Science Journal of Civil Engineering & Architecture
ISSN: 2276-6332
http://www.sjpub.org/sjcea.html

Published By
Science Journal Publication
International Open Access Publisher

Research Article Volume 2012, Article ID sjcea-279, 6 Pages, 2012. doi: 10.7237/sjcea/279

Parametric Investigation of Soil Susceptibility to Compaction Using Temperature Deviation Curves

Uno E Uno, Moses E Emetere, Adelabu, J. S.*

Department of Physics, Federal University of Technology Minna P.M.B 65, Minna.
* Department of Physics, University of Abuja, Nigeria.

Accepted 17th March, 2012

Abstract

Soil compaction can be explained using basic properties of soil. Cohesive soil sample were collected from five major region of the main site of investigation. Unlike other method of analyzing soil compaction, temperature deviation curves were used as the determinant for testing for compaction. It was discovered also that the temperature deviation curves can be used to find the annual amplitude of the surface soil temperatures. Soils in Abuja displayed some degree of compaction except for Gwagwalada that showed negligible compaction. Garki location produced the highest compaction at 14cm depth. The highest annual amplitude of the surface soil temperatures was noticed in Kuje and the lowest in Bwari.

Keywords:soil compaction, soil bulk density, temperature deviation curve,soil moisture, annual amplitude of the surface soil temperatures

Introduction

Soil compaction, though an old time discuss has attracted much publications from diverse discipline. Recently, researches are still ongoing in different discipline on same subject matter. Initially, the shovel was the first tool used to detect soil compaction, latter proctor methods, pocket penetrometer, cone penetrometer, motor-driven penetrometer, X-band microwave frequency, L-band radiometry [5,7,9] e.t.c. Compacted soil has smaller pores and fewer natural channels, hence water infiltration is drastically reduced and this causes greater surface wetness, more run off, which in turn increases erosion, and longer drying time.[2] From past research work on soil compaction, some soil properties were used to measure the degree of compaction e.g soil moisture content, soil bulk density, soil temperature, soil compressibility, soil strength, penetration resistance, soil structure e.t.c.
The denser the soil, the greater the volume ratio of solid particles to air, and the larger the dielectric permittivityofdrysoil,[1]moreso,ithasbeendiscoveredthatthebulk density of soil density affects the real and imaginary partsofcomplex permittivity.[9]Soilstrengthissaidtoincrease as bulk density and water potential increases. [5,6] Another soil properties discussed when investigating soil compaction is the moisture content, research has shown that as the moisture content increases, compactibility increases until the moisture content is approximately capacity point, when a condition known as the optimum moisture content for compaction is reached. [4,14] The proper estimation of soil moisture content is a fundamental issue as well in food security research, land management systems, pollution detection, nutrient flows, (wild-)fire detection, (desert) locust and carbon balance modeling.[4] Soil moisture content is one of the prime environmental variables related to land surface climatology, hydrology and ecology. It has been discovered that plastic flow contributes to the complete destruction of soil structure and macro- pores, therefore it can be used to determine soil compaction.[3]
Many researchers' have shown that the moisture-holding capacity of soil is significantly influenced by temperature.[8,11]This research is aimed at investigating soil compaction through the use of a different method i.e. temperature deviation curves. The Al-Nadhabandi andKohnkesoilcompactionmethod[16,11]wascloselystudied and modified to account for its short comings.

