Ecological function of the land after Merapi eruption

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Abstract. The forest area of Mount Merapi has been designated as the Mount Merapi National Park (TNGM) since 2004. The satellite imagery has shown that there are 3 levels of damage to forest ecosystems in TNGM, namely minor, moderate, and severe damage. This study aims to determine the progress of the landscape function in several regions that suffered damage to forest ecosystems due to the eruption of Mount Merapi. The research method consists of: (1) Determination of research location, (2) measurement of microclimates, (3) Measurement of soil characteristics, and (4) Landscape Function Analysis (LFA): characterization of landscape organizations and Soil Surface Assessment (SSA). The value of land stability in the zone of minor, moderate, and severe damage is respectively: 48.00, 52.90 and 45.50%. The infiltration value of water in the zone of minor, moderate and severe damage is respectively: 26.50, 28.40 and 29.70%. The value of the soil nutrient cycle in the minor, moderate, and severe damage zones is respectively: 20.80, 23.60, and 16.30%. The progress of the ecological function of the zone of moderate damage is better for land stability and the soil nutrient cycle, while water infiltration is better in the zone of severe damage.

Keywords: Mount Merapi, landscape function analysis, restoration, soil surface assessment, succession.

1. Introduction

Mount Merapi National Park (TNGM) has a vast ecosystem with a combination of volcanoes, mountains, and highland forests. The forest ecosystem in TNGM serves as a source of water absorption for the districts surrounding it. Also, the forest ecosystem is a place for the protection of flora and fauna and potential germplasm sites.

The impact of Mount Merapi eruption in 2010 occurred in all regions of TNGM that was indicated by traces of the volcanic ash. Observation of the satellite images has shown that the ecosystem of Merapi forest which suffered minor damage was 39.68%, moderate damage was 18.84%, and severe damage was 19.37%. Minor damage is characterized by the presence of relatively intact vegetation and volcanic ash that attached to the soil surface and leaves. Moderate to severe damage is indicated by partial loss of vegetation to whole vegetation in erupted land [1].

Ecosystem recovery in minor to severe damage can be done by restoration, rehabilitation, and reclamation methods according to the structure and initial function of the ecosystem [2]. Regulation, habitat, production, and information are 4 ecosystem functions in a landscape [3]. Landscape functions as an area of the energy flow, storage of the energy material, and site of the biogeochemical processes. The landscape component consists of patch as a place where resources are accumulated and inter patch as a place for resource flows [4]. The ecosystem function can be analysed by using the Landscape...
Function Analysis (LFA) method. The method can also be used to measure land management and land-use change in response to climate change [5]. The evaluation report regarding the ecological function of the land after Merapi eruption by using the LFA method has never been done before. This study aims to determine the progress of landscape function in several areas of forest ecosystems that had damaged due to the eruption of Mount Merapi.

2. Materials and methods

This study was conducted in August 2018 at 3 different locations in Mount Merapi National Park, namely Pluyon Kalikuning as minor damage zone, Kinahrejo as moderate damage zone, and Bunker Kaliadem as severe damage zone. Microclimate conditions such as air humidity, air temperature, wind speed, and light intensity were measured in each damage zones. In addition, soil characteristics such as temperature, moisture, pH, organic matter, and bulk density were also measured.

Landscape characteristic was analyzed by Landscape Function Analysis (LFA) method with modifications. The method was carried out through the characterization of landscape organizations and the Soil Surface Assessment (SSA). The transects were made 3 times in each damage zones and were made in the water flow (high to low). The characterization of landscape organization by determining the patches and inter patches in 3 transects that were made in each damage zones. The transect line was made until the same 6 patches are found. The soil surface assessment was carried out on all patch and inter patch that has been determined based on the condition of soil cover, litter cover and degree of litter decomposition, perennial vegetation cover, cryptogam cover, soil erosion type and severity, deposited material, soil surface resistance to disturbance, soil surface roughness, slake test, and soil texture. The SSA results contribute to the 3 LFA indices: land stability, water infiltration, and soil nutrient cycle [4].

