Indian J. Agric. Res., 52(5) 2018: 472-480
Print ISSN:0367-8245 / Online ISSN:0976-058X

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com/www.ijarjournal.com

Soil morphogenesis diversity at the southern flank of Merapi Volcano, Indonesia five years post-eruption

Lis Noer Aini[1], Bambang Hendro Sunarminto[2], Eko Hanudin* and Junun Sartohadi[2]

Department of Soil Sciences,
Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.
Received: 18-01-2018 Accepted: 09-08-2018 DOI: 10.18805/IJARe.A-325

ABSTRACT

This study aims to find out the soil morphology diversity at the southern flank of Mt.Merapi Yogyakarta, Indonesia. The field research was conducted using purposive sampling method where each site of geomorphological unit as representing of the cone, upper, middle and lower slopes of Mt.Merapi. Poligenesis of the soil morphology was observed at pedon P1 with composition of the upper and buried soil was Typic Hapludands-Typic Hapludands, P3 (Andic Eutrudepts-Vitrandic Udorthents), P4 (Vitrandic Udorthents -Typic Hapludands), and P5 (Andic Eutrudepts-Andic Eutrudepts). Whereas the monogenesis of the soil morphology was observed at pedon P2, P6, P7 and P8 with subgroups of Typic hapludands, Andic Eutrudepts, Andic Dystrodepts and Typic Udorthents, respectively. Soil morphogenesis diversity (polygenesis) shown by the presence of a pedon having more than one soil profile was not a limiting factor for crop roots growth, so the agro-ecosystem recovery process was relatively fast.

Key words: Eruption, Merapi Volcano, Poligenesis, Soil morphonesis.

INTRODUCTION

The massive eruption that occurred in 2010 caused hot clouds and lava out of the crater to have devastated the ecosystem on the southern slopes of Merapi Volcano. After five years post-eruption, there has been a recovery process in both soil and crop conditions, however, the information related to soil morphology is still scarce. Based on the history of eruption, Mt.Merapi has two eruption patterns: 1) effusive, followed by lava dome growth, which repeats every 4-6 years and produces pyroclastic flow known as Merapi-type nuées ardentes, 2) explosive eruptions with ruins and pyroclastic flows reaching 10-15 km from the crater (Budi-Santoso *et al.*, 2013; Fiantis *et al.*, 2009; Voight *et al.*, 2000). After Eruption in November 1994, Enryd (1998) observed that profiles taken further down the slope followed the normal processes in a catena coarser texture and therefore also higher drainage and lower shear strength.

Mt.Merapi as an active volcano which has stratotype posses a unique landform. The landform is a reflection of the interaction between material types and geomorphic processes that occur. The landform may affect the soil types and groundwater characteristics (Summerfield, 1991; Brown, 1995; Gerrard, 1995). The shape of the land affects the velocity and amount of the deposited volcanic material. Areas that are in close proximity to the source of the eruption or often passed by lava will have a unique soil morphology. The higher the frequency of the area gets additional new material, poligenesis will occur. This study aimed to find out the soil morphogenesis variability at the southern flank of Merapi Volcano post-eruption 2010.

MATERIALS AND METHODS

Field work: This research was a field study with purposive sampling method based on the analysis of the landscape. The study area was divided into four sections based on the geomorphological unit, namely: cone, upper slope, midle slope and lower slope (Fig.1). Each region posses 2 representative soil profiles, thus, in total the number of soil pedon was 8 profiles with size 1.5 x 2 m. Site and soil profile description procedure refered to National Soil Suvey Handbook from USDA (2014; 2016). Site observation was subjected for geographical position, altitude, slope, and vegetation. Soil profile description was subjected for the thickness of horizons, the pattern and clarity of horizon boundaries, color, rooting, rocky, pores, texture, consistency and others. Soil samples were collected from each horizons and analyzed for physical and chemical properties.

Description of the studied area: Mount Merapi is located near the center of the Java Island, about 32 km north of Yogyakarta, Indonesia. The study area, the southern flank of Mt.Merapi is located between 7°32’5’’SL and 110° 26’5’’EL with altitude ranging from 447 to 1197 meters above sea level (asl) and slope from flat (0-3%) to steep (>40%). Volcanic ash derived from Mt. Merapi could be classified as intermediate andesitic because of the amount of

*Corresponding author’s e-mail: ekohanudin@ugm.ac.id
[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Indonesia.
[2]Department of Soil Sciences, Faculty of Agriculture UGM, Yogyakarta 55281, Indonesia.

