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Diversity of Soil Physical Properties of Andisols in Toposequence Results from the Eruption of Mount Tangkuban Parahu in Sukawana Tea Plantation

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ABSTRACT: Topography is one of the soil forming factors that affect soil properties and crop productivity. Soil properties that affect crop productivity include soil physical properties. The purpose of this research was to identify the characteristics of soil physical properties including permeability, bulk density, and soil porosity at various slope positions and identify the effect of slope position on soil physical properties. This research was conducted on a toposekuen located in Sukawana Tea Plantation which has an undulating to hilly topography with a slope of 25 - 45%. This research was conducted in May - July 2024. The research method used was comparative descriptive survey method based on direct observation in the field and continued with F-test to see the effect of slope position on soil physical properties with DMRT further test. Soil samples were taken as many as three replicates on each slope position (top, middle slope, lower slope). The results showed that the slope position did not significantly affect the permeability, bulk density, and porosity of the soil.

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KEYWORDS: slope, topography, toposequence

1. INTRODUCTION

Indonesia is formed through the process of major tectonic plate collisions and sits at the convergence of three primary plates in the world—Eurasia, Pacific, and Australia—resulting in numerous volcanoes scattered along the Ring of Fire. Indonesia hosts approximately 13% of the world's volcanoes (Sudrajat, 2009). West Java Province, in particular, boasts several volcanoes such as Mount Tangkuban Parahu and Mount Tampomas. The soils in Parongpong, West Java, are formed from the eruptions of Mount Tangkuban Parahu and contain essential nutrients crucial for plant growth. Based on soil classification, these soils belong to the Andisols order, which are rich in organic matter. Soil-forming factors such as parent material, climate, topography, organisms, and time interact to shape soil properties that significantly influence plant productivity, as observed in Sukawana Tea Plantation.

Sukawana Tea Plantation in Parongpong, West Java, is situated in a region characterized by undulating to hilly topography. The soils in Sukawana Tea Plantation are derived from Tjp2 parent material, formed from phreatomagmatic eruptions during the Young Tangkuban Parahu phase following the Old Tangkuban Parahu magmatic phase, dating back to the Quaternary period (2.58 million years ago). The climate falls under agroclimate zone C2, with wet months between January - May and October - December, and dry months from June - August. Despite tea being the dominant vegetation, the varying topography in this area is believed to influence the diversity of soil physical properties, warranting further study.

Slopes play a crucial role in soil formation and development through processes such as erosion, transportation, and deposition. Erosion can lead to the reduction of the A horizon layer, soil depth, and deterioration of soil physical and chemical properties (Suriadikusumah et al., 2014). Slope steepness and length determine the speed and volume of surface runoff, while slope position determines the level of erosion (Asdak, 2002).

Rainfall impact on upper slopes can disrupt soil aggregates, causing soil particles to detach and be transported by surface runoff. Consequently, there is sediment deposition of eroded soil on lower slopes, resulting in greater soil surface thickness there. The concept of toposequence illustrates changes in soil properties due to variations in topography (Wardhana, 2010). These changes are influenced by erosion processes in the area, as described by Omokaro (2023), demonstrating the relationship between topography and soil characteristics such as depth, texture, organic matter content, and others. This study aims to understand the differences in soil physical properties across various slope positions in the area, influenced by varied topography.

2. MATERIALS AND METHODS

2.1 Time and Location

The study was conducted from May 2024 to July 2024 at a toposequence in Sukawana Tea Plantation, Parongpong District, Parongpong, West Bandung Regency, West Java Province, owned by PTPN 1 Regional 2. Soil physical properties analysis was performed at the Soil Physics Laboratory, Soil and Water Conservation, Genesis & Classification, Land Evaluation (FKGE) Universitas Padjadjaran, Jatinangor, West Java.

2.2 Equipment and Materials

The equipment used in this research included: 1) Munsell Soil Color Chart, 2) GPS (Global Positioning System), 3) ring sampler, 4) measuring tape, 5) soil auger, 6) plastic bags, 7) clinometer, 8) labels, 9) A-frame, 10) hoe, 11) shovel, 12) stationery, 13) laboratory equipment for soil physical properties analysis, 14) Software ArcMap 10.8 and SmartStat XL.

