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The Effects of Some Physical and Chemical Factors on Apparent Resistivity of Surface Soil in the University of Mosul, Mosul City, Northern Iraq

Bashar A. Al-Juraisy
Department of Geology, College of Science, University of Mosul, Mosul, Iraq

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Abstract

Soil resistivity depends on many overlapping factors, which influence it in various ways. The aim of this study was to determine the effects of some physical and chemical factors on soil apparent resistivity. The results of field, laboratory, and statistical studies revealed a complex relationship between water content, pH, and salinity with soil apparent resistivity. The results showed that water content had a clear effect on apparent resistivity, as it increased significantly when water content value decreased to less than about 5%. The results also showed that increasing the salinity ratio at the expense of water content led to an increase in the apparent resistivity values. The apparent resistivity values also increased significantly when pH values fell below about 7.7.

The increase in air temperature caused an increase in water evaporation from the soil, which led to increasing the apparent resistivity. The rise in air temperature also caused an increase in the concentration of salts at the expense of water content; since salts are considered to be insulators, unless they are dissolved in water, they cause an increase in the value of apparent resistivity.

Keywords: Soil, Apparent resistivity, Water content, pH, Salinity.

تأثير بعض العوامل الفيزيائية والكيميائية على المقاومية الظاهرية للتربة السطحية في جامعة الموصل, مدينة الموصل, شمال العراق

بشار عزيز الجريسي
قسم علوم الأرض, كلية العلوم, جامعة الموصل, الموصل, العراق

الخلاصه

تعتمد مقاومة التربة على العديد من العوامل المتداخلة ، والتي تؤثر بطرق مختلفة على هذه المقاومة. الهدف من هذه الدراسة كان لتحديد تأثير بعض العوامل الفيزيائية والكيميائية على المقاومية الظاهرية للتربة. أظهرت نتائج الدراسة الحقلية والمخبرية والإحصائية وجود علاقة معقدة بين المحتوى المائي ودرجة الحموضة والملوحة مع المقاومية الظاهرية للتربة. أظهرت النتائج أن المحتوى المائي كان له تأثير واضح على المقاومة الظاهرية حيث ازدادت بشكل ملحوظ عندما انخفضت قيمة المحتوى المائي إلى أقل من ما يقرب من 5٪. كما أظهرت النتائج أن زيادة نسبة الملوحة على حساب المحتوى المائي يؤدي إلى زيادة قيم المقاومية الظاهرية. ازدادت قيم المقاومية الظاهرية أيضًا بشكل كبير عندما انخفضت قيم الأس الهيدروجيني إلى أقل من 7.7 تقريبا.

*Email: basharaziz@uomosul.edu.iq

تؤدي زيادة درجة حرارة الهواء إلى زيادة تبخر الماء من التربة ، مما يؤدي إلى زيادة المقاومية الظاهرية. كما يتسبب ارتفاع درجة حرارة الهواء في زيادة تركيز الأملاح على حساب المحتوى المائي ، حيث ان الأملاح تعتبر عوازل ما لم تذوب في الماء مما يؤدي إلى زيادة المقاومة الظاهرية.

1. Introduction

Soil characteristics are of a great importance in many applied fields, such as agriculture [1], construction [2], and earthing installation [3]. One of the important physical properties of soil is the electrical resistivity (ρ), which can be defined as the resistance in ohms between the opposite faces of a unit cube of the material. The term resistivity is used when the earth is a uniform half-space within the range of the survey; otherwise, this term represents some complicated averaging of the resistivities of all materials zones which the current is flowing it is called apparent resistivity (ρa).

Resistivity is associated with a number of variables that include mineralogy [4], type and amount of porosity [5], cracks [6], water content [7], salinity [8], temperature [3], and acidity [9]. Therefore, the determination of electrical resistivity is still a challenge. Archie, in 1942, suggested a clear relationship (the Archie's law) depending on the measurements of clean sandstone samples taken in the laboratory [10], but it is only applicable to saturated rock or sandy soil. Electrical resistivity in clayey soil is also affected by grain size distribution, as well as the electric charge density on particle surfaces. In this study, due to the fact that measurements for the same sites were taken in different time periods, some factors could have a constant effect on the electrical properties, while others could have a varying effect during the time.

