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Soil Characterization using the Electrical Resistivity Tomography (ERT) Approach on Non-Typical Land of *Ipomoea Batatas "Cilembu"*

Teuku Abdullah Sanny[1*], Muhammad Luthfi Asrib[1], Arkan Zhafran Matin Insani[2]

[1] Department of Geophysics Engineering, Faculty of Mining and Petroleum Engineering, Institute of Technology Bandung, Bandung, Indonesia.

[2] Department of Agrotechnology, Faculty of Agriculture, Padjajaran University, Bandung, Indonesia.

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Corresponding Author:
Teuku Abdullah Sanny
sanny@itb.ac.id

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Abstract: The market demand for Cilembu sweet potato is increasing from year to year. Therefore it is necessary to develop Cilembu sweet potato land in other areas to solve this problem, including non-typical Cilembu sweet potato land. Investigations on the distribution of fertile soils are carried out on non-typical agricultural lands so that farmers can assess fertility problems in the soil, which can increase crop productivity. This specialty uses a high-precision agricultural approach to developing geophysical technology, one of which is Electrical Resistivity Tomography (ERT). This research was conducted to determine the characteristics of non-typical Cilembu sweet potato agricultural land in the Cicalengka sub-district. The results show that the resistivity values range from 10 to 800 Ωm, indicating that this area results from weathering of sedimentary rocks. The study results stated that the Cilembu variety of sweet potatoes could be developed on non-typical land in this area by considering the inhibiting factors. Knowing these inhibiting factors is expected to determine the steps in land management as a solution so that non-typical areas can help market demand for the availability of Cilembu sweet potato varieties.

Keywords: Agriculture geophysics; Cicalengka; Cilembu sweet potato; ERT

Introduction

Market demand for Cilembu variety sweet potato production has increased from year to year. Therefore, it needs to be balanced with an increase in supply in terms of productivity and quality. The problem faced in increasing supply is that Cilembu sweet potato which has the best productivity and quality only grows in a typical Cilembu area (Solihin et al., 2017). In order to preserve the Cilembu variety of sweet potato and its market potential, efforts need to be made to find alternative land that is in accordance with the conditions and characteristics needed for Cilembu sweet potato cultivation. Another alternative is to find problems in non-typical sweet potato varieties of Cilembu. If a solution can be found for this problem, non-typical land can contribute to increasing the productivity and quality of the Cilembu sweet potato variety. Therefore, the importance of this study is aimed at knowing the characterization of non-typical land where this is very much needed in order to be able to overcome quality and productivity problems in non-typical land. So that non-typical land can help Cilembu sweet potato production to meet market demand.

Soil quality is usually related to soil fertility for agriculture which is determined by the interaction of several physical, chemical and biological properties of the parts of the soil inhabited by active plant roots (Hanafiah, 2007). To find out areas that have good soil fertility covering a large area of land, it is necessary to map the characteristics of the soil that has sufficient fertility indications in the Cilembu sweet potato variety

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so that farmers can evaluate soil fertility problems so that there is an increase in crop productivity and productivity into consideration in the recommendation of fertilization on the Cilembu sweet potato variety.

Mapping of soil characteristics can be done using a high precision agriculture approach with currently developing geophysical technology. One of the geophysical methods that can be applied is the geoelectric method, namely Electrical Resistivity Tomography (ERT). The Geoelectrical method is one of the geophysical methods that can be used to map and characterize the spatial and temporal variations of soil physical properties (Sudha et al., 2009; Aizebeokhai, 2014). The geoelectric method is considered cheap, fast and reliable to make it easier to estimate the physical properties of the soil (Kearey et al., 2002). Several external and internal factors such as rainfall, seasonal variations, soil temperature, porosity, salinity, soil structure, and changes in soil water content can also cause significant changes in soil electrical conductivity (Dafalla & Al Fouzan, 2012). So far, research using geoelectricity has been more widely used in identifying water or mineral content in soil for agricultural land. Several references using the geoelectric method for agricultural purposes can be seen in the research of Ganiyu et al. (2020), and Lumenta et al. (2017).

This study attempts to apply geoelectrical data processing by the Electrical Resistivity Tomography (ERT) method in mapping the distribution of soil characteristics based on resistivity values in Cilembu sweet potato non-typical fields. This research is expected to provide information in the form of a map of the distribution of resistivity values in non-typical Cilembu sweet potato soil which is related to the determination of fertile soil in the study area. Finally, this study aims to become a reference for similar research in determining the soil fertility status of an agricultural land.

