

Variation of Surface Soil Characteristics in Landslide Deposition Areas Based on Landslide Activities and Slope Position in Bompon Sub-Watershed, Magelang

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ABSTRACT

The physical characteristics of the surface soil are the crucial soil characteristics related to landslides. They can cause landslides and change due to landslides. The physical characteristics of the surface soil in agricultural land play an important role in providing nutrients and as a medium for plant growth. Landslide activities and slope position can change soil characteristics significantly. Studies on the physical characteristics of surface soil in landslide deposition areas have been studied previously, however most of those studies are not discussed yet in regarding with relation of this landslide deposition and agricultural land. The purpose of this study is to characterize and examine the variation of physical characteristics of the surface soil in landslide deposition areas among different landslide activities and slope positions.

The method used in this study was purposive sampling based on landslide activities (active, inactive) and slope position (upper-, middle-, and lower slope). Soil samples were taken on the landslide deposits with a depth of 0-30 cm. Soil samples were 11 variations.

The results showed that the physical characteristics of surface soil based on landslide activities or slope position were fine texture or clay; particle density, bulk density, and porosity were uniform; high atterberg numbers; slightly slow permeability; and low c-organic as well as organic matter content. Variation of the physical characteristics of surface soil showed high values on active landslides and lower slopes. The most influenced soil property due to landslide activities and slope position was soil permeability.

Keywords: *physical soil properties, landslide activity, slope position, agriculture, Bompon*

1. INTRODUCTION

The study of variation of surface soil physical characteristics in landslide deposition received less attention in agriculture. The physical characteristics of the surface soil are an important part of the soil body. The physical characteristics of the surface soil play an important role in providing nutrients and a place for plant growth. Each type of soil has unique characteristics, can be useful for certain land uses, and has the potential to cause natural disasters. Soil characteristics can change over time as well as naturally

occurring land dynamics. Sartohadi et al. (2018) explained that the land in the landslide deposition section shows fertile soil conditions and is good for plant growth.

Landslide is a natural phenomenon that can be caused by internal or external factors. According to Nursaba'an (2010), landslides can be caused by three conditions: a steep slope, a waterproof layer, and sufficient water content in the soil. Pranata et al. (2016) added that high rainfall was accompanied by soil conditions resulting from thick volcanic ash weathering, and the presence of a waterproof layer will further

increase the occurrence of landslides. Naryanto et al. (2019) added that landslides can occur due to the presence of volcanic breccia, which is easily weathered, causing a thick layer of soil, so it is easily saturated and disturb slope stability.

Active landslides and inactive landslides are found mostly on the upper slopes, middle slopes, and lower slopes of hills. Jacob et al. (2016) explained that active landslide is a landslide which was still moving during the last 5 years. Generally, active landslides are characterized by slope conditions in the former steep landslides and have not been widely used. According to Masruroh (2016), active landslides provide an overview of the conditions of mixed soil. Varnes (1968) said that the absence of material movement during the last 12 months characterizes inactive landslides. Inactive landslide is characterized by fairly stable slope conditions and has been widely used by local residents.

The Bompon sub-watershed is one of the landslide-prone areas in Central Java. The Bompon sub-watershed has a thick layer of soil and a high content of clay. This condition is due to the Bompon Sub-watershed located in the volcanic transition zone of the Sumbing Volcano and Menoreh Mountains and the alteration process (Pulungan, 2016; Sambodo et al., 2018). Budianto (2016) explained that the presence of sensitive clay content with a high sensitivity level makes Bompon sub-watershed prone to landslides. BPBD (2020) recorded that there were 247 landslide cases in Magelang during the past year, 36 of which occurred in the Kajoran sub-district. This situation causes landslides to become a crucial hazard to be revealed in the study area.

Landslides in the Bompon sub-watershed occur during the intensive rainy season. The types of landslides that occurred at the research location were rotational and translational. Based on previous research (Masruroh, 2016) it was found that the landslide inventory data in the Bompon Sub-watershed contained 17 rotational type inactive landslides, 14 rotational active landslides, and 4 translational active landslides. The total area of landslides that have been identified through the interpretation of 15 small format aerial photographs of the entire Bompon sub-watershed is 44.09% or 1.32 Ha. Landslides that occur in the Bompon Sub-watershed are caused by triggering factors (slope conditions) and controlling factors (rock and soil conditions).

