Evaluation of soil fertility: a case study in Aceh Besar district

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Abstract. Plant growth requires nutrients and their functions in plants cannot be replaced by other elements so that if there are not enough nutrients in the soil, plants cannot grow normally. The nutrient content in the soil and the ability of the soil to provide nutrients for plant growth is different. So that the type of fertilizer and the amount of fertilizer given to each type of soil will be different and it depends on the type of plant being cultivated. To determine the requirements of fertilizers and the types of fertilizers required for each type of soil, need some research about the evaluation study of soil fertility. The research was conducted in Aceh Besar with located between 5° 2’ -5° 8’ N and 95°80’- 95° 88’E. Assessment of soil fertility status based on the criteria of several soil chemical properties, CEC (cation exchange capacity), alkaline saturation, C-Organic, P2O5 (HCL, 25%) mg / 100g, and K2O (HCL, 25%) mg / 100g. The analysis results obtained from 11 sample points show that Aceh Besar has soil fertility status from medium to low.

1. Introduction

Plant growth is related proportionally to soil fertility. According to [1], soil fertility is the ability of the soil to provide essential nutrients in available forms and in an appropriate balance. The decrease in soil fertility can be seen from the loss of soil nutrients and can occur due to the process of harvesting results in plants (nutrient absorption/nutrient harvesting), runoff, and leaching. Nutrient loss caused by the absorption process depends on the amount of production and the way of absorption in plants [2],[3].

Based on the amount needed for plant growth, nutrients are divided into macronutrients and micronutrients. Macronutrients are nutrients needed in large amounts (0.1% - 5%) such as C, H, O, N, P, K, Ca, Mg, and S, while micronutrients are required nutrients, plants in small quantities, namely 0.025%, among others, Fe, Mn, B, Mo, Cu, Zn, Cl, and Co [4]. The nutrient content in the soil and the ability of the soil to provide nutrients for plant growth vary. So that the type of fertilizer and the dose of fertilizer given for each type of soil will also be different and very dependent on the type of plant being cultivated. To find out the need for the dose of fertilizer and the type of fertilizer needed for each type of soil, it is necessary to conduct an evaluation study of soil fertility. Evaluation of soil fertility is a way to diagnose nutrients in the soil, evaluation of soil fertility is also important to...
determine the status of soil fertility in agricultural land, according to [5] various types of land use can affect soil fertility.

Soil fertility status assessment is important for assessing and monitoring soil fertility in order to identify the nutrient constraint for plants[6]. Determination of soil fertility status is aimed at assessing soil characteristics and determining the main obstacles to soil fertility. The main obstacle to soil fertility can be minimized by providing alternative management of soil fertility in an effort to increase soil productivity [7].

2. Materials and methods

The research was conducted in Aceh Besar with the location located between 50 2’ - 50 8’ North Latitude and 95°80’ - 95° 88’ East Longitude and survey activities, research data collection. Nutrient analysis was carried out at the Soil Chemistry Laboratory, Soil Science Study Program, Faculty of Agriculture, Syiah Kuala University.

The tools used in this research are (1) a soil sampling device, (2) GPS (Global Positioning System). The materials used in this study were (1) 11 soil samples from several lands use, (2) Administration Map 1:50,000 scale (from BAPEDDA Banda Aceh), (3) Soil type map at 1:25,000 scale (from BAPEDDA Banda Aceh), (4) Map of land use scale 1:25,000 (from BAPEDDA Banda Aceh ), and (5) Map of slope scale 1:25,000. This research went through several stages, namely preparation and sampling of soil, determination of soil fertility status.

3. Results and discussion

3.1 Evaluation of soil fertility status

Soil fertility status is necessary to determine whether an agriculture business can be categorized as having low to high nutrients. Based on Table 1, there are several criteria that can be considered as an assessment of the value or status of soil fertility, namely [6]:

- If the CEC/BS is high, and P2O5/K2O/C-Organic is high or medium without being low, the soil fertility status is high. However, if there is at least one low P2O5/K2O/C-Organic, then the soil fertility status is medium. If CEC is high, BS is medium, and P2O5/K2O/C-Organic is high with a maximum of one being medium, the soil fertility status is high. However, if P2O5/K2O/C-Organic is high with a maximum of one being low or medium with a maximum of one being high, the soil fertility status is medium. Apart from this combination, the soil fertility status is low.
- If the CEC is low, BS is high, and P2O5/K2O/C-Organic is high or medium without being low, the soil fertility status is medium. However, if P2O5/K2O/C-Organic is low or there are other combinations, the soil fertility status is low.

