Vegetation Analysis of the Middle Slope Geomorphic Units on the Southern Flank of Mount Merapi

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Abstract. Merapi is an active volcano located in the border between DIY and Central Java. The eruption of Mount Merapi has changed the soil conditions as well as the surrounding vegetation. This study was aimed to identify the vegetation distribution shaped after the 2010 eruption in the geomorphic units of the middle slope located in the southern flank of Mount Merapi. This study was carried out through survey followed by descriptive and spatial analysis. Vegetation distribution was evaluated by determining density value, frequency, dominance, importance value index and diversity index. Middle slope geomorphic units, Southern flank considered as disaster-prone areas zone II and III, were covered by 33 species composed of 209 individuals. Of all species found, the most abundant species were Chinese albizia (so-called sengon) (*Albizia chinensis*), mahogany (*Swietenia mahogany*) and green wattle (*Acacia decurens*). The abundance of these three species was indicated by its high importance value index associated with high adaptability of the species, even grown in the eruption-affected areas.

Keywords: Mount Merapi, eruption-affected areas, vegetation diversity, Chinese albizia, mahogany, green wattle

1. Introduction

Merapi is one of the active volcanoes in Indonesia. This 3,000 m basaltic-andesite volcanic complex is located about 25 km north of Yogyakarta and surrounded by several young volcanoes (Merbabu, Telomoyo, Ungaran, Sumbing, Sundoro and Dieng complex) located in the northwest [1]. Since 1960, Mount Merapi had experienced more than eight times of eruption with an interval of 4 to 6 years. During the eruption occurred in 2006, the pyroclastic flow had reached the distance of 7 km to the Gendol basin [2, 3]. Meanwhile, the eruption occurred on 26 October 2010 caused the collapse of dome formed since 2006 [2]. Greater destruction indicated by the overlying crust, pyroclastic flow and ash release was recorded during the eruption on 3 and 5 November 2010. It also caused severe destruction to the surrounding conservation areas, where the worst ones were found in Cangkringan and Kemalang [4]. Volcanic materials (pyroclastic flows, debris avalanches and lahars) released during the eruption potentially damages the surrounding ecosystems, including plantations and settlements [3, 5]. Regarding the soil condition itself, lava damaged properties, unfavorable for plant growth, who stated that the accumulation of lava deposition resulted from the eruption of Mount Merapi had damaged the soil properties, thus making it highly unfavorable for plant growth [6].

The southern flank of Mount Merapi are divided into several geomorphic units based on its height and landscape characteristic, namely old Merapi, upper slope, middle slope, lower slope and foot slope
As an active volcano, Mount Merapi had been reported experiencing both effusive and explosive eruption. Effusive eruption commonly recurs once in 4 to 6 years and is marked with lava dome formation and pyroclastic flow. Explosive eruption is known to occur approximately once in 100 years indicated by massive release of debris and pyroclastic flows [9]. However, considering the impact of Mount Merapi eruption pedologically, the deposit of volcanic materials may rejuvenate the soil with abundant macro and micronutrients, thus resulting in highly fertile soil [10, 11].

Other significant post-eruption changes occurred was the formation of new vegetation composition found in the affected area. Apart from severe ecosystem damage caused by the eruption in 2010, several species were found to be successfully survive then dominated the affected areas, such as green wattle (Acacia decurrens) and shrubs. Shabirin et al. [12] reported that the vegetation found in Kinahrejo and Umbulharjo was dominated by tree-shaped habitus, while the highest diversity was recorded from bush-shaped habitus. Nadirman et al. [13] reported that Brachiaria reptans and Digitaria nuda were found to grow invasively after the eruption in 2010. Significant changes occurred in the landscape of the southern flank due to the eruption in 2010 had affected southern flankland surface condition and vegetation. Great disturbance caused by the volcanic eruption may create the succession process leading to species establishment and ecosystem composition change [14]. The dynamic of vegetation establishment in the main areas affected by the eruption would be an indicator of this succession process. This information is needed to develop the best fit restoration program plan for those affected areas, including the middle slope in southern flank of Mount Merapi. Therefore, this present study was aimed to identify the vegetation composition and diversity in middle slope geomorphic units of southern flank of Mount Merapi.