In general, water content is an important factor in determining the electrical properties of soil, as most soils are composed of non-metallic minerals that are poorly conductive to electrical current. Even salts are poorly conductive to current unless dissolved by a quantity of water [11]. Laboratory studies showed that resistivity increases with decreasing water content of the soil [12]. In addition to the shape and type of pores, water content is related to many other factors, the most important of which is the surrounding climate in terms of the amount of rain and temperature, as the rains increase the water content while higher temperatures reduce it [13].

Salinity is defined by the presence of the main dissolved inorganic solutes (primarily Na^{+1}, Mg^{+2}, Ca^{+2}, K^{+1}, Cl^{-1}, $SO4^{-2}$, HCO^{-3}, $NO3^{-1}$ and $CO3^{-2}$) in aqueous samples. Most of laboratory studies performed to establish the relationship between salinity and clay soil resistivity revealed that the two have a strong relationship [8, 14]. This relationship came from the fact that the separation and movement of positive and negative ions, while applying an electric potential to the solution, greatly helps in the transfer of electrical charge (current flow).

Low annual rainfall and excessive water evaporation in hot arid and semiarid climates can be considered as important factors in increasing the salinity concentration [15].

The soil pH indicates its acidity or alkalinity, and it ranges between 4.0 to 9.0 for most soils [16]. pH is greatly affected by the acidity of the water in pores and the size of the particles [17], and it is seasonally variable [18]. Regression analysis carried out on resistivity and pH showed that resistivity varied inversely with pH. The relationship was, however, weak, based on the low (0.22) coefficient of correlation [19].

2. Site Description

The study was carried out in a semi-flat area of 225 m^2 inside the University of Mosul at the longitude of $43^{\circ}:8^{\prime}:10^{\prime\prime}$ and the latitude of $36^{\circ}:23^{\prime}:22^{\prime\prime}$ (Figure 1). In general, the study area and its surroundings are covered by 2-10 m. of river terrace layers composed of different sizes of sediments, ranging between very coarse sandy conglomerate to silty conglomerate [20].

These are topped by a layer of clayey ore sandy clay soil with a thickness ranging from a few centimeters to a few meters.

