THE EFFECT OF SLOPE AND ALTITUDE ON SOIL CHARACTERISTICS IN TEA PLANTATION AREA, CENTRAL JAVA, INDONESIA

Marianti
Department of Soil Science, Faculty of Agriculture,
Gadjah Mada University,Indonesia,
Email: marianti@mail.ugm.ac.id

Nur Ainun H. J. Pulungan
Department of Soil Science, Faculty of Agriculture,
Gadjah Mada University, Indonesia,
Email: nurainun.pulungan@ugm.ac.id

Rachmad Gunadi
Department of Soil Science, Faculty of Agriculture,
Gadjah Mada University, Indonesia,
Email: rachmadgunadi@ugm.ac.id

ABSTRACT

Slope and altitude are crucial soil forming factors especially in a rough topographic area like tea plantation. The difference of slopes and altitudes are suspected to cause differences in soil characteristics. PT. Pagilaran is one of the successful tea plantations in Java. Understanding well about the soil characteristics in the tea plantation becomes the key to maintaining productivity of the tea. The productivity of tea plants must be supported by suitable soil characteristics so that the availability of plant nutrients can be fulfilled, then plants can grow optimally. The objective of this research is to find out the characterization of physico-chemical soil properties on different slopes and altitude as a basic data for increasing the tea productivity. The sampling method applied in this study was stratified sampling, based on two different slope classes (0-8% and 15-25%), and four different altitude levels (700-800, 800-900, 900-1000, and 1000-1100 msl). Soil samples were taken by soil drill at a depth of 0-15cm from the surface using the composite method. Soil properties analyzed were Soil texture, pH H2O, pH KCl, pH NaF, Cation Exchange Capacity, Total Organic Carbon, Total N, Available P, Available K, and Soil Moisture. Based on analysis of variance, the results showed that there were significant different of the effect of slope and altitude towards pH KCl, pH NaF, C-Organic, Organic matter, Cation Exchange Capacity, and Soil moisture. Overall results showed that altitudes are more influence towards soil properties than slopes. According to polynomial regression, the influence of altitudes towards soil properties are much higher than the influence of slopes towards soil properties.

Keywords: *altitude, slope, soil characteristics, tea plantation*

INTRODUCTION

Tea is a type of perennial plant that can grow and produce for a long time. Tea is one of the leading plantation commodities in Indonesia which comes from subtropical areas and is in great demand as a raw material for refreshing products (Saefas et al., 2017). The tea plant is an annual plant that grows for a long time, the growth of the plant will take nutrients from the soil continuously, the roots will exploit the soil around the plant, this will result in reduced nutrient availability in the soil (Wulansari, 2015). The growth and production of tea is influenced by three main factors, such as: (1) crop (population, plant age, plant type, crop age and genetic potential); (2) the environment in which to grow (climate, which consists of rainfall and rainy days, air temperature, humidity, and length of sunshine); (3) soil, which includes the type, topography, altitude, physical, chemical and biological soil (PPTPK Gambung, 2005).

The development of tea productivity in Indonesia during 2003-2014 tended to fluctuate (Pusat Data dan Sistem Informasi Pertanian, 2015). These conditions are partly due to the fact that most of the tea plant areas are not to use superior seeds, the age of the plants used tends to be old, the plant population per hectare is not full and the maintenance of tea plants is less intensive. Apart from these causes, there are factors that play an important role, namely the planting or growing medium and the availability of nutrients in it. The availability of nutrients or nutrients for plants determines the development and growth of plants, especially tea plants.

The principle of growing conditions for tea plants is climate and soil suitability (Effendi et al., 2010). Other requirements needed to growth and production, tea plants require land resource conditions that are determined by water availability, root media, nutrient retention, available nutrient toxicity, and potential for mechanization. Nutrient retention is the temporary ability of the soil to absorb nutrients or colloids in the soil, so that if the conditions in the soil are suitable for certain nutrients, the absorbed nutrients will be released and can be absorbed by plants. Nutrient retention in the soil is influenced by KPK, alkaline saturation, pH and C-organic.

