Soil quality degradation under horticulture practices in volcanic slope soil, East Java – Indonesia

S Kurniawan1, M P Agustina2, R A Wiwaha2, A Y Wijaya2 and A D Fitria3

1Soil science department, Faculty of Agriculture, Universitas Brawijaya, Malang, Indonesia
2Agroecotechnology study program, Faculty of Agriculture, Universitas Brawijaya, Indonesia
3Soil and water management study program, Faculty of Agriculture, Universitas Brawijaya, Indonesia

E-mail: syahrul.fp@ub.ac.id

Abstract. Volcanic slope soils in Indonesia may have degradation due to forest conversion to intensive agriculture since more than three decades. This research aimed to assess soil characteristics from different land uses and slopes in volcanic slope soil, East Java. Three different land uses, namely crops, apple orchard and forest were chosen as different land-use factors, where each land-use was examined in four slope classes (e.g. 0-8 %, 8-15 %, 15-25 %, and > 25 %), except forest with three slopes area, and each plot repeated three times. Soil samples were taken from three sub-plots at 0-10, 10-30, and 30-50 cm. Variables measured included soil texture, bulk density, pH, CEC, and soil nutrients. Degradation soil quality under horticulture practices (i.e. crops and apple orchard) is shown by the increases of 27-40% soil bulk density and decreases of 17-65% soil nutrient content (i.e. C, N) as compared to forest. The impact of slope on soil fertility degradation was more pronounced in the forest soil as compared to horticultural lands. Our study suggested the benefit of tree density and diversity in the forest to maintain soil fertility, and proper soil conservation in the horticultural lands to slow down volcanic slope soil degradation.

1. Introduction
Indonesia is known as the country having the most active volcanoes in the world (129 active volcanoes or 30% of the total active volcanoes in the world), of which 45 mountains (30%) are located in Java island [1]. Therefore, most of the lands that are spreading in Indonesia are volcanic soils formed by volcanic eruptions. Volcanic soils are characterized by dark soil color with a relatively low bulk density (≤ 0.90 g cm-3) so that the soil is light and has loose consistency due to a well macro pore [2]. Volcanic soils are also classified as young and developing soils and having different physical and chemical properties in the same area due to different eruption periods. This difference influences the growth of vegetation related to the nutrients supply to plants such as calcium (Ca), sodium (Na), potassium (K), and Magnesium (Mg) [2-4].

Forest is the dominant land-use in volcanic slope having experience on land use change during the past three decades. In the period of 2000 to 2012, primary forest loss in the upland and montane area within Java and Bali islands were approximately 8,000 ha from the area 2,200,000 ha [5]. Based on analysis of land cover change using Landsat imagery, Kali Kungkuk micro watershed is one of the areas in the volcanic soil in East Java having forest loss approximately 667 ha (30%) during the period of 1995 to 2019. In the other hand, the area of agricultural land, shrubs, and settlement increased
dramatically during that period. Changes in forest cover affect the decrease in canopy cover, understory, litter input [6], and plant root diversity. As a result, the ability of plants and litter to intercept rainwater is decreased so that there is a high surface runoff and erosion. The previous research that was conducted in montane area of Central Sulawesi reported that changes in forest cover to annual crops reduced soil fertility [7].

Horticulture plants (i.e., vegetables and fruits) are widely cultivated on agricultural land in volcanic slope soils within Java island due to the climatic condition. However, horticulture cultivation on a high slope cause soil loss through runoff, erosion and landslide due to there was not having strong roots, as well as has low canopy cover and litter input [2, 8]. Many previous researches reported that 88% of erosion occurs on conventional agricultural land and around 3% occurs on other agricultural land [9-11]. In addition, soil erosion causes the loss of nutrients, especially nitrogen and phosphorus that are much needed by agricultural plants [11]. As consequently, farmers apply a high amount of inorganic fertilizers for increasing nutrient availability, but these practices may also speed up soil fertility degradation. Fertilization carried out on annual crop-land (after forest conversion) was only influential in the short term [12]. In the long run, nutrient content and nutrient return to the soil in lands originating from forest conversion continues to decline [13, 14].

Up to now, studies about soil quality degradation among various land-use systems and slopes in micro watershed scale in volcanic slope soil within East Java province are very limited. Since soil quality is a key factor for the sustainability of agricultural production systems, the research aimed to assess soil properties from different land uses and slopes within Kali Kungkuk micro Watershed - East Java.

