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Land Suitability and Plant Types Based on Soil Electrical Properties and Remote Sensing

Studi Kesesuaian Lahan dan Jenis Tanaman Berdasarkan Sifat Kelistrikan Tanah dan Penginderaan Jauh

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Abstract - Regional development in Panimbang District, Banten Province, Indonesia, is executed so that the tourism area is not centered solely on the west coast of Pandeglang but also in the surrounding area. The development is carried out in stages from government offices, education facilities, and public facilities. One of the public facilities to be built is a garden. This study aimed to evaluate the condition of the soil layers and fertility for garden construction. The resistivity method determines the soil layer pattern using dipole configuration. Remote sensing methods are used to assess land suitability and soil fertility. Land suitability based on agro-climatic data soil fertility based on physical and chemical parameters is taken from SoilGrids 250 m. The results of the resistivity method showed various values between 1 – 110 Ωm, and there are three layers of soil up to a depth of 3.58 m The first layer is assumed to be silty clay (15 – 30 Ωm), the second layer is assumed to be clay (1 – 5 Ωm), and the third layer is assumed to be silty and sandy soil (70 – 110 Ωm). Based on the remote sensing data, the first layer had an ideal bulk density and cation exchange value, but the pH value and nitrogen content are less ideal. The second layer had an ideal value of cation exchange capacity and pH, a rather ideal bulk density value, and a low nitrogen content and is considered a fertile layer of soil.

Keywords: Remote sensing, resistivity, soil fertility, soil layers, SoilGrids250 m

Abstrak – *Pengembangan wilayah Kabupaten Panimbang, Provinsi Banten, Indonesia dilakukan agar kawasan pariwisata tidak hanya terpusat di Pantai Barat Pandeglang. Pembangunan dilakukan secara bertahap mulai dari kantor pemerintahan, fasilitas pendidikan, dan fasilitas umum. Salah satu fasilitas umum yang akan dibangun adalah taman. Penelitian ini bertujuan untuk mengevaluasi kondisi lapisan tanah dan kesuburan tanah untuk pembangunan taman. Metoda yang digunakan adalah metode resistivitas dan penginderaan jauh. Metode resistivitas digunakan untuk menentukan pola lapisan tanah menggunakan konfigurasi dipol. Metode penginderaan jauh digunakan untuk menentukan kesesuaian lahan dan kesuburan tanah. Kesesuaian lahan berdasarkan data agroklimat serta kesuburan tanah berdasarkan parameter fisika dan kimia diambil dari SoilGrids 250 m. Hasil metode resistivitas menunjukkan nilai yang bervariasi antara 1 – 110 Ωm, dan terdapat tiga lapisan tanah hingga kedalaman 3,58 m. Lapisan pertama diasumsikan berupa lempung lanauan (15 – 30 Ωm), lapisan kedua diasumsikan lempung (1 – 5 Ωm), dan lapisan ketiga diasumsikan tanah pasiran 70 – 110 Ωm. Berdasarkan data penginderaan jauh, lapisan pertama memiliki bulk density dan nilai tukar kation yang ideal, namun nilai pH dan kandungan nitrogennya kurang ideal. Lapisan kedua memiliki nilai tukar kation, bulk density, dan pH yang ideal dengan kandungan nitrogen yang rendah dianggap sebagai lapisan tanah yang subur.*

Katakunci: *Pengenderaan jauh, resistivitas, kesuburan tanah, perlapisan tanah, SoilGrids 250 m*

INTRODUCTION

There are several things to be considered to build a garden, one of which is the soil layers and soil fertility condition, and the land suitability with the type of plants to be planted. The content of organic matter is the leading indicator of soil fertility (Soepardi, 1983). Using geophysical methods in agriculture, geophysical surveys are focused on a depth of 0 – 2.5 meters below the surface to determine the soil thickness and fertility (Allred *et al.*, 2008). However, since the number of available soil data is still little and takes a long time to obtain (Scull *et al*., 2003), remote sensing methods are considered to be time and cost-effective in getting the soil data needed (Bousbih *et al.*, 2019).

