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Tree Vegetation Analysis after 10 Years of Mount Merapi Eruption

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Abstract. The 2010 Mount Merapi eruption caused variety of damage level in Mount Merapi National Park (MMNP). Over time, composition of vegetation and carbon stocks continues to change towards a climax. The objective of this study is to analyze the vegetation composition and tree carbon stocks in MMNP forest land with variations of damage level forest land after 10 years of Mount Merapi eruption in 2010. Data collection was administered from December 2019 to January 2020 in Dlimas (heavy damage), Gandog (moderate damage) and Tritis (minor damage). Plot placement was determined randomly in each location by making the main plot of 20 x 100 m for large trees and a subplot of 5 x 40 m for small trees (poles, saplings, seedlings). The composition vegetation analysis was performed using an inverted J curve, Importance Value (IV) index and Shannon-Wiener Diversity Index (H'). The calculation of carbon stock and woody necromass (dead trees) using allometric equations. Based on the results of data analysis, there are 40 species from 34 families. Moderate damage location has the highest diversity index H' for large trees of 0.45 and small trees of 2.23. The highest carbon stock of tree stands and woody necromass was in minor damage of 172.06 ton ha-^{1}, followed by moderate damage of 119.42 ton ha-^{1} and minor damage as much as 10.29 ton ha-^{1}. Moderate and minor damage locations have curves that are close to inverted J shape with the density of seedlings and saplings more than large trees as a form of secondary forest regeneration. Abiotics correlated to carbon stock and tree density consist of air temperature, air humidity, soil pH, soil moisture, land slope and elevation. Ten years after the eruption, forests with moderate dan minor damage in MMNP Yogyakarta Province have high regeneration rate and carbon stock.

Keywords: allometric, damage, Merapi, succession, trees

Running title: 10 Years After Merapi Eruption

INTRODUCTION

Mount Merapi is a volcano with the highest volcanic activity in the world (BPS, 2001), recorder that 2010 was one of the biggest eruptions since the last 150 years (BNPB, 2011). According to Gunawan et al. (2013), due to 2010 Merapi eruption, caused environmental losses of 3.39 trillion and the economy of 2.63 trillion rupiah. Lava material, pyroclastic flow and volcanic dust were released during the eruption of Merapi caused fires in trees and damaged forest ecosystems in the Mount Merapi National Park (MMNP) area. Marhaento and Kurnia (2015), stated that forest with heavy damage is characterized by the entire area completely destroyed by pyroclastic flow or nuèes ardentes, moderate damage is characterized by some areas affected by hot lava, leaving woody necromass (dead trees), and minor damage is only affected volcanic dust without destroying the vegetation.

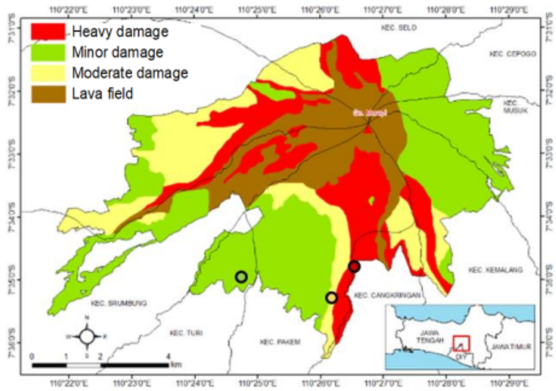
Since the eruption in 2010, Mount Merapi has continued to change towards a climax or called succession (Krisnawati et al., 2011). The level of land damage affects the succession process, in which heavy damage causes longer process to climax (Sutomo, 2019). Several indicators to determine whether the succession process has occurred can be seen from the diversity of plants, tree stands and carbon stocks (Krisnawati, 2011; Mukhtar and Heriyanto, 2012). According to Indriyanto (2006) and Butarbutar (2009), increasing number of trees stands in damaged forest areas shows that the succession process has progressed to the secondary forest stage. The increase of tree density and diversity is also in line with the increase in tree carbon stock value (Krisnawati, 2011). The carbon stock which was recommended by Erly et al. (2019) and Rahayu and Harja (2013) for tropical forests in Indonesia ranging from 100 to 300 ton ha^{-1}.

