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Classification, physicochemical, soil fertility, and relationship to *Coffee robusta* yield in soil map unit selected

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ABSTRACT

The research was aimed to classify, characterize the physicochemical properties, determine the fertility of the soil, and to obtain the relationship of soil fertility on the character yield for *Coffee robusta* in the 10 units of the soil map (SMUs) selected. This research was conducted in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia from July 2014 to June 2017. This research was conducted by overlay the maps, classifying soil profiles, characterizing soil, soil fertility assessing, and regression analysis of soil fertility with the yield for *Coffee robusta* using IBM SPSS Statistics v.20 software. The result showed the ten from 18 SMUs selected for *Coffee robusta* had the highest area in sequentially, namely SMU 11, 14, and 1. Based on the ten SMUs selected, found in two representative soil profiles, include the profile 1 (SMU 1, 2, 8, 9, 11, 13, 14, 16, 18) covering an area of 1,703.30 ha with the inceptisol and profile 10 (SMU 10) covering an area of 176.81 ha with the entisol. Inceptisol has greater thesoil physicochemical properties compared to entisol from ten SMUs selected for *Coffee robusta*. The effect of cation exchange capacity, base saturation, P-total, K-total, and C-organic have significantly increased the productivity of *Coffee robusta* by 89.30%. However, the effect was not significant to the 100 grains of dry weight.

Key words: Entisol; *Coffee robusta*; Inceptisol; Overlay; Soil fertility.

1 INTRODUCTION

Coffee is a plantation crop that can be supporting the human economy in Indonesia. Statistics of Indonesia (2019) reported that Indonesia coffee export volume over the last 10 years (2010 until 2019) experienced fluctuating and reached 355,766.5 ton with total area of 1,258 thousand ha in year 2019. Statistics of Indonesia (2019) also reported the countries that were the main export destinations for Indonesia coffee found in the United States by 58,666.2 ton, and were followed in Italy of 35,452.2 ton, Malaysia of 34,662.2 ton, Egypt of 34,285 ton, and Japan of 25,587.8 ton. It is shows that coffee yield has the opportunity to be exported and can support the income of Indonesia coffee farmers.

The coffee area is dominated by smallholder with an area of 1,194,081 ha (96.16%) of the total coffee area in Indonesia, while the residual of 47,632 ha (3.84%) are government and private estate. Farmers in Indonesia grow three types of coffee, such as *robusta, arabica,* and *liberica*. *Coffee robusta* plant is the most widely grown by farmers in Indonesia, followed by arabica and liberica with area reached 879,117 ha (70.80%) and 314,963 ha (25.36%), respectively. The distribution of the planting areas for *Coffee robusta* in sequentially found in the regions Sumatra of 596,610 ha, Java of 106,161 ha, Nusa Tenggara and Bali of 88,108 ha, Sulawesi of 57,427 ha, Kalimantan of 26,315 ha, Maluku and Papua of 4,495 ha (Indonesian Agency for Agricultural Researchand Development, 2015).

Statistics of Indonesia (2019) reported that North Sumatra Province has a coffee area of 97.50 thousand ha from the Sumatra region and is in 4th place after South Sumatra Province of 251 thousand ha, Lampung of 156.90 thousand ha, Aceh of 125.30 thousand ha. Statistics of Sumatera Utara (2018) reported that the area for *Coffee robusta* planted in North Sumatra was 17,437.64 ha with the yield up to 6,788.70 ton and the largest area for planting in Dairi District was 8,427 ha or 48.33% compared to other districts in 2018. Thus the productivity for *Coffee robusta* in Dairi District was 402.02 kg ha^{-1} and was classified as lower compared to the national rate of 723.01 kg ha^{-1}.

The low productivity *Coffee robusta* in Dairi District could be caused by several factors, one of them is the decrease in land productivity in supporting coffee yield. Thus it is necessary to research the status of soil fertility at Dairi District in detail, covering the overlay Soil Map Unit (SMU), the classification and characterization of soil, and analysis of the relationship between soil fertility on the yield characteristics for *Coffee robusta*. It has been reported that the classification and characterization of soil in several plantation areas for *Coffee robusta* in Dairi District. Marbun et al. (2016) reported that an area of 891.99 ha in the SMU 3 until 7 in the Silima Pungga-Pungga sub-District, Dairi District had inceptisol orders with the character the cation exchange capacity (CEC) was classified as low until very high, base saturation (BS) and C-organic were classified as very low until low. Marbun et al. (2018) also added a land area of 2,241.42 ha at SMU 12, 15, and 17 from Silima Pungga-Pungga sub-District, Dairi District had andisol order with the characters CEC was classified as low until moderate, BS and C-organic were classified as very low until low.