2. Theory and calculation

Hilel (10) gave the annual variation of daily average soil temperature at different depths, he described it with the following sinusoidal function.

$$T(z,0) = T_a + A_0 e^{-z/d} \sin\left(-\frac{z}{d} - \frac{\pi}{2}\right) \qquad 1$$

where T(z,t) is the soil temperature at time t (d) and depth z (m), T_a is the average soil temperature (°C), A_0 is the annual amplitude of the surface soil temperature (°C), d is the damping depth (m) of annual fluctuation and t_0 is the time lag . Since modern method of testing soil compaction requires relatively small time, therefore

$$T(z) - T_a = A_0 e^{-z/d} \sin\left(-\frac{z}{d} - \frac{\pi}{2}\right) \qquad 2$$

This can be further analysed as

$$T(z) - T_a = A_0 e^{-z/d} \sin\left(-\frac{z}{d} - \frac{\pi}{2}\right)$$

Corresponding Author: Moses E Emetere
Department of Physics, Federal University of Technology Minna P.M.B 65, Minna, Nigeria. Email: emetere@yahoo.com

It is assumed that $T(z) - T_a = \Delta T$ can also be known as temperature deviation. Through calculation, $\frac{z}{d} = \frac{\rho_s}{\rho_b}$ Where ρ_s = soil particle density which is a approximately 2.66gcm-3 by latest research [9], ρ_b = soil bulk density. Therefore,

$$\Delta T = A_0 e^{-\rho_s/\rho_b} \sin\left(-\frac{\rho_s}{\rho_b} - \frac{\pi}{2}\right) \quad 3$$

3. Material and Method

The study area is Abuja, Federal Capital Territory (FCT), central part of Nigeria . The soil samples were collected from five Local Government Areas in Abuja i.e. Abaji, Bwari, Garki, Gwagwalada and Kuje local Government Areas which are good representation of federal capital territory, Abuja. The region of study is located between latitude 8o 24'N - 9o 20'N of the equator and between longitudes 7o 30'E - 8o 48'E of the Greenwich Meridian. The study was carried at 14cm soil depth. The subsoil were identified with particles 68.58% sand,26.14% clay,5.25% silt, 0.64% organic carbon,1.10% organic matter. Ten PVC tubes, each of length 30cm and diameter 8.0cm had been drilled along the tubes at 2.0cm intervals. Holes through which thermometer could be inserted were drilled. One end of each tube was sealed with copper plate to prevent the soil sample from falling off. Varying known quantity of water (ranging from 0.5-2.0liters) was sprinkled evenly over equal quantities of well spread samples which were initially air-dried for six days. The samples were thoroughly mixed to ensure uniform moisture distribution .Small quantity of the soil sample was collected in a crucible for oven drying; this helped in the computation of the moisture content of the soil. The rest of the samples were packed into PVC tubes, one was used for soil water content measurement and other was used as a reference for soil temperature measurement. Thermometers (0oC -110oC) were inserted in each of the PVC tubes at the reference soil column at depths of 14 cm, 12 cm and 10 cm to monitor the vertical temperature variation. At each depth, two thermometers were installed 3 cm apart to monitor the horizontal temperature variation. The top of the PVC tubes were covered with a black polythene sheet then placed in the open field to be heated by solar energy.

4. Results and Discussion

The results obtained during the experiment are shown below in table 1 and table 2.

Table 1: Mean maximum temperature at 14cm depth in five local government Areas of Abuja.

Mean maximum Temperature	T1(oC)	T2(oC)	T3(oC)	T4(oC)	T5(oC)	T6(oC)	T7(oC)	T8(oC)	T9(oC)	T10(oC)
Abaji	51·0	52·0	56·0	55·0	52·0	50·0	52·0	49·0	44·0	48·0
Bwari	40·0	44·0	41·0	40·0	38·0	39·0	40·0	40·0	39·0	38·0
Garki	42·0	53·0	52·0	49·0	54·0	53·0	55·0	52·0	49·0	51·0
Gwagwalada	45·0	48·0	43·0	42·0	43·0	46·0	46·5	47·0	46·5	46·0
Kuje	52·0	55·0	47·0	52·0	53·5	56·0	52·0	51·0	52·5	57·0

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Table2:Bulk density and moisture contents at 14cm depth in five local

Bulk density (gcm-^{3})	1.32	1.34	1.36	1.43	1.45	1.48	1.52	1·50	1·55	1·56
Moisture contents (%)	7·70	9·40	14·20	17·70	20·20	21·00	22·70	25·00	30·00	31·30

