Soil chemical characteristics at three slope positions in the smallholder’s *Piper nigrum* L. in Lhokseumawe City, Aceh Province

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Abstract. The spatial variation of soil properties is significantly influenced by several factors. Slope position belongs to a component of topography as one soil-forming factor which would be influenced by soil development. The purpose of this study is to understand the pedogenesis of soil chemical characteristics on the diversity of slope positions in the smallholder’s *Piper nigrum* L. in Lhokseumawe City Aceh Province, start from October to December 2017. The research was conducted using the descriptive survey method and fifteen soil samples from three slope positions, i.e. upper slope position [33%], middle slope position [22%], and lower slope position [6.6%] were collected. The soil samples were analyzed using appropriate methods such as soil pH using pH meter, soil organic carbon using Walkley and Black, total nitrogen using Kjehdahl, available phosphorus using Bray II, and potassium exchangeable using Morgan. This research has studied the correlation between soil chemical properties and the differentiation of soil chemical characteristics at each slope position by the DMRT test method. The result showed that the slope position affected soil chemical properties. The slope position had affected water movement from the upper to the lower slope position and this process caused variation of soil chemical characteristic formation. The value of soil pH, soil organic carbon, total nitrogen, available phosphorus, and potassium exchangeable was higher in the lower slope position than those in the middle and upper slope positions.

1. Introduction

Topography as one of the soil-forming factors is divided into three components, namely the shape of the earth's surface, the height of the place from the sea level, and the position of the slope [slope]. The slope position component consists of several sub-components such as the summit, shoulder, straight [backslope], foot and toe slopes [1] [2].

The position of the slope as a sub-component topography can affect the characteristics of a soil that was formed. It was caused by the differentiation of the slope position in geomorphic processes [erosion, deposition, and mass movement] and the genesis of soil [1]. These influences include the amount of rainwater that can be absorbed or can be retained by the soil. The position of the slope also affects the depth of groundwater, affecting the amount of erosion because it can direct the movement of water and the materials dissolved in it [3]. Therefore, even though the other soil-forming factors are the same, different soil characteristics can be formed if the relief conditions are different.

The position of the upper and middle slopes often getting soil erosion due to rain erosion. This causes the solum at the top of the slope to be thinner and the change in the structure of the soil, in addition to the condition of groundwater at various slope positions, it will affect the chemical reactions...
in the soil. While on the lower slope usually the addition of new material [deposition] originating from the upper and middle slope, so that the characteristics of the soil will be different from the original soil. Generally, in the lower slope position, the soil solum will be thicker, organic matter will increase, nutrient content will increase, base saturation will also increase. The deposition of new material due to deposition from the top of the slope was able to increase calcium levels by more than 1% and increase base saturation to 80% [4]. Each slope on the Tectona grandis stand soil in Savana, South Guinea, Nigeria has a different pH value, ie the pH value in the upper slope land was 6.7, in the middle slope was 6.8 and the lower slope was 7.4 [5]. The highest Organic-C surface horizon level was found in the upper slope of 1.53%, followed by the middle slope of 0.87% and the lower slope of 0.85%. The Total-N content of the soil shows a low percentage on each slope but the lowest percentage is on the middle slope with a value of 0.01%. Phosphorus availability of the soil is higher on the lower slope by 15 ppm, while on the upper and middle slopes is only about 8 ppm.

Plants or vegetation are part of organisms that play a major role in the soil formation process. Plants and soil have an interrelated relationship, where plants can determine the characteristics of the soil formed, on the other hand, the nature of the soil also affects plant growth. The effect of plants on the characteristics of the soil formed can be through the top of the plant and the roots. Plant roots will emit organic compounds that affect soil characteristics, while the presence of plant canopies will affect sunlight, rainwater flow and the litter of plants that will fall to the ground where this condition greatly affects the increase in levels of Total-N, Organic-C, and soil pH [2].

Land in Indonesia has a variety of slope forms and is also widely used for various cultivation purposes, including pepper cultivation. Pepper [Piper nigrum L.] plants have their characteristics, both in terms of stems, leaves, and roots. Therefore, the cultivation of pepper plants on the diversity of slopes is expected to affect the properties of the soil formed, especially the chemical properties of the soil.