The reports the previous research is incomplete because there are still areas cultivation for *Coffee robusta* of 1880.11 ha or 10 SMUsin the Silima Pungga-Pungga sub-District, Dairi District that has not been classified in detail based overlay mapping of land. The research was aimed to (1) classify, characterize the soil physicochemical properties, determine the status of soil fertility, and (2) obtain the relationship CEC, BS, P-total, K-total, and C-organic toward productivity and weight of 100 grains of dry weight for *Coffee robusta* at the ten SMUs selected in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

2 MATERIAL AND METHODS

2.1 Research Area for *Coffee robusta*

The research was conducted in the Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia with the coordinates $2^0 80'$- $2^0 88'$ NL and $98^0 04'$-$98^0 17'$ EL in the altitude of 400 until 800 m above sea level from July 2014 until June 2017. Soil analysis was conducted at the Research and Technology Laboratory, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia.

2.2 Map Overlay and Soil Profile Classification

A survey was conducted to make a soil profile. Soil profiles were conducted on Soil Map Unit (SMU) based on a map overlay technique between soil type, altitude, and slope with a scale of 1: 25,000 respectively using ArcView GIS 3.2a (Figure 1).

Observation of the morphology and characteristics of the soil in each profile was conducted using the reference book such as "Guidelines of Soil Observation in Field" by IAARD press and "Key to Soil Taxonomy 2014" by Soil Survey Staff USDA. Soil profile classification was conducted by determining the epipedon horizon, subsurface horizon, and other identifiers properties, then it was determined the order, sub-order, great group, and sub-group.

