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A Preliminary Study of the Application of Electromagnetic Conductivity Meter on Soil Properties of Paddy Cultivation Areas at Wue Village, Jantho, Aceh Besar District, Indonesia

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Abstract - Conventional soil sampling is time consuming and requires meticulous laboratory analysis. Hence, mapping of soil apparent in respect to electrical conductivity (ECa) has been developed to identify areas of contrasting soil properties. Such ECa values are represent measures of soil properties. The sensor system, GF Instrument model CMD-4 were used to analyze soil physical properties. This system consists of three important parts, ECa sensor, data logger and Global Positioning System (DGPS) receiver. This research was aimed to evaluate the relationships between ECa and soil properties as well as the yield of rice (paddy) in paddy's farming fields. One study site was chosen. The sensor was pulled through a plotted area of 0.25 km^2. The distribution map of ECa was developed to identify the contrast of ECa. More than 100 ECa of data points were collected in 3-hour for the large plot. The data was later transferred to a notebook computer for generation of ECa maps using Surfer 11 software. According to the data analyses, field and ECa showed positive correlation. The average values of ECa are significantly different between hilly area and drainage canal area signifying differences in soil structure. Soil ECa could provide a measure of the spatial differences associated with soil physical and chemical properties, which for paddy soil may be a measure of soil suitability for crop growth and its productivity. This sensor can measure the soil ECa through the field quickly for detailed features of the soil and can be operated by just one worker. The ECa map provides some ideas for future soil management.
Keywords: Electrical Conductivity (ECa); CMD-4 Electromagnetic Sensor; Soil Study; Jantho

Introduction

Jantho is situated in Aceh Besar District, Province of Aceh, Indonesia. Jantho has area with a unique ecology in the arid/semi-arid area with its availability of water and potential for agriculture, which makes it one of the most prominent areas for paddy cultivation in Aceh. It was widely recognized that there is considerable variability within soils (Brevik *et al.*, 2003; Doolittle *et al.*, 1996; Miller, 2012). Soil apparent with respect to electrical conductivity map can be used as an indirect indicator of a number of soil physical properties at an agriculture area. The application of electromagnetic conductivity sensor is widely used by soil scientists to better understand the spatial variability of soils and soil properties at field and landscape scales (Corwin and Lesh, 2003). Soil sensor is a practical tool in mapping soil apparent using electrical conductivity (ECa) in order to identify areas of contrasting soil properties such as the CMD-4 sensor. In non-saline soils, ECa values are measurements of soil texture – relative amounts of sand, silt and clay. Soil texture is directly related to water holding capacity, which is key ingredients of productivity (Tromp-van Meerveld and McDonnell, 2009).

There are two techniques used to measure soil ECa in the field namely electromagnetic induction (EM) and contact electrode. In this research, however, EM surveys method used as techniques to measure soil ECa. EM surveys are conducted by introducing electromagnetic energy into geological materials using a current source that passes over the soil surface, but does not make physical contact. Furthermore, a sensor in the device measures the resulting electromagnetic field that this current induces. The strength of this secondary electromagnetic field is directly proportional to the ECa of the soil.

Electromagnetic induction sensors measure changes in the apparent of electrical conductivity (ECa) on the subsurface without direct contact with the sampled volume (Allred *et al*., 2008). Apparent electrical conductivity is a depth-weighted, average conductivity measurement for a column of soils to a particular depth (Greenhouse and Slaine, 1983). Variations in ECa are produced by changes in the electrical conductivity of soils. Apparent electrical conductivity will increase with increases in soluble salt, water, clay contents, and temperature (Brevik *et al*., 2003).

The electromagnetic surveys were performed at paddy cultivation areas to evaluate distribution of conductivity values. It is also explains the use of a new GF instrument, the CMD-4 Electromagnetic Conductivity Meter and its applicability to agriculture prospecting and monitoring. The most important advantage of electromagnetic conductivity meters is fast mapping of apparent conductivity. The objective of the research was to study soil properties of paddy cultivation areas using application of electromagnetic conductivity meter.

