Proceedings of the 10th International Conference on Agriculture, Vol.8, Issue 1, 2023, pp. 75-85

ISSN 2682-7018 online
DOI: https://doi.org/10.17501/26827018.2023.8107

CHARACTERIZATION OF CILEMBU IPOMOEA BATATAS TYPICAL AGRICULTURAL LAND USING ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) AND MICROTREMOR APPROACHES

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Abstract: Agricultural productivity is highly correlated with soil physical characteristics. Generally, the characterization of agricultural land is done traditionally, but this research raises a new problem in agriculture where the characterization of the physical properties of agricultural land is determined based on microtremor data processed using the HVSR method. Determination of the physical characteristics of the soil in this study was conducted to determine the relationship between the physical properties of the soil on the productivity of sweet potato farming land. This research was conducted on sweet potato farms in Cilembu village. The results of this study provide information about the structure of shallow soil layers in Cilembu sweet potato farms, also can be used by farmers to determine good land for planting sweet potato by knowing the thickness of the layer and the friability of the soil based on the value of the dominant frequency and amplification obtained from microtremor processing data. The results of HVSR method show that the more fertile areas frequency values are in range 9 – 14 Hz, and amplification from the range 2.5 – 4. Meanwhile, the range of resistivity values shows a quite large value in range 100 – 2400 Ωm, indicated that the soil in the Cilembu area originates from weathering of young volcanic rocks.

Keywords: agricultural geophysics, ERT, microtremor, soil characterization

Introduction

The depth of geophysical investigations for agricultural applications is generally smaller than the depth of other geophysical investigations. Agricultural geophysics only focuses on the zone 2 m just below the soil surface which includes the plant root zone and soil profile (Allred et al., 2008). Research using microtremors has been widely used for geotechnical and seismicity this far. Several studies have used microtremor to identify the thickness of the intrabasaltic weathered layer based on estimated soil Vs values, characterizing the shear-wave velocity structure as an evaluation of the HVSR method in detecting the contact depth between saprolite and bedrock, also to obtain information about underground structures in the southwestern Etnean (Singh et al., 2020; Nelson & McBride 2019; Panzera et al., 2016). Meanwhile, not many studies have used microtremor surveys to determine the physical characteristics of soil in agriculture.

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Researchers have carried out various ways and methodologies. One of them is the land suitability assessment carried out by matching methods between crop productivity and land characteristics as parameters with land suitability class criteria that have been prepared based on the requirements for use or plant characteristics, as well as the conditions of crops or other commodities that are evaluated. Land characteristics, both soil and climatic properties affect the production and quality of Cilembu sweet potatoes (Solihin et al., 2018).

Mujiono & Kurniawati (2019) conducted a comparative test of land characteristics between growing locations. It is known that there are several different land characteristics between typical locations of Cilembu sweet potato in Cilembu village, typical locations outside Cilembu village (Rancakalong and Sukasari), and non-typical locations or new cultivation locations (Cicalengka and Jalaksana). The most optimal location for planting is in the origin area of Cilembu sweet potato, more precisely in Cilembu Village, Pamulihan Subdistrict.

Physical properties of the soil, in terms of clay fraction, play an important role in the rooting medium. Cilembu sweet potato requires fine soil texture compared to coarse texture. This is related to the role of clay as a soil colloid in supporting and providing nutrients to plants, while sand is less active in exchanging or supporting cations in the soil. In addition, Wu et al. (2011) found that clay texture is better than sand in supporting the available water content in the soil. In addition to the texture aspect, the effective depth of the soil plays an important role in the growth of roots and tubers in the soil. Obstructions to root growth, e.g. solid rock, prevent nutrient movement and tuber growth.

Effective soil depth and texture are essential for the growth and production of crops, especially the potential to distinguish sweetness classes. The properties of the soil are correlated to suitable rhizosphere conditions in terms of the easiness of crops' roots through in soil, nutrient availability for crops in soil, and water availability. Increasing soil depth positively affects crop growth and yield (Hirzel & Matus, 2013). Sandy soil has stunted the growth of crops due to the lack of water in the soils (Wu et al., 2011). A good soil for the cultivation of Cilembu yam is a brown latosol soil that contains a lot of organic matter and has good aeration and drainage. In general, former rice fields are very good for this crop. The optimum soil condition is one that is not muddy or waterlogged and has a pH in the range of 5.5 to 7.5. The most optimal location for planting is in the origin area of Cilembu yam, more precisely in Cilembu village, Pamulihan subdistrict (Mujiono & Kurniawati, 2019).

