

Chemical Characteristics of Soils Based on Toposequence under Wet Tropical Area in Bukit Sarasah Padang

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Abstract— Topography is a factor affecting soil characteristics. Chemical characteristic of a soil is a factor determining the productivity of the land. A research was conducted in Bukit Sarasah Padang, an area receiving > 5000 mm rainfall annually. The purpose of this research was to determine the chemical characteristics of soils at sequence topography in hill-slope of Bukit Sarasah. Soils were sampled at 3 different altitudes in the research area from 315 m – 515 m asl with 100 m interval. At each location, soil samples were taken from two depths (0-20 cm and 30-50 cm) for soil chemical characteristics (pH, CEC, organic-C, N-total, C/N, Ca-, Mg-, K-, Na-, Al-, and H-exchangeable). Based on the data resulted, it was found that there was a tendency of decreasing soil organic matter (SOC) content by increasing location from 315 to 515 m asl as well as from the top 0-20 cm to 30-50 cm soil depth. The same tendency was also found for the CEC, pH, N-total, and C/N ratio of the soil. On the other hand, exchangeable-Al and -H tended to increase by increasing elevation in Bukit Sarasah. There was no significant difference found for the concentration of exchangeable cations among the elevations and between the depths. The soil chemical characteristics on the top 20 cm were generally better than those on 30-50 cm soil depth, however, different elevation did not gave significant difference of the concentration.

Keywords— Soil chemical characteristics; soil depth; topo-sequence; wet tropical area

I. INTRODUCTION

As land use change intensively happens in Indonesia nowadays, people have used marginal land such as sloping areas for food crop farming. Farming in sloping areas is not only risky for the erosion but also problematic to the fertility. One of several factors determining soil fertility is the chemical properties. Soil chemical characteristics are not only affected by the parent material of the soils, but also by climate, topography, organisms, and time. As other factors are the same, different soil chemical characteristics will be due to the topography.

Topography will affect temperature controlling decomposition process in soil and types of plant growth. The soils from the different elevation will have different characteristics due to different microclimate affected the soils. One of the microclimate affected soil characteristics was temperature. Temperature is climate element influencing decomposition process in soil. In fact, temperature decreases by increasing position of an area. Based on Braaks [1] air temperature decreases by 0.60C by each 100 m increase in above sea level. Soil temperature can be derived from the air temperature on which by adding 2.50C to the air temperature [2]. Therefore, by increasing elevation the reaction activity will decrease. It means that

area at higher elevation will receive lower reaction activity, affecting soil development process, and as a consequence, soil characteristics. As reported by Sidari et al [3] that in general soil properties and microclimate showed significant differences in Aspro Monte mountains (Italy). The difference may be attributed to topography aspect-induced microclimate differences, which causes differences in the biotic soil component, organic matter trend, affecting soil fertility.

In general, soils at higher slope will have lower fertility than at lower slope, because some soil materials from the top will be eroded and deposited in the lower part. Soil as well as the plant nutrients contained will go out of the original place. Therefore, the fertility of the soil on the lower part will be higher than that on the upper and middle slope.

Furthermore, since an area at lower elevation has higher temperature than that at higher elevation, the soil organic matter produced by crops will be decomposed faster and the nutrients will be more available for plant growth. Therefore, it is hoped that soil under lower has higher fertility than that at higher elevation.

Bukit Sarasah, a small hill in Kuranji Watershed, has elevation up to 582 m asl, and some has been cleared by people for farming, especially for cacao, and other perennial fruit crops. However, it is not impossible that in near future the area will be used for annual crop farming such as corn,

soybean, and vegetable crops. Farming of seasonal crops needs good chemical properties to support their growth. Whether the chemical characteristics of the soils in the sequent topography (from 315 to 515 m asl) of the hilly area under wet tropical rainforest the same or not, it is interesting to know.

II. MATERIALS AND METHOD

The research was conducted by using survey methods and soils were sampled randomly in every a 100-meter elevation at the same slope. There were three locations (315 m, 415 m, and 515 m *asl*) chosen for sampling the soils. Vegetation at each location was dominated by *Axonopus compresses*, *Imperata cylindrical*, *Sticherus truncatus*, and *Melamastoma malabathricum*. The higher the elevation was the less the percentage of grasses covering the soil surface. At the 515 m *asl* the soil was covered by some wide-leave trees. Disturbed soil samples were taken at 0-20 cm and 30-50 cm depth in each location. Soil samples were air-dried, ground, and sieved as needed for the analyses.

