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ORIGINAL ARTICLE

Electrical Conductivity of the Volcanic Soil on Fertilizer-Exposed Agricultural Field: A Case Study in Parompong, West Java

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Abstract

Parongpong, West Java, is an agricultural area with volcanic soil that has been cultivated for over a decade. Prolonged fertilizer application can alter soil properties, particularly electrical conductivity (EC). This study aims to investigate the impact of fertilizer exposure on soil conductivity using Huma EC technology. Measurements were conducted on agricultural land with long-term fertilizer application and non-agricultural land as a control. Data were collected using a 7×7 survey grid for agricultural land and a single 7-meter transect for non-agricultural land, with conductivity values derived from resistivity measurements based on the Wenner configuration. The results indicate that agricultural land exhibits higher conductivity values (1.44 to 15.11 mmhos/cm) compared to non-agricultural land (0.72 to 2.7 mmhos/cm), suggesting that accumulated fertilizer residues contribute to increased ion concentration. Topographical factors also influence conductivity distribution, with higher values observed in lower-elevation areas due to ion migration. The study demonstrates the effectiveness of Huma EC technology in capturing these variations, offering a rapid and non-invasive approach to assessing soil conditions.These findings provide valuable insights into soil electrochemical properties in volcanic agricultural regions. Future research should explore long-term conductivity changes, evaluate different fertilization practices, and integrate additional geophysical techniques to enhance soil health monitoring. The study contributes to the development of sustainable agricultural management strategies to mitigate soil degradation.

Keywords: volcanic agricultural, electrical conductivity, cation transfer capacity, fertilize exposed, HUMA-EC

Introduction

The agricultural sector is crucial for fulfilling a region's food requirements, frequently necessitating the use of materials like fertilizers to enhance output (Kunstyastuti et al., 2011) Nonetheless, the overuse of synthetic fertilizers can result in soil pollution. The research was conducted in

Parongpong farming area, Parongpong sub-district, including one of agriculture production centers potency in the West Bandung area (Ajidirman et al., 2010). Parongpong Lembang is one of the areas used for agricultural land of short-lived crops. Commodities produced on the farm are vegetables such as potatoes, cassava, corn, tomatoes, mustard, and chili.

Volcanic soil is soil that occurs from the weathering of volcanic rocks, either from stone that has been frozen or from volcano ash. The soil tuff occurs from volcanic ash and is very fertile. One part of the volcanic soil is the Andosols soil. Characteristics of Andosols soil one of them is brownish red to dark black. Andosols soil is perfect for agricultural and plantation areas. One West Java area with Andosols soil type is agricultural land in Lembang, Bandung. Ajidirman's research (Telford et al., 1990) on the volcanic ground of Mount Merapi and Singgalangan shows that the soil that develops from volcanic ash has a higher fertility rate than other areas (Rhoades et al., 1981).

The quality of soil is an essential element that affects crop yield and sustainability, where factors such as texture, moisture content, organic matter, and nutrient availability play a substantial role in plant development (Vasu et al., 2020). In recent times, geophysical techniques have attracted interest in agricultural studies due to their capacity to assess soil characteristics without disturbance. A significant measure, electrical conductivity (EC), has been extensively utilized to analyze soil traits, such as salinity, moisture content, and fertilizer contamination levels (Lumenta et al., 2017)

Huma EC is a tool that utilizes electrical properties to identify subsurface conditions using the same principles as geoelectricity. Previous studies have demonstrated its effectiveness in detecting variations things in soil, yet its application in fertilizer-exposed volcanic soils remains underexplored. Understanding the impact of fertilizers on soil conductivity is crucial, as excessive or imbalanced fertilizer application can lead to soil degradation and contamination (Theresa et al., 2020). This research presents an opportunity to investigate how different types and amounts of fertilizers influence EC readings, potentially leading to better management practices for sustainable agriculture in these unique soil environments.