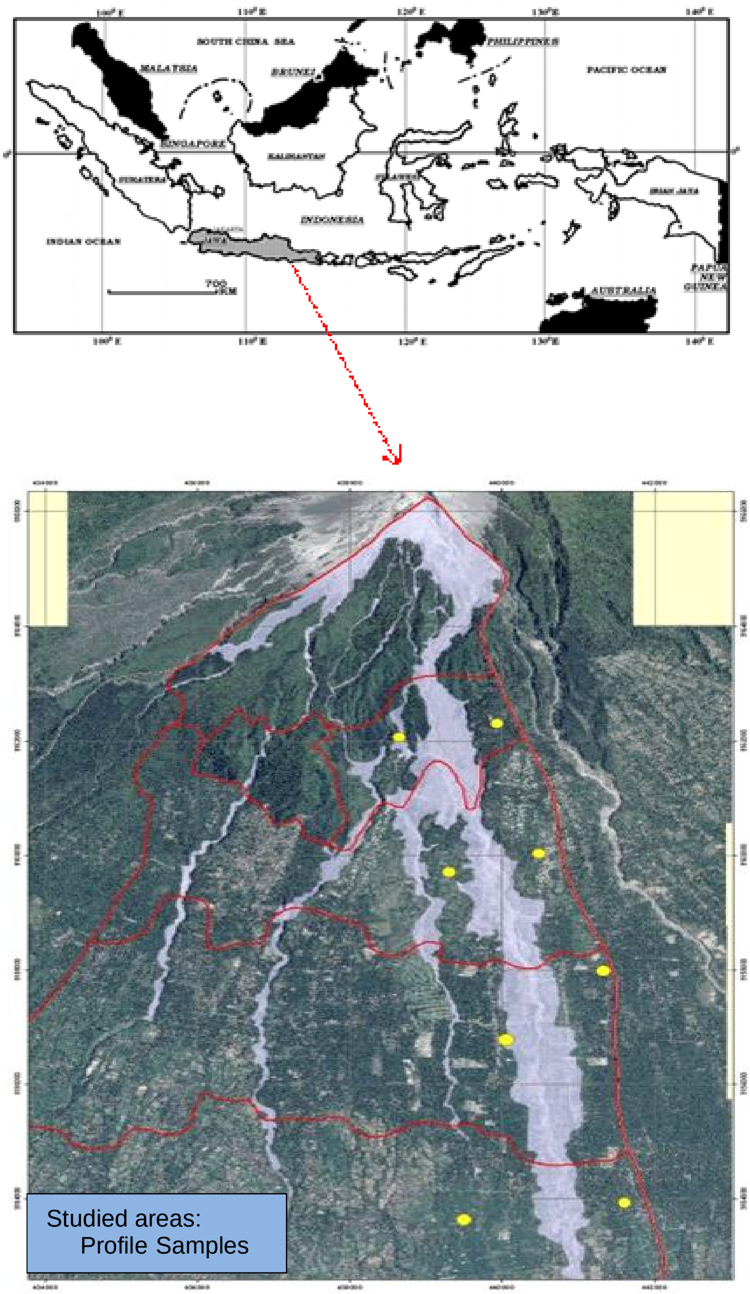

Fig 1: Soil profile location ( ) at studied areas (modified from Enryd[6])

SiO_2 range between 55.2 - 60.3% (Wulaningsih *et al*, 2013). The dominant soil types in the regions are Entisols, Inceptisols and Andisols. Vegetation grown in the area include: *Imperata cylindrica, Eupatorium riparium, Anaphalis javanica, Athyrium macrocarpum, Brachiaria paspaloides,Dichantium caricosum, Selaginella doederleinii, Eleusine indica, Cyperus flavidus, Calliandra callothyrsus and Acacia decurrens* (Sutomo, 2010; Sutomo *et al*, 2011; Afrianto *et al*, 2017). Based on data from the Meteorology and Geophysics (BMG) climatology station, during past 10 years (2006-2015) the average value of the lowest temperature reached 17.2 OC and the highest temperature reached 30.1 OC. Therefore, the temperature regime could be categorized as *isohyperthermic*, because of the mean annual soil temperature was ≥22°C (Soil Survey Staff, 2014). The annual precipitation varies from 2,558-2,623 millimetres. The distribution of rainfall in the studied area is presented in Fig.2.

Fig 2 shows that the dry season occurs in July-September. Thus, the moisture regime could be catgorized as *udic*, because of the dry seasons < 90 cumulative days (Soil Survey Staff, 2014). Schmidt and Ferguson (1951) used

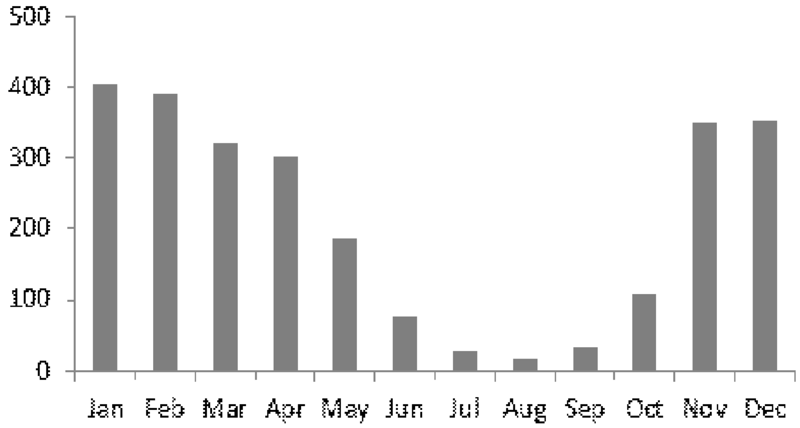

Fig 2: Distribution of the rainfall average at range of January-December for 2006-2016.

the Q value (Table 1) as percentage of the dry and wet month average. The classification of dry, moist and wet months is based on rainfall average of <60, 60-100 and >100 mm, respectively. Therefore, the studied area has Q value of 37.5 that catregorized as C type (rather wet).

Laboratory analysis: Perticle size distribution was determined using pipette method, while BD was by core sampling (gravimetry) (USDA, 1996). Bulk density was computed according to the following formula:

$$Db = \frac{ODW\text{-}RF\text{-}CW}{CV\text{-}\left(\frac{RF}{PD}\right)}$$

Where: Db = bulk density of < 2 mm fabric at sampled (g cm^{-3}), ODW = oven dry weight, RF = weight of rock fragmets, CW = empty core, CV = core volume, and PD = density of rock fragments. Soil pH was measured in suspensions of H_2O and 1 N KCl (soil:solution ratio = 1:2.5) with a glass electrode after 2 h of mechanical shaking. The pH-NaF was determined in a suspension of 1 g soil in 50 ml (Eviati and Sulaeman, 2012). Soil organic matter (SOM) was determined by dry combution method (loss on ignition) (Campos, 2010; Wang *et al*, 2012). The weight loss percentage was determined using the following formula:

$$SOM\ (g/kg) = \frac{Weight\ 105 - Weight\ 550}{Weight\ 105} \chi\ 1000$$

where Weight105 is that of the soil sample after heating at 105°C and Weight 550 is that of the soil sample after ignition at 550°C. For characterizing andic properties (Alo+½Feo), the content of Al and Fe extracted with NH_4-oxalate pH3 was conducted at a ratio of 1:100. After shaking for 4 h in the dark, the Al and Fe presented in the solution was measured by atomic absorption spectrophotometry (AAS) (USDA, 1996).

