Soil fertility status in tidal land of Tirtomarto reservoir, Central Java, Indonesia

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Abstract. Reservoir tidal land used for agriculture is generally done when the reservoir water level begins to shrink. This land is used as a moor in dryland or lowland rice fields in the wetland. The purpose of the study was to determine the soil fertility status of the tidal land of the Tirtomarto reservoir, Central Java. Parameters tested include cation exchange capacity (CEC); base saturation (BS); C-Organic; total soil P and K levels according to the technical instructions for evaluating soil fertility. Soil samples were taken from three location points by the purposive sampling method. The results showed that most of the soil samples contained low to very low nutrients, except for the total P content which had a high value. Therefore, the fertility status in the tidal land of the Tirtomarto reservoir, Central Java, can be categorized as low. The low fertility status of the soil at the study site was due to the limiting factors, namely the low C-organic content of the soil, low K total soil, and low cation exchange capacity and base saturation.

1. Introduction
Reservoir tidal land is formed from reservoir sedimentation and during the rainy season, they will always be submerged in water. The state and nature of tidal reservoirs are different from those on the coast. Reservoir tides are annual tides resulting from fluctuations in reservoir water level [1]. This land will dry up and open up as the reservoir water shrinks. This opportunity is used by farmers to expand their agricultural land by utilizing land at the bottom of the reservoir and close to the reservoir water source. This, of course, will result in differences in the quality and characteristics of tidal land with irrigated land or dry land which is commonly known by farmers [2].

The properties and characteristics of tidal land include inundation, peat layer, sulfidic material which, when oxidized, will lower the soil pH to very acidic, followed by the appearance of toxic substances (Al and Fe), high salinity (seawater intrusion), and low soil fertility and in dry conditions in the dry season there will be a process of pyrite oxidation in the soil-forming sulfate compounds which can lower the soil pH to very acidic. While the social aspects are the low level of education, limited manpower, capital, and facilities.

Based on the nature and characteristics of the tidal land, one of the obstacles faced in agriculture in tidal land is the low level of land fertility [3]. Soil conditions and management are important factors that will determine the growth and yield of cultivated plants. Soil is a growing medium for plants, and contains the necessary nutrients. Based on the particle size, soil is a mixture of sand, silt, and clay. The
finer the particles, the larger the surface area of the particle per unit weight. Clay is the soil fraction with the largest surface area compared to the other two fractions. Various chemical reactions that occur in the soil are located on the surface of these particles which will then affect the fertility of soil [4].

One way that is often used in assessing the fertility of the soil is by soil analysis or soil testing. Soil analysis is one way to assess nutrient status in assessing nutrient fertility, which has the concept that plants will respond to fertilization if the nutrient content is lacking or the amount available is not sufficient for optimal growth so that from this analysis fertilization recommendations will be obtained. Soil analysis can be carried out in the laboratory or directly in the field with the Swamp Soil Test Equipment [5]. There are five soil fertility parameters used in this study to assess soil fertility status, namely CEC; KB; C-organic; P and K levels of total soil according to technical guidelines for evaluating soil fertility. This study aims to determine the status of soil fertility in the tidal land of the Tirtomarto reservoir, Central Java, Indonesia.

2. Method

2.1. Location and time
Sampling was carried out from September to November 2019 in an area of the tidal land, Tirtomarto Reservoir. The research location is in Delingan Village, Karanganyar District, Karanganyar Regency, Central Java Province. Tirtomarto reservoir is located at coordinates 07° 35' 17.94" South Latitude and 110° 59' 11.56 East Longitude at an altitude 237 meters above sea level.

![Figure 1. Map of research location](image)

2.2. Data collecting methods
The research includes two main activities, namely soil sampling and soil analysis in the laboratory. Soil samples were taken using random and purposive sampling methods. The soil was taken at a depth of 0-30 cm (topsoil). Three sampling locations represented five sub-samples to then be composited into soil samples. The point of collection location was adjusted to the distance of the point from the area that is still inundated. This is because areas that are still inundated have an increased fertility rate due to the accumulation of nutrients due to water immersion [1]. The sample points were:

a. Location point 1 is a sample point 10 meters from the inundated area
b. Location point 2 is a sample point located 5 meters from the inundated area
c. Location point 3 is a sample point within 0.5 meters from the inundated area
3. Result and discussion

3.1. Physical condition of tidal land Tirtomarto reservoir

Generally, tidal reservoirs have a topography in the form of soil conduction with various slopes. With the existence of tidal and low tide movements in the reservoir, this area will become an increasingly sloping area. Soil is defined as a material consisting of solid mineral aggregates (granules) that are not bound to each other (chemically bonded) and decomposed organic matter [6]. The soil at the bottom of the reservoir is the result of deposition from the accumulation of suspended materials that enter along with the flow of reservoir filling water [7].