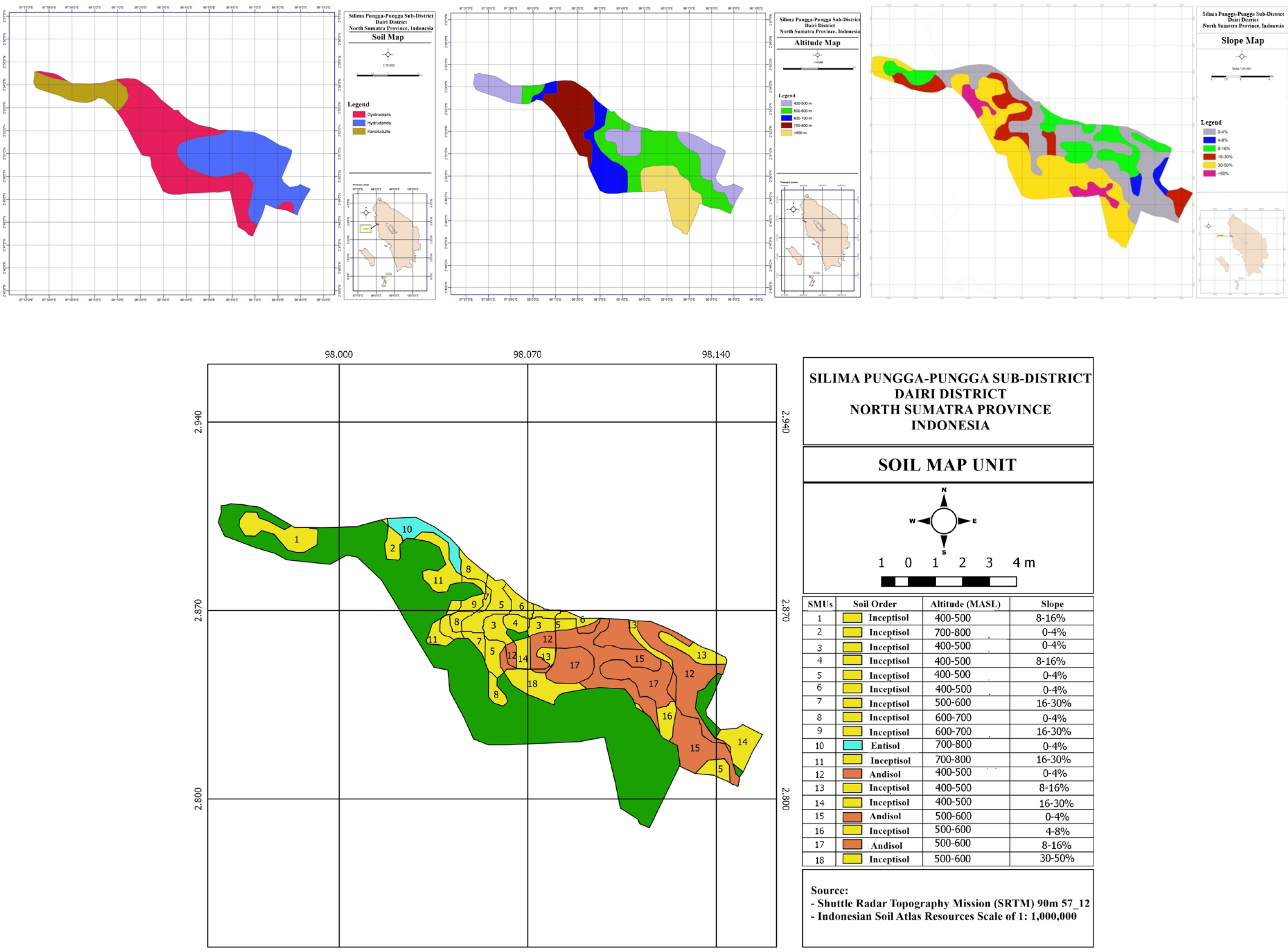

Figure 1: SMUs for *Coffee robusta* with an overlay technique between maps of soil types, altitude, and slope in Silima Pungga-Pungga Sub-District, Dairi District, North Sumatra Province, Indonesia.

2.3 Soil Physicochemical Properties

Soil ph ysicochemical properties were conducted by taki ng soil samples from each horizon at 10 SMUs selected, include Cation Exchange Capacity (CEC) and Base Saturat ion (BS) with the extraction method of NH_4OAc (pH 7), C-organic with the Walkley & Black method, soil pH (H_2O, KCl, NaF), salinity with the platinum electrode method, soil color using the Munsell Soil Color Chart book, soil st ructure, soil consistency with the Atterberg method, soil te xture with the Hydrometer method, and bulk density using a ring sample.

2.4 Soil Fertility Assessment

Assessm ent of soil fertility was determined by the mai n soil chemical characteristics, such as: CEC and BS, meanwhile other soil chemical characteristics are det ermined through P-total, K-total, and C-organic. Overall, soil chemical characteristics were obtained using a parametric method, and the soil fertility assessment was determined based on the CEC, BS, P_2O_5, K_2O, and C-organic on upland acid soils in Southeast Asia by Dierolf, Fairhurst and Mutert (2001).

2.5 Multiple Linear Regression Analysis

The productivity and 100 grains of dry weight for *Coffee robusta* were collected from 30 farmers in each SMU selected and then weighed. Multiple linear regression analysis (F-test and determination coefficient) was performed in the influence of CEC, BS, P-total, K-total, and C-organic on productivity and 100 grains of dry weight for *Coffee robusta* using IBM SPSS Statistics v.20 software.

3 RESULTS

3.1 Soil Map Unit (SMU)Selected

The ten of 18 SMUs were selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province (Table 1).

Based on the overlay results obtained the ten of 18 SMUs selected for *Coffee robusta* with three SMUs have the highest an area in sequentially,namely SMU 11 (great group dystrudept, altitude ranged by 700 to 800 m, slope ranged by 16 to 30%), SMU 14 (great group dystrudept, altitude ranged of 400 to 500 m, slope ranged of 16 to 30%) and SMU 1 (great group dystrudept, altitude ranged by 400 to 500 m, slope ranged by 8 to 16%).

3.2 Soil Classification for *Coffee robusta*

Determination of the epipedon horizon, subsurface horizon, other identifiers properties, the order, sub-order, great group, sub-group of 10 SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District (Tables 2 and 3). Based on ten SMUs selected, obtained two representative soil profiles in Silima Pungga-Pungga sub-District, Dairi District, such as profile 1 include SMU 1, 2, 8, 9, 11, 13, 14, 16, 18 covering an area of 1,703.30 ha with the umbric epipedon, the cambic subsurface horizon, inceptisol order, udept sub-order, dystrudept great group, typic dystrudept sub-group, and it had the Ap-B-C horizon. The profile 10, only SMU 10 covering an area of 176.81 ha with the ochric epipedon, it does not have a characteristic subsurface horizon, entisol order, orthent sub-order, udorthent great group, typic udorthent sub-group, and it had the horizon Ap-A-C.

