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Soil macrofauna diversity in andisol after eight years of Mount Sinabung eruption in Sumatra, Indonesia

MARIANI SEMBIRING♥, HIDAYATULAH MUNAWAROH, MUKHLIS, BENNY HIDAYAT, TENGKU SABRINA
Faculty of Agriculture, Universitas Sumatera Utara. Jl. Prof. A. Sofyan No. 3, Kampus USU Padang Bulan, Medan 20155, North Sumatra, Indonesia. Tel.: +62-61-8213236, Fax.:+62-61-8211924, ♥email: mariani.sembiring29@yahoo.com; marianisembiring@usu.ac.id

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Abstract. *Sembiring M, Munawaroh H, Mukhlis, Hidayat B, Sabrina T. 2021. Soil macrofauna diversity in andisol after eight years of Mount Sinabung eruption in Sumatra, Indonesia. Biodiversitas 22: 3024-3030.* The eruption of Mount Sinabung resulted in the volcanic ash covering the soil of various thicknesses. That will affect the population and diversity of macrofauna in it. This research aimed to determine the Andisol soil macrofauna in Karo District with various thicknesses of volcanic ash covering from Mount Sinabung. This research was conducted in May 2019. Plots were placed in four locations, Location I: processed land (0 cm), Location II: Land covered by thin ash (≤2 cm), Location III: Land covered by medium ash (2-5 cm), Location IV: Land covered by thick ash (≥5 cm). Sampling was conducted by using the Pitfall trap, Monolith squared, and Hand sorting methods. The research results indicated that the thicker the volcanic ash covering the soil surface, it would reduce soil moisture, soil water content, organic C, and soil pH, but on the other hand, increase the soil temperature. A total of 20 species were able to live on the Andisols affected by the eruption of Mount Sinabung.

Keywords: Ash thickness, soil macrofauna, diversity, Mount Sinabung

INTRODUCTION

Soil organisms play a major role in increasing the availability of soil nutrients and the carbon cycle in the ecosystem and also plays an important role in decomposition, the dynamics of organic matter and affect the physical characteristics of the soil (Bardgett and Van Der Putten 2014; Siqueira et al. 2014; Moura et al. 2015; Wall et al. 2015). According to Fierer et al. 2012 and Siqueira et al. 2014, soil macrofauna is part of soil biodiversity that plays an important role in improving the physical, chemical and biological properties of soil through immobilization and humification processes. Organic matter content and environment are strongly influencing the existence of soil macrofauna (Peritika et al. 2012). Organic matter is a source of food for organisms in the soil. The research results of Munawaroh et al. (2020) stated that the lower the soil C organic, then the fewer macrofauna species can live.

Mount Sinabung volcanic ash has a low pH. Soil mixed with volcanic ash from Mount Sinabung (topsoil) is considered acidic. According to Sinaga et al. (2015), the thicker the volcanic ash, then the lower the soil pH by 3.74 – 4.50. Volcanic ash thickness can affect the physical, chemical, and biological properties of the soil. Based on the research of Simbolon et al. (2018), Qadaryanti et al. (2020), and Zebua et al. (2020), the thicker the volcanic ash covered the soil, then it will affect the decreasing of the soil properties, including soil moisture, C-organic, water content, and soil pH. The organic matter content will decrease when volcanic ash that covers the soil becomes thicker because soil organisms are difficult to survive in that condition, resulting in the inhibition of the decomposition process. Soil water content and soil pH have the greatest effect on fauna distribution. Volcanic ash that covers the soil surface can hinder the entry of sunlight into the soil. The intensity of sunlight received by ecosystems is an important determinant of primary productivity affecting species diversity and nutrient cycling (Oliveira et al. 2014; Wagg et al. 2014).

The ash thickness will affect the amount and the activity of soil macrofauna on the land affected by the eruption of Mount Sinabung. According to Hanafiah et al. (2010), macrofauna is called ecosystem regulators because they greatly affect the soil structure. Their impurities produce organic matter or a mixture of organic minerals. A microhabitat is directly affected by the physical and chemical properties of the soil and its nutrient content (Widyati 2013). Biotic and abiotic environmental factors (Nugroho et al. 2018; Carvalho et al. 2012) that can affect the activity of soil organisms are rainfall, temperature, soil pH, humidity, soil temperature, nutrients, and vegetation. Land cultivation will affect soil macrofauna (Quintero 2012). Maintaining soil quality is essential for conserving biodiversity and sustainable management of renewable resources (Vasconcellos et al. 2013). This research aimed to identify macrofauna diversity in Andisol soil covered with various thicknesses of volcanic ash and related to soil macrofauna life after eight years of being affected by the eruption of Mount Sinabung.

