The Evaluation of Soil Chemistry Fertility in Dryland, Agroforestry, and Forest

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Abstract. This study aims to evaluate the level of soil fertility with the parameters of soil fertility chemistry in the form of organic-C, Phosphorous (P) available, Calium (K), Natrium (Na) available, Cation exchangeable capacity (CEC), and Base saturation (KB) soil. The research method used is a descriptive qualitative method of phenomenology by conducting quantitative land survey and laboratory analysis. Determination of status soil fertility based on technical guidelines for evaluating soil fertility at the Soil Research Center. The results showed the organic-C and P available content low in each land use, except for organic-C in forest land. The content of K in forest land and dryland agriculture is classified as high to low, whereas in agroforestry land is classified as moderate to low. Based on CEC in forest land and dryland agriculture is classified as high, whereas in agroforestry is classified as moderate. Based on KB, the condition of soils in forest land and agroforestry is classified as fertile on the surface horizon, while subsurface the fertility level is classified as infertile, while in the dryland agriculture the soil fertility is classified as moderate.

1. Introduction

Decreased of fertile land in Java consequences of conversion land used, requires sub-optimal land use to meet the needs of food and raw materials for agricultural industries so that they are met from domestic production [1]. Sub-optimal land is land that has experienced low soil degradation and fertility and is unable to support optimal plant growth [2].

The development of sub-optimal land can be an alternative to optimize the national food security program. Indonesia has a large potential of land resources, which is around 148 million ha of dryland and around 40.2 million ha in the form of wetlands including swampland [3]. The spread of acid soils varies from lowlands to highlands with flat to mountainous areas, generally wet climate with rainfall > 2000 mm year⁻¹ and formed from various types of soil parent materials.

The variations of Climate and high intensity of rainfall in Western Indonesia results in a level of leaching of basic cations (Ca, Mg, K, and Na) on uplands soils so that the base content becomes low and the soil becomes acidic [4]. Otherwise polyvalent cations such as Al³⁺, Fe³⁺, and Si⁴⁺ will accumulate in the soil to form new particles such as minerals 1:1 and oxide Al, Fe, and Mn [5], so the development of dryland with wet climates has its challenges related to soil fertility.
Cisarua is one of the subdistricts in Bogor Regency, West Java, which is in the Upper Ciliwung Watershed (DAS). The majority of the population is working in agriculture, both seasonal crops (horticulture) and annual crops (plantations). Besides that, the Cisarua subdistrict is a mountainous tourist area, located at the foot of Mount Gede-Pangrango. The intensive of land used and long-term with management without conservation rules causes a decrease of soil fertility and nutrient imbalance in the soil or land degradation. To maintain agricultural land in the Ciliwung watershed, with sustainable, which can sustainably support plant growth, so that a good soil management effort is needed based on soil chemical fertility and the needs of cultivated plants. Therefore, it is necessary to study the soil fertility status.

2. Metodologi

The study was conducted from May 2017 to February 2018 on three different land uses in the Upper Ciliwung Watershed, Cisarua District, Bogor Regency, West Java. This research is a phenomenal qualitative descriptive study [6], carried out by quantitative land survey and laboratory analysis.

Sampling locations are based on overlaying soil type maps and land cover maps. Each type of land use is represented by two soil profiles made with a distance of 5-10 m in the position of the middle slope sloping from 16 to 35° (30-70%). The soil profile is made up of the soil horizons limit with a size around 1 m x 1 m x 1.5 m. The soil disturbed samples were taken as much as 500 g at 4 horizons in each soil profile of the three types of land use. Then soil samples are put in plastic bags, labeled, and stored in the cooler box for soil analysis in the laboratory.

The analysis of soil samples in the Laboratory of Chemical and Soil Fertility, Department of Soil Science and Land Resources, Bogor Agricultural University (IPB) and Laboratory of Soil Research Institute, Agency for Agricultural Research and Development (BBSDLP) Bogor, West Java. The parameters research and soil analysis methods include soil pH of H2O and KCl extract, organic-C with of Walkey and Black method, CEC extract N NH4OAc pH 7, N-total with Kjeldahl method, P-total extract of HCl 25%, P available with Bray I method and soil texture using the pipette method.