RESULTS AND DISCUSSION

Site characteristics of the studied area: The site characteristics of the pedons showed that investigation was conducted at area with young merapi formation and uniform parent material ie. intermediate andisitic. Soil profiles were situated at terrain with flat to steep lanform (Table 2). Each pedon represented different geomorphological unit, namely: Pedon Kalitengah Lor (P1) and Kinahrejo (P2) (cone), Pedon Srunen (P3) dan Sidorejo (P4) (upper slope), and Pedon Gading (P5) and Balong (P6) (midle slope), Pedon Mudal (P7) and Ngemplak (P8) (lower slope). The pedons were also representatives of different agroecosystem: secondary forest (P1 and P2), agroforestry (P3, P4 and P5), and multiple croping (P6, P7 and P8).

Soil morphology and classification: The pedons exhibited differences in sequence of horizons with range of 5-13 horizons (Table 3). The pedon (P1) that has the highest number of horizons (13) was located at the cone area with an elevation of 1197 m asl. While the lowest horizon number (5) was P8 situated at the lower slope areas with 477 m asl altitude. The number of pedons as many as 8 split by Gendol river, 4 pedons were located on the left side and 4 others were on the right side (Table 3). The number of horizons on the right side tends to be more than the left one. This indicated

Table 1: Climate classification system according to Schmidt and Ferguson (1951).

Climate Type	Q Value (%)	Categorizatio
A	0 – 14,3	Very wet
B	14,3 – 33,3	Wet
C	33,3 – 60,0	Slightly Wet
D	60,1 – 100,0	Medium
E	100,1 – 167,0	Slightly Dry
F	167,1 – 300,0	Dry
G	300,1 – 700,0	Very Dry
H	>700,1	Extremely Dry
H	>700,1	Extremely Dry

Table 2: Site characteristics and land use/cover of the studied area.

Pedon/ Location	Coordinates		Altitude (m asl)	Landform	GU	PM	Slope (%)	Vegetation	Land Use Type
	Latitude	Longitute							
P1 Kalitengah Lor	110°27′19.258″	7°34′41.09″	1197	Steep	C	IA	>40	A.decurens, Para grass	Secondary Forest
P2 Kinahrejo	110°26′50.043″	7°34′46.882″	1155	Steep	C	IA	>40	A.decurents, Albasia,Cogongrass	Secondary Forest
P3 Srunen	110°27′37.612″	7°35′55.968″	925	Hilly	US	IA	8-15	Albasia, Para grass	Agroforestry
P4 Sidorejo	110°26′9.959″	7°36′15.184″	848	Hilly	US	IA	8-15	Albasia, Para grass	Agroforestry
P5 Gading	110°28′5.202″	7°37′2.575″	730	Hilly	MS	IA	15-25	Albasia, Para grass, Bamboo,	Agroforestry
P6 Balong	110°26′8.962″	7°37′12.245″	690	Flat	MS	IA	0-3	Albasia, Mahogany, Gnetum gnemon Mahogany, Coffee,	Multiple Cropping
P7 Mudal	110°28′15.495″	7°39′14.199″	460	Flat	LS	IA	0-3	Coconut, Rambutan, Bamboo, Banana, Mangosteen	Multiple Cropping
P8 Ngemplak	110°27′5.678″	7°39′23.929	477	Flat	LS	IA	0-3	Gnetum gnemon, Bamboo	Multiple Cropping

Note: GU= Geomorphological Unit, C= Cone, US= Upper Slope, MS= Midle Slope, LS=Lower Slope, SP= Slope position, PM=Parent Material, IA = Intermediate Andesitic.

that the right side areas of the river were more often affected by the supply of new materials. The highest soil depth was observed in P1 located at the cone area, while the lowest one in P8 was located at the lower slope. In other words, the soil solum tends to decrease toward the lower geomorphological unit.

The soils that distributed on the southern flank of Mt. Merapi from the cone to the lower slopes terrain could be categorized as young soils, thus its properties were influenced by the parent material features. The dominant fraction was sand and silt, so it has a texture ranging from silty loam to sand, except for the IIIB horizon of the P1 and IB horizon of pedons P5 pedon which has a clay loam texture (feel method) (Table 3). Because the soil was dominated by a coarse fraction, the structure ranges from structureless to granular with a weak degree. Soil consistency in moist conditions ranges from loose to very frieable. Percentage of coarse fragments tends to vary from none to few, only to the C2 horizon of pedon P4, the IC horizon of pedon P5 and pedon P8 on all horizons encountered many coarse fragments.

The soil color from the cone to the lower slopes area has the same wavelenght color (Hue value 10YR). While the Value ranges from 3-7 and chroma value ranges from 1-4. There are 4 main factors influence the colour of a soil: 1). Mineral matter derived from the constituents of the parent material, 2). Organic matter (OM), 3). The nature and abundance of Fe-oxide, and 4). Drainage condition. If OM and Fe-oxide are not covering the mineral grains, the natural color of the grains is visible. Most mineral grains are naturally gray (Owens and Rutledhe, 2005).