Soil Fertility

Soil structure affects plant growth, groundwater balance, and soil workability. A good soil structure can carry water and oxygen through the soil, so it can help plant growth, boost nutrition recycling, and groundwater recharge (Rabot *et al*., 2018). Poor soil structure limits water infiltration and gas exchange, resulting in water runoff, soil erosion, and anoxic conditions that limit plant growth (Chen *et al*., 2014; Jordanova *et al.,* 2011). Soil properties significantly affect water, air, and plant nutrient availability (Mahi, 2013). The physical properties of soil include texture, bulk density, and the content of coarse particles. The chemical properties of soil include pH, organic carbon, and nutrient.

Resistivity

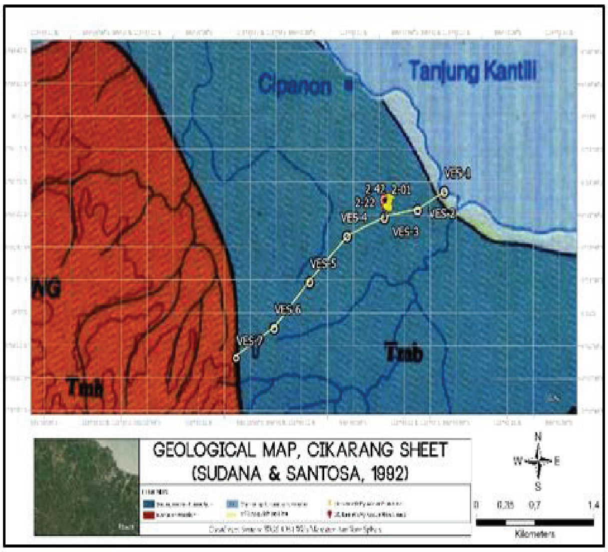
The resistivity method is an active method in geophysics that utilizes electrical properties. This method uses an artificial electric current source by injecting the current into the ground through a current electrode, and the potential field is then measured using a potential electrode (Seidel & Lange, 2007). Resistivity is a function of several soil properties, including the properties of solids (particle size, mineralogy), cavity arrangement (porosity, pore size distribution), water saturation (water content), fluid, electrical resistivity (solute concentration), and temperature (Samouelian *et al.,* 2005). Resistivity is even very sensitive to the microstructure of clay. This sensitivity benefits agricultural land mapping (Agustine & Irawan, 2020).

Remote Sensing

Remote sensing or earth observation represents the acquisition and measurement of data or information on some properties of a phenomenon, object, or material using a recording device that is not in physical contact with the observed object (Al-ajmi & Uddin, 2009). Soil data is fundamental for managing land resources and monitoring the environmental impacts of development (Rossel, *et al.,* 2006). The use of remote sensing methods is considered cost and time effective in acquiring soil data (Bousbih, *et al.*, 2019). Global and regional soil data are already available on SoilGrids250m, and it shows results that are close to the field conditions and have a pretty good resolution (Tifafi *et al*., 2017; Krpec *et al.,* 2020).

Geological Condition

Based on the regional geological map of the Cikarang Sheet, Pandeglang Regency, Banten (Figure 1), the research area generally belongs to the Bojongmanik Formation (Tmb). According to Sudana and Santosa, this rock formation consists of an alternation of flaky sandstones and claystone interspersed with marl, conglomerate, limestone, tuff, and lignite. The Bojongmanik Formation was deposited during the Miocene-Pliocene (23-2 mya) and had a lateral relationship with the Honje Formation. The Bojongmanik Formation has a northwest-southeast trending distribution. The structure that develops is anticline-syncline folds and fault alignments in the same direction. Cross-sections show that this unit tends to form an anticlinorium with wings tilted to the northeast and southwest.



source: Sudana & Santosa (1992)

Figure 1. Geological Map, Cikarang Sheet.