Table 1: The soil map unit (SMU) was selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

SMUs	Great Group	Altitude (m)	Slope (%)	Villages	Area (ha)
	SMU 1 Dystrudept 400-500		8-16	Lae Rambong	253.16
SMU 2	Dystrudept	700-800	0-4	Lae Ambat	22.22
SMU 8	Dystrudept	600-700	0-4	Lae Ambat	184.99
SMU 9	Dystrudept	600-700	16-30	Lae Ambat	133.68
SMU 10	Udorthent	700-800	0-4	Lae Ambat	176.81
SMU 11	Dystrudept	700-800	16-30	Lae Ambat	293.24
SMU 13	Dystrudept	400-500	8-16	Sinatah, Parongil, Polding Anak-anak, Sumbari	247.95
SMU 14	Dystrudept	400-500	16-30	Palipi	261.02
SMU 16	Dystrudept	500-600	4-8	Bakal Gajah, Sumbari, Uruk	89.88
SMU 18	Dystrudept	500-600	30-50	Parongil, Longkotan, Palipi, Tungtung Batu, Polding Anak-anak, Longkotan, Tungtung Batu, Siboras, Uruk Belin, Bakal Gajah, Sumbari, Lae Panginuman, Sumbari, Bonian	217.16
Total					1,880.11

3.3 Soil Physicochemical Properties for *Coffee robusta*

The soil physicochemical properties in each representative soil profile of ten SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District could be seen in Tables 4 and 5. Based on the physical properties of ten SMUs selected, showed that the profile 1 (SMU 1, 2, 8, 9, 11, 13, 14, 16, 18) had the soil structure of the granular until blocky, the soil consistency of the soft until slightly hard, the soil texture of the sandy clay loam until clay, and bulk density ranged of 1.04 to 1.12 $g.cm^{-3}$. Profile 10 (SMU 10) had the soil structure of the granular, the soil consistency of the soft until very soft, soil texture of sandy loam until sandy clay loam, and bulk density ranged of 1.18 to 1.26 $g.cm^{-3}$.

Based on the chemical properties of ten SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, it was obtained that profile 1 (SMU 1, 2, 8, 9, 11, 13, 14, 16, 18) had the soil pH had strongly acid to acid, CEC ranged of13.21 until 21.09 me/100 g (low to moderate), C-organic ranged of 0.49 until 1.70% (very low until low), BS rangedof 15.13 until 18.51% (very low), Ca-exchangeable was classified as very low, K-exchangeable was classified as low, Na-exchangeable was classified as low until moderate, and Mg-exchangeable was classified as low until high. In profile 10 (SMU 10) had the soil pH was classified as strongly acid to acid, CEC ranged of 9.99 until 11.89 me/100 g (low), C-organic ranged by 0.48 until 1.36% (very low until low), BS ranged of 14.43 until 17.00% (very low), Ca- and Mg-exchangeable were classified as very low, K-exchangeable was classified as very low to low, and Na-exchangeable was classified as low. The salinity rate in both soil profiles were classified as very low.

3.4 Soil Fertility Assessment

The soil fertility rate of inceptisol and entisol of ten SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District (Table 6). The result showed that the inceptisol at SMU 1, 8, 9, 11, and 16 had the soil fertility were classified as very low, meanwhile at SMU 2, 13, 14, and 18 were classified as low. The entisol order (SMU 10) had the soil fertility was classified as very low.

3.5 Multiple Linear Regression Analysis between Soil Fertility to Yield Characters for *Coffee robusta*

The effect of CEC, BS, P-total, K-total, and C-organic on the productivity and 100 grains of dry weight for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District (Table 7). The result showed that the effect CEC, BS, P-total, K-total, and C-organic were significantly affected by the productivity *Coffee robusta* with a value of 0.8930. It was indicated that CEC, BS, P-total, K-total, C-organic could be increasing the productivity *Coffee robusta* by 89.30%. The CEC, BS, P-total, K-total, and C-organic was not significant effect on the 100 grains of dry weight for *Coffee robusta*. However, it had a value of 0.7640. It was indicated that CEC, BS, P-total, K-total, C-organic could be increasing the 100 grains of dry weight for *Coffee robusta* by 76.40%.

