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Selected Physical Properties of Andisols under Different Land Use Condition in Gunung Kerinci Subdistrict, Jambi

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ABSTRACT

Selected Physical Properties of Andisols under Different Land Use Condition in Gunung Kerinci Subdistrict, Jambi (Endriani): Objective of the research was to study the effect of different land use at some land slope condition on some physical properties of Andisols in Gunung Kerinci Subdistrict, Jambi.. The research was conduct using field survey and purposive random sampling methods to collect soil. The land use which was using in this study were: forest, cultivation, cinnamon, and coffee plantation, while land slope level weres: 3-8%, 8-15%, 15-25 %, and > 25%. The results showed that among land use types, the rank of soil physical properties, such as: soil organic matter, bulk density, porosity, percentage of agregation, stability of agregate, pore distribution and permeability were in order of : forest > cultivation > cinnamon > coffee. Land conversion from forest to agricultural land caused decreasing in the soil physical properties. The higher level of land slope caused the decreasing of soil physical properties at all type of land use.

Keywords: Andisols, land slope, land use, soil physical properties

INTRODUCTION

Conversion forest to agricultural land generally cause a declining in hydrological functions of forest (Wilk *et al*. 2001). This activity is caused by increasing population who utilize the land for farming without applying rules of water and soil conservation and land capability. Due to limited of land area suitable for agriculture, farmers were expanding their land by clearing of forest land in the area of the mountaineus slope (Utami *et al.* 2005).

Utilization of land resources that have a steep slope for agriculture has a big risk to erosion, especially when the land was used for farming of annual crops. The conversion of forests into agricultural of annual crops involves a complex factors, including of soil tillage, planting, maintenance, and harvesting of plant cultivation. These activities will provide a significant impact on soil properties (Asdak 2004). Several studies in the past have shown that changing of land use may have significant impact on erosion and agricultural soil properties, soil degradation by acidification, nutrient leaching and organic matter depletion (Salomon *et al*. 2002; Szilassi *et al.* 2006; Dariah *et al.* 2008).

Most of land degradation in Indonesia occurs in the cultivated land of which is caused mainly by erosion, deterioration of soil physical properties, and problems on water and nutrient availability in soil. Furthermore, conversion of forest land in the plantation areas will enable to give the effect of erosion and runoff smaller than cultivation crops (Saidi 2000; Benjamin *et al*. 2007; Partosedono, 1977; Yao *et al*. 2010). The results showed that the effect of different land use system on soil physical properties following in order: forest > cinnamon > paddy > coconut > cultivation (Saidi and Rostim 2003). Tree-based land use has a level far below the erosion-based land use cultivation. However, when the floor of the plantation was processed and used for intensive cultivation crops, then the erosion

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increased (Vadari and Agus 2003). Land use changes from forest to coffee agroforestry systems, coffee monoculture and grass land caused the deterioration of soil physical properties by reducing soil macro pores in a row of about 59%, 71% and 38%, respectively.

Erosion is a major cause of land degradation in Indonesia. Land degradation was indicated by declining value of the physical properties and chemical properties, reduction in soil biological activity, and declining crop yields. If these conditions are not immediately repaired, land degradation will continue and slowly emerges a new critical (Gisladottir and Stocking 2005). Furthermore, it is explained that the main factor causing erosion in Indonesia is the high amount and intensity of rainfall, especially in Western Indonesia. Even in Eastern Indonesia which was classified as dry climates, the erosion is quite high, although total annual rainfall is low (Kurnia *et al.* 2005).

Slope factor is also the cause of erosion in dryland farming. In Indonesia, annual crop farming is mostly done on dry land slope. It is difficult to avoid because most dry land in Indonesia have a slope greater than 3% with form regions wavy, undulating, hilly and mountainous include 77.4% of all land. In Jambi Province, upland slope is very dominant and more than 81.34% have a wavy, undulating and hilly to mountainous, and only about 18.66%, relatively flat. From the area, about 40.98% upland slopes located at Kerinci Regency (Hidayat and Mulyani 2005). The hilly area of Loess Plateau has the highest soil erosion rates in the world, serious soil erosion causes great losses of plant nutrients. In almost all land use in Loess Plateau, slope farmland was contributed most on the soil erosion (Meng *et al*. 2008)

Conversion from forest into cultivation land and cinnamon in slope area caused a decreasing in soil physical properties. Increasingly steep slope affected soil permeability and soil structure and decreased soil organic matter is low, however it increased soil erosion potential (Endriani 2008). Yulnafatmawita (2004) showed that the change of land use of tropical rain forests into pasture decreased soil organic C from 6.9 to 5.6% and total N from 0.63 to 0.53%.