In addition, from this combination, the soil fertility status is low. If the CEC/BS is medium, and P2O5/K2O/C-Organic is high with a maximum of one being medium or low, the soil fertility status is medium. In addition, from this combination, the soil fertility status is low. If the CEC is medium, BS is low, and P2O5/K2O/C-Organic are all high, then the soil fertility status is medium. In addition, from this combination, the soil fertility status is low. If the CEC is low, BS is high, and P2O5/K2O/C-Organic is high or medium without being low, the soil fertility status is medium. However, if P2O5/K2O/C-Organic is low or there are other combinations, the soil fertility status is low. If the CEC is low, the BS is medium, and the P2O5/K2O/C-Organic is high with a maximum of one being medium, the soil fertility status is medium. In addition, from this combination, the soil fertility status is low. If the CEC/BS is low, and P2O5/K2O/C-Organic are all combinations, the soil fertility status is low.

The existence of information on the status or level of soil fertility is expected to be taken into consideration in the context of soil conservation efforts that will be carried out by various interested parties [8]. Agricultural business depends on soil fertility, soil with low fertility levels will increase
higher inputs so that the cost of farming will be more expensive. Therefore, soil characteristics and quality are important factors in agricultural development [9].

The results of the measurement of soil fertility parameters and soil fertility status in the study are presented in table 1.

a. Cation exchange capacity (CEC)

Cation exchange capacity is a chemical property of soil that is closely related to soil fertility. If the CEC of the soil is high, the soil is able to absorb and provide nutrients better than the soil that has a low CEC value. The cation exchange capacity or CEC is influenced by several factors, such as the type and number of clay particles that make up the soil, the texture, and the content of soil organic matter. Based on the results of the analysis of the soil samples shown in Table 1, shows that samples with numbers P1, P2, P12, and P8 have high CEC values. While the sample with numbers P3, P4, has a medium CEC.

b. Base saturation (BS)

The soil reaction that shows the acidity and alkalinity of a research soil. In general, nutrients in the soil can be absorbed by plants in neutral conditions. Too low a pH in the soil will cause plants to become poisoned. Base saturation in the research area is classified as very low to high, ranging from 14.12% - 52.50%. High base saturation was obtained in fields P2 and P8, while low base saturation was found in fields P5, P6, P11, and very low base saturation in fields P3 and P4.

c. Soil C-organic content

If the organic C content in the soil is low, it indicates that the production of organic matter from the sample or agricultural land is low. The results of the analysis show that Aceh Besar district has very low to low organic C levels in the soil ranging from 0.08% - 1.31%.

d. Soil Phosphorus Content

The phosphorus content in the research soil samples was classified as very low to very high ranging from 0.24 (HCl, 25%) mg/100g - 71.20% (HCl, 25%) mg/100g. Phosphorus content in the soil as affected by pH. According to [8], phosphorus is a macronutrient needed by plants in large quantities, the function of phosphorus is to stimulate root growth, accelerate flowering, and fruiting. While in the soil the available phosphorus is less than the nitrogen and potassium nutrients.

e. Soil potassium content

Potassium is the third important element after N and P. Potassium functions to improve the photosynthesis process, increase plant resistance to disease, and make stems stronger. The larger CEC was able to hold K. Potassium content in the research soil was low to very high ranging from 0.24 (HCl, 25%) mg/100g to 71.20 (HCl, 25%) mg/100g.

Based on the results of the evaluation of soil fertility status, Aceh Besar Regency has a low soil fertility status, so it is recommended to add fertilizer to increase crop yields. The low status of soil fertility in the study area is due to the low organic C content of the soil. Soil organic C content can be maintained by applying mulch, for example from straw, compost, and manure.

3.2 Intruction on management of research areas

Based on the results obtained, it can be said that for areas with medium fertility status of more than 75% - 100% of plant yields that can be expected without the potential for adding nutrients, a small part is no doubt with fertilization to increase crop yields. While the status of low soil fertility is more than 50% - 75% of the potential crop yields that can be expected without the addition of nutrients, some of the needs are not added with fertilization in order to increase crop yields [6]. The results of the analysis showed that the average C-Organic content in the study area was very low. The content of C - Organic indicates the ability of soil to maintain soil fertility and productivity and is a central element.
in soil fertility, land productivity, and land quality[10]. According to research conducted by [11], soil types on dry land in Aceh Besar District are generally included in soils that are not suburban. In addition to CEC and C Organic content, base saturation with soil fertility. The following is shown in Figure 1 regarding the Map of Land Units and Soil Fertility Status in Aceh Besar District.

