Relationship between soil morphology and variability of upland degradation in Bogowonto Watershed, Central Java, Indonesia

Krishna Aji¹, Azwar Maas², Makruf Nurudin²*

¹ Master Program in Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Jalan Flora, Bulaksumur, Yogyakarta 55281, Indonesia
² Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Jalan Flora, Bulaksumur, Yogyakarta 55281, Indonesia

*corresponding author: makruf@ugm.ac.id

Received 23 January 2020, Accepted 4 March 2020

Abstract: Land-use change and lack of conservation in Bogowonto Watershed area have caused land degradation due to erosion and landslides. The rate of land degradation can be measured through the morphological characteristics of the soil and landscape. This study aimed to identify the relationship between the morphological characteristics of the soil and the rate of land degradation in Bogowonto Watershed area. The research framework initiated from the interpretation of thematic maps, surveys and field observations, and verification using land degradation assessment software. Sample points were determined using a stratified random sampling method. In general, land degradation is affected by slope, limited soil development, suboptimal conservation measures, and land-use change. Particularly, land degradation is affected by the type of landscape and the morphological characteristics of the soil. Volcanic hilly landscapes show a degradation rate of fine to very fine, characterized by thick soil depth (>60 cm), generous root distribution, loamy textured soil, fine soil particle size (Ø <0.002 mm), and good soil structure. The distribution of easily weathered volcanic ash causes volcanic hills to have thick and fertile soil characteristics. Quaternary-tertiary volcanic transition landscapes show a degradation rate of damaged to heavily damaged, characterized by thin soil depth (<60 cm), limited rooting, dominant coarse fraction (Ø 2–0.05 mm), and contact with fields lithological discontinuity. The data obtained provide information on the morphological characteristics of the soil and land degradation in Bogowonto Watershed area. The results of the study can also be used as a formulation for the conservation of Bogowonto Watershed area.

Keywords: Bogowonto Watershed, landform, land degradation, soil conservation, soil morphology

To cite this article: Aji, K., Maas, A. and Nurudin, M. 2020. Relationship between soil morphology and variability of upland degradation in Bogowonto Watershed, Central Java, Indonesia. J. Degrade. Min. Land Manage. 7(3): 2209-2219, DOI: 10.15243/jdmlm.2020.073.2209.

Introduction

Land degradation is defined as the inability of land to provide ecosystem function, thereby triggering threats to food security and human socio-economic life (Lal et al., 2012; Crossland et al., 2018). Land degradation in the watershed area is a serious threat to the agricultural sector. The degraded soil is unable to provide nutrient availability for plants, making it unproductive. Arsyad (2010) states that land degradation in tropical climate regions is triggered by leaching of nutrients in top soils, an overhaul of organic matter, and rapid weathering of minerals. Land degradation triggers landscape changes affecting the ecosystems in it (Haase and Richter, 1980; Baude et al., 2019). Bank (1998) and Jiang et al. (2019) reported that the expansion of irrigation channels in the upstream region triggered an increase in salinity in the downstream region of Phewa Watershed in Nepal. As a result, the diversity of ecosystems suffered considerable damaged, especially in the downstream areas around the coast (Micklin, 2004; Jiang et al., 2019). Land degradation due to mismanagement leads to
a decrease in organic matter content. Land degradation in semi-arid areas with soil types of Inceptisol and Alfisol, where both soil types have a sensitive aggregate fraction, causes a decrease in soil carbon by 49% and 54%, respectively (Traoré et al., 2014). Changes in anthropogenic activity affect land degradation. According to Montgomery (2007) and Bednár and Sarapatka (2018), land management activities in the form of intensive agricultural mechanization interventions cause carbon to be easily lost. Land degradation can be triggered by geomorphic processes in the form of erosion. Sampietro-Vattuone et al. (2019) state that erosion is the most visible cause of land degradation. Sutrisno dan Nani (2013) state that erosion causes a decrease in soil productivity, a decline in ecosystems in the downstream watershed, and drought and silting of rivers. The slope of 3-30% results in relatively high erosion values in the range of 60-625 t/ha/year. Fu et al. (2005;2009), Zhao et al. (2012), and Jia et al. (2019) state that erosion causes topsoil, nutrients, and organic matter loss. Bednár and Sarapatka (2018) reported a case study of land degradation occurring in the Czech Republic due to water erosion threatened more than 50% of agricultural land, wind erosion of 17.99%, compaction associated with 49% of agricultural land, and acidification of up to 43%.

