Comparison between The Measured and Predicted moisture contents as affected By Some Soil Improvements

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Abstract. Predicted equation were used for best fitting between measured and calculated moisture contents of two soils texture located at Ninevah governorate under the effect of soil improvements. Soil samples were sieved by 2 mm sieves and saturated to measure the soil moisture characteristic curve of 10, 33, 100, 200, 400, 600, 800, 1000 and 1500 Kpa. By using both pressure plates and membrane and pressure compared its value by using predicted equations. Results indicated that the values of both θs and θr were highest of P3O0 treatment for the clay texture compared with the loamy texture soil. The values of m, n and α of VanGenuchten equation, for the first location were lower than the second location and the value of n was higher than both m and α. The value of α of Van&Mua was higher than both locations. The values of a of Van&Mua, while b and b were variable and b was lower than b for both locations. The values of a, c and hr were higher for P3O2 treatment of Fred & Xing compared with the lower values of P0O0 for both location. On the other hand, the a value of Pere&Fred was equal to the same value of both Van&Mua and Van&Bur and the b value equal to Van&Bur and c value was variable and similar to m values of VanGenuchten. Best fitting between the measured and calculated values at higher suction by Fredlund & Xing equation for both location and at lower suction by (VanGenuchten, Van&Mua, Van&Bur and Pere&Fred). Equation VanGenuchten gave best first to the measured value at 33 Kpa for the second location while equation Van & Bur gave best first at 100-400 Kpa for both location and Pere&Fred at 33 Kpa for first location.

1. Introduction

Soil Moisture Characteristic Curve represents the relationship between the moisture tension (ψ) and the soil moisture content. So, most of the researches that employ this relationship takes the moisture content into consideration on the basis of size (volume) [1] The tension used in this curve stands for the matrix potential, suction potential. Fredlund [2] made several attempts to determine the values of variables of moisture prediction equations under unsaturated conditions and comparing them to the conditions of the saturated soil. Soils characteristics that express the non-lineal function of these variables were dealt with by [3] and they require the developments in the Moisture Characteristic Curve (MCC) including the measurements of matrix potential by several tensions to attain the necessary data of the prediction equations. Good compatibility conditions for the (MCC) without deriving or integrating the equations are limited in terms of application. Some of these equations are valid within certain conditions and give a best fitting, while the contrary happens in other conditions within the domains of moisture matrix potentials. The equations that involve 3-4 variables give best fitting to the (MCC) [4]. Therefore, best fitting cannot be get with these values in most of the soils. Finding good compatibility match between the laboratory values and the equations employed requires a number of laboratory measurements for the matrix potentials depending on the number of unknown variables in the selected functions. So, soil matrix potentials measurements can be classified as direct or indirect measurements although the direct measurements involve using the laboratory devices such as the pressure plates,
pressure membranes. They [5]; [6] observed that the points obtained from the relationship between the matrix potentials and the moisture content should be conducted in the laboratory to match them with the values obtained when applying the mathematical models to find the best compatibility. Other options to get the (MCC) is to predict these values, depending on the size distribution of the particles in addition to other characteristics.

2. Materials and Methods

A field experiment was conducted in two sites with different texture in Nineveh governorate in spring 2012. The first site is AlGubbah site with clay texture and this site is located to the north of Mosul city. It classified as the Calciorthids represented by group as Aridisols. The second site is located to the south east of Mosul with loam texture and classified as Ustifluvents with a group of Entisol, represented by the site of the farmer according to the American Classification System as mentioned by [7]. The topography of the two sites is plain and planted with potato, wheat and barley. Samples of the soil were collected with depth (zero – 0.3 m) by using soil auger and three samples were taken from each site within the area exploited to conduct the experiment. After that the samples were dried by air, blended, grinded and sieved with 2mm sieve to identify certain physical and chemical properties of the soil in question.