The materials used in this research were: 1) soils developed in Sukawana Tea Plantation, 2) Contour Map of Sukawana Tea Plantation scale 1:25,000, 3) Slope Map of Sukawana Tea Plantation scale 1:25,000, 4) Soil Map of Sukawana Tea Plantation scale 1:50,000, 5) Geological Map of Bandung Sheet scale 1:100,000, 6) Soil physical properties analysis materials Pesticides.

2.3 Research Method

This research utilized a comparative descriptive survey method involving direct field observations, laboratory soil analysis, and statistical data processing. Aerial photo-based physiographic systems were employed to understand the site conditions before conducting the survey. The research comprised four stages: preparation, field research, laboratory analysis, and data analysis.

2.3.1 Preparation Stage

In the preparation stage, data and map inventories were conducted to determine soil sampling points in Sukawana Tea Plantation. Communication with PTPN 1 Regional 2 West Java for research permits was also carried out. Soil sample points were selected based on contour maps as references, with sampling points at P_1 (top), P_2 (middle slope), and P_3 (lower slope). The top was chosen based on criteria indicating areas unaffected by soil runoff from slopes above it with slopes ranging from 25% to 45%.

During the preparation stage, a pre-survey was conducted to assess the actual conditions of the selected observation locations. This stage also involved identifying the presence of allophane by analyzing soil pH using NaF solution (pH NaF). A pH NaF value greater than 9.4 indicates the presence of allophane.

2.3.2 Primary Research

Primary research was conducted by collecting soil samples at each location point along the predetermined toposequence. Undisturbed soil samples were taken from a depth of 0-30 cm using a ring sampler to determine soil permeability, bulk density, and porosity.

Sampling of undisturbed soils was carried out in three replicates and duplicates. Replicates of undisturbed soil samples were taken along the same contour line. The contour line was determined using an A-frame. The contour line creation process began by establishing point A, followed by identifying point B at a lower slope position according to the desired vertical interval (maximum 1.5 m). One leg of the A-frame was placed at point B, and the other leg was moved until the plumb line was centered over the marked crossbar. This new point was called point B1, which is at the same elevation as point B. This process was repeated to obtain a series of points forming a contour line. These points were connected using raffia string to form the contour line. Soil samples for replicates were then taken along the same contour line. This procedure was carried out at each slope position within the predetermined toposequence.

2.3.3 Laboratory Analysis

Laboratory analysis was conducted at the Soil Physics, Soil and Water Conservation, Genesis & Classification, and Land Evaluation Laboratory (FKGE) at Padjadjaran University to study soil physical properties. The parameters analyzed included bulk density, porosity, and permeability. The laboratory results were statistically tested using the F-test method in SmartStat XL to determine the influence of slope position on soil physical properties..

3. RESULTS AND DISCUSSION

3.1 General Conditions of the Research Site

3.1.1 Research Location

Administratively, Sukawana Tea Plantation is located in Parongpong Sub-district, West Bandung Regency, West Java. Geographically, Sukawana Tea Plantation is situated between the coordinates of longitude 107.58009 to 107.59704 and latitude -6.76557 to -6.79605, encompassing a total area of 231 hectares. The land at the research location is a tea plantation with tea planting patterns following the contour lines. Fertilization or maintenance is carried out once every six months. Soil samples were taken from a toposequence covering approximately 0.83 hectares with steep slopes (25-45%).

3.1.2 Slope

The Sukawana Tea Plantation area has varying slopes due to its hilly topography. This is evident from the various slope classes ranging from flat to steep (0 to >45%).

3.1.3 Climate

The annual rainfall in the research area over the past five years ranges from 1,869 to 3,090 mm/year. The average annual rainfall over the past five years is 2,627 mm/year. Monthly rainfall in the research area ranges from 51 to 424 mm. The average monthly rainfall at the research site is 219 mm. According to the Oldeman climate classification (1975), wet months (≥ 200 mm/month) are observed from January to May and October to December, while dry months (< 100 mm/month) are observed from June to August. This indicates that the research area falls within the "C2" agroclimatic zone according to Oldeman's classification.

3.1.4 Soil Types

The Sukawana Tea Plantation area consists of two soil types: Typic Udipsamments and Typic Hapludands (Sukarman et al., 2016). However, the soil sample location has Typic Hapludands soil. Typic Hapludands in the research location are Andisols containing humic substances.