MATERIAL AND METHODS

Land Suitability

Land suitability is used to see the compatibility between the plants to be planted and the physical properties and the plants' surrounding environment to be more productive. The data used are agro-climatic parameters adapted to the technical guidelines for land evaluation for agricultural commodities (Ritung *et al.*, 2011; figure 2). The commodities used are ornamental plant commodities. The satellite data is taken from January 1st, 2019 to October 30th, 2020. The data are then inputted into the Google Earth Engine and assessed for suitability based on the classification of land suitability subclasses.

Soil Grids

The physical and chemical properties of the soil are taken from SoilGrids 250 m, a digital soil mapping system based on a global compilation of soil profiles, environmental layers, and remote sensing data. SoilGrids 250 m models approximately 150.000 soil profile data worldwide, including Indonesia. Remote sensing data on SoilGrids 250 m distinguish between soil and non-soil areas. In addition, soilGrids 250 m provides data on soil physical properties (contents of sand, clay, silt, and bulk density) and soil chemical properties (nitrogen, soil organic carbon, pH, and cation exchange capacity).

2D Resistivity

This study employed the DC resistivity method with vertical mapping to obtain information on subsurface conditions. The measuring instrument used is the Resistivity Meter Small Scale Digital (RMSS-D). The number of lines is two lines with an electrode spacing of 0.5 m, and the electrodes used are 42 pieces on each line. The condition around the measurement is soil overgrown with several plants and vegetables that grow randomly with the flat ground condition. The measurement results are then processed using RES2DInv, which produces a 2D cross-section based on the soil resistivity value (Hunt, 2005). Finally, remote sensing data and resistivity are correlated to determine the soil fertility condition based on the ideal value of each parameter and soil layering based on the value of soil resistivity.

RESULTS AND DISCUSSIONS

Land Suitability

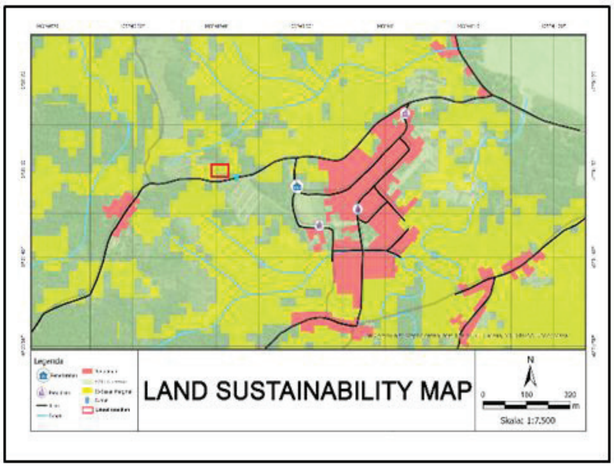
Guidelines for Evaluation of Agricultural Land, Ministry of Agriculture (2011). The land suitability map is based on the Technical Guidelines for Evaluation of Agricultural Land (Ritung *et al.*, 2011), shown in Figure 2. The commodities are ornamental plant commodities, and the parameters used are agro-climatic data. Based on the map, the research area is dominated by suitable land.

Physical and Chemical Properties

Figure 3 shows the soil's clay, sand, and silt content used to classify the soil texture, representing the soil's main particle size distribution. The first layer, with a thickness of 42 cm, is assumed to be silty clay with a clay content of >40%. The second layer, with a thickness of 1.08 m, is assumed to be clay with clay content that dominated >40%. The deeper layer, the greater clay content, while the less silt and sand.

Based on the soil texture, the first layer which is assumed to be silty clay, had a bulk density (shown in Figure 4) value of <1.1, while the second layer had a value of 1.1 – 1.16 and is assumed to be less suitable for the growth of the plant root. The presence of coarse fragments is proportional to the bulk density. The coarse fragments' presence affects the soil's mechanical and hydraulic properties since the total pore space is reduced, so the plants will dry out.