The research aim was to study the physical properties, such as: organic matter content, volume weight, total pore space, soil permeability, available pore, slow drainage pores and pore water, aggregate stability and soil aggregation under the different land use on some conditions slopes in Gunung Kerinci District, Jambi Province.

MATERIALS AND METHODS

Time and Site of Study

The research was conducted from April 2008 to November 2008, at Subdistrict Gunung Kerinci, Jambi Province. Our research is an integral part of integrated studies at the site that has been established by considering the topography and current land use (Figure 1). Site selected were represent the area of land with a slope conditions varied and diverse land use.

Research Methods

Research was conducted by survey methods. Soil sampling was done by purposive random sampling method based on the work map created from the overlay map of soil types, topographical maps and land use maps.

The land-use systems studied were: forest, cinnamon, coffee plantation, and cultivation. Topography of the study area was slope of 3-8%, 8-15%, 15-25%, and > 25%. Materials and equipments used in this study were the global positioning system (GPS), administrative maps, soil types map, topographical maps, land use maps, geological maps, abney level, clinometer, tape, stationery, and the camera as well as materials and equipment for soil analysis in the laboratory.

Research Stages

The study involved several steps as follows:

Preparation

The preparation stage was collecting all the supporting data including the administrative map, the map of soil types, land use maps, and topographical maps. Working map prepared by overlaying the maps. It also permits the study of administrative correspondence and prepared well permit from the agency itself as well as researchers in the study area. Furthermore, materials and the equipment for field survey were prepared.

Preliminary Survey

At the preliminary survey, preliminary data was cross checking with actual conditions in the field. Cross-checking was done on the land use of current and future plans, topography of land in each land use type, as well as perceptions and knowledge of farmers