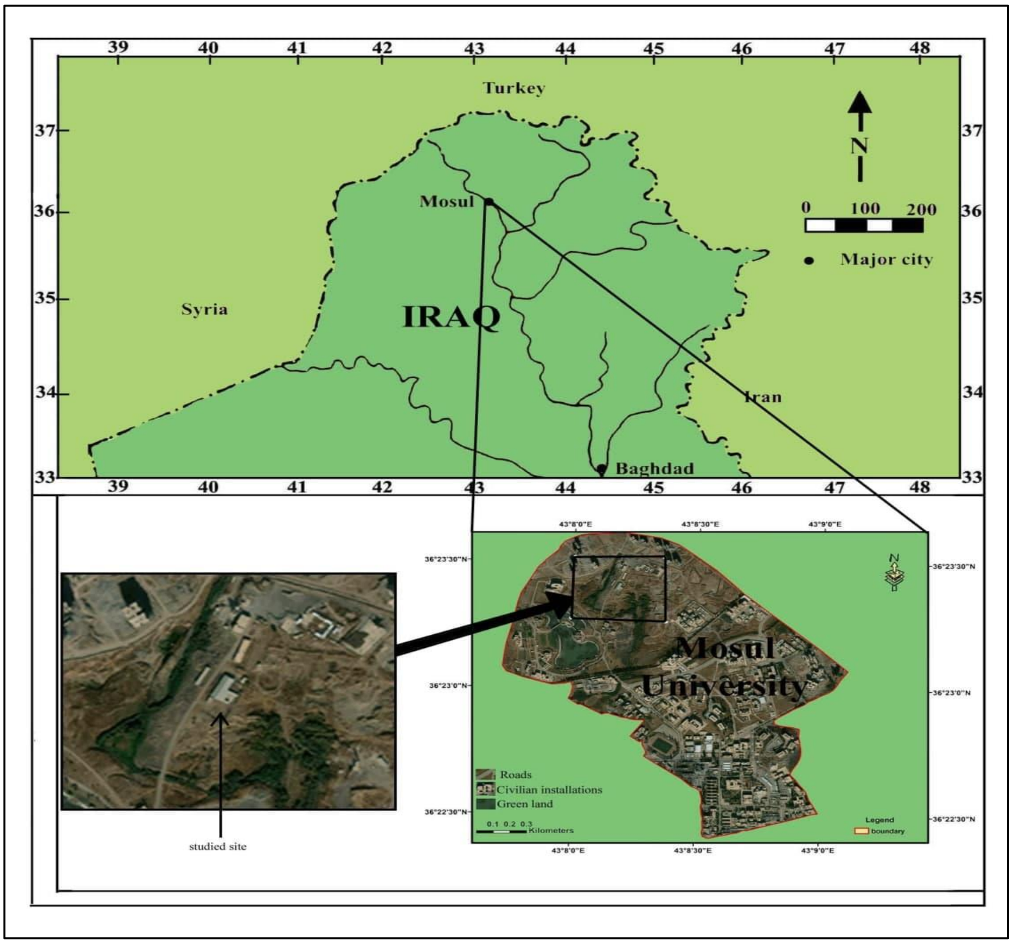

Figure 1- Google satellite image showing the location of study area

3. Materials and methods

3-1 Field work

The area was divided into six traverses (L1-L6) of 15 m. in length for each traverse, and the distance between one traverse and another was 3 m. (Figure 2). On the 4th March , 2013, a Wenner array resistivity survey was started along these traverses with 1 m. electrode space (3m. spread length) using a LandMapper ERM-02 device which is usually used in soil surveys. The distance between the centers of measurement points was 3 m. In each of the five time periods (4th March, 28th March, 28th May, 1st Oct, 2013 and 3rd Feb, 2014), immediately after surface measurement of the apparent resistance near the six sites (S1-S6) showed in Figure 2, about 1000 cc of soil was taken and placed in a tightly closed plastic bag to avoid exposure to the atmosphere and direct sunlight. Thirty soil samples were collected during the current study. The samples were then carefully transported immediately to the laboratory for acidity, salinity, and moisture assays The water content was measured for all of these samples, while salinity and acidity measurements were made for most of the samples due to damages to some samples during transportation or when measuring them. Soil samples were collected from the surface of the earth to a depth of about 0.5 m. Because the median depth of the investigated sites was equal to “0.173* spread length“ [21], which resulted in a value of 3 m in the current survey, about 70% of the content of each sample was collected from a depth of 0.5 m. Also the average temperature inside the soil (from the surface to 0.5m depth) for the sampling sites was measured using an alcohol thermometer. Because of the inability of the LandMapper ERM-02 to measure at temperature higher than 40 °C), the measurements were not taken in the hot summer months.

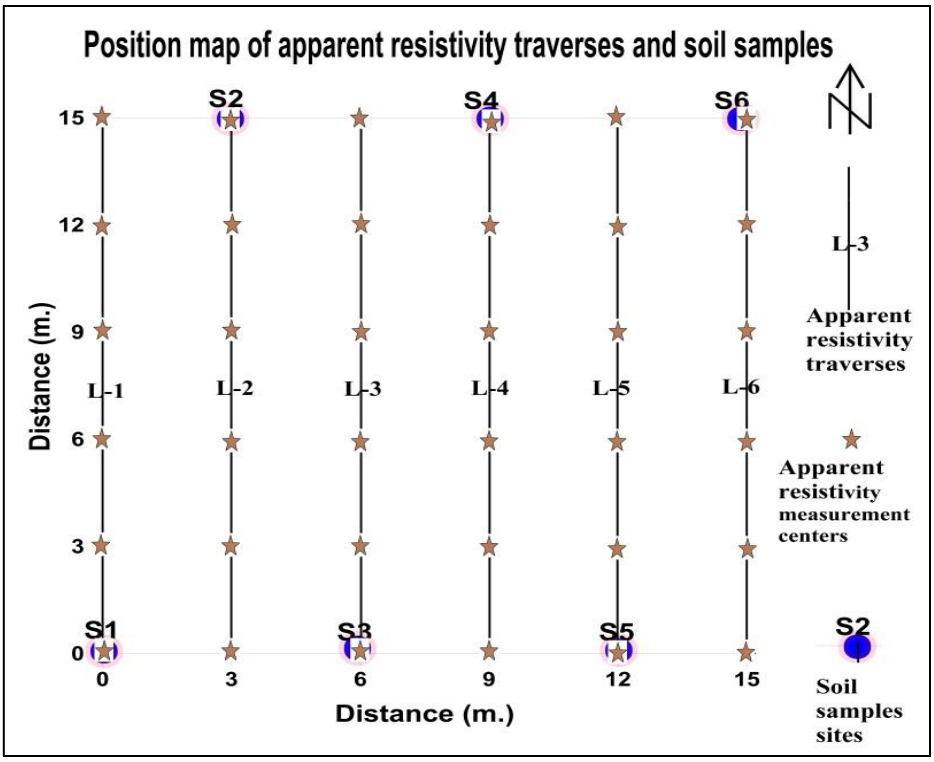

Figure 2- Illustrative diagram showing the locations of the apparent resistivity measurement lines and the soil samples.