Materials and Methods

Study area

This research was conducted in Jantho Sub-District, Aceh Besar Regency on 23 November 2014. The electromagnetic survey was performed in a paddy cultivation area at Weu Village, Jantho (Figure 1). The primary data (apparent of conductivity) in millisiemens per meter (mS/m) was acquired from geophysical electromagnetic survey in the field. The data were measured using one GF Instrument, the CMD-4 Electromagnetic Conductivity Meter which is an electromagnetic sensor obtaining subsurface conductivity values in 3 - 6 meters full depth range. This low-frequency electromagnetic instrument operates at 9.8 kHz with eight cells alkaline battery which is retained for 15 – 30 hours. In addition, secondary data obtained by differential GPS was associated with each sensor reading to provide positional information with an accuracy of 3-meter or better.

Electromagnetic induction method

Electromagnetic induction methods measure the electrical conductivity for a bulk volume of soil directly beneath the surface. A geophysical tool called a ground conductivity meter is normally employed for relatively shallow electromagnetic induction surveys. In operation, an alternating electrical current is passed through one of two electric wire coils spaced a set distance apart and housed within the ground conductivity meter that is positioned at, or a short distance above, the ground surface. The applied current produces an electromagnetic field around the "transmitting" coil, with a portion of the electromagnetic field reaching into the subsurface. This electromagnetic field, called the primary field, induces an alternating electrical current within the ground, in turn producing a secondary electromagnetic field (Figure 2). Part of the secondary field spreads back to the surface and air.

The second wire coil acts as a receiver measuring the resultant amplitude and phase components of both the primary and secondary fields. The amplitude and phase differences between the primary and resultant fields along with the inter-coil spacing were then used to calculate an "apparent" value for soil electrical conductivity (or resistivity). Furthermore, the sensor can measure the soil ECa through the field quickly for detailed features of the paddy soil, and can be operated by just one operator. Actually, the conductivity multi-depth is one of electromagnetic method which is fast mapping of apparent conductivity with possibility of electromagnetic.

Figure 1. The location of acquisition electrical conductivity data at Weu Village, Jantho.

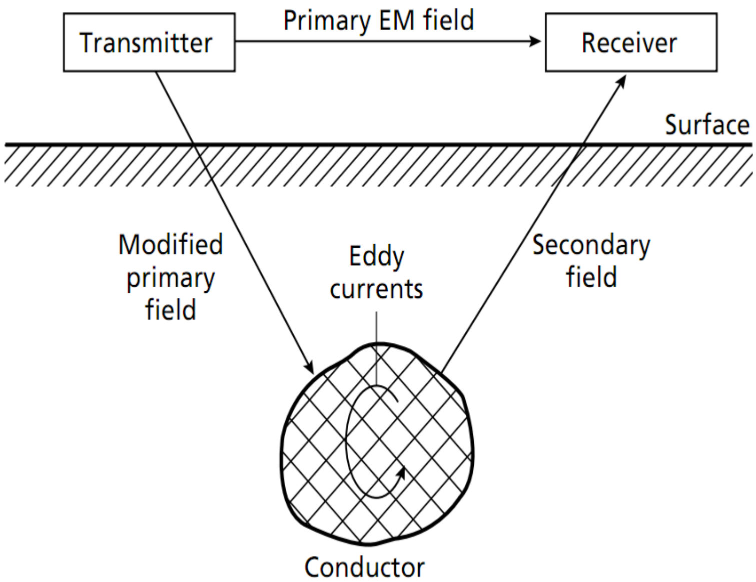

Figure 2. General principle of electromagnetic surveying (Kearey *et al.*, 2002)

Each station point has the data acquired from random sampling acquisition with 20-25 meters spacing per point. Then, GPS (Figure 3b) was used to take coordinate in each datum point and assistant performed rewriting the data (mS/m and datum coordinates) in a notebook. All conductivity objects should be removed and taken away from the CMD (Figure 3a) operator in order to reduce the unwanted (noise) effect. The procedure of the data acquisition is simple and the acquisition process is in time efficient way (Figure 4). To obtaining the soil electrical

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conductivity map data were sorted by using worksheet program and then spatial variability maps were generated using geo-statistical gridding technique in Surfer 11.