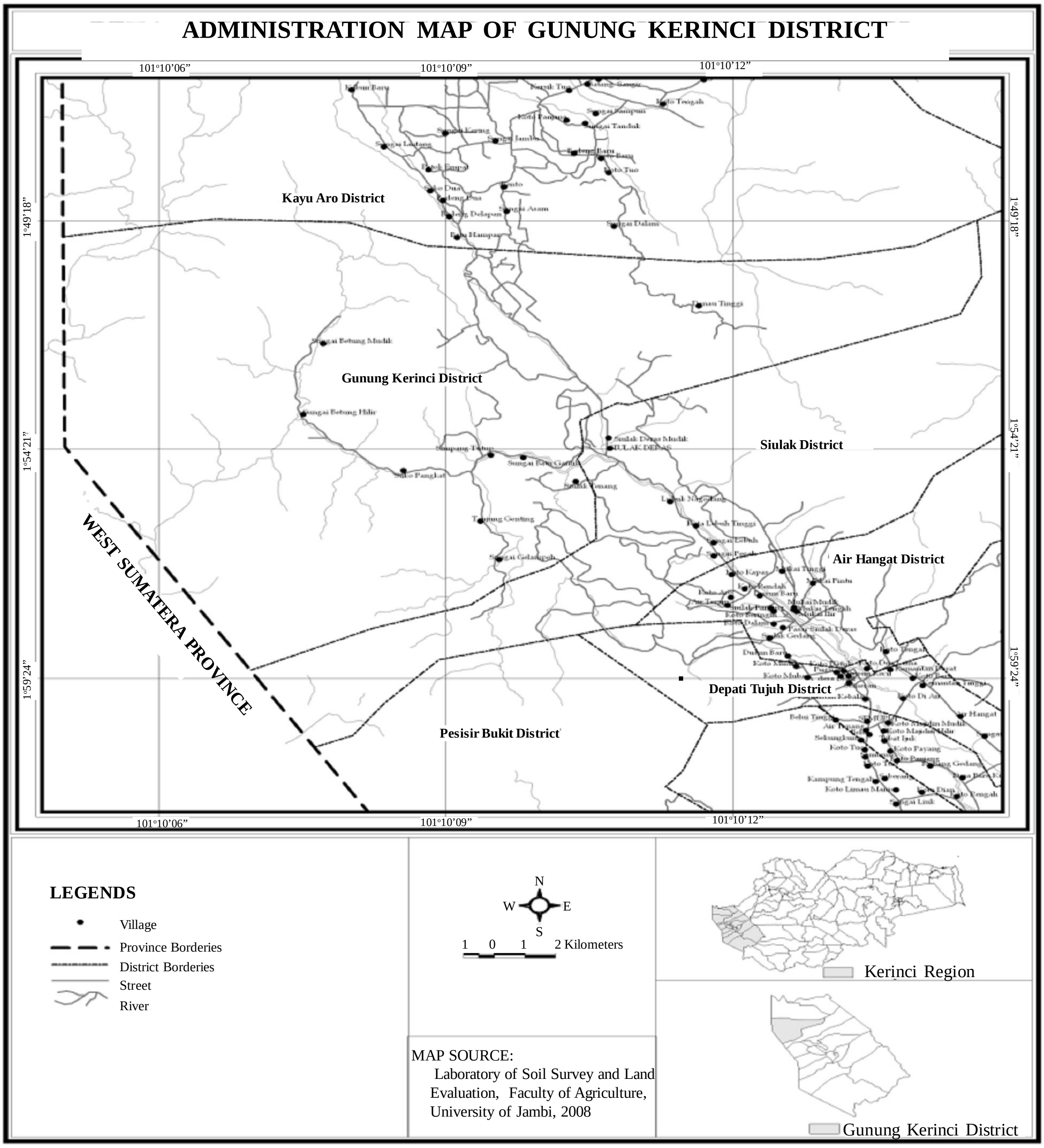

Figure 1. Research site.

about conservation farming. Thorough observations of the condition on the field were conducted to obtain starfish representative sampling of work as outlined on the map.

Main Survey

The main survey was done by collecting data physical and spatial characters of the land. On this occasion, the soil samples were taken by using purposive random sampling at a depth of 0-30 cm and 30-60 cm for soil physical properties analysis in the laboratory. The soil samples were taken using the ring samples for analysis of particle density, weight of volume, total pore space, permeability, and soil water retention at different pF values. Disturbed soil sample was also taken for analysis of organic materials, and soil particle size distribution. In addition, soil samples were taken for analysis of intact soil aggregation and stability of soil aggregates. Besides of soil sampling, measurements and observations of physical properties in the field, also carried out on slope steepness, slope length, cover crop, and soil management.

Data Collection and Analysis

Data collections in the field were conducted using GPS, which include: data slope and slope length. The physical properties of soil under study included soil organic matter was analyzed using camouflage dry methods, particle density, volume and weight of the total soil pore space by gravimetric methods, aggregation by dry sieve method analizer, aggregate stability by wet sieve method analizer, and fast drainage pores, slow drainage pores and pores of available based on water levels at several values pF were using the pressure plate and pressure membrane apparatus.

The results obtained were interpreted based on the assessment criteria based on the physical properties of soil and land use types and slope.

RESULTS AND DISCUSSION

Organic matter, Bulk density, Total Porosity and Permeability of Soil

The observation of the organic matter content, bulk density, total porosity and permeability of soil in different land use and slope were presented in Table 1. Organic matter content in four types of land use were already in succession from high to low, namely forest > cinnamon > coffee plantation > cultivation. Soil organic matter on cultivation, cinnamon and coffee plantation, was lower than expected due to the contribution of organic matter from both litter leaves and dead roots in the agricultural land were lower than the forest. Soil organic matter in the cultivation was the lowest since the mixture had a short growth layers (0-30 cm to 30-60 cm) and soil organic matter were decreased with the depths. Jinbo *et al.* (2006) reported the impact of using agricultural land to total-C content, in which the upper agricultural land were usually bare, especially between harvesting and next planting time which caused the existing organic matter decomposed.

Furthermore, the longer soil nurient cycle, the contribution of organic material are not throughout the year. In addition, organic matter layer reached a maximum up to 30 cm, then decreased with increasing soil depth. This is because the plant root systems distributed at the maximum depth. Furthermore, increasing steep slopes, decreased soil organic matter at four land use studied. This is apparently due to the litter from fewer plants were eroded into the bottom of the slope.

Soil bulk density (BD) in the four land use from low to high were: forest < cultivation < coffee < cinnamon. The opposite happens in the total porosity (f) of land that is forest> cultivation> coffee > cinnamon. This was apparently associated with soil organic matter content, whereby the higher soil organic matter, the lower bulk density but the higher soil porosity. These results were in agreement with Endriani *et al*. (2003), Emadi *et al*. (2008), and Khresat *et al*. (2008) who also reported that bulk density of surface and subsoil and organic matter decreased in cultivated soil compared to the forest soil. Cultivated soils were found to exhibit a significantly lower status in physical soil properties as compared to forest soils. This general declining in the soil physical and chemical properties, in turn, contributed to soil erosion, reduction of soil fertility and land degradation. Benjamin *et al*. (2007) reported that perennial crops system was more effective in improving soil physical properties than annual crops that are harvested each year. The perennial crop has root system contributes to the pore size distribution which was more stable.