The study area is close to the Cileunyi Tanjungsari fault as shown at Figure 1, so it is interesting to conduct microtremor measurements with the aim of seeing the physical characteristics of the soil. Based on this information, the research we conducted focused on the Cilembu area, Pamulihan kec. This study attempts to apply microtremor data processing using the HVSR method, to determine the sediment thickness, soil homogeneity, and friability in typical land of the Cilembu sweet potato by knowing soil physical properties such as dominant frequency, and amplification. This research is also expected to identify the soil type, soil horizon thickness, and effective depth used in the cultivation of Cilembu sweet potato based on direct description and visual observation, and to know the relationship between the physical characteristics and soil fertility in Cilembu and its effect on sweet potato productivity in Cilembu. In addition, a correlation between the microtremor data and the ERT data processing results was performed to strengthen the interpretation of the soil type of the study area based on the rock resistivity value.

Regional Geology

The research area is geographically located in West Java, Indonesia between 5050^o – 7050^o southern latitude and 104048^o – 108048^o eastern longitude. It can be seen from the geological map of West Java; the research area is included in the deposits of volcanic activity. Based on the Geological Map of Bandung from the Geological Research and Development Center, as seen in Figure 1, the study area comprises of Undecomposed Young Volcanic Products consisting of tuff sand, lapilli, breccias, lava, agglomerates. Some come from Mount Tangkubanprahu, and some from Mount Tampomas.

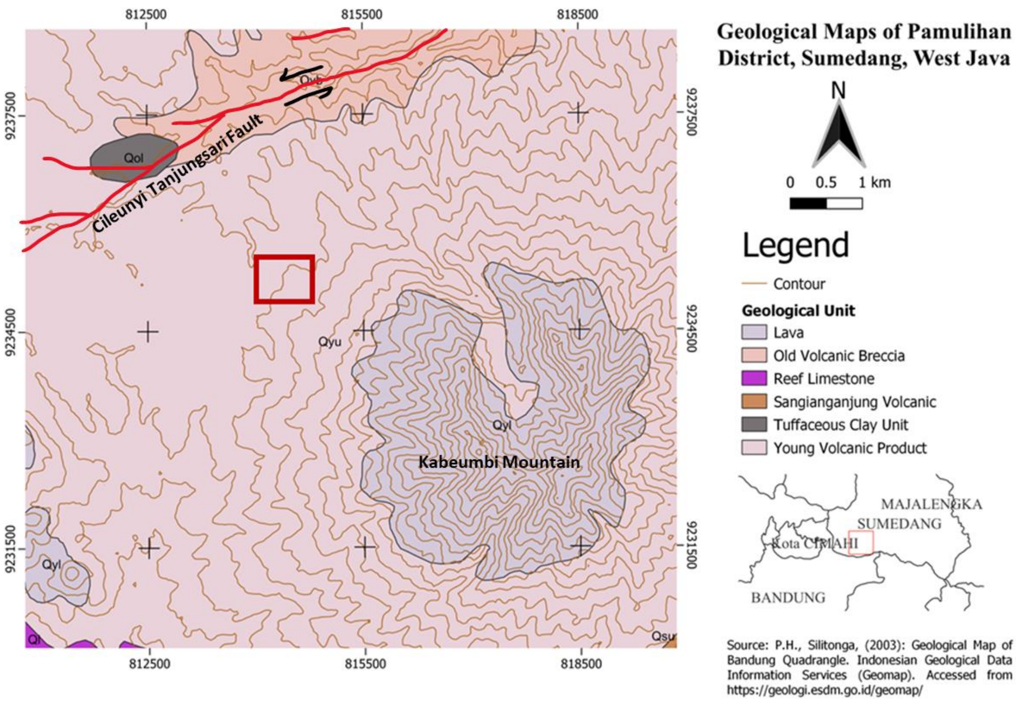

Figure 1: Geological map of Bandung (modified from Silitonga, 2003)

The soil in the study area is classified as andosol, inceptisol order, i.e., immature soil with a weaker development profile than mature soil, and still has properties resembling those of the parent material; generally, such soils have good soil fertility because they come from easily weathered minerals (Hardjowigeno, 1993; Solihin, 2017). The soils in this area are made of volcanic origin, generally including wet tropical climates with an average annual rainfall of 2105.17 mm/year (Solihin, 2017). Pamulihan sub-district is the most optimal location for planting Cilembu sweet potatoes and is one of the areas with high productivity specifically for Cilembu sweet potatoes (Mujiono & Kurniawati, 2019).