Soil as a growing medium which is very important for plant growth needs to be considered. The productivity of tea plants must be supported by suitable soil characteristics so that the availability of plant nutrients can be fulfilled so that plants can grow optimally. The height and slope of the slope are the main aspects of the topographic elements that can affect soil development. Tea is suitable for planting in the highlands. In the soil, there are several nutrients that are needed by plants. Some of the main macro nutrients needed for plants are Nitrogen (N), Phosphorus (P) and Potassium (K). On the other hand, the position of the slope can change the availability of soil nutrients.

Almost all volcanic soils have superior physical characteristics so that they are widely used. Andosols (andisols) that develop from volcanic ash and have andic properties, namely the content of organic matter is less than 25% and the content of amorphous materials (allophane, imogolite and Al-humus complex compounds) is quite high. Chemically, Andosol (andisol) has high phosphate retention, and may have limitations in K and some micro nutrients. Nutrient characterization is an effort that can be made to determine the content or status of soil and plant nutrients in an area or place. Soil and plant nutrient status is meant to be related to the presence and availability of nutrients in the soil as well as nutrients in plant tissue such as leaves. So that fertilization and soil management can be carried out effectively and efficiently. Fertilization is carried out to meet nutrient availability in the soil and nutrient availability for plants and can improve soil physical properties, soil chemistry, and soil biology. Both of these can affect the ability of a plant to increase production yields. The objective of this research is to find out the characterization of physico-chemical soil properties on different slopes and altitude as a basic data for increasing the tea productivity.

METHODS

Pagilaran plantation is located on the slopes of the Kemulan Mountains, which is to the north of the Dieng Mountains, precisely in Keteleng Village, Blado, Batang, Central Java Province. Pagilaran plantation has a sloping and hilly topography at an altitude of 700-1600 meters above sea level. Type of soil in this area is dominated by Andisols which has high water binding properties, loose, crumbly structure, smooth and easy to cultivate so it is very suitable for tea plants. Since it is located in a highland area, Pagilaran has very high rainfall ranging from 3500-6000 mm/year, with 280-300 rainy days and 30-60 dry days.

The sampling method applied in this study was stratified sampling, based on two different slope classes and four different altitude levels. The observation plots were design as below:

At 0-8% slope
1. Blok Pulosari III (700-800 msl)
2. Blok Gamblok II (800-900 msl)
3. Blok Gamblok III (900-1000 msl)
4. Blok Karangnongko (1000-1100 msl)

At 15-25% slope
1. Blok Pulosari III (700-800 msl)
2. Blok Gamblok II (800-900 msl)
3. Blok Gamblok III (900-1000 msl)
4. Blok Karangnongko (1000-1100 msl)

A data set of soil was sampled by 4 times duplication in each plot, therefore, the total samples were 32 samples. Soil samples were taken by soil drill within the depth of 0-15cm from the surface. Soil properties analyzed were:

1) Soil texture using pipette method
2) pH H_2O, pH KCl, pH NaF using pH-meter
3) Cation Exchange Capacity pH 7 with NH_4Cl 1M extraction
4) Total Organic Carbon using muffle method
5) Total N using Kjeldahl method
6) Available P using Bray method
7) Available K using flame Photometer
8) Soil moisture using gravimetry method

Data analysis were conducted through Variance Analysis in order to know the significant difference between the slope and the altitude factors towards soil characteristics. Non-linear regression analysis (polynomial analysis) was performed using Microsoft Excel 2010 which aimed to assess Coefficient of determination (R^2). Coefficient of determination (R^2) was applied in order to reveal how far the influences of slope/altitude in explaining the variation of soil characteristics. The value of the coefficient of determination is between zero and one. If R^2 value is small means that the influences of the slope/altitude in explaining the variation of soil characteristics is very limited. Value that close to one means that slope/altitude provide almost all information needed to predict the variation of soil characteristics.

RESULTS & DISCUSSION

Soil properties under slope and altitude effect

The results showed that soil textures in both 0-8% and 15-25% slopes within each altitude had the same type, dominated by clay loam. It was evident how slopes and altitudes did not affect the distribution of particle size in the plantation area. It was probably caused by the practice of minimum tillage or no-tillage applied in the plantation area, as well as no crop rotation within such a long period were able to maintain the soil slope.