3. Results

3.1 General Condition and Microclimate Condition in three damage zones

The height of the study location ranges from 800-1100 masl with varying topography ranging from sloping, steep slopes to hilly. The type of vegetation in the three study zones after the Merapi eruption can be said to vary, starting from the level of stakes, poles, and trees. *Schima wallicii*, *Lithocarpus elegans*, and *Acacia decurens* plants are commonly found in minor and moderate damage zones, whereas in severe damage zone there are *Trema orientalis*, reeds, and edelweiss plants (table 1). The *Acacia decurens* is an invasive plant that invades the Mount Merapi National Park area because it was able to grow rapidly, while other plants were native species of Mount Merapi National Park which could be used as pioneers for forest vegetation recovery. Vegetation diversity in a forest ecosystem affects the physical soil and the content of organic matter which can contribute to the rate of soil infiltration [6].

| Damage zone | Vegetation | Descriptions |
|-------------|------------|--------------|
| Minor       | *Acacia decurens*  
              *Schima wallicii*  
              *Lithocarpus elegans* | The canopy and soil cover (herbs and litter) are quite dense, there is a lot of pioneer plants |
| Moderate    | *Schima wallicii*  
              *Acacia decurens* | The canopy and soil cover (herbs and litter) are denser than minor and severe zone, |
| Severe      | reeds  
              Edelweiss  
              *Trema orientalis* | The canopy and soil cover (herbs and litter) are lower than minor and moderate zone, dominated by bare soil, there is a lot of pioneer plants |
Microclimates on the study locations have shown a maximum average temperature of 28.50°C, a maximum average humidity of 66.52%, a maximum average light intensity of 16533 lux, and a maximum average wind speed of 0.29 m/s. The severe damage zone has the lowest temperature range and the highest humidity, which are 22.4-24.6°C and 72.30-78.73%. The range of light intensity in the moderate damage zone is 7910-16990 with wind speeds of 0.0 m/s (table 2).

| Damage zone | Temperature (°C) | Humidity (%) | Light Intensity (lux) | Wind speed (m/s) |
|-------------|-----------------|--------------|----------------------|-----------------|
| Minor       | 29.7-31.1       | 51.00-56.30  | 6410-13450           | 0.0             |
| Moderate    | 22.4-24.6       | 72.30-78.73  | 7910-16990           | 0.0             |
| Severe      | 25.7-29.8       | 58.70-64.53  | 6400-19160           | 0.0-0.86        |

3.2 Characteristic at three damage zones

The type of soil in the three damage zones is regosol soil. The minor and moderate damage zones have sandy clay loam-sandy loam, while the severe damage zone has sandy loam-sandy silt. The severe damage zone has a lower organic matter and bulk density values than other zones, respectively 0.91% and 0.34 g/cm3. The temperature is inversely proportional to humidity, the higher temperature will make the humidity lower. The severe damage zone has the highest temperature and the lowest humidity, respectively 29°C and 11.89%. The degree of acidity in the three study zones was 7 (table 3). This value causes nutrients to dissolve easily in water so that they can be absorbed easily by the soil [7].

| Damage zone | Temperature (°C) | Humidity (%) | Bulk density (g/cm³) | Organic material content (%) | pH | Humidity (%) |
|-------------|-----------------|--------------|----------------------|----------------------------|----|--------------|
| Minor       | 24              | 0.40         | 2.1                  | 7.0                        | 16.94 |
| Moderate    | 25              | 0.35         | 1.2                  | 7.1                        | 12.55 |
| Severe      | 29              | 0.34         | 0.91                 | 7.2                        | 11.89 |

3.3 Landscape Function Analysis

The landscape function analysis has illustrated the land stability, soil nutrient cycle, and water infiltration in the damage zones. Land stability describes the ability of soil to resist the erosion and reformation of soil structures after disturbances. Land nutrition cycle describes the effectiveness of the availability of soil organic matter and the formation cycle of soil organic matter [4]. The highest percentage for land stability and soil nutrient cycle are in the moderate damage zone, which are 52.90% and 23.60% (figure 1). Water infiltration describes the distribution of water falling to the ground, the availability of water for plants, and the flow of water-borne material [4]. The highest percentage for water infiltration is in the severe damage zone, which is 29.70%. The percentage of the three LFA indices were contributed by the dominance of grass patches in the three damage zones.
4. Discussion

4.1 Microclimate Condition in three damage zones
The existence of vegetation in the study zone affects the range of parameters of air temperature, air humidity, light intensity, and wind speed. The amount of vegetation can reduce the amount of sunlight and do evapotranspiration so that it decreases the air temperature [8]. The moderate damage zone has denser vegetation cover than other zones. It causes a lower range of air temperature and higher humidity in the zone of moderate damage. In addition, the denser vegetation reduces light intensity and wind speed in that zone.