3.1.5 Parent Material

The research site area consists of soils derived from volcanic ash parent material, dominated by silt and sand fractions, resulting in low bulk density and poor water retention capacity (Delmelle et al., 2015). According to the parent material map taken from the Bandung Geological Map at a scale of 1:100,000 (Silitonga, 1973), the parent material forming the soil at the research site is predominantly Tjp2. This Tjp2 material was produced by phreatic eruptions during the young Tangkuban Parahu episode following the magmatic phase of the old Tangkuban Parahu episode (Kartadinata et al., 2002).

3.2 Karakteristik Sifat Fisika Tanah

3.2.1 Permeability

Table 1. The Effect of Slope Position on Soil Permeability

Slope Position, P	Permeability (cm/h)
P_1 (top)	61.66 a
P_2 (middle slope)	55.52 a
P_3 (lower slope)	42.14 a

Explanation: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 significance level.

The laboratory analysis of soil permeability revealed that the values at each slope position were classified as very fast, according to the permeability class criteria by Uhland and O'Neal (1951). The high permeability values are influenced by the organic matter content, which increases the percentage of macro pores in the soil, facilitating water flow in saturated conditions. Additionally, the high percentage of sand fractions also contributes to the high permeability, as sand efficiently allows water to pass through.

Data in Table 1 show that there is no significant effect of slope position on permeability values at P_1, P_2, and P_3. This lack of significant variation may be due to the limited scope of sampling, which results in less pronounced differences in permeability values. The average permeability values tend to decrease from the top (P_1) to the middle slope (P_2), and further to the lower slope (P_3). This decline is suspected to be caused by the high organic matter and sand fraction content at P_1, which enhances soil porosity. According to Putri and Adinegoro (2020), high porosity affects increased soil permeability. The lowest permeability value was recorded at P_3, likely due to the accumulation of material at the lower slope, which impedes water flow and reduces soil permeability.

3.2.2 Bulk Density

Table 2. Effect of Slope Position on Soil Bulk Density

Slope Position, P	Bulk density (gr/cm^3)
P_1 (top)	0.84 a
P_2 (middle slope)	0.82 a
P_3 (lower slope)	0.81 a

Explanation: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 significance level.

Soil bulk density at the slope positions falls into the low category. This is due to the fact that the soil order is Andisols, which generally has a bulk density of > 0.9 g/cm^3. Analysis using the F-test indicates that the bulk density values at P1, P2, and P3 do not differ significantly ($\alpha = 0.05$), suggesting that slope position does not have a significant effect on bulk density (Table 2). However, there are differences in average bulk density values among slope positions, likely influenced by erosion and sedimentation processes.

Bulk density tends to decrease with lower slope positions, due to erosion affecting the top soil thickness at P1 and soil accumulation at P3. This change can affect soil porosity, with P3 generally having higher porosity compared to P1, consistent with the theory that bulk density is inversely related to porosity (Hardjowigeno, 2003).

3.2.3 Porosity

Table 3. Effect of Slope Position on Soil Porosity

Slope Position, P	Porosity (%)
P_1 (top)	68.13 a
P_2 (middle slope)	69.19 a
P_3 (lower slope)	69.31 a

Explanation: Mean values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 significance level.

Data analysis was conducted using the F-test to assess significance at the 5% level, examining the effect of slope position on soil porosity. Table 3 shows that the mean porosity values for each slope position are followed by the same notation, indicating that slope position does not have a significant effect on soil porosity in this study. The lack of significant effect may be attributed to the small scope of the toposequence. Additionally, the sampling distances at each slope position were not extensive, resulting in similar or non-significant differences in porosity results. Soil porosity at the research site tends to increase, likely due to the high organic matter content. Furthermore, soil porosity is influenced by several factors, including soil structure and texture (Hardjowigeno, 2007).

4. CONCLUSION

1. There are no diversity in bulk density, permeability, and porosity across each slope position.
2. There is no significant effect of slope position on certain physical properties of the soil within a toposequence at Sukawana Tea Plantation.

5. RECOMMENDATIONS

Although no significant effect of slope position on certain soil physical properties was found, further research could be conducted to consider external factors that may influence the results. For instance, investigating the impact of rainfall and soil erosion on the toposequence and examining the effects of existing vegetation on the soil could provide additional insights.

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