Permeability of soil in the four land use decreased with increasing steep land slope. Furthermore, the soil permeability from high to low was in the order: forest > cultivation > cinnamon > coffee plantation. The magnitude permebaility was affected by soil physical properties, where the nest soil has high permeability. These results were in agreement with Endriani (2008) who had also reported that permeability of soil decreased with increasing steep slopes.

Soil Pore Size Distribution

The average value distribution of soil pores on the forest, cultivation, cinnamon and coffee plantation, as well as different slopes are presented in Table 2.

Aeration pores and available water pore in the four land use from high to low was in the order: forest > cinnamon > coffe > mix crop (cultivation). The highest aeration and available water pore was found at forest lands because forests have a better soil structure and the nest so that the soil pore size

Table 1. Soil organic matter (SOM), bulk density (BD), total porosity (f) and permeability (K) of soils on site research.

Land Use	SOM (%)			BD (g cm^{-3})			Porosity (%)			Permeability (cm h^{-1})		
	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean
Forest 3-8%	12.64	7.78	10.21	0.67	0.75	0.71	66.77	64.76	65.76	20.13	12.40	16.27
Forest 8-15%	11.80	7.62	9.71	0.69	0.80	0.74	65.79	62.37	64.08	16.32	12.69	14.50
Forest 15-25%	10.77	7.52	9.14	0.71	0.66	0.68	65.40	58.04	61.72	15.44	12.52	13.98
Forest >25%	10.16	7.40	8.78	0.73	0.91	0.82	64.76	43.06	53.91	14.54	12.40	13.47
Mean	11.34	7.58		0.70	0.78		65.68	57.06		16.61	12.51	
Cultivation 3-8%	7.87	5.25	6.56	0.67	0.75	0.71	68.37	65.31	66.84	16.32	11.62	13.97
Cultivation 8-15%	7.55	4.80	6.18	0.70	0.80	0.75	66.93	62.88	64.90	15.79	11.86	13.83
Cultivation 15-25%	7.31	3.97	5.64	0.72	0.83	0.78	65.82	61.68	63.75	14.03	11.40	12.71
Cultivation >25%	6.64	3.88	5.26	0.75	0.90	0.82	64.98	58.78	61.88	14.13	11.44	12.79
Mean	7.34	4.47		0.71	0.82		66.53	62.16		15.07	11.58	
Cinnamon 3-8%	10.24	7.03	8.63	0.75	0.89	0.82	63.39	58.01	60.70	15.71	12.67	14.19
Cinnamon 8-15%	9.31	6.89	8.10	0.78	0.92	0.85	62.39	56.64	59.51	15.38	12.40	13.89
Cinnamon 15-25%	9.06	6.53	7.79	0.81	0.92	0.87	60.92	57.15	59.03	14.82	11.69	13.25
Cinnamon >25%	8.02	6.69	7.36	0.85	0.96	0.90	59.76	55.09	57.42	14.04	11.52	12.78
Mean	9.16	6.78		0.80	0.92		61.61	56.72		14.99	12.07	
Coffee 3-8%	8.94	7.01	7.98	0.68	0.78	0.73	67.73	63.21	65.47	14.82	12.78	13.80
Coffee 8-15%	8.22	6.54	7.38	0.71	0.81	0.76	66.13	61.96	64.04	14.08	12.49	13.28
Coffee 15-25%	8.13	6.51	7.32	0.74	0.89	0.81	64.96	59.27	62.11	13.72	12.48	13.10
Coffee >25%	7.64	5.79	6.72	0.75	0.89	0.82	64.75	58.26	61.50	13.44	12.40	12.92
Mean	8.23	6.46		0.72	0.84		65.89	60.67		14.02	12.54	

distribution was dominated by aerasion pores and the available water pore. McVay *et al.* (2006) stated that the land with a big slope has a greater surface runoff and less groundwater stored in the soil profile. This is closely related to soil organic matter content and soil surface which is covered by crop canopy. Arsyad (2006) stated that organic matter can hold water two to four times its weight so that soil containing high organic matter will have high soil moisture content.