3-2 Laboratory work

The percentage of silt and clay was calculated by thoroughly mixing 400 g of one of the soil samples (S2), after drying with about 2 liters of distilled water and pouring the mixture into a sieve with opening of 0.065 mm. Then, the weight of the part passing through the sieve was calculated after drying it. Thus, the ratio of the weight of the part passing through the sieve opening after drying to the weight of the sample (400 g) was used to calculate the percentage of clay and silt. The results showed that the soil is made up of 80% clay and silt. The water content, salinity, and pH values of the samples were determined in the laboratory immediately after the end of each day of field work.

Water content of the soil samples was calculated by weighing the soil directly after it was brought from the field (W1) and then weighing it after drying for 24 hours in an oven at 100°C. (w2); Water content (%) = ((W1 – W2) / (W2)) * 100 [22].

Salinity and pH were calculated by soaking the sample in distilled water and then measuring the salinity and acidity of the dissolved water using a TDS 3 device. We were not able to take the measurement in some of the hot summer months. SPSS program was used to calculate the relationship between apparent resistivity and the factors of water content, acidity, and salinity, as well as the relationship between temperature and water content.

4. Results and Discussion

The results of the apparent resistivity survey of the surface soil (less than one meter thick) showed a range of 5.3 to 46.2 ohm.m (Figure 3), which represents the normal range of resistance of clay soil [11].

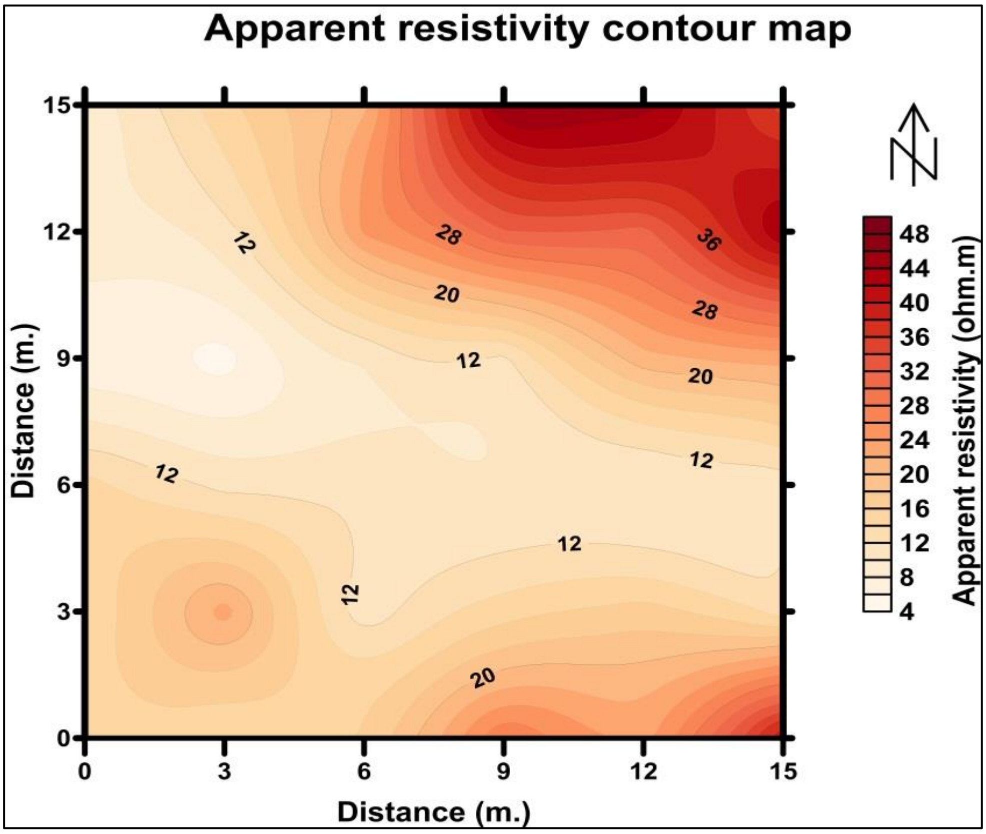

Figure 3- Apparent resistivity contour map of the study area

The water content values of the six studied samples over five different times ranged from 2.48 to 19%, and the highest values were recorded in March, which is characterized by abundance of rain and relatively moderate temperature. The minimum values of water content were recorded in October, after a few months that were characterized by high temperature and lack of rain. According to the American Salinity Laboratory [23] and based on the amount of dissolved salts, that were measured in the lab., this water was of the fresh type, as its percentage did not exceed 500 parts per million for all measured soil samples.