There are variations in land degradation in Bogowonto Watershed area. Watershed land degradation refers to hydrological units. The hydrological units of watersheds are known through their ecological point of view (Forch dan Schutt, 2014). Watershed components include vegetation, soil, rivers, and humans. The watershed has structural and functional characteristics, and hence, watershed ecology is important knowledge for watershed handlers (O’Keefe et al., 2017). Bogowonto Watershed is in Central Java Province, and a small part of it is in Yogyakarta Province. The upstream to the middle Bogowonto Watershed presents different landforms, soil morphology, and human activities with agricultural livelihoods. The upstream side is a volcanic landform (Ekoregion Jawa, 2013). The middle side is the transition zone of Sumbing Quaternary Volcanic System and Menoreh Tertiary Volcanic-Structural System. Most of the middle side constituent material is based on weathered volcanic material and additional volcanic ash material, and is, therefore, extremely vulnerable to geomorphic processes (Sartohadi et al., 2018). Generally, land degradation in the agricultural sector causes a decrease in the soil quality and quantity in producing biomass, thereby disrupting the stability of the ecosystem, which impacts the harmony of human life. The perception of land degradation comes from the perspective of landforms, soil morphology, conservation actions, and agricultural activities by humans. However, the perspective of land degradation from the perspective of soil morphology, which has not been much explored, becomes urgent, considering the importance of land resources for human life.

This study aimed to identify the relationship between soil morphology and variations in land degradation in Bogowonto Watershed.

Materials and Methods

Study area

The study was conducted in Bogowonto Watershed from the upstream to the middle, located in the southern part of Java Island, covering an area of 362,854 km². The study area is located at 7°26'24.80" S-7°26'35.40" S and 109°58'07.60" E-110°08'36.12" E (Figure 1). The research area is administratively located in Wonosobo, Magelang, Purworejo, and Kulonprogo Regencies. The geomorphology of the study area is the volcanic region on the upstream side and the transition zone of Sumbing Quaternary Volcanic System and Menoreh Tertiary Volcanic-Structural System on the middle side. The topography of the study area is indicated by a steep slope to a very steep slope. The average rainfall in the study area varies between 2200 to 4000 mm/year.

Lithology in the study area are deposits of Young Sumbing Volcano (tuff, sandy tuff, andesitic breccia), deposits of Old Sumbing Volcano (andesitic breccia, agglomerate, and tuff), Sentolo Formation (limestone and marley sandstone), Jonggrangan Formation (conglomerate, tuffaceous marls, limestone sands interspersed with limestones layers and coral limestone), Kebobutak Formation (andesitic breccia, tuff, lapilli tuff, agglomerate, and interspersed andesitic lava flow), Halang Formations (sandstone formations, limestone, marl and tuff interspersed with breccia), Peniron Formation (breccia of various materials with components of andesite, claystone, limestone, tuffaceous sandstone base, and interspersed tuff), and Andesite (the composition of hypersthene andesite to hornblende-augite andesite and trachyandesite, dacite that penetrates andesite, and breccia groups (volcanic breccia are andesite, andesitic lava, and tuff).
Soil sampling and design

The soil sampling method used in this study was stratified random sampling based on the landform and land degradation rate. There were nine soil profiles representing variations in landform and land degradation. The soil profile was described based on the concept of a book by Notohadiprawiro (1983). The determination of land degradation was started with the interpretation of the thematic maps, including Administrative Map (scale of 1: 25,000), Regional Soil Type Map of Bogowonto Watershed (scale of 1: 250,000), Slope Map (scale of 1: 25,000), and Land Use Map from Topographic Map of Indonesia (scale of 1: 25,000). The maps were then overlayed into Land Unit Map. The data from the Land Unit Map were tabulated for mapping the projection of land degradation. The status of land degradation was determined based on Government Regulation No. 150 of 2000 and land parameters. All land parameters were based on scoring analysis. Details of land parameters are presented in Table 1.