Table 1. shows some physical and chemical properties of the soil.

| Site    | Texture | K ex. c. mole.kg⁻¹ | P availability g.kg⁻¹ | N availability g.kg⁻¹ | O.M g.kg⁻¹ | Ec µc | PH | Hyd. Cond. cm.h⁻¹ falling | infiltratio n cm.h⁻¹ | porosity % | bulk density mega gram.m⁻³ | Soil particles g.kg⁻¹ | clay | silt | Sand | texture | Site |
|---------|---------|---------------------|-----------------------|------------------------|------------|------|----|------------------------|---------------------|------------|--------------------------|---------------------|------|------|------|---------|------|
| Site 1  | clay    | 1.278               | 0.0073                | 0.277                  | 17.24      | 246.7| 7.2 | 1.20                   | 2.2                 | 42.5       | 1.40                     | 490                 | 365  | 145  |      | clay    | Site 1|
| Site 2  | loam   | 0.511               | 0.0041                | 0.177                  | 12.7       | 107.5| 7.69 | 1.578                  | 2.62                | 47.0       | 1.314                    | 230                 | 470  | 300  |      | loam    | Site 2|

Polymer treatment: Four polymer levels were used added in 21 and 22/2/2012

1. First treatment (Control) P0 = zero without polymer addition
2. Second treatment P1 = 10 kg.donum⁻¹ of polymer (PAM) added inside the furrows.
3. Third treatment P2 = 20 kg.donum⁻¹ of polymer (PAM) added inside the furrows.
4. Fourth treatment P3 = 40 kg.donum⁻¹ of polymer (PAM) added inside the furrow.

Animal amendment Treatment: Three levels were used as follows:

1. First treatment (Control) O0 = zero without adding animal amendments.
2. Second treatment O1 = 4 tons.donum⁻¹ of animal amendment that was added in 16/12/2011 blended and mixed with the soil and then the field is left.
3. Third treatment: O2 = 2 tons.donum⁻¹ of animal amendment that was added in 16/12/2011 blended and mixed with the soil and the field is left. In 20/2/20212, 2 tons.donum⁻¹ of animal amendment was added as lines and they were blended with the furrows. The values of the bulk density, porosity and the organic material were measured by [8] after adding the polymer and animal amendment in the period 20-30/4/2012 and the values were recorded (table 3).

2.1 Soil Moisture Characteristic Curve

Soil samples sieved in 2 mm sieve were taken after they were saturated with water to expose them to matrix potential (33, 100, 200, 400, 600, 800, 1000 and 1500) Kpa using a pressure plate and a pressure membrane. The available water was estimated by finding the difference between the moisture content at the matrix potential 33-1500 Kpa as mentioned by [9]. The size of pores using the (MCC) after determining the value of the remaining moisture content (θ) at matrix potential of 1500 Kpa and the moisture content with a saturation of (θs) at 0 matrix potential. In April the moisture content at various matrix potentials was measured to determine the variation in the available water for each treatment in order to identify the role of soil improvements that resulted in changing the moisture content values for the treatments compared to the control treatment at the measured matrix potential.
The following equation shows the quantity of available water [8]; [10].

\[
AW = \theta_c - \theta_p
\]

(1)

where; \( AW \) = The available water content in the soil (%).

\( \theta_c \) = weight moisture content at the field capacity (%).

\( \theta_p \) = weight moisture content at the permanent withering point (%).