Pedon P1 observed the surface mantle of new material with 30-35 cm in thick. The first epipedon A1 was ochric because its thickness is 15-20 cm, dark greyish brown (10 YR 4/2, moist) color, very low organic matter, sandy loam texture. The ochric epipedon fails to meet the definitions for any of the other seven epipedons because it is too thin and has too high color value, contains too little organic carbon. Within 60 cm of soil surface, particularly at subsurface horizon, Bw (cambic) had andic properties. Table 4 presented the soil physico-chemical properties also meet with andic properties such as BD 0.73 g cm^{-3}, sand 58%, silt 39.52%, pH-NaF 11.51, Alo+Feo 2%, P-retention 65,76%, (Yuliani *et al.* 2017). This soil was Andisols, Typic Hapludands. Under this soil profile there was buried horizons, namely: IAb1, IAb2, IBwb1, IBwb2 and IC. As genetic horizons, it was placed a "b" suffix after the horizon designators for buried A, and B horizons. The "b" suffix is used only with genetic horizons; it is not used with C horizons (parent materials) (NRCS, 2011; Galbraith, 2014; Soil Survey Staff, 2014). The buried soil was also categorized as Typic hapludands, because andic features observed for the buried ochric epipedon and cambic endopedon such as a smeary nature, pH-NaF 11.38, BD 0.87 g cm^{-3}, sand 48.7%, silt 46.1%, Alo+Feo 2.42%, P-retention 65,76%. The IIBwb and IIC is too thin (5 cm) to be a cambic horizon, so the horizon could not be considered as a complete profile. Pedon P1 had 2 soil profiles, so the morphology could be classified as polygenesis.

Table 3: Selected morphological properties of the soil pedons.

Pedon	Horizons	Depth (cm)	Boundary	Color (moist)	Texture (Feel method)	Structure	Consistency	Coarse fragment (%)	Roots
	C1	0-5	C, S	10YR 6/1	Sand	G,W	Loose	Few (>3%)	Ma:+, Mo:+, Mi:+++
	C2	5-30	C, S	10YR 5/1	Sand	S	Loose	Few (>3%)	Ma:+, Mo:+, Mi:+++
	C3	30-35	C, S	10YR 7/1	Sand	S	Loose	Few (>3%)	Ma:+, Mo:+, Mi:+++
	A	30/35 - 50	C, W	10YR 4/2	Sandy loam	G,W	Loose	Few<1%	Ma:+, Mo:+, Mi:+++
P1	B	50-68	C, S	10YR 5/3	Sandy loam	G,M	Loose	Few<1%	Mi:++
Kalitengah	C	68-77	C, S	10YR 5/2	Sand	S	Loose	Few (>3%)	Mi:+
Lor	IAb1	77-90	C, S	10YR 4/3	Silty loam	G,W	Very friable	Very few <1%	Mi:+
	IAb2	90-100/115	C, W	10YR 4/2	Sandy loam	G,W	Very friable	Very few <1%	Mi:+
	IBwb1	100/115-132/138	C, W	10YR 4/4	Silty loam	G,W	Very friable	Few (>3%)	Mi:+
	IBwb2	132/138-178	C, W	10YR 4/4	Silty loam	G,W	Very friable	Very few <1%	Mi:+
	IC	178-190	C, S	10YR 3/4	Sand	S	Loose	Few (>3%)	Mi:+
	IIBwb	190-195	C, S	10YR 3/4	Clay loam	G,M	Friable	Very few <1%	-
	IIC	>195	C, S	10YR 3/4	Sand	S	Loose	Few (>3%)	-
	C	0-24	A, S	10YR 4/1	Sand	S	Loose	Very few <1%	Mo:+. Mi:+
	A1	24-53	C, S	10YR 3/2	Sandy loam	G,W	Very friable	Few (>3%)	Mo:++, Mi:+++
P2	A2	52-70/80	C,W	10YR 4/2	Sandy loam	G,W	Very friable	Few (1-3%)	Mo:++, Mi:+++
Kinahrejo	Bw1	70/80-70/110	C,W	10YR 5/3	Sandy loam	G,W	Very friable	Very few <1%	Mo:+, Mi:++
	Bw2	70/110-117-180	C,W	10YR 5/3	Silty loam	G,W	Very friable	None	Mo:+, Mi:+
	Bw3	117/180-193	C,W	10YR 5/3	Silty clay	G,W	Friable	None	Mi:+
	C1	0-12	C, S	10YR 6/1	Silt	G,W	Very friable	None	Ma:+, Mo:+, Mi:+++
	C2	12-26	C, S	10YR 5/2	Silty loam	S	Very friable	None	Ma:+, Mo:+, Mi:++
	A1	26-35	C, S	10YR 4/2	Sandy loam	G,W	Very friable	Very few <1%	Mo:+, Mi:+
P3	A2	35-62	C, S	10YR 5/3	Sandy loam	G,W	Very friable	Very few <1%	Mo:+, Mi:+
Srunen	Bw1	62-91	C, S	10YR 5/3	Sandy loam	G,W	Very friable	Very few <1%	Mo:+, Mi:+
	Bw2	91-127	C, S	10YR 5/4	Loam	G,W	Very friable	Very few <1%	Mo:+, Mi:+
	IAb	127-145/150	D, W	10YR 4/2	Silty loam	G,W	Very friable	Few (>3%)	Mi:+
	IC	>145/150	C, S	10YR 5/1	Sandy loam	G,W	Very friable	Few (>3%)	Mi:+
	A1	0-20	C, S	10YR 3/1	Loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:++, Mi:+++
	A2	20-55/75	C, S	10YR 3/1	Loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:++, Mi:+++
P4	C1	55/75-70/90	C, W	10YR 2/1	Sand	S	Loose	Common (>5%)	Ma:+, Mo:++, Mi:+++
Sidorejo	C2	70/90-110/130	C, W	10YR 3/1	Sand	S	Loose	Many (>25 %)	Ma:+, Mo:++, Mi:+++
	IAb	110/130-130/155	C, W	10YR 3/2	Sandy loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:++, Mi:++
	IBwb	130/155-180	C, W	10YR 3/2	Sandy loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:+, Mi:+
	C1	0-10	C, S	10YR 6/1	Sand	S	Loose	Few (>3%)	Mi:+++
	C2	10-30	C, S	10YR 6/2	Sand	S	Loose	Few (>3%)	Mi:+++
P5	A1	30-55	C, S	10YR 6/2	Sandy loam	G,W	Very friable	Few (>3%)	Mi:++
Gading	A2	55-70	C, S	10YR 6/3	Sandy loam	G,W	Very friable	Few (>3%)	Mi:++
	Bw	70-90/100	C, W	10YR 6/4	Sandy loam	G,W	Very friable	Few (>3%)	Mi:+
	IAb	90/100-100/110	C, W	10YR 5/4	Loam	G,W	Very friable	Few (>3%)	Mi:+
	IBwb	100/110-130	C, W	10YR 4/2	Clay loam	G,M	Very friable	Few (>3%)	Mi:+
	IC	>130	C, W	10YR 7/3	Sand	S	Loose	Many(>25%)	Mi:+