2. Materials and methods

2.1 Study site characteristics

The study was conducted in the Kali Kungkuk micro watershed (112°17'10.90" - 122°57'11" E and 7°44'55.11" - 8°26'35.45" S) located in Batu City, East Java - Indonesia, with elevations between 1,000-3,000 m above sea level (a.s.l). This watershed covers an area of 3507 ha, having an average annual rainfall of 1876 mm year⁻¹, with wet months between November to April and dry months between May to October, and an average annual temperature of 24.3°C [15]. The soil in the study area is derived from the parent material of volcanic material (i.e., breccias, lava, tuff breccias, and tuffs) from the Arjuna, Welirang, and Anjasmara complex volcano [16], and generally classified as Andisol (USDA classification). Topography in Kali Kungkuk micro watershed ranges from low or flat (< 8%) to very high or steep (> 25%). Based on digital elevation model (DEM), the steep areas cover 56% (1,956 ha) of Kali Kungkuk micro watershed, followed by the medium slope (slope 8-15 %), with an area around 666 ha) and the high slope (slope 15-25 % with an area approximately 545 ha), and the rest is the low slope (slope 0-8 % covers around 340 ha).

2.2 Research design

The research was designed on 3 land-use systems (e.g., vegetable crops, plantations, and forests) and 4 slope classes including low (0-8 %), medium (8-15 %), high (15-25 %), and very high or very steep (> 25%), except Forests only have 3 slope classes due to the study was unable to obtain a plot with a slope of 15-25% (Figure 1). Each combination of land use and slope has 3 replications, totally 33 research plots. The preliminary field survey was conducted to select representative plots in each land use and slope class, sized 20 x 20 m, with the distance between observation plots was at least 200 m. Soil samples was collected at 3 soil depths, namely at a depth of 0-10 cm, 10-30 cm, and 30-50 cm.

The forest area in the Kali Kungkuk micro watershed includes the production forest and the conservation forest, named as Taman Hutan Raya R. Soerjo (Tahura R. Soerjo). Tahura R. Soerjo covers an area of 1,731 ha or 49 % of the area of the Kali Kungkuk micro watershed. All the plot in the forest area is located in the Tahura R. Soerjo due to the forest reflects natural forests and human intervention in land management is very limited. Tahura R. Soerjo is a nature conservation area for the purpose of collecting natural or artificial plants and or animals, native or non-native species, which are used for
research, science, education, supporting cultivation, culture, tourism and recreation [17]. The forest plots are characterized by high tree density (600-712 ha$^{-1}$ trees), canopy cover ($\pm$ 89%), standing litter mass (8.88-9.94 t ha$^{-1}$), and basal area (33.50-40.05 m$^2$ ha$^{-1}$). Among slope classes within forest plots, the sites with slope 0-8% have lower tree density, canopy cover, surface litter, and basal area compared to other slope classes (8-15% and $>25$%). Tree species that dominantly grow in all sloped areas within forest include *Nepheleium juglandifolium*, *Ficus sp.*, *Pterocarpus indicus*, *Vatica bantamensis*, *Trema orientalis*, *Duabanga moluccana*, *Dipterocarpus*, *Dendrocalamus asper*, and *Quercus sundaicus*. *Dipterocarpus* species grow more in forest areas with slope class of 0-8% compared to other slope classes.

The plantation in Kali Kungkuk micro watershed has an area of 203 ha (5.8% of the total area), which is dominated by apple. Apple was first planted around Batu in 1934, but this plant developed rapidly in 1980's [18]. In apple orchards, apple plants are in 3 slope classes (0-8%, 8-15% and 15-25%) is planted with 2.5 x 2.5 m spacing (with apple population ± 2,500 trees ha$^{-1}$), whereas in slope classes $>25$% apples are planted with a spacing of 3 x 3 m (population of 1,111 apple trees ha$^{-1}$). Based on field measurement, apple plantations have moderate canopy cover (50-57%), a basal area between 0.22-0.26 m$^2$ ha$^{-1}$, and standing litter mass ranging from 0.45 to 0.89 t ha$^{-1}$. Apple is planted in a bench and / or individual terrace to minimize soil loss through runoff and erosion. Soil management is carried out by apple farmers includes application of chicken manure (2.3 t ha$^{-1}$ year$^{-1}$) and inorganic fertilizers such as NPK (1.6 t ha$^{-1}$ year$^{-1}$) and SP-36 (1.2 t ha$^{-1}$ year$^{-1}$), these fertilizers are applied two times each year. In addition, apple farmers abort apple leaves to stimulate flowering of apple plants and leave the litter in the field as organic matter additives to the soil.