The water content-apparent resistivity relationship of soil samples (Figure 4) showed that water content significantly affects the apparent resistivity when it is less than 5%, but when it exceeds 5%, its effect is limited; water content value was fluctuating and tended to be inversely proportional to resistivity values.

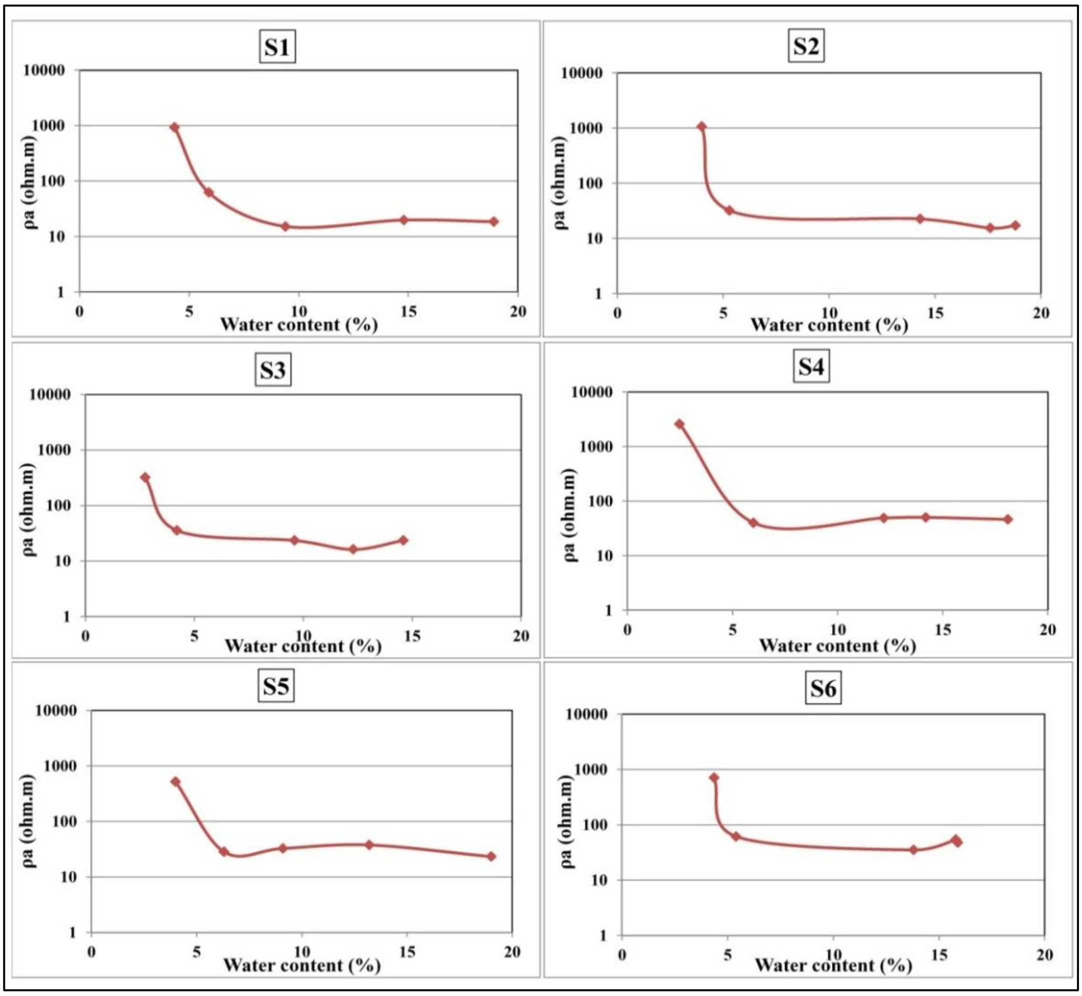

Figure 4- Water content-apparent resistivity relationship

This was confirmed by the values of the statistical correlation coefficient (R), which showed a true inverse proportion (-0.506**) between water content and apparent resistivity values (Table 1). This is consistent with most of the previous studies [4, 7, 24].