MATERIALS AND METHODS

This research was conducted in April-September 2019 in Kuta Rakyat and Sigarang-garang Villages, Naman

Teran Sub-district, Karo District, North Sumatra, Indonesia with an altitude of 1,300-1,600 m above sea level, and the temperatures ranging from 16-17ºC. Soil sampling was carried out by the transect method with four location points. Soil sampling points are differentiated based on the ash thickness; Location I: Processed land, Location II: Covered by thin volcanic ash (<2 cm), Location III: Covered by moderate volcanic ash (> 2-5 cm), and Location IV: Covered by thick volcanic ash (> 5 cm) (Figure1). Each location was taken 10 sample points with a minimum distance of 10 m. Soil sampling was carried out to a depth of 0-30 cm. Measurement of soil moisture and temperature is carried out in the field before the soil is taken. The moisture and temperature of soil were measured by using a soil tester and a soil thermometer, respectively. Soil pH and C-Organic soil measurements were carried out in the laboratory. Soil pH was measured using a pH meter and C-Organic using the Walkley and Black method.

A sampling of active soil macrofauna on the soil surface was carried out using the Pitfall Trap method. At each sampling point that had been determined, Ten pitfall traps were placed and planted in a plastic container with a diameter of 15 cm with a distance of at least 10 m from one another. The surface of the container is planted parallel to the soil surface, and then this container is given a roof with a size of 30 × 30 cm^2 ± 15 cm high from the ground to avoid rainwater and sunlight. Then the container is filled with a 70% alcohol solution of ± 250 ml mixed with a little detergent solution. These Pitfall Trap containers were installed at 08.00 AM and collected in the next three days. Quadratic and hand sorting methods are used for sampling soil macrofauna that is less active at the soil surface. Soil samples at the sampling point were taken to a depth of 30 cm using a square monolith measuring 30 × 30 cm. Sampling was conducted between 06.00-09.00 AM. Furthermore, the identified soil macrofauna was taken by hand sorting method. The identified soil macrofauna was then collected and preserved with 70% alcohol. Macrofauna observations were carried out using a microscope and identified macrofauna based on references of Borror et al. (1992), Christina et al. (1991), and Suin (2012).

Data analysis

Soil macrofauna species and the number of individuals in each identified species were analyzed for the Density (D), Relative Density (RD), Attendance Frequency (AF), Shannon-Wiener Diversity Similarity Index (Q/S) values. To determine the soil macrofauna community was calculated according to Husaman et al. (2017) and Suin (2012) formulas.

Density (D)

$$D = \frac{\text{Number of individuals of a species}}{(\text{Number of plots} \times \text{plot area})}$$

Relative Density (RD)

$$RD = \frac{\text{The density of a species}}{\text{Total density of all species}} \times 100\%$$

Attendance Frequency (AF)

$$AF = \frac{\text{The number of plots a species occupies}}{\text{The total number of plots}} \times 100\%$$

The AF value based on its constancy as follows:
AF value : 0-25%: Accidental Constancy (very rare)
AF value : 25-50% : Accessory Constancy (rare)
AF value : 50-75% : Constan Constancy (often)
AF value : >75% : Absolute Contancy (very often)

Sorensen's Similarity Index (Q/S)

To identify the similarity value of each soil macrofauna between locations, it was calculated using the following formula:

$$\mathbf{Q/S} = \frac{\mathbf{2J}}{\mathbf{(A+B)}} \times \mathbf{100\%}$$

Note:
Q/S : Similarity index between locations
J : The number of the same species at two different sites
A : Number of species at Location I
B : Number of species at Location II
The value of Q/S was as follows:
Q/S value: < 25%: The similarities are not very similar
Q/S value: 25-50%: The similarities are not similar
Q/S value: 50-75% : The similarities are similar
Q/S value: > 75%: The similarities are very similar

A B C D

Figure 1. The thickness of the ash at the research location, namely (A) Location I: Land that has been processed, (B) Location II: Covered by thin volcanic ash (<2 cm), (C) Location III: Covered by moderate volcanic ash (> 25 cm), (D) Location IV: Covered by thick volcanic ash (> 5 cm)