Parameters analyzed were soil organic carbon (OC) (wet oxidation method), soil pH (pH-meter), total nitrogen (digestion method), exchangeable cations (using AAS), and cation exchange capacity (CEC) (leaching using ammonium acetat at pH 7.0). Specifically, soil samples were separated from the fresh OM found before they were analysed. Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables.

III. RESULTS AND DISCUSSION

A. Soil Cemical Characteristics

Organic-C content of the soil in the hill-slope of Bukit Sarasah was affected by the elevation. The OC percentage significantly decreased by increasing elevation from 315 to 515 m *asl* on the top 0-20 cm (Table 1 and Fig. 1-a), but not on the 30-50 cm depth (Fig. 1(a)). Soil OC decreased by 48% and 63% on the top 20 cm and 26% and 33% on the 30-50 cm soil depth for the 415 m and 515 m, respectively, compared to site 315 m. Between both depths, it decreased by 84%, 77%, and 72%, on the 30-50 cm compared to the top 20 cm soil, respectively for altitude 315, 415, and 515 m *asl*. The decrease in the SOC might be due to the difference in OC source of the soils and OM decomposition rate. Soil at 315-m location had the highest OC content on the top 20 cm, because the soil surface was almost 100% covered by grass (*Axonopus compressus*). Grass which is known has short term life, so it can produce and contribute more organic matter to soil per year compared to the higher plants or trees.

Furthermore, the activity of decomposing microbes was more intensive under grass than under forest dominated by trees. This correlates to the temperature of the soil surface, or microclimate, inducing decomposing microbial activity. Direct sunlight to soil surface under grasses had also increased the temperature of the surface soil providing better environment for microbial activity. Temperature is one of several factors affecting soil organic matter (SOM) decomposition. As reported by reference [5] amount of CO₂

release, as an indicator of OM decomposition, from soil under higher temperature (26°C) was about 164 % larger than that under lower temperature (19°C) at the same soil water potential. At low elevation, air and soil temperature is higher than that at higher one, as stated by Braak,1928 [1] air temperature will decrease by 0.6°C as elevation increases by 100 m *asl*.

Since the soils in the research location were not cultivated, SOC increased by time under grassland but not under trees in higher elevation, even though fresh OM was found in large amount there. As found by [6] that reduction of decomposition rate of OM sources had increased labile C as well as total nitrogen by increasing altitude under experimental forest in the Oregon Cascade Mountains (USA). It means that the SOM was mostly dominated by fresh OM. On the other hand, OM content of the soil in this research was classified as decomposed OM matter, indicated by low C/N ratio Table1).

Unlike on the top 20 cm soil, SOC on 30-50 cm depth was lower and did not significantly decrease as elevation increased from 315 to 515 m *asl*. This is due to the fact that the main source of SOC is derived from above soil surface. On the lower depth, the SOC was derived from plant roots as well as from soil microbes and the root exudates. Since the activity of microbes was higher under higher temperature (lower elevation), while more roots were found under higher elevation (derived from tree roots), the total contribution of both to SOC was not significantly different.

As SOC content, total nitrogen (total-N) of the soil performed the same tendency, it decreased by increasing elevation (Tabel 1). This was due to fact that either OC or

TABLE I
CHEMICAL CHARACTERISTICS OF SOILS ALONG TOPOSEQUENCE IN BUKIT SARASAH PADANG AT 0-20 CM DEPTH

Soil Parameter	315 m	415 m	515 m
Soil pH-H ₂ O (1:1)	4.85	4.58	4.19
Soil pH-KCl (1:1)	3.62	3.64	3.57
Organic-C (%)	4.08	2.11	1.50
N-total (%)	0.46	0.27	0.16
C/N Ratio	8.96	7.82	5.49
Exchangeable-Na (me/100 g)	5.08	5.04	4.80
Exchangeable-K (me/100 g)	2.36	2.78	2.58
Exchangeable-Ca (me/100 g)	1.05	1.25	1.09
Exchangeable-Mg (me/100 g)	1.83	2.31	2.06
Exchangeable-Al (me/100 g)	2.40	2.60	7.00
Exchangeable-H (me/100 g)	0.18	0.29	1.47
Soil CEC (me/100 g)	28.04	13.64	11.43
Al-saturation (%)	8.56	19.06	61.26

N was originated from the vegetation growing on the soils. The higher the SOC content is the higher the N content of the soil since the OM source is the same. For both depths, the N-total (Fig. 1(b)) of the soils followed the tendency of SOC.