Unstable slope conditions can be a trigger factor for landslides in the Bompon Sub-watershed. The physical appearance in the Bompon Sub-watershed is influenced by human activities such as clearing mixed gardens and cultivation land, as well as cutting slopes for houses and roads which can cause unstable slopes. Landslide susceptibility in the Bompon Sub-watershed consists of three classes of vulnerability : high 20.44%, medium

52.13%, and low 27.43% (Masruroh, 2016). The landslide susceptibility in the Bompon sub-watershed is caused by the influence of the velocity of the water flow which erodes laterally at the foot of the slope, causing the slope to be unstable.

The controlling factor for soil formation in the Bompon Sub-watershed is influenced by the alteration process in the bedrock supported and weathering of volcanic ash surface material. Soil formation due to alteration and weathering processes causes soil conditions to be more than 4 meters thick and dominated by clay. The clay material resulting from the alteration and weathering process has wrinkle-swelling properties, is sensitive, and is easy to destabilize the slope. Sensitive clay is a fine material that will experience leaching and lose its structure when interacting with water (L'Heureux et al., 2014), soften as the water content increases and trigger landslides (Budianto, 2016), and cause the soil to crack easily as the initial initiation of the landslides process (Wulandari, 2018)

2. METHOD

The research was conducted in the Bompon sub-watershed, Magelang, which is the volcanic transition zone of the Sumbing Volcano and Menoreh Mountains. Sampling was carried out in the area of active landslides and inactive landslides. Data collection was carried out by collecting data from previous researchers, field surveys, and laboratory analysis. The sample points were determined by using the purposive sampling method based on landslide activities and slope positions. Determination of sample points was done by utilizing information on landslide activity, slope position, and land use. The sampling points were obtained as many as 11 variations of landslide deposition points which were spread upstream to downstream of the Bompon sub-watershed. Sampling points were carried out on the landslide deposition section with a depth of 0-30 cm. Soil samples were taken in the form of disturbed soil samples and undisturbed soil samples. Soil physics parameters used were texture, bulk density, particle density, porosity, liquid limit, plastic limit, shrinkage limit, permanent wilting point, plasticity index, maximum water holding capacity, permeability, cole index, and organic matter. Data processing was performed using Microsoft Excel and then analyzed to find the standard deviation value.

3. RESULT AND DISCUSSION

Soil characteristics can influence the geomorphological processes that occur in that area. The physical characteristics of the soil were affected by landslides cause the arrangement of the soil horizon to change irregularly, affecting the pedogenesis process.

Noviyanto et al. (2020) explained that the landslide deposition area showed a random horizon arrangement because it has experienced stirring. Soil physical characteristics can be used as a parameter to assess the impacts and consequences of landslides.

Active and inactive landslides show different landslide movements in the field. Active landslides have dynamic movements characterized by intensive geomorphological processes and temporally continue to experience landslide expansion (Cruden and Varnes, 1996). Active landslides in the Bompon Sub-watershed

are mostly found downstream because they are influenced by slopes, river flow speeds, and human activities in land use. The Inactive Avalanche did not show significant movement for more than 12 months (Varnes, 1968). The distribution of inactive landslides in the Bompon Sub-watershed follows the watershed ridge pattern. More inactive landslides are found in the upstream part of the watershed with a wider landslide area compared to inactive landslide areas in the downstream area.

Table 3.1. The Effect of Active and Inactive Landslides on the variation of Physical Characteristics of Surface Soil in the Landslide Deposition Area

Parameter	Active Landslide						Inactive Landslide				
	Range Data (%)		Mean	STD	STD (%)	Range Data (%)		Mean	STD	STD (%)	
	Min	Max				Min	Max				
Texture	Sand	7.65	15.50	11.27	2.98	26.43	5.90	26.66	13.39	6.46	48.28
	Silt	8.51	23.22	15.11	4.99	33.02	6.00	18.58	13.47	4.60	34.12
	Clay	61.27	83.84	72.30	8.22	11.36	57.54	88.10	73.14	9.12	12.47
Bulk Density (gr/cm3)	1.03	1.24	1.14	0.08	7.33	1.05	1.40	1.16	0.12	10.20	
Particle Density (gr/cm3)	2.07	2.29	2.15	0.08	3.93	2.06	2.32	2.20	0.09	4.25	
Porosity (%)	41.36	51.47	46.88	3.63	7.74	39.66	52.17	46.73	3.76	8.05	
Liquid limit (%)	49.35	79.03	63.08	9.92	15.72	40.80	68.00	57.53	8.78	15.27	
Plastic limit (%)	43.79	63.96	54.28	7.00	12.90	37.50	60.90	52.13	8.29	15.90	
Shrinkage limit (%)	35.65	49.48	42.83	5.05	11.80	30.50	52.70	41.68	7.86	18.87	
Permanent wilting point (%)	23.02	43.82	33.70	7.36	21.83	10.10	33.22	25.14	8.20	32.61	
Plasticity Index (%)	12.68	29.55	20.09	6.35	31.61	10.30	18.68	15.99	3.47	21.73	
Shrinkage Index (%)	8.14	18.12	11.46	3.56	31.06	7.00	15.11	10.45	2.70	25.83	
Water Holding Capacity (%)	19.17	56.01	29.22	13.66	46.74	21.59	46.60	32.39	9.08	28.04	
Permeability (cm/jam)	0.37	3.02	1.53	0.96	62.88	0.02	4.52	1.94	1.57	80.74	
Cole Index	0.08	0.13	0.10	0.02	18.16	0.05	0.12	0.09	0.03	28.69	
C-Organic	0.08	1.35	0.96	0.45	46.93	1.11	2.80	1.68	0.64	37.73	
Organic matter content (%)	0.14	2.32	1.65	0.77	46.81	1.91	4.83	2.90	1.10	37.77	