After the eruption as well, several studies have been conducted on the vegetation analysis and measurement of carbon stocks. The results of remote sensing by Soraya et al. (2016), show that five years after the eruption, 28% of the ecosystem in MMNP has improved. Afrianto et al. (2016), explained that six years after the 2010 Merapi eruption, 25 tree species from 18 families were found and dominated by herbs. Gunawan et al. (2016), Afrianto et al. (2017) and Haryadi et al. (2019) added that there is an increase in the number of invasive alien species *Acacia decurrens* Wild. at heavy damage location, Cangkringan and Kemalang resorts. The succession process continued in the areas affected by the eruption. The data collection on vegetation composition and carbon stock was continuously administered as a data base for the succession in MMNP. Vegetation composition and carbon stock data have to be conducted as a data base for the succession in MMNP. The objective of this study is to analyze vegetation and tree carbon stocks in MMNP forest land with variations of damage level 10 years after the Merapi eruption in 2010.

MATERIALS AND METHODS

Study area

Data were collected from December 2019 to January 2020. The research location was in Mount Merapi National Park (MMNP) forest area D.I. Yogyakarta Province, especially Dlimas at Cangkringan Resort for heavy damage representative, Gandog at Pakem Resort for moderate damage representative and Tritis at Turi Resort for minor damage representative (Figure 1). Distribution of research location is based on the damage level distribution map made by Marhaento and Kurnia, (2015). Conditions for sampling locations can be seen in Figure 2.



Note: Dlimas S 07°34.675' E 110°26.546'; Gandog S 07°35.830' E 110°26.124'; Tritis S 07°34.991' E 110°24.970'
Figure 1. Location of sampling: Dlimas (O red), Gandog (O yellow) and Tritis (O green) (modified by Marhaento dan Kurnia, 2015)

Figure 2. Landscape of sampling location in 2020: Dlimas as heavy damage (left), Gandog as moderate damage (center), Tritis as minor damage (right)

Procedures

Plot making

According to Soerianegara and Indrawan (2005), Hairiah and Rahayu (2007) to analyze vegetation and tree carbon stock, it is necessary to make plot with size of 20x100 m^2 for large trees (DBH > 35 cm), and sub-plot of 5x40 m^2 for small tree. The small trees were divided into poles (10 cm< DBH < 35 cm), saplings (high > 1.5 m and DBH <10 cm) and seedlings (high<1.5 m). Furthermore, carbon stock measurements were also conducted for woody necromass (dead trees). Plot sampling design can be seen in Figure 3.

Vegetation data collection

Data taken to measure tree diversity were species's name, density, frequency, and tree dominance. Then, the data were ratified to calculate the Importance Value (IV) index and the Shannon Wiener Diversity Index (H') (1) (Utami and Putra, 2020). H' values less than 1 indicate low diversity, between 1-3 indicate moderate diversity, and more than 3 indicate high diversity. Moreover, the density of seedlings, saplings, poles and large trees was used for analyzing the inverted J curve. The number of species data between locations was used for calculating the Sorensen Similarity Index (SI) (2). Data taken to measure carbon stock of tree and necromass were tree biomass and woody necromass biomass which will be calculated later into carbon stock. Measurement of tree biomass in tropical regions with rainfall of 1,500-4,000 mm was administered using the allometric equation (3) according to Hairiah et al. (2001). Measurement of woody necromass biomass was conducted using the allometric equation (4) according to Hairiah and Rahayu (2007). Carbon stock was measured by multiplying 46% of the total tree biomass and woody necromass (Hairiah et al., 2011).

Abiotic data collection

Abiotic parameters measured were wind speed, light intensity, air temperature and humidity, soil temperature, soil pH and humidity, elevation, coordinate points and land slope. The abiotic parameters were measured in each sub-plot of 20x20 m^2 marked X in Figure 3.