High OC content in a soil will cause in high cation exchange capacity which is able to adsorb more cations and reduce the leaching process of basic cations. More basic cations in soil colloids and soil solution will bring the soil becomes less acidic. Therefore, the soil pH (Tabel 1 and Fig 1(c)) followed the tendency of OC and N-total concentration within the soil depths. However, the soil pH at lower depth (30-50 cm) does not significantly different from the top 20 cm. This probably was due to leaching process of the cations. As the area is located under wet tropical rainforest with annual temperature > 5000 mm, the leaching process becomes intensive. This is proved by the concentration of some basic cations, especially Na, K, Ca, and Mg (Fig. 1(g), 1(h), 1(i), and 1(j)) which was not significantly different from the ones on the upper depth.

High OC at the 315 m site contributed to more negative charges (CEC) to the soil. This CEC decreased as the pH was lower at higher elevation (415 and 515 m). As stated by [7] that besides mineral colloid (clay), the CEC in tropical soil can be derived from organic colloid (humus) which has pH dependent charge. This meant that the soil is able to retain more nutrients in form of cations before crops uptake them, and the efficiency of fertilizer use increases at high pH. The CEC values of the soil decreased by 51% and 59% on the top 20 cm and by 25% and 15% on the 30-50 cm depth at the 415 m and 515 m respectively compared to the 315 m site. Between both depths, the decrease in CEC (Fig. 1(d)) tended to be larger as the elevation increase from 315 to 515 m *asl*. Soil CEC on the 30-50 cm depth decreased by 50%, 33%, but increased by 5% at the 315, 415, and 515 m *asl*, respectively, compared to the top 20 cm.

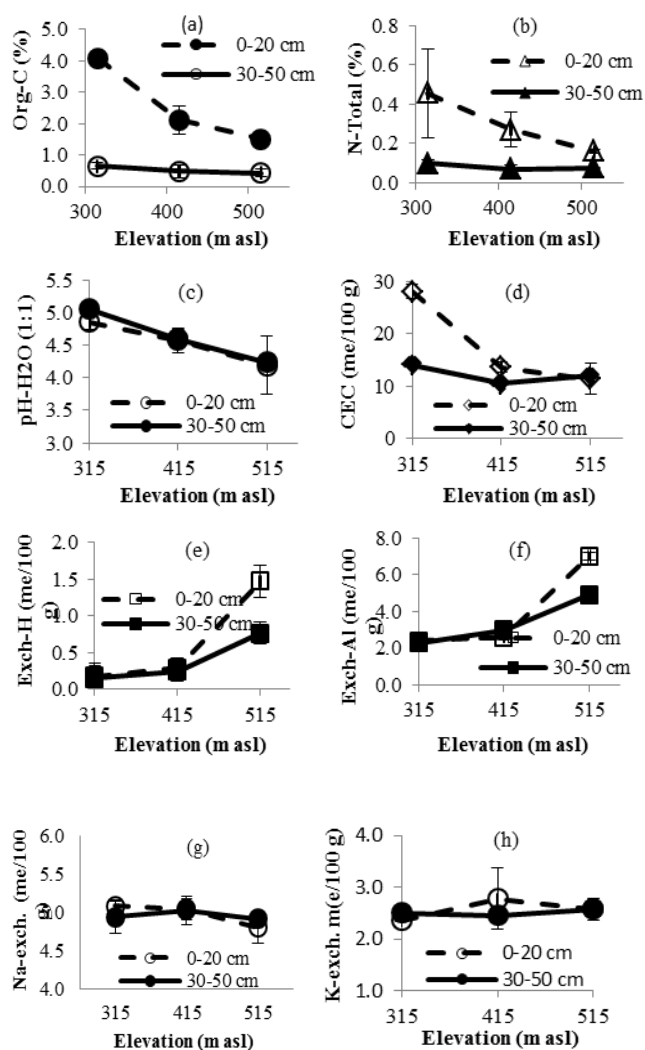
Reference [6] also reported that soil pH at Oregon Cascade Mountains was significantly lower on the higher elevation. Reference [3] found that topography in Aspromonte Mountains in Southern Italy gave significant differences in soil properties. The differences could be due to differences in microclimate induced by topography, which alter the OM trend, affecting soil fertility. Reference [8] reported that interactions between topography and land use in south-western China controlled soil pH, OM, N, P, Ca, and Mg. Reference [9] found that topography was an important factor affecting soil properties. Reference [10] reported that SOM, total-N (TN), total-P (TP), available N (AN), and available P (AP) showed an increase values from upper to foot slopes from a specific land use structure (fallow land-shrub land-fallow land-cropland-woodland-orchard) in the loess plateau, China.