Table 1- The correlation coefficient values between apparent resistivity and water content, pH, and salinity.

	Pearson correlation coefficient		
Apparent resistivity	Water content	pH	Salinity
	-0.506**	-0.708**	0.426
Temperature	-0.858**		

**Correlation is significant at the 0.01 level (2-tailed).

On the other hand, water content values were directly related to the temperature values of the soil, which are mainly dependent on the sun's heat, as the high temperatures lead to the drying of the soil and the decrease in water content as a result of evaporation, except for some periods of heavy rain (Figure 5).

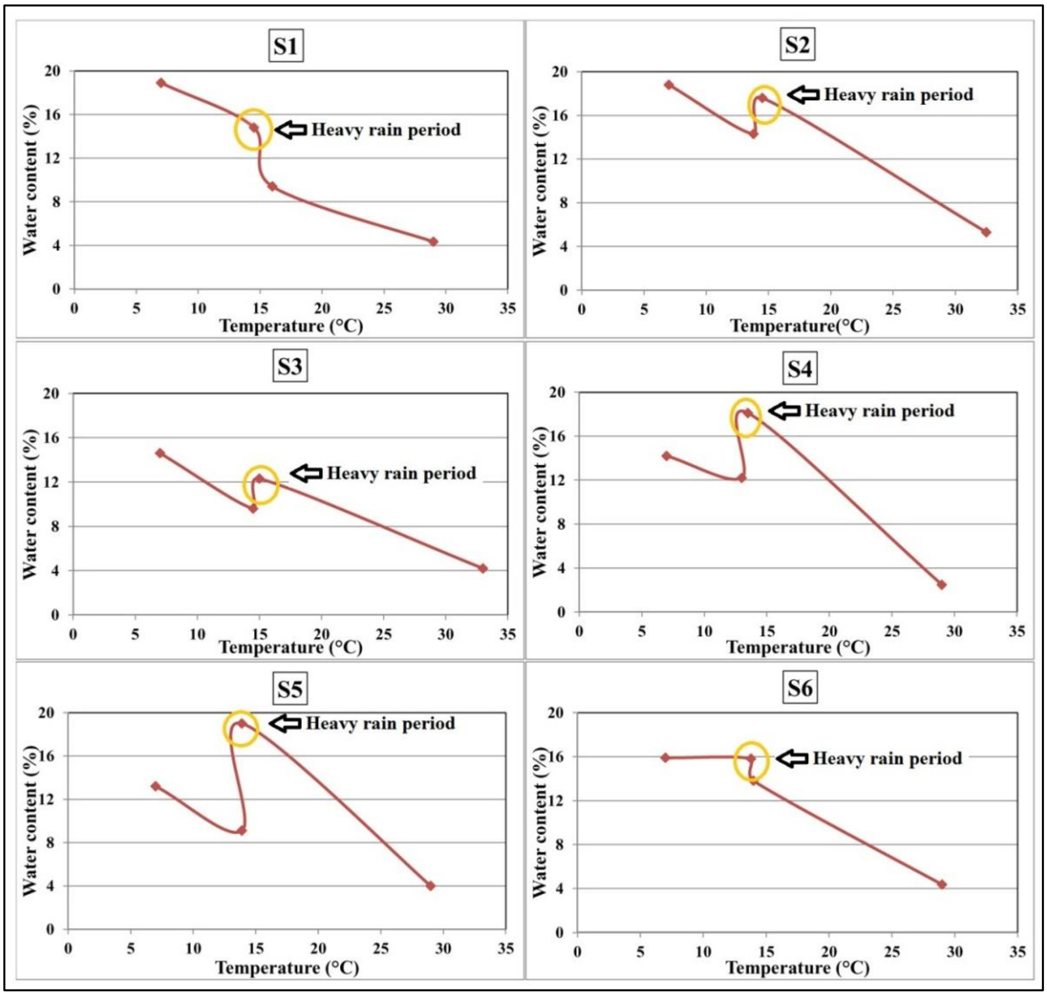

Figure 5-Water content-temperature relationship

From figure 6, it can be seen that soil temperature during the measurement periods of apparent resistivity ranged 7-34 °C. Since this range does not cause a large variation in soil resistivity values [25], its effect on soil apparent resistivity was through the effect on the amount of water evaporated from the soil, which greatly affects the apparent resistivity of the soil.