In general, soils in both 0-8% and 15-25% slopes had a nearly neutral actual pH, however, 0-8% slope had lower pH than 15-25% slope. In other sides, soils in 0-8% slope had slightly higher pH KCl and pH NaF than 15-25% slope. Furthermore, soils in 15-25% slope had lighter bulk volume, higher CEC, higher Total N, higher available P, lower available K, lower C-Organic, and lower soil moisture than those in 0-8% slope.

Soils in the study area was classified into Andisols. Bulk volume showed in 0-8% and 15-25% slopes were in accordance with the characteristics of the Andisols which had a weight volume of ≤ 0.85 (g / cm3). Also, the pH NaF is one of the indicators whether a soil is classified as Andisol or not. It is because pH NaF can be used to detect the existence of andic materials in soils. A soil can be classified as Andisols if it has a pH value of NaF > 9.4. Here, according to the results, it showed that all of the samples had the high pH NaF around 11. Therefore, it can be concluded that the soil in the study area is Andisols. This is inline with the study of Devnita (2010) which resulted in high pH NaF indicating as a strengthen of the character of developing land from volcanic eruptions.

Tabel 1. The average of soil properties in 0-8% slope

PARAMETER	NILAI			
	Pulosari III 700-800 mdpl	Gamblok II 800-900 mdpl	Gamblok III 900-1000 mdpl	Karangnongko 1000-1100 mdpl
Texture	Clay loam	Clay loam	Clay loam	Clay loam
Bulk volume (g/cm^3)	0,55	0,6	0,72	0,59
pH actual	5,9	6,0	6,0	6,2
pH potensial	4,6	4,9	4,7	4,5
pH NaF	11,94	11,95	11,81	11,95
CEC (cmol(+)/kg)	20,26	16,46	16,78	20,6
Total N (%)	0,49	0,45	0,35	0,75
Available P (ppm)	1,72	3,63	2,81	1,77
Available K (cmol/kg)	0,21	0,15	0,18	0,15
C-organik (%)	14,84	14,15	13,66	17,30
Soil moisture(%)	46,14	56,34	56,82	60,80

The results at 0-8% slope showed that there was no pattern of soil properties values among the increased in altitudes. All soil properties values fluctuated with increasing altitudes but pH H2O and soil moisture. Table showed that the increase in altitudes was followed by an increase in soil moisture content, which ranged from 46.14 to 60.80%. The increase of soil moisture were in accordance with the theory where the increasing an altitude will cause the air temperature to decrease (Wang et al., 2011) and increase the air humidity. Thus, the increase in air humidity will slow down the rate of evaporation so that moisture levels in the soil are stored longer. Furthermore, this condition also affect the acidity of the soils. The results showed that the increased in soil moisture caused the decreasing of acidity which then resulted in almost neutral pH which ranged from 5.9-6.2.

In specific, the average value of pH H2O, pH NaF, and available K at each altitude were not significantly different from one another. It means that the data variance of those properties were not affected by the increased altitudes. In other side, there were significant difference of the value of average of pH KCl, CEC, total N, available P, C-Organic, and soil moisture at each altitude which were different from one another. It means that the data variance of those properties were crucially affected by the increased altitudes.

Tabel 2. The average of soil properties in 15-25% slope

PARAMETER	**Average values**			
	Pulosari III 700-800 mdpl	**Gamblok II 800-900 mdpl**	**Gamblok III 900-1000 mdpl**	**Karangnongko 1000-1100 mdpl**
Texture	Clay loam	Clay loam	Clay loam	Clay loam
Bulkvolume (g/cm^3)	0,58	0,59	0,57	0,55
pH actual	6,2	6,2	5,6	5,8
pH potensial	4,6	4,7	4,5	4,4
pH NaF	11,80	11,68	11,66	11,95
CEC (cmol(+)/kg)	19,66	18,64	20,68	21,41
Total N (%)	0,47	0,46	0,48	0,75
Available P (ppm)	3,03	1,97	2,91	1,98
Available K (cmol/kg)	0,15	0,14	0,16	0,18
C-organik (%)	14,75	14,50	13,65	17,38
Soil moisture(%)	43,51	55,50	42,46	62,77

The results within 15-25% slope also showed that there was no pattern of soil properties values among the increased in altitudes. All the properties showed fluctuated values by the increased in altitudes.