Vegetable crops are intensively cultivated as monoculture systems in an area of 1,085 ha (30% of the total Kali Kungkuk area) and there are no trees inside the land. The crops are planted three times per year, with a crop rotation system. The main crops to be cultivated are potatoes (*Solanum tuberosum*, 2 times per year), while plants used for rotation include cabbage (*Brassica oleraceae*), carrots (*Daucus carota*), mustard greens (*Brassica chinensis*) and broccoli (*Brassica oleraceae* var. *Italica*). Potato plants are planted with a spacing of 20 x 20 cm. In sloped areas, farmer creates terrace to conserve soil from runoff and erosion. In each potato lands, farmers applied chicken manure (5 t ha$^{-1}$ year$^{-1}$), NPK fertilizer (1.2 t ha$^{-1}$ year$^{-1}$), Ammonium sulphate (900 kg ha$^{-1}$ year$^{-1}$), SP-36 (900 kg ha$^{-1}$ year$^{-1}$), and KCl (150 kg ha$^{-1}$ year$^{-1}$) to maintain soil fertility.
2.3 Soil samples collection
Soil sampling was carried out in 33 observation plots between January and April 2019. In each study plot (size 20 x 20 m), 3 representative subplots of 5 x 5 m were randomly determined (Figure 2). Soil samples were taken in each subplot at 3 soil depth intervals namely 0-10 cm, 10-30 cm and 30-50 cm using a soil auger. Soil samples that have been taken were placed in plastic bags and coded according to land use and slope class. Then, the soil sample transported to the Department of Soil, Faculty of Agriculture – Universitas Brawijaya to be air-dried for ± 7 days, and mashed until it passes a 2 mm sieve.

A soil sample from each subplot within replicate plots that has been air dried and passed through a 0.05 mm sieve was weighed (about 20 grams) and was composited for measurement of soil biochemical characteristics (e.g. soil pH, organic C, total N, soil exchangeable K, Na, Ca, Mg, CEC, and base saturation), as well as measurements of soil physical characteristics (soil particle size distribution and soil bulk density). Measurement of soil texture was carried out using soil that has dried air and escapes a 2 mm sieve. A sampling of soil bulk density was carried out in each representative plot at 3 depths of the soil using soil core and given a location code.

![Figure 2. Soil sampling design for each plot.](image)

2.4 Laboratory analysis and calculation of soil nutrient stocks
Air-dried soil samples that passed through 2 mm sieved were used for measuring of soil pH (by using H₂O at a ratio of 1: 1), soil organic C [19], total N [20]. While, the fine soil samples (passed 0.05 mm) were used to analyzed CEC (using NH₄OAc 1N percolation pH 7), and base cations (K-dd, Na-dd, Ca-dd and Mg-dd) by using soil filtrate analyzed by spectrophotometer and EDTA titration [21]. Base saturation was calculated from total exchangeable base cations divided by cation exchange capacity (CEC). Soil bulk density was measured using the soil core and the soil texture was determined by the pipette method [22]. The soil nutrient stocks expressed in g m⁻² or kg m⁻² was obtained from the following calculation [23]:

\[
\text{Soil nutrient stocks (g m}^{-2}\text{)} = \frac{\text{Ec (g kg}^{-1}\text{)} \times \text{BD (g cm}^{-3}\text{)} \times \text{AD (cm)} \times 10,000 \text{ cm}^{2} \text{ cm}^{-3}}{1,000 \text{ g kg}^{-1}}
\]

Noted: Ec = soil nutrient concentration, BD = bulk density (the value was used from forest area), and AD = soil depth. Then, the soil nutrient stocks (g m⁻²) was converted to kg m⁻² as a final unit.

We assumed the effect of parent materials on differences in soil chemical properties at the study site is relatively small. This assumption based on the result of the coefficient of variation (CV) test between parent materials for all soil parameter, which was showed that the CV of soil properties between parent materials is less than 20%. In addition, there have been land use change from forest to agricultural lands (i.e. apple orchard and vegetable crops) had happened for long time ago. Therefore, the forest was used as the reference site and calculation of nutrient stock in our agricultural sites (i.e. apple orchard and ...
vegetable crops) used soil bulk density from the forest site. Since the study was unable to set up the plot in the slope 16-25% within forest areas, the calculation of soil nutrient stock was used the average bulk density from three slopes (0-8, 8-15, and > 25%) within forest plots.

2.5 Statistical analysis
Statistical analysis was carried out to determine the effect of differences in land uses and slopes on soil characteristics at each soil depth (0-10 cm, 10-30 cm, and 30-50 cm). The normality test was performed using the Shapiro Wilk’s test for all parameters. Data analysis was performed using the Linear Mixed Effects (LME) model to determine the effect of land use and slope factors, where each factor was compared as a fixed factor and a random factor [24]. Fisher's least significant difference (LSD) test was used at the 5% level to find significant differences between 3 land uses. The difference was considered statistically significant if P ≤ 0.05. Statistical data analysis was also carried out on varies slope classes in each land use for all soil chemical characteristics. The relationships among soil characteristics, as well as the correlation among soil nutrient stocks with vegetation characteristics (i.e. basal area, standing litter mass, canopy cover) and soil properties (e.g. soil fraction such as sand, silt, and clay content) was analyzed by averaged replicate plot, then weighing averages of soil depth in each land-use systems to minimize the spatial effect (replication). All statistical analyzes were carried out using R statistics software.

