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Effects of Soil Moisture Content on Groundwater Electrical Resistivity Values in Irrigation Paddy Scheme, Tanjong Karang, Malaysia

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***Abstract*— Electrical Resistivity Tomography (ERT) analyses have been conducted in Irrigation Paddy Scheme, Tanjong Karang, Malaysia as part of investigation on groundwater potential aquifer to provide an alternative water resource for paddy irrigation. Based on recent studies on groundwater resistivity in paddy field, irrigation system mentioned as soil moisture content was observed to affect the value of electrical resistivity and subsurface geological profile resulted from ERT analysis. The objective of this study was to proof any correlation between soil moisture content and electrical resistivity values and to determine at what level of soil moisture content which will be the best condition to conduct ERT survey. ERT analysis was conducted by using ABEM Terrameter SAS 4000 of Wenner-Schlumberger array with 5.0 meter and 10.0 meter for minimum and maximum electrode spacing. Visually, based on subsurface geological profile resulted from ERT analysis soil moisture content affected (changed) electrical resistivity values. With all different treatments of soil moisture ranged from 16.96% to 27.50%, electrical resistivity values decreased in certain points and in certain depth along with the increase of soil moisture content. This was proofed by ANOVA and Duncan's multiple range tests showing that Pr > F value was less than 0.0001. Further on Chi-square test showed that at soil moisture level of 22.54%, it was the best condition which gave more correct counts of electrical resistivity values compared to well lithology. This was assumed to be the best condition to conduct ERT survey.**

***Keywords*— Groundwater; Electrical resistivity tomography; Irrigation; Soil moisture.**

I. INTRODUCTION

Surface water as major resource for irrigation in paddy field in Malaysia now is facing huge problems such as drought, pollution and its quantity which is limited to fulfil the needs of irrigation [1]. One way to overcome this problem is to look for other alternative resource to substitute function of surface water.

Many researches in Malaysia have studied about the possibility to use subsurface water (groundwater) as water resources for irrigation in paddy field [2],[3]. As mentioned by Azhar [4] that groundwater stored in subsurface aquifer throughout Malaysia is estimated at 5000 billion m^3, or 90% of Malaysian freshwater resource which is stored as groundwater.

One way to determine the potential subsurface aquifer is by using Electrical Resistivity Tomography (ERT) survey. This survey has been used widely to overcome groundwater problems such as salinity, pollution, capturing freshwater lens in an island, and groundwater conservation [5] - [9].

This study focused on using ERT survey to find potential location for groundwater aquifer in paddy field. Based on several ERT surveys which have been conducted in Sawah Sempadan - Irrigation Scheme, Tanjong Karang, Malaysia, it was occurred that ERT results would change for every different paddy planting stages (saturation, transplanting, vegetative stage, mid-season stage, late season stage), due to irrigation activity by farmers. This became background for this study and helped writer to come up with two hypotheses; 1) soil moisture content affects electrical resistivity values, and 2) electrical resistivity values will be achieved at certain level of soil moisture content.

The objectives of this study are to proof that soil moisture content affects electrical resistivity values in paddy field, and to determine at what level of soil moisture content which will give correct results of electrical resistivity based on well/soil lithology.

II. METHODOLOGY

This study was located in two different blocks (block C and block F) of paddy field in Sawah Sempadan – Irrigartion

Scheme, Tanjong Karang, Malaysia. Block C was intended to be used for preliminary study because the location was close to main road and easy to access, while block F was intended to be used for site survey because there is located a well which will be used as standard for ERT results.

ERT method conducted in this study was using 1 unit set of ABEM Terrameter SAS 4000 with array Wenner-Schlumberger. Survey line was set to have 400 meter length and electrode spacing for inner and outer cable was 5.0 meter and 10.0 meter. Along in survey line 5TE soil moisture sensors were installed to record soil moisture changes in soil. The sensors were connected to Em50 data logger and recorded soil moisture content (%) with reading interval of 2 minutes for as long as approximately 45 minutes. ERT installation on site was described in Fig. 1 below:

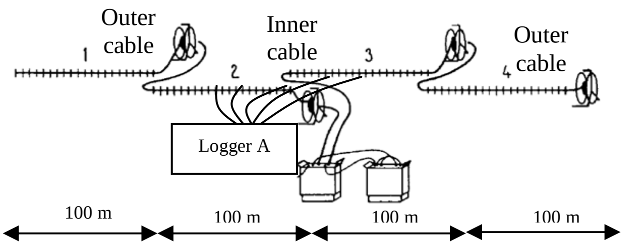

Fig. 1 ERT method installation on field

A. Calibration of 5TE Soil Moisture Sensor

This calibration was conducted on soil and water conservation engineering laboratory by using 30 different treatments of soil condition. Sensor calibration installation is shown in Fig. 2 below.