3. Results and Discussions

3.1.1. General conditions of location study.

The location research in the upper Ciliwung watershed, administratively located in Cisarua District, Bogor Regency, West Java. Soil samples were taken collectif in three land uses is forest land at latitude 6°69'443 "LS and 106°98'889" BT, agroforestry at latitude 6°69'737 "LS and 106°97'673" BT, and dryland agriculture at latitude 6°69'530 "LS and 106°98'726 "BT. The rainfall monthly data during 2012-2016 in the study locations are presented in Table 2. Soil types generally in the research location are classified in the order of inceptisol, is the undeveloped order. The locations soil sample showed is Figure 1.

The general condition of forest land and dryland agriculture is on one slope around 16-35°, which is dryland right under forest land. Forest land is protected forest managed by Perum Perhutani Forest Management Unit (KPH) Bogor with its plant species including damar (Agathis sp.), Bananas (Musaceae), bamboo (Bambusoideae), and pine (Pinaceae). Upland fields are fallow land (not planted for > 6 months) belonging to residents and have been made of terraces, types of plants that have been cultivated in the form of carrots (Daucus carota L.), potatoes (Solanum tuberosum) and cabbage (Brassica oleracea). On agroforestry types of clove plants (Syzygium Aromaticum), resin (Agathis dammara), cinnamon (Cinnamomum Verum) and coffee (Coffea arabica, C. robusta), while crops that have been cultivated include beans (Phaseolus vulgaris), cabbage (Brassica oleracea) and mustard (Brassica rapa var. Parachinensis).
Figure 1. The locations soil sample are land used forest, agroforestry, and dryland agriculture

Table 1. The monthly average rainfall during 2012-2016

| Year's | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012   | 384.1 | 347.3 | 238.9 | 315.2 | 140.8 | 64.3 | 41.6 | 11.0 | 121.4 | 260.5 | 363.5 | 422.9 |
| 2013   | 852.2 | 338.8 | 402.8 | 318.5 | 492.6 | 121.9 | 272.2 | 131.5 | 70.4 | 263.9 | 259.0 | 542.6 |
| 2014   | 1 206.8 | 596.6 | 295.6 | 395.6 | 219.9 | 199.1 | 344.1 | 249.8 | 33.6 | 94.2 | 554.3 | 460.9 |
| 2015   | 357.3 | 376.8 | 376.0 | 227.9 | 173.3 | 14.9 | 3.1 | 59.0 | 19.2 | 50.1 | 521.7 | 421.4 |
| 2016   | 361.6 | 581.7 | 546.4 | 481.2 | 232.0 | 201.8 | 252.6 | 82.6 | 365.9 | 393.6 | 312.1 | 146.7 |
| Average| 632.4 | 448.2 | 371.9 | 347.7 | 251.7 | 120.4 | 182.7 | 106.8 | 122.1 | 212.5 | 402.1 | 398.9 |

Source: Station of BMKG Citeko-Bogor

Based on the climate classification system [7], the research of location is climate type B, which is a wet area with tropical rainforest vegetation. During the last five years, the highest monthly rainfall that occurred in January is 632.4 mm, while the lowest was in August 106.8 mm. Rainfall patterns over the past five years indicate that in September-May there was an increase in rainfall, then in June-August rainfall began to decrease (Table 1).
3.1.2. Characteristics of physical and chemical properties of soil in the study site

One of plant growth is determined by the type of soil, besides as a place to grow plants play a role in the supply of plant nutrients. The process of soil formation is influenced by soil parent material, climate, topography, and time. The parent material continues to experience weathering and mixing organic matter with mineral materials to form a soil profile with various other processes where the physical, chemical and biological processes are interrelated. Climate is a major factor in the process of formation and development of land in the tropics, besides that, it is also influenced by land use above. The results of the analysis of the physical and chemical properties of soils on forest land, agroforestry, and dryland agriculture in the Ciliwung watershed are presented in Tables 2 and 3.