Table 2. values of the moisture content (\( \theta_w \)) gm.gm\(^{-1}\) for the two sites for the period 20-30/4/2012.

| Values of the moisture content (\( \theta_w \)) of the treatments | Matrix potential Kpa | Sites |
|---------------------------------------------------------------|----------------------|-------|
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) \( O_5 \) \( P_5 \) | 14.900 14.780 14.590 14.380 14.190 13.88 13.780 13.690 13.290 13.560 13.34 13.175 1300 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 16.910 16.720 16.350 16.35 16.034 15.810 15.618 15.515 15.00 15.213 15.194 14.832 1000 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 18.360 18.060 17.600 17.400 17.255 16.990 16.720 16.550 15.490 16.220 15.970 15.254 800 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 19.930 18.740 18.060 17.860 17.540 17.340 17.160 16.930 16.390 16.800 16.683 16.279 600 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 19.47 19.290 18.90 18.61 18.33 17.88 17.88 17.610 17.00 17.45 17.25 16.87 400 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 20.89 20.68 20.30 19.99 19.790 19.40 19.37 18.92 18.00 18.605 18.222 17.79 200 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 22.97 22.84 22.23 21.93 21.75 21.30 20.98 20.29 19.21 19.74 19.41 19.00 100 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 28.94 28.85 28.54 28.38 27.91 27.57 27.38 27.20 26.64 26.95 26.87 26.59 33 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 34.15 33.75 33.00 32.80 32.58 32.09 31.85 31.62 31.145 30.90 30.767 30.44 10 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 10.85 10.81 10.77 10.63 10.54 10.46 10.4 10.34 10.12 10.29 10.185 10.09 1500 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 11.86 11.77 11.60 11.525 11.43 11.30 11.20 11.12 10.64 10.87 10.76 10.57 1000 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 12.79 12.67 12.58 12.46 12.34 12.18 11.97 11.85 11.31 11.62 11.51 11.24 800 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 13.75 13.61 13.49 13.40 13.18 12.90 12.79 12.54 12.18 12.38 12.25 12.145 600 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 13.92 13.81 13.69 13.58 13.46 13.22 13.18 12.90 12.48 12.76 12.60 12.425 400 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 15.75 15.69 15.48 15.26 15.08 14.89 14.52 14.30 13.73 14.229 14.14 13.496 200 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 28.39 24.07 17.88 17.63 17.58 17.16 17.00 16.89 16.11 16.555 16.35 15.98 100 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 28.635 24.17 18.24 23.88 23.75 23.55 23.30 23.02 22.38 22.76 22.585 22.125 33 |
| \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | 28.77 24.24 18.59 28.085 27.675 27.375 26.815 26.245 25.700 25.975 25.732 25.48 10 |

Table 3. Measuring of bulk density, porosity and the organic material in the period 20-30/4/2012

| Treatments | \( P_1 \) \( O_2 \) \( P_2 \) \( O_3 \) \( P_3 \) \( O_4 \) \( P_4 \) | properties | site |
|------------|-----------------------------|----------------|------|
| 1.131d     | 1.213bc                    | PbMg. m\(^3\)  | Site1 |
| 53.65a     | 44.95d                     | PbMg. m\(^3\)  | Site2 |
| 30.93a     | 24.18b                     | O.Mgm.kgm\(^-3\)| Site1 |
| 1.115c     | 1.13bc                     | PbMg. m\(^3\)  | Site2 |
| 55.01a     | 48.1bc                     | O.Mgm.kgm\(^-3\)| Site1 |
| 32.14a     | 27.43b                     | O.Mgm.kgm\(^-3\)| Site2 |
Table 4. Values of the moisture content ($\theta$) cm$^3$.cm$^{-3}$ of the two sites of for the period 20-30/4/2012