RESULTS AND DISCUSSION

The presence of soil macrofauna is largely determined by environmental factors. Based on the research, when the volcanic ash covering the soil surface for a long time, it will settle and harden on the soil surface depending on the thickness level. This will affect soil temperature, humidity, soil water content, soil C-organic content and soil pH (Table 1). Changes in soil temperature are increasing with the thickness of the volcanic ash on the soil surface. The increase in soil temperature was 11-16%. According to Nugroho et al. 2018 and Carvalho et al. 2012, temperature greatly affects the life of organisms. The humidity decreased to 61.70%, while C-organic water content and pH of soil decreased to 25.42%. This indicated that the thicker the volcanic ash above the soil surface, then the air circulation in the soil becomes obstructed; hence the soil temperature increases. This also resulted in the inhibition of rainwater from entering the soil so soil moisture and soil water content decreased. The low level of soil C-organic in Location IV was due to the reduced activity of organisms and fewer plant roots hence C-organic in the soil decreased. This will affect the soil macrofauna population at each study location (Fig. 2)

The decreased in pH and its relation to the volcanic ash thickness because the ash covering the soil can contribute to soil acidity. Research results by Simbolon et al. (2018), Sembiring and Fauzi 2017, Sembiring et al. (2016, 2017) stated that the soil pH in Andisols affected by Sinabung eruptions ranged from 4.1-5.5. Soil macrofauna is very sensitive to soil pH. Soil organisms grow best at a pH around neutral hence this is a limiting factor. The research results by Sinaga et al. (2015) also indicated that the thicker the volcanic ash that covers the soil, then the organic matter content becomes lower. This is because soil organisms are difficult to survive. Therefore the decomposition process is inhibited, which affects the soil organic matter content. The research results by Fatmala et al. (2015) stated that soil with an ash thickness of > 5 cm has a very acidic pH which is the optimal condition for fungal growth. The existence of fauna in the soil is largely determined by environmental factors and organic matter as food (Bragina 2016; Sari 2014).

The highest number of species was Location I (20 species), followed by Location II (15 species), Location III (12 species), and Location IV (7 species) (Table 2). This indicated Location I has a better carrying capacity for various soil macrofauna species. At Location I, two species of Phylum Annelida, 15 species of Phylum Arthropod, and three species of Phylum Mollusca were found. The existence and the distribution of fauna species are always related to the habitat and ecological niches where they occupy (Hanafiah et al. 2010). The species belong to Phylum Annelida were more common in Locations I and II, while they were not found in Locations III and IV. The Arthropod decreased along with the reduced soil water content at Location IV. Arthropods prefer environmental conditions in which water content is available (Moura et al. 2015; Sari, 2015). Therefore, dry soil conditions can cause soil macrofauna bodies to lose water, and this is a big problem for their survival (Bhadauria and Saxena 2010; Laossi et al. 2010).

The density and soil fauna presence can be affected by soil pH content. Phylum Annelida, especially earthworms (*Megascolex* sp.), were not found at Location IV with 4.21-4.32 soil pH content. According to Moura et al. 2015, earthworms require a close to neutral soil pH for optimum growth. Phylum Mollusca generally prefers pH 5-9. If the pH is < 5 or > 9, it will create unfriendly conditions for their growth (Joesidawati 2008; Slessarev et al. 2016). Mollusca prefers to live in relatively low soil temperatures and high humidity with sufficient water content (Schowalter et al. 2003b). According to Suin (2012), Phylum Mollusca can live well in high C-organic conditions. Species of *Phyllophaga* sp. (ground beetle) and *Bradybaena similari*s were only found in Location I. This is presumably that *Phyllophaga* sp. and *Bradybaena similari*s prefer habitats with high water content and organic matter. The factor that causes the high population density of a species compared to others is thought to be the ability to adapt and compete in occupying a habitat. The factors affecting the number of species that are only found in certain locations are the different activity and ability to adapt to the environment and also the effect of the planted plants (Hanafiah et al. 2010; Slessarev et al. 2016).

The highest total density value was Location I (771.90 Ind/m^2), while the lowest was Location IV (73.05 Ind/m^2) (Table 3). The high total density of soil macrofauna at Location I was because the land was not covered by volcanic ash. This makes the physical and chemical factors of the soil such as moisture, soil temperature, pH, soil water content, and C-Organic are better with more suitable conditions compared to the other locations. *Odontoponera* sp. (black ants) was the dominant soil macrofauna in all locations (D value= 477.71, RD value= 61.89%.) This value gradually decreased with the increasing thickness of the volcanic ash covering the land.