Table 2. The physical and chemical properties of land in the use of forest land, agroforestry, and dryland agriculture

| Landuse          | Horizon Soil | depth (cm) | C-org. (%): pH | Classifications | Sandy (%): % | Silt (%): % | Silty rough (%): % | Silty smooth (%): % | Class Texture |
|------------------|--------------|------------|----------------|----------------|--------------|--------------|-------------------|-------------------|-----------------|
| **Forest**       | Ao           | 0-15       | 12.18: 4.57: 4.40 | Very acid      | 38.41: 15.10: 7.63 | 38.86        | Sandy clay       |                   |                 |
|                  | A1           | 15-30      | 3.83: 5.20: 4.76 | Acid           | 45.47: 26.83: 6.74 | 20.96        | Sandy clay       |                   |                 |
|                  | B1           | 30-110     | 3.29: 5.33: 4.80 | Acid           | 30.59: 24.21: 9.78 | 35.42        | Sandy clay       |                   |                 |
|                  | B2           | 110-150    | 0.82: 5.05: 4.51 | Acid           | -             : -     : -     | -             | -                 |                   |                 |
| **Agroforestry** | Ap           | 0-15       | 4.16: 4.98: 4.39 | Very acid      | 17.09: 46.90: 12.64 | 23.36        | Clay loam        |                   |                 |
|                  | A2           | 15-40      | 4.09: 5.13: 4.69 | Acid           | 23.47: 48.43: 9.48 | 18.61        | Sandy clay       |                   |                 |
|                  | B1           | 40-70      | 1.62: 5.08: 4.71 | Very acid      | 20.60: 47.28: 9.71 | 22.41        | Clay loam        |                   |                 |
|                  | B2           | 70-100     | 0.63: 4.97: 4.29 | Very acid      | -             : -     : -     | -             | -                 |                   |                 |
| **Dryland**      | Ap           | 0-25       | 2.16: 4.82: 4.21 | Very acid      | 46.61: 25.42: 2.19 | 25.77        | Sandy loam       |                   |                 |
|                  | A2           | 25-50      | 0.26: 4.95: 4.53 | Acid           | 22.37: 45.77: 13.79 | 18.01        | Sandy loam       |                   |                 |
|                  | B1           | 50-75      | 0.09: 4.92: 4.40 | Acid           | 11.04: 55.81: 18.11 | 15.06        | Clay loam        |                   |                 |
|                  | B2           | 75-110     | 0.22: 4.97: 4.29 | Very acid      | -             : -     : -     | -             | -                 |                   |                 |

Description: Ao = horizon dominated by organic matter; A1 = horizon with the accumulation of smooth organic matter mixed with mineral materials and not dominated by the horizon H or E; B1= horizon formed under A, E, or O or the intermediate horizon where the parent material is still visible; B2= maximum/transition accumulation horizon from B to C or R, there is an illustration of clay, Fe, Al, hummus, carbonate, or one of the combinations.

The results of the analysis show that the content of organic materials (C-organic) is sequentially highest on forest land, then agroforestry, and dryland agriculture with a decreasing distribution at the depth of the soil horizon in each land use. The content of C-organic in forest land and agroforestry is classified as high on the surface horizon but low on the subsurface horizon, while in the dryland it is classified as low on each land horizon. Generally, the low content of organic matter in dryland agriculture is caused by the intensity of processing of the land higher than agroforestry and forest land. Whereas in agroforestry land, the age of the plants is still relatively easy with the annual plant canopy being relatively low. Naturally in the topsoil has a higher amount of organic matter than the subsurface horizon.

The results of the analysis soil reaction (pH) H₂O showed the actual level of acidity of the soil, while analysis with KCl showed the potential level of acidity of the soil. Soil reactions for each land use are classified as acid to very acidic, this is the same as with the research by [8], the pH of the soil
in West Java is classified as an acid. The soil texture shows the rough or smooth state of the soil and consists of sand, dust, and clay fractions. Based on the soil texture triangle shows that the texture of the soil in the forest land at Ao and B1 horizons is sandy loam textured, while at horizon A1 is sandy clay. On agroforestry at the horizon Ap and B1 textured soils are clay loam, while in the horizon A2 is sandy loam textured. On dryland agriculture at the surface horizon (Ap and A2) the texture is sandy loam, while in horizon B1 it is clay loam textured (Table 2).