Electrical Conductivity

Electrical conductivity is the ability of a material to carry an electric current which is generally expressed in units of millimeters per meter (mS / m). According to (Dennis et al., 2008), the electrical conductivity value of a material is inversely related to the electrical resistivity value, which can be mathematically written as follows:

$$\sigma=1/\rho \tag{1}$$

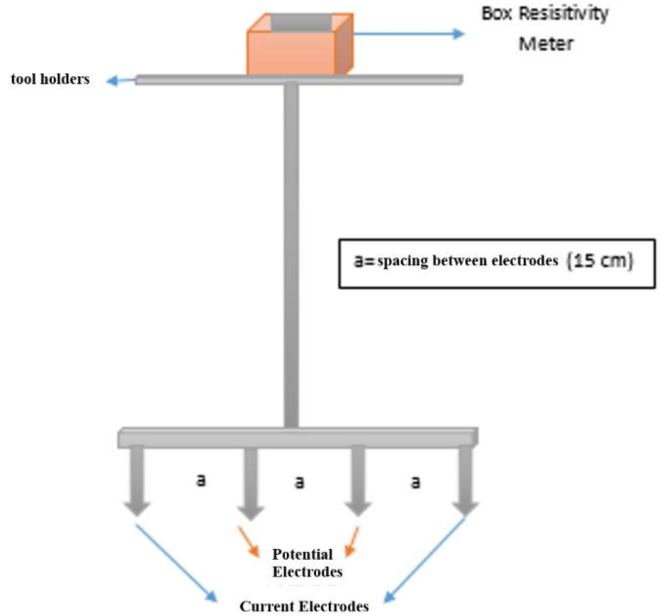
Where,
σ : Electrical conductivity ($\Omega-1$ or mS/m)
Ω : Electrical resistivity (Ωm)

Effect of Fertilization on Soil Conductivity

One of the most commonly used inorganic fertilizers is Sodium, Potassium, and Potassium (NPK). According to Eleonora et al., (2013) applying N, P, and K fertilizers can increase the Cation Transfer Capacity (CEC). The presence of cations with higher valency will increase the conductivity value. The content of acidic inorganic contaminants can dissolve substances that form the soil structure. Generally, if groundwater contains acid, conductivity values will also increase (Alfred et al., 2008).

HUMA EC Technology

Huma EC is a tool that utilizes electrical properties to identify subsurface conditions using the same principles as geoelectric. The Huma EC tool has three main components: box resistivity meter, tool handle, and electrode. Two multimeters work for current and voltage readings in the box resistivity meter component. There is also an injection button to inject the current into the ground.



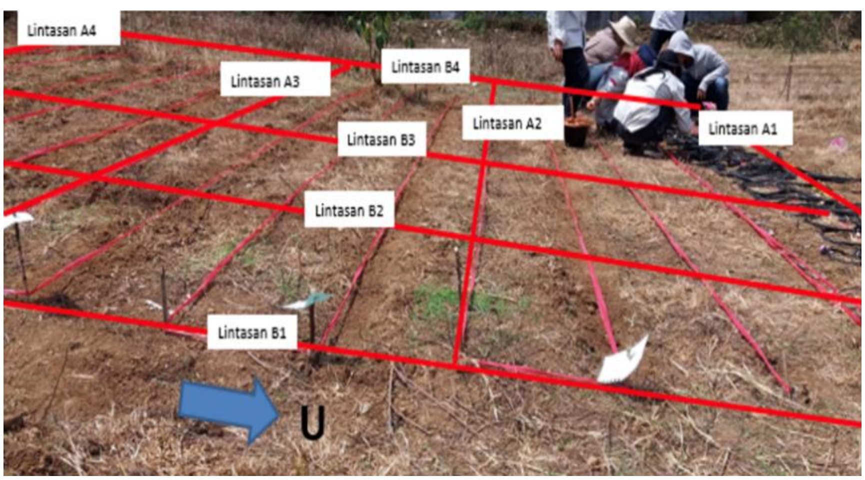


Figure 1. Survey area; survey was conducted using 8 line that forming grid. Line A1, A2, A3, A4 heading East-West and line B1, B2, B3, B4 heading North-South.