As SOC, and other soil chemical properties such as N-total, CEC, and soil pH also tended to decrease by increasing elevation, but concentration of H^+ (Fig. 1(e)) and Al-exchangeable (Fig. 1(f)) showed an opposite tendency. Soil pH decreased by 6% and 14% on the top 20 cm and by 9% and 16% on the 30-50 cm depth at the 415 m and 515 m compared to 315 m site. Between both depths, it did not show a significant difference in each site.

Highest soil pH or lowest $[H]^+$ at 315 m *asl* was probably associated with higher SOC at the research location. Higher pH value under 315 m elevation causes Al and Fe precipitated, so less H^+ was found in soil solution. Increasing pH value as increasing SOM also reported by [11], in which soil pH increased from 5.86 to 6.03 (in 2007)

and from 5.43 to 6.20 (in 2008) by addition of 10 ton manure/ha on Alfisols (Oxic tropudalf) in Nigeria. Reference [12] also found that increasing soil pH as OM added to Reiff loam soil (coarse-loamy, mixed, nonacid, thermic Mollic Xerofluvents) and Yolo silt loam soil (fine-silty, mixed, nonacid, thermic Typic Xerorthents) in California, USA. During their research, soil pH value consistently increased for 8 years (1988-1996) research. They, furthermore, explained that one of the factors causing an increase in soil pH as OM added to soil was due to contribution of cations from OM decomposition to the soil.

Contrary to the pH values, the exchangeable aluminum increased under higher elevation. Al-saturation increased by 2.23 times at the 415 m and 7.16 times at the 515 m on the top 20 cm and by 1.74 times at the 415 and by 2.51 times at the 515 m on the 30-50 cm soil depth compared to those at the 315 m location. Higher Al-saturation percentage on higher locations (415 and 515 m *asl*) seemed to be due to lower soil pH as well as low SOM content which could deactivate the Al cations. Between both depths in each location it was found an increase in Al-saturation on the 30-50 cm by 1.91 times, 1.49 times, and decrease by 0.67 times for location 315, 415, and 515 m, respectively, compared to the Al-saturation on the top 20 cm soil surface.



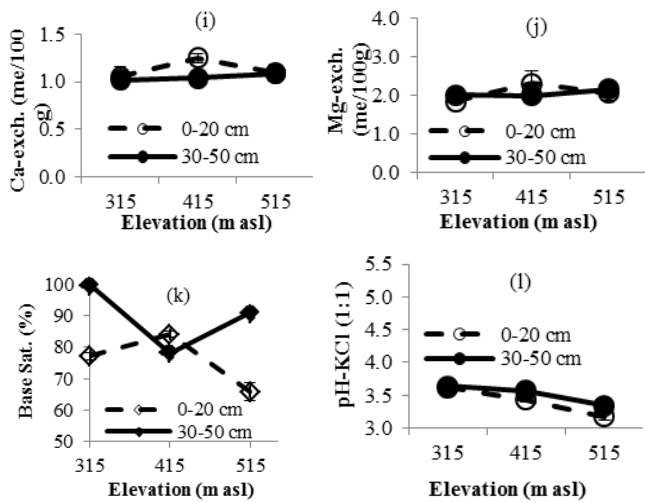


Fig. 1 Soil chemical characteristics (a=OC, b=Tot-N, c=pH H₂O, d= CEC, e=H-exch, f=Al-exch, g=Na-exch, h=K-exch, i=Ca-exch, j=Mg-exch, k=base sat, l=pH KCl) at different altitude under wet tropical area from two (0-20 cm and 30-50 cm) depths

B. Relationship Between soil pH and Exchangeable Cations

Decomposed organic matter will contribute plant nutrients such as N, Ca, Mg, dan K to the soil, therefore, higher OM content of a soil will contribute to high soil cations. As the soil pH increased, soil CEC also increased due to organic colloids. Therefore, the cations (Ca, Mg, and K) were adsorbed on colloid surface and finally contributed to higher base saturation (Fig. 1(k)) of the soils.

However, there was no significant difference of the cations (Na, K, Ca, Mg) found in the research site (315, 415, and 515 m asl) even though the soil had different pH values. This was probably due to the fact that soil pH was generally classified as acid (pH < 7) that cations were equally affected. The exchangeable cations were not significantly different. Since the soil was dominated by Ultisols (high clay content with low SOM on the soil surface, except at 315 m altitude covered by pasture), the cations were mainly contributed by the mineral fraction of the soils.