2. Materials and Methods

There are 12 stations of microtremor measurement, and ERT data acquisition using Wenner configuration up to 3 lines: CL1, CL2 and CL3, each 14 meters long, as shown at Figure 2. Microtremor data is processed using the Horizontal to-vertical spectral ratio (HVSR) method. This method is an empirical technique for estimating the resonance characteristics of subsurface layers, which is resulting important parameters in the form of dominant frequency (f_0) and amplification factor (A) that are related to subsurface physical parameters (Herak, 2008).

Figure 2: microtremor measurement stations (A, B, C, D, E, F, G, g1, H, I, J, K), and ERT design acquisition (CL 2, CL 2, CL 3)

Dominant frequency and amplification parameters are obtained from the HVSR curve, which is processed using Geopsy software, the parameters used are STA 1 s, LTA 30 s, STA/LTA 0.1-2.5, window length 30 s, and a bandpass filter with a frequency of 0.5 – 20 Hz to separate noise from microtremor data. The dominant frequency and amplification from the HVSR curve are selected from the second peak because the high dominant frequency represents a shallower area (Kanai, 1983).

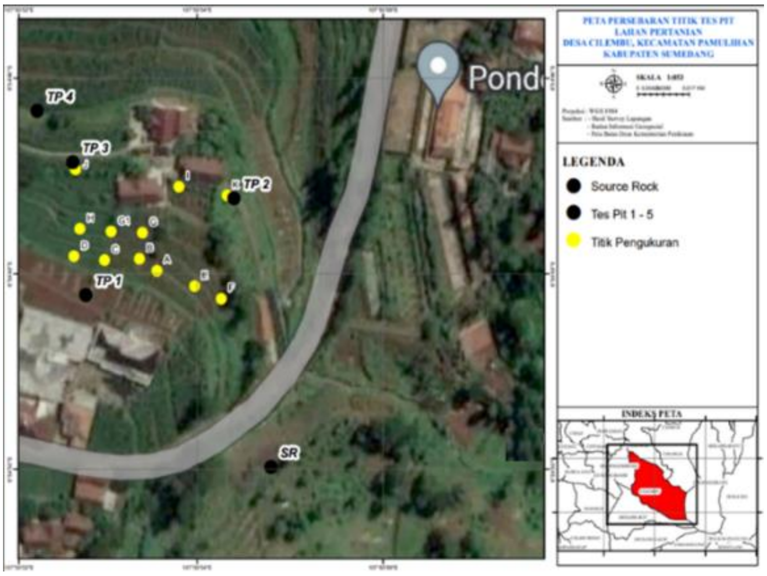

Figure 3: test pit location (TP1, TP2, TP3, TP4), and source rock locations (SR).

Pit test was conducted to see the horizon of sweet potato farming soil, and as a validation between the results of microtremor data processing and direct observations in the field. In this study, pit test points were carried out at 4 points, namely TP1, TP2, TP3, and TP4 as shown in Figure 3. The process of taking a pit test is carried out by digging the soil to a depth of 1.6 m which shows the soil horizon layer, then identification is carried out according to the soil profile classification.

3. Results and Discussion

This research shows that microtremor data can be used to characterize the best areas for Cilembu sweet potato farming based on its physical parameters, such as dominant frequency, amplification factor, and shear wave velocity. There are areas with sufficient thickness and moisture content and sufficiently friable. Direct observation data have validated this result in the field and from the statements by local farmers.

