Evaluation and mapping of soil fertilizer status in the international geopark Ciletuh area, Sukabumi Regency

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Abstract. The Ciletuh Geopark area is an international geopark area recognized by UNESCO. As the area is undergoing development, it certainly raises some land and environmental problems, especially in agriculture. This study is intended to determine soil characteristics and collect field data and other supporting data from soil and social, physical factors, so that these data can be useful in the development of the Ciletuh Geopark Area, especially the development of agricultural areas. The purposes of this study were 1) To obtain comprehensive field data so that the soil characteristics of the Ciletuh Geopark area can be known, 2) How to spread the soil fertility status in Geopark Ciletuh Area, Ciomas District, Sukabumi Regency. This research was expected to provide an overview of soil fertility based on chemical and physical properties of the soil and can provide detailed soil resource information for the development of science to support research activities, and it was expected to provide preliminary information or primary data on soil fertility as part of the development of Ciletuh Geopark. The location of the study was conducted in the Ciletuh Geopark Area, Ciomas District, Sukabumi Regency, West Java Province. The study was conducted with qualitative, descriptive, and comparative methods and survey methods. The sampling of land was carried out in each unit of land, which is determined by transect based on the results of environmental observations so that it is sufficiently representative to represent the land in the area. Analysis of physics properties, soil chemistry, was carried out in the Laboratory of Plant Chemistry and Nutrition, Universitas Padjadjaran. Mapping analysis was carried out at the Land Evaluation Laboratory of the Department of Soil Science, Universitas Padjadjaran. The results showed that soil fertility status at the study site was moderate to low criteria with limiting factors P (phosphorus) and carbon organic soil. Land management that needs to be done was by adding organic materials and phosphorus fertilization regularly so that soil fertility can be good maintained and can be sustainable.

1. Introduction
The ciletuh Geopark area is a National Geopark area established by the Indonesian National Committee for UNESCO and the Ministry of Energy and Mineral Resources. This geopark area is located in Sukabumi Regency. According to [1], the geopark region is included in the oldest rock group (Pre-Tertiary), which is exposed to the surface with rocks aged 65-120 million years.

Geomorphology of Ciletuh Geopark including the Southern Java Mountains in the form of mountainous landforms with varied topography. According to [2], this area consists of alluvial sedimentary, ultrabasic of mountain beas, melange complex, citirem formation, ciletuh formation, and
jampang formation. The Ciletuh Geopark region based on morphogenetics is included in the faulted folded hill, intrusion hill, volcanic hill, and alluvial plain. All of these geomorphological processes will allow differences in soil chemical and physical properties. This difference in chemical properties can affect the level of soil fertility, especially on agricultural land.

Assessment of soil fertility in an area does not provide an indicator of the adequacy of other growth factors because the land that is considered fertile is not necessarily productive [3]. The status of soil fertility is closely related to the soil chemical and physical properties because chemically fertile soils are not necessarily fertile in physical terms and vice versa. There are several ways to determine soil fertility status, which is to see the indication of nutrient deficiency, plant tissue analysis, soil biology and chemical analysis [4].

Survey and mapping is a method in the field to determine the spread of soil fertility status in an area including this ciletuh geopark area. The purpose of this survey is to evaluate the potential of the soil, including soil fertility through laboratory analysis [5]. The results of the mapping get a distribution of soil fertility through maps, which can be used as a basis for regional planning and land use management.

The characteristics of the Ciletuh Geopark area on agricultural, plantation and forestry land have not been widely studied and developed, both from universities and related institutions, especially regarding the fertility status of the land. Therefore research is needed on evaluation and mapping of soil fertility status in Ciletuh Geopark, Regency Sukabumi.

2. Methods

![Observation point and soil sampling](image)

**Figure. 1** Observation point and soil sampling

The research location is in the Ciletuh Geopark Area, Ciomas District, Sukabumi Regency, West Java Province. Analysis of soil properties (chemistry and physics) were conducted at the Laboratory of Soil
Chemistry and Plant Nutrition, Universitas Padjadjaran. Mapping analysis was conducted at the Land Evaluation Laboratory of the Department of Soil Science, Universitas Padjadjaran.

The study was conducted with qualitative, descriptive, and comparative methods and survey methods. The survey method was carried out by a physiographic approach. Soil sampling was carried out in each representative land unit, which is determined by transect based on the results of environmental observations and mapping observations so that it was sufficiently representative to represent the land in the area. Assessment of soil fertility status was based on soil fertility technical guidelines from the Soil Research Center.