2. Materials and Methods

The study was conducted in middle slope geomorphic units of southern flank of Mount Merapi. The middle slope geomorphic unit includes three villages, namely Turi, Pakem and Cangkringan. Survey of vegetation composition was performed in 16 representative points selected through purposive sampling within these three districts (Fig. 1). Sampling of the vegetation was determined using the quadrants method by making plots of 10 m x 10 m according to tree vegetation sampling standards [15]. Each vegetation found was identified based on its species. Analysis of species dominance was carried out by calculating the relative density, relative frequency, relative dominance and importance value index.

Figure 1. Overview of geomorphic units in Southern flank of Mount Merapi. Area highlighted in black is the middle slope geomorphic unit and the yellow dot represents the sampling location.
In addition, soil samples of rhizosphere (representing each vegetation found) were collected with 30 cm depth in this quadrant. Soil analysis was performed in Soil Laboratory of the Faculty of Agriculture, UMY. Total N content was determined using the Kjeldahl method. Soil C-organic content was assessed using Walkley and Black method. Soil physical properties representing each sampling location was also observed.

3. Results and Discussion

Periodic eruption of Mount Merapi, especially at the southern flank, had changed the topography of the surrounding areas and divided into several layers of geomorphic units based on the altitude. Middle slope of southern flank has an area of 1,530 hectares. Pyroclastic materials deposited in the middle slope area then formed the Regosol sediment; while the deposited ash formed Andisol layers in several parts of its slopes. Previous studies also reported the similar finding highlighting the distribution of Regosol and Andisol in middle slope geomorphic unit at the southern flank [7, 16].

Recent geographical condition found in middle slope geomorphic unit showed that the vegetation was dominated by several plants, such as guava, chinese albizia, mahogany, jackfruit and green wattle (Fig. 2a). However, divergent array of species was also found, even with low population (less than 10 individuals) (Fig. 2b). Since the middle slope covered three villages, the level of vegetation diversity based on the number of species was found to be different among villages (Fig. 3). It might be associated with the impact of post-eruption geographical changes occurred in each village that triggered the species establishment during the succession process. In addition, vegetation found in each village also showed different composition of plant species (Fig. 4), thus emphasizing that the impact of post-eruption shaped the vegetation establishment of each village in different way. Moreover, the difference of the most dominant species found in each village portrayed the difference in soil condition change during the succession process.

Figure 2. Distribution of plant species mostly found (indicated by number of individual plants per species) in middle slope geomorphic units (a) and various plant species found with less than 10 individual plants (b).

Overall, this study found 33 plant species distributed in all representative points of middle slope (Table 1). Each species showed different level of dominance suggesting its suitability towards the change of soil condition caused by post-eruption effect. Table 2 highlighted that the most dominant species composing the vegetation in this area was chinese albizia (A. chinensis) indicated by the highest IVI (66.31 %) among other plant species. High dominance of chinese albizia found in this geomorphic unit occurred due to the human intervention. Local community cultivated this plant purposely since it was known as one of fast-growing plants. Other consideration underlying the decision of chinese albizia replanting was based on the vulnerability level of middle slope area. Middle slope at the southern flank of Mount Merapi is categorized as an area with disaster-prone level II and III. Severe destruction caused
by Mount Merapi eruption in 2010 had damaged most of secondary forests previously existed in this area. Therefore, replanting of chinese albizia was considered as an effective way to immediately stimulate the forest recovery in this area.

**Figure 3.** Difference of plant species diversity (based on number of species) among three villages in middle slope geomorphic unit at the southern flank of Mount Merapi.

**Figure 4.** Comparison on vegetation composition found in three villages located in middle slope geomorphic unit. Number in color box represented the percentage of each species population. Species with the same color box indicated the same number of individuals.