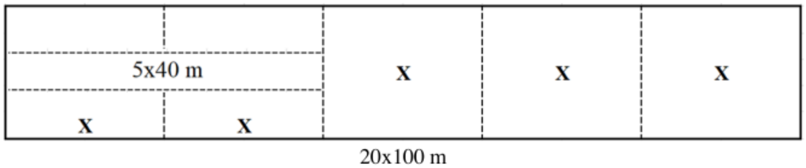


Figure 3. Sampling plot with X as abiotic parameter taking point (Hairiah and Rahayu, 2007)

$H' = -\Sigma\, pi \log pi$ ………………………………..………………. (1)

$pi = (n/N)$

Note: H' = the Shannon Wiener diversity index

n = important value species x

N = total number of the Important Value

$IS = \frac{2C}{A+B} \times 100\%$………………………………………………….. (2)

Note: IS = the Sorensen similarity index

A = total number of species at A community

B = total number of species at B community

C = same number of species and occur in both communities

$B = 0{,}118 \times DBH^{2{,}53}$……………………………………… …… (3)

Note: B = tree biomass (ton ha^{-1})

DBH = *Diameter at Breast Height* (cm)

$BK = \frac{\pi \rho H D^2}{40}$ ………………………..……………………………..... (4)

Note: BK = woody necromass biomass (kg $necromass^{-1}$)

D = diameter of necromass (cm)

H = length / height of necromass (m)

ρ = density of necromass (0.4 g cm^{-3})

Data analysis

Tree density, tree carbon stock and abiotic data from research locations was statistically tested using a correlation test to see the relationship between abiotic, tree density and carbon stock. Statistical test began with a normality test using the Kolmogorov-Smirnov test. Furthermore, Levene test homogenity test was conducted to determine whether data is normally distributed homogeneous or not. The value of ρ-value (Significant) >0.05 indicates that the data were normally distributed and homogeneous. Then, the correlation test was conducted using Pearson's parametric method provided that the data was normally distributed and homogeneous. If the method requirements parametric was not fulfilled, the Spearman non-parametric test was performed.

RESULTS AND DISCUSSION

Composition of Trees

Tree density analysis of each life form was used for analyzing secondary forests rate of regeneration. According to Utami and Putra (2020), a disturbed forest experiences succession to secondary forest, characterized by a low density of large trees and high density of saplings and seedlings. The density curves of each life form that are close to the inverted J is assumed to have the best regeneration rate for secondary forest. The high density of seedlings and saplings illustrated an abundant supply of trees in the future. The highest density of seedlings and saplings was in the locations of minor and moderate damage with values of 2,750 individual ha^{-1} and 2,650 individuals ha^{-1}. Based on Figure 4, heavy damage location does not show an inverted J curve because density of seedlings was still low. Figure 2 shows that there are not many small or large trees in Dlimas location. The opposite result is indicated by moderate and minor damage location which forms a curve close to inverted J because the density of seedlings and saplings is higher than large trees. The curve in both locations shows that regeneration of the trees began to occur after 10 years of Merapi eruption in 2010. According to Sidiyasa (2009), Dendang and Handayani (2015), inverted J curve shows dynamic and balanced forest conditions. Irawan (2011), Wahyuni and Kafiar (2017), Utami and Putra (2020), emphasized that an inverted J curve indicates that germination process of seedlings and saplings continues to provide supply for mature forest.