Table 3 continue........

Table 3 continue.......

	A1	0-20/30	D, W	10YR 4/2	Silty loam	G,W	Very friable	Few (>3%)	Ma:+++, Mo:++, Mi:++
	A2	20/30-50/53	D, W	10YR 5/2	Silty loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:+, Mi:++
P6	Bw1	50/53-65	C, W	10YR 5/3	Sandy loam	G,W	Very friable	Few (>3%)	Ma:+, Mo:+, Mi:+
Balong	Bw2	65-115	C, S	10YR 5/3	Sand	S	Loose	Few (>3%)	Mo:+, Mi:+
	C1	115-130	C, S	10YR 4/1	Sand	S	Loose	Few (>3%)	Mo:+, Mi:+
	C2	130-145	C, S	10YR 5/4	Sand	S	Loose	Few (>3%)	Mo:+, Mi:+
	C3	145-155	C, S	10YR 5/2	Sand	S	Loose	Few (>3%)	Mo:+, Mi:+
	C4	>155	C, S	10YR 5/2	Sand	S	Loose	Few (>3%)	Mo:+, Mi:+
	C1	0-5	C, S	10YR 7/1	Silt	G,W	Very friable	Few (>3%)	Mo:+++, Mi:+++
P7	A1	5-30	D, S	10YR 6/3	Silty loam	G,W	Very friable	Few (>3%)	Ma:++, Mo:+++, Mi:+++
Mudal	A2	30-60	D, S	10YR 6/2	Silty loam	G,W	Very friable	None	Ma:+++, Mo:+++, Mi:+++
	A3	60-110	D, S	10YR 5/3	Silty loam	G,W	Very friable	None	Ma:+++, Mo:+++, Mi:++
	Bw	>110	D, S	10YR 5/4	Silty loam	G,W	Very friable	None	Ma:++, Mo:++, Mi:++
	A	0-51	D, S	10YR 5/3	Silty sand	G,W	Loose	Many(>25%)	Ma:+++, Mo:+++
P8	C1	51-75	D, S	10YR 4/1	Sand	S	Loose	Many(>25%)	Mo:+, Mi:+
Ngemplak	C2	75-105	D, S	10YR 3/1	Sand	S	Loose	Many(>25%)	Mo:+, Mi:+
	C3	>105	D, S	10YR 3/1	Sand	S	Loose	Many(>25%)	Mo:+, Mi:+

Note: A= abrupt, C= clear, D= diffuse, S= smooth, W=wavy, G=granuler, W= weak, M= moderate, S= structureless, Ma= macro, Mo= meso, Mi= micro, Few= +, Medium= ++, Many= +++,

Pedon P2 even though it was in cone area but had only 1 profile, no buried soil, so its morphology was categorized as monogenesis. The surface mantle of new material with 24 cm in thickness. The epipedon A1-A2 was observed at depth of 24-70/80 cm, color value of 3 (moist), color chroma of 2 (moist), very low organic matter, sandy loam texture. So the epipedon could be categorized as ochric. The genetic horizon (Bw1-Bw3) was observed at 70-193 cm depths, brown (10YR 5/3) color, the texture of sandy loam-clay loam, a smeary nature, pH-NaF 11.1, BD 0. 97 g cm^{-3}, sand 55.8%, silt 36.86%, Alo+Feo 2.62%, P-retention 77.43 %. The soil was categorized as Typic hapludands.

Pedon P3 observed the surface mantle of new material with 26 cm in thickness. The epipedon A1-A2 was observed at depth of 26-62 cm, color value of 4 (moist), color chroma of 2-3 (moist), organic matter 2.9-7.0%, sandy loam texture (sand 61.7-71.8, silt 2.9-22.8, clay 53.3%). So the epipedon could be categorized as ochric. The genetic horizon (Bw1-Bw2) was observed at 62-127 cm in depth, brown (10YR 5/3-5/4), the texture of sandy loam-loam, a smeary nature, pH-NaF 10.75-11.3, BD 1.32-1.21 g cm-3, sand 61.7-57.5%, silt 36.8-28.7%, Clay 13.81-21.24%, base saturation 82.7%, and Alo+Feo 1.22-2.38%. The genetic horizon was cambic. The soil was categorized as Incepticols. Although the soil had BD > 1 g cm^{-3} but it contained Alo+Feo > 1%, so the andic properties are more prominent, therefore the subgroups was Andic Eutrudepts. Under the soil was observed buried ochric epipedon at 127 cm in depth, dark greyish brown (10YR 4/2) color, silty loam, pH-NaF 11.35, organic matter 15.8%. The subsurface genetic horizon was not observed in this soil, so according to soil taxonomy, the soil could be classified as Entisols. The content of Alo+Feo 2.36%, so that great group level could be classified into Vitrandic Udorthents. Pedon P3 posses 2 soil profiles, so it could be categorized as having a morphology of polygenesis.