Fig. 2 5TE Soil moisture sensor calibration on laboratory

Calibration was done by comparing soil moisture measurement results from 5TE Soil moisture sensor and oven dried method, and plot the results on a graph to see R2 value. The closer the R2 value to 1 the more accurate the sensor to measure soil moisture content.

B. Preliminary ERT Survey

This preliminary survey was conducted in Block C of Sawah Sempadan, Tanjong Karang, Malaysia. This study was intended to see the changes of electrical resistivity in relation to soil moisture content.

Three different conditions of soil moisture content were applied in this preliminary study. After ERT survey conducted in each condition, ERT values were then converted and analysed by using RES2DINV software to produce subsurface geological profile in .DAT file.

C. Site Survey

Site survey was conducted in Block F, Sawah Sempadan, Tanjong Karang, Malaysia. Like preliminary survey, site survey was done by using same method and three different conditions of soil moisture content.

This survey was intended to see correlation between soil moisture content and electrical resistivity values. And further, it can be determined at what level of soil moisture content which will be the best condition to conduct ERT survey, compared to well lithology electrical resistivity values in Blok F. ERT survey installation on site is shown in Fig. 3 below.

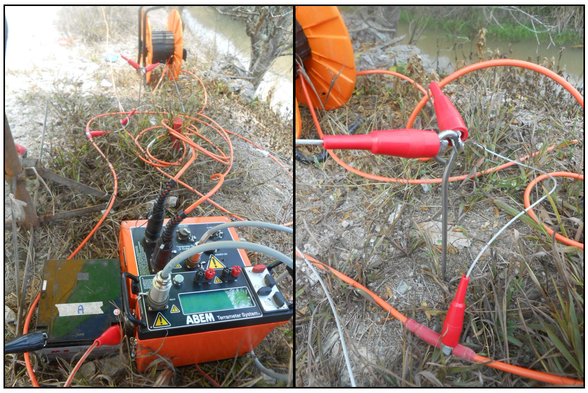

Fig. 3 ERT survey installation on site

D. Statistical Analysis

Statistical analysis was carried out in order to proof hypothesis that soil moisture content affects electrical resistivity values. This analysis was conducted by using 1,800 sample points from 102.5 meter survey line of ERT survey resulted from ERT conversion using RES2DINV software.

First analysis was by using ANOVA and Duncan's multiple range tests. This was conducted to find out the correlation between soil moisture content and electrical resistivity values.

Further statistical analysis was by using Chi-square test on Minitab 16 software. This was aimed to determine at what level of soil moisture content which will give the correct values of electrical resistivity.

III. Results and Discussion

A. 5TE Soil Moisture Sensor Calibration

Fig. 4 below shows soil moisture content measurement of oven dried method and 5TE soil moisture sensor.

Based on 30 different treatments of soil condition measured by using oven dried method and 5TE soil moisture sensor, it was resulted that R^2 value was 0.8182 and y=0.9946x. Thus, it can be concluded that 5TE soil moisture sensor was capable of measuring soil moisture with 99.46 % of satisfaction results.

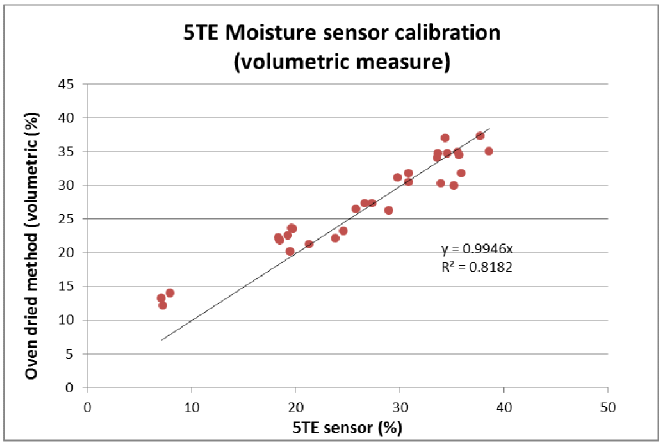

Fig. 4 5TE soil moisture sensor calibration graph

B. Preliminary ERT Survey

This preliminary survey was intended to see if there is any differences in electrical resistivity values when soil moisture content changes. Fig. 5 describes the changes of electrical resistivity values pictured in subsurface geological profile in preliminary survey.