Theoretical Background

Pedology (Soil Geology)

Pedology is the study of several aspects of soil geology, namely phylogeny (soil formation), physical and chemical properties and characteristics of soil (soil morphology), and soil classification (Hardjowigeno, 2003). There are 5 soil-forming factors, namely: climate, parent material, organisms, topography, and time. Climate influences the development of soil structures, such as rainfall and temperature. These two factors determine the chemical reactions and physical properties of the soil (Mustofa, 2007). In soil growth, soil depends on the type of parent material that determines the physical and chemical properties of the resulting soil (Mursito & Kawiji, 2002). The next factor is topography. This factor affects soil formation by affecting the amount of rainwater absorbed or retained by the soil mass, affects the depth of groundwater, affects the degree of erosion, the direction of movement of water and materials dissolved in it (Supadma & Dibia, 2006). The activity of soil organisms also affects the accumulation of organic matter, nutrient cycling and the formation of a stable soil structure (Supriyadi, 2008). In the latter factor, time affects soil where soil is a natural object that is always changing due to continuous weathering and leaching processes, so that the layer will become old and thin (Solihin, 2017).

Clasification of soil

In general, soils in Indonesia are volcanic soils, namely soils formed from volcanic eruption material or decomposition volcanic ash (Ritung et al., 2015). The fertility of volcanic soils is very high because they contain nutrients which are often found in mountainous areas or lava flows on the banks of rivers which are very fertile. There are two types of volcanic soil, namely coarse-grained regosol soil in the form of new alluvial deposits and andosol soil which usually comes from tephra with brownish-gray physical properties (Rosmarkam & Yuwono, 2002).

Geology of the Research Area

Based on the Geological Map of the Bandung Sheet from the Geological Research and Development Center (Silitonga, 2003), the study area is composed of Lake Sediment Products (Ql) consisting of tuffaceous clay, tuffaceous sandstone, tuffaceous gravel, and conglomerate. This area contains limestone concretions, plant remains, freshwater molluscs, and bones of vertebrates.

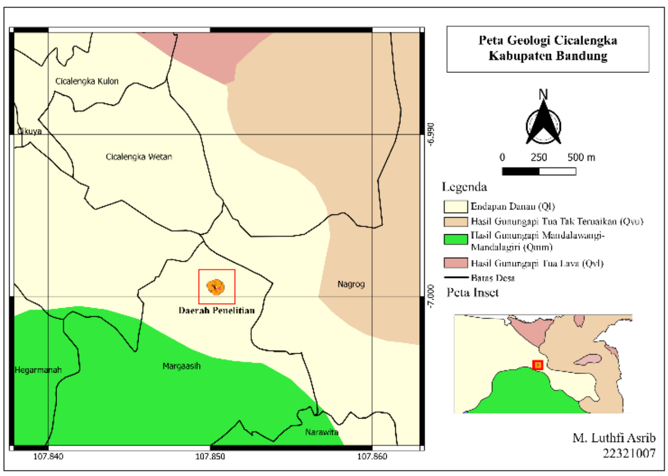

Figure 1. Geological map of research locations

Survey Design of Research Area

The area used as the research object is the land area of Margaasih Village, Cicalengka District, Bandung Regency, West Java. The research area has a decreasing topography from east to west. Margaasih Village has a tropical climate which is influenced by monsoon winds with an average rainfall of between 1,500 mm to 2,300 mm/year. The air temperature ranges from 20 degrees C to 26 degrees C and the humidity varies between 78% during the rainy season and 70% during the dry season.

Figure 2. ERT measurement survey design

There are 3 tracks as shown in Figure 1.1, where each track has 48 electrodes spaced 30 cm apart. So that the length of each track is 14 m. It is expected that the estimated depth reaches 2 m.

Method

Electrical Resistivity Tomography (ERT)

The Electrical Resistivity Tomography (ERT) method is a geophysical method that calculates changes in the resistivity of the subsurface layer by injecting an electric current into the soil. ERT measurements can obtain variations in resistivity vertically and laterally. The ERT method can be used for several applications such as: groundwater table determination, investigation of geological structures and fractures, and mineral exploration (Reynolds, 2011).