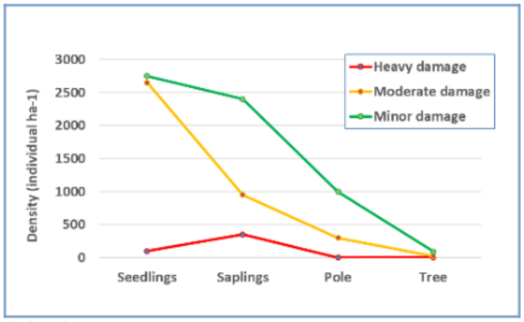


Figure 4. Inverted J curve at three study locations

Species found in three locations consisted of 40 species from 34 families. Based on Table 1, the highest number of species was in minor damage locations with 22 species, followed by moderate damage locations with 16 species, and the lowest was in heavy damage locations with 2 species. The difference number of species was influenced by the level of damage in initial community. Indriyanto (2006) and Rianti (2017) asserted that greater level of damage, will make the succession process slower. Dominant family in heavy damage location was Theaceae family, moderate damage location was Fabaceae family and minor damage location was Solanaceae family (Table 1). The discovery of dominant family differenced according to the number of species discovered from that family. Based on Table 1, dominant family in heavy damage location was from Theaceae family, such as *Schima wallichii*. Theaceae family can thrive in tropical and subtropical forests, especially in Southeast Asia. This family consists of nine genera and has 460 species (Prince, 2007). The dominant family in moderate damage location is Fabaceae, such as *Albizia chinensis, Caesalpinia pulcherrima* and *Calliandra calothyrsus*. Fabaceae family consisted of 770 genera and more than 19,500 species. Pod fruit can be spread by wind (Rahmita et al., 2019). Dominant family in minor damage location is Solanaceae family, such as *Cestrum nocturnum*. Solanaceae family comprises of 3,000 species and grows maximum near the equator line (Jagatheeswari, 2014).

Table 1. Tree composition on research location

Location (level of damage)	Number of species	Number of family	Dominant family	The highest IV index	Life form
Dlimas (heavy)	2	2	Theaceae	*Trema orientalis* (L.) Blume	Large tree
				-	Pole
				Schima wallichii Choisy	Saplings
				Schima wallichii Choisy	Seedlings
Gandog (moderate)	16	13	Fabaceae	*Albizia chinensis* (Osbeck) Merr.	Large tree
				Mallotus peltatus (Geiseler) Müll.Arg.	Pole
				Albizia chinensis (Osbeck) Merr.	Saplings
				Calliandra calothyrsus Meisn.	Seedlings
Tritis (minor)	22	19	Solanaceae	*Pinus merkusii* Jungh. & de	Large tree
				Cestrum nocturnum L.	Pole
				Cestrum nocturnum L.	Saplings
				Cestrum nocturnum L.	Seedlings
Total	40	34	-		

Table 1 shows that the highest Important Value (IV) index for large tree at heavy damage location is *Trema orientalis*. According to Sundarapandian and Swamy (2000), Abdiyani, (2008), the highest IV index indicates that a species has the most important role in that area. These species can adapt well and have the most dominant influence on the changes in environmental conditions and existence of other species. *T. orientalis* or Anggrung for the local name has a status as a native species in MMNP. Anggrung was discovered at altitude of 1,169.25 meters above sea level (m asl) with an air temperature of 27.6°C. This condition is in accordance with Orwa et al. (2009), that *T. orientalis* is able to grow at high altitudes 0-2,000 m asl with an air temperature of 20-27 °C. Furthermore, species with the highest IV index at heavy damage location for seedling and sapling was *Schima wallichii* or Puspa as the local name, a native species in MMNP. According to Purnama et al. (2016), Puspa can grow in highlands above 1,000 m asl. Furthermore, Puspa also can adapt well by fire damage. Puspa has thick bark and its seedlings are able to grow rapidly in the rainy season. Puspa found in Dlimas was the result of planting from restoration activities by *Balai Taman Nasional Gunung Merapi* (Department of Mount Merapi National Park). The existence of this planting was marked by discovery of bamboo to support tree seedlings. Restoration efforts conducted by *Balai Taman Nasional Gunung Merapi* aims to restore the condition of Dlimas in Cangkringan Resort as a location affected by heavy damage and maintaining native species in MMNP. Afrianto et al. (2017), Haryadi et al. (2019), explained that an invasive alien species was found, which was *Acacia decurrens* Wild. at MMNP Cangkringan and Kemalang Resort. *A. decurrens* invasion was still visible and dominated in Dlimas but it grows rapidly outside the research plot on steep slopes.