According to the National Land Agency of Karanganyar Regency, the type of soil in Karanganyar District is included in the latosol soil category. This also applies to the soil in the tidal land of the Tirtomarto Reservoir, because before the reservoir was built, the original land was of the latosol type. This soil is an old type of soil that is created from flint that undergoes further erosion. This soil is acidic, has low to moderate organic matter content, is red to yellow, and has a clay structure. However, it is possible that the soil in the tidal area of the reservoir also accumulates from sediment carried by water.

Soil texture shows the roughness of the soil [8]. Soil texture is the ratio between grains of sand, silt, and clay. Soil textures are grouped into 12 texture classes. The twelve texture classes are distinguished based on the percentage content of sand, silt, and clay. The following is a table of soil texture at the research site.

| Sample code | Fraction (%) | Texture |
|-------------|--------------|---------|
|              | Sand  | Silt  | Clay |
| Point-1      | 10    | 17    | 73   | Clay |
| Point-2      | 9     | 22    | 69   | Clay |
| Point-3      | 12    | 29    | 59   | Clay |

The results show that the soil texture in the tidal land of Tirtomarto Reservoir is dominated by clay texture. The characteristics of clay textured soils are >35% ability to store water and high soil nutrients, the existing water is absorbed with high energy, so the availability of water is sufficient for plant needs [9].

3.2. Soil chemical analysis result

3.2.1. Cation exchange capacity (CEC). The cation exchange capacity of the soil is the amount of negative charge of the soil both originating from the surface of inorganic colloids (clay) and organic colloids (humus) which are cation-exchange sites. Soil organic matter, although depending on the degree of humification, has the highest CEC compared to clay colloids [4]. The CEC value in the research location has medium and low criteria.

| Sample code | CEC (cmol(+)/kg) | Criteria |
|-------------|------------------|----------|
| Point-1     | 15.03            | Low      |
| Point-2     | 17.62            | Medium   |
| Point-3     | 11.39            | Low      |

The low CEC value in tidal land of Tirtomarto Reservoir is caused by the low content of organic matter. With the decreasing content of organic matter soil, hummus (organic colloid) as a source of negative soil charge is also decreasing so that the positive charge (cations) in the soil that can be exchanged is also lower [10].
3.2.2. **Base saturation.** Base saturation value of soil is the percentage of the total cation exchange capacity occupied by base cations, namely the elements Ca, Mg, Na, and K. Base saturation value is very important to consider fertilization and predict the ease of nutrients available to plants. Base saturation shows the ratio between the number of all cations (acidic cations and basic cations) contained in the soil adsorption complex. Base cations are generally nutrients needed by plants [11]. The following is a table of base saturation values for tidal land of Tirtomarto reservoir.

**Table 3. Soil base saturation value tidal land of Tirtomarto reservoir**

| Sample code | Base Saturation (%) | Criteria |
|-------------|---------------------|----------|
| Point-1     | 24                  | Low      |
| Point-2     | 37                  | Low      |
| Point-3     | 31                  | Low      |

The base saturation value at the research site is included in the low criteria. The CEC value of the soil is usually directly proportional to the base saturation of the soil because base saturation is an illustration of the high number of cations in the colloidal soil complex [12]. Base saturation effects to soil pH. Soils with low pH generally have low base saturation, as well as soils with high pH have high base saturation (Table 4). Soils with low base saturation are dominated by acidic cations such as aluminum (Al) and hydrogen (H). If too much acid cations can cause poisoning to plants [13].

**Table 4. Soil pH of tidal land of Tirtomarto reservoir**

| Sample code | pH (%)   | Criteria    |
|-------------|----------|-------------|
| Point-1     | 5.25     | Acid        |
| Point-2     | 6.44     | Slightly acid |
| Point-3     | 6.70     | Neutral     |

The results of the analysis showed that the pH at the research site was acidic, slightly acidic, and neutral with a pH value of >5. Generally, nutrients are easily absorbed by plant roots at a neutral pH. Neutral pH makes nutrients easily soluble in water. Soil pH also affects the development of soil microorganisms. These microorganisms thrive at pH 5.5 or 8. If less than 5.5 the development of microorganisms will be inhibited. Meanwhile, fungi can thrive at all levels of soil acidity. Nitrogen-fixing bacteria from the air as well as other nitrifying bacteria can only thrive at a pH of more than 5.5 [14].

3.2.3. **Soil organic carbon.** Organic matter is a material that can be renewed, recycled, and remodeled by soil bacteria into elements that can be used by plants without polluting the soil and water [4].