Two types of landslides occur in the Bompon Sub-watershed, namely rotational and translational types. The translational and rotational landslide is part of the slip-slide but has a different shape. Rotational landslides have a perimeter shape and a landslide body like a curve. Most of the rotational landslides have a smaller slope angle than the translational type of landslides. Rotational landslides occur in soil conditions that are undergoing soil development from R to C. Rotational landslides are part of the landslide body are used for agricultural land in the form of mixed gardens. Rotational landslides produce more volume of landslide material than translational landslides. Most of the rotational landslides have major and minor escarpment planes. This condition shows that in rotational landslides there are several times of material movement. The translational landslide has a perimeter shape and a

planar landslide body, which causes the landslide material to move gliding. The steep slope conditions in the translational landslide caused most of the landslide bodies to be not used.

The typical physical characteristics of surface soils can be differentiated from the active and inactive landslide scars. The physical characteristics of the surface soil in the landslide section in active and inactive landslide activities showed different variations (Table 3.1). The physical characteristics of the surface soil in active landslides showed more variety than those in inactive landslides. In general, soil permeability showed that soil parameters were heavily affected by landslide activities because it showed the highest standard deviation value in both active (62.88%) and inactive (80.74%) landslide.

Table 3.2. Slope at the Research Landslide Location

Landslide Activity	Position	Land Use	Slope (%) / (°)
Active Landslide	Upper Slope	Mixed Garden	45% ; 24°
	Middle Slope	Mixed Garden	28% ; 16°
		Cultivation Land	45% ; 24°
	Lower Slope	Mixed Garden	63% ; 32°
Inactive Landslide	Upper Slope	Cultivation Land	34% ; 19°
		Mixed Garden	21% ; 12°
	Middle Slope	Cultivation Land	30% ; 16°
		Mixed Garden	30% ; 16°
		Cultivation Land	26% ; 15°
Lower Slope	Mixed Garden	30% ; 16°	
	Cultivation Land	27% ; 15°	

The physical characteristics of the surface soil in active landslides showed a higher variation than those in inactive landslides. Active landslides showed that there were still visible cracks in the lowlands (Figure 3.1), water seepage (Figure 3.2), sparse land cover, and steep slope conditions (table 3.2). Active landslides indicated the condition of the soil material which stolen actively moving. Masrurroh (2016) explained that active landslides provided an overview of the mixed soil condition, so it has sparse vegetation and looks brown. Mixing soil at different types of landslides caused the topsoil and subsoil to mix, so soil characteristics' distribution varied. Noviyanto et al. (2020) added that active landslides caused a change in soil morphology in the body and legs to become irregular, so it caused a higher variation of physical characteristics of the surface soil.



Figure 3.1. Cracking in the main scarp

Inactive landslides showed a slightly lower variation of soil characteristics than active landslides. Inactive landslides indicated a more stable slope condition than active landslides (Table 3.2). However, the permeability of the surface soil in inactive landslides has a high variation compared to other soil parameters. Inactive landslides showed denser and more diverse vegetation conditions. Soil characteristics inactive landslides showed a high variation of bulk density and porosity

values, so the soil permeability was also more diverse (Table 3.1). According to Chen (2009), soil permeability has a dynamic value where the relationship between porosity, organic matter, texture, slope, and land cover can be controlled.