At moderate damage location, the highest IV index for large trees and saplings was *Albizia chinensis*, for poles was *Mallotus peltatus* and for seedlings was *Calliandra calothyrsus*. *A. chinensis* or its local name Sengon, is a native species in MMNP (Gunawan et al., 2013). According to Krisnawati et al. (2011), Sengon can live on volcanic soils, with pH range from neutral to acidic soils and an air temperature range of 22-29 °C. Gandog site is at an altitude of 891.2 m asl and has volcanic soil with soil pH average of 5.86 and an air temperature of 25.3 °C. *Mallotus peltatus* with Tutup putih as local name, is native species in MMNP. According to Slik and Van Welzen (2001), *M. peltatus* can be found in primary and secondary forest types with an altitude of up to 1,800 m asl. *M. peltatus* can also grow optimally in open land and adapt to both rock and volcanic soil like in Gandog, Turi Sub-district. The next species, *Calliandra calothyrsus*, with the local name Kaliandra, is an alien species from Guatemala in MMNP (Plantlist, 2020). According to Orwa et al, (2009) and Gunawan et al. (2013), Kaliandra is commonly discovered on the Java Island with an altitude of 250-800 m asl. Moreover, Kaliandra is able to live in acidic soil conditions with an air temperature of 22-28 °C.

At minor damage locations, the highest IV index value for large trees was *Pinus merkusii*, while the poles, saplings and seedlings were *Cestrum nocturnum*. *P. merkusii* or its local name Pinus is a native species in MMNP. According to Corryanti and Rahmawati (2015), pinus discovered in an altitude of 400-1,500 m asl with an air temperature of 20-30 °C. Based on measured abiotic data, altitude in Tritis, Turi Sub-district was 1,045 m asl with an air temperature of 21-25 °C. Furthermore, *C. nocturnum* with the local name Arumdalu is an alien species from Jamaica (Plantlist, 2020). According to Shaista and Amrita (2016), Arumdalu can live in altitude of 100-2,500 m asl which has a pH soil of 6.6-7.5 which is in accordance with the geographical conditions of Tritis. Tjitrosoedirdjo et al. (2016) and Thapa et al. (2018), stated that invasive alien species pose a real threat to diversity because they have the potential to damage native ecosystems in that area. The costs incurred for controlling invasive alien species are relatively large so that it becomes an international issue for biodiversity conservation.

Data on the occurrence of species between research locations illustrate the similarity of communities between locations. The rsults of the comparison of the Sorensen similarity index were not found in the same communities from the three research locations. It is shown by the similarity index value <50% in table 2. According to Siappa et al. (2016) and Nurjaman et al. (2017), the community similarity index has a value range between 0-100%. A value of 50-100% indicates community similar, and a value <50% indicates inequality. The differences in communities found from the three research locations could be caused by differences in the number of species. Furthermore, differences in topography and altitude may also affect the results of SI value. Dlimas has a steep mountain slope topography with an altitude of 1,169.25 m asl. Gandog has a slightly steep topography but dominantly slopes with an altitude of 891.05 m asl. Tritis has a very sloping topography with an altitude of 1,045 m asl. Destaranti et al. (2017) and Sitanggang et al. (2017), stated that of the location is a limiting factor for several habitats for plant species which cause differences in stand composition and structure.

Table 2. Sorensen community similarity index between each location

Compared location	IS (%)
Dlimas (heavy) and Tritis (minor)	0.00
Dlimas (heavy) and Gandog (moderate)	2.17
Gandog (moderate) and Tritis (minor)	6.28

Diversity of Tree

Ten years after the 2010 Merapi eruption, the diversity of trees in the research location was still classified as moderate and even low. Heavy damage location (Dlimas) has H' value of 0.00, which means that tree diversity is very low. Large tree diversity in all locations is also low in diversity (Figure 5). Moderate diversity is reflected in large tree communities where moderate and minor damage with H' value of 2.23 and 1.96. Diversity value provides information about the wealth and abi14 of tree communities to restore damaged environments (Kasim and Hamid 2015; Safe'I and Tsani 2016). Samin et al. (2016), Toni et al. (2017), Sutrisna et al. (2018), asserted that forest areas with high diversity can be achieved if the distribution of different species is evenly distributed 5nd not dominated by just one species. Conversely, if a community has a low species diversity value, the community is composed of few species and there are dominant species. In line with Hidayat (2017), the level of diversity is also influenced by the number of species and individuals. Tritis location has a high number of individual trees, but it is dominated only by *P. merkusii* so that the diversity level is very low.