Three different treatments on preliminary study gave an average value of soil moisture content of 25.6%, 46.8% and 48.1%. From Fig. 5 it can be seen that these treatments gave the same pattern of subsurface geological profile, but different ranges of electrical resistivity values. In Fig. 5 (a) the electrical resistivity values on depth of 74.7 meter, ranged from 0-40 ohmmeter, and in Fig. 5 (b), the values ranged from 0-10 ohmmeter, while in Fig. 5 (c) majority values ranged from 0-70 ohmmeter and in several points ranged from 0-250 ohmmeter. Further on ANOVA and Duncan's multiple range test, showed that these treatments were highly significant difference at level 1% with Pr > F value was less than 0.0001, and treatment 3 was significantly different compared to other 2 treatments. These results concluded that electrical resistivity values would change along with soil moisture content.

C. Site Survey

Three different conditions of soil moisture content in this survey were in an average of 16.96%, 22.54%, and 27.50%. Each condition gave different subsurface geological profile as shown in Fig. 6.

It can be seen that from Fig. 6 electrical resistivity values

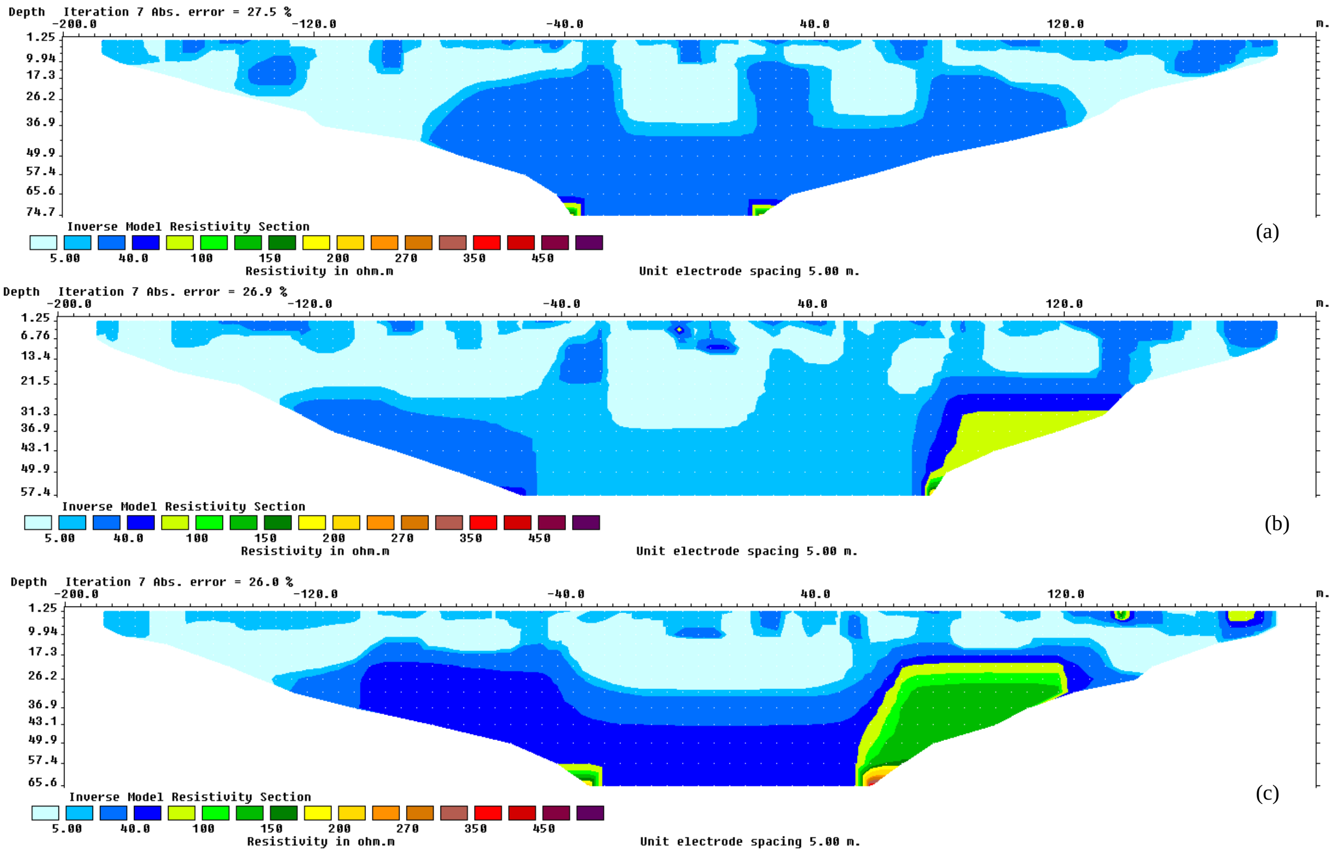

Fig. 5 Comparison of subsurface geological profile on preliminary study. Treatment with normal condition, soil moisture of 25.6 % (a), soil moisture of 46.8 % (b), and soil moisture of 48.1 % (c)