In specific, the average value of pH KCl, pH NaF, Bulk Volume, Total N, and available K at each altitude were not significantly different from one another. It means that the data variance of those properties were not affected by the increased altitudes. In other side, there were significant difference of the value of average of pH H2O, CEC, available P, C-Organic, and soil moisture at each altitude which were different from one another. It means that the data variance of those properties were crucially affected by the increased altitudes.

Non-linear regression analysis of soil properties

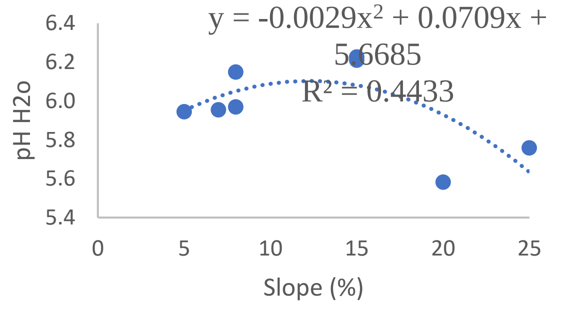
Based on the comparison of Table 1 and Table 2 showed that the difference in the slopes (P=0.005) showed the difference in pH NaF, pH KCl, Bulk Volume, CEC, Total N, available P, available K, C-Organic, and Soil Moisture in the soil profile. Mostly, Bulk Volume, pH KCL, pH NaF, available K, and Soil Moisture decreased as the slope increases. However, CEC, Total N, available P, and C-Organic increased as the slope increases.

Coefficient of determination (R^2) was applied in this study to reveal the influence of slope and altitude towards soil properties. Based on Fig.1, it was found that there was a great influence between slope and salt pH of NaF and between slope and available K. A significant influence was shown by coefficient of determination value (R^2) > 0.50. The most influenced properties due to slope was shown by available K which had coefficient of determination (R^2) 0.78.

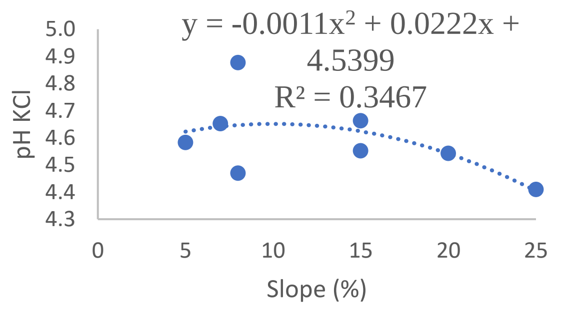
The pattern of influence of slopes on pH NaF and on available P showed the same trend wherein pH NaF and Potassium decreased quadratic following an increasing in slope until a certain degree of slope, but then increased again quadratic. The results showed that the steeper the slope, the salt pH (NaF) tends to decrease or get closer to neutral. Based on Fig.1, the NaF pH at a slope of 20% has the lowest value of 11.66. Furthermore, the results are in accordance with the study of Banjarnahor et.al. (2018), that the increasing of the slope will be followed by a decrease in soil pH. The increase and decrease in the NaF pH can be caused by amorphous materials containing an active hydroxide group (Al/Fe). The higher the amorphous material, the higher the NaF pH, and vice versa (Ratnadi et al., 2005).