Distribution of dominant frequency (f_0) and amplification (A)

The HVSR curve shows that the inceptisol soil in the study area has a value of f_0 7.389 – 16.48 Hz, and the value of A is in the range of 2.0 – 4.3. Based on the dominant frequency distribution map (Figure 4a), the study areas were grouped into three groups; there are agricultural areas with a moderate f_0 of 9 – 14 Hz marked in green which represents medium sediment thickness, areas with a low f_0 of < 9 Hz shown in blue – purple representing thicker sediment thickness, and areas with high f_0 >14 Hz shown in yellow – red represent thin sediment thickness.

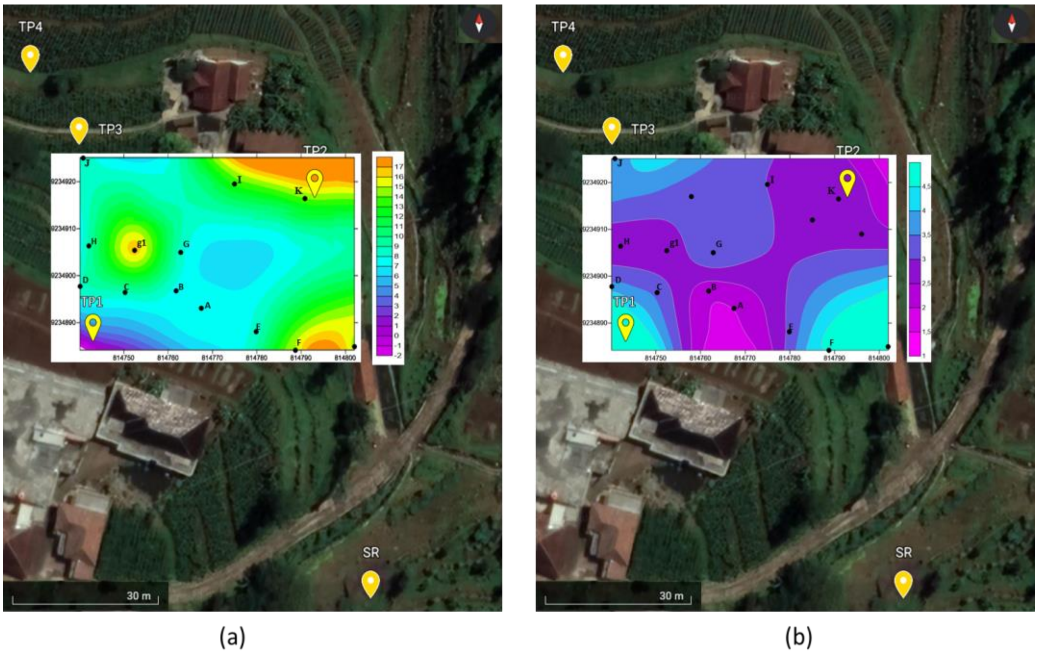

Figure 4: Distribution map of (a) dominant frequency value (f_0), (b) amplification value (A).

The amplification value represents the difference in the contrast of the density of the soil layer, and agricultural studies can indicate the soil's homogeneity level. A low amplification value suggests no differences in contrasting physical characteristics between layers or can be described as homogeneous, whereas the same weathering process causes soil homogeneity. Based on the amplification distribution map (Figure 4b), the blue color indicates high amplification (> 4), dark purple indicates moderate amplification (2.5 – 4), and light purple indicates low amplification (< 2.5). In agricultural areas with an amplification value of 2.5 – 4 suggests that in that area the soil is heterogeneous and loose, which allows the soil to absorb water so that in that area, the soil is more fertile than soil with low amplification (< 2, 5) which indicates that the soil is denser or harder.

Soil Profile Based on Pit Test

TP1 was taken near to point C of the microtoremor measurement in the southern area (Figure 5) with a pit depth of 1.2 m, which shows three horizon layers, namely horizon A with a thickness of 0 to 0.3 meters, horizon B with a thickness of 0.3 to 1.2 meters. In this area, the soil is drier, and according to local farmers, the agricultural land in this area is less fertile than the land to the north such as TP3 which is close to point J and TP 4 to the north of point J, which is fertile and good for planting crops. Based on the observations made, a well in the TP1 area requires a depth of up to 20 meters to reach the water table.