2. Materials and Methods
The research was carried out at the Lhokseumawe Municipal People's Pepper Plantation. Soil analysis was carried out at the Central Plant Seed and Plant Protection Laboratory [BBPPTP] and the Palm Oil Research Center [PPKS] Medan. This research was conducted from October to December 2017 using a survey method and data analysis which includes; [1] research preparation, [2] research on the field, [3] soil analysis in the laboratory, and [4] data analysis.

2.1. Research preparation
The stages of research preparation include literature study, secondary data collection [climate data, regional administration maps, soil type maps, and slope maps], conducting preliminary surveys at research sites, arranging research permits, and preparing equipment to support research activities. During the preliminary survey stage, the determination of observation location and soil sampling based on the slope was also conducted.

2.2. Soil samples collecting and chemical properties analysis
In this study, soil samples were taken at the research location based on the slope position, which is the lower slope, middle slope, and upper slope. At each slope five soil samples were taken, each sample consisted of sub-sample [composite] soils. Soil sampling was done using a soil drill at a depth of 20 cm. The soil was packed in 1 kg plastic bags and then labeled.

The 15 total samples were analyzed in the laboratory. Observational variables were pH [H2O], Organic-C, Total-N, P-available, and Exchangeable K of the soil. Soil pH was analyzed by the 1: 5 suspension method with a glass electrode meter equipped with platinum. Then the soil Organic-C content was tested by the Walkley and Black method. Total-N levels in the soil were analyzed using the Kjeldahl method. Then soil P-available levels were measured using the Bray II method. Whereas the exchangeable K of the soil was analyzed by using the Morgan method.
### 2.3. Data analysis

After analyzing soil samples in the laboratory, the data obtained were statistically analyzed using DMRT to determine the correlation between soil chemical properties.

### 3. Results

The results of the analysis of the soil chemical properties that were analyzed in the laboratory can be seen in the following table.

| Table 1. Chemical properties of the soil samples based on the slope type |
|---------------------------------------------------------------|
| Upper slope samples | pH [H₂O] | Organic-C [%] | Total-N [%] | P-available [ppm] | Exchangeable K [cmol/kg] |
|---------------------|----------|----------------|-------------|-------------------|--------------------------|
| 1                   | 6.69     | 4.65           | 0.24        | 13.99             | 0.53                     |
| 2                   | 7.12     | 3.92           | 0.21        | 20.02             | 0.60                     |
| 3                   | 6.76     | 4.14           | 0.16        | 7.02              | 0.66                     |
| 4                   | 6.20     | 4.05           | 0.17        | 5.31              | 0.38                     |
| 5                   | 6.62     | 4.31           | 0.22        | 9.22              | 0.35                     |
| Mean                | 6.68     | 4.22           | 0.20        | 11.11             | 0.50                     |
| Middle slope samples | pH [H₂O] | Organic-C [%] | Total-N [%] | P-available [ppm] | Exchangeable K [cmol/kg] |
|---------------------|----------|----------------|-------------|-------------------|--------------------------|
| 6                   | 6.62     | 4.32           | 0.12        | 5.29              | 0.46                     |
| 7                   | 5.98     | 4.47           | 0.17        | 3.86              | 0.57                     |
| 8                   | 6.65     | 4.39           | 0.19        | 3.59              | 0.52                     |
| 9                   | 6.50     | 4.02           | 0.21        | 3.73              | 0.50                     |
| 10                  | 6.71     | 3.61           | 0.17        | 29.61             | 0.44                     |
| Mean                | 6.50     | 4.16           | 0.17        | 9.22              | 0.50                     |
| Lower slope samples | pH [H₂O] | Organic-C [%] | Total-N [%] | P-available [ppm] | Exchangeable K [cmol/kg] |
|---------------------|----------|----------------|-------------|-------------------|--------------------------|
| 11                  | 6.55     | 4.17           | 0.25        | 34.28             | 1.20                     |
| 12                  | 6.79     | 4.59           | 0.29        | 80.94             | 0.98                     |
| 13                  | 6.89     | 4.82           | 0.28        | 48.99             | 1.18                     |
| 14                  | 6.61     | 4.29           | 0.25        | 88.63             | 1.26                     |
| 15                  | 6.94     | 3.67           | 0.20        | 49.14             | 1.35                     |
| Mean                | 6.76     | 4.31           | 0.25        | 60.40             | 1.20                     |