Scoring Calculation

\[
\text{Results} = \left( \frac{\text{Score 1}}{100} \times \frac{\text{Score 2}}{100} \times \ldots \times i \right) \times 100\%
\]

Value of each land degradation status is as follow: very fine (≥46%), fine (36-45%), moderate (28-35%), damaged (17-27%), and heavily damaged (<16%)

Sample analysis

Nine soil profiles were analyzed qualitatively and quantitatively. The description of the qualitative soil profile was based on horizon development, and the determination of soil classification was based on the field observations, while the quantitative soil profile was analyzed in the laboratory. Soil samples tested were taken at two depths based on root circumference. Samplings were taken at depths of 30-30 cm and 30-60 cm to support biomass production. Laboratory test variables included (1) soil bulk density (wax clod laboratory method), (2) soil specific gravity (pycnometer method), (3) total porosity (comparison of soil bulk density and soil specific gravity), (4) soil texture (pipette method and granulometric analysis), and (5) soil organic matter content (Walkley and Black wet method).
Table 1. Parameters for determining land degradation.

| No | Landscape and Soil Parameters | Type Score |
|----|--------------------------------|------------|
| 1  | Rainfall (mm)                  | ≤2500: 100 >2500: 80 |
| 2  | Slope (%)                      | <8: 100 8-15: 80 15-25: 70 25-40: 60 >40: 50 |
| 3  | Conservation                   | None: 1 Terrace: 1.6 Pile: 1.3 |
| 4  | Land use                       | Open Pasture: 70 Paddy Field: 100 Moor: 80 Grassland: 100 Nursery: 90 |
| 5  | Flooding (Mg)                  | None: 100 <2: 90 2-8: 80 >8: 70 |
| 6  | pH                             | <4.5: 80 4.5-8.5: 100 >8.5: 80 |
| 7  | Electrical Conductivity (mS)   | <2: 100 2-4: 90 >4: 80 |
| 8  | Soil Depth (cm)                | ≤20: 60 30: 70 40: 80 50: 90 ≥60: 100 |
| 9  | Bedrock (%)                    | <40: 100 ≥40: 80 |
| 10 | Sand Fraction (%)              | ≤80: 100 >80: 60 |

Results

Soil morphology

Soil morphology in the study area, based on the nine soil profiles, has different characteristics. The soil texture characteristics on the upstream side are dominated by a balanced class between coarse and fine. The soil texture in Profile 3 is relatively finer, indicated by clay formation (Figure 2c). The soil structure on the upstream side of the study area is relatively similar, which is subangular blocky. Wet consistency on the upstream side of the study area is slightly sticky. Rooting systems in the study area are relatively the same, which are meso-sized. On the middle side, the soil texture in Profile 4, Profile 7, and Profile 8 are coarse, while the soil texture in Profile 5, Profile 6, and Profile 9 are relatively gradual from slightly fine to fine (Table 2). However, there is a difference in Profile 5, in which there is a very fine texture in Layer 2. The soil structure is relatively the same, which is blocky except Profile 7 and 8 that are dominated by granular structures. Soil consistency in wet conditions varies (Table 2). Soil consistency in Profiles 4, 6, 7, and 8 are not sticky, while in Profile 5 and Profile 6 are slightly sticky and sticky. The rooting system is relatively gradual from micro to meso and meso to macro. Different rooting systems occur in Profiles 5 and 9 that are dominated by micro-size (Figures 2e and 2i).

Physicochemical properties of soils

The highest bulk density value was in sample 7B (1.42 g/cm$^3$), and the lowest value was in sample 1B (0.80 g/cm$^3$) (Table 3). Hartati (2018) said that the high bulk density would facilitate the roots in penetrating the soil due to the availability of sufficient pores, either macro or micropores. The highest value of soil specific gravity was in sample 5B (3.0 g/cm$^3$). Soil specific gravity describes the weight of solid particles in the soil. The value of soil porosity in Bogowonto Watershed ranges between 49-60%. The highest value was in sample 2B. Soil with a high porosity value has a larger number of micropores compared to macropores, resulting in better storability in the rhizosphere area (Hakim et al.,1986; Hartati, 2018). Soil texture is a comparison of the three soil fractions, which are sand, silt, and clay, expressed in percentage units (%) (Table 3). The highest percentage of clay fraction was in 5B and 9B samples (42% and 58%), indicating the soil development is already at an advanced stage (Table 3). The highest organic C and organic matter content were in sample 1A (2.6% and 4.4%) (Table 3). The organic matter content can increase with the increasing amounts of carbon in the soil.