The cation exchange ranged from 18% to 21% (shown in Figure 5), meaning it is in a fairly good range. The nitrogen content is very little and far from the ideal range of nitrogen content in soils (250 – 500), so to overcome this problem, fertilizers can help increase the soil's nitrogen content. The high organic carbon content in the topsoil reached 8.5% but decreased along the increasing depth. The pH value at a depth of 0 -80 cm is in the range of <5.5, but at a depth of 81 – 150 cm, it had a value of 5.5



Source:Ritung et al., (2011)

Figure 2. Land suitability map of the research area made according to the technical Guidelines for Evaluation of Agricultural Land.

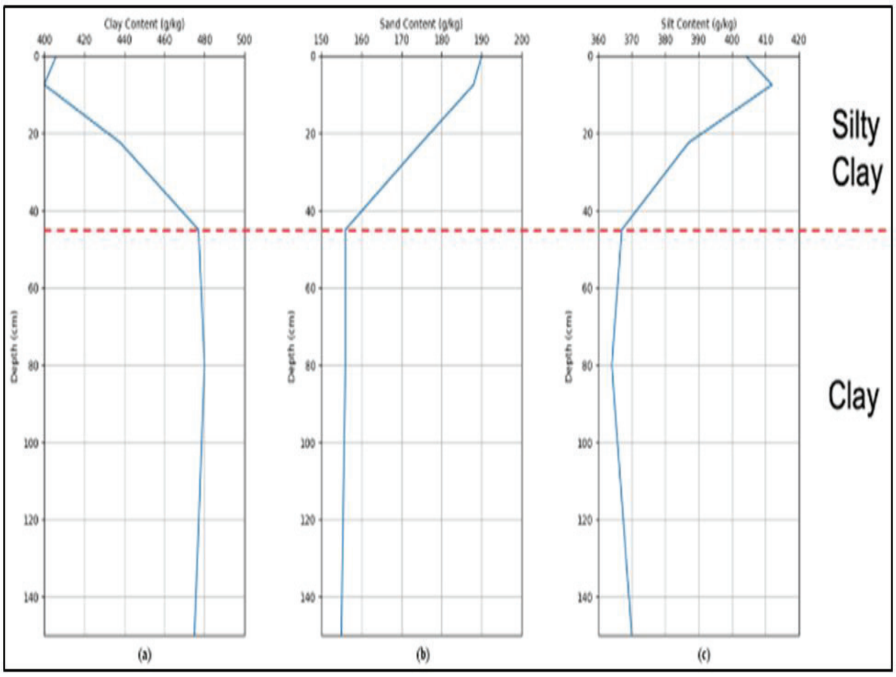


Figure 3. (a) Clay content, (b) Sand content, and (c) Silt content on soil up to 150 cm depth.