The distribution of conductivity values in the agricultural area was mapped using Surfer 12 software. Surfer is used to create contour maps by interpolating irregular XYZ data into a regular grid. The mapping process involved inputting field measurement data, where latitude and longitude coordinates formed the X and Y components, and the calculated conductivity values formed the Z component. This approach enabled the visualization of the spatial distribution of electrical properties in the study area.

Results and Discussion

The results indicate that the electrical conductivity (EC) of agricultural land is significantly higher than that of non-agricultural land. The conductivity values for agricultural land range from 1.44 to 15.11 mmhos/cm, whereas non-agricultural land exhibits values between 0.72 and 2.7 mmhos/cm. This can be seen in the graph displayed in (Figure 3). This disparity suggests that prolonged fertilizer application increases the concentration of dissolved ions, enhancing the soil's ability to conduct electricity. The highest conductivity values were observed in the northern region of the study area, likely due to the accumulation of residual fertilizers transported by surface runoff and infiltration.

Similar research has been conducted by A. Meddich (Meddich et al., 2020) who stated that the soil's electrical conductivity level before planting was lower than after harvesting. This indicates the accumulation of fertilizer deposits during the planting period. Meddich further emphasized that fertilizer application significantly influences the soil's electrical conductivity. The intensive provision of fertilizer causes characteristics of more conductive agricultural land over a long time. Adding NPK inorganic fertilizers can increase the value of CEC (Cation Exchange Capacity) caused by an increase in soil reaction rate (pH). An increase in pH may affect the electrical conductivity of the area.

Soil conductivity is mapped to show its distribution (Figure 4). High conductivity is situated northward of the survey area since the survey area is inclined from south to north. High conductivity occurred because the residue of inorganic fertilization accumulated in lower (north) areas.

Self-potential of soil was mapped to show polarization distribution (Figure 5). X indicated that high potential area correlated with high conductivity. Z suggested a rock water system since its self-potential had negative values. To confirm residue accumulation, the electrical flow of fluid in the soil (Figure 6) was calculated based on a gradient of potential and slope of water pressure in the ground. Electrical flow on the X (high potential area) discharged due to fluid flow from high potential to low potential. Electrical flow in the Z (rock water system area) is released due to fluid saturation (high pressure).

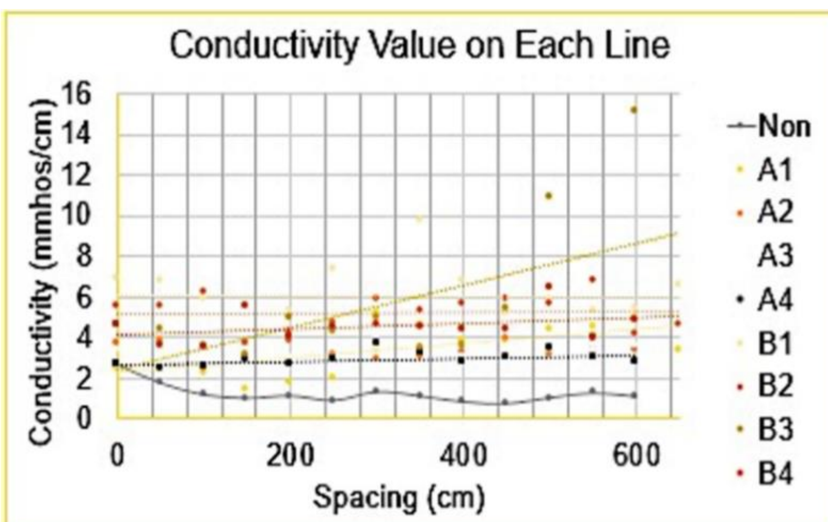


Figure 3. Conductivity value on each line. Conductivity on agricultural field had higher value compared to non-agricultural. It occurred when soil contaminated by fertilizer residue in long term.