Table 2: Establishment of the epipedon horizon, subsurface horizon, and other identifiers properties in 10 SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

Soil Profiles	SMUs	Epipedon horizon	Subsurface horizon	Other identifiers properties
1	1; 2; 8; 9; 11; 13; 14; 16; 18	Including the umbric; because it is located above the soil surface; with color value and chroma of 3 or less (humid); base saturation <50% and the soil is humid for more than 3 months	Including the cambic; because it had the sandy loam texture; the thickness of the horizon is more than 15 cm; the absence of clay illuviation process and not part of the Ap horizon and does not experience aquic conditions	Has the udic humidity regime because the soil has never been dry in 90 days (cumulative); which is more than 90 days or the average rainfall data for wet months ranged by 7-10 months each year or 210 until 300 days (cumulative); and has the isohipertermic temperature soil regime
10	10	Including the ochric; because the value or chroma is more than 3 (humid).	It does not have a characteristic subsurface horizon because it is not yet developed	

Table 3: Establishment of order, sub-order, great group, and sub-groupof 10 SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

Soil Profiles	SMUs	Order	Sub-order	Great group	Sub-group
1	1; 2; 8; 9; 11; 13; 14; 16; 18	Including the inceptisol; because it had an umbric epipedon and had subsurface horizon of cambic at a depth of less than 100 cm from the ground surface	Including the udept sub-order because it has udic soil moisture regime	Including the dystrudept because it has another udept	Including the typic dystrudept sub-group because it has others dystrudept
10	10	Including the entisol; because it does not have a subsurface horizon and has a little horizon arrangement	Including the orthent sub-order because it has other entisol characteristics	Including the udorthent because it has other orthent characteristics	Including the typic udorthent sub-group because it has others udorthent

Table 4: Physical characteristics of soil profiles from 10 SMUs selected in *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

Soil Profiles	Horizons	Depth (cm)	Soil Color	Soil Structure	Soil Consistency	Texture Fraction (%)			Soil Texture	BD ($g.cm^{-3}$)
						Sand	Silt	Clay		
Profile 1 (SMUs 1; 2; 8; 9; 11; 13; 14; 16; 18)	Ap	0-34	5 YR 3/3	Granular	Soft	49.84	26.56	23.60	SCL	1.09
	B	34-104	5 YR 6/3	Blocky	Slightly hard	39.84	18.56	41.60	C	1.12
	C	104-150	5 YR 5/8	Blocky	Slightly hard	31.12	15.28	53.60	C	1.04
Profile 10 (SMU 10)	Ap	0-29	10 YR 4/6	Granular	Soft	65.12	21.28	13.60	SL	1.18
	A	29-38	10 YR 4/3	Granular	Soft	59.12	21.28	19.60	SL	1.21
	C	38-150	10 YR 5/6	Granular	Very soft	53.84	19.28	26.88	SCL	1.26

Note: Criteria for Soil Texture (SL= sandy loam; SCL= sandy clay loam; C= Clay).

Table 5: Chemical characteristics of soil profile from 10 SMUs selected in *Coffee robusta*in Silima Pungga-Pungga sub-District, DairiDistrict, North Sumatra Province, Indonesia.

Soil Profiles	Horizons	Depth (cm)	Soil pH			CEC (me/100g)	C-organic(%)	EC (dS/m)
			H_2O	KCl	NaF			
Profile 1 (SMUs 1; 2; 8; 9; 11; 13; 14; 16; 18)	Ap	0-34	4.98 (A)	3.65	9.82	15.21 (L)	1.70 (L)	0.95 (VL)
	B	34-104	5.06 (A)	3.47	9.80	13.21 (L)	0.87 (VL)	0.55 (VL)
	C	104-150	4.36 (SoA)	3.67	10.30	21.09 (M)	0.49 (VL)	0.55 (VL)
Profile 10 (SMU 10)	Ap	0-29	4.46 (SoA)	4.05	9.07	9.99 (L)	1.36 (L)	0.40 (VL)
	A	29-38	4.61 (A)	4.04	9.45	8.88 (L)	0.92 (VL)	0.75 (VL)
	C	38-150	4.75 (A)	4.01	9.63	11.89 (L)	0.48 (VL)	0.70 (VL)