Effect of slope on the pore size distribution shows that the higher gradients of slope the lower the aeration pore and water available pore are. This is apparently because the land is steeper causing soil structure formation process is not running well due to soil erosion. Erosion causes destruction of soil structure and decreasing organic matter so that the formation of soil structure is not going well.

Stability of Aggregate and Soil Aggregation

Stability of aggregate and the percentage of aggregate formed in the use of forest land, cultivation,

Table 2. Aeration pores, drainage pore and water available pore on site research.

Land Use	Aeration pore (%)			Drainage pore (%)			Water available pore (%)		
	0-30	30-60	Mean	0-30	30-60	Mean	0-30	30-60	Mean
Forest 3-8%	20.03	14.82	17.43	6.28	2.93	4.61	18.64	14.29	16.47
Forest 8-15%	17.29	13.96	15.63	5.48	2.95	4.22	15.84	13.41	14.63
Forest 15-25%	18.07	13.21	15.64	4.35	2.92	3.64	15.41	13.44	14.43
Forest >25%	17.82	12.96	15.39	3.70	2.43	3.07	14.61	13.11	13.86
Mean	18.30	13.74		4.95	2.81		16.13	13.56	
Mix crop 3-8%	19.01	17.15	18.08	6.89	3.06	4.98	15.29	13.06	14.18
Mix crop 8-15%	17.17	14.79	15.98	5.02	3.14	4.08	15.27	12.77	14.02
Mix crop 15-25%	17.57	14.01	15.79	4.61	5.15	4.88	14.78	11.87	13.33
Mix crop >25%	16.75	11.52	14.14	4.51	4.80	4.66	14.61	11.05	12.83
Mean	17.63	14.37		5.26	4.04		14.99	12.19	
Cinnamon 3-8%	16.63	13.42	15.03	2.72	3.08	2.90	13.13	11.54	12.34
Cinnamon 8-15%	14.01	13.01	13.51	2.24	2.61	2.43	12.17	11.06	11.62
Cinnamon15-25%	14.71	13.83	14.27	2.19	2.67	2.43	12.01	10.78	11.40
Cinnamon >25%	14.07	12.32	13.20	3.26	2.72	2.99	11.75	10.27	11.01
Mean	14.86	13.15		2.60	2.77		12.27	10.91	
Coffee 3-8%	17.82	15.91	16.87	3.32	3.45	3.39	14.86	12.65	13.76
Coffee 8-15%	16.03	15.03	15.53	3.19	2.72	2.96	14.62	12.57	13.60
Coffee 15-25%	16.74	14.15	15.45	2.95	2.55	2.75	14.42	11.31	12.87
Coffee >25%	16.12	13.50	14.81	2.95	3.12	3.04	13.73	11.12	12.43
Mean	16.68	14.65		3.10	2.96		14.41	11.91	

Table 3. Aggregate stability and aggregation percentage on site research.

Land use	% Stability of aggregate					% Aggregation		
	0-30		30-60		Mean	0-30	30-60	Mean
Forest 3-8%	92.20	vs	82.07	vs	87.13	91.03	83.62	87.32
Forest 8-15%	89.87	vs	77.67	s	83.77	86.00	79.79	82.90
Forest 15-25%	88.89	vs	75.26	s	82.08	83.84	78.98	81.41
Forest >25%	86.37	vs	74.33	s	80.35	82.48	76.78	79.63
Mean	89.33		77.33			85.84	79.79	
Mix crop 3-8%	68.03	s	64.77	s	66.40	67.57	62.27	64.92
Mix crop 8-15%	65.59	s	63.81	s	64.70	66.84	61.68	64.26
Mix crop15-25%	64.88	s	62.17	s	63.53	66.27	59.54	62.90
Mix crop >25%	60.72	s	56.76	rs	58.74	64.60	58.05	61.32
Mean	64.81		61.88		63.34	66.32	60.39	
Cinnamon 3-8%	84.90	vs	82.84	vs	83.87	79.69	71.76	75.72
Cinnamon 8-15%	80.82	vs	78.47	s	79.65	75.82	68.24	72.03
Cinnamon 15-25%	79.01	s	77.72	s	78.37	71.68	65.12	68.40
Cinnamon >25%	75.73	s	68.80	s	72.26	67.51	61.34	64.42
Mean	80.11		76.96			73.67	66.61	
Coffee 3-8%	79.74	s	73.07	s	76.40	77.98	74.35	76.16
Cofee 8-15%	74.49	s	71.32	s	72.90	75.47	73.04	74.25
Cofee 15-25%	71.34	s	69.93	s	70.63	73.90	67.55	70.73
Coffee >25%	69.39	s	61.09	s	65.24	68.48	62.34	65.41
Mean	73.74		68.85			73.95	69.32	

Note: vs = very stable, s = stable, rs = rather stable.

cinnamon and coffee plantations, in the different slopes are presented in Table 3.