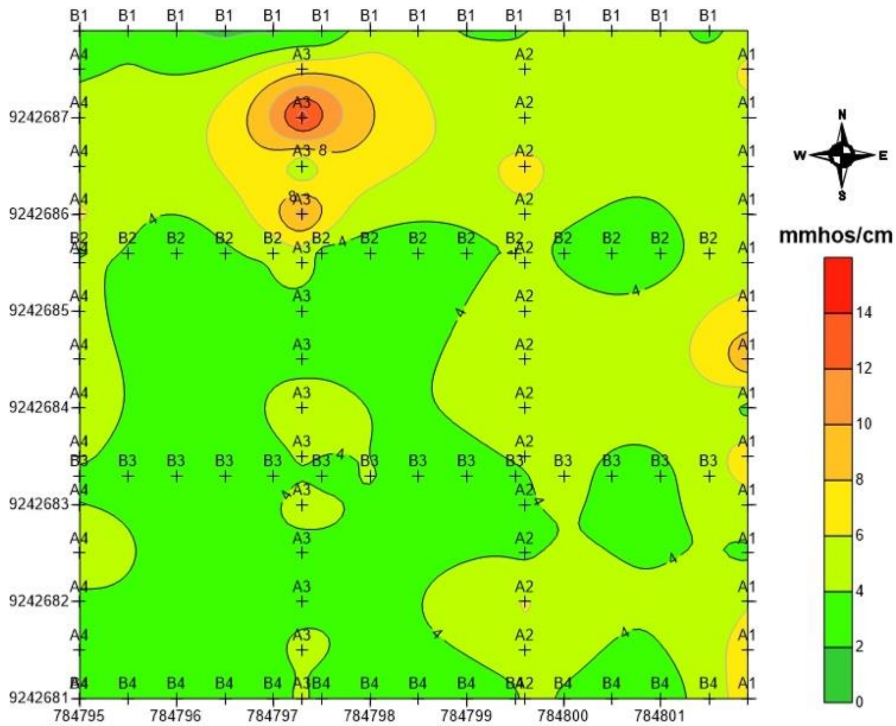


Figure 4. Soil conductivity map of survey area. Conductivity varies from 1.44 to 15.11 mmhos/cm. High conductivity situated on the northward of survey area since the survey area inclined from south to north.