Soil Profiles	Horizons	Depth (cm)	Exchangeable Cations (me/100g)				Ca^{2+}/K^{+}	Mg^{2+}/K^{+}	BS (%)
			Ca	Mg	K	Na			
Profile 1 (SMUs 1; 2; 8; 9; 11; 13; 14; 16; 18)	Ap	0-34	0.926 (VL)	0.962 (L)	0.174 (L)	0.240 (L)	5.32	5,53	15.13 (VL)
	B	34-104	0.999 (VL)	0.701 (L)	0.328 (L)	0.528 (M)	3.05	2.14	17.84 (VL)
	C	104-150	1,296 (VL)	2.187 (H)	0.171 (L)	0.250 (L)	7.58	12.79	18.51 (VL)
Profile 10 (SMU 10)	Ap	0-29	0.985 (VL)	0.344 (VL)	0.126 (L)	0.201 (L)	7.82	2.73	16.58 (VL)
	A	29-38	0.672 (VL)	0.176 (VL)	0.091 (VL)	0.342 (L)	7.38	1.93	14.43 (VL)
	C	38-150	1.486 (VL)	0.204 (VL)	0.075 (VL)	0.256 (L)	19.81	2.72	17.00 (VL)

Note: Criteria for pH H2O (strongly acid/SoA < 4.5; acid/A= 4.5-5.5; slightly acid/SiA= 5.5-6.5; neutral/N= 6.6-7.5; slightly alkaline/SAl= 7.6-8.5; alkaline/Al >8.5); Cation Exchange Capacity/CEC (very low/VL < 5 me/100 g; low/L= 5-16 me/100 g; moderate/M= 17-24 me/100 g; high/H= 25-40 me/100 me/100 g; very high/VH > 40 me/100 g); C-organic (very low/VL < 1%; low/L= 1-2%; moderate/M= 2.01-3%; high/H= 3.01-5%; very high/VH > 5%); salinity (very low/VL < 1 dS/m; low/L= 1-2 dS/m; moderate/M= 2-3 dS/m; high/H= 3-4 dS/m; very high/VH > 4 dS/m) (Soil Research Institute 2009).

Table 6: Soil fertility in *Coffee robusta* based on 10 SMUs selected in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

Order	Sub-group	SMU	CEC (me/100 g)	BISA (%)	P-total (%)	K-total (%)	C-organic (%)	Productivity (kg ha^{-1})	Soil Fertility
Entisol	Typic Udorthent	SMU 10	10.91 (L)	16.61 (VL)	0.04 (L)	0.35 (VH)	0.85 (VL)	1346.20	Very low
Inceptisol	Typic Dystrudept	SMU 1	14.94 (L)	16.77 (VL)	0.03 (L)	0.33 (VH)	1.70 (L)	666.05	Very low
		SMU 2	14.31 (L)	28.94 (L)	0.04 (L)	0.33 (VH)	1.21 (L)	1082.98	Low
		SMU 8	10.36 (L)	15.98 (VL)	0.07 (M)	0.29 (VH)	1.47 (L)	1363.35	Very low
		SMU 9	10.18 (L)	15,50 (VL)	0.06 (L)	0.27 (VH)	0.81 (VL)	1411.58	Very low

Continue...

Table 6: Continuation.

Order	Sub-group	SMU	CEC (me/100 g)	BISA (%)	P-total (%)	K-total (%)	C-organic (%)	Productivity (kg ha^{-1})	Soil Fertility
Inceptisol	Typic Dystrudept	SMU 11	12.87 (L)	13.04 (VL)	0.37 (VH)	0.28 (VH)	1.10 (L)	688.73	Very low
		SMU 13	13.85 (L)	26.67 (L)	0.11 (VH)	0.14 (H)	1.56 (L)	902.36	Low
		SMU 14	13.21 (L)	28.98 (L)	0.10 (H)	0.17 (H)	1.25 (L)	797.89	Low
		SMU 16	9.50 (L)	14.45 (VL)	0.11 (VH)	0.16 (H)	0.80 (VL)	1201.40	Very low
		SMU 18	10.55 (L)	22.21 (L)	0.09 (H)	0.17 (H)	1.10 (L)	1089.22	Low

Note: Criteria for Cation Exchange Capacity/CEC (very low/VL<5 me/100 g; low/L= 5-16 me/100 g; moderate/M= 17-24 me/100 g; high/H= 25-40 me/100 g; very high/VH > 40 me/100 g); Base Saturation/BS (very low/VL < 20%; low/L= 20-40%; moderate/M= 41-60%; high/H= 61-80%; very high/VH> 80%); C-organic (very low/VL< 1%; low/L= 1-2%; moderate/M= 2.01-3.00%; high/H= 3.01-5.00%; very high/VH > 5%); P-total (very low/VL < 0.03%; low/L= 0.03-0.06%; moderate/M= 0.06-0.079%; high/H= 0.08-0.10%; very high/VH > 0.10%), K-total (very low/VL < 0.03%; low/L= 0.03-0.06%; moderate/M= 0.07-0.11%; high/H= 0.12-0.20%; very high/VH > 0.20%) (Soil Research Institute 2009); Soil fertility quality (very low = VL; low = L) adopted from Dierolf,Fairhurst and Mutert (2001).