Land degradation rate

The rate of land degradation varies from the upstream to the middle side of the watershed (Table 4). The upstream side is dominated by a degradation rate of fine and very fine. The middle side of the watershed begins to vary with a degradation rate of damaged and moderate. The rate of land degradation is influenced by climatic conditions, slope, conservation, land use, flooding, soil depth and type, and bedrocks.
### Table 2. Soil profile description.

| No | Soil Parent Material | Horizon (depth in cm) | Texture | Structure | Wet Consistency | Root | Root Total | Color | pH H₂O | EC (μs/cm) | Soil Classification (Ordo) |
|----|-----------------------|-----------------------|---------|-----------|-----------------|------|------------|-------|--------|------------|--------------------------|
| 1  | Volcanic Ash Material | 1A (0-31)             | LS      | C         | Slightly sticky | Meso | Many       | 10YR 5/6 | 5.9     | 8          | Inceptisols               |
|    |                       | Bw (31-70)            | SIL     | SB        | Slightly sticky | Meso | Common     | 7.5YR 4/6 | 5.8     | 11         |                          |
|    |                       | 2A/Bw (70-100)        | SIL     | SB        | Slightly sticky | Meso | Moderately Few | 10YR 5/8 | 5.7     | 12         |                          |
|    |                       | 2Bw (100-140)         | VFSL    | SB        | Slightly sticky | Meso | Moderately Few | 7.5YR 4/6 | 6.4     | 14         |                          |
| 2  | Volcanic Ash Material | A (0-45)              | SL      | C         | Slightly sticky | Meso | Common     | 10YR 5/6 | 5.9     | 20         | Inceptisols               |
|    |                       | Bw1 (45-80)           | SIL     | SB        | Slightly sticky | Meso | Many       | 7.5YR 5/6 | 6.1     | 31         |                          |
|    |                       | Bw2 (80-120)          | FSL     | SB        | Slightly sticky | Meso-Macro | Moderately Few | 7.5YR 4/6 | 5.9     | 27         |                          |
| 3  | Volcanic Ash Material | A (0-52)              | SICL    | SB        | Slightly sticky | Sticky | Micro-Meso | Moderately Few | 5YR 4/4 | 6.6 | 19 | Inceptisols               |
|    |                       | Bw (52-120)           | SICL    | SB        | Slightly sticky | Sticky | Micro-Meso | 10YR 4/6 | 6.5     | 23         |                          |
| 4  | Weathered Andesitic Breccias | A (0–40) | LFS | SB | Non-sticky | Meso-Macro | Few | 10YR 6/4 | 5.9 | 14 | Entisols |
| 5  | Weathered Andesitic Breccias | C (70–100) | SL | SB | Non-sticky | Meso-Macro | Moderately Few | 10YR 5/4 | 6.3 | 32 | Entisols |
| 6  | Weathered Andesitic Breccias | Bt (40–100) | SICL | SB | Slightly sticky | Micro | Few | 10YR 3/6 | 5.8 | 29 | Alfsols |
| 7  | Weathered Andesitic Breccias | Bw (80–100) | C | AB | Slightly sticky | Micro | Few | 10YR 5/6 | 6.6 | 17 | Entisols |
| 8  | Weathered Andesitic Breccias | A (0–53) | SL | G | Non-sticky | Micro | Few | 10YR 3/6 | 6.5 | 17 | Entisols |
| 9  | Weathered Andesitic Breccias | AC (0–100) | LS | G | Non-sticky | Meso-Micro | Few | 10YR 4/6 | 6.4 | 35 | Entisols |
| 10 | Weathered Andesitic Breccias | A (0–52) | SICL | SB | Sticky | Micro | Very Few | 7.5YR 5/6 | 5.8 | 19 | Entisols |
| 11 | Weathered Andesitic Breccias | Bw/C (52–100) | SCL | AB | Sticky | Micro | Very Few | 7.5YR 5/8 | 6 | 17 | Entisols |

Remarks: C = clay, FSL = fine sandy loam, LFS = loamy fine sand, LS = loamy sand, SC = sandy clay, SCL = sandy clay loam, SICL = silty clay loam, SIL = silty loam, SL = sandy loam, VFSL = very fine sandy loam, AB = angular blocky, SB = subangular blocky, C = crumb, G = granular, EC = electrical conductivity.
Figure 2. Soil profile.
Remarks: (a) Profile 1, (b) Profile 2, (c) Profile 3, (d) Profile 4, (e) Profile 5, (f) Profile 6, (g) Profile 7, (h) Profile 8, and (i) Profile 9
Relationship between soil morphology and variability of upland degradation