TP2 is located in the northern area close to point K (Figure 5), behind a local house. This land is a former bamboo forest that has not been used for agriculture. The pit depth at this point is 1.5 meters and shows the B horizon layer with a thickness of 0 to 0.3 meters, and the C horizon with a thickness of 0.3 to 1.5 meters. The soil at TP3 and TP4 is classified as fertile and has been used as sweet potato and sweet corn farmland. TP3 shows the O, A, B horizon layers with thicknesses of 0 to 0.3 meters, 0.3 to 0.9 meters, and 0.9 to 1.5 meters respectively at a pit depth of 1.5 meters.

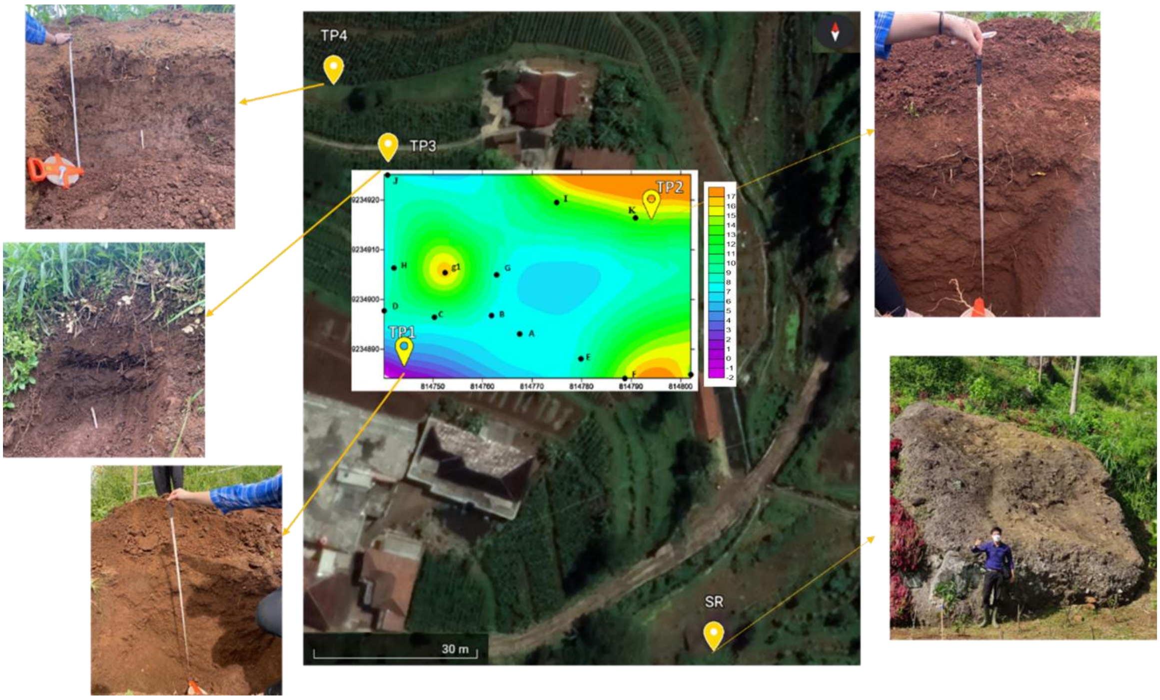

Figure 5: Soil profile correlated to dominant frequency

The pit depth at TP4 is 1.6 meters which shows the A, B, and C horizon layers with thicknesses of 0 to 0.4 meters, 0.4 to 1.2 meters, and 1.2 to 1.6 meters respectively. Meanwhile, there is a rock outcrop (Figure 5) indicated by point SR with a size of approximately 4×3 meters in the southern part of the study area. The outcrop is thought to be the source rock of the soil in the farmland.

Microtremor-Soil Correlation

The results obtained from the pit test correlated to dominant frequency results shows the southern area (TP1) is an infertile area due to thicker sediment characterized by a lower dominant frequency value of < 9 Hz and an amplification value of > 4. The thicker sediments make it difficult for plant roots to get water.