3. Results and discussion

3.1. Results

3.1.1. Effect of land-use systems and slopes on soil physical properties. In general, agricultural practices strongly affected (p <0.01) to the soil bulk density at all depths (0-10, 10-30, and 30-50 cm); shown by soil bulk density in the horticulture lands (i.e. apple orchards and vegetable crops) which were 27-40% higher than that of the forest (Figure 3). This was presumably due to soil tillage on vegetable crops and apple orchards as well as the low input organic matter and/or litter; litter thickness in the forest 3 - 10 times higher than the provision of organic fertilizer in vegetable crops and litter in apple orchards. This was supported by a negative correlation between soil bulk density and clay content (r = -0.82, P ≤ 0.05, N = 7), as well as the negative correlation with soil organic C (r = -0.71, P ≤ 0.05, N = 7). In contrast, soil bulk density had strong positive correlation with sand concentration (r = 0.85, P ≤ 0.01, N = 7).

At each land use, differences in soil bulk density among slopes were found at a depth of 10-30 cm (i.e. forest) and 30-50 cm (e.g. of forest and annual crops). Whereas in the apple orchards, the study was unable to detect differences in soil bulk density among slopes at varies depth of soil. In the forest land, the soil bulk density at depths 10-30 cm and 30-50 cm was lower on the steep slopes (> 25%; 0.58 ± 0.00 and 0.57 ± 0.00 g cm⁻³) as compared to that of the flat slope (0-8 %; 0.64 ± 0.02 and 0.65 ± 0.01 g cm⁻³) and medium slope (8-15%; 0.63 ± 0.01 and 0.58 ± 0.01 g cm⁻³). Whereas in the vegetable crop land, the soil bulk density was 16-33% lower (p <0.01) in the medium slopes (8-15%; 0.69 ± 0.03 g cm⁻³) and steep slopes (> 25%; 0.67 ± 0.04 g cm⁻³) as compared to that of the flat slope (0-8%; 0.80 ± 0.03 g cm⁻³) and the high slopes (15-25%; 0.89 ± 0.02 g cm⁻³), especially in a depth of 30-50 cm. This was presumably due to variation in accumulation of eruption material and soil conservation practices in the steep slope (i.e. terrace) to minimize soil loss through erosion. Overall, the results of the study showed that the soil bulk density (i.e. forest and apple orchards) tend to be lower as the slope of the land increases. This is expected due to vegetation cover (i.e. forest) on steep areas (slopes> 25%) is denser than flat - undulating areas (slopes 0-15%); supported by the higher tree population, basal area, and litter in steep slopes (> 25%) compared to the low – medium slopes (0-8 and 8-15%; Table 1).
Unlike the soil bulk density, the distribution of particle size (sand, silt, and clay) between slope classes tended to fluctuate. At each land use, the percentage of fraction size (sand, silt, and clay) was not significantly different between slopes at depth 0-10, 10-30, and 30-50 cm. However, in apple orchards, the percentage of silt fraction at 0-10 cm soil depth tended to be lower (P = 0.053) in the high slope (15-25%; silt: 36.7 ± 11.85%) as compared to the flat slope (0-8%; silt: 74.3 ± 6.67%). In all slopes, differences in the percentage of particle size between land uses (forest, apple orchards, vegetable crops) were found in the sand fraction (30-50 cm soil depth) and clay fraction (10-30 and 30-50 cm of soil depth). Forest land has a lower fraction of sand (13.7 ± 0.8%) than apple orchards (30.9 ± 4.5%). In contrast, clay fractions at 10-30 cm and 30-50 cm of soil depths were higher in the forest (24.7 ± 5.3% and 33.7 ± 8.1%) than apple orchards (10.0 ± 1.6% and 13.1 ± 2.5%). This was indicated that the loss of fine soil fractions such as clay (e.g. through surface runoff and leaching) was due to decreased in the forest cover, and the presence of soil organic matter was capable of binding soil particles so that they were not easily lost (e.g. erosion, surface runoff, leaching), supported by a positive correlation between the clay fraction and soil organic C (r = 0.85, p-value <0.01).