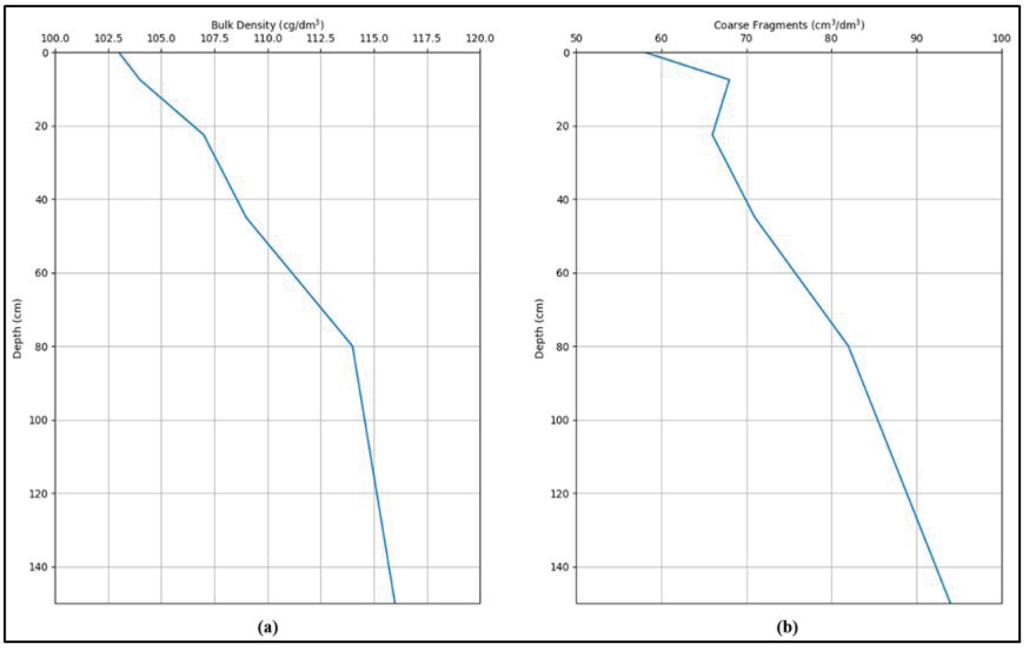


Figure 4. (a) Bulk density value and (b) coarse fragments value on soil up to 150 cm depth.

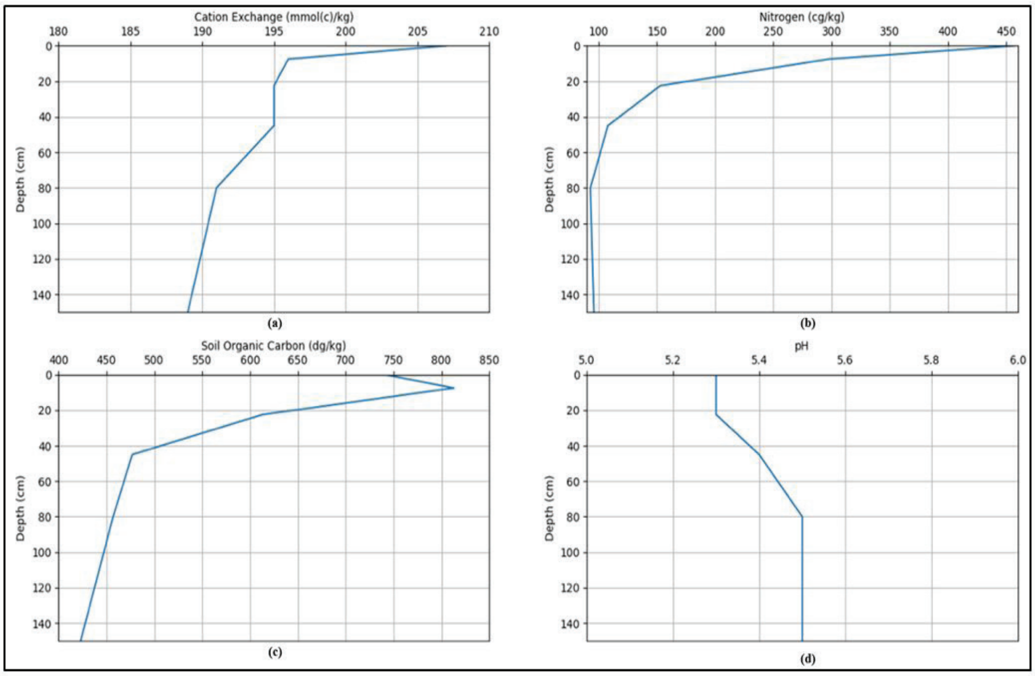


Figure 5. Soil chemical properties; (a) Cation Exchange, (b) Nitrogen, (c) Soil Organic Carbon, and (d) pH

L.1 & L.2 2D Resistivity

Figure 6 shows that the soil depth reached up to 3.58 m. The depth reached is shallow because the formation of the soil itself takes a long time, so a depth of 3.58 meters has provided sufficient information. Moreover, agricultural geophysics tends to focus on the two-meter zone below the soil surface, which includes the plant root zone and all or most of the soil profile (Allred *et al.,* 2008). There are three layers of soil at a depth of 3.58 meters. The first layer with a resistivity value range of 15 – 50 Ωm is assumed to be a layer of silty clay and soil with a moist condition tendency. The second layer had a small resistivity value among other layers with a value range of 1 – 5 Ωm, which is assumed to be clay under very humid conditions. It had a layer thickness of 1.6 – 1.8 m. The third layer with unidentified thickness is at a depth of 2.7 m with the highest resistivity value ranging from 70 – 110 Ωm, which is assumed to be silty and sandy soil.