At pedon P4 there was no surface mantle. The epipedon A1-A2 was observed at depth of 20-55/75 cm, very dark grey (10YR 3/1, moist) color, organic matter 2.3-6.4%, loamy sand texture (sand 70.51-83.57%, silt 15.38-29.46, clay 0.03-1.03%). Therefore, the epipedon could be categorized as ochric. The genetic horizons have not been formed on the subsurface soil. Taking into account the characteristics of soil texture, pH-NaF and Alo+Feo 1.87-2.19%, so this soil could be classified as Vitrandic Udorthents. Under the soil there was buried horizons, namely: IAb and IBwb. The buried ochric epipedon (Iab) was observed at 110/130-155 in depth, very dark greyish brown (10YR 3/2, moist), and sand texture (sand 93.91%). The buried cambic endopedon (IBwb) was observed at depth of 130-180 cm, sandy loam texture (sand 70.15%, silt 28.99% and clay 0.87%), BD 0.88 g cm^{-3}, pH-NaF 11.17, P-retention 77.92%. This soil was Andisols, Typic

Table 4: Soil physical and chemical properties of the genetic horizons.

Pedon	Horizon	Thickness (cm)	Particle Size Distribution (%)			Textural Class	Bulk Density	pH-NaF	OM (%) ($g\ cm^{-3}$)	Alo+½Feo
			Sand	Silt	Clay					
	A	30/35 - 50	59.83	34.95	5.22	Sandy loam	0.89	11.31	0.75	1.460
P1	Bw	50-68	58.46	39.52	2.02	Sandy loam	0.73	11.51	0.22	1.998
Kalitengah	IAb1	77-90	53.24	45.78	0.98	Sandy loam	1.13	11.26	1.40	1.858
Lor	IAb2	90-100/115	46.65	52.93	0.42	Silt loam	1.28	11.12	1.54	1.800
	IBwb1	100/115-132/138	50.09	45.79	4.11	Sandy loam	0.90	11.38	0.34	3.863
	IBwb2	132/138-178	48.73	46,12	5.15	Sandy loam	0.87	11.26	0.40	2.428
	A1	24-53	76.84	23.02	0.14	Loamy sand	1.67	11.04	0.27	1.881
P2	A2	52-70/80	71.69	27.30	1.02	Loamy sand	1.02	11.15	0.21	1.799
Kinahrejo	Bw1	70/80-70/110	81.20	11.70	7.11	Loamy sand	0.73	11.21	0.20	2.622
	Bw2	70/110-117-180	55.80	36.86	7.34	Sandy loam	0.79	11.1	0.15	1.137
	Bw3	117/180-193	58.21	33.54	8.25	Sandy loam	0.70	9.84	0.10	0.603
	A1	26-35	61.70	32.96	5.33	Sandy loam	0.92	10.9	7.92	1.663
P3	A2	35-62	71.84	22.83	5.33	Sandy loam	1.25	10.91	2.91	1.497
Srunen	Bw1	62-91	61.71	36.78	13.81	Sandy loam	1.32	10.75	1.79	1.219
	Bw2	91-127	57.49	28.70	21.24	Sandy clay loam	1.21	11.3	4.85	2.381
	IAb	127-145/150	48.74	22.23	7.21	Loam	0.72	11.35	15.81	2.364
	A1	0-20	70.51	29.46	0.03	Loamy sand	1.21	11.36	6.38	2.191
P4	A2	20-55/75	83.57	15.38	1.05	Loamy sand	0.93	11.07	2.30	1.869
Sidorejo	IAb	110/130-130/155	93.91	2.21	3.88	Sand	1.14	10.9	2.54	1.582
	IBwb	130/155-180	70.15	28.99	0.87	Sandy loam	0.88	11.17	3.25	1.857
	A1	30-55	71.74	25.02	3.24	Sandy loam	1.10	11.23	7.35	2.180
P5	A2	55-70	43.97	44.60	11.43	Loam	0.68	11.25	7.96	2.055
Gading	Bw	70-90 /100	52.94	32.23	14.83	Sandy loam	1.42	11.18	9.72	2.073
	IAb	90/100-100/110	53.69	28.61	17.70	Sandy loam	1.07	11.30	12.05	2.347
	IBwb	100/110-130	63.39	22.11	14.50	Sandy loam	1.20	11.31	11.95	2.062
	A1	0-20/30	91.60	5.53	2.86	Sand	1.32	10.53	0.38	1.866
P6	A2	20/30-50/53	96.34	2.52	1.14	Sand	1.24	10.63	0.29	1.768
Balong	Bw1	50/53-65	94.91	0.33	4.75	Sand	2.46	10.19	0.26	1.826
	Bw2	65-115	96.21	3.27	0.52	Sand	2.46	9.96	0.23	1.425
	A1	5-30	61.94	33.06	5.00	Sandy loam	1.66	11.20	0.32	1.067
P7	A2	30-60	64.27	25.80	9.93	Sandy loam	1.68	11.21	0.32	1.642
Mudal	A3	60-110	62.55	27.94	9.51	Sandy loam	1.37	11.10	0.26	1,867
	Bw	>110	59.52	26.81	13.67	Sandy loam	1.35	11.01	0.25	1,889
P8	A	0-51	84.41	15.56	0.03	Loamy sand	1.31	9.22	0.19	0,436
Ngemplak										

Note: Alo and Feo was Al and Fe extracted with NH_4-oxalate pH 3.

Hapludands. Pedon P4 posses 2 soil profiles, so it could be categorized as having a morphology of polygenesis as well.