Table 7: Multiple linear regression analysis of the CEC, BS, P-total, K-total, C-organic on the yield characteristics for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province, Indonesia.

Yield Characteristics	Model	Sum of Squares	df	Mean Square	F	Sig.	r^2
Productivity	Regression	629804.71	5	125960.94	6.68*	0.045	89.30%
	Residual	75448.93	4	18862.23			
	Total	705253.64	9				
100 grains of dry weight	Regression	108.75	5	21.75	2.58^{ns}	0.189	76.40%
	Residual	33.67	4	8.42			
	Total	142.42	9				

Note: *significant at the level of 95%; ns= not significant at the level of 95%.

4 DISCUSSION

The overlay result showed ten of 18 SMUs were selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District, North Sumatra Province and dominant at an altitude ranged of 400 to 600 m above sea level (MASL) covering an area of 1,069.19 ha compared to an altitude of 600 to 800 MASL at an area of 810.92 ha. According to Directorate General of Estate Crops (2015) the appropriate altitude for growing the *Coffee robusta* ranged from 100 until 600 MASL and the highly suitable land suitability class at an altitude of 300 to 500 MASL and a slope of 0 to 8%. Arvi, Syakur and Karim (2019) stated that an altitude and slope did not significant and negatively correlated (R = -0.372 and -0.182) on the weight of the net beans for *Coffee arabica* Gayo, it means that at each increase in altitude 200 MASL and the slope of 1% could be decreased the net beans weight of 0.14% and 0.007% per hectare, respectively. The higher an altitude causes the lower temperature will result that the ripening process of the fruit the slower and lower the fruit filling. Salima, Karim and Sugianto (2012) reported that the flat slope (0 until 8%) could be produced a higher yield for *Coffee arabica*. The slope relating to the availability of C-organic, Al-dd, pH, P-available, and N-total.

Based on ten SMUs selected, found in two representative soil profiles such as profile 1 (umbric, cambic, inceptisol, udept, dystrudept, typic dystrudept, and the horizon Ap-B-C), and the profile 10 (ochric, it does not have a characteristic subsurface horizon, entisol, orthent, udorthent, typic udorthent, and the horizon Ap-A-C). The result indicated that the order inceptisol has the characteristics of CEC, C-organic, and BS were higher ranged of 13.21 to 21.09 me/100 g; 0.49 to 1.70%; and 15.13 to 18.51%, respectively compared to entisol (Table 5). According to Schaetzl, Krist Junior and Miller (2012) the index soil productivity (ISP) for inceptisol had a value of 9 and was higher compared to entisol of 6. Hadi, Sutikto and Bowo (2019) reported that the classification of the inceptisol order, udept sub-order, dystrudept great group, typic dystrudept sub-group from *Coffee robusta* plantations in Rayap-2 locations, Jember District had ISP value at 7 and was higher compared to the entisol order, orthent sub-order, udorthent great group, typic udorthent sub-group with ISP value of 6 in Sidomulyo location, Jember District. The productivity index based on soil taxonomy has a very strong correlation (r= 0.84) with the productivity for *Coffee robusta*. The higher the ISP value will result the higher the productivity for *Coffee robusta*.

Based on the physical properties of ten SMUs selected, showed that the consistency, structure, and texture of soil on both soil orders were classified as supporting root activity in elongation and growth of the roots for *Coffee robusta*. According to Khalil et al. (2015) the soil characteristics including the physical, chemical, and biological caused the chain changes in physiological, biological, and chemical on the growth, yield, and quality of biomass, and fiber plants. Pardo, Amato and Chiarandà (2000) stated that the soil structure could be supporting the growth of *Cicer arietinum* and the spread of roots to absorb water and nutrients. Avelino et al. (2002) reported that soil texture and acidity could affect the quality of coffee beans. Gil et al. (2012) reported that soil texture could affect the movement and availability of water, air, and nutrients. Chaudhari et al. (2013) reported that soil texture could affect the bulk density of soil and stimulate the yield of plants. Vetterlein et al. (2007); Bada and Raji (2010) also reported that soil texture was significant for the absorption efficiency of plants.