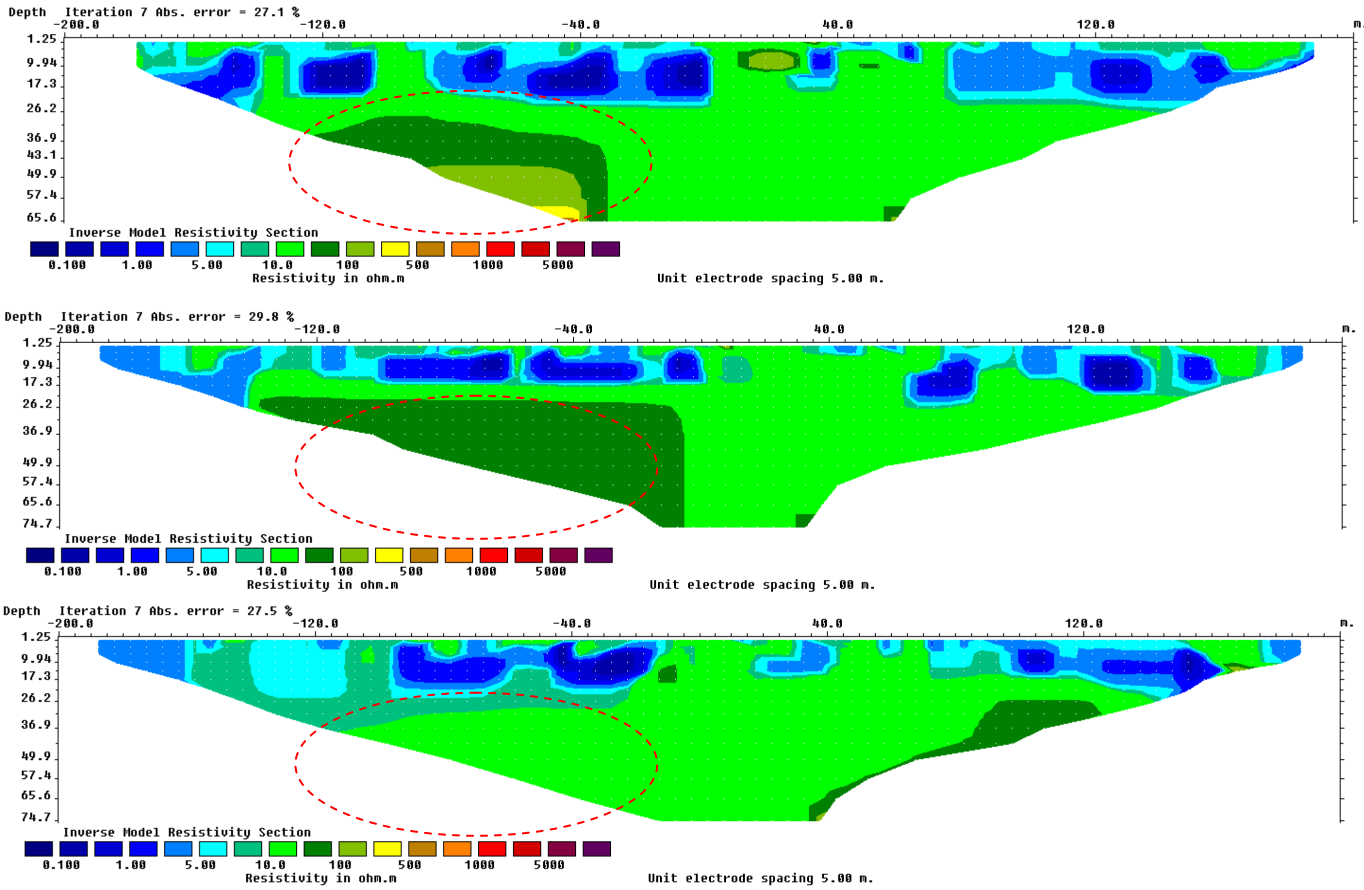

Fig. 6 Comparison of subsurface geological profile on site survey. Treatment with normal condition, soil moisture of 16.96% (a), 22.54% (b), and 27.50% (c)

along with the increase of soil moisture content. In Fig. 6 (a) electrical resistivity value at certain depth (red circle) decreased from 50-500 ohmmeter, in Fig. 6 (b) electrical resistivity value ranged from 50-100 ohmmeter. In Fig. 6 (c) electrical resistivity value ranged from 10-50 ohmmeter. Statistical analysis on single ANOVA test showed Pr > F value was less than 0.0001. This means that these three different conditions were significantly different at level 1%. Further on Duncan's multiple range tests results showed that each treatment (different soil moisture condition) gave different letters, meaning that these treatments were significantly different. Thus, it can be concluded that soil moisture content will give effect on electrical resistivity values.