The ERT work system is by injecting electricity using a current electrode and received by a potential electrode where the longer the distance between the current electrodes, the deeper the penetration of the electric current (Reynolds, 2011). The results of the subsurface electric current will be recorded and read as apparent resistivity (Lowrie & Fichtner, 2020). Apparent resistivity will be processed by inversion method using RES2DINV software to produce the actual resistivity.

Apparent resistivity is the result of ERT measurements on non-homogeneous media. Apparent resistivity will provide a qualitative description of the subsurface resistivity distribution (Reynolds, 2011). The apparent resistivity value can be calculated in:

$$\rho_a = K \frac{V}{I} \quad (1)$$

Where ρ_a is the apparent resistivity, K is the geometry factor, V is the electric potential, and I is the electric current. The value of K will depend on the electrode configuration to be used in the measurement. In general, the value of K can be written as:

$$K = 2\pi \left[\frac{1}{AM} - \frac{1}{MB} - \frac{1}{AN} + \frac{1}{NB}\right]^{-1} \quad (2)$$

Where AM is the distance between A and M, MB is the distance between M and B, AN is the distance between A and N, and NB is the distance between N and B (see Figure 3 for a better illustration).

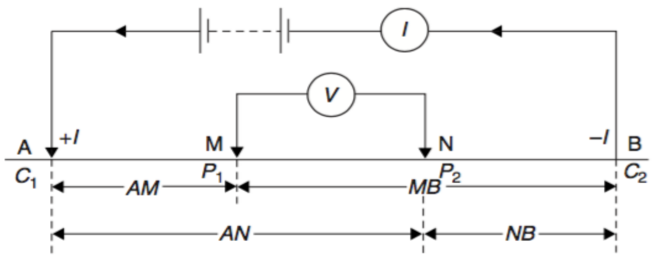

Figure 3. Illustration of the electrode configuration model (Reynolds, 2011)

In this study, the electrode configuration to be used is the Wenner-Schlumberger configuration. The Wenner-Schlumberger configuration was chosen because it is sensitive to local inhomogeneity, resulting in better results for viewing changes in vertical and horizontal resistivity (Loke, 1999). The Wenner-Schlumberger array has the same array as the Wenner Alpha but the potential electrodes (A and B) and the current electrodes (M and N) are "n" times the distance between the two potential electrodes. Using the apparent resistivity equation, we can get the equation for the Wenner-Schlumberger array as:

$$\rho_a = 2\pi \left[\frac{1}{AM} - \frac{1}{MB} - \frac{1}{AN} + \frac{1}{NB}\right]^{-1} \left(\frac{V}{I}\right) \quad (3)$$

$$\rho_a = \pi n(n+1)a \left(\frac{V}{I}\right) \quad (4)$$

Loke (1999) has made a guideline for the interpretation of ERT, which is the general range of resistivity and conductivity of hard, soft, and soil rocks. The range description can be seen in the following Table 1.

The data collection process was carried out using the Electrical Resistivity Tomography (ERT) Wenner-Schlumberger configuration. The position of the current electrode and potential electrode is placed as shown in Figure 4.

Table 1. Material Resistivity

Types of Material	Resistivity (Ωm)
Igneous and Metamorphic	
Rocks	$5 \times 10^3 - 10^6$
Granite	$10^3 - 10^6$
Basalt	$6 \times 10^2 - 4 \times 10^7$
Slate	$10^2 - 2.5 \times 10^8$
Marble	$10^2 - 2 \times 10^8$
Quartzite	$10^2 - 10^8$
Sedimentary Rocks	
Sandstone	$8 - 4 \times 10^3$
Shale	$20 - 2 \times 10^3$
Limestone	$50 - 4 \times 10^2$
Soils and Water	
Clay	1 – 100
Alluvium	10 – 800
Groundwater	10 – 100
Sea Water	0.2

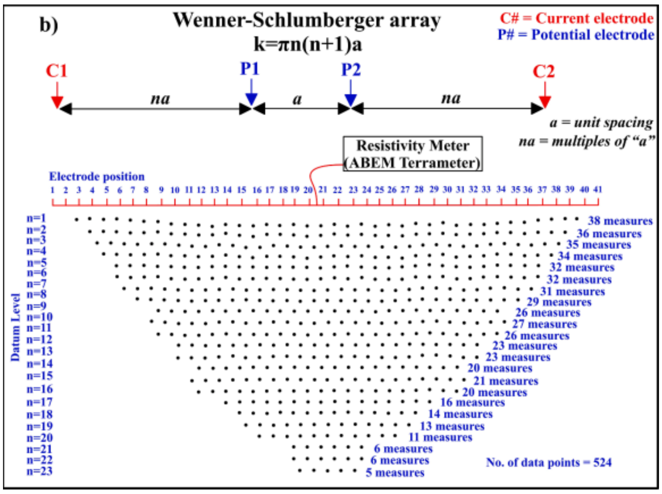

Figure 4. Wenner-Schlumberger configuration (Kumar et al., 2021)