3. Results And Discussion

3.1. Overview of Location

The research location was in Ciemas District, Sukabumi Regency with an area of 26,696 ha. The topographic conditions in Ciemas District consist of hilly and mountainous with a slope of 0-40%, the altitude of the place is between 0-500 m above sea level. Most of the Ciletuh geopark area based on soil maps has Latosol covering an area of 14,825, 73 Ha, Podsolic covering an area of 8,599.35 Ha, while Alluvial is 6,950.33 Ha.

![Figure 2 Map of land use in the research area](image)

The results of the interpretation of Landsat imagery in the study area show that the distribution of land use in the study sites was primary forest covering 13,504.58 ha, secondary forest 570.28 ha, plantations 4,674.52 ha, gardens 1,087.67 ha, rice fields 1,986.51 ha, shrubs 8,138.41 ha and built land covering an area of 308.85 ha.

The wet tropical climate has influenced by wind. Munson is a climate at the Ciletuh Geopark area. Air temperature between 20-32°C. The population of Ciemas Subdistrict was 48,290 in 2016. The majority of the population's livelihoods are farmers (11,382 people) and farmworkers as many as 6,783 people.
The Ciletuh Geopark region is a horseshoe-shaped plateau (amphitheater) that leads to Ciletuh Bay [2]. The center of the amphitheater is the oldest rock in West Java, which is effeminate and ophiolite, based on its history of the rock, which is the result of deposition from collision activity between oceanic crust and continental crust in the limestone era (> 65 million years). These rocks form the Ciletuh Formation.

Figure. 3 Map of slope in the research area

3.2. Chemical Properties of Soil
The soil chemical properties analyzed were soil pH, C-Organic, N-Total, C / N Ratio, P-available, K-available, Base Saturation, and Cation Exchange Capacity (CEC) in Table 1.

| SPT | Land use  | pH | C-Organik | N-Total | P$_2$O$_5$ HCl 25% | K$_2$O HCl 25% | CEC | Base Saturation |
|-----|-----------|----|-----------|---------|-------------------|----------------|-----|----------------|
| 1   | Secondary forest | 5.72 | 4.37 | 1.97 | 0.28 | 16.32 | 68.08 | 38.43 | 35.23 |
| 2   | Secondary forest | 6.07 | 4.16 | 2.29 | 0.19 | 21.47 | 2.27 | 15.2 | 24.93 |
| 3   | Secondary forest | 6.03 | 4.69 | 2.76 | 0.36 | 30.84 | 8.04 | 23.72 | 26.81 |
| 4   | Secondary forest | 5.08 | 4.36 | 1.12 | 0.14 | 27.74 | 17.97 | 18.3 | 44.15 |
| 5   | Plantation    | 5.74 | 4.53 | 3.05 | 0.35 | 29.72 | 13.76 | 49.23 | 29.35 |
| 6   | Plantation    | 6.27 | 4.88 | 1.41 | 0.17 | 22.02 | 54.39 | 32.04 | 41.19 |
| 7   | Plantation    | 6.21 | 4.63 | 2.49 | 0.36 | 37.09 | 11.9 | 33.4 | 21.49 |
| 8   | Cultivation  | 6.34 | 4.28 | 1.97 | 0.23 | 6.69 | 15.21 | 34.46 | 34.81 |
### 3.2.1. N-Total

The results of the laboratory analysis showed that the total N content of the land in the study area ranged from 0.11% - 0.36% classified as low to moderate. These results are related to vegetation, which contributes to soil organic matter and has not been entirely decomposed so that it is similar to organic carbon results in low to moderate research locations. According to [7], the layer of tillage generally contains 0.02 - 0.40% N. The N content of this soil depends on its environmental conditions such as climate and type of vegetation. The growing vegetation and the speed of the decomposition reaction are factors that cause changes in the N content in the soil.

### 3.2.2. P available

The results of laboratory analysis showed that the P-available content of the soil in the study area ranged from 0.15 ppm - 5.95 ppm. It was showed the land in the ciletuh geopark region originates from parent material, which is deficient in P elements, and the P content in organic materials at the location is also low. According to [8], P in the soil comes from the disintegration of minerals containing P such as apatite, and decomposition of organic matter. There is a small amount of soil available on the ground because the solubility of inorganic P compounds and organic P in the soil is generally very low. Soil pH also affects, where pH will cause high Al solubility, so P becomes unavailable. Acidic soil (low pH), soluble P will react with Al and Fe and other hydrous oxides that form Al-P and Fe-P compounds which are relatively insoluble, so that P cannot be absorbed by plants [9].