The surface mantle of new material was found at pedon P5 with thickness of 30 cm. The soil morphology of the pedon also categorized as polygenesis, because it had 2 profiles. The first profile had ochric epipedon with thickness of 40 cm, light brownish grey-pale brown (10YR 6/2-3) color, and sand loam texture (sand 43.97-71.74%, silt 25.02-44.6%, clay 3.24-11.43%). The cambic endopedon was encountered at 70/90-100 cm in depth, sandy loam texture (sand 52.94%, silt 32.23% and clay 14.83%), BD 1.42 g cm^{-3}, base saturation 76%, and Alo+Feo 2.07%. The soil was categorized as Inceptisols. Even though the soil possessed BD > 1 g cm^{-3} but the content of Alo+Feo > 1% so the andic properties were more prominent, therefore the subgroups were Andic Eutrudepts. The second profile possessed the buried ochric epipedon with thickness of 20 cm, yellowish brown (10YR 5/4) color, and sandy loam texture (sand 53.69%, silt 28.61%, clay 17.70%). The buried cambic endopedon was encountered with thickness of 30 cm, clay loam texture (sand 63.39%, silt 22.11% and clay 14.5%), BD 1. 2 g cm^{-3}, base saturation 101%, and Alo+Feo 2.06%. This soil was Andic Eutrudepts as well.

There was no surface mantle and buried soil at Pedon P6, so the soil morphology was monogenesis. The ochric epipedon was observed with depth of 20/30-50/53 cm, dark greyish brown (10YR 4/2) color, very low organic matter (0.38%), and sand texture (sand >91%). The cambic endopedon was encountered at depth of 53/65-115 cm, sand texture (sand >94%), BD 2.46 g cm-3, base saturation 73% in average, pH-NaF 9.96-10.19 and Alo+Feo 1.4-1.8%. Although the soil possessed BD > 1 g cm^{-3} but the content of Alo+Feo 1.4-1.8% (>1%, soil taxonomy requirement) so the andic properties were more prominent, therefore the subgroups were Andic Eutrudepts.

The surface mantle of new material was observed at pedon P7 with thickness of 5 cm, and no buried soil, therefore, the soil morphology was monogenesis. The epipedon A1-A3 was observed at depth of 5-110 cm, soil color range of pale brown (10YR 6/3) to brown (10YR 5/3, moist), very low organic matter (0.26-0.32%), sandy loam texture (sand 61.94-64.27%, silt 25.8-33.06%, clay 5-9.93%). Therefore, the epipedon could be categorized as ochric. The subsurface genetic horizon (cambic) was observed at >110 cm in depth, yellowish brown (10YR 5/4, moist), loamy sand texture (sand 59.52%, silt 26.81%, clay 13.67), and very low organic matter (0.25%). At the great groups level, the soil categorized as Dystrudepts, because of the base saturation only 50% (>60%, soil taxonomy requirement). Even though the BD was 1.3 g cm^{-3} but the content of Alo+Feo 1.89% (>1%), so for subgroup level was Andic Dystrodepts.

The last pedon P8 was located at the lower slope area presented with no surface mantle and buried genetic horizons. The ochric epipedon was observed with thickness of 51 cm, brown (10YR 5/3, moist) color, very low organic matter (0.19%), and loamy sand texture. The subsurface genetic horizon was not observed in this soil, so according to soil taxonomy the soil could be classified as Entisols. Below the ochric epipedon was not observed any lithic or paralhitic contact, so the soil could be classified as Typic Udorthents.

Implication of soil morphological diversity on plant roots development: Soil morphology has an important role in roots development. Table 4 revealed that plant roots were able to penetrate the stratification of horizons in the soil profile. The thickness of the horizon and the number of layers in the soil profile (P1-P8) tends to decrease towards the lower regions.

In Pedon P1 observed that macro and meso-sized roots of A.docurents were able to penetrate new volcanic deposit until the A horizon at the depth of 50 cm. Whereas, the micro-sized roots (1 mm) were able to penetrate all the layer/horizons until the buried soil profile up to 190 cm (P1) and 193 cm (P2) under the soil surface. The micro-roots of Albasia were able to penetrate the layer/horizon of Pedon P3, P4, and P5 up to the depth of 150, 180, 130, respectively. In Pedon P6 and P7, the micro-roots of Mahogany and the other perenial plants were able to penetrate the layer/horizon up to the depth of 155 cm and 110 cm, respectively. At the last Pedon P8, the micro-roots of Gnetum gnemon were able to penetrate the layer/horizon up to the depth of 105 cm from the soil surface. These indicated that the variability of soil morphology with various thicknesses and properties did not become a limiting factor for root development in the area. Micro-sized roots with θ <1 mm were active roots that play an important role in water and nutrient absorption for plants.

The micro-sized root had hair roots and a root cap. The root cap was able to excrete an exudate (mucigel) containing a wide variety of organic compounds in relatively large quantities including: polysaccharides, proteins, carbohydrates, phenolics, fitosiderofores, amino acids, and organic acids (Marschner, 1995; Jones, 1998; Huang and Germida, 2002). Organic acids produced by roots include low molecular weight (LMMOAs) such as acetic acid, butyrate, oxalate, malate, propionate, succinate, citrate, tartaric, and fumarate. The size and magnitude of these organic acids are strongly influenced by plant species and cultivars (Marschner, 1995). These organic acids have the greatest contribution in dissolution of minerals that exist around plant roots.

Soil morphogenesis diversity (poligenesis) shown by the presence of a pedon having more than one soil profile was not a limiting factor for crop roots growth, so the agro-ecosystem recovery process was relatively fast. Only part of the land covered by rock block was relatively slowly recovered.

