Comparing Electrical and Magnetic Properties of Soil Layer from Sag Pond near Lembang Fault, West Java, Indonesia

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Abstract— **Electrical and magnetic properties have been used in soil characterization for various types of soils except for soil originated from sag pond sediment. Formed near fault line, sag pond provides a unique environment for sedimentation. In this study, electrical conductivity and magnetic susceptibility of soil samples obtained by coring process were measured to find out how these two properties were related. A 364 cm core was obtained in a sag pond located next to Lembang Fault in West Java, Indonesia. The core covers two different layers that are differ not only on their coloration and texture but also showed variations in their electrical conductivity and magnetic susceptibility. In the first layer, termed silty loam (above 165 cm), electrical conductivity correlates positively with magnetic susceptibility whereas in the second layer, termed silty-clay (below 165 cm) the correlation is negative. These differences are probably due content of magnetic minerals that is high in silt but low in clay. The results of this study infer that correlation between electrical conductivity and magnetic susceptibility could then be used as a tool to delineate soil layers.**

Keywords: sag pond; electric-magnetic properties; silty-loam; silty-clay; Indonesia

I. INTRODUCTION

Studies on organic soils, including peat, have been carried intensely since the last two decades [1, 2]. The objective of such studies, among others, was the proper determination of thickness of organic layers. In many cases, electromagnetic-based method, such as ground-penetrating radar (GPR) has been used in determining the thickness of peat layer in different types of environment [1, 3-7]. The effectiveness of GPR depends largely on how well the velocity of EM wave is known. The velocity of EM waves in turn depends on electrical and magnetic properties. So far, little is known about how electrical and magnetic properties correlate in organic soil. Previous works often measure either electrical or magnetic properties but not both properties [8-13].

In this study, electrical conductivity and magnetic susceptibility of coring samples of sag pond soil were measured and analyzed. Sag pond is depression or basin formed near fault line. Soil in sag pond could also be classified as organic soil similar to that of peat. The objective of this study is to seek whether electrical properties correlate magnetic properties and to seek whether such correlation (if any) vary between layers of organic soil.

II. METHODS

Soil samples were obtained from sag pond in Karyawangi Village, West Bandung Regency, West Java, Indonesia (06º 49.063’ S and 107º 35.134’ E with elevation of 1238 m above sea level). This sag pond is located near a 34 km long Lembang Fault, about 10 km north of the city of Bandung (Fig. 1). Samples were obtained by coring using a 4 cm diameter Hand Auger through the depth of 364 cm. The color of the cored soil samples were identified using Munsell Soil Color Chart before they were stored in PVC pipes.

Samples were subjected to measurements of electrical conductivity and dielectric permittivity using probe sensors 5 TE (for electrical conductivity) and EC-5 (for dielectric permittivity). Both sensors are made by Decagon Devices Inc., USA. The measurements were carried out by shifting the probes for every centimeter. The results of the measurements were stored in EM50 data logger. For magnetic susceptibility measurement, samples were sliced 1 cm thick and placed in cylindrical plastic holders (2.5 cm in diameter, 2.2 cm in height). The mass of each sample was measured using Ohaus

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analytical balance. Each sample was then measured for mass-based magnetic susceptibility using the Bartington MS2 magnetic susceptibility system (Bartington Instruments Ltd., England) with MS2B sensor set to frequency of 470 Hz.