### 3.2.3. Potassium

The results of the Potassium analysis are in the range of 2.27 - 68.08 mg / 100 g. The availability of K is closely related to soil minerals at the study site. The K element in the research location is the result of weathering from the type 2: 1 clay mineral, namely mica. In addition, the occurrence of K-feldspar weathering that occurs and more weathering is slower than mica. The variation of K values in the study location is due to the weathering of the soil, the results of weathering level analysis show that the soil in the research location is in moderate to advanced weathering, so moderately weathered soils contain high K whereas highly weathered soils low K levels.

### 3.2.4. Cation Exchange Capacity (CEC)

The soil CEC value in the study location ranged from 15.20 - 49.23 cmol. Kg\(^{-1}\), classified as low to high. This is because sand fractions and clay fractions dominate the soil constituent particles in the study location. The sand fraction has a small colloidal surface area, so the soil CEC is also low whereas the clay fraction has a large colloidal surface area so that the soil CEC is also high. CEC is also closely related to soil pH. Most of the researched land has a slightly acidic pH so that it affects the value of soil CEC. The amount of soil CEC is influenced by the nature and characteristics of the soil, including soil pH, texture or amount of clay, and types of clay minerals and organic matter [10].

|   | Cultivation |   |   |   |   |   |   |   |
|---|-------------|---|---|---|---|---|---|---|
| 11 | Rice field  | 5.61 | 4.36 | 2.81 | 0.30 | 27.94 | 56.6 | 54.98 |
| 12 | Rice field  | 6.04 | 7.66 | 1.33 | 0.19 | 65.94 | 15.16 | 32.28 |
| 13 | Rice field  | 5.88 | 4.71 | 1.03 | 0.14 | 70.38 | 10.29 | 44.24 |
| 14 | Rice field  | 6.46 | 7.92 | 0.81 | 0.12 | 49.88 | 17.86 | 15.39 |
| 15 | Rice field  | 6.09 | 4.36 | 2.23 | 0.19 | 31 | 4.14 | 19.75 |
| 16 | Shrubs      | 5.87 | 4.42 | 2.17 | 0.24 | 34.62 | 3.27 | 23.72 |
| 17 | Shrubs      | 5.87 | 4.42 | 2.17 | 0.24 | 34.62 | 3.27 | 23.72 |
| 18 | Shrubs      | 6.09 | 4.36 | 2.23 | 0.19 | 34.62 | 3.27 | 23.72 |
| 19 | Shrubs      | 6.09 | 4.36 | 2.23 | 0.19 | 34.62 | 3.27 | 23.72 |

The results of the laboratory analysis showed that the total N content of the land in the study area ranged from 0.11% - 0.36% classified as low to moderate. These results are related to vegetation, which contributes to soil organic matter and has not been entirely decomposed so that it is similar to organic carbon results in low to moderate research locations. According to [7], the layer of tillage generally contains 0.02 - 0.40% N. The N content of this soil depends on its environmental conditions such as climate and type of vegetation. The growing vegetation and the speed of the decomposition reaction are factors that cause changes in the N content in the soil.

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3.2.5. Base Saturation
The base saturation value is a percentage of the total cation exchange capacity consisting of base cations, namely potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na). The results of laboratory analysis showed differences in the value of Base Saturation in each land use, which ranged from 9.52% - 57.50% with very low to moderate criteria.

Base saturation is determined by the number of base cations and soil pH. Soil pH with base saturation is positively related, meaning that the soil pH is higher, the base saturation is high too, and vice versa, if the soil pH is low then base saturation is also low [11].

3.3. Soil Texture
Soil texture analysis in the laboratory shows that in the research location generally the class texture of silty clay loam. The silt fraction is relatively more compared to the clay fraction, while the clay content is less than the silt fraction.