Retrieval of geoelectrical data is carried out by passing current through two current electrodes and measuring the potential difference between the two potential electrodes at a certain distance (Fukue et al., 199). The research data obtained and used are the distance between the current electrode and the sounding point (AB/2), the distance between the potential electrode and the sounding point (MN/2), current (I), potential difference (V), geometry factor (k) and apparent resistivity (apparent ρ). During data collection, the resistivity value is checked using Bilog paper to avoid data errors, so that the quality control can be taken (McCarter, 1984; Michot et al., 2003). Data processing uses RES2DINV Software by entering values by entering electrode positions, smallest electrode spacing, multiplier factors and apparent resistivity values. The data that has been processed will produce a cross section that forms a subsurface layer with the actual resistivity value. The 2D modeling resulting from the inversion can be interpreted to estimate the type of layer, so that the soil type can be determined from the results of rock weathering identified on the ERT section (Edwards, 1977).

Result and Discussion

The results of the Electrical Resistivity Tomography (ERT) data processing are in the form of 2D cross-sectional images based on each path being measured. The following is the interpretation of the results of each research trajectory.

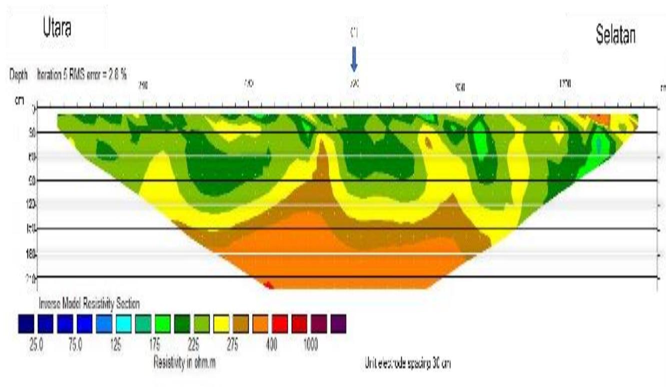

Figure 5. Cross-sectional results of track 1

Based on Figure 5 the results of the interpretation on the track have a variety of layers that have various resistivity values, with an RMS error of 2.8%. Furthermore, the interpretation of subsurface Track 1 can be seen in Table 2.

Table 2. Interpretation of the Subsurface on Track 1

Resistivity (Ωm)	Layer	Depth (cm)	Thickness (cm)
175–225	Horizon O	0–90	90
250–300	Horizon A	90–150	60
400	Horizon B	> 150	> 60

In table 2, the first layer is light green to dark green with a depth of 0–90 cm and has a resistivity value between 175–225 Ωm. This layer is indicated as an O horizon which consists of organic material but has a low mineral fraction. The second layer is a yellow to brownish yellow layer with a depth of 90–150 cm and has a resistivity value between 250–300 Ωm. This layer is indicated as horizon A (Subsurface) which is the result of the accumulation of fine organic matter that has been weathered and mixed with minerals from the parent rock in the soil. The bottom layer is orange with a depth of more than 150 cm and has a resistivity value of up to 400 Ωm. This layer is indicated as horizon B (Subsoil) where this layer has experienced horizon development. Most to all of the original rock structures are characterized as having disappeared.

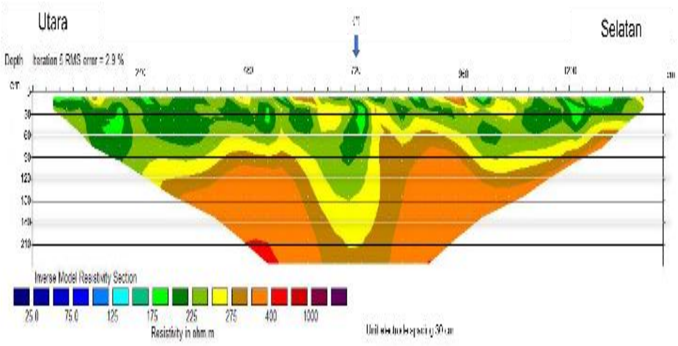

Figure 6. Cross-sectional results of track 2

Based on Figure 6 the interpretation results on line 2 have a variety of layers that have various resistivity values, with an RMS error of 2.9%. Furthermore, the interpretation of the subsurface Track 2 can be seen in Table 3.