Table 3. Physicochemical properties of soils.

| Sample No | BD (g/cm³) | PD (g/cm³) | Total Porosity (%) | Particle Size Distribution | Texture | OC (%) | OM (%) |
|-----------|------------|------------|--------------------|---------------------------|---------|--------|--------|
| 1A        | 0.90       | 2.46       | 64                 | Sand 32 Silt 42 Clay 26    | L       | 2.6    | 4.4    |
| 1B        | 0.80       | 2.36       | 66                 | Sand 46 Silt 30 Clay 24    | L       | 1.8    | 3.1    |
| 2A        | 0.97       | 2.61       | 63                 | Sand 46 Silt 31 Clay 23    | L       | 1.9    | 3.3    |
| 2B        | 0.82       | 2.46       | 67                 | Sand 34 Silt 32 Clay 35    | CL      | 1.6    | 2.8    |
| 3A        | 1.20       | 2.69       | 55                 | Sand 34 Silt 44 Clay 23    | L       | 1.2    | 2.1    |
| 3B        | 1.22       | 2.71       | 55                 | Sand 36 Silt 32 Clay 33    | CL      | 0.95   | 1.6    |
| 4A        | 1.31       | 2.60       | 50                 | Sand 35 Silt 41 Clay 24    | L       | 0.77   | 1.3    |
| 4B        | 1.37       | 2.66       | 48                 | Sand 58 Silt 25 Clay 16    | SL      | 0.35   | 0.61   |
| 5A        | 1.39       | 2.77       | 50                 | Sand 33 Silt 34 Clay 32    | CL      | 0.81   | 1.4    |
| 5B        | 1.47       | 3.00       | 51                 | Sand 27 Silt 31 Clay 42    | C       | 0.34   | 0.59   |
| 6A        | 1.04       | 2.54       | 59                 | Sand 37 Silt 34 Clay 29    | CL      | 1.2    | 2.0    |
| 6B        | 1.16       | 2.51       | 54                 | Sand 50 Silt 15 Clay 34    | SCL     | 0.15   | 0.26   |
| 7A        | 1.34       | 2.59       | 48                 | Sand 58 Silt 20 Clay 22    | SCL     | 0.46   | 0.80   |
| 7B        | 1.42       | 2.81       | 49                 | Sand 78 Silt 12 Clay 10    | LS      | 0.33   | 0.56   |
| 8         | 1.18       | 2.65       | 56                 | Sand 54 Silt 35 Clay 11    | SL      | 0.50   | 0.87   |
| 9A        | 1.15       | 2.64       | 56                 | Sand 37 Silt 30 Clay 32    | CL      | 0.47   | 0.80   |
| 9B        | 1.17       | 2.64       | 56                 | Sand 36 Silt 6 Clay 58     | C       | 0.17   | 0.29   |

Remarks: BD=Bulk Density, PD=Particle Density, OC=Organic Carbon, OM=Organic Matter, L=Loam, CL=Clay Loam, SL=Sandy Loam, SCL=Sandy Clay Loam, LS=Loamy Sand, C=Clay.