Also, the statistical correlation coefficient values (Table 1) revealed a strong inverse relationship (-0.858) between water content and temperature values.

pH-apparent resistivity relationship (Figure 6) indicated that, in general, the effect of acidity (pH) is limited on the apparent resistivity values, when the pH values exceed about 7.7. This effect increases greatly when the pH value is less than about 7.7 in most samples. This is supported by the value of the correlation coefficient (Table 1), which showed the existence of a significant inverse relationship (-0.708**) between pH and apparent resistivity.

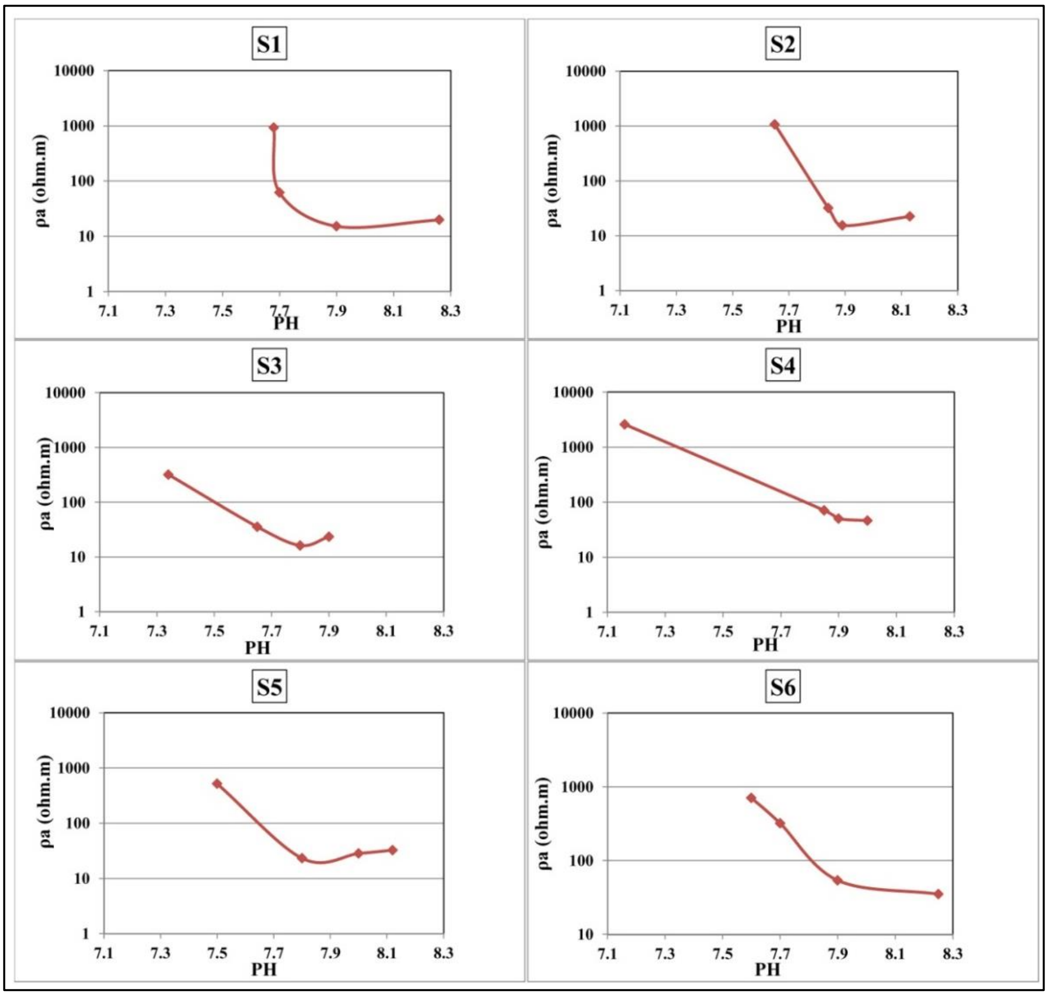

Figure 6- pH-apparent resistivity relationship

Salinity-apparent resistivity relationship (Figure 7) exhibited an unexpected increase in apparent resistivity values when the salinity ratio is higher than 200 or 350 ppm. This unexpected increase in apparent resistivity may be due to the decrease in water content, which is the most influencing factor, at high temperatures.