3.1.2. Impacts of land uses and slopes on soil chemical properties and soil nutrient stocks. Differences in fertilizers application on agricultural lands (i.e. annual crops and apple orchards) and litter input (quantity and quality) which are represented by standing litter mass, are thought to affect the soil chemical properties between land uses (forests, apple orchards, vegetable crops). At 0-10 cm of soil depth (Table 1), the seasonal crop has a higher CN ratio and base cations (i.e. soil exchangeable K, Na, and Ca) (P = <0.001 - 0.03) as compared to forest and apple orchards. In addition, vegetable crop was also had higher (P <0.05) CN ratio and soil exchangeable Na than forest and apple orchards at depths of 10-30 cm and 30-50 cm. However, the forest had higher levels (33% - 200%) of total N and soil organic C at depths from 0 to 50 cm compared to agricultural land (apple orchards and seasonal crops); Soil pH and exchangeable K in the forest was also higher (5-9% and 25-82%, respectively) compared to apple
orchards (Table 1). The results showed a significant correlation between soil organic matter and total N ($r = 0.36$, $P < 0.05$, $N = 33$) at depths of 0-10 cm, and the percentage of clay fraction with soil exchangeable K ($r = 0.39$, $P < 0.05$, $N = 33$) at a depth of 30-50 cm. Conversion of forests into agricultural land (annual crops and apple orchards) results in a decrease of N stocks by 37 - 180% at 50 cm depth of soil. In addition, soil C stock at 50 cm depth of soil was decreased up to 50% in apple orchards as compared to the forest (Figure 4).

![Figure 4](image)

Figure 4. Soil nitrogen (A) and carbon (B) stocks from three land uses (Forest, Apple orchard, vegetable crop) at 50 cm depth of volcanic slope soil in Kali Kungkuk micro watershed, East Java.

Differences in soil chemical properties between slopes are more common in the forest land as compared to agricultural land (apple orchard and vegetable crops). This is allegedly due to the absence of soil cultivation practices (fertilization) and nutrient loss through harvesting on forest land that has the potential to affect the soil chemical properties. At depths of 0-10 cm within forest land, the steep slopes (> 25%) had lower CEC and nutrient content (i.e. soil organic C, total N, and soil exchangeable K; $P \leq 0.05$) as compared to the flat slopes (0-8%) and undulating slope (8-15%), especially for pH and total N. In addition, steep slopes (> 25%) was also had lower ($P = 0.001 - 0.08$) CEC and nutrient content (organic C and soil Exc. K) as compared to the flat slope (0-8%) at depths of 10-30 cm and 30-50 cm within forest land.

On agricultural land, especially apple orchard, differences in soil chemical properties between slope classes was only found in exchangeable cations at 0-10 cm and 30-50 cm (e.g. K and Na). In 10-30 cm depth of soil, the lower (i.e. K, Mg) in the steep slope (> 25%) than in the flat slope (< 8%) resulted in significantly decreases of base saturation until 117%. Whereas in the vegetable crops, the high slope (15-25%) and the steep slope (> 25%) had higher soil organic C ($P = 0.006 - 0.04$) than that of the flat slopes (0-8%) and the medium slope (8-15%) at depths of 0-10 cm and 10 - 30 cm. Conversely, total N and soil exchangeable K was lower ($P = <0.01 - 0.02$) in the high slopes (15-25%) and the steep slope (> 25%) than the flat (0-8%) and medium (8-15%) at depths of 0-10 cm and 10-30 cm. At 30-50 cm depth, the steep slopes (> 25%) had lower total N as compared to the flat (0-8%) and medium (8-15%) slopes, in contrast exchangeable K was higher in the steep slope (> 25%) than the flat slope (0 - 8%). The flat slope (0-8%) was also had greater base saturation compared to the steep slope (> 25%) at a depth of 0-10 cm.
Table 1. Soil properties from different land-uses on all slopes in Kali Kungkuk micro watershed, East Java – Indonesia.

| Soil properties                      | Forest   | Apple orchard | Vegetable crops |
|--------------------------------------|----------|---------------|-----------------|
|                                      | 0-10 cm  | 10-30 cm      | 30-50 cm        |
| Soil organic C (g kg⁻¹)              | 52.9 ± 2.0ab | 30.1 ± 2.1b   | 39.8 ± 0.8b     |
| Total N (g kg⁻¹)                     | 7.3 ± 0.4a | 5.1 ± 0.0b    | 2.4 ± 0.1c      |
| Soil exchangeable K (mole 100 g⁻¹)   | 0.36 ± 0.00b | 0.38 ± 0.01b | 0.42 ± 0.01a    |
| Soil exchangeable Na (mole 100 g⁻¹)  | 0.30 ± 0.00c | 0.83 ± 0.02b | 1.39 ± 0.06a    |
| Soil exchangeable Ca (mole 100 g⁻¹)  | 8.08 ± 0.04a | 6.21 ± 0.13b | 9.06 ± 0.45a    |
| Soil exchangeable Mg (mole 100 g¹)   | 1.00 ± 0.35b | 4.14 ± 0.45a | 1.92 ± 0.14ab   |
| Soil pH                               | 5.43 ± 0.02 | 5.38 ± 0.03c  | 5.35 ± 0.09     |
| CEC (mole 100 g⁻¹)                   | 48.97 ± 1.16 | 56.56 ± 0.78 | 57.62 ± 3.18    |
| Base saturation (%)                  | 20.31 ± 0.23 | 20.49 ± 1.35 | 23.08 ± 1.20    |