Figure 3.2. Water Seepage on Active Landslide

The physical characteristics of the surface soil at each slope position showed different variations (Table 3.3). The lower slope showed the most varied organic matter content compare to other soil parameters. The lower slope showed the accumulation zone causing the soil material to mix. Miheretu and Yimer (2017) explained that the organic matter content on the lower slope showed the most variation values due to the transportation of organic material from the upper and middle slopes.

The upper and middle slopes showed the most variation surface soil permeability compared to other soil physical parameters. The surface soil permeability on the middle slope was the lowest compared to the upper and lower slopes. Permeability was influenced by the conditions of bulk density and soil porosity. The soil porosity on the upper slope showed the highest standard deviation value compared to the middle and lower slopes (Table 3.3). The middle slope showed the

porosity value, which also has the lowest variation. Alvarez et al. (2018) stated that the value of porosity can be caused by differences in cultivation practices, the activity of soil fauna, and root activity in the soil.

Fashaho et al. (2020) also stated that soil porosity was related to disturbances in the soil such as fauna activities and soil cultivation. Soil layer was deeper so soil disturbance will be less.

Table 3.3. Effect of Slope Position on Variation of Surface Soil Physical Characteristics in Landslide Deposition Areas

Parameter	Upper Slope					Middle Slope					Lower Slope					
	Range Data		Mean	STD	STD (%)	Range Data		Mean	STD	STD (%)	Range Data		Mean	STD	STD (%)	
	Min	Max				Min	Max				Min	Max				
Texture	Sand	5.90	13.72	9.09	3.35	36.86	9.21	14.01	11.72	2.00	17.04	9.99	26.66	15.64	6.73	43.02
	Silt	6.00	14.66	9.72	3.64	37.42	8.57	17.21	13.14	3.29	25.00	15.81	23.22	18.66	2.81	15.08
	Clay	71.62	88.10	81.19	6.98	8.60	70.91	79.08	75.14	3.52	4.69	57.54	71.02	64.06	5.10	7.97
Bulk Density (gr/cm3)	1.07	1.40	1.23	0.13	10.93	1.14	1.24	1.18	0.04	3.70	1.03	1.10	1.06	0.03	2.43	
Particle Density (gr/cm3)	2.10	2.32	2.22	0.09	4.13	2.09	2.29	2.20	0.10	4.34	2.06	2.21	2.13	0.07	3.19	
Porosity (%)	39.66	52.17	44.40	5.54	12.48	45.45	47.16	46.10	0.64	1.38	46.58	51.47	49.29	1.82	3.68	
Liquid limit (%)	53.65	68.00	61.41	5.92	9.63	49.35	67.08	60.03	6.87	11.45	40.80	79.03	59.06	13.56	22.95	
Plastic limit (%)	45.72	60.70	52.28	6.26	11.97	43.79	63.96	55.72	7.73	13.88	37.50	59.39	51.12	8.19	16.02	
Shrinkage limit (%)	35.80	50.80	41.68	6.54	15.69	35.65	52.70	43.33	6.53	15.08	30.50	49.48	41.46	6.98	16.84	
Permanent wilting point (%)	21.40	35.33	29.60	5.95	20.10	22.40	43.82	31.50	7.84	24.90	10.10	38.22	26.14	10.76	41.16	
Plasticity Index (%)	17.20	24.14	20.01	2.98	14.92	12.20	20.39	16.49	3.58	21.74	10.30	29.55	17.60	7.42	42.17	
Shrinkage Index (%)	9.90	11.97	10.60	0.97	9.16	18.12	15.11	12.39	4.35	35.14	7.00	12.56	9.66	1.99	20.58	
Water Holding Capacity (%)	21.59	46.60	31.81	10.71	33.67	21.24	42.50	28.32	8.48	29.93	19.17	56.01	32.92	13.94	42.35	
Permeability (cm/jam)	0.02	2.28	1.49	1.04	69.82	0.32	1.40	0.95	0.43	45.12	0.37	4.52	2.75	1.50	54.50	
Cole Index	0.05	0.13	0.10	0.04	35.59	0.07	0.10	0.09	0.01	12.45	0.08	0.12	0.09	0.02	17.72	
C-Organic Organic matter content (%)	1.29	2.30	1.65	0.46	28.09	1.11	1.39	1.20	0.11	9.41	0.08	2.80	1.29	0.98	75.74	
	2.23	3.97	2.84	0.80	28.16	1.91	2.39	2.07	0.19	9.26	0.14	4.83	2.22	1.68	75.65	

In general, the lower slopes showed a higher surface soil physical characteristics variation than the middle and upper slopes. Residual zones and landslide initiation zones characterized upper slopes. The middle slope of the hills was characterized by an erosional zone where intensive erosion processes occurred. The hill's lower slopes were characterized as an area for deposition of soil material from erosion or landslides. The lower slope was characterized as an area of soil material accumulation, causing the surface soil's physical characteristics to be more varied. Baskan et al. (2016) added that topographic conditions only affected the process of erosion, transportation, and deposition of the related soil material.