The first layer with a resistivity value range of 5 – 15 Ωm is assumed to be silty clay and soil layer with relatively humid conditions. The second layer had a smaller resistivity value than other layers with the range of 1 – 5 Ωm, which is assumed to be a very sticky layer of clay. The third layer with unknown thickness is at a depth of 3.2 meters with the highest resistivity value ranging from 70 – 110 Ωm, which is assumed as a layer of silty and sandy soil (shown in figure 7).

Correlation

Based on the resistivity data, generally, there are three soil layers up to a depth of 3.58 m, with the first layer presumed to be silty clay soil, the second layer presumed to be clay, and the third layer to be silty and sandy soil with a rather dry condition. This layer, correlated with the results of SoilGrids 250 m, has two layers up to the depth of 1.5 meters, with the first layer assumed to be silty clay and the second layer to be clay (shown in Figure 8 and Table 1).

CONCLUSION

Based on resistivity data analysis interpreted there are three layers. The first layer with a resistivity value of 15 – 30 Ωm is presumed to be silty clay with a depth of 8 – 80 cm. The second layer with a resistivity value of 1 – 5 Ωm is presumed to be clay in a humid and wet condition with a layer thickness of 1.6 – 2.3 m. The third layer with a resistivity value of 70 – 110 Ωm is presumed to be silty and sandy soil with a dry tendency compared to the layers above with unidentified thickness. Based on the analysis result of the remote sensing data, fertile soil is located in the second layer of soil with a bulk density value of 1.15, cation exchange capacity of 18.8 – 19.5 mmol(c)/kg, pH 5.5, and nitrogen content of 100 cg/kg.

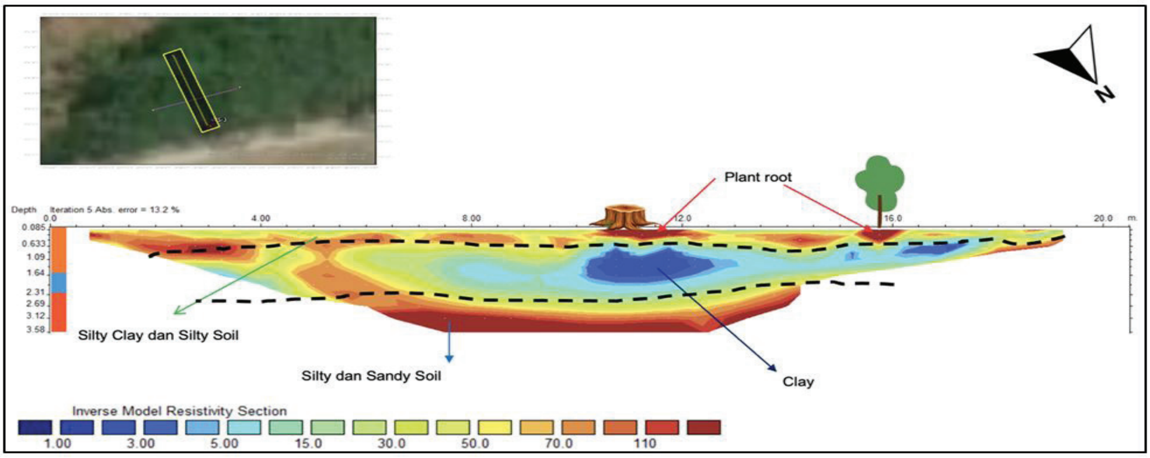


Figure 6. 2D Cross section Line 1.