Table 1. Soil conditions at the research location

Location	Parameter				
	Soil temp. (°C)	Moisture (%)	Soil water content (%)	C-organic (%)	pH H_2O
I	18-19	76-78	45.28-46.35	6.06-7.01	5.28-5.42
II	19-20	71-73	38.23-40.04	5.06-5.21	5.01-5.25
III	19-20	66-70	36.04-37.41	1.33-1.65	5.01-5.30
IV	20-21	41-47	23.50-24.76	0.64-2.23	4.21-4.32

Note: Location I: Processed land, Location II: Land covered by thin ash (≤2 cm), Location III: Land covered by moderate ash (2-5 cm), Location IV: Land covered by thick ash (≥5 cm)

Table 2. Identified soil macrofauna in various research locations

Phylum, class	Order	Family	Species	Locations			
				I	II	III	IV
Annelida							
Oligochaeta	Haplotaxida	Megascolecidae	*Megascolex* sp.	+	+	-	-
			Pheretima sp.	+	-	+	+
Arthropods							
Arachnida	Araneae	Lycosidae	*Trochosa canapii*	+	+	+	-
			Cheiracanthium sp	+	-	+	-
Chilopoda	Lithobiomorpha	Lithobiidae	*Lithobius* sp.	+	+	+	-
Diplopoda	Polydesmida	Polydesmidae	*Polydesmus* sp.	+	+	+	-
Insecta	Blattodea	Ectobiidae	*Blattella germanica*	+	-	-	-
	Coleoptera	Carabidae	*Calosoma* sp.	+	+	+	-
			Stenolophus sp.	+	+	+	-
		Melolonthidae	*Phyllophaga* sp.	+	-	-	-
		Scarabaeidae	*Lepidiota stigma*	+	+	+	+
	Dermaptera	Carcinophoridae	*Euborellia* sp.	+	+	-	-
	Diptera	Tipulidae	*Tipula* sp.	+	+	+	+
	Hymenoptera	Formicidae	*Odontoponera* sp.	+	+	+	+
	Orthoptera	Gryllotalpidae	*Gryllotalpa* sp.	+	+	-	-
		Gryllidae	*Gryllus* sp.	+	+	+	+
Malacostraca	Isopoda	Philosciidae	*Philoscia* sp.	+	+	+	+
Mollusca							
Gastropoda	Stylommatophora	Arionidae	*Hemphillia* sp.	+	+	-	-
		Bradybaenidae	*Bradybaena similaris*	+	-	-	-
		Hygromiidae	*Monacha* sp.	+	+	+	+
Total number of identified species				20	15	13	7

Note: Location I: Processed land, Location II: Land covered by thin ash (≤2 cm), Location III: Land covered by moderate ash (2-5 cm), Location IV: Land covered by thick ash (≥5 cm). (+): present, (-): absent

Table 3. Density (Individual/meter^2) and relative density (%) values of soil macrofauna at each research locations

Species	Location I		Location II		Location III		Location IV	
	D (Ind/m)	RD (%)	D (Ind/m^2)	RD (%)	D (Ind/m^2)	RD (%)	D (Ind/m^2)	RD (%)
Blattella germanica	3.54	0.46	-	-	-	-	-	-
Bradybaena similaris	6.25	0.81	-	-	-	-	-	-
Calosoma sp.	50.58	6.55	41.86	9.00	7.61	6.32	-	-
Cheiracanthium sp.	1.39	0.18	-	-	11.42	9.48	-	-
Euborellia sp.	12.50	1.62	3.47	0.75	-	-	-	-
Gryllotalpa sp.	4.86	0.63	4.17	0.90	-	-	-	-
Gryllus sp.	17.69	2.29	11.76	2.53	15.22	12.64	22.83	31.25
Hemphillia sp.	35.67	4.62	11.76	2.53	-	-	-	-
Lepidiota stigma	8.33	1.08	13.33	2.87	7.79	6.47	13.50	18.48
Lithobius sp.	1.39	0.18	7.96	1.71	3.81	3.16	-	-
Megascolex sp.	46.53	6.03	38.89	8.37	-	-	-	-
Monacha sp.	24.77	3.21	6.75	1.45	5.19	4.31	11.42	15.63
Odontoponera sp.	477.71	61.89	257.09	55.30	8.32	6.91	16.97	23.23
Pheretima sp.	10.42	1.35	-	-	5.56	4.61	3.47	4.75
Philoscia sp.	13.89	1.80	5.56	1.20	12.46	10.34	4.17	5.70
Phyllophaga sp.	6.25	0.81	-	-	-	-	-	-
Polydesmus sp.	12.00	1.56	8.30	1.79	4.17	3.46	-	-
Stenolophus sp.	2.81	0.36	11.42	2.46	19.03	15.79	-	-
Tipula sp.	26.85	3.48	19.03	4.09	9.00	7.47	0.69	0.95
Trochosa canapii	8.47	1.10	23.53	5.06	10.90	9.05	-	-
Total	771.90	100	464.86	100	120.46	100	73.05	100