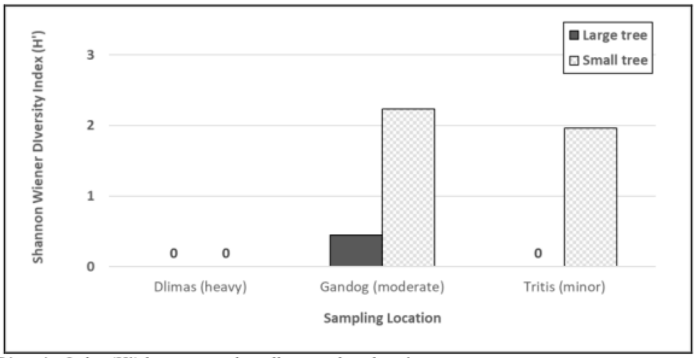


Figure 5. Shannon Wiener Diversity Index (H') large tree and small tree at three locations

Carbon stocks for Trees and Woody Necromass

Tree stand and necromass biomass calculations were conducted first to determine amount of tree carbon stock, and also woody necromass (dead trees). Tritis as minor damage location has the highest carbon stock with 172.06 tons ha^{-1} followed by moderate damage location with 119.42 tons ha^{-1} and heavy damage location with 10.29 tons ha^{-1} (Table 3). The total amount of carbon stock in Tritis and Gandog is in accordance with the recommendations of Rahayu and Harja (2013) and Erly et al. (2019), who explained that carbon stock for secondary tropical forests in Indonesia ranges from 100-300 ton ha^{-1}. Furthermore, Reducing Emission from Deforestation and Forest Degradation or REDD + (2010) adds 3 criteria for carbon stocks in forest ecosystems, which were low carbon stock (<35 tonnes ton ha^{-1}), medium carbon stock (35 - 100 ton ha^{-1}), and high carbon stocks (> 100 ton ha^{-1}). Based on these criteria, heavy damage location was classified as having low carbon stock, while moderate and minor damage location have high carbon stocks. The difference in amount of carbon stock from three locations was caused by variations in damage due to the 2010 eruption of Merapi. The eruption which caused loss of several tree stands in heavy damage location so that after 10 years of Merapi eruption, the amount of carbon stock was still low. It is different with moderate and minor damage location, there has been regeneration of large and small trees after 10 years of the eruption so that carbon stock is high. It is supported by the opinion of Marispatin et al. (2010) and Oktavianto et al. (2015), that forest destruction may reduce the amount of tree biomass and carbon stock and increase in line with the succession. Apart from the level of damage, biomass and carbon stock are also influenced by climatic factors such as rainfall. Based on Badan Meteorologi Klimatologi dan Geofosika (BMKG, 2020) or Department of Meteorology Climatology and Geophysics, when data sampling was administered, the rainfall from December 2019 to January 2020 was high with a value of 396.40 mm. Budiman et al. (2015) added that high rainfall can reduce leaf evaporation so that leaves remain fresh and do not fall easily. Conversely, the lower rainfall, higher air temperature cause leaves to fall. It indirectly affects the amount of biomass and carbon stock of tree stands.

Table 3. Tree biomass and carbon stock

Location (damage level)	Tree stand biomass (ton ha^{-1})	Woody necromas biomass (ton ha^{-1})	Total biomass (ton ha^{-1})	Tree and necromas carbon stock (ton ha^{-1})
Dlimas (heavy)	8.87	13.49	22.36	10.29
Gandog (moderate)	177.28	82.34	259.62	119.42
Tritis (minor)	374.04	0.00	374.04	172.06

Abiotic from research location consisting of light intensity, wind speed, air temperature, air humidity, soil pH, soil moisture, soil temperature, elevation and soil slope was tested for correlation with tree carbon stock and tree density. Before the correlation test was conducted, the data were tested for normality and tested for homogeneity. Spearman's non-parametric test results between tree density and tree carbon stock show a correlation between two data. Furthermore, there is an abiotic correlating with tree carbon stock and tree density consisting of air temperature, air humidity, soil pH, soil humidity, soil slope, and elevation by value of Significant (2-tailed) < 0.05 (Table 4). The correlation between tree density and tree carbon stock based on Table 4 is very strong and positive with correlation coefficient of .820**. These results are in accordance with the conditions of research location which has many large and small tree stands with high density especially at moderate and minor damage locations. Nowak and Crane (2002), found that high tree density has the potential to produce carbon stocks in very large quantities. Adinugroho (2011), Lubis et al. (2013), and Sato et al. (2014) added that number of stands and tree diameter is directly proportional to amount of carbon stock, so that the increasing in diameter and number of trees stands more carbon stock is produced. The abiotic that has a positive correlation with carbon stock and density is soil humidity. The results of the measurement of average soil moisture in the study area were 36.28%. According to Batheba et al. (2016), the soil moisture is related to the availability of water used by plants as a solvent in metabolic processes. The better metabolism and plant growth, the higher the carbon stock. Kirkham (2005) emphasized that soil humidity more than 40% is classified as wet, and strongly supports the value of carbon stock and tree density in a forest.