| Site | Matrix potential Kpa | $P_0 O_0$ | $P_0 O_1$ | $P_0 O_2$ | $P_1 O_0$ | $P_1 O_1$ | $P_1 O_2$ | $P_2 O_0$ | $P_2 O_1$ | $P_2 O_2$ | $P_3 O_0$ | $P_3 O_1$ | $P_3 O_2$ | $P_3 O_3$ |
|------|----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Site 1 | 1500 | 0.1843 | 0.1626 | 0.1556 | 0.1836 | 0.1667 | 0.1836 | 0.1556 | 0.1626 | 0.1843 | 1500 |
|       | 1000 | 0.2064 | 0.1852 | 0.1746 | 0.2073 | 0.1746 | 0.1852 | 0.2073 | 0.1746 | 0.2073 | 1000 |
|       | 800  | 0.2123 | 0.1946 | 0.1862 | 0.2015 | 0.2140 | 0.1946 | 0.2015 | 0.2140 | 0.1946 | 800  |
|       | 600  | 0.2266 | 0.2033 | 0.1928 | 0.2062 | 0.2265 | 0.1928 | 0.2062 | 0.2265 | 0.1928 | 600  |
|       | 400  | 0.2348 | 0.2102 | 0.2028 | 0.2238 | 0.2348 | 0.2028 | 0.2238 | 0.2348 | 0.2028 | 400  |
| Site 2 | 1500 | 0.1322 | 0.1160 | 0.1152 | 0.1315 | 0.1175 | 0.1152 | 0.1315 | 0.1175 | 0.1152 | 1500 |
|       | 1000 | 0.1385 | 0.1225 | 0.1216 | 0.1383 | 0.1264 | 0.1216 | 0.1383 | 0.1264 | 0.1216 | 1000 |
|       | 800  | 0.1472 | 0.1311 | 0.1300 | 0.1473 | 0.1347 | 0.1300 | 0.1473 | 0.1347 | 0.1300 | 800  |
|       | 600  | 0.1591 | 0.1395 | 0.1391 | 0.1583 | 0.1431 | 0.1391 | 0.1583 | 0.1431 | 0.1391 | 600  |
|       | 400  | 0.1628 | 0.1435 | 0.1435 | 0.1622 | 0.1474 | 0.1435 | 0.1622 | 0.1474 | 0.1435 | 400  |
|       | 200  | 0.1768 | 0.1614 | 0.1614 | 0.1784 | 0.1626 | 0.1614 | 0.1784 | 0.1626 | 0.1614 | 200  |
|       | 100  | 0.2093 | 0.1862 | 0.1850 | 0.2094 | 0.1927 | 0.1850 | 0.2094 | 0.1927 | 0.1850 | 100  |
|       | 33   | 0.2898 | 0.2572 | 0.2546 | 0.2909 | 0.2617 | 0.2546 | 0.2909 | 0.2617 | 0.2546 | 33   |

Equations of predicting the moisture content:

1. Equation of Van-Genuchten (1980): $0W = 0r + \frac{\theta_s - \theta_r}{[1 + \{\alpha h\}^n]^{m}}$ (2)

2. Equation of Van-Genuchten and Burdine (1980): $0W = 0r + \frac{\theta_s - \theta_r}{[1 + \{h/a\}^b]^{(1-2/b)}$ (3)

3. Equation of Van-Genuchten and Mulam (1980) : $0W = 0r + \frac{\theta_s - \theta_r}{[1 + \{h/a\}^m]^{(1-1/mo)}}$ (4)

4. Equation of Fredlund and Xing (1994) : $0W = C(h) \times [\frac{\theta_s}{L_a \exp (1 + (h/a)^b)}] - [\frac{L_a (1 + (h/h_c))}{L_a (1 + (10^b/h_c))}]$ (5)

5. Equation of Pereira and Fredlund (2000) : $0W = 0r + \frac{\theta_s - \theta_r}{[1 + \{h/c\}^b]^{v}}$ (7)
where:
\[ \theta_W = \text{the predicted moisture content at a certain matrix potential (cm}^3\text{.cm}^{-3}) \]
\[ \theta_r = \text{the remaining volume moisture content (cm}^3\text{.cm}^{-3}) \]
\[ \theta_s = \text{the saturated moisture content (cm}^3\text{.cm}^{-3}) \]
\[ h = \text{the matrix potential} \]
\[ \alpha, n, \text{and} m = \text{the constants of equation (2)} \]
\[ a \text{ and} b = \text{the constants of equation (3)} \]
\[ a \text{ and} bm = \text{the constants of equation (4)} \]
\[ a, b \text{ and} c = \text{the constants of equation (5)} \]
\[ c, b \text{ and} a = \text{the constants of equation (7)} \]

The constants values can be determined depending on some physical properties related to the moisture content.