| SPT | Land use         | Slope | Texture | Criteria of Texture |
|-----|------------------|-------|---------|---------------------|
|     |                  | %     | Sand    | Silt    | Clay    |                     |
| 1   | Secondary forest | 0-8   | 14      | 45      | 41      | Silty clay          |
| 2   | Secondary forest | 16-25 | 41      | 51      | 8       | Silty loam          |
| 3   | Secondary forest | 26-40 | 57      | 29      | 14      | Sandy loam          |
| 4   | Secondary forest | 8-15  | 10      | 46      | 44      | Silt clay           |
| 5   | Plantation       | 0-8   | 15      | 46      | 39      | Silty clay loam     |
| 6   | Plantation       | 15-26 | 16      | 52      | 32      | Silty clay loam     |
| 7   | Plantation       | 8-15  | 10      | 31      | 59      | Clay                |
| 8   | Cultivation      | 0-8   | 11      | 43      | 46      | Silty clay          |
| 9   | Cultivation      | 8-15  | 6       | 44      | 50      | Silty clay          |
| 10  | Cultivation      | 16-25 | 53      | 31      | 16      | Loam                |
| 11  | Cultivation      | 26-40 | 17      | 55      | 28      | Silty clay loam     |
| 12  | Rice field       | 16-25 | 16      | 44      | 40      | Silty clay loam     |
| 13  | Rice field       | 8-15  | 12      | 54      | 34      | Silty clay loam     |
| 14  | Rice field       | 26-40 | 16      | 44      | 40      | Silty clay loam     |
| 15  | Rice field       | 0-8   | 10      | 24      | 66      | Clay                |
| 16  | Shrubs           | 26-40 | 25      | 29      | 46      | Clay                |
| 17  | Shrubs           | 8-15  | 1       | 92      | 7       | Silt                |
| 18  | Shrubs           | 16-25 | 13      | 53      | 34      | Silty clay loam     |
| 19  | Shrubs           | 0-8   | 9       | 47      | 44      | Silty clay          |

The silt fraction dominates the texture at the research site. The high silt content in the location of this study is thought to be a weathering process from coarse materials to more exceptional materials. Sand fractions, especially fine sand, dominate the land use of the secondary forest. The soil which is dominated by sand fraction generally does not have plastic and sticky properties and has the water holding capacity to low. According to [12], sand is a separate item that stands alone and acts as a soil skeleton. The sand fraction has a characteristic that is a small surface area so that its role is minimal in the event of a chemical reaction, has macro pores, so that aeration runs smoothly and also has the water holding capacity is low.
3.4. Evaluation of Soil Fertility

The assessment of soil fertility status in this study was based on technical guidelines for evaluating soil fertility from the Soil Research Center. In evaluation, some parameters are used as a reference, namely soil CEC, base saturation, organic matter, and P available.

Table 3. Soil Fertility Status in Research Site

| SPT | Land use     | Slope   | Soil fertility Status |
|-----|--------------|---------|-----------------------|
| 1   | Secondary forest | 8-15%   | Moderate              |
| 2   | Secondary forest | 16-25% | Low                   |
| 3   | Secondary forest | 0-8%   | Low                   |
| 4   | Secondary forest | 26-40% | Low                   |
| 5   | Plantation    | 15-26% | Low                   |
| 6   | Plantation    | 0-8%   | Moderate              |
| 7   | Plantation    | 8-15%  | Low                   |
| 8   | Cultivation   | 26-40% | Low                   |
| 9   | Cultivation   | 0-8%   | Low                   |
| 10  | Cultivation   | 8-15%  | Low                   |
| 11  | Cultivation   | 16-25% | Low                   |
| 12  | Rice field    | 8-15%  | Low                   |
| 13  | Rice field    | 26-40% | Low                   |
| 14  | Rice field    | 16-25% | Low                   |
| 15  | Rice field    | 0-8%   | Low                   |
| 16  | Shrubs        | 0-8%   | Low                   |
| 17  | Shrubs        | 26-40% | Low                   |
| 18  | Shrubs        | 8-15%  | Low                   |
| 19  | Shrubs        | 16-25% | Low                   |

Soil fertility status is a condition of soil fertility at a specific place and time that is assessed based on the standard criteria of soil fertility parameters by the Technical Guidelines for Evaluating Soil Fertility [13].

Based on soil fertility analysis, the location of the study showed that the soil fertility rate was mostly low, except for secondary forests (8-15% slope) and gardens (0-8% slope) with moderate criteria. The limiting factors are low soil C-organic values and low P-total soil. Low soil P content indicates a low content of organic matter and minerals that contain P elements so that the total P-content of the soil is low. According to [14], P in the soil comes from the results of mineral disintegration containing P and decomposition of organic matter. The low C-organic content in the study site is caused by low soil organic matter due to the reluctance of farmers to add organic fertilizer in their farming practices and lack of knowledge of farmers regarding fertilization.