#### 3.1. Soil pH Value

The highest soil pH value was 6.76 found on the lower slope, while the lowest soil pH [6.50] was on the middle slope [Table 1]. The high pH [H₂O] of the soil in the lower slope was estimated due to the addition of alkaline elements originating from the upper and middle slope soils carried by the surface flow [run-off], in addition to that higher organic matter in the lower slope also contributes to the increase in soil pH on the lower slope. The decomposition of organic matter can release basic elements such as K, Ca and Mg and organic acids into the soil. Organic acids can chelate elements Al, Fe and Mn [6]. The low pH [H₂O] of the soil on the middle slope was very likely to occur because the soil has lost alkaline elements. In the condition of the sloping slope facilitates the flow of water to erode the soil, this is because the gravitational force will attract distributed soil particles to the lower slope. Rainwater that falls to the surface of the ground would damage the soil grains with kinetic energy, and carry soil suspension through run-off and percolation. As it flows...
through the pores of the ground, this water dissolves whatever elements were in the soil. Furthermore, H + caused acidity of the soil could change the basic elements such as K which was in the surface of the sorption complex [exchangeable K] or K which was in the position between layers so that K was released into the soil solution, the exchange process was very likely to occur because it was in accordance with the lyotropic series, colloidal soil sorption to H + > K +, and then K+ could also be diagnosed by Fe3+ ions because it was based on a lyotropic series, colloidal sorption of Fe3+ > K+. So that the basic elements were eroded, then deposited in a lower slope position and all that remains was the acidic element [30].

Based on the results of the statistical analysis, the soil pH has a significantly positive correlation with P-available. Positive correlation showed that if an increase in pH [H2O] of the soil to a certain extent will increase the soil P-available significantly. Soil acidity is one factor that also determines the availability of soil nutrients. The higher P-available soil element is found in neutral to slightly alkaline soils, where at neutral pH [H2O] the Al-P, Fe-P, and Mn-P bonds have been decomposed so that the P ion content in the soil increases [7] [8] [9].

3.2. Soil organic carbon [Organic-C]
The highest soil Organic-C content was 4.31% on the lower slope, while the lowest was 4.16% on the middle slope [Table 1]. The high content of Organic-C on the lower slope, due to the activity of soil erosion on the upper slope by the kinetic energy of the rain, thus creating a surface run-off that causes soil organic matter to be deposited on the lower slope soil. Besides, the low activity of soil microorganisms in utilizing carbon as an energy source causes carbon to remain high in the soil. High or low carbon content in the soil, in addition, to be influenced by microorganism activity is also influenced by evapotranspiration or carried along with harvest yields [10] [11] [12].

The low content of Organic-C on the middle slope was caused by the nature of the wet tropical area which has a very fast weathering rate of organic matter and the presence of leaching activities that cause organic matter on the middle and upper slopes decreased [13] [26]. The difference in land cover density also contributes to the difference in Organic-C, and the influence of slope position makes the distribution of abnormal upper and middle slopes so that most of Organic-C was more distributed on the lower slope. That was because the water content was influenced by topography, depth of soil formation, erosion and deposition. The position of the lower slope receives water from the upper slope through run-off and through-flow. The higher the water content, the more dense vegetation so that the contribution of organic material will be higher, where the organic material with ideal water content would form an ideal environment also for the growth of fungi and bacteria. That would accelerate lignin degradation and accelerated the humification process so that the Organic-C content was higher on the lower slope [27].