3. Results and Discussion

Constants of the moisture content prediction equations: Using the soil improvements represented by the PAM polymer and animal amendments had an effect on the soil moisture preservation with the domain of root zone in addition to their impact on some physical properties. At the matrix potentials (1500, 1000, 800, 600, 400, 200, 100, 33 and 1) at both sites, a variation in the values of weight and volume moisture content was observed (tables 2 and 4) in addition to a variation in the bulk density due to the improvements used (table 3). Equation (2) When applying this equation, we find that the constants of the equation are (m, n and \( \alpha \)) and after that we obtain \( \theta_s \) and values \( \theta_r \). The values of \( \theta_s \) at 1500 Kpa were taken as equal to \( \theta_r \) values as mentioned by [11]. Results of \( \theta_s \) values were (0.540 - 0.560 cm\(^3\)cm\(^{-3}\)) and \( \theta_r \) values (0.1556 - 0.1979 cm\(^3\)cm\(^{-3}\)) for P3O2 and P0O0 treatments respectively for site 1 (table 5). This difference in the values of \( \theta_s \) and \( \theta_r \) in the treatments is due to the variation in \( \theta_r \) values that results from the differences in the weight moisture content \( \theta_m \) (tables 2, 4) and also the bulk density (table 3). Moreover, there are difference in the values of \( \theta_r \) and \( \rho S \) in terms of the treatments within the calculation of VanGenuchten1980 equation (table 7). The \( m \) constant value was (0.2432 - 0.2592) and the n constant value was (1.3214 - 1.3499) for both the treatments P3O2 and P0O0 respectively, while the value of \( \alpha \) constant (0.170 – 0.02080) for each treatment of P3O1 and P0O2 respectively (table 5). This difference is due to the increase of moisture content of the soil as a result of soil improvement treatment that led to changing \( \theta_r \) among the treatments and a difference in the values of the equation constants concerning site 2 which is of loam texture (clay ratio = 230 g.kg\(^{-1}\)) compared to site 1 with a clay texture (clay ratio = 490 g.kg\(^{-1}\)). Values of the constant \( m \) were (0.263 – 0.2741), values of n constant were (1.3568 – 1.3776) for the treatments P3O2 and P0O0 respectively (table 6).

The two constant of this equation are (a and bm). The constant a depends on particle size and basically on clay, sand, porosity and bulk density. The change of bulk density values results in the change of the porosity values and thus a change takes place in the constant (a) value between the various parameters, while the constant (mb) depends on \( \theta_r \) values which depends on (\( \theta_m \)) and the bulk density in addition to the values of \( \theta_s \) (\( \theta_r \)). So, the constant (a) values were (4.656 - 6.441)Kpa for the treatments P3O2 and P0O0 respectively and the values of the constant (bm) were (1.302 - 1.315) for the treatments P3O2 and P0O0 respectively and bm were (1.298-1.314)for the treatments P0O2 and P3O0 respectively(tables 6, 7 show bm- to find the constants a , bm).