Discussion

Bogowonto Watershed with different landforms results in various processes of land development and land degradation. The development of the upstream side is influenced by Sumbing Quaternary Volcanic landform, and the middle side at the transition zone is affected by the Sumbing Quaternary Volcanic System and Menoreh Tertiary Volcanic-Structural System. There is soil development, which is formed through Polygenesis on the upstream side by periodic additional material (Figure 2a). The periodic addition of material from volcanic eruption activities varies depending on the composition of the magma elements produced (Lowe, 2010; Nurcholis et al., 2019). The development of the soil that is influenced by the pile of volcanic material of Sumbing Volcano produces thicker soil depth and relatively balanced texture, which tends to be smooth (O <0.002 mm), and a blocky structure has been formed. A good soil structure is blocky because it does not intersect with soil particles, and many pores are available (Hardjowigeno, 2007; Hartati, 2018). Furthermore, the pedogenesis process produces more organic matter. The high content of organic matter indicates good moisture and nutrition (Power and Prasad, 1997; Bednár and Sarapatka, 2018). Soil development in the middle side varies. Soil development is influenced by weathering of old andesite rocks originating from Menoreh Tertiary Volcanic Hills. There is soil development at an advanced stage that is characterized by clay accumulation in Profile 5 (Figure 2e). The formation of clay accumulation occurs due to the process of illuviation and weathering of coarse particles. Furthermore, the development of soil on the middle side is relatively limited, characterized by the discovery of horizon C (Figures 2d, 2g, 2h, and 2i) in the layer and embankment material in the form of coarse particles originating from the upper region (Figure 2f). Denudational landforms affect the process of pedogenesis in this region. Denudational landforms are characterized by geomorphic processes in the form of landslides and rockfalls at the foot of the slope (Santosa, 2016). Besides, this region lies in the Geological Formation of the Old Andesite group. The weathering process of rocks is easily eroded and finally transported gravitationally by surface flow and accumulated on the slope units of the hilly feet. As a result, soil depth is relatively shallow and less productive (Kurniawan and Sadali, 2015). Land degradation is influenced by landscape factors and soil morphological conditions. Climatic conditions with an average monthly rainfall of >250 mm and an average annual rainfall of more than 2000 mm/yr have the potential to cause erosion (Maas, 2007). The change in land functions by deforestation can cause erosion and loss of nutrients in the body of the soil (Ritsema et al., 2005).
Table 4. Verification data on the field.

| Site | Rainfall (mm) | Slope (%) | Conservation | Land use | Flood (mg) | Depth (cm) | SR (%) | BR (%) | pH | EC (mS) | Land Degradation |
|------|---------------|-----------|--------------|----------|------------|------------|--------|--------|----|--------|------------------|
| 1    | >2500         | 25        | Terrace      | SF       | None       | >60        | ≤80    | <40    | 4.5-8.5 | <2 | Very Fine |
| 2    | >2500         | 35        | Terrace      | M        | None       | >60        | ≤80    | <40    | 4.5-8.5 | <2 | Very Fine |
| 3    | >2500         | 30        | Terrace      | SF       | None       | >60        | ≤80    | <40    | 4.5-8.5 | <2 | Very Fine |
| 4    | >2500         | 18        | Terrace      | SF       | None       | 40         | >80    | <40    | 4.5-8.5 | <2 | Fine |
| 5    | ≤2500         | 18        | None         | SF       | None       | >60        | ≤80    | <40    | 4.5-8.5 | <2 | Moderate |
| 6    | ≤2500         | 35        | None         | SF       | None       | 40         | ≤80    | <40    | 4.5-8.5 | <2 | Fine |
| 7    | ≤2500         | 45        | None         | SF       | None       | 45         | >80    | ≥40    | 4.5-8.5 | <2 | Damaged |
| 8    | ≤2500         | 55        | None         | SF       | None       | 30         | >80    | ≥40    | 4.5-8.5 | <2 | Moderate |
| 9    | ≤2500         | 35        | None         | SF       | None       | >60        | ≤80    | <40    | 4.5-8.5 | <2 | Heavily Damaged |

Remarks: SF= Sand Fraction, BR= Bedrock, EC= Electrical Conductivity, SF= Secondary Forest, M= Moor.
The concept of conservation that only focuses on reducing erosion by water and does not consider the magnitude of erosion by the wind causes the land to be easily degraded (Dorren dan Rey, 2000). Flooding affects biotic activity in soil bodies (Maas, 2007). The bedrocks >40% causes the land to be damaged, which is marked by the limited and lateral soil development. Soil depth less than 60 cm results in easily degraded land, causing trees to collapse because the roots do not get enough water and nutrients. The land degradation in Bogowonto Watershed area varies from the upstream to the middle side. The land degradation on the north side is dominated by a degradation rate of very fine and fine, while on the middle side, the degradation rate is damaged to heavily damaged (Figure 3). The degradation rate of damaged to heavily damaged land is affected by geomorphic processes. Geomorphic processes by intensive erosion remove the topsoil. The limited soil development and bedrocks above 40% cause the land to be easily eroded (Figure 4). Meanwhile, soil textures with high clay content tend to be compressed, and therefore the root system is limited and lateral (Bednár and Sarapatka, 2018).