The results of the analysis soil chemical properties (Table 4) based on the assessment criteria for the results of soil analysis [15] indicate that the distribution pattern of N-total decreases with the soil horizon depth (from the Ao horizon/ to horizon B2) to each land use. On forest land the N-total is classified as high to very high at the horizon Ao of 1.11%, decreasing to 0.2% on the horizon B2. In agroforestry is classified as moderate is the horizon Ap of 0.22% decreases to 0.06% on the horizon B2, whereas in the dryland agriculture is relatively low, the horizon Ap is 0.46%, decreases to 0.18% on the horizon B2.

The results of analysis of P content in soil indicate that P is available (Bray I) for plants smaller than total P (25% HCl) in soil (Table 4) with a distribution decrease pattern at the depth of the soil horizon for forest and agroforestry land, meanwhile in dryland agriculture is fluctuating distribution patterns. This is because of dryland agriculture more intensive land processing than forest land and agroforestry, where there is a reversal of soil layer by farmers. The level of P absorption is seen to be very high in forest land, agroforestry, and dryland agriculture, this is can be seen from the number of available P is much lower than the total P in the soil. Low organic matter content (Table 3) on dryland causes P to be available less than in forest land and agroforestry. This is because organic material acts as a competitor and chelates metals in the soil.

The highest concentrations of Mg, K, Na, and CEC contents were found on forest land, then agroforestry, and dryland agriculture with a decrease distribution pattern based on soil horizon depth in each land use. The organic matter plays a role in increasing the absorption and exchange of cations, the availability of N, P, and S, as well as the nutrient dissolution of minerals by humic acid. Soils with higher CEC's have a greater capacity to store nutrients such as Ca$^{2+}$, Mg$^{2+}$, and K$^+$ which have the potential to be available to plants, thereby reducing leaching from the soil [9].

The pattern of distribution K content on forest land and agroforestry decreases with the depth of the soil horizon, but on the contrary on the dryland agriculture pattern is fluctuated due to the high intensity of tillage. The content of K on forest and dryland agriculture is classified as high to low, while in agroforestry land is classified as moderate to low. This situation is caused by the rock/mineral constituent of the soil in the area is low in terms of basic cations, besides high rainfall causes the leaching base cations [10].

According to [11], that in young soils where weathering is not yet advanced and leaching is relatively small, base cations such as Ca and Mg are cations that occupy the colloidal surface a lot, but if weathering is advanced and leaching is large due to high rainfall, the number of cations-cation of base is reduced and minerals containing alkaline cations will disappear due to leaching. Besides being due to mineral content and leaching processes, it can also be caused because these base cations are reduced because they are absorbed by plants and transported by harvest (in plants), and do not carry out the return of alkaline cations through fertilization or liming.

Based on the assessment criteria of the results of soil analysis [12], the concentration of soil cation exchange capacity (CEC) decreases based on the depth of the soil horizon. On land forest, CEC soil classified as high around 24.11-34.27 cmol(+)/kg, agroforestry is classified as moderate around 21.07-25.91 cmol(+)/kg, while in dryland agriculture is classified as high around 32.74-36.01 cmol(+)/kg.
This is supported by soil acidity in each land use classified as acidic (Table 3). According to [13], the big of soil CEC is influenced by the nature and characteristics of the soil, is soil pH, organic matter, soil texture, and types of clay minerals.