Hasan [11] equation: It was observed that the constants of this equation are represented by (a, b and b-). The constant (a) is the same that is used equation, but the constant (b) is obtained from identifying the particle size, especially the ratio of clay, ratio of sand and the porosity values, while the constant (b-) is obtained from a mathematical relation with the constant (bb) as shown in (table 7). The variation in constant (b) values in the treatments is due to the variation of porosity. As for the values of \( \theta_s \) and \( \theta_r \), they are not different from the previous equation. So, it was observed that site1 with clay texture had values of the constant (b) (1.3546 - 1.3553) for the treatments P3O1 and P3O2 and the difference between them was very slight as there was no difference in the soil particles within each site but the difference was in the values of porosity. Also, it was noticed that the values of the constant (b) in this equation is almost similar to the values of the constant (n) in equation Van, while the values of b- were (2.7711 - 2.7764) for the treatments P0O1 and P3O2 (table 5). The difference in
these values is due to using the improvements in the soil treatments, which resulted in differences in the values of \( \theta_s \), \( \theta_r \), a, b and \( b^- \) that were influenced with the variation in \( \theta_v \) values and by the effect of the bulk density and porosity (tables 3, 4). The constants of the above equation for site 2, which differs in the ratio of its soil particles from site 1, the values of constant (a) were not different from its values in equation and the values of constant (b) were (1.3576 - 1.3542) and \( b^- \) were (2.771 - 2.7878) for the treatments \( P_1O_0 \) and \( P_3O_2 \) respectively (table6), the reason for that is related to what mentioned in site 1.

The constants values of this equation are (a, b, c and hr), which depend on identifying the plastic index values (wpl) that represents the difference between the terms of the liquid and plastic and each treatment alone. It was observed that there is a variation in plasticity index values in the treatments due to the variation in the polymer levels PAM and the animal amendments added to the soil. The value of the plasticity index was higher (due to preserving the moisture by the improvements) compared to the control treatment (table 7). In site 1, it was observed that wpl value of the control treatment P0O0 was (4.852), but it was (6.70) for \( P_3O_2 \) (table 7). By determining the plasticity index value (wpl), it was found that the (a) constant value was (31.131 – 39.93) Kpa and the value of (hr) constant was (1105.222 – 1467.212) Kpa, (c) constant value (0.6071 - 0.6245) while the value of the constant \( b^- \) was (1.2845 – 1.2372) Kpa for the treatments \( P_3O_0 \) and \( P_3O_2 \) (table 5). The difference in these values is attributed to the capacity of the intervention treatment \( P_3O_2 \) to increase the moisture retention and consequently increasing the plasticity compared to the control treatment in which the value decreased. For site 2, the values of the constant (a) was (20.668 - 25.496) Kpa, hr was (701.038 - 883.666) Kpa, values of (c) was (0.5772-0.5928) and the value of (b) was (1.3772- 1.326) Kpa for the treatments \( P_3O_0 \) and \( P_3O_2 \) respectively (table 6). The improvements had a positive role in increasing the plasticity (wpl) and in increasing the values of the constants (a, c and hr) with a corresponding decrease in the values of (b) (table 7). It was observed that the constants of this equation are represented by (a, b and c). The constant (a) is the same that is used in Van equations, but the constant value (b) is represented by the same values in equation, which depended on the soil particles especially the ratios of clay and sand in addition to the values of porosity that were influenced by the treatment of adding improvements to the soil, i.e. the values of the constant (a) and (b) exist as mentioned earlier. For the values of the constant (c), they are also correlated to the soil particles and porosity and the values are calculated through the relationship with the agent \( bb \). It was noticed that there is a difference in the values of \( bb \) that are correlated with the soil particle and porosity, which were (0.3542- 0.3553) (table 7). The values of (c) constant were (0.2622 - 0.2616) for the treatments \( P_3O_1 \) and \( P3O2 \) in site 1 (table 5), and also for site2 (table 6). It was observed also that the values of the constants a and b exist as mentioned before, but the values of (c) constant were (0.2615- 0.2634) for the treatments \( P_3O_0 \) and \( P_3O_2 \). The values of \( bb \) were (0.3542 - 0.3576) for the same equations (table 7).

From: what has been mentioned above, it is evident that soil improvements (Polymer PAM and animal amendments) had a positive effect on increasing the soil moisture content which effect on the values of \( \theta_v \), \( \theta_s \) and \( \theta_r \), and bulk density, porosity values and plasticity index (wpl) values also effect on the constants of the above equations.