Figure 3. Land degradation map of Bogowonto Watershed.
Relationship between soil morphology and variability of upland degradation

Figure 4. Limited soil development and bedrock >40%.

Conclusion
The relationship between soil morphology and the variability of upland degradation in the Bogowonto Watershed was explained through information in the field and analysis in the laboratory. This study concludes that soil morphology influenced by volcanic activity resulted in better land degradation status compared to the Sumbing Quaternary Volcanic System and Menoreh Tertiary Volcanic-Structural System. Volcanic ash material from an easily weathered volcano produces a thick soil depth with balanced soil texture and fertile, while the volcanic-tertiary transition region produce a thin soil depth with a dominated by coarse texture and there is contact with fields lithological discontinuity. Thus, the study of land degradation can also be used as a formulation for the conservation in the up-land Bogowonto Watershed to avoid sustainable land degradation in the future.

References
Arsyad, S. 2010. Soil and Water Conservation. Second Edition. IPB Press. Bogor (in Indonesian).
Bank, T.W. 1998. Aral Sea Basin Program. Water and Environmental Management Project, (Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan).
Baude, M., Meyer, B.C. and Schindewolf, M. 2019. Land use change in an agricultural landscape causing degradation of soil based ecosystem services. Science of the Total Environment 659: 1526-1536.
Bednár, M. and Sarapatka, B. 2018. Relationships between physical - geographical factors and soil degradation on agricultural land. Environmental Research 164: 660-668, doi: 10.1016/j.envres.2018.03.042.
Blake, G.R. 2008. Particle Density. In: Chesworth W. (eds) Encyclopedia of Soil Science. Encyclopedia of Earth Sciences Series. Springer, Dordrecht.
Crossland, M., Ann, L., Pagella, T., Hadgu, K. and Sinclair, F. 2018. Implications of variation in local perception of degradation and restoration processes for implementing land degradation neutrality. Environmental Development 28:42-54, doi: 10.1016/j.envdev.2018.09.005.
Dorren, L. and Rey, F. 2000. A review of the effect of terracing on erosion. Scape Soil Conservation and Protection for Europe, 97-108.
Forch, G. and Schutt, B. 2014. Watershed Management - An Introduction. Proceedings-Lake Abaya Research Symposium, (May).
Fu, B.J., Zhao, W.W., Chen, L.D., Zhang, Q.J., Li, Y.H., Gulinick, H. and Poesen, J. 2005. Assessment of soil erosion at large watershedscale using RUSLE and GIS: a case study in the Loess Plateau of China. Land Degradation and Development 16(1): 73–85.
Fu, B.J., Wang, Y.F., Li, Y.H., He, C.S., Chen, L.D., and Song, C.J. 2009. The effects of land-use combinations on soil erosion: a case study in the Loess Plateau of China. Progress in Physical Geography: Earth and Environment 33(6): 793-804.
Haase, G. and Richter, H. 1980. Geographische Landschaftsforschung als Beitrag zur Lösung von Landskunde und Umweltproblemen. Sitzungsberichte der Akademie der Wissenschaften der DDR (5 N), pp. 23–51.
Hakim, N., Nyakpa, M.Y., Lubis, A.M., Nugroho, S.G., Saul, M.R., Diha, M.A., Hong, G.B., and Bailey, H.H. 1986. Fundamentals of Soil Science. Universitas Lampung. Lampung (in Indonesian).
Hardjowigeno, S. 2007. Soil Science. Akademiaka Pressindo. Jakarta (in Indonesian).
Hartati, T.M. 2018. Dissertation: Evaluation of Land Appropriation, Soil Fertility of Several Plantation Crops and Improvement of Soil Properties to Increase Production of Pala in Galela, North Halmahera. Fakultas Pertanian. Universitas Gadjah Mada (in Indonesian).
Jia, L., Zhao, W. R., Zhai, R., Liu, R.Y., Kang, M. and Zhang, X. 2019. Regional differences in the soil and water conservation efficiency of conservation tillage in China. Catena 175: 18-26, doi: 10.1016/j.catena.2018.12.012.
Jiang, L., Jiapeaer, G., Bao, A., Li, Y. and Guo, H. 2019. Assessing land degradation and quantifying its drivers in the Amudarya River delta. Ecological Indicators 107: 105595, doi: 10.1016/j.ecolind.2019.105595.
Kurniawan, A. and Sadali, M.I. 2015. Privileges Area of Yogyakarta. Gadjah Mada University Press. Yogyakarta (in Indonesian).
Relationship between soil morphology and variability of upland degradation

Lal, R., Safriel, U. and Boer, B. 2012. Zero Net Land Degradation: A New Sustainable Development Goal for Rio+20. A report prepared for the Secretariat of the United Nations Convention to combat Desertification. United Nations Convention to combat Desertification, Bonn.

