer on each pedon. The properties of such soil were quite beneficial because the soil will be easy to process and the roots of plants will grow up well.

Table 1. Characteristics of morphology and physical properties of soil research sites

| Transect/Profile | Layer | Depth (cm) | Color (Moist) | Fraction Percentage (%) | Texture Class (USDA) |
|------------------|-------|------------|---------------|-------------------------|---------------------|
| P1               | P1A   | 0-10       | 3/2.5 YR      | 56 27 17                | Sandy clay          |
|                  | P1B1  | 10-45      | 3/3 10 YR     | 61 22 18                | Sandy clay          |
|                  | P1B2  | 45-90      | 3/2.5 YR      | 63 15 21                | Sandy clay          |
| P2               | P2A   | 0-15       | 2/1 10 YR     | 50 36 14                | Clay                |
| P3               | P2B1  | 15-35      | 3/2.75 YR     | 16 47 38                | Silty clay          |
|                  | P2B2  | 35-70      | 4/2.75 YR     | 89 5 6                  | Sandy clay          |
| P4               | P2B3  | 70-100     | 2.5 / 7.5YR   | 79 10 11                | Sandy clay          |
|                  | P2B4  | 100-130    | 4/2 10 YR     | 47 36 18                | Clay                |
| P5               | P2B5  | 130-150    | 3/1 5 YR      | 73 13 15                | Sandy clay          |
| P3               | P3A   | 0-20       | 3/1.75 YR     | 76 11 12                | Sandy clay          |
|                  | P3B1  | 20-50      | 2.5 / 1 5YR   | 56 29 14                | Sandy clay          |
|                  | P3B2  | 50-90      | 3/1 5 YR      | 58 21 21                | Sandy clay          |
| P6               | P3B3  | 90-110     | 3/2 7.5 YR    | 68 10 23                | Sandy clay          |
| P4               | P4A   | 0-12       | 3/2.75 YR     | 68 15 17                | Sandy clay          |
|                  | P4B   | 12-40      | 4/3.75 YR     | 53 28 19                | Sandy clay          |
|                  | P4C   | 40-110     | 4/4 10 YR     | 49 24 27                | Sandy clay          |
| P5               | P5A   | 0-10       | 3/2 5 YR      | 63 11 26                | Sandy clay          |
|                  | P5B1  | 10-30      | 3/1 10 YR     | 75 12 14                | Sandy clay          |
|                  | P5B2  | 30-60      | 4/3 10 YR     | 56 27 17                | Sandy clay          |
| P6               | P5B3  | 60-90      | 3/3 7.5 YR    | 52 38 10                | Clay                |
| P4               | P6A   | 0-20       | 3/1.75 YR     | 82 9 9                  | Clay sand           |
|                  | P6B   | 20-90      | 3/27.5 YR     | 95 2 3                  | Sand                |
Table 2. Characteristics of morphology and physical properties of soil research sites

| Transect | Layer | Soil structure | Soil consistency | Soil pore | Root | Surface rock (%)
|----------|-------|----------------|------------------|----------|------|-------------------|
|          |       | Shape | Size      | Quantity | Size | Quantity | Size |
| P1       | P1A   | Granular | Fine    | Many     | Medium | Common   | Fine, medium |
|          | P1B1  | Granular | Medium  | Many     | Fine   | Common   | Fine, medium |
|          | P1B2  | Granular | Fine    | Common   | Medium | Moderately few | Fine |
| P2       | P2B3  | Subangular | Blocky | Medium   | Friable | Common | Fine, moderately few, Fine |
| P3       | P3B2  | Subangular | Blocky | Medium   | Friable | Few     | Very fine, Few, Very fine |
| P4       | P4B   | Granular | Fine    | Many     | Medium | Common   | Fine |
| P5       | P5B1  | Subangular | Blocky | Medium   | Friable | Few     | Fine |
| P6       | P6A   | Granular | Fine    | Many     | Coarse | Many     | medium, Coarse|