Also (m) values equation are similar to (c) values equation.

On The other hand, (n) values of Van Genuchten1980 equation are similar to the (bm) values of and it is also similar to (b) values the values of (a) for [11] equation is the same in the equations.
Table 5. Values of the constants of the matrix potential of moisture content in site 1

| Pereira & Fredlund 2000 | Fredlund & xing 1994 | Burden & VanGenuchten 1980 | VanGenuchten & Mualem 1980 | VanGenuchten 1980 |
|------------------------|----------------------|-----------------------------|-----------------------------|-------------------|
| c                      | B                    | a KPa                       | b'                          | a KPa             |
| 0.2621                 | 1.3551               | 6.441                       | 1105.222                    | 0.6071            |
| 0.2616                 | 1.3542               | 0.198                       | 1199.556                    | 0.6122            |
| 0.2619                 | 1.3550               | 4.751                       | 1212.404                    | 0.6129            |
| 0.2619                 | 1.3549               | 6.361                       | 1171.919                    | 0.6108            |
| 0.2616                 | 1.3542               | 5.112                       | 1267.694                    | 0.6157            |
| 0.2620                 | 1.3551               | 4.721                       | 1289.597                    | 0.6167            |
| 0.2618                 | 1.3547               | 6.214                       | 1319.610                    | 0.6181            |
| 0.2616                 | 1.3543               | 5.173                       | 1334.028                    | 0.6188            |
| 0.2621                 | 1.3552               | 4.688                       | 1355.015                    | 0.6197            |
| 0.2617                 | 1.3546               | 6.169                       | 1400.022                    | 0.6217            |
| 0.2616                 | 1.3544               | 5.084                       | 1437.498                    | 0.6253            |
| 0.2622                 | 1.3553               | 4.656                       | 1467.212                    | 0.6245            |

Table 6. Values of the constants of the matrix potential of moisture content in site 2

| Pereira & Fredlund 2000 | Fredlund & xing 1994 | Burden & VanGenuchten 1980 | VanGenuchten & Mualem 1980 | VanGenuchten 1980 |
|------------------------|----------------------|-----------------------------|-----------------------------|-------------------|
| c                      | b                    | a KPa                       | b'                          | a KPa             |
| 0.2617                 | 1.3544               | 5.956                       | 701.038                     | 0.5772            |
| 0.2624                 | 1.3557               | 4.917                       | 752.543                     | 0.5796            |
| 0.2630                 | 1.3568               | 4.664                       | 734.716                     | 0.5804            |
| 0.2617                 | 1.3545               | 5.891                       | 719.347                     | 0.579             |
| 0.2624                 | 1.3558               | 4.905                       | 743.398                     | 0.5812            |
| 0.2631                 | 1.3571               | 4.625                       | 762.637                     | 0.5830            |
| 0.2616                 | 1.3543               | 5.842                       | 781.311                     | 0.5846            |
| 0.2625                 | 1.3559               | 4.876                       | 793.885                     | 0.5857            |
| 0.2632                 | 1.3572               | 4.573                       | 812.844                     | 0.5872            |
| 0.2615                 | 1.3542               | 5.810                       | 838.381                     | 0.5893            |
| 0.2626                 | 1.3561               | 4.822                       | 857.655                     | 0.591             |
| 0.2634                 | 1.3576               | 4.510                       | 883.666                     | 0.5928            |

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The reason of the variation in the constants values of the moisture content which predicted by equations (tables 5, 6 and 7), also the variation between measured and predicted values related to increase of moisture content due to positively improvements of physical and hydraulic properties of the soil in terms of influencing the moisture content measured at different potentials. These result agree with the laboratory study conducted by [12]. The levels of polymer affected on soil moisture content under pressure plate and pressure membrane. The polymer led to decreases the moisture content lost in the soil compared with control treatment at pressure of (1500 and 300 Kpa), these results were similar to [13]; [14]; [15].

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