3.3. Soil nitrogen total [Total-N]
The highest soil Total-N content was [0.25%] in the lower slope position, while the lowest [0.17%] was in the middle slope [Table 1]. The highest Total-N content in the lower slope was due to the high organic matter as the main source of N, and the higher soil moisture compared to the upper slope. Higher humidity on the lower slope could occur due to the position of the slope that received water flow from the upper slope and the intensity of sunlight that was obstructed by the higher slope position. This condition causes lower evaporation or loss of water from the soil. Lower slope position generally has a higher clay content, where the ability to retain water more than the silt or sand fraction. Moist soils will reduce the process of N volatility in the soil. Soil pH values on the lower slope approaching neutral support the high Total-N content in the position of this slope because of the activity of microorganisms especially bacteria in the nitrification process increases [2] [14].

Low Total-N soil content on the upper and middle slope was caused by organic matter content and N elements which were partially carried by surface run-off to the lower slope position. In the middle slope position, weeds grew denser and it was believed that the N elements were absorbed by weeds so
that the Total-N content of the soil decreased. Pepper and weed plants that were not too dense population on the upper slope increased the activity of leaching by rainfall so that it can damage the soil aggregate on the upper slope. The rainfall would destroy the soil aggregate so the silt and clay fraction would be moved from the soil, so the soil fraction becomes coarser. The coarser soil texture generally contains less organic matter and nitrogen elements. Nitrogen element is a mobile nutrient. It was easily lost by leached to groundwater and eroded. In conditions where the soil is more open and less humid, there will be a denitrification process from NO$_3^-$ to N$_2$, volatility NH$_4^+$ to NH$_3$, which causes low Total-N content [10] [15] [16] [17] [18] [19].

Statistical analysis showed that Total-N soil was positively and significantly correlated with P-available soil. This correlation shows that the high Total-N soil at certain limits will increase the soil P-available content. An increase in Total-N and P-available soil content is very possible given by the neutral pH value of the soil. Another study also reported that soil Total-N has a real positive correlation to soil P-available [20].

3.4. Soil phosphor available [P-available]

The highest soil P-available content was 0.40 ppm found on the lower slope, while the lowest P-available soil content was 9.22 ppm found on the middle slope [Table 1]. The high content of soil P-available on the lower slope was related to the pH and content of organic matter. Higher soil pH [near neutral] indicated the low Al and Fe elements that can fix the P element. High soil organic matter content and fertilizing activity on the lower slope were the reasons for the high P-available in the soil. Soil organic matter can be also used as energy for degradable microorganisms [5] [18] [21]. Fertilization of pepper plants in the soil on the upper slope, causing some nutrients will be carried by surface run-off to the lower slope.

Based on the results of statistical tests, P-available soil is positively and significantly correlated to the Exchangeable K value of the soil. This correlation can be interpreted that the increasing content of P-available in the soil, the Exchangeable K content of the soil will also increase. Potassium which is an alkaline element, its presence will increase if the pH [H$_2$O] of the soil increases. This followed the results of the soil analysis that was carried out that the pH of the soil on each slope does not indicate the presence of chelating elements. The pH value [H$_2$O] of the soil which is near neutral can increase the presence of P-available and Exchangeable K in the soil, this is because the absorption of orthophosphate anions can increase the negative charge on the soil so that it can absorb base cations such as Exchangeable K of the soil [22] [23].

3.5. Soil exchangeable potassium [Exchangeable K]

The highest soil Exchangeable K content was 1.20 cmol/kg found on the lower slope, while the lowest soil Exchangeable K content was [0.50 cmol/kg] was found on the upper and middle slopes [Table 1]. The high Exchangeable K content of the soil on the lower slope was caused by the nature of the K element which is very soluble and leached so that the run-off activity easily distributes Exchangeable K to the lower slope. On the lower slopes, organic matters and plant residues content was higher, which can then be the main source of K for the soil apart from fertilization. This phenomenon was proven by the Organic-C content of the lower slope soil was higher than the middle and upper slope soil. Also, differences in the development of vegetation were the cause of high Exchangeable K on the lower slope land. Pepper plants as the vegetation on the lower slope were more developed because it was influenced by the microclimate created by the shape of the slope. The intended microclimate is in the form of humidity and temperature which affect the microorganism activity. This is important because high humidity will form lower slope pepper plants for better and more stable soil chemical properties [2] [11].