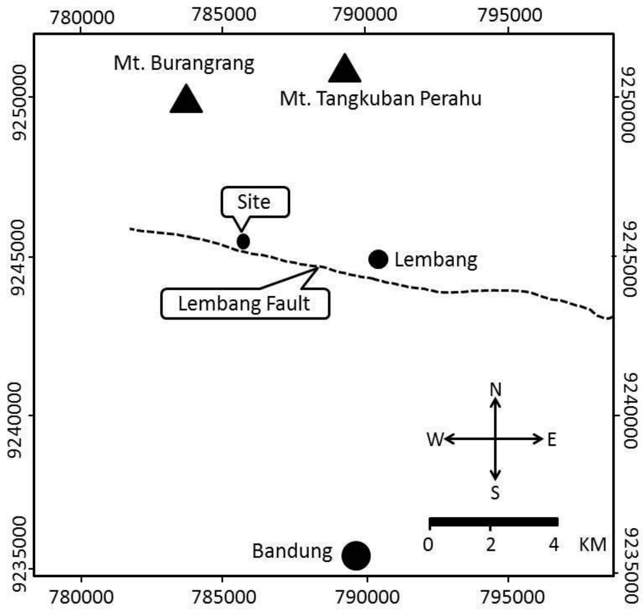

Figure1. Location of sag pond of this study

III. Result and discussion

Based on Munsell Soil Color Chart, the samples have distinct coloration. Those samples above 165 cm have value and chroma of 3/1 (very dark grey) to 4/1 (dark grey), whereas those below 165 cm have value and chroma of 2/1 (black). Nevertheless, all samples have similar hue of 10YR (yellowish red). Meanwhile, electrical conductivity (σ) of the samples vary from the minimal value of 0.38 dS/m to maximum value of 2.31 dS/m. Relative dielectric permittivity (ε_r) varies from 8.7 to 28.3. Figure 2 shows variation of σ and ε_r with depth. It shows σ values are relatively small above 165 cm but they are higher below 165 cm. On the other hand ε_r values vary erratically within the core. In general, however, the ε_r values are, on average, higher for samples below 165 cm. Figure 2 also show variation of χ with depth. Samples below 165 cm have higher χ compared to those above 165 cm. The minimum and maximum values of χ are respectively -0.1×10^{-8} and 184.2×10^{-8} m^3/kg. Based on coloration, σ and χ, it is clear that the core could be divided into two different layers, *i.e.*, layer I (above 165 cm) and layer II (below 165 cm). This distinction is shown as broken line in Figure 2.