Stability of soil aggregates on the use of forest land, cultivation, cinnamon and coffee plantation was stable to very stable, and well on hilly or sloping terrain. This was apparently due to the location of the research has the organic matter content of 7.31% at cultivation (mixcrop) and 12.64% on forest at slope 3-8% (Table 1). Soil organic matter acts as a material of cementing agents in soil agregation and formulation of soil structure. Hardjowigeno (2003) states that soil organic matter play a role as a granulator in the formation of soil structure. In addition, the research area has Andisol parent material derived from volcanic ashes which is dominated by amorphous materials resulting in a stable structure. Besides soil organic matter play a role as an adhesive so that the grains of soil aggregates formed and will be more and more with the higher soil organic matter content. Arsyad (2006) states that the organic material acts as an adhesive soil aggregates into ground nests.

Endriani *et al*. (2003) reported that soil aggregate stability was higher and the percent of aggregation formed over many pores and pore water available was higher than the land with bad structure. Yao *et al*. (2010) added that compared to natural forest, agricultural and tree-plantation activities had a negative impact on soil organic carbon content, but mixed-tree plantations has less impacted less than tree monoculture systems and mixed-crop fields.

Increasing steep slope makes the forming of aggregate stability and aggregation was lower. This was apparently because the land with high slopes has low soil organic matter due to erosion so that the aggregate stability and aggregation was lower. These results were in agreement with Prasetya *et al*. (2008) who also reported that natural forest land has the best soil aggregation and the most stable soil aggregate compared to other land use because of high organic carbon content at forest land. Percentage of organic-C 2-3% can be sized to form aggregates > 2 mm.

Particle Size Distribution

Soil particle size distribution on the use of forest land, cinnamon, and coffee plantations, and cultivation, and on different slopes are presented in

Table 4. Soil particle size distribution in the research location.

Land use	% Sand	% Silt	% Clay	Texture class
Forest 3-8%	41.5884	36.1147	22.2969	Loam
Forest 8-15%	41.6953	36.0293	22.2754	Loam
Forest 15-25%	35.2479	42.6464	22.1057	Loam
Forest >25%	38.0215	39.8434	22.1352	Loam
Mean	39.1383	38.6584	22.2033	
Mix crop 3-8%	49.4512	31.9178	18.6311	Loam
Mix crop 8-15%	49.3648	32.6950	17.9402	Loam
Mix crop 15-25%	42.7820	44.5788	12.6392	Loam
Mix crop >25%	46.6707	43.0015	10.3279	Loam
Mean	47.0672	38.0483	14.8846	
Cinnamon 3-8%	49.8647	40.9836	9.1517	Loam
Cinnamon 8-15%	42.8669	43.1064	14.0267	Loam
Cinnamon 15-25%	47.6216	42.2907	10.0877	Loam
Cinnamon >25%	51.6369	41.7493	6.6138	Loam
Mean	47.9975	42.0325	9.9700	
Coffee 3-8%	50.0657	30.3597	19.5746	Loam
Coffee 8-15%	43.5521	39.4909	16.9569	Loam
Coffee 15-25%	42.5951	41.2565	16.1484	Loam
Coffee >25%	45.5220	32.6419	21.8361	Loam
Mean	49.5534	38.8707	11.5759	

Table 4. The table shows that the four land use with different slope have relatively similar texture classes (loam).

Relatively the same texture class of the four land use show that land use does not affect the texture of soil particles because of the formation was more influenced by climate. Besides, the four land use had the same parent materials. The process requires the destruction of the parent material was a long span of time, both the destruction of the biological, physical or chemical. Darmawidjaya (1990) stated that no class difference in texture on some land units caused by the land units have the same parent material. Soil texture is very difficult to change. Similarly Soepardi (1983) stated that the process of soil formation through the destruction of rocks and minerals needs a long time, which is estimated at 100-200 years.

CONCLUSIONS

Among the types of land use, soil physical properties such as: the weight of volume, total pore space, pore size distribution, aggregate stability, percent of aggregation, permeability, and soil organic matter from the best to the worst like in the order: forest > cinnamon > coffee> mix crop. The changes of forest lands into agricultural land caused a decrease in soil physical properties. The higher of slope, caused a decreasing of soil physical properties on all land use studied.

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