Figure 1. Non-linear regression of soil properties and slopes

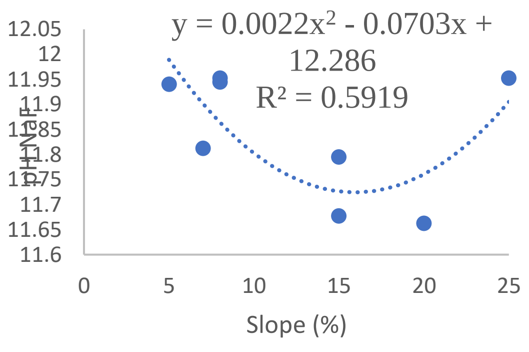
pH H2O



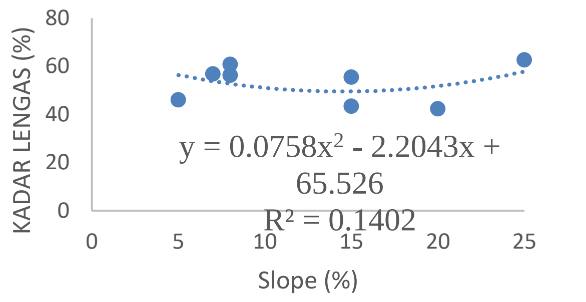
pH KCl

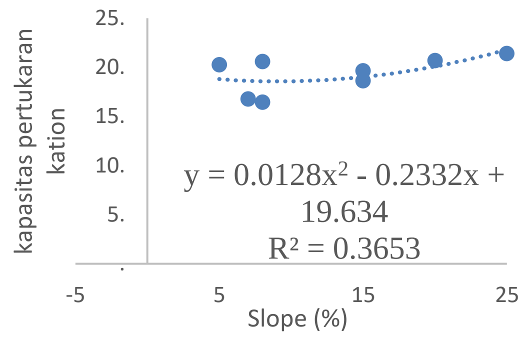


pH NaF

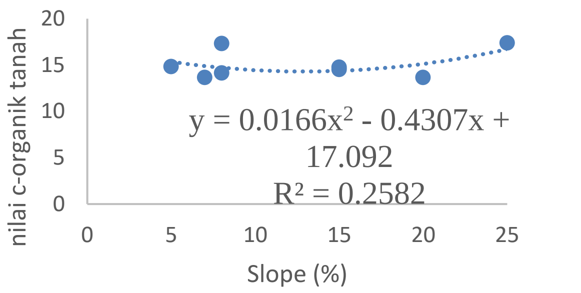


Soil moisture	CEC

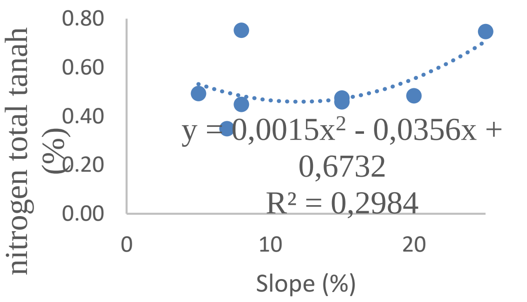




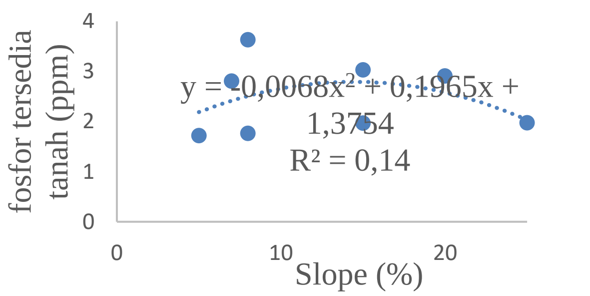
C-Organic



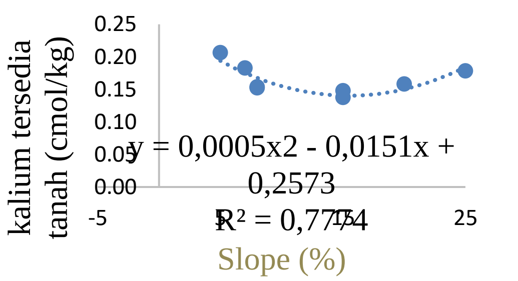
N-Total



Available-P



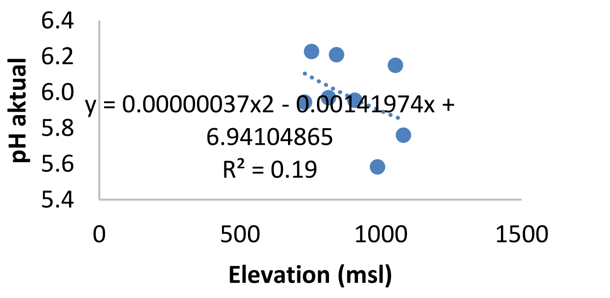
Available K



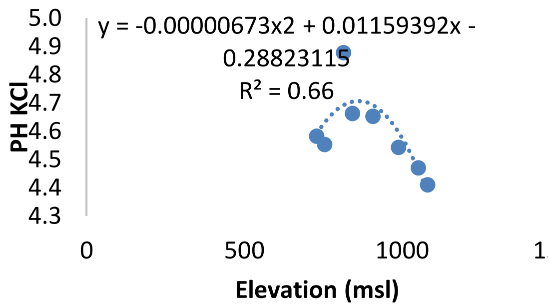
The availability of potassium in the soil at a slope of 5% was quite large and decreased at a slope of 15% and increased again to a slope of 25%. These results indicated that the availability of elemental potassium decreases with increasing slope up to a slope of 15%. The potassium element in the soil is usually in low availability, where this low potassium according to Novizan (2002) can occur due to several factors, including the uptake of potassium by plants, leaching of potassium by water, and erosion. In addition, potassium in the soil has a mobile nature (easy to move) so that it is easily lost through the washing process, especially due to large slopes. This is because at the colloidal soil surface, K is not held tightly. Consequently, the influence of slopes in holding K in the soil is significant, proved by high coefficient of determination which was 0.78.