**Table 5. Soil organic carbon of tidal land of Tirtomarto Reservoir**

| Sample code | Organic Carbon (%) | Criteria |
|-------------|--------------------|----------|
| Point-1     | 1.69               | Low      |
| Point-2     | 1.42               | Low      |
| Point-3     | 1.63               | Low      |

Indirectly, the low C-Organic content indicates the low production of soil organic matter in the study site. Soil organic matter is one of the parameters that determine soil fertility. One of the causes of the low organic C value at the study site is the transportation of crop residues outside the planting area because tidal land is in the reservoir. So that the rest of the harvest must be removed so as not to reduce the water storage capacity when the rainy season arrives.

3.2.4. **Phosphorus (Total-P)**

Phosphorus (P) is an important element in photosynthesis and root development. The availability of elemental phosphorus in rare earth piles is more than 0.01% of the total phosphorus. Most forms of phosphorus are bound by soil colloids so that they can’t be absorbed by plants [15].
Table 6. Soil total phosphorus value of tidal land of Tirtomarto Reservoir

| Sample code | Total P (mg/100g) | Criteria |
|-------------|-------------------|----------|
| Point-1     | 54                | High     |
| Point-2     | 47                | High     |
| Point-3     | 43                | High     |

At neutral pH conditions, the phosphorus content is at high criteria, this is because the ion exchange complex is dominated by alkaline cations due to a neutral pH conditions, so that nutrient exchange is quite effective because at neutral pH, the availability of nutrients is quite optimal [16]. The total P-value at the study site is a high criterion. In soils that have a low pH, the solubility of Al and Fe ions is relatively high so that it can fix P in the soil which causes poor plant growth. Element P is not easily lost from the soil due to the leaching process (except in very sandy soils) but is still adsorbed on the colloidal surface of the soil [17].

3.2.5. Total potassium (Total-K). Potassium has a valence of one and is absorbed in the form of K+ ions. Potassium is an element that plays a role in the transportation system in plant tissues [18]. Total potassium content in the soil is generally quite high and is estimated at 2.06% of the total weight of the soil, but the available potassium in the soil is quite low. Fertilization of nitrogen and phosphorus nutrients in large quantities also increases the absorption of potassium from the soil [19].

Table 7. Soil total potassium value of tidal land of Tirtomarto Reservoir

| Sample code | K-Total (mg/100g) | Criteria |
|-------------|-------------------|----------|
| Point-1     | 0.45              | Very low |
| Point-2     | 1.01              |          |
| Point-3     | 1.26              |          |

Total-K value of the soil in the research location is in the very low category. This is due to the nature of the element K which is easy to move in the soil, easily washed off by rainwater, and especially in soils with low cation exchange capacity (CEC). Potassium itself in its natural state usually has low availability, where this low potassium can occur due to several factors including the absorption of potassium by plants, leaching, and erosion [20].

3.3. Evaluation of tidal land of Tirtomarto reservoir fertility status

Soil fertility status is a condition of soil fertility in a certain place and at a certain time which is assessed based on standard criteria for soil fertility parameters. The results of soil fertility in tidal land of Tirtomarto Reservoir are presented in the following table.

Table 8. Soil fertility status classification of tidal land Tirtomarto reservoir

| Sample Code | CEC (cmol(+)/kg) | Base Saturation (%) | C-Organic (%) | Total P (mg/100g) | K-Total (mg/100g) | Fertility status |
|-------------|------------------|---------------------|---------------|-------------------|-------------------|-----------------|
| Point-1     | 15.03            | 24                  | 1.69          | 54                | 0.45              | Low             |
| Point-2     | 17.62            | 37                  | 1.42          | 47                | 1.01              |                 |
| Point-3     | 11.39            | 31                  | 1.63          | 43                | 1.26              |                 |

The low status of soil fertility in the study site was caused by factors including: low soil C-organic content, low total-K soil, and low cation exchange capacity and base saturation. The content of C-organic (organic matter) of the soil affects the ability of the soil to maintain fertility and productivity through the activity of soil microorganisms. The effect of organic matter on chemical properties can increase the negative charge so that it will increase the cation exchange capacity. Organic matter gives a significant value to the contribution to cation exchange capacity of soil. In general, as much as 20-70% of soil exchange capacity comes from humus colloids. So there is a correlation between organic matter and cation exchange capacity of soil. The effect of organic matter on biological properties can increase the activity and population of microorganisms in the soil, especially those related to the activity
of decomposing organic matter [21]. Organic matter can increase the base saturation of the soil. Organic matter in the form of hummus has a negative charge that can bind K+ so that the potential for potassium to undergo leaching is lower. Soil pH setting for acidic pH can be increased to alkaline that can be absorbed by plants. Therefore, knowing the status of soil fertility is very important, because it shows the ability of the soil to provide nutrients for plant growth.

4. Conclusion
In general, the status of soil fertility in the tidal land of the Tirtomarto Reservoir is low. Special treatment is needed such as fertilization and addition of soil nutrients so that they can be utilized for optimal agricultural land development. However, it should be noted that the tidal land is located within the reservoir area so it does not neglect the operational continuity of the Tirtomarto Reservoir.

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