![Figure 1. Map of land units and location of sample points for aceh besar district.](image)

In the research area sample, Aceh Besar District has several types of soil: Litosol, Podsolic, Alluvial Soil, Latosol and Andosol and the chemical characteristics of the soil vary according to the type of soil. Overall, based on the analysis, it can be seen that the values of CEC, P2O5 and K2O in the study area vary from high to low values, with an average base saturation level of low value and the value of C Organic content very low. The direction to Aceh Besar District is that fertilization is needed so that crop yields can increase. Fertilization must be carried out appropriately on various plant varieties. Soil must contain organic nutrients, inorganic nutrients, water and air to support soil fertility [12-15].
| No | Sample | Parameter | Value      | Criteria | Status    | Location  |
|----|--------|-----------|------------|----------|-----------|-----------|
| 1  | P1     | CEC (me/100 g) | 25.20      | High     | Medium    | Alue Gintong |
|    |        | Base Saturation (%) | 46.51      | Medium   |           |           |
|    |        | Soil C-organic Content (%) | 0.80       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 182.16     | Very High|           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 71.20      | Very High|           |           |
| 2  | P2     | CEC (me/100 g) | 26.40      | High     | Medium    | Lamnga    |
|    |        | Base Saturation (%) | 52.50      | High     |           |           |
|    |        | Soil C-organic Content (%) | 0.08       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 27.60      | Medium   |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 22.40      | Medium   |           |           |
| 3  | P3     | CEC (me/100 g) | 20.40      | Medium   | Low       | Panca     |
|    |        | Base Saturation (%) | 17.45      | Very Low |           |           |
|    |        | Soil C-organic Content (%) | 1.18       | Low      |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 34.96      | Medium   |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 61.60      | Very High|           |           |
| 4  | P4     | CEC (me/100 g) | 20.40      | Medium   | Low       | Cot Jambo |
|    |        | Base Saturation (%) | 14.12      | Very Low |           |           |
|    |        | Soil C-organic Content (%) | 0.63       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 15.56      | Low      |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 18.40      | Low      |           |           |
| 5  | P5     | CEC (me/100 g) | 12.00      | Low      | Low       | Pudeng    |
|    |        | Base Saturation (%) | 26.33      | Low      |           |           |
|    |        | Soil C-organic Content (%) | 0.29       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 44.16      | High     |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 0.24       | Very Low |           |           |
| 6  | P6     | CEC (me/100 g) | 15.60      | Low      | Low       | Aweek     |
|    |        | Base Saturation (%) | 28.85      | Low      |           |           |
|    |        | Soil C-organic Content (%) | 0.91       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 29.16      | Medium   |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 0.24       | Very Low |           |           |
| 7  | P7     | CEC (me/100 g) | 11.60      | Low      | Low       | Ladong    |
|    |        | Base Saturation (%) | 45.17      | Medium   |           |           |
|    |        | Soil C-organic Content (%) | 0.34       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 7.36       | Very Low |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 28.80      | Medium   |           |           |
| 8  | P8     | CEC (me/100 g) | 28.80      | High     | Medium    | Data Makmur|
|    |        | Base Saturation (%) | 52.36      | High     |           |           |
|    |        | Soil C-organic Content (%) | 1.17       | Low      |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 25.76      | Medium   |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 59.20      | High     |           |           |
| 9  | P9     | CEC (me/100 g) | 10.00      | Low      | Low       | Alue Gintong|
|    |        | Base Saturation (%) | 35.60      | Medium   |           |           |
|    |        | Soil C-organic Content (%) | 0.79       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 8.10       | Very Low |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 14.40      | Medium   |           |           |
| 10 | P10    | CEC (me/100 g) | 11.60      | Low      | Medium    | Pudeng    |
|    |        | Base Saturation (%) | 42.41      | Medium   |           |           |
|    |        | Soil C-organic Content (%) | 0.29       | Very Low |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 44.16      | High     |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 3.92       | Very Low |           |           |
| 11 | P11    | CEC (me/100 g) | 12.00      | Low      | Low       | Bira Cot  |
|    |        | Base Saturation (%) | 25.75      | Low      |           |           |
|    |        | Soil C-organic Content (%) | 1.31       | Low      |           |           |
|    |        | P₂O₅ (Hcl, 25%) mg/100g | 5.52       | Very Low |           |           |
|    |        | K₂O (Hcl, 25%) mg/100g | 3.68       | Very Low |           |           |

*Source: Analysis source, 2021*
4. Conclusions
Based on the results of research and discussions that have been carried out, it can be concluded:
Several types of soil in the study area, Litosol, Podsolic, Alluvial Soil, Latosol and Andosol and the chemical characteristics of the soil vary according to the type of soil. Overall, through the analysis, it can be seen that the values of CEC, P2O5 and K2O in the study area vary from high to low values, with an average base saturation level of low value and very low Organic C. Soil organic content is an obstacle to soil fertility status in the study area. The analysis results obtained from 11 sample points show low to moderate soil fertility in the case study in Aceh Besar District. Based on the results of the evaluation of soil fertility, it was concluded that fertilization was needed to increase crop yields.

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