Figure 2. Non-linear regression of soil properties and altitudes

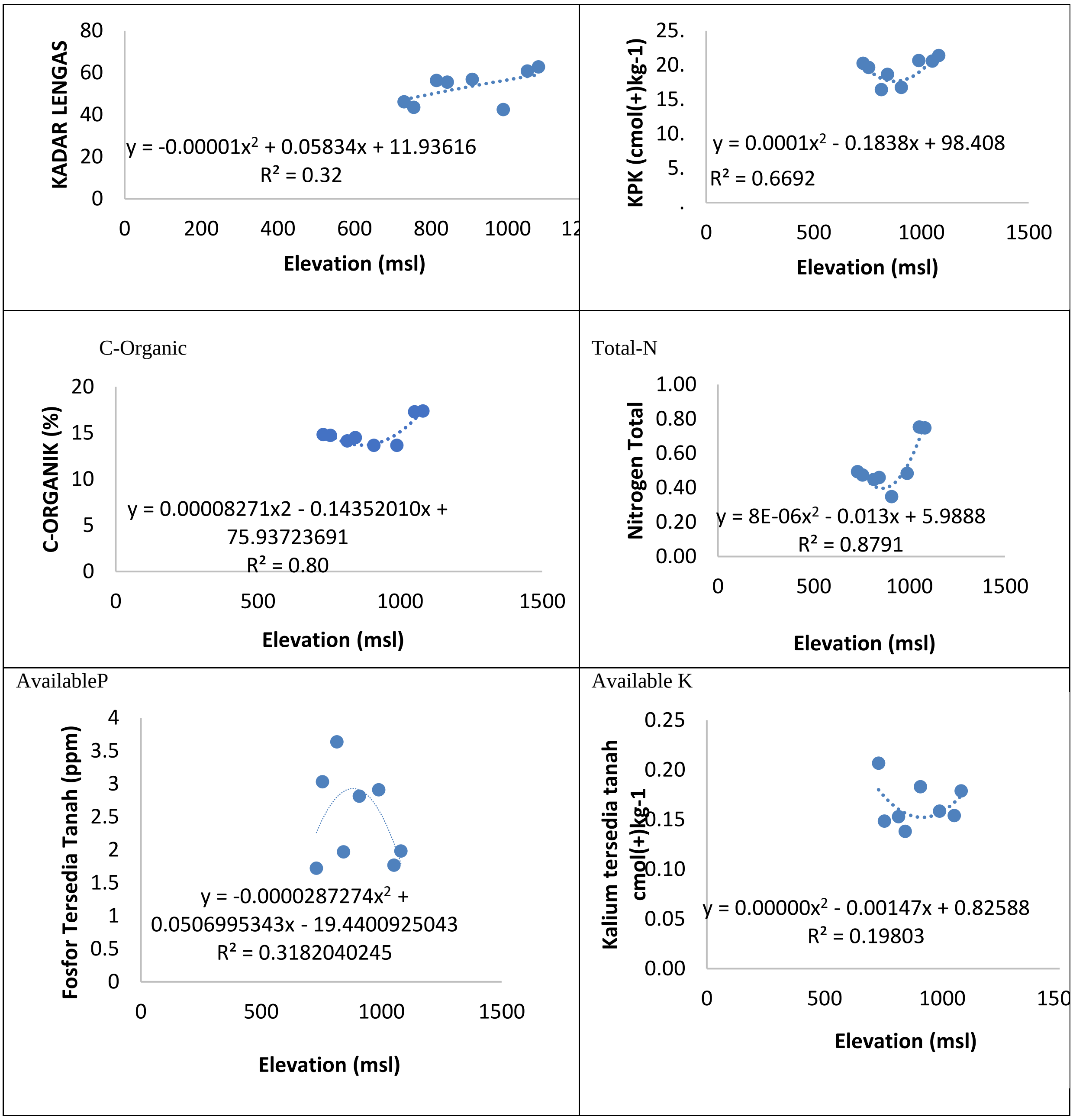
pH H2O



pH KCl



Soil moisture | CEC



Altitude can be a limiting factor on the growth of tea plants, because climatic conditions will be affected as altitude increases. Based on Fig.2, it was also found that there was a great influence between altitude and pH KCl, Total N, CEC, and C-Organic. A significant influence was shown by the determination value of (R^2) > 0.50. Among those particular influenced properties, the most influenced properties due to altitude were shown by Total N and C-Organic which had coefficient of determination (R^2) 0.88, and 0.80, respectively.

It was found that the influence of altitude on total soil Nitrogen and on C-organic was very significant. It was proved by very high coefficient of determination which were > 0.80. Total soil Nitrogen and soil C-organic increased quadratic following the increase in altitude. The pattern of influence of altitude on total soil Nitrogen and on C-organic showed the same trend wherein total soil Nitrogen and on C-organic decreases at an altitude of 1000 msl and increases again to an altitude 1500 msl. The influence of altitude on the increase in total soil Nitrogen was about 88% and the influence of altitude on the increase in soil C-organic was about 80%. C-Organic and total soil N were very affected by the decomposition of organic matter (Rusdiana & Lubis, 2012). This is because the high content of organic matter (C-organic) can increase the nitrification process so that the N content increases (Kidanemariam et al., 2013; Purwanto, Hartati, & Istiqomah, 2014; Sipahutar et al., 2014).

Litter decomposition is a very important process in nutrient dynamics in an ecosystem (Devianti and Tjahjaningrum). The rate of litter decomposition is influenced by environmental factors, pH; climate (temperature, humidity); chemical composition from litter and soil microorganisms. Inline with this, according to Ping et al. (2013) higher rainfall intensity and lower temperatures in mountainous areas will accelerate the decomposition of organic matter, and thus, will increase the amount of litter/humus which is the main source of organic matter. Threfore, an increasing in altitude will be followed significantly by an increase in total soil nitrogen and organic matter.