The lowest Exchangeable K content of the soil was found on the upper and middle slopes due to the nature of the element which is very easily washed. On dry soils [non-paddy soils] the number of base cations tends to be lower, which is caused by leaching which carries base cations either through run-off or infiltrated into the soil [13] [24].
3.6. Difference Test of Soil Chemical Properties on Slope Diversity

The results of the analysis of soil chemical properties [Table 2] shown that the parameters pH [H₂O] and Organic-C soil were not significantly different between the top slope, middle slope, and lower slope. The average pH [H₂O] of successive soils from the lower, middle, and upper slopes was 6.76, 6.50, and 6.68. The average Organic-C content of soils from the lower, middle, and upper slopes was 4.31%, 4.16%, 4.22%. However, Total-N, P-available, and Exchangeable K of soil were significantly different in each slope. The soil Total-N content increased from 0.17% to 0.25%, soil P-available increased from 9.22 to 60.40 ppm, and Exchangeable K of the soil increased from 0.50 to 1.20 cmol/kg. Statistically, the lower slope soil has significant Total-N, P-available, and Exchangeable K content.

**Table 2.** The average value of soil chemical properties on the diversity of slope positions.

| Slope position | pH [H₂O] | Organic-C [%] | Total-N [%] | P-available [ppm] | Exchangeable K [cmol/kg] |
|----------------|----------|---------------|-------------|-------------------|--------------------------|
| Lower [6.6%]   | 6.76 a   | 4.31 a        | 0.25 a      | 60.40 a           | 1.20 a                   |
| Middle [22%]   | 6.50 a   | 4.16 a        | 0.17 b      | 9.22 b            | 0.50 b                   |
| Upper [33%]    | 6.68 a   | 4.22 a        | 0.20 b      | 11.11 b           | 0.50 b                   |

Note: The numbers followed by the same letter are not significantly different based on the DMRT test at the 0.05 level.

The lower slope has higher pH, Organic-C, Total-N, P-available, and Exchangeable K values than the soil chemical parameters on the other slopes, while the lowest value, namely the lower slope includes pH, Organic-C, N parameters -Total, P-available, and K-exchangeable land. This is due to the influence of a more favorable microclimate for nutrient enrichment on the lower slope, run-off factors that also distribute nutrients to the lower slope, as well as more soil water content stored by the lower slope causing more dense vegetation so that the contribution of organic material many. The availability of abundant organic matter with ideal water content causes an ideal pH so that microorganisms abound and easily degrade organic material which would release N, P, and K on the lower slopes [27] [28]. Nutrient content varies significantly in different topographic positions due to washing, transportation and accumulation [pH, Organic-C and nutrient contents significantly varied in different topographic positions due to leaching, transporting and accumulation [29].

The high nutrient content on the lower slope is the result of changes in soil chemical properties caused by differences in slope and erosion factors and vegetation density to support nutrient differences. The increase in Total-N, P-available, and Exchangeable K of the land is in line with the decreasing slope position [14] [25].

The difference in slope elevation at the research site caused differences in the reception of solar radiation. This affects the decrease in moisture in the soil on the upper slope. Moisture is a very influential factor in the pedogenesis of soil which results in differences in the level of decomposition of organic matter and soil nutrient availability. In addition to solar radiation, the intensity of rain falling on the upper and middle slopes will cause nutrient leaching to be higher than on the lower slope soil. Also, the slope factor has an impact on the transportation of solute substances so that sedimentation occurs on the soil on the lower slope [11].