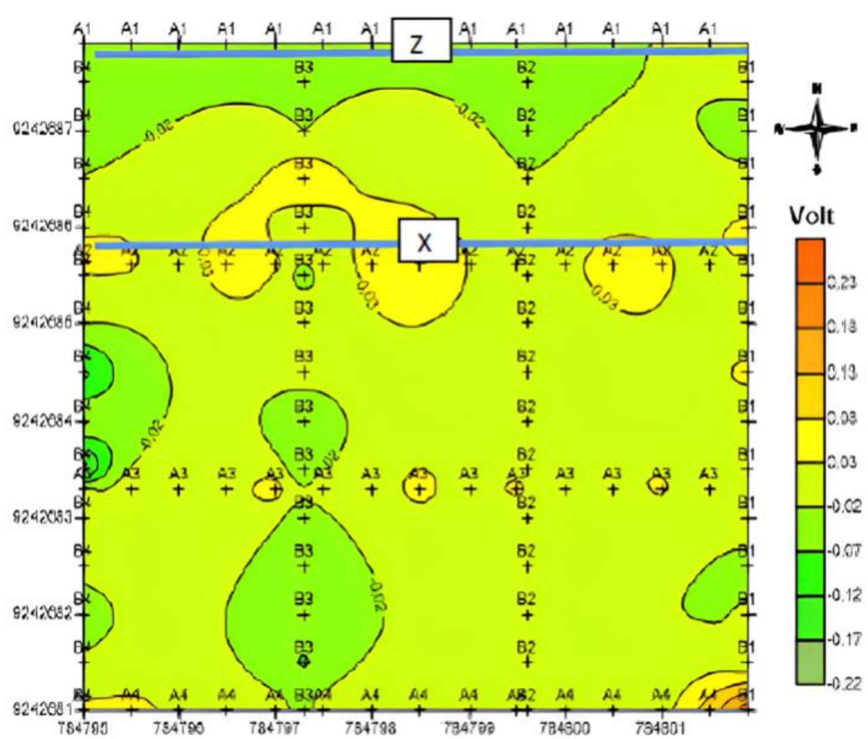


Figure 5. Self-potential map of survey area. Self-potential showed that northward survey area had higher potential. X indicated high potential, and Z suggested rock water system.

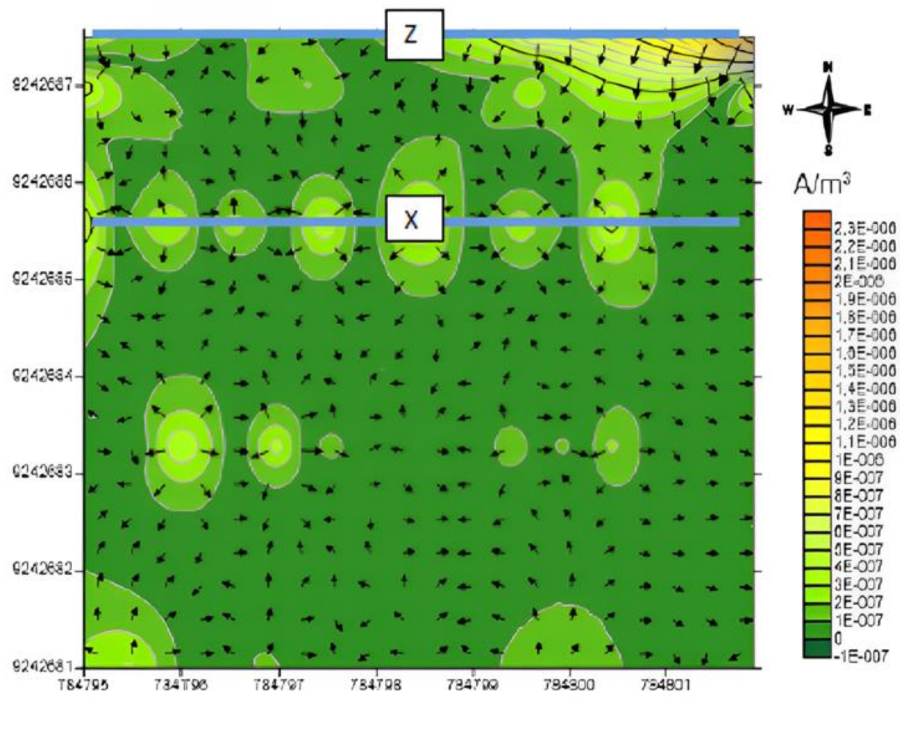


Figure 6. Electrical flow map of survey area. High potential area (X) lead to discharge of electric current.

Conclusions

This study successfully characterized the electrical conductivity (EC) of volcanic soils in the Parongpong agricultural area, West Java, using Huma EC technology. The results revealed that agricultural soils exposed to long-term NPK fertilizer application exhibited significantly higher conductivity values (1.44–15.11 mmhos/cm) compared to non-agricultural soils (0.72–2.70 mmhos/cm). This increase in conductivity is attributed to the enhanced cation exchange capacity (CEC) and elevated soil pH caused by fertilizer residues.

The findings highlight the impact of excessive fertilizer use on soil electrochemical properties and provide a valuable conductivity database for volcanic agricultural soils. These results underscore the importance of adopting sustainable fertilization practices to mitigate soil contamination and maintain soil health in volcanic regions. Future research should explore the long-term effects of fertilizer residues on soil quality and crop productivity, as well as the potential of geophysical methods like Huma EC for large-scale soil monitoring.

Conflicts of Interest

The authors bear no conflicts of interest.

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