4.2 Soil Characteristic at three damage zones
The value of soil temperature in three damage zones was influenced by the closure of vegetation canopy and the presence of litter on the ground. The severe damage zone has the highest value of soil temperature and it was caused by the sunlight affects the soil surface directly so that the value of the soil temperature in the severe damage has increased. The loose soil texture in the severe damage zone has caused the lowest value of soil moisture. The loose soil texture has a low ability to keep the water [9]. Therefore, the severe damage zone has lost more water so that the moisture value was low.

Soil characteristics for bulk density and soil organic matter are also influenced by soil texture. Bulk density indicates the suitability between soil permeability and plant root growth [10]. The sandy soil texture in the three damage zones has greater porosity. The large soil pores will accelerate the water movement and the root penetrating power in its spread [11]. It causes a low bulk density value in the three damage zones. Sandy soil also tends to have a rough texture. Coarser soil texture is difficult to hold water and nutrients [12]. Therefore, the moderate and severe damage zones have organic material content below 2% due to low water content. The normal range of organic matter content generally is 2-3% [13].

4.3 Landscape Function Analysis
The characteristic of landscape organization has shown the diversity of patches and inter patch compositions at the damage zones. *Lithocarpus elegans*, *Acacia decurens*, *Schima wallicii*, *Trema orientalis*, Edelweiss, reeds, and stone are types of patch, while grass and bare soil are inter patch. The percentage of land stability in the moderate damage zone was caused by higher land cover and litter cover. Both closures were affected by the vegetation around the damage zone. Vegetation cover prevents and breaks down the raindrops so that it does not form the erosion [4]. It indicates that the severe damage zone has a weak erosion rate due to the rainwater was held on by vegetation. Weak erosion rate causes a high level of soil resistance to disturbance.
Litter cover not only contributes to the land stability index but also the soil nutrient cycle through the carbon as litter decomposition result. The carbon will be used for vegetation and microbial growth [14]. The presence of higher cryptogam in the moderate damage zone indicates that the presence of litter supports the growth of cryptogam which can also affect the land stability and the soil nutrient cycle.

The higher percentage of water infiltration in the severe damage zone was due to the sandy soil texture. The texture has large pores and it is not coherent so that it increases the water infiltration. Low infiltration rate can be caused by high water content in the soil [15]. It indicates that the severe damage zone has a low water content that has caused low soil temperature and higher water infiltration index.

Litter cover also influences the water infiltration. A thick litter layer will cause a high infiltration rate. Litter will hold the raindrops on its surface so that it does not fall directly on the soil surface [15]. The retained water will evaporate into the air thereby reducing the water flow at the ground and reducing the strength of the rainwater that can damage the soil [16]. The severe damage zone had a moderate of litter decomposition degree and it has caused a higher percentage for water infiltration index.

Grass patches are the largest contribution to the three LFA indices in all damage zones. The grass contribution has a higher soil cover and litter cover. Grass can prevent water runoff which can break down the soil particles into the smaller ones. Therefore, soil cover by grass can prevent erosion formation so that it can maintain the land stability and water infiltration. The presence of grass is also able to withstand organic material on the ground. It indicates that grass can maintain the soil nutrient cycle because nutrients are not carried away by the water flow.

5. Conclusion
The highest value of soil stability and soil nutrient cycle are in the moderate damage zone, which are 52.90% and 23.60%. The highest value of water infiltration is in the severe damage zone, which is 29.70%. The data of three Landscape Function Analysis (LFA) has illustrated the progress of the ecological function of the land is better in moderate damage zone for soil stability and soil nutrient cycle, while the water infiltration is better in the severe damage zone. Also, land restoration efforts are needed on three damage zones to ecosystem function recovery.

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