Table 3. Interpretation of the Subsurface on Track 2

Resistivity (Ωm)	Layer	Depth (cm)	Thickness (cm)
175–225	Horizon O	0–60	60
250–300	Horizon A	60–150	90
400–500	Horizon B	> 150	> 60

In Table 3, the first layer is light green to dark green with a depth of 0–60 cm and has a resistivity value between 175–225 Ωm. Same as track 1, this layer is indicated as an O horizon which consists of organic material but has a low mineral fraction. The second layer is a yellow to brownish yellow layer with a depth of 60–150 cm and has a resistivity value of between 250–300 Ωm. This layer is also indicated as the A horizon (Subsurface) which is the result of the accumulation of fine organic matter that has been weathered and mixed with minerals from the parent rock in the soil. The bottom layer is orange with a depth of more than 150 cm and has a resistivity value of up to 400 Ωm. This layer is also indicated as a B horizon (subsoil) where this layer has experienced horizon development. Most to all of the original rock structures are characterized as having disappeared. On this trajectory there is a phenomenon of decreasing O layer at the 18th electrode to the 25th electrode with a length of 2.1 m. This is thought to be due to activities on the ground surface or the accumulation of water and minerals in the area.

The cross-sectional results shown in Figure 6 are the result of crossing paths 1 and 2 with an RMS error value of 7.1%. This is done to see the distribution of resistivity values with a different stretch orientation (West-East). From this cross-section, it can be interpreted that the layers formed still have varying resistivity values. It ranges from light green to dark green (175–250 Ωm), yellow to tawny (350–500 Ωm), red to purple (> 600 Ωm). From the 3 sections presented, it is known that there are differences in the conductivity of each layer due to differences in soil characteristics. This is related to the electrical conductivity which is affected by the presence of liquid in the pores of the rock and the degree of saturation of water and minerals in the soil.

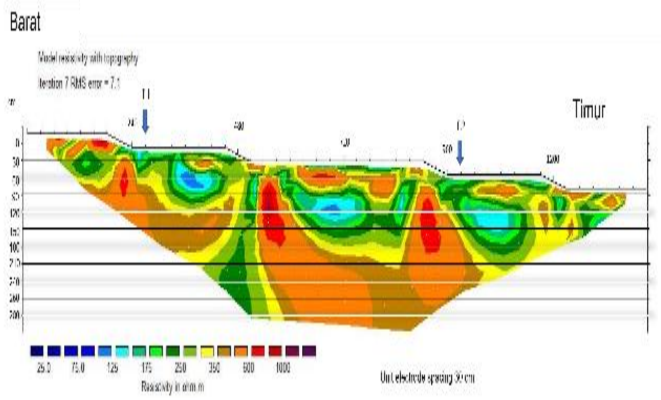

Figure 7. Track 3 cross-sectional results

Interpretation of 2D Electrical Resistivity Tomography (ERT) sections is accompanied by taking a test pit as validation. Taking a test pit can be seen in Figure 8 below.

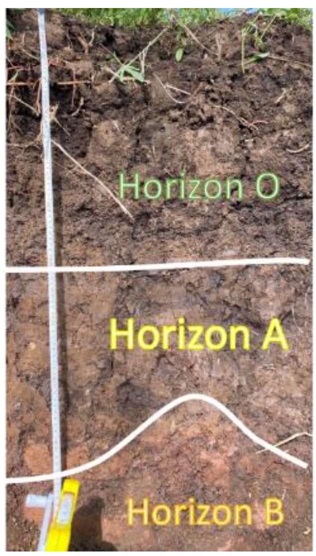

Figure 8. Pit test results on the geoelectric trajectory

To strengthen the analysis in this study, a grain size test was carried out as soil type data and a mineral test to determine the soil content in the study area. This test uses 5 samples from each point of land. This test and analysis was carried out through PT Sucofindo's laboratory. The results of lab testing can be seen in Table 4.