IVI (importance value index) defined the level of dominance contributed by certain species to the environment where the species was inhabited [17]. Most ecological studies used this parameter to describe the ecological importance of a species in a specific ecosystem. This parameter also suggested the priority level of species conservation for those species showing low IVI [18]. In terms of vegetation
composition, vegetation in middle slope geomorphic unit showed overall value of diversity index up to 2.74 (Table 1). Diversity index defined the distribution of each plant species in shaping the vegetation of a certain ecosystem or area. This diversity index also conferred the stability of the vegetation community towards the environmental changes.

Table 1. Dominance of plant species found as vegetation in middle slope geomorphic unit based on the importance value index (IVI).

| No | Species                        | Density | Relative (%) | Dominance | IVI (%) | Diversity Index |
|----|--------------------------------|---------|--------------|-----------|---------|-----------------|
|    | Chinese albizia (Albizia chinensis) | 26.32   | 13.48        | 26.51     | 66.31   | 0.35            |
| 2  | Mahogany (Swietenia mahagony)    | 14.35   | 7.87         | 16.49     | 38.71   | 0.28            |
| 3  | Green wattle (Acacia decurrens)  | 10.05   | 4.49         | 7.79      | 22.33   | 0.23            |
| 4  | Jackfruit (Artocarpus heterophyllas) | 4.78    | 4.49         | 10.03     | 19.31   | 0.15            |
| 5  | Avocado (Persea americana)       | 2.87    | 5.62         | 3.82      | 12.31   | 0.10            |
| 6  | Guava (Psidium guajava)          | 5.26    | 6.74         | 0.24      | 12.24   | 0.15            |
| 7  | Pine (Casuarina equisetifolia)   | 2.39    | 2.25         | 6.87      | 11.51   | 0.09            |
| 8  | China berry (Melia azedarach)    | 1.91    | 2.25         | 6.62      | 10.78   | 0.08            |
| 9  | Coffee (Coffee sp.)             | 3.83    | 5.62         | 0.66      | 10.11   | 0.12            |
| 10 | Mahoe (Hibiscus iliiaceus)       | 2.87    | 4.49         | 1.27      | 8.64    | 0.10            |
| 11 | Banana (Musa paradisiaca)        | 2.87    | 4.49         | 0.96      | 8.33    | 0.10            |
| 12 | Jabon (Neolamarckia cadamba)     | 2.39    | 2.25         | 3.34      | 7.98    | 0.09            |
| 13 | Acacia (Acacia mangium)          | 2.39    | 1.12         | 4.16      | 7.68    | 0.09            |
| 14 | Melinjo (Gnetum gnemon)          | 1.91    | 3.37         | 2.23      | 7.51    | 0.08            |
| 15 | Coconut (Cocos nucifera)         | 1.91    | 2.25         | 1.63      | 5.79    | 0.08            |
| 16 | Petal (Parkia speciosa)          | 1.44    | 3.37         | 0.90      | 5.71    | 0.06            |
| 17 | Clove (Syzygium aromaticum)      | 0.96    | 2.25         | 2.19      | 5.39    | 0.04            |
| 18 | Gamal (Gliciridia sepium)        | 1.44    | 3.37         | 0.19      | 5.00    | 0.06            |
| 19 | Cassava (Manihot esculenta)      | 1.91    | 2.25         | 0.25      | 4.41    | 0.08            |
| 20 | Cashew (Anacardium occidentale)  | 0.48    | 1.12         | 1.99      | 3.59    | 0.03            |
| 21 | Longan (Dimocarpus longan)       | 0.96    | 2.25         | 0.12      | 3.32    | 0.04            |
| 22 | Bamboo (Bambuseae)               | 0.96    | 2.25         | 0.05      | 3.25    | 0.04            |
| 23 | Durian (Durio zibethinus)        | 0.48    | 1.12         | 1.44      | 3.04    | 0.03            |
| 24 | Weeping fig (Ficus benjamina)    | 0.96    | 1.12         | 0.01      | 2.09    | 0.04            |
| 25 | Papaya (Carica papaya)           | 0.48    | 1.12         | 0.41      | 2.01    | 0.03            |
| 26 | Sawo Kecik (Manilkara kauki)     | 0.48    | 1.12         | 0.25      | 1.85    | 0.03            |
| 27 | She-oak (Casuarinaceae)          | 0.48    | 1.12         | 0.20      | 1.80    | 0.03            |
| 28 | Sandalwood (Aquilaria malaccensis) | 0.48   | 1.12         | 0.20      | 1.80    | 0.03            |
| 29 | Pakel (Mangifera foetida)        | 0.48    | 1.12         | 0.11      | 1.71    | 0.08            |
| 30 | Mango (Mangifera indica)         | 0.48    | 1.12         | 0.05      | 1.65    | 0.03            |
| 31 | Palm (Arecaceae)                 | 0.48    | 1.12         | 0.02      | 1.62    | 0.03            |
| 32 | Snakefruit (Salacca zalacca)     | 0.48    | 1.12         | 0.00      | 1.61    | 0.03            |
| 33 | Indian mulberry (Moringa citrifolia) | 0.48  | 1.12       | 0.00      | 1.60    | 0.03            |