Abiotic parameters that have a negative correlation with tree carbon stock and tree density include air temperature, air humidity, soil pH, elevation, and soil slope. Air temperature having a negative correlation indicates that lower air temperature value, more accumulated carbon stock will be, and number of tree stands will increase. Air temperature at the study site has an average of 25.7 °C. Setiawan (2009) and Servina, (2019), stated that the air temperature needed for tropical plants to conduct the germination process ranges from 20-25 °C. The humidity recorded at the research location has an average of 53.78%. Servina (2019), asserted that humidity in the range of 50-60% can help the process of flower formation and germination. According to Rusdiana and Lubis (2012), soil pH indirectly affects the amount of carbon stock because it assists the process of absorption of nutrients in the soil. Nutrients are used in the growth process, thus it increases the amount of carbon stock absorption and density. Rahmawanto et al. (2015) and Karamina et al. (2017), added that the ideal soil pH for plants has a susceptible value of 5-7. Soil pH at the research location has an average pH of 6.32 which is slightly acidic. Soil pH which is slightly acidic comes from the decomposition of litter and leaf dropping in the study site. The elevation is negatively correlated with carbon stock and land density and slope negatively correlated with density, indicating that the lower elevation and degree of slope of the land, the higher carbon stock and tree density. The results of the measurement of average elevation at the study location was 1,034.62 m asl with an average slope of 13.41°. Andrian et al. (2014) and Yulina et al, (2015) stated that land in mountainous locations with a slope of ≥ 15° is at great risk of experiencing landslides. The results of landslope is able to form deposits of minerals and nutrients on the lower slopes of the mountain, so that these piles can be used properly by plants. Based on this theory, the location conditions with lower elevations and sloping topography are ideal for tree growth so that they affect carbon stocks and tree stands.

Table 4. The results of Spearman correlation test on tree carbon stock, tree density and abiotic from three research locations

Compared Parameters		Correlation Coefficient
Tree carbon stock	Tree density	.820**
	Air temperature	- .415**
	Air humidity	- .534**
	Soil pH	- .335*
	Soil humidity	.457**
	Elevation	- .332*
Tree density	Tree density	.820**
	Air temperature	- .411**
	Air humidity	- .534**
	Soil pH	- .335*
	Soil humidity	.405*
	Elevation	- .406*
	Soil slope	- .416**

Other uncorrelated abiotic indicate that research environment has not yet formed a comfortable or appropriate condition for amount of tree carbon stock and tree density. Furthermore, the conditions when field data were collected could have an effect on abiotic measurement results. When collecting data, the condition of the research location had entered the rainy season (December 2019 - January 2020). This condition affects low light intensity, wind speed and soil temperature. Low light intensity can inhibit plant growth due to the availability of sunlight. Low wind speeds inhibit the seed and spore dispersal process. Low soil temperatures can inhibit soil mineral extraction activities (Indriyanto 2006; Hardanto et al. 2009; Nahdi and Darsikin, 2014).

CONCLUSIONS

Ten years after 2010 Merapi eruption, 40 tree species from 34 family were discovered in three research locations. Gandog as representative of moderate damage locations and Tritis as representatives of minor damage locations have good vegetation regeneration where the density of each tree life form forms a curve like an inverted J. Large trees and small trees in research location still have a moderate or even low diversity level. The diversity of small and large trees is the highest, which is in moderate damage location. The highest tree carbon stocks and woody necromass were found in minor damage locations, followed by the moderate damage locations.

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