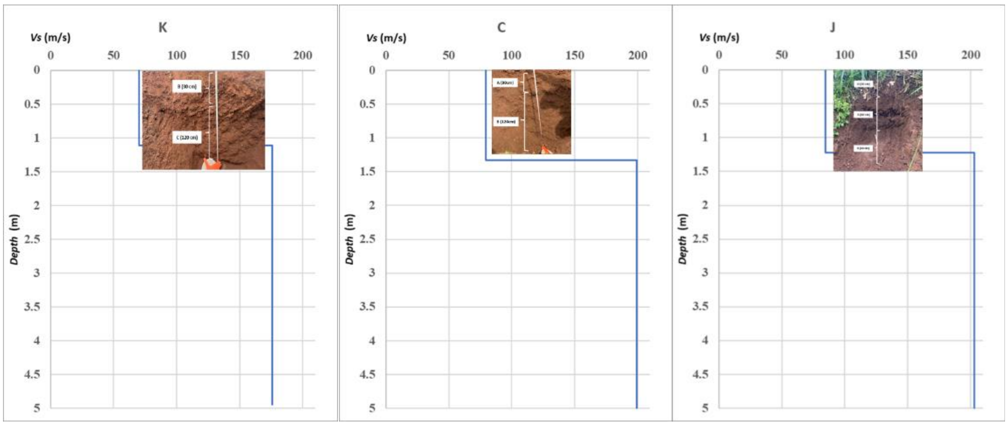

Figure 6: Test pit Correlation with the Vs profile from inversion results

An area with an amplification <2.5 indicates that it is homogeneous and possibly denser or has not been weathered, making it difficult for plant roots to grow. Meanwhile, the regions with the best productivity (TP3 and TP4) are characterized by moderate frequency values of 9 – 14 Hz and amplifications between 2.5 – 4. After being correlated with the Vs profile respected to depth, the Vs value obtained from the inversion results at that depth is 70 – 208 m/s (Figure 6). The correlation between pit test and HVSR inversion shows that the great position of agricultural land for Cilembu sweet potato is the O horizon to the A horizon, these horizons are only at a depth of 0 – 1.5 m.

Electrical Resistivity Tomography (ERT) Results

Electrical Resistivity Tomography (ERT) is a geophysical method used to determine the characteristics of the earths subsurface. The working principle of this method is by providing electricity with current electrodes and detecting it with the help of potential electrodes on the earth's surface.

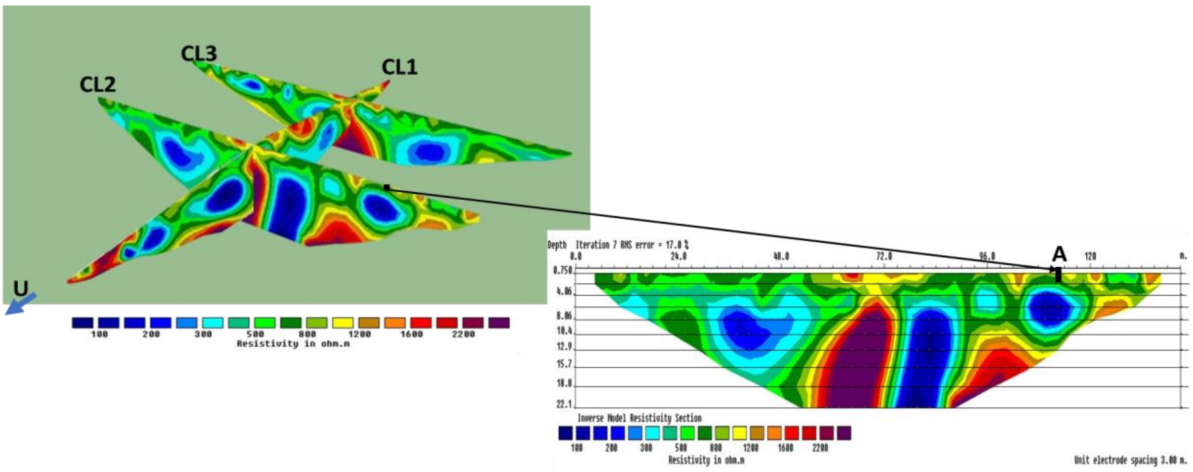

Figure 7: Distribution of resistivity value generated from ERT

ERT results show the distribution of resistivity values from 75 Ωm until >2000 Ωm that identify the presence of layers in the study area (Figure 7). The resistivity value in the study area is classified into three zones, namely the aquifer zone and soft zone, dry zone, and bed rock, with details as shown in Table 1.