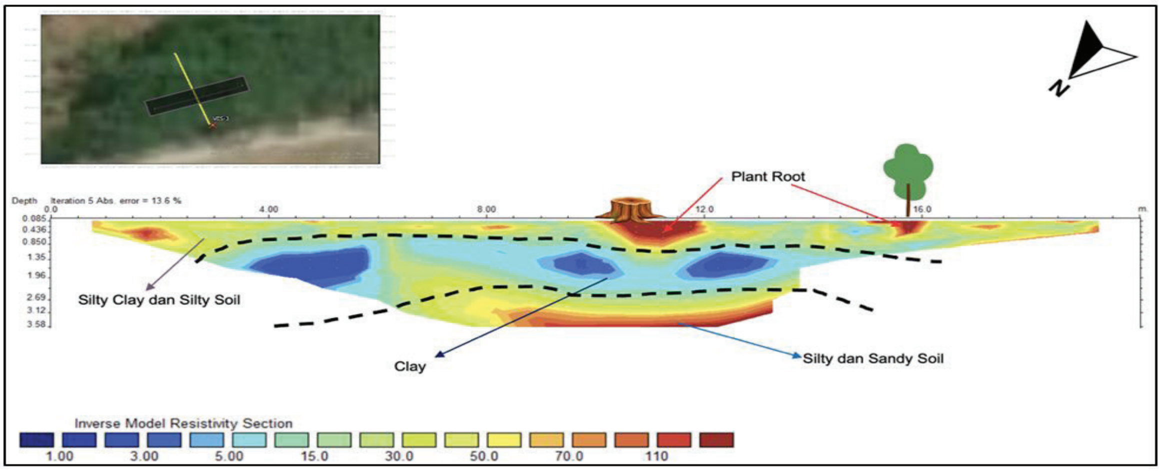


Figure 7. 2D Cross section Line 2.

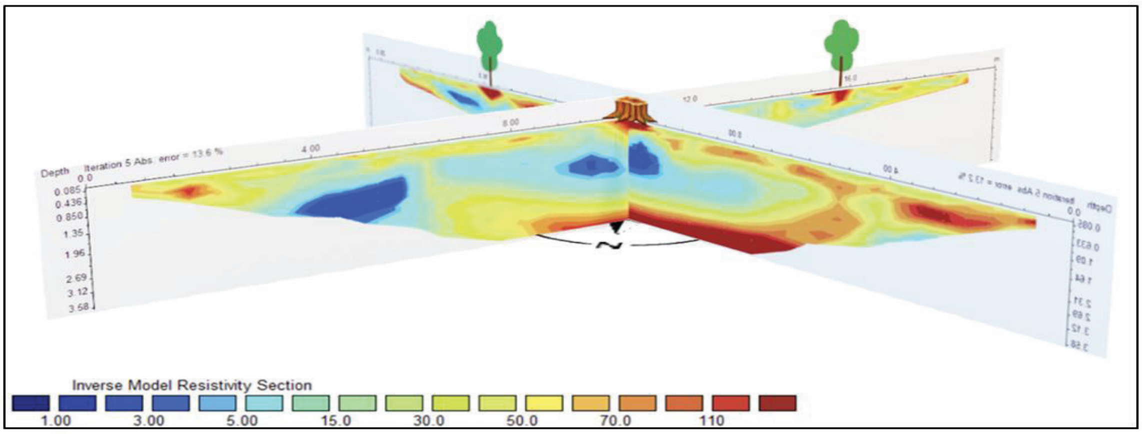


Figure 8. Pseudo 3D Cross section Line 1 and Line 2.

Table 1. Measurement Result 2D Resistivity

Layer	Soil Fertility Parameters	Ideal Values	Measurement Results
First Layer (0 – 80 cm)	*Bulk Density*	< 1.4 g/cm^3	1.1 – 1.15 g/cm^3
	Nitrogen Content	250 – 500 cg/kg	100 – 450 cg/kg
	Cation Exchange Capacity	5 – 25	19.5 – 21
	pH	5.5 – 6.5	5.3 – 5.5
Second Layer (80 – 150 cm)	*Bulk Density*	< 1.1 g/cm^3	1.15 g/cm^3
	Nitrogen Content	250 – 500 cg/kg	< 100 cg/kg
	Cation Exchange Capacity	5 – 25	18.8 – 19.5
	pH	5.5 – 6.5	5.5

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