Statistically [Table 2] shows that the Total-N, P-available, and Exchangeable K contents of the soil on the upper slope were lower, and the lowest on the central slope. This was caused by the slope which influences the amount of rainwater flowing to the lower slope so that some rainwater will be infiltrated, and some will flow laterally to the lower slope as surface flow. The middle slope will get additional water from the upper slope, this causes more intensive leaching of the soil on the central slope. The total Total-N, P-available, and Exchangeable K content of the soil were low on land on the middle slope [2].
4. Conclusion

Based on the results of this study it could be concluded that the highest value of soil pH, soil Organic-C, soil Total-N, soil P-available, and soil Exchangeable K were on the lower slopes with the values were 6.76, 6.50%, 0.25%, 60.40 ppm, and cmol/kg, respectively. Then increasing the pH, Total-N and Exchangeable K of the soil would also increase the value of P-available in the soil. Soil pH and Organic-C did not differ in all slope positions, whereas Total-N, P-available, and Exchangeable K soils had different values between the lower slope and the middle and upper slopes.

References
[1] SW Buol, FD Hole, and RJ McCracken 1980 Soil Genesis and Classification 2nd Edition (Iowa State University Press America IA-USA) 404 page.
[2] DA Rachim 2007 Dasar-Dasar Genesis Tanah (Fakultas Pertanian Institut Pertanian Bogor-Bogor)
[3] S Hardjowigeno 2015 Ilmu Tanah (Akademia Presindo –Jakarta)
[4] Y Chen, M Song, and M Dong 2002 Soil Properties along A Hill Slope Modified by Wind Erosion in The Ordos Plateau Semi-arid China Geoderma 106 (3-4) 331–340
[5] BA Lawal, PA Tsado, PC Eze, KK Idefoh, AA Zaki, and S Kolawole 2014 Effect of Slope Positions on some Properties of Soils under a Tectona grandis Plantation in Minna, Southern Guinea Savanna of Nigeria. International Journal of Research in Agriculture and Forestry, 1 (2) 37-43
[6] KD Sasmita and E J Bambang 2011 Hubungan Kandungan Hara Tanah dan Produksi Gambir di Sumatera Barat. Bulletin Ristri, 2 (3) 353-360
[7] KU Tan. 2008 Soils in The Humid Tropic and Monsoon Region of Indonesia (CRC Press Taylor and Francis GroupBoca Raton-New York)
[8] SL Tisdale, WL Nelson, JA Beaton, and JL Halvin. 1993. Soil Fertility and Fertilizers Fifth Edition (Macmillan Publishing Co. Inc - New York)
[9] M Utomo, T Sabrina, S Sudarsono, J Lumbanraja, B Rusman, and W Wawan 2016 Ilmu Tanah, Dasar-Dasar dan Pengelolaan (Prenadamedia Group-Jakarta)
[10] I Nariratih, MMB Damanik, and G Sitanggang 2013 Ketersediaan Nitrogen pada Tiga Jenis Tanah Akibat Pemberian Tiga Bahan Organik dan Serapannya pada Tanaman Jagung Jurnal Online Agroekoteknologi 1(3) 479-488
[11] H Rezaei, AA Jafarzadeh, A Alijanpour, F Shahbazi, and KV Kamran 2015 Effect of Slope Position on Soil Properties and Types Along an Elevation Gradient of Arasbaran Forest, Iran. International Journal Advanced Science Engineering Information Technology 5 (6) 449-456
[12] W Wilson, S Supriadi, and G Hardy 2015 Evaluasi Sifat Kimia Tanah pada Lahan Kopi di Kabupaten Mandailing Natal Jurnal Online Agroekoteknologi, 3 (2) 642-648
[13] D Nursyamsi, A Budiarto, and L Anggria 2002. Pengolahan Kahat Hara pada Tanah Inceptisols untuk Meningkatkan Pertumbuhan Tanaman Jagung Jurnal Tanah dan Iklim 20 56-68