Similar pattern was also shown by the influence of altitude on CEC. The effect of altitude on CEC increases quadraticly with increasing in altitude. Altitude influences the increasing in CEC about 67%. This is because the higher the altitude with high organic matter, it will affect the CEC of the soil significantly. The high organic matter contributes a number of values to the soil CEC. However, the regression correlation analysis between CEC and C-organic showed a negative relationship, which means the higher organic matter will cause CEC are getting lower. This can be explained by the variable charge of Andisols, which causes the charge and CEC of the soil to be highly dependent on pH, i.e. CEC will be high if the soil pH is high. Meanwhile, high organic C actually makes the soil more acidic or the pH will small, so that it will actually make the soil CEC decrease (Devianti, 2010). Therefore, it can prove that CEC was significantly influenced by the increase in altitude. In additional, according to Utami and Suci (2003), organic matter contributes a very large negative charge to the soil through its very high surface area, so that the addition of organic matter can increase the cation exchange capacity. This is based on the theory presented by (Bowden et al., 1980) that the negative charge on the soil surface or CEC will increase if the pH or activity of hydroxyl ions (OH-) in the soil solution increases.

The effect of soil KCl pH increased quadratic following an increasing in altitude until a certain altitude, but then decreases again quadraticly. The altitude has an influence of 66% on the increase and decrease in soil pH. Temperature and environmental conditions in high areas will affect the rate of decomposition of organic matter. The addition of immature organic matter will also slow down the process of increasing soil pH because organic matter has not decomposed properly and still releases organic acids (Suntoro, 2003).