Table 3. The chemical properties in forest land, agroforestry, and dryland agriculture

| Land use          | Horizon Soil | depth (cm) | Kjeldahl N (%) | Bray I P (ppm) | HCl25% P (ppm) | NH4OAc pH 7.0 Mg (cmol(+)/kg) | K (cmol(+)/kg) | Na (cmol(+)/kg) | CEC (cmol(+)/kg) | KB (%) |
|-------------------|--------------|------------|----------------|---------------|----------------|-------------------------------|----------------|----------------|-----------------|--------|
| Forest            | Ao           | 0-15       | 1.11           | 6.62          | 386.57         | 6.4                          | 1.5             | 0.8            | 0.8             | 27.57  |
|                   | A1           | 15-30      | 0.66           | 5.90          | 278.95         | 3.2                          | 0.8             | 0.3            | 0.3             | 34.13  |
|                   | B1           | 30-110     | 0.29           | 5.90          | 372.10         | 2.3                          | 0.3             | 0.5            | 0.5             | 26.07  |
|                   | B2           | 110-150    | 0.20           | 5.81          | 421.96         | 2.5                          | 0.2             | 0.3            | 0.3             | 24.11  |
| Agroforestry      | Ap           | 0-15       | 0.46           | 5.68          | 498.10         | 1.8                          | 0.4             | 0.3            | 0.3             | 25.91  |
|                   | A2           | 15-40      | 0.51           | 6.68          | 548.09         | 0.5                          | 0.3             | 0.3            | 0.2             | 25.68  |
|                   | B1           | 40-70      | 0.24           | 6.38          | 427.32         | 0.7                          | 0.1             | 0.1            | 0.1             | 22.42  |
|                   | B2           | 70-100     | 0.18           | 5.61          | 429.71         | 0.7                          | 0.2             | 0.2            | 0.2             | 21.07  |
| Dryland agriculture| Ap          | 0-25       | 0.22           | 4.61          | 244.43         | 5.8                          | 0.1             | 0.4            | 0.4             | 36.01  |
|                   | A2           | 25-50      | 0.08           | 4.52          | 232.10         | 5.7                          | 0.8             | 0.4            | 0.4             | 34.01  |
|                   | B1           | 50-75      | 0.06           | 4.70          | 166.31         | 5.0                          | 0.2             | 0.3            | 0.3             | 32.74  |
|                   | B2           | 75-110     | 0.06           | 3.66          | 163.86         | 4.7                          | 0.1             | 0.4            | 0.4             | 33.20  |

The results of soil analysis (Table 4) show that distribution pattern of base saturation (KB) of land in forest and agroforestry land decreases based on the depth of the soil horizon (Ao/Ap to B2), but meanwhile in dry fields increasing based on the depth of the soil horizon. According to [14], the base saturation of land <50% shows that soil is infertile, while land with KB of 50-80% is classified as land with moderate fertility, while land with KB> 80% is classified as soils fertile.

The results of soil analysis showed that the soil conditions at the surface horizon in forest land were classified as fertile, whereas below the surface the fertility level was classified as infertile, with a concentration of KB at horizon Ao of 87.02% decreasing to 46.96% in horizon B2. Meanwhile, the soil conditions on agroforestry land were classified as infertile on the surface horizon and the subsurface horizon with a KB concentration of 24.13% in horizon Ap decreased to 16.03% in horizon B1, then increased to 22.20% in horizon B2. On the other hand, in the upland fields, the soil conditions are classified as being on the surface horizon and subsurface in the horizon with a concentration of KB at the Ap horizon of 66.22%, increasing to 77.42% on the horizon B2. This is because the condition of soil pH in each land use is classified as acidic. KB values are interrelated with the level of soil acidity and soil fertility, acidity will decrease and will increase soil fertility. The rate of release of adsorbed cations for plants depends on the level of base saturation soil [10]. According to [11], based on the Bogor Soil Research Center (PPT) determine the fertility status of soil chemistry based on the status of soil CEC, value of base saturation, the content of organic (C-organic) material in the soil, and P-available.

4. Conclusion

Based on the results of the study it can be concluded that:
1. The level of soil fertility in forest land, agroforestry, and dryland agriculture decrease based on the depth of the soil horizon.
2. The forest land, agroforestry, and dryland agriculture have high soil acidity and available P absorption.
3. The status of soil fertility in forest land and agroforestry is determined by low KB values, acidity, and P, while dryland agriculture is determined by organic C, acidity, and P.

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