A landslide caused movement of soil material which will change the position and composition of the soil material. A landslide causes the soil material to become loose, so it is prone to erosion when it rains, triggering another landslide. Landslides in other parts of the landslide body will eventually change the meso morphology shape in the landslide body. This condition caused the hillside that experienced landslides to reach a stable angle for longer. At that time, there has been a change in the shape of the slope at a macro level (Candraningrum, 2017).

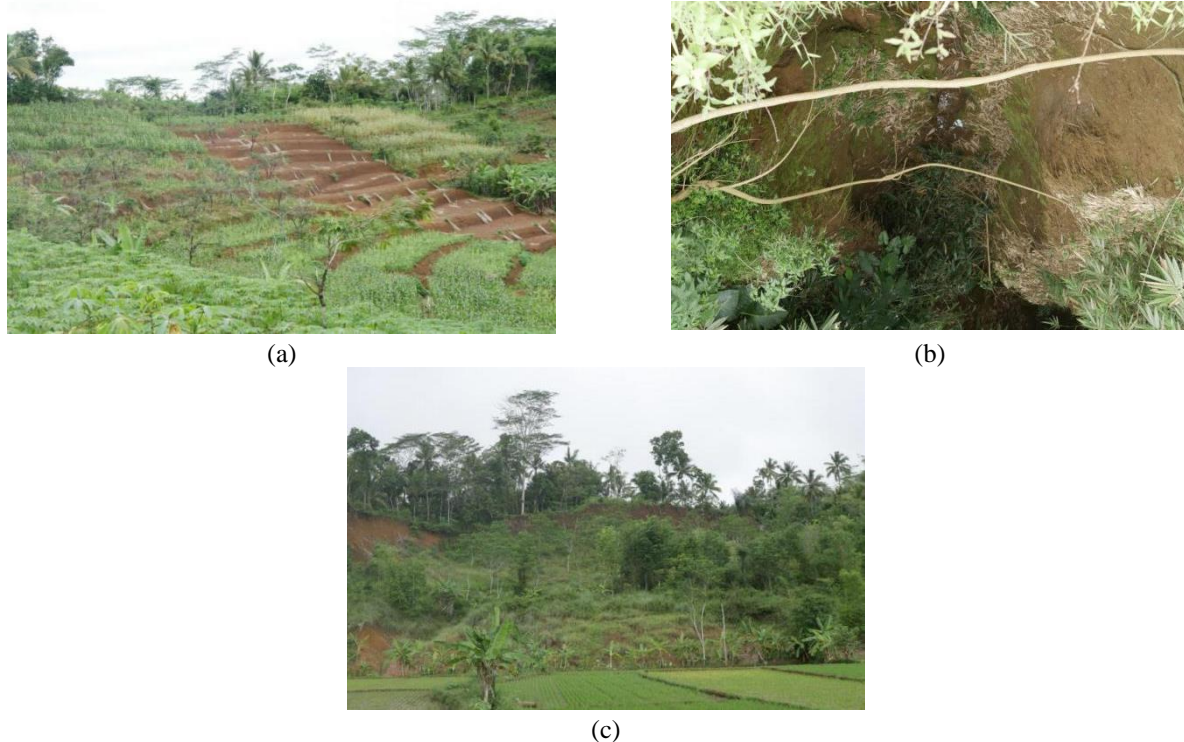


Figure 3.3. Landslide at any slope position. (a) Upper Slope (b) Middle Slope (c) Lower Slope

4. CONCLUSION

The physical soil characteristics in the landslide deposition area in the Bompon sub-watershed resulted in variations value of properties based on its landslide activity and slope position. The physical characteristics of the surface soil that are most affected by landslide activity and slope position were soil permeability. The physical characteristics of the surface soil in landslide deposition have a higher variation for active landslides and lower slopes than inactive landslides, upper slopes, and hilly middle slopes. Differences in vegetation and slope in active and inactive landslides caused variation in the physical properties of the surface soils. The variation of surface soil physical characteristics in terms of slope position was influenced by the process of redistribution of soil surface material at each slope position. The stirring soil process influenced the variation of surface soil physical characteristics in terms of landslide activity.

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