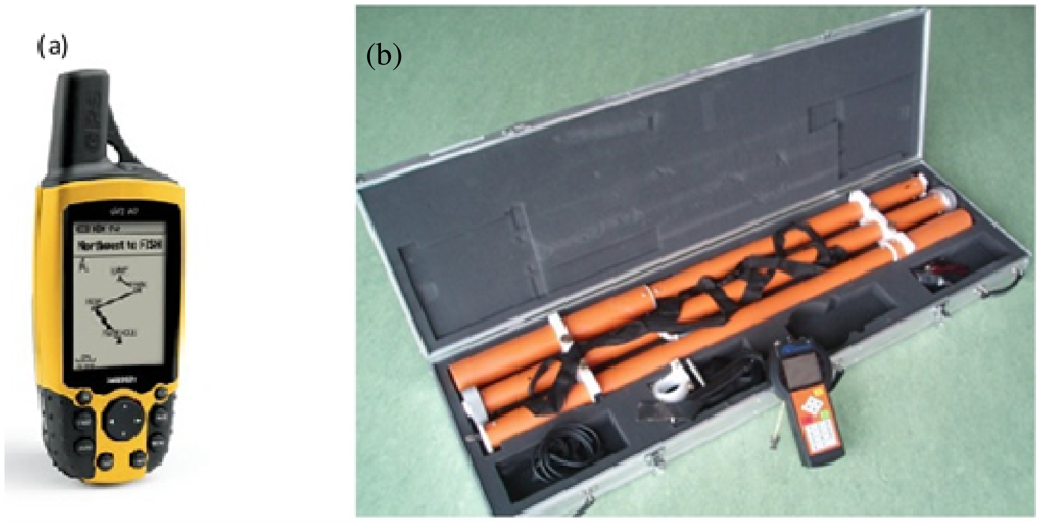

Figure 3. Survey equipments; (a) Global position system (b) Conductivity Multi-depth (CMD)-4 Electromagnetic Conductivity Meter.

Figure 4. Data acquisition at paddy cultivation area at Weu Village, Jantho. Aceh Besar District, Indonesia

Results and Discussions

Soil electrical conductivity (ECa) could provide a measure of the spatial differences associated with soil physical and chemical properties, which for paddy soil could be a measure of soil suitability for crop growth (Ezrin *et al.*, 2010), its water demand and its productivity(Corwin *et al.*, 2005). Soil ECa could provide a measure of the spatial differences associated with soil physical and chemical properties, which for paddy soil may be a measure

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of soil suitability for crop growth (Nayanaka, 2010), its water demand and its productivity. The ECa map is indicating the similarity to some soil nutrient maps (Aimrun *et al.*, 2011). The study found that the operation time for the small plot of 0.25 km^2 was only about 3 hours and the sensor can collect more than 100 data points with random sampling technique. The other methods such as grid sampling techniques will require more time to cover the acreage. In this study , the part of the field having low Eca value was 25 mS / m and high ECa one was 175 mS / m. Each material has differ ECa values of conductivity , based on the standard units of measure of bulk soil conductivity (Grisso, 2009) which is clay has ECa value by 100-175 mS / m and silt has ECa value by 25-100 ms / m . while the area of the clay was in the east part, but the area of silt was almost area. As the result, the area of study dominated by silt material. In soil properties, some of the most obvious reasons are differences for value variability. Soil ECa has the potential to estimate variations in some soil physical properties in field.