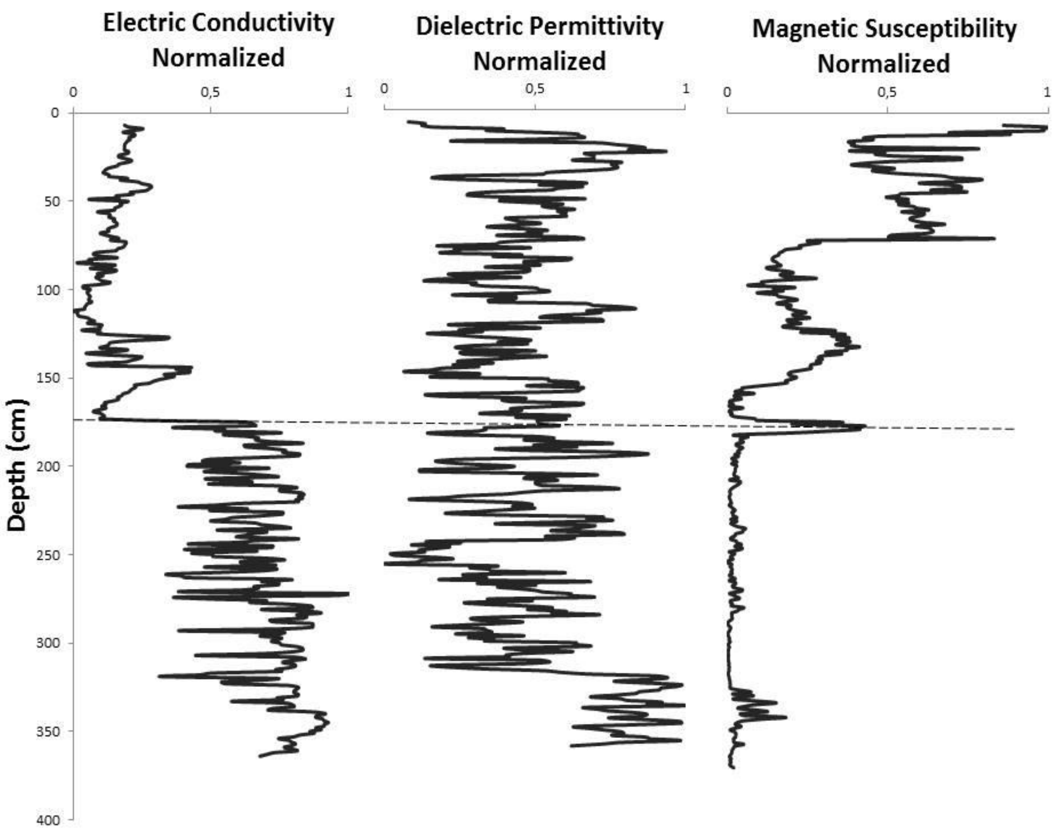

Figure 2. Normalized profiles of electric conductivity (left), dielectric permittivity (center), and magnetic susceptibility (right) as functions of depth.

Next, correlations between σ, ε_r, and χ were measured for each layer (159 samples in layer I and 199 samples in layer II). The results are given in Table 1. Correlation is significant if the confidence level exceeds 95% or in our case if $r > 0.17$. Table 1 show that correlations between σ and χ are significant in both layers, whereas that between ε_r and χ are insignificant. Moreover, correlation between σ and χ is positive in layer I but is negative layer II.

To examine why correlations between σ and χ in layer I differ greatly with that in layers II, the texture of the samples from these layers were analyzed. Composite samples for layers I and II were dried in an oven at 105 centigrade for 2 hours. They were then sieved using three different sieve sizes (10, 30, and 325) so that the sand, silt, and clay contents of the samples could be determined. The results show that these two layers have distinct texture as the sand, silt, and clay content of layer I are respectively 20%, 62%, and 18% whereas that of layer II are respectively 19%, 39%, and 42%. Layer I is classified as silty loam while that of layer II is silty clay [14].

TABLE 1. Determination and Correlation Coefficient between Electric and Magnetic Properties of soil layer

	Electric Conductivity vs Magnetic Susceptibility	**Dielectric Permittivity vs Magnetic Susceptibility**
Layer I , n = 159		
Sand : Silt : Clay = 20 : 62 : 18		
Determination Coefficient	$r^2 = 0.0345$	$r^2 = 0.0113$
Correlation Coefficient	$r = 0.1857$	$r = 0.1063$
Layer II, n = 199		
Sand : Silt : Clay = 19 : 39 : 42		
Determination Coefficient	$r^2 = 0.0645$	$r^2 = 0.0097$
Correlation Coefficient	$r = -0.2539$	$r = 0.0984$

Variations in silt and clay content in soil layer might be the cause of differing correlation between σ and χ. Soil with high silt content such as layer I might store substantial amount of fluid. Higher content of silt reflects higher water content. As water content contributes to σ [15] then variation in σ, in turn, is associated with silt content. As the location of sag pond is the vicinity of an active volcanic complex, sediments, which were then transformed into soil, might contain substantial magnetic minerals. Compared to sand and clay, silt might contain higher content of magnetic particles so that variation in χ, to certain extent, also reflects variation in silt content. As both σ and χ might represent silt content, thus σ and χ have significant positive correlation in layer I.

In layer II, however, clay-size particles dominate the texture. Like silt, clay could also absorb and retain fluid so that the variation of σ in layer II is also controlled by clay content. However, clay-sized particles or clay minerals generally contain smaller amount of magnetic particles. In fact, higher content of clay normally means lower magnetic susceptibility. Thus, unlike that in layer I, in layer II σ correlates negatively with χ.

IV. Conclusions

Based on the above results, the soil layers in the observed sag pond shown two distinct layers; one above 165 cm and the other one below 165 cm to at least 364 cm. These two layers termed respectively as layers I and II differ in terms of coloration and texture (layer I being silty loam, while layer II is silty clay). σ and χ correlates positively in layer I, but the correlation is negative in layer II. The differences, possibly due to the variations in silt or clay content, might be used and exploited as tools in delineating soil layers.

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