In order to get level of soil moisture which would give correct value of electrical resistivity, then, electrical resistivity values from each treatment should be compared to electrical resistivity values of well lithology. Table 1 below is electrical resistivity values of well lithology in Block F.

TABLE I
WELL LITHOLOGY AND ELECTRICAL RESISTIVITY VALUES OF WELL LITHOLOGY IN BLOCK F

No.	Lithology	Depth	Res. Value (ohm.meter)
1	Sticky clay	0-5	10-15
2	Silty clay	5-15	20-69
3	Sandy clay	15-22	57-109
4	Clay	22-27	37-88
5	Silty sand	27-30	29-57
6	Very fine sand	30-45	81-171
7	Medium sand	45-52	45-59
8	Silty sand	52-70	29-57
9	Sand	70-91	81-257

Chi-square Test showed that from three different conditions of soil moisture content, each treatment gave correct counts of electrical resistivity values of 82, 108, and 54, respectively for treatment 1, 2, and 3, compared to well lithology. From total data of 600 for each treatment, the percentage correctness of electrical resistivity for each treatment was 0.14%, 0.18%, and 0.09%, respectively. Thus, the highest percentage of correct values was from treatment 2 (soil moisture of 22.54 %). From this analysis it can be concluded that soil moisture of level 22.54% gave more correct value of electrical resistivity than other soil moisture level (16.96% and 27.50%).

Other research[10] stated that soil moisture level at different paddy planting season was 27 % (before planting), 50 % (mid planting), and 35 % (after harvest) on top soil (depth 30 cm) of paddy soil. From Fig. 7 below we can see at what level of soil moisture content which will affect electrical resistivity values.

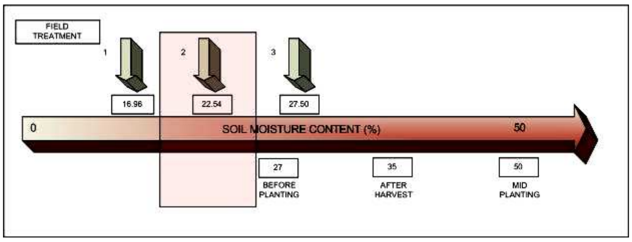

Fig. 7 Soil moisture content changes in paddy planting season

Field treatment on this study proofed that each different level of soil moisture content from treatment 1, 2, and 3 would gave significant different on electrical resistivity analysis, and came up that soil moisture 22.54% would be the best condition to get a correct electrical resistivity values (red rectangle zone on Fig. 7) - more field trials are requested to get exact number. Thus, it can be inferred that the best condition to conduct ERT analysis was on before planting season. However, further studies will be required to proof this result by soil sampling on certain depth of survey line, and measure its electrical resistivity directly. This, somehow will take more times and efforts on site and laboratory as well.

IV. CONCLUSIONS

Based on this study and statistical analysis which has been conducted, it is concluded that for paddy soil, soil moisture content will affect (change) electrical resistivity values (ohmmeter), referred to ANOVA and Duncan’s multiple range test with Pr > F value was less than 0.0001. This study also came up that soil moisture content at level 22.54% in paddy soil was the best soil moisture condition to conduct ERT survey, in order to achieve a more accurate electrical resistivity result. Based on Fig. 7, the best condition to conduct ERT survey was in before paddy planting season where level of soil moisture was approximately 27%. However, further studies will be required to proof this result. It is recommended to conduct soil sampling in certain depth on ERT survey line and directly measure its electrical resistivity values and compare it to well lithology. Thus, the results will be more precise and more accurate, but this will be more time and efforts consuming.

Another recommendation for this study is to conduct ERT analysis on different type of soil, because soil moisture content will affect differently on electrical resistivity values of different soil type. Thus, to conduct ERT survey each soil type will be given different treatment (soil moisture condition), in order to have correct values of electrical resistivity and to produce correct subsurface geological profile.

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