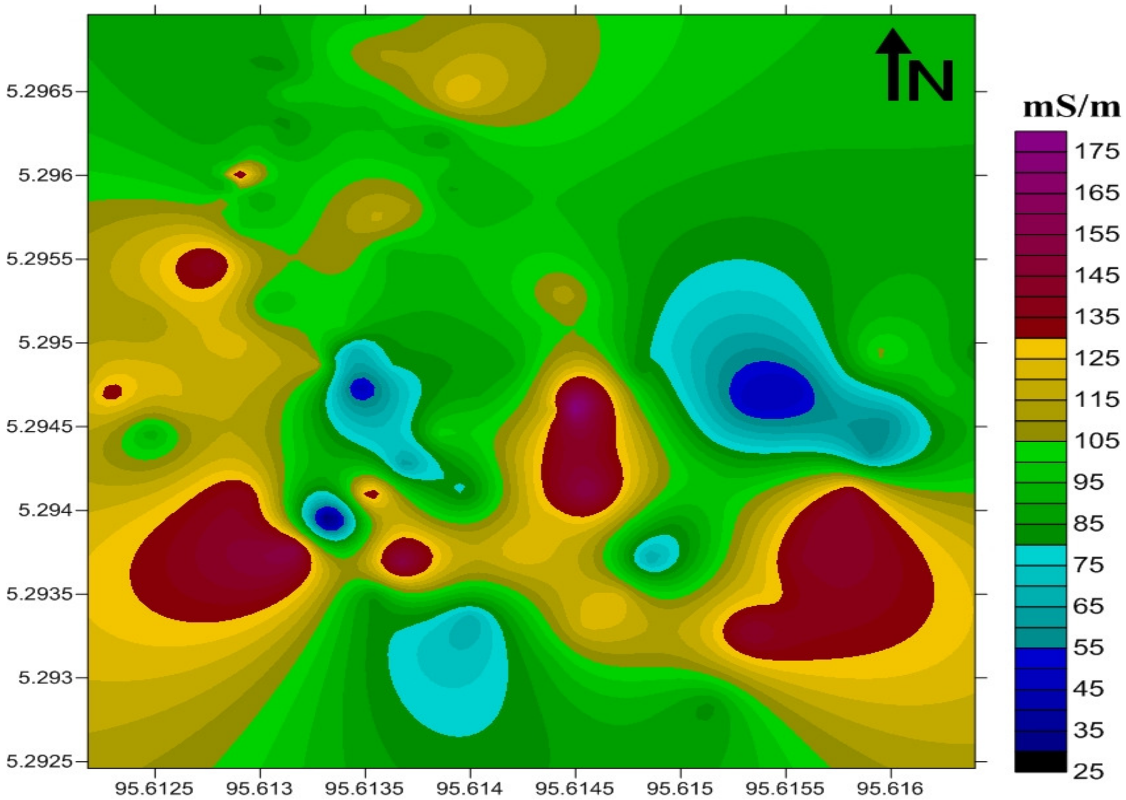

Figure 5. The result of measurement conductivity

Therefore, in the map, it show the spatial distribution, there was the contrast character of spatial distribution in the survey location which meant the area with high conductivity lied mostly in the down side part of the study area near the drainage canal, and the area with low conductivity lied in the center-east part of the study area near the hill, the soil conductivity trended to increase from east to west, which validated the trend effect caused by the canals. Based on the maps, the spatial variability of soil ECa within a field or the adjacent field is clearly shown. For more detail ECa, the higher values are distributed in the southern part and higher than in the north as shown in Figure 5. The average ECa values from map show that the area near drainage system has higher ECa than the hilly area because the soils of the near drainage have higher clay content. The result shown that soil water content most influenced value ECa conductivity with all other measured soil properties nearly equally, but weakly, correlating with ECa (McCutcheon *et al.,* 2006). Further work is being carried out to determine the correlation of rice yield with ECa measurement and other soil fertility parameters in the paddy field.

Conclusions

CMD electromagnetic conductivity meter can be used as an efficient and practical geophysical tool to delineate physical properties in an agriculture area. More accurate soil properties of maps are needed to successfully implement precision farming decisions. Inadequate sampling density and the high cost of conventional soil sampling and analysis may prevent soil property segregation and classification. However, the use of soil ECa measurements represents an alternative for intensive soil sampling and could both improve the resolution (increased sampling density) and reduce the cost of soil maps. Soil ECa maps can be used to define management zones reflecting obvious trends in soil properties. Each zone can be sampled and treated independently.

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