3.2. Characteristics of Soil Chemistry

The pH value of H2O varies between 5.8 - 6.8, indicating that the soil pH was neutral to slightly acidic range. The relatively high range of soil soils pH was quite beneficial for plant growth because of the nutrient content of the soil in a favorable condition. Based on [13] that the number of soil samples with pH in the range of 5.5 - 6.5 shows that Andosol soil in Indonesia was dominated by amorphous clay minerals originating from areas with high rainfall and parent and andicytic-basaltic materials. The pH value of NaF was used as a way to determine properties in volcanic soils [7]. The results of the analysis presented in the Table 4 show that the average NaF pH value in each pedon has a value of ≥ 9.4 which indicates the presence of an inherent characteristic and confirms that the soil profile originates from volcanic activity.
The value of electrical conductivity (EC) each soil profile <1 dSm\(^{-1}\). The EC value was very low, so that the soil in this area was not classified as saline soils. The C-organic content in each soil profile was generally higher than the B horizon position of hilltops and foothills. The CEC was strongly influenced by the type and amount of colloidal clay minerals, the content of clay and organic matter. The low part of the soil CEC was thought to be caused by low levels of organic matter and clay content. The low part of the soil CEC was thought to be caused by low levels of organic matter and clay content. The low part of the soil CEC was thought to be caused by low levels of organic matter and clay content. The low part of the soil CEC was thought to be caused by low levels of organic matter and clay content. The low part of the soil CEC was thought to be caused by low levels of organic matter and clay content. 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Wibisono and Prasetyo's opinion, the results of the study were obtained with a high percentage of P retention, whereas the percentage of Al and Fe was low. This is presumably because the high calcium (Ca) content causes phosphate in the soil to be bound by Ca$^{2+}$.

3.3. Soil Mineralogy

Minerals are the main constituent elements of the soil and play an important role in determining the chemical and physical properties of soil. Mineral is one of the important indicators of weathering that has occurred, so that the presence or absence of a type of mineral in the soil can be interpreted as a guide to how the process of soil formation occurs. Minerals in the soil are distinguished from primary minerals (sand fraction minerals) and secondary minerals (clay mineral fractions) [17]. In this study a thin section method was used to analyze the type of mineral sand fraction in the soil. The mineral composition of the total sand fraction of the six pedons showed a relative composition with different percentages (Table 4). Generally, it was dominated by plagioclase and volcanic glass which were classified as easily weathered minerals, while Opaque minerals are only about ≤ 25% which were classified as resistant minerals, which reflect weathering still in its early stages. The amount of easily decomposed reserves including glass volumes was still very high, which was between 50-75% so that the soil nutrient reserves were quite high as a result of weathering these minerals.

| Transect | Profile | Mineral Composition (%) |
|----------|---------|-------------------------|
| P1       | Plagioclase (40)  
Opaque (10)  
Rock Fragment (Lithic) (35)  
Volcanic Glass (15) |
| P2       | Plagioclase (45)  
Opaque (15)  
Rock Fragment (Lithic) (25)  
Volcanic Glass (15) |
| P3       | Plagioclase (50)  
Opaque (25)  
Rock Fragment (Lithic) (5)  
Volcanic Glass (20) |
| P4       | Plagioclase (40)  
Opaque (15)  
Rock Fragment (Lithic) (25)  
Volcanic Glass (20) |
| P5       | Plagioclase (35)  
Opaque (25)  
Volcanic Glass (40) |

3.4. Soil Classification Based on USDA Soil Taxonomy

Based on the soil taxonomy system [7], the soil types in research site in three different topographic positions are presented in Table 5 and distribution of the soil type in the Banda Island showed in the Figure 2.
### Table 5. Types of soil in three different topographic positions in Banda Island District

| Topographic position | Profile | Island | Type of soil |
|----------------------|---------|--------|--------------|
|                      |         |        | Order | Sub-Order | Great Group | Sub Group |
| Hilltop              | P1      | Banda Naire | Entisols | Psammments | Udipsammments | Typic Udipsammments |
|                      | P4      | Lonthor (Banda Besar) | Entisols | Psammments | Udipsammments | Typic Udipsammments |
| Slope                | P2      | Banda Naire | Inceptisols | Udepts | Dystrudepts | Vitrandic Dystrudepts |
|                      | P5      | Lonthor (Banda Besar) | Inceptisols | Udepts | Eutrudepts | Vitrandic Eutrudepts |
| Foothills            | P3      | Banda Naire | Inceptisols | Udepts | Eutrudepts | Vitrandic Eutrudepts |
|                      | P6      | Lonthor (Banda Besar) | Andisols | Undands | Hapludands | Typic Hapludands |

**Figure 2.** Soil type map of Banda Island Indonesia

### 4. Conclusion

The characteristics and classification of soils formed from deposits of recent volcanic ash in Banda Island Indonesia vary in various geomorphic positions and topographic forms. Based on the research results showed that the soil profile at the position of the foothills and slopes in Banda Naire and the Banda Besar morphologically have Andisols properties, but physically and chemically characteristics of each soil profile didn’t not match with the Andisols requirements so that they were classified into Inceptisols (Vitrandic Eutrudepts and Vitrandic Dystrudepts) (in the slope), while those which qualify as the Andisols
(Typic Hapludands) were profile 6 (P6) (in the foothills). While at the top of the hill were classified as Entisols (Typic Udipsamments).

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