Then the results of the test analysis can be correlated with the results of the resistivity section that has been made as tie data. From the results of the cross-sectional interpretation, it shows that the O horizon layer in the study area has a fairly large thickness. This affects the availability of macro nutrients (P and K) as nutrients that are very necessary for plants (Susanto et al., 2014). However, the test analysis showed a neutral-alkaline pH value and sufficient potassium value. An alkaline pH value correlates with a high phosphorus (P) content. Meanwhile, the potassium value which is quite high indicates that the erosion and leaching activity on the land is not too high. Because potassium is a transport element that is easily lost due to erosion and leaching (Wandana et al., 2012). Judging from the value of the macro element Nitrogen (N) represented by N-Total, this value is high. This is evidenced by the resistivity section showing the thickness of the O horizon in the land area and the high vegetative area on the land surface. Excessive N content results in the vulnerability of plants to pests and diseases (Barry & Susylowati, 2004). If we look at the value of organic carbon (C-Organic), the value still includes a maintained soil ecosystem, namely 3-5%. This means that food intake for soil microbes is still balanced between beneficial and unfavorable microbes (Arifin et al., 2006).

Table 4. Results of mineral and grain size testing

Testing	Result	Description
Types of soil	Clay Silt	The average percent (Sand 5%, Clay 70%, Silt 25%)
pH	Neutral-Alkaline	Average of the samples 7.75
N-Total		Average of the samples 17.36%
C-Organic		Average of the samples 3.82%
Ca		Average of the samples 195.8 mg/Kg
Mg		Average of the samples 528 mg/Kg
Na		Average of the samples 47.64 mg/Kg
K		Average of the samples 61.06 mg/Kg

With this explanation, even though the O horizon layer in the study area is quite thick, it is not balanced by the availability of macro nutrients, so the quality of the Cilembu sweet potato variety in this area is only of good quality but not superior in terms of soil fertility when compared to typical areas.

Then, when viewed from the rooting conditions, the non-typical areas of this study have soil types that tend to be clay and silt and the correlation with the range of resistivity values indicates alluvium soil type of 10-800 Ωm. This means that the type of soil in the study area is a factor inhibiting root growth, both in terms of distribution, number, and amount of leaching (Widijanto et al., 2008). The clay texture of the soil will make it difficult for the roots to penetrate and be hampered from growing. As a result, Sweet Potatoes will tend to be small and elongated.

Based on the results of the correlation between the interpretation of 2D Electrical Resistivity Tomography (ERT) sections, test pit results, and analysis of mineral and grain size testing, it can be concluded that the Cilembu variety sweet potato can be developed on non-typical land in this study area by taking into account the inhibiting factors that already mentioned. Knowing these inhibiting factors is expected to determine the steps in land management as a solution so that non-typical areas can help market demand for the availability of Cilembu sweet potato varieties.

Conclusion

Based on the results of this study, the Electrical Resistivity Tomography (ERT) method can provide an overview of the land conditions in non-typical research areas in the village of Margaasih, Cicalengka sub-district. Where this area can still be developed better by paying attention to the inhibiting factors in the form of soil fertility conditions and root conditions. This inhibiting factor was obtained from the results of the correlation between the interpretation of 2D Electrical Resistivity Tomography (ERT) sections, test pit results, analysis of mineral testing, and grain size. Where seen from the resistivity section, the O horizon layer in the study area is quite thick, but this condition is not matched by the availability of macro nutrients, so that the quality of the Cilembu sweet potato variety in this area can be concluded that it only has good quality but is not superior in terms of soil fertility. When viewed from the rooting conditions, the non-typical areas of this study have soil types that tend to be clay and silt and their correlation with the range of resistivity values indicates alluvium soil type of 10-800 Ωm. This means that the type of soil in the study area is a factor inhibiting root growth. The clay texture of the soil will make it difficult for the roots to penetrate and be hampered from growing. As a result, Sweet Potatoes will tend to be small and elongated. The inhibiting factors above are only based on the physical feasibility of the soil without considering other factors such as the use of fertilizers, processing methods, etc. So that this research is expected to be an ongoing research or a reference for similar research in determining policies in increasing the productivity and quality of the Cilembu sweet potato variety.

Author Contributions

Teuku Abdullah Sanny: Conceptualization, methodology, formal analysis, interpretation, validation, writing—review; Muhammad Luthfi Asrib: Methodology, software, formal analysis, data curation, interpretation, writing—original draft preparation and editing; Arkan Zhafran Matin Insani: Investigation, formal analysis, interpretation, writing—review and editing.

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Conflicts of Interest
Authors declare no conflict of interest.

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