Table 1: Layer zone classification based on resistivity value.

Resistivity Ωm	Zones	Depth (cm)	Thickness (cm)
75 – 500	Acquifer & Soft zone	40 – 200	± 60 – 100
600 – 1800	Medium – Dry Zone	0 – 40 60 – 180	± 40 – 120
> 2000	Bedrock	> 180	> 70

Microtremor – Electrical Resistivity Tomography (ERT) Correlation

The relationship between microtremor and ERT is that the high frequency values indicate thin sediments, and the varied resistivity values indicate that weathering in the study area is low, which is related to the high mineral content. This is also supported by the Vs value of the HVSR inversion results in the research area which is 70-208 m/s which can be classified as soft to medium soil types (based on SNI-1726, (2012) site classification).

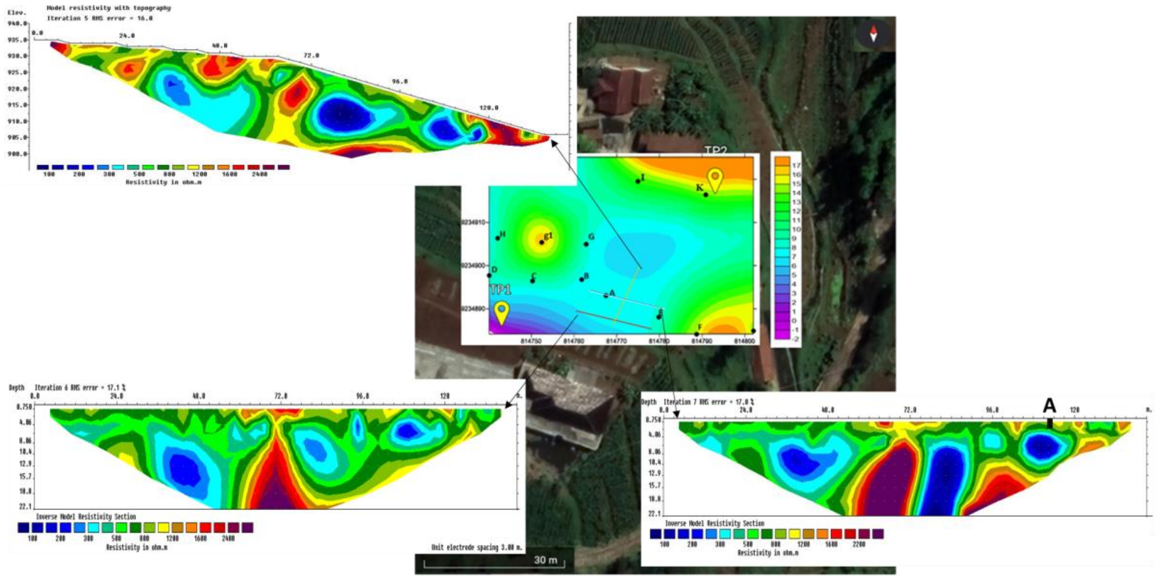

Figure 8: Dominan frequency correlated to resistivity value.

4. Conclusion

Soil profiles used in agriculture are from the O horizon to the B horizon, which has an effective depth 0 – 1.5 meters. In general, the soil characteristics of typical area has dominant frequency values from 7 – 15 Hz and amplification values from 2 – 4. The medium frequency and amplification values indicate that the study area is friable and has medium sediment thickness. The study area is a good area for planting cilembu sweet potatoes because they have a moderate level of weathering which still contains many minerals. Based on the ERT results, the study area is dominated by sandstone and gravel with some clay, represented by resistivity values ranging from 400 – 1200 Ωm. Soil friability, sediment thickness, and soil density are strongly related to fertility as they relate to root growth and water absorption. Farmland in the north is more fertile than farmland in the south, so farmland in the north is likely to have higher productivity than farmland in the south.

To improve better conclusions from this study, more microtremor measurement points that represent the study area is needed, also a comparison with other Cilembu sweet potato farming areas, especially in areas with different parent material zones, climates, and topography. In the future, research using microtremor to characterize agricultural land is expected to be used to open new agricultural land for Cilembu sweet potato or other plants based on physical parameters that have been specifically classified.

Declaration of Interest Statement

The authors declare that they have no conflict of interests.

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