Inceptisol order has greater the soil chemical properties compared to entisol from ten SMUs selected for *Coffee robusta* in Silima Pungga-Pungga sub-District, Dairi District. It is due to the highest content of CEC, BS, and C-organic found in the inceptisol order. The C-organic content could be affected by cation exchange with the result that nutrients become available to support the growth and yield for *Coffee robusta*. In addition, on the Ap horizon with the soil depth of 0-34 cm in the inceptisol order obtained the ratios of $Ca^{2+}/K^{+}$and Mg^{2+}/K^{+} of 5.32 and 5.53, respectively. The result indicated the nutrients balance of Ca and Mg which can support plant roots to absorb the nutrients needed and affect to yield plant. According to Sousa et al. (2018) the soil organic matter significantly increased the content of N-total and S in the leaves of coffee plants from Minas Gerais. Kufa (2011); Kilambo et al. (2015) stated that humus colloids have the higher cationic absorption compared to clay colloids with the result that the higher organic matter could be increasing the value of soil CEC. Loide (2004) stated that the relationship between K/Mg was significantly and positive correlation (r= 0.889) on the yield plants. The yield increased until the ratio of K/Mg achieved 0.6-0.7: 1. The potassium content increases, it occurs a decrease in the yield of *Trifolium pratense*, except the magnesium nutrient was added to manage the balance of K/Mg. In addition, the overage of Mg-exchangeable in the soil which is un-balanced with Ca will deteriorate the physiological characteristics of the roots and lead to decreased the yield plant.

The soil fertility assessment of the inceptisol in the location research was greater than the entisol. It was caused the highest content of CEC, BS, P-total, and C-organic found in the inceptisol of 14.94 me/100 g; 28.98%; 0.37%, and 1.70%, respectively. According to Malavolta et al. (1979); Chaves, Pavan and Miyazawa (1991) the increased Ca-exchangeable content had a linear and significant relationship with increased the yield of coffee beans. Bradl (2004) reported that organic matter had a positive correlation with soil cation exchange. Alves et al. (2015) reported that base saturation up to 60% was significantly and positively correlated (R= 0.722 and 0.9883) to the dry weight of *Crambe abyssinica* roots at 35 and 55 days after growing.

The effect of CEC, BS, P-total, K-total, and C-organic were significantly affected on the productivity and was not significant effect on the 100 grains of dry weight for *Coffee robusta* with the determination coefficient by 89.30% and 76.40%, respectively. According to Supriadi, Randriani and Towaha (2016) the content of C-organic, CEC, N-total, and soil pH significantly increased on the normal beans and 100 beans weight for *Coffee arabica* in the highlands of Garut District, West Java Province, Indonesia. Cyamweshi et al. (2014) stated that soil pH, Cacontent, P-available, N-total, and C-organic were positively correlated with the determination coefficient by 71%; 56%; 62%; 30%, and 52.7% respectively of coffee yield in Nyamagabe District, Southern Rwanda Province. Clemente et al. (2013) stated that K nutrient content had the quadratic response to growth, bean size, and coffee bean yield.

5 CONCLUSIONS

The result obtained ten from 18 SMUs selected for *Coffee robusta*and had the highest area in sequentially, such as SMU 11, 14, and 1. Area growing for *Coffee robusta* dominant at an altitude ranged of 400 until 600 MASL with an area of 1,069.19 ha. Based on the ten SMUs selected, found in two representative soil profiles, include the profile 1 (SMU 1, 2, 8, 9, 11, 13, 14, 16, 18) covering an area of 1,703.30 ha with the inceptisol, had horizon of Ap-B-C, soil structure of granular until blocky, soil consistency of the soft until slightly hard, the soil texture of the sandy clay loam until clay, and bulk density ranged of 1.04 to 1.12 g cm^{-3}, the chemical properties was classified as very low until high,and soil fertility was classified as very low. In profile 10 (SMU 10) covering an area of 176.81 ha with the entisol, had horizon of Ap-A-C, soil structure of the granular, soil consistency of the soft until very soft, soil texture of sandy loam until sandy clay loam, bulk density ranged of 1.18 to 1.26 g cm^{-3}, the chemical properties was classified as very low until low, and the soil fertility was classified as very low. Effect of CEC, BS, P-total, K-total, and C-organic significantly increased the productivity *Coffee robusta* by 89.30%. However, the effect was not significant to the 100 grains of dry weight.

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