Notes: Location I: Processed land, Location II: Land covered by thin ash (≤2 cm), Location III: Land covered by moderate ash (2-5 cm), Location IV: Land covered by thick ash (≥5 cm). D: Density, RD: Relative Density

The types and populations of macrofauna at each location varied greatly. According to Suin (2012), *Tipula* sp. is 'temporary' soil macrofauna that lays its eggs on the soil. These eggs require organic matter as food for growth. Therefore, *Tipula* sp. could not live in Locations III and IV because in both locations the soil was covered with thick volcanic ash; hence this species can't lay the egg. Lavelle et al. (2006), stated that the species whose tolerance range is wide to many certain environmental factors, such as temperature, water, and humidity, will have a wide distribution and a large number compared to fauna whose tolerance is narrow. Another factor that has an influence is the availability of food (Hanafiah et al. 2010).

The attendance frequency of the presence of macrofauna among the study sites was different. These results indicated that there was soil macrofauna whose activities dominate at several locations and some at all locations (Table 4). *Calosoma* sp. was 'Accessories' (often) at Location I, II, and III, but this species was not found at Location IV. It was suspected that the decrease in the attendance frequency of *Calosoma* sp. because volcanic ash covering changed soil physical properties that disrupted the macrofauna activities. *Odontoponera* sp. species dominated in all locations with the attendance frequency was 'Absolute' (very often) at Location I and at Location IV, the attendance frequency decreased to 'Accessory' (rare). *Odontoponera* sp. was identified in all locations with an abundance of numbers and a wide distribution because it was able to adjust by modifying the physical structure of the soil, making nests and chambers in the soil, and foraging for food above the ground (Ruiz and Patrick 2008). This result similar to Borror et al. (1992), which stated that the Formicidae family, including *Odontoponera* sp. generally has a wide tolerance range in the environment, so the distribution is quite wide (cosmopolitan). Ruiz and Patrick (2008) added that diversity increases when the community becomes more stable. High diversity also characterizes the availability of a large number of supporting factors.

The similarities index showed that Locations I and II were very similar, whereas Locations I and IV were not similar (Table 5). This indicated that the environmental conditions of Location I and II were not much different, while the environmental conditions between Location I and Location IV were very different because Location IV was covered with volcanic ash with > 5 cm thickness, which can affect soil temperature, humidity, and pH. Research results by Simbolon et al. (2018), Sinaga et al. (2015), Zebua et al. (2020), and Qadaryanty et al. (2020) indicated that the thicker volcanic ash covering the soil surface, then soil pH, C-organic, and soil moisture will decrease. If soil moisture and the availability of organic matter in the soil decrease, soil organisms can die or migrate, thus affecting the diversity of soil fauna in the area.

Table 5. Similarity index value of soil macrofauna at each research locations

Q/S	Similarity index (%)
Location I and Location II	85.71
Location I and Location III	78.79
Location I and Location IV	51.85
Location II and Location III	78.57
Location II and Location IV	54.55
Location III and Location IV	70.00

Notes: Q/S value= < 25%: The similarities are not very similar, Q/S value= 25-50%: The similarities are not similar, Q/S value= 50%-75%: The similarities are similar, Q/S value= > 75%: The similarities are very similar

Table 4. Attendance frequency value of soil macrofauna at each research locations