CONCLUSION

The active Merapi Volcano resulted in poligenesis of the soil morphology as observed at pedon P1 with composition of the upper and buried soil was Typic Hapludands-Typic Hapludands, P3 (Andic Eutrudepts-Vitrandic Udorthents), P4 (Vitrandic Udorthents -Typic Hapludands), and P5 (Andic Eutrudepts-Andic Eutrudepts). Whereas the monogenesis of the soil morphology was observed at pedon P2, P6, P7 and P8 with subgroups of Typic hapludands, Andic Eutrudepts, Andic Dystrodepts and Typic Udorthents, respectively. Soil morphogenesis diversity (polygenesis) shown by the presence of a pedon having more than one soil profile was not a limiting factor for crop roots growth, thus, the agro-ecosystem recovery process was relatively fast.

ACKNOWLEDGEMENT

We would like to express our gratitude to the Directorate General of Research and Community Service, Research and Technology Ministry of Indonesia who has provided financial assistance to complete this research with the contract no: 015/SP2H/LT/DRPM/II/2016.

REFERENCES

Brown, A.G. (1995). Geomorphology and Ground water. John Wiley & Sons, New York.

Budi-Santoso, A., Lesage, P., Dwiyono, S., Sumarti, S., Subandriyo, S., Surono, Jousset, P., Métaxian,J.P. (2013). Analysis of the seismic activity associated with the 2010 eruption of Merapi volcano, Java. *Journal of Volcanology and Geothermal Research*, **261:**153-170.

Campos C, A. (2010). Analyzing the relation between loss-on-ignitionand other methods of soil organic carbon determination in a Tropical Cloud Forest (Mexico). *Communications in Soil Science and Plant Analysis*, **41:**1454–1462.

Enryd, M.C. (1998). The Spatial Relationship between Physical Features and the Utilization of Land. Thesis. Department Of Physical Geography Göteborg University.

Eviati and Sulaeman. (2012). Technical Guidelines Soil Chemistry Analysis, Water and Fertilizers. 2nd Edn., The Indonesian Agency for Agricultural Research and Development-Ministry of Agriculture, Indonesia, ISBN: 978-602-8039-21-5.

Fiantis, D., Nelson, M., Van Ranst, E., Shamshuddin, J. and Qafoku, N.P. (2009). Chemical weathering of new pyroclastic deposits from Mt.Merapi (Java), Indonesia. *Journal of Mountain Sciences,* **6:** 240–254.

Galbraith, J.M. (2014). Identifying/Classifying Buried Soil Horizons. Virginia Tech University. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_ 050996.pdf (accessed 13 November 2017).

Gerrard, J. (1995). Soil Geomorphology. Chapman & Hall. London.

Huang, P.M. and Germida, J.J. (2002). Chemical and Biochemical Processes in Rhizosphere: Metal Polutants. In: Interaction between Soil Particels and Microorganism: Impact on the Terrestrial Ecosystem. P.M. Huang, J.M. Bollag, and N. Senesi (Eds). John Wiley and Sons, New York, 381-438.

Jones, D.L. (1998). Organic acids in the rhizosphere—a critical review. *Plant and Soil,* **205:** 25–44.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. Academic Press. London.

NRCS. (2011). Buried Soils and Their Effect on Taxonomic Classification. Soil Survey Technical Note No. 10, National Soil Survey Center. Natural Resources Conservation Service-USDA. Nebraska.

Owens, P.R., and Rutledge, E.M. (2005). Morphology. In: Encyclopedia of Soils in the Environment, pp. 511–520

Schmidt, F. H dan Ferguson, J. H. A. (1951). Rainfall Types Based on Wet and Dry Period Rations for Indonesia with Western New Guinea. Jakarta.

Soil Survey Staff. (2014). Keys to Soil Taxonomy. Twelfth Edition. United States Department of Agriculture Natural Resources Conservation Service. Washington D.C.

Summerfield, M.A. (1991). Global Geomorphology. Longman Scientific & Technical, New York.

Sutomo, Hobbs, R. and Cramer, V. (2011). Plant community establishment on the volcanic deposits following the 2006 nuées ardentes (pyroclastic flows) of Mount Merapi: Diversity and floristic variation. *Biodiversitas*, **12** (2): 86-91.

Sutomo. (2010). Plant Succession Following Nuées Ardentes of Mt.Merapi Vocano, Java Indonesia. M.Sc Thesis, School of Plant Biology, University of Western Australia.

Sutomo. (2013). Ecological Succession on Volcanic Ecosystem of Mount Merapi Indonesia and Its Implication for Restoration. Biotrop. Bogor. pp.113.

USDA. (1996). Soil Survey Laboratory Methods Manual. Soil Survey Investigation Report No.42. Version 3.0. National Survey Center, National Resources Conservation Service, United States Department of Agriculture.

USDA. (2014). Soil Survey Field and Laboratory Methods Manual.Soil Survey Investigations Report No. 51.Version 2.

USDA. (2016). National Soil Survey Handbook. Natural Resources Conservation Service. United States Department of Agriculture. Voight, B., Constantine, E.K., Sismowidjoyo, S., Torley, R. (2000). Historical eruptions of Merapi Volcano, Central Java, Indonesia, 1768-1998. *Journal of Volcanology and Geothermal Research*, **100**: 69-138.

Wang, X., Wang, J. and Zhang, J. (2012). Comparisons of Three Methods for Organic and Inorganic Carbon in Calcareous Soils of Northwestern China. *PLOSOne* **7**(8): e44334. doi:10.1371/journal.pone.0044334.

Wulaningsih ,T., Humaida, H., Harijoko, A., and Watanabe, K. (2013). Major element and rare earth elements investigation of Merapi Volcano, Central Java, Indonesia. *Procedia Earth and Planetary Science* **6**: 202 – 211.

Yuliani, N., Hanudin, E. and Purwanto, B.H. (2017). Chemical characteristics and morphology of amorphous materials derived from different parent materials from Central Java, Indonesia. *International Journal of Soil Science*, **12** (2): 54-64.