The value of the statistical correlation coefficient value (Table 1) indicates a weak relationship (0.426) between the salinity ratio and the apparent resistivity value. This may be due to the interaction of the influences of salinity and water content, as salinity percentage increases with decreasing water content, which leads to an increase in the apparent resistivity values.

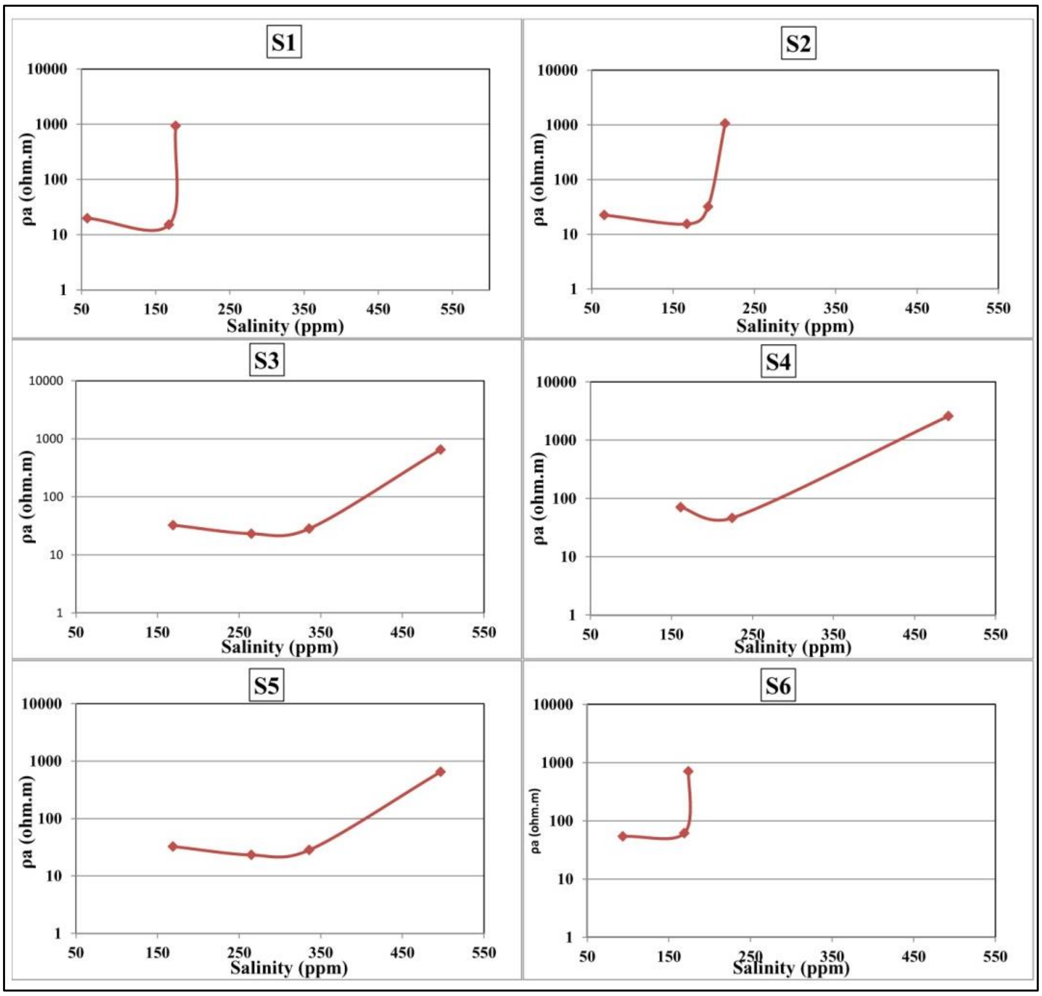

Figure 7- Salinity-apparent resistivity relationship

5. Conclusions

Among the many overlapping physical and chemical factors affecting soil apparent resistivity, moisture is the most influential factors that is directly related to air temperature.

The increase in air temperature leads to the increase in salinity at the expense of water content, that also causes an unexpected increase in apparent resistivity, especially when salinity exceed approximately 180 ppm.in most cases.

Apparent resistivity increases significantly when water content of soil falls below about 5%.

The increase in air temperature causes the increase in the salt concentration, which leads to the increase in pH.

Acidity increases its effect when its value increases over approximately 7.7.

The increase in air temperature causes an increase in water evaporation from the soil, which leads to the increase in apparent resistivity.

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