There was no correlation found between soil pH and exchangeable cations either based on the elevation or based on the soil depth. Different soil pH did not alter exchangeable cations (Fig.2(a)). This seemed to be due to the difference in soil pH among the sites and between the depths was not quite high. All soil pH values in the research sites were classified into acid (between 4.19 to 5.06 or < 6). This agreed with the results reported by [13].

The cations in the research site were mostly leached due to high annual rainfall, because the soils (Ultisols) were dominated by kaolinite clay mineral, having low permanent charge density. Since the solum of the soil > 100 cm in average, the leaching cations could go far under rooting zone (0-50 cm). Therefore, the amounts of cations were not significantly different either between top 20 cm and 30-50 cm soil layers or among the elevation (315 m – 415 m - 515 m asl).

Based on Table 1, there was no significant difference for exchangeable basic-cations (Ca, Mg, Na, and K) among the research sites and between both depths in each site. Even though the soil pH and the soil OC decreased by increasing

elevation (Figure 1(d) and 1(a)), the exchangeable cations were generally the same.

Soil pH value did not affect the concentration of exchangeable cations (Fig. 2(a)). This might be due to the parent material of the soil which is acidic and the soil is classified into to Ultisols (Wakatsuki et al, 1986) which has low base saturation. A part from it, high annual rainfall caused more cations leached by time. Since the area has been well developed and has reached the final decomposition process, the solum was quite thick. It is thought that both depths (0-20 and 30-50 cm) were still at A horizon from which the cations were leached into deeper depth.

Even though the exchangeable basic-cations were not significantly different among elevations and between depths, The exchangeable Al and H as well as the percentage of Al-saturation increased by increasing elevation for both depths. Increasing Al-saturation by increasing elevation was due to the fact that the Al-exchangeable (Fig. 1(f)) increased as the numerator and the CEC as the denominator decreased. Both exchangeable Al and H were highly correlated (R²= 0.82 and 0.88) to the pH values of the soil (Fig. 2(b)).

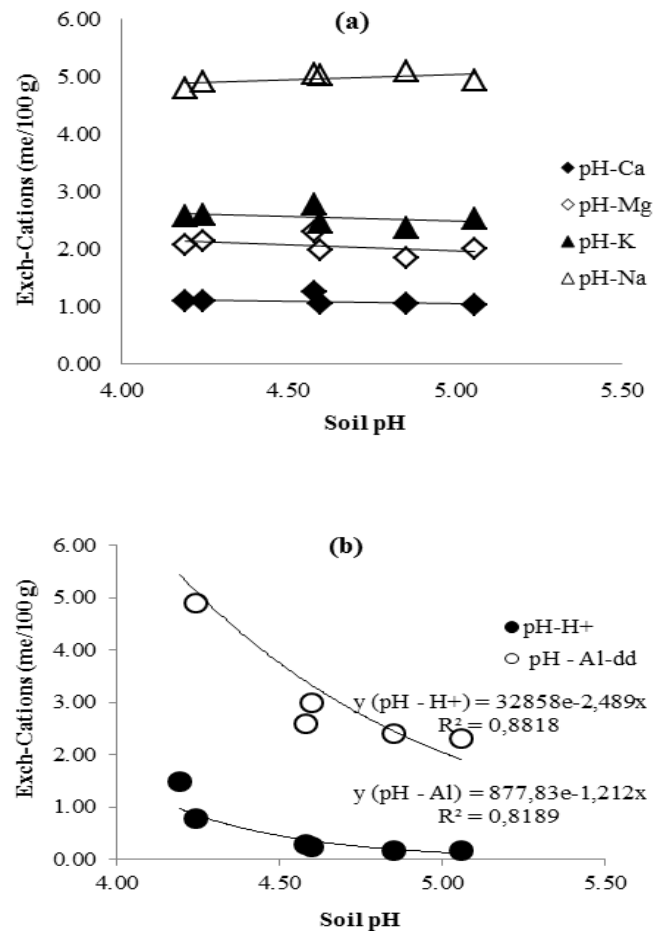


Fig. 2. Relationship between soil pH and exchangeable basic (a) and acidic (b) cations

IV. CONCLUSIONS

Based on the data analysed, the chemical properties of the soil from different altitudes in a wet tropical area in Bukit Sarasah Padang, West Sumatra, Indonesia, can be concluded that the soil reaction was considered acidic (generally < 5.0), high acidic cations (Al_3^+ and H^+) and low soil nutrient content, especially basic cations. Based on these chemical properties, the areas (315, 415, 515 m *asl*) were not recommended for annual crop farming, otherwise there are external inputs to meet crop needs as long as the action is not against conservation rule.

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