[14] S Beshir, M Lemeneh, and E Kissi 2015 Soil Fertility Status and Productivity Tend S Along a Toposequence: A case of Gilgel Gibe Catchment in Nada Assendabo Watershed, Southwest Ethiopia International Journal of Environmental Protection and Policy 3 (5) 137-144
[15] S Winarso 2005 Kesuburan Tanah; Dasar Kesehatan dan Kualitas Tanah (Gava Media-Yogyakarta)
[16] N Barus, MMB Damanik, and S Supriadi 2013 Ketersediaan Nitrogen Akiabat Pemberian Berbagai Jenis Kompos Pada Tiga Jenis Tanah dan Efeknya Terhadap Pertumbuhan Tanaman Jagung (Zea mays L.) Jurnal Online Agroekoteknologi 1 (3) 570-582
[17] AH Sipahutar, P Marbun, and F Fauzi 2014 Kajian C-Organik, N Dan P Humitropepts pada Ketinggian Tempat yang Berbeda di Kecamatan Lintong Nihuta Jurnal Online Agroekoteknologi 2 (4) 1332-1338
[18] S Rahmah, Y Yusran, and H Umar 2014 Sifat Kimia Tanah pada Berbagai Tipe Penggunaan Lahan di Desa Bobo Kecamatan Palolo Kabupaten Sigi Warta Rimba 2 (1) 88-95
[19] GT Yeshaneh 2015 Effect of Slope Position on Soil Physico-Chemical Properties with Different Management Practices in Small Holder Cultivated Farms of Abuhoy Gara Catchment, Gidan District, North Wollo American Journal of Environmental Protection 3 (5) 174-179
[20] M Buyinza and M Nabalegwa 2011 Effect of Slope Position and Land-Use Changes to Bio-Physical Soil Properties in Nakasongola Pastoral Rangeland Areas, Central Uganda, Soil Erosion Issues in Agriculture, Dr. Danilo Godone [Ed.]. InTech, Doi:10.5772/24979
[21] N Hidayati, S Maimunah, and N Hanafi 2017 Kajian Kimia Tanah di Hutan Pendidikan [KHDTK] Universitas Muhammadiyah Palang Karaya Ziraa’ah 42 (3) 169-173
[22] C H Silahoo 2008 Efek Pupuk KCl dan SP-36 Terhadap Kalium Tersedia, Serapan Kalium dan Hasil Kacang Tanah (Arachis hypogaea L.) pada Tanah Brunizem Jurnal Agro 36 (2) 126–132
[23] A Aprilio, R Suntari, and S Syekhfani 2015 Uji Efektifitas Aplikasi Pupuk Teh Kompos Kulit Pisang untuk Meningkatkan Ketersediaan dan Serapan Kalium Serta Produksi Umbi Bawang Merah pada Tanah Alfisol Jurnal Tanah dan Sumber Daya Lahan 2 (2) 211-217
[24] A Rahayu, SR Utami, and ML Rayes 2014 Karakteristik dan Klasifikasi Tanah pada Lahan Kering dan Lahan yang Disawahkan di Kecamatan Perak Kabupaten Jombang Jurnal Tanah dan Sumber daya Lahan 1 (2) 79-87
[25] B Bezabih, A Aticho, T Mossisa, and B Dume 2016 The Effect of Land Management Practices on Soil Physical and Chemical Properties in the Gojeb Sub-river Basin of Dedo District, Southwest Ethiopia Journal of Soil Science and Environmental Management, 7 (10) 154-165
[26] S Yasin and Y Yulnafatmawita 2018 Effects of Slope Position on Soil Physico-chemical Characteristics Under Oil Palm Plantation in Wet Tropical Area, West Sumatra Indonesia AGRIVITA JAS, 40 (2) 328-337
[27] TRhanor 2013 Topographic position and land cover effects on soil organic carbon distribution of loess-veneered hillslopes in the central United States (Doctoral dissertation, Southern Illinois University Carbondale)
[28] PI Ezeaku and FU Eze 2014 Effect of land use in relation to slope position on soil properties in a semi-humid Nsukka area, Southeastern Nigeria Journal of Agricultural Research 52 (3) 369-381
[29] S Karaca, F Gülser, and R Selçuk 2018 Relationships Between Soil Properties, Topography and Land Use in the Van Lake Basin, Turkey Eurasian Journal of Soil Science 7 (2) 115-120
[30] D Nursyamsi 2011 Mekanisme Pelepasan K terfiksasi menjadi tersedia bagi Pertumbuhan Tanaman pada Tanah-Tanah yang Didiminasi Smekstik Jurnal Sumber Daya Lahan 5 (2) 61-74