Lowe, D.J. 2010. Quaternary Volcanism, Tephra, and Tephra-Derived Soils in New Zealand: an Introductory Review. In D.J. Lowe, V.E. Neall, M. Hedley, B. Clothier, & A. Mackay (Eds.), Guidebook for Pre-conference North Island, New Zealand, Volcanoes to Oceans field tour (pp. 7-29). North Palmerston, New Zealand: Soil and Earth Sciences Occasional Publication No. 3, Massey University.

Maas, A. 2007. Assessment, countermeasures, and recovery of land damage. Center for Land Resources Study. Universitas Gadjah Mada. Yogyakarta.

Micklin, P. 2004. The Aral Sea crisis, Dying and Dead Seas Climatic Versus Anthropic Causes. Springer, pp. 99–123.

Montgomery, D.R. 2007. Soil erosion and agricultural sustainability. Proceedings of the National Academy of Science of the United States of America 104: 13268-13272.

Notohadiprawiro, T. 1983. Land-Quick Questionnaire in the field. Laboratorium Pedologi, Jurusan Ilmu Tanah, Fakultas Pertanian, Universitas Gadjah Mada. Ghalia Indonesia. Jakarta Timur (in Indonesian).

Nurcholis, M., Yudiantoro, D.F., Haryanto, D., Dianputra, A.B. and Aji, K. 2019. Process and mineralogy of volcanic materials on the south side of the old Lawu Volcano in Java Island. Sains Tanah 16(2): 127-138, doi: 10.20961/stijssa.v16i2.27118 (in Indonesian).

O'Keefe, T.C., Scott, R. and Elliott, R.J.N. 2017. Introduction to Watershed Ecology, 1-37. The University of Washington. http://www.epa.gov/watertrain

Power, J. and Prasad, R. 1997. Soil Fertility Management for Sustainable Agriculture. CRC Press, America, doi: 10.1201/9781439821985.

Pusat Pengelolaan Ekoregion Jawa. 2013. Java ecoregion Environment Status (in Indonesian).

Ritsema, C.J., van Lynden, G.W.J., Jetten, V.G. and de Jong, S.M. 2005. Factors and Processes Affecting Degradation of Soils. In Degradation (pp. 370-377). The Netherlands: Elsevier Ltd.

Sampietro-Vattuone, M.M., Peña-monné, J.L., Roldán, J., Belén, A., Gabriel, M., Gisela, M. and Amelia, M. 2019. Catena Land management and soil degradation evidence during the Late Holocene in Northwest Argentina (La Costa 2-Tafi valley). Catena 182: 104115, doi: 10.1016/j.catena.2019.104115.

Santosa, L.W. 2016. Yogyakarta Privileges from Geomorphological Point of View. Gadjah Mada University Press. Yogyakarta (in Indonesian).

Sartohadi, J., Ainun, N., Jennie, H., Nurudin, M. and Wahyudi, W. 2018. The ecological perspective of landslides at soils with high clay content in the middle Bogowonto Watershed, Central Java, Indonesia. Applied and Environmental Soil Science volume 2018 |Article ID 2648185, doi: 10.1155/2018/2648185.

Sutrisno, N. and Nani, H. 2013. Land and water conservation technology for controlling agricultural land degradation on the sloping area. Jurnal Litbang Pertanian 32(3): 122-130 (in Indonesian).

Traoré, S., Ouattara, K., Istedt, U., Schmidt, M., Thiombiano, A., Malmer, A. and Nyberg, G. 2014. Effect of land degradation on carbon and nitrogen pools in two soil types of a semi-arid landscape in West Africa. Geoderma 241-242: 330-338, doi: 10.1016/j.geoderma.2014.11.027.

Zhao, W.W., Fu, B.J. and Chen, L.D. 2012. A comparison of the soil loss evaluation index and the RUSLE model: a case study in the loess plateau of China. Hydrology and Earth System Sciences 16: 2739–2748.