Species	Location I	Location II	Location III	Location IV
	AF (%)	AF (%)	AF (%)	AF (%)
Blattella germanica	3.12 (Aks)	-	-	-
Bradybaena similaris	12.50 (Aks)	-	-.	-
Calosoma sp.	25.00 (Ass)	21.87 (Aks)	6.25 (Aks)	-
Cheiracanthium sp.	6.25 (Aks)	-	6.25 (Aks)	-
Euborellia sp.	21.87 (Aks)	12.50 (Aks)	-	-
Gryllotalpa sp.	15.62 (Aks)	6.25 (Aks)	-	-
Gryllus sp.	15.62 (Aks)	21.87 (Aks)	9.375 (Aks)	15.62 (Aks)
Hemphillia sp.	50.01 (Kon)	40.62 (Ass)	-	-
Lepidiota stigma	34.37 (Ass)	25.00 (Aks)	15.62 (Aks)	21.87 (Aks)
Lithobius sp.	6.25 (Aks)	12.50 (Aks)	3.12 (Aks)	-
Megascolex sp.	50.02 (Kon)	43.75 (Ass)	-	-
Monacha sp.	34.37 (Ass)	6.25 (Aks)	15.62 (Aks)	6.25 (Aks)
Odontoponera sp.	84.37. (Abs)	43.75 (Ass)	28.12 (Aks)	28.25 (Ass)
Pheretima sp.	25.00 (Aks)	-	9.37 (Aks)	9.37 (Aks)
Philoscia sp.	15.62 (Aks)	25.00 (Aks)	9.37 (Aks)	625 (Aks)
Phyllophaga sp.	3.00 (Aks)	-	-	-
Polydesmus sp.	25.00 (Aks)	9.37 (Aks)	15.62 (Aks)	-
Stenolophus sp.	12.50 (Aks)	9.37 (Aks)	12.50 (Aks)	-
Tipula sp.	25.00 (Aks)	6.25 (Aks)	3.12 (Aks)	15.62 (Aks)
Trochosa canapi	9.37 (Aks)	18.75 (Aks)	12.50 (Aks)	-

Notes: Location I: Processed land, Location II: Land covered by thin ash (≤2 cm), Location III: Land covered by moderate ash (2-5 cm), Location IV: Land covered by thick ash (≥5 cm). AF: Attendance Frequency, Aks: Accidental (very rare), Ass: Accessories (rare), Kon: Constant (often), Abs: Absolute (very often)

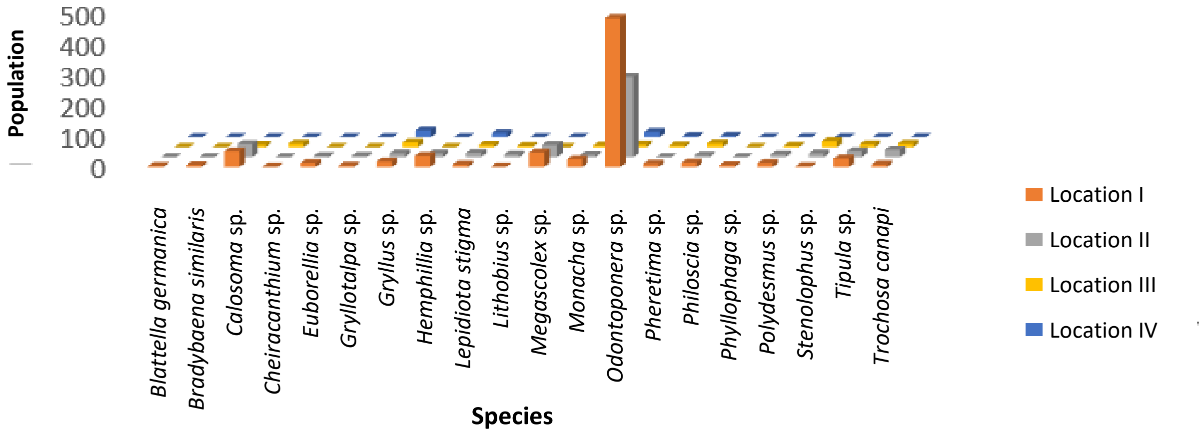

Figure 2. Macrofauna population at each location

In conclusion, the thicker the volcanic ash covering the soil surface will reduce the number of species, density, diversity, and attendance frequency of macrofauna at each location. Based on the identification, soil macrofauna consisted of 3 phyla, 7 classes, 12 orders, 17 families, and 20 species. *Odontoponera* sp. presented in all research locations. (RD value ≥ 10% and AF value ≥ 25%).

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