CONCLUSIONS

The soil properties under slope and altitude effect showed that soils in both 0-8% and 15-25% slopes had a nearly neutral actual pH. Furthermore, soils in 15-25% slope had lighter bulk volume, higher CEC, higher Total N, higher available P, lower available K, lower C-Organic, and lower soil moisture than those in 0-8% slope. The influence of altitudes towards soil properties were much higher than the influence of slopes towards soil properties. Among the soil properties, only the pH KCl showed a strong relationship with the slopes. However, a strong relationship between soil properties and altitude are showed by C-Organic, Total N, CEC, and pH KCl.

REFERENCES

Banjarnahor, N., K.S. Hindarto., Fahrurozi. (2018). Hubungan Kelerengan Dengan Kadar Air Tanah, pH Tanah, dan Penampilan Jeruk Gerga di Kabupaten Lebong, *Jurnal Ilmu-Ilmu Pertanian Indonesia,* 20 (1), 13-18

Devnita, R. (2010). Karakteristik Sifat Kimia dan Fisika Tanah Beberapa Andisol di Jawa Barat. *Laporan Penelitian,* Fakultas Pertanian, Universitas Padjadjaran

Effendi, D.S., Syakir, M.,Yusron, M., Wiratno. (2010). *Budidaya dan Pasca Panen Teh*. Pusat Penelitian dan Pengembangan Perkebunan, Kementrian Pertanian

Hardjowigeno, S. (2003). *Ilmu Tanah*. Edisi Baru, Penerbit Akademika Pressindo, Jakarta.

Novizan. (2003). *Petunjuk Pemupukan yang Efektif.* PT. Agromedia Pustak,. Jakarta

PPTK Gambung. (2005). *Rekomendasi Pemupukan Tanaman Teh Tahun 2005*. PPTK Gambung, Bandung, 54 hal

Pusat Data dan Sistem Informasi Pertanian. (2015). *Outlook Teh.* Sekretaris Jenderal, Kementerian Pertanian

Saefas, S.A., S. Rosniwaty., Y. Maxiselly. (2017). Pengaruh konsentrasi zat pengatur tumbuh alami dan sintetik terhadap pertumbuhan tanaman teh (Camellia sinensis (L.) O. Kuntze) klon GMB 7 setelah centering. *Jurnal Kultivasi*. (16) (2) 368-372.

Setyamidjaja, D. (2000). *Teh : Budi Daya dan Pengolahan Pascapanen.* Kanisius, Yogyakarta.

Shoji, S., T. Ito., M. Saigusa., I. Yamada. (1984). Properties of non-allophanic Andosols in Japan. *Soil Sci.,* 139 (7), 112-134.

Silahooy, C.H. (2008). Efek Pupuk KCl dan SP-36 terhadap kalium tersedia , serapan kalium dan hasil kacang tanah (Arachis hypogea L.) pada tanah brunnizem. *Buletin Agronomi,* (36) (2), 126-132

Simamora, J., M. Purba, L. Alida. (2015). Penentuan Jenis Mineral Liat Alofan Tanah Andisol di Desa Dolat Rakyat Kecamatan Tiga Panah Kabupaten Karo. *Jurnal Online Agroteknologi* vol. 3, no. 3 : 1005 – 1011.

Soil Survey Staff. (1975). *Soil Taxonomy A Basic System of Soil Classification for Making and Interpreting Soil Surveys*. Soil Conservation Service USDA, Washington DC.

Suntoro, W.A. (2003). *Peranan Bahan Organik Terhadap Kesuburan Tanah dan Upaya Pengelolaannya*. Pidato Pengukuhan Guru Besar, Universitas Negeri Semarang. Semarang.

Tan, K.H. (1991). *Dasar-dasar Kimia Tanah.* Gadjah Mada University Press, Yogyakarta.

Utomo, W.H. (1989). *Erosi dan Konservasi Tanah*. IKIP Malang, Malang

Wulansari, Restu. (2015). Kajian Status Hara Tanah Dan Tanaman Di Perkebunan Teh Jawa Barat Dan Sumatera Utara. CR Journal 1: 16-30.

Wang, K., Sun, J., Cheng, G. et al. (2011). Effect of altitude and latitude on surface air temperature across the Qinghai-Tibet Plateau, J. Mt. Sci. 8, 808–816 , https://doi.org/10.1007/s11629-011-1090-2