Table 1: Value derived from average 4 slopes and 3 replications

3.2 Discussion

Volcanic slope soils in Kali Kungkuk micro watershed is characterized by low soil bulk density (0.60 - 0.83 g cm⁻³), soil pH (5.26 – 5.61), base cations (0.30 – 0.38 me K 100 g⁻¹ and 0.31 – 1.38 me Na 100 g⁻¹), and base saturation (18 – 20 %) at 50 cm depth of soil. In contrast, the soil had high soil organic matter (range from 4.2 – 6.8 %) and cation exchange capacity (52.08 – 59.10 cmol kg⁻¹). The low soil bulk density in our study plot was comparable to the soil bulk density value from Andisol in Indonesia (0.80 ± 0.05 g cm⁻³) [19]. In addition, the low soil bulk density in these soils was probably due to the volcanic loose soils in Kali Kungkuk micro watershed was derived from volcanic ash (i.e. from the mountain of Arjuno, Welirang, and Anjasmoro), supported by more than 50% of soil particle is silt fraction. Small particle densities of allophane and imogolites as a factor determining the low soil bulk density, however the study was not able to determine those minerals [25].

Land-use systems and soil management practices play an important role in changing of soil characteristics of volcanic slope soils (i.e. soil bulk density, soil organic C, total N). Soil compaction (indicated by soil bulk density value) in agricultural lands (i.e. apple orchards and vegetable crops) increased by 27 to 45 % at 50 cm depth of soil, as compared to forest soils. The negative correlation
between soil bulk density with clay concentration ($r = -0.82$, $P \leq 0.05$, $N = 7$), and the positive correlation between soil bulk density and sand fraction ($r = 0.89$, $P \leq 0.01$, $N = 7$) indicated that soil bulk density is partially affected by soil texture (i.e. sand and clay). This result in line with the results of previous studies who clearly reported the effect of clay on soil bulk density [26, 27]. [7] measured soil bulk density and clay content from different land-use systems (i.e. natural forest, forest fallow, agroforestry, and maize) in upland Central Sulawesi – Indonesia and they was also reported that clay content of the soil was negatively correlated to soil bulk density. The mechanism of the effect clay content on decreasing soil bulk density may relate to the soil porosity, where clayey soil tends to have higher soil porosity than sandy soils [28]. In addition, the increase of soil bulk density in agricultural land was influenced by the decreases in soil organic C ($r = -0.71$, $P \leq 0.05$, $N = 7$). The previous research in UB Forest reported that soil bulk density was also lower in reference site (i.e. forest) as compared to the restoration areas [29]. The higher soil organic C concentration and the lower soil bulk density was also recorded in the natural forest as compared to agroforestry systems and oil palm plantations [30]. The effect of soil organic matter on the soil bulk density is also evident when comparing soil bulk density among slope classes in the forest. Forests with steep slopes (> 25%) have lower soil bulk density than the flat slope (0-8%) due to the steep area had higher vegetation cover (i.e. tree population, basal area), surface litter (i.e. standing litter biomass) and soil organic matter compared to those in the flat slope (0-8%) within forest areas. Organic matter might decrease the compression index so that the decrease in soil organic matter affected the increase in soil bulk density [31]. Another factor that influences the increase in soil compaction on agricultural land is soil tillage [32, 33, 34]. It was clearly shown that soils within apple orchards and vegetable crops experienced more intensive tillage than those in the forest land, which resulted in damage to soil stability and increased soil compaction, represented by the increases in soil bulk density.

Furthermore, land use systems affected to changes in soil organic matter. Forest soils in the Kali Kungkuk micro watershed stored 112.1 ± 7.2 Mg C ha$^{-1}$ at top 50 cm depth of soil, and this was lower than the soil C stock from forest soil within UB Forest in the Arjuno mountain (> 152 Mg C ha$^{-1}$; [35]) and natural forest in Central Sulawesi (200 Mg C ha$^{-1}$; [7]). The more intensive land use systems (e.g. apple orchard) decreased soil organic matter (SOM) concentration up to 65 %, whereas SOM in vegetable crops at 0-50 cm depth decrease around 15-19 %, as compared to those in forest soils. The losses of soil organic matter in horticulture practices (i.e. apple orchard) resulted in strongly decrease of soil C stock up to 52%. The decrease of SOM in apple orchard was higher than the meta-analysis from the conversion of forest to crop-land (from 74 publications) where an average decline of soil carbon at 60 cm depth of soil around 40-50 % [36]. The large decrease of soil organic matter in the apple orchard was due to the lower organic matter input in the apple site (0.45 - 0.89 t ha$^{-1}$ year$^{-1}$ from standing litter mass and 2-3 t ha$^{-1}$ year$^{-1}$ from organic fertilizer) as compared to vegetable crops ($\pm 5$ t ha$^{-1}$ year$^{-1}$ from organic fertilizer) and forest (standing litter mass 8.9 - 9.9 t ha$^{-1}$) sites.