Total of diversity index 2.74
Considering the diversity index obtained in this study, the vegetation found in middle slope area was categorized as a highly stable ecosystem. This result was in line with Ariyanto et al. [19]. Such a diverse and stable vegetation community could be created when the plants were grown in a favorable condition, including the soil fertility. Based on the soil properties collected from 16 representative points (Table 2), all points showed neutral pH soil with high content of organic C and N total. These features indicated that the middle slope at the southern flank of Mount Merapi could be considered as highly fertile soil.

Table 2. Properties of soil collected in all representative points of middle slope geomorphic unit.

| No | Sampling Locations | Content (%) | Soil pH | Texture (%) |
|----|--------------------|-------------|---------|-------------|
|    |                    | N-total     | Organic-C | Silt | Clay | Sand |
| 1  | Ngepring 1         | 1.85        | 11.59    | 7.11 | 18.29 | 6.10 | 75.61 |
| 2  | Ngepring 2         | 0.28        | 7.78     | 7.01 | 14.56 | 2.91 | 82.53 |
| 3  | Ngandong           | 0.15        | 9.56     | 7.04 | 47.81 | 6.38 | 45.81 |
| 4  | Bojong             | 1.42        | 9.85     | 7.18 | 11.93 | 2.98 | 85.09 |
| 5  | Kaliurang          | 0.28        | 10.88    | 7.22 | 21.14 | 6.04 | 72.82 |
| 6  | Kaliurang Timur    | 0.42        | 9.51     | 7.21 | 20.81 | 5.95 | 73.24 |
| 7  | Palemsari          | 0.72        | 5.56     | 7.21 | 8.77  | 2.92 | 88.31 |
| 8  | Tangkisan          | 0.32        | 13.18    | 7.29 | 35.36 | 3.54 | 61.11 |
| 9  | Giriharjo          | 0.32        | 12.55    | 7.26 | 37.20 | 0.00 | 62.80 |
| 10 | Balong             | 0.28        | 4.73     | 7.21 | 5.63  | 5.63 | 88.74 |
| 11 | Petung             | 0.44        | 10.82    | 7.35 | 21.83 | 3.12 | 75.05 |
| 12 | Batur              | 0.15        | 8.43     | 7.29 | 25.02 | 3.13 | 71.85 |
| 13 | Kalitengah Kidul  | 0.28        | 4.4      | 7.25 | 5.62  | 2.81 | 91.57 |
| 14 | Srunen             | 1.41        | 5.42     | 7.29 | 8.53  | 5.69 | 85.78 |
| 15 | Bandesari          | 0.99        | 7.1      | 7.29 | 34.66 | 2.89 | 62.45 |
| 16 | Singlar            | 0.28        | 8.13     | 7.36 | 23.42 | 2.93 | 73.65 |

Mean value 0.60 8.72

4. Conclusion
This present study showed that the impact of Mount Merapi’s post-eruption had significantly changed the soil properties in middle slope geomorphic unit, thus triggering the establishment of highly diverse yet stable vegetation community. These findings also emphasized that the eruption effect in this middle slope is now providing the area with such a highly fertile soil.

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