3.5. Direction for Managing Soil Fertility

In general, the constraints encountered in each unit of land in the study location are the limiting factor P and carbon organic. Management alternatives that need to be done are fertilizing and adding organic matter. Fertilization is preferred, which is phosphorus. Fertilization and addition of organic materials are routinely carried out so that soil fertility in the research location can be maintained well and can be sustainable. Addition of organic matter to the soil can also increase the availability of P elements, as seen from the role of soil organic matter, which can reduce the absorption of P, increasing the amount of organic P. In line with [14], which states that the administration of organic matter to the soil can increase the P content for plants. Organic matter has a role that is the formation of organophosphate...
complexes, alternation of H$_2$PO$_4^-$ anions, coating Fe/Al oxide by humus and reducing P uptake and increasing the amount of mineralized organic P to inorganic P.

Figure 4 Map of soil fertility in the research area

P fertilization is essential for land units with low P status to replace P elements transported by plants and increase P levels in the soil. In addition to fertilizing P, the research location also requires the addition of organic material in its fertilization efforts, in addition to improving soil quality as well as avoiding declining organic matter through decomposition and mineralization. According to [7] that the content of organic matter in the form of carbon organic in the soil must be maintained no less than 2 percent. The addition of organic matter at the time of soil management is necessary every year so that the ability of the soil to maintain soil fertility and productivity is maintained. The critical role of adding ingredients is to increase soil fertility. According to [6], the role of organic matter in the soil is to form granulations in the soil and to form stable soil aggregates.

4. Conclusion
The results of observations in the Ciemas Subdistrict, Sukabumi, have several uses of agricultural land, namely moor, fields, mixed gardens, plantations, and secondary forests. Vegetation, in general, is food crops, fruits, and annual crops. Soil fertility status at the study site shows the criteria of moderate to low with limiting factors P (phosphorus) and carbon organic soil. One of the land management that needs to be done is the addition of organic material and phosphorus fertilization, to increase soil fertility to be sustainable.
References

[1] D M Schiller 2018 *Eocene submarine fan sedimentation in Southwest Java.*

[2] C Solihin, A Taufik, F H Muhamad and R Denya 2018 Studi Geofisika Untuk Menentukan Batas Formasi Jampang dan Formasi Ciletuh di Kawasan Geopark Ciletuh (Wahana Fisika)

[3] A Yamani 2010 Kajian Tingkat Kesuburan Tanah Pada Hutan Lindung Gunung Sebatang Di Kabupaten Kotabaru Kalimantan Selatan J. Hutan Tropis.

[4] J L Havlin, J D Beaton, S L Tisdale and W L Nelson 1999 *Soil Fertility adn Fertilizers: An Introduction to Nutrient Management* (Soil Fertility and Fertilizers)

[5] S W Buol, R J Southard, R C Graham and P A McDaniel 2011 *Soil Genesis and Classification: Sixth Edition.*

[6] A Rosmarkam and N W Yowono 2002 *Ilmu Kesuburan Tanah* (Kanisiun)

[7] I W Suarjana, A A N Supadma and I D M Arthagama 2015 Kajian Status Kesuburan Tanah Sawah Untuk Menentukan Anjuran Pemupukan Berimbang Spesifik Lokasi Tanaman Padi Di Kecamatan Manggis vol 4 no 4 pp 314–323

[8] M Zulkarnain, B Prasetya and Soemarno 2013 Pengaruh kompos, pupuk kandang, dan custom bio terhadap sifat tanah, pertumbuhan dan hasil tebu (saccharum officinarum L.) pada entisol di kebun Ngrakah-Pawon, Kediri. Indonesian Green Technology Journal.

[9] A Rahmi and M P Biantary 2014 Karakterisik Sifat Kimia Tanah dan Status Kesuburan Tanah Lahan Pekarangan dan Lahan Usaha Tani beberapa Kampung di Kabupaten Kutai Barat Ziraa’ah vol 39 no 1 pp 30–36

[10] P Pusat and T Lingkungan 2009 Tingkat Kesuburan Tanah Ultisol Pada Lahan Pertambangan Batubara Sangatta vol 10 no 3 pp 337–346

[11] P W Birkeland 1985 *Soils and Geomorphology* (Geological Magazine)

[12] K D Susila 2013 Studi Keharaan Tanaman dan Evaluasi Kesuburan Tanah di Lahan Pertanaman Jeruk Desa Cenggiling , Kecamatan Kuta Selatan vol 3 no 2 pp 13–20

[13] B B Santoso 2011 *Dasar-dasar hortikultura*

[14] S Puniindoong, W J N Kumolontang and R I Kawulusan 2017 *Respon Tanaman Bayam* (Agroekoteknologi, Jurusan Tanah, Fakultas Pertanian, Universitas Sam Ratulangi)