Last, land use systems in Kali Kungkuk micro watershed influenced soil nitrogen changes. Soil N stocks at 50 cm depth of soils in the apple orchards and vegetable crops were decreased 37 % and 180 %, respectively. The decrease in N stock at horticulture practices (i.e. apple orchard and vegetable crops) expected due to the high N losses through leaching, erosion, and emission. The study in West Java, Indonesia reported that soil N stock at upper 1 m in depth of soil in Andisol after long-term horticulture crops was $1.7 - 1.8$ kg m$^{-2}$ [37], whereas soil N stock at 50 cm depth of soil under horticulture practices (i.e. apple orchard and vegetable crops) in our study ranges from 0.64 to 1.3 kg m$^{-2}$. Comparing between apple orchard and vegetable crops, soil N stock at upper 50 cm depth in the vegetable crops was lower than apple orchard even though the vegetable crops is applied higher N input as compared to apple orchards. Annually, soil in the vegetable crops received N from chicken manure (5 t ha$^{-1}$ year$^{-1}$), NPK fertilizer (1.2 t ha$^{-1}$ year$^{-1}$), and Ammonium sulphate (900 kg ha$^{-1}$ year$^{-1}$). Whereas in the apple orchards, addition of N into soil by apple farmers through chicken manure (2-3 t ha$^{-1}$ year$^{-1}$) and NPK (1.6 t ha$^{-1}$ year$^{-1}$) is slightly lower than vegetable farmer. The more intensive fertilization in vegetable crop lands as compared to apple orchard and forest within Kali Kungkuk micro watershed affected to slow down soil nutrient degradation (i.e. K, Na, Ca, Mg) in the top 50 cm depth of soil. This was shown by the un-
significant difference of soil nutrient stocks (i.e. K, Ca, Mg) among three land-uses, and the higher Na stocks in horticultural land (i.e. apple orchard and vegetable crops) than that of forest.

Our findings also showed that slope was significantly impacted on soil N loss in vegetable crops, but there were not affected in the apple orchards. This was possibly due to the apple farmer create terraces in apple cultivation to minimize soil erosion and run off. Contrary to our findings, difference in spatial distribution of soil nitrogen in apple orchard are affected by relief, however, the methods were not comparable to ours due to their research classified the relief (10 classes of the slope) more detail than our study site (4 classes of the slope) [38]. The slope influence nutrient movement and accumulation in the soil especially N through surface run off, erosion, and ground water movement [39], resulted in an increase of N stock in the lower slope than in the higher slope, especially in our vegetable crop sites.

4. Conclusions
Volcanic slope soils in Kali Kungkuk micro watershed had experiences on soil fertility degradation, shown by increasing soil bulk density and decreasing soil nutrient content and soil nutrient stocks (i.e. C and N) from 15 to 65 % for soil C stock and from 37 to 180 % for soil N stock, especially in agricultural land such as apple orchard and/or vegetable crops. The impact of slope on soil fertility degradation was more pronounced in the forest soil as compared to agricultural land. Differences on soil fertility among slopes in the forest sites was due to differences in tree density and diversity, as well as standing litter mass. While, the un-significant different in soil fertility among slopes within apple orchards and crops were due to farmer create terrace to minimize the effect of slope on soil loss through runoff and erosion. Application of fertilizer by farmer in apple and and vegetable crops is expected to slow down decrease in soil nutrient content (i.e. K, Na, Ca, Mg) and determine the sustainability of agricultural practices in Kali Kungkuk micro watershed.

Acknowledgments
The study was implemented and partly funded by PNBP research fund of Agriculture faculty Universitas Brawijaya 2019. The author thanks to Perum Perhutani Divisi Regional Jawa Timur, Taman Hutan Raya R. Soerjo Jawa Timur, and the landowner for the permission to collect soil samples, Sri Padmi Wulandari and Wahyu Indrayanto for soil laboratory analysis. Also, thanks to Yosi Andika for helping in land use map preparation and Puji for the fiedwork.

References
[1] Yatno E and Zauyah S 2008 Indonesian Journal of Agricultural Science 9 44-54
[2] Neall V E 2009 Volcanic Soils (Soils and soil sciences part 2 vol VII) ed W H Verhaye (United Kingdom: Eolss) pp 23-45
[3] Latif D O, Rifa’i A and Suryolelono K B 2016 International Journal of GEOMATE 11 2606-2610
[4] Utami S N H, Purwanto B H and Marwasta D 2018 Planta Tropika: Journal of Agro Science 6 32-38
[5] Margono B A, Potatov P V, Turubanova S, Stolle F and Hansen M C 2014 Nature Climate Change 4 730-735
[6] Hairiah K, Sulistyani H, Suprayogo D, Widianto, Purnomosidhi P, Widodo R H and van Noordwijk M 2006 Forest Ecology and Management 224 45-57
[7] Dechert G, Veldkamp E and Anas I 2004 Plant Soil 265 197–209
[8] Fiantis D, Hakim N and Ranst EV 2005 JIFS 2 29-37
[9] Pagiola S 2000 Environment Department (World Bank) pp 1-29
[10] Mhazo N, Chivenge P and Chaplot V 2016 Journal Agriculture, Ecosystems and Environment 230 231-241
[11] Wijayanti F, Kurniawan S and Suprayogo D 2019 Journal Degraded and Mining Lands Management 7 1965-1976
[12] Ngoze S, Riha S, Lehmann J, Verchoit L, Kinyangi J, Mbugua D and Pell A Glob. Change Biol. 14 2810–2822
[13] Corre M D, Dechert G and Veldkamp E 2006 Soil Sci. Soc. Am. J. 70 359–366
[14] Davidson E A, de Carvalho C J R, Figueira A M, Ishida F Y, Ometto J P H B, Nardoto G B, Saba R T, Hayashi S N, Leal E C, Vieira I C G and Martinelli L A 2007 Nature 447 995–998
[15] Badan Pusat Statistik Kota Batu 2015 Statistik Daerah Kota Batu (in Bahasa)
[16] Santoso S 1992 Pusat Penelitian dan Pengembangan Geologi (Indonesia, Bandung)
[17] Pemerintah Provinsi Jawa Timur 2002 Peraturan Daerah Propinsi Jawa Timur No 8 tahun 2002 (Provincial Regional Regulation of East Java No. 8, 2002) Pengelolaan Taman Hutan Raya R. Soerjo (in Bahasa)
[18] Kartono D T and Budi A C 2018 Advances in Social Science, Education and Humanities Research 251 189-192
[19] Walkley A and Black I A 1934 Soil Sci. 37 29-38
[20] Kjeldahl J 1883 Z. Anal. Chem. 22 366-382
[21] Indonesia Soil Research Institute 2005 Balai Penelitian Tanah Bogor pp 7-28
[22] Gee G and Bauder J 1986 Particle-size Analysis (Methods of Soil Analysis Part 1) ed Klute A (Madison: Soil Science Society of America) pp 383-411
[23] Allen K, Corre M D, Kurniawan S, Utami S R and Veldkamp E 2016 Geoderma 284 42–50
[24] Crawley MJ 2009 The R book (Chichester: John Wiley and Sons Limited)
[25] Wada K 1989. Allophane and imogolite (Minerals in Soil Environments 2nd ed) ed Dixon J B and Weed S B (Madison: Soil Sci Soc Am) pp 1051–1087
[26] Ruehlmann J and Körshens M 2009 Soil Sci. Soc. Am. J. 73 876-885
[27] Keller K and Hakansson I 2010 Geoderma 154 398-406
[28] Chauhdari P R, Ahire D V, Chkravarty M and Maity S 2013 International Journal of Scientific and Research Publications 3 1-8
[29] Yusuf M, Fernandes A A, Kurniawan S and Arisoesilaningsih A 2020 Journal of Physics: Conference Series 1563 1-7
[30] Hairiah K, van Noordwijk M, Sari R R, Saputra D D, Widianto, Suprayogo S, Kurniawan S, Prayogo C and Gusli S 2020 Agriculture, Ecosystems and Environment 294 1-12
[31] Soane B D 1990 Soil & Tillage Research 16 179-201
[32] Benjamin M, Mikha P C, Nielsen M F, Vigil F, Calderon H and Hary W B 2007 Soil Sci. Soc. Am. J. 71 1160-1165
[33] Emadi M, Emadi M, Baghernejad M, Fathi H and Saffari M 2008 Journal of Applied Science 8 496–502
[34] Yatno E, Hikmatullah H and Syakir M 2016 Jurnal Tanah dan Iklim 40 1-10
[35] Kurniawan S, Utami S R, Mukharomah M, Navarette I A and Prasetya B 2019 AGRIVITA Journal of Agricultural Science 41 416-427
[36] Guo L B and Gifford R M 2002 Glob Chang Biol. 8 345–360
[37] Anda M and Dahlgren 2020 Catena 194 1-13
[38] Wicaksono K S, Suratman S, Suharyadi R and Murti S H 2019 Journal of Degraded and Mining Lands Management 6 1713-1718
[39] Tsui C C, Chen Z S, Hsieh C F 2004 Geoderma 123 131-142