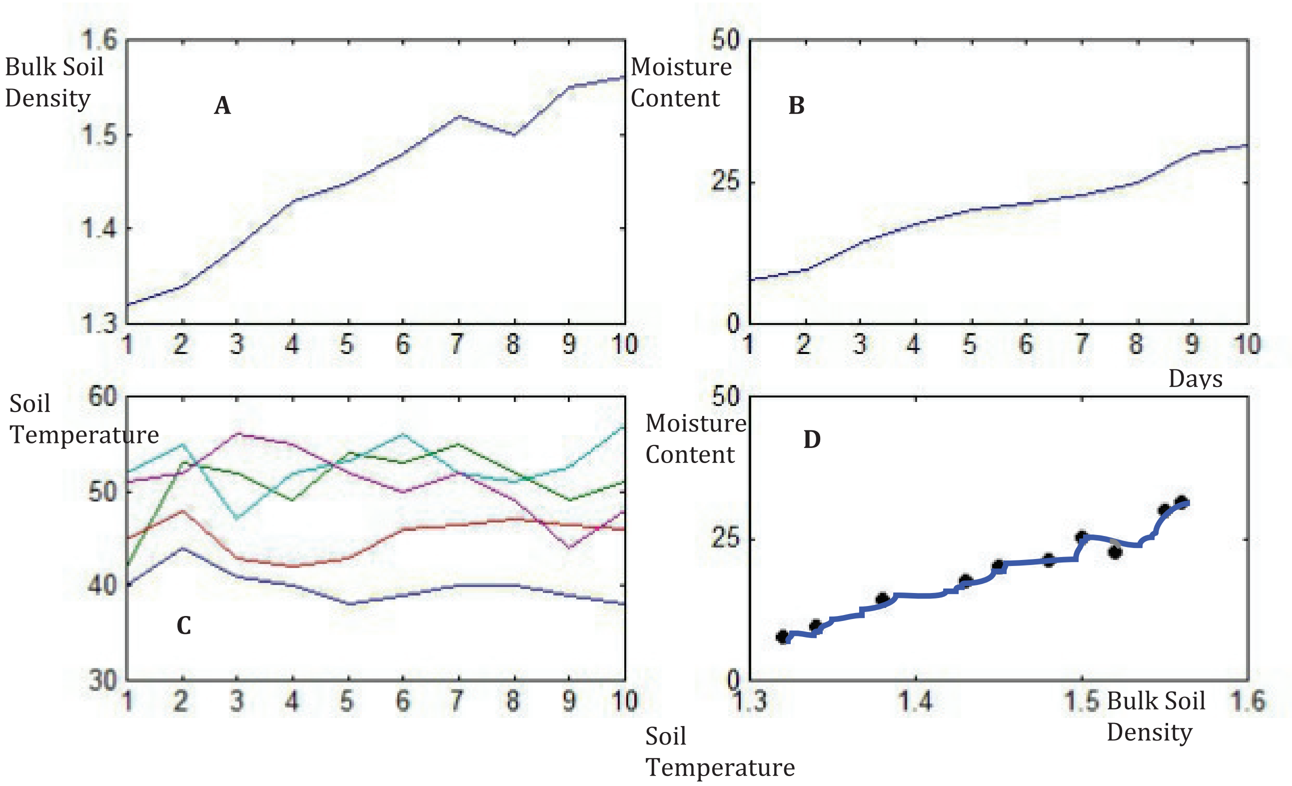

Fig 1.1: (A) Bulk density progressions per day (B) Soil moisture content progression per day (C) Soil temperature progressions per day-blue line signifying Bwari L.G.A., red line signifying Gwagwalada L.G.A., purple line signifying Abaji L.G.A., Green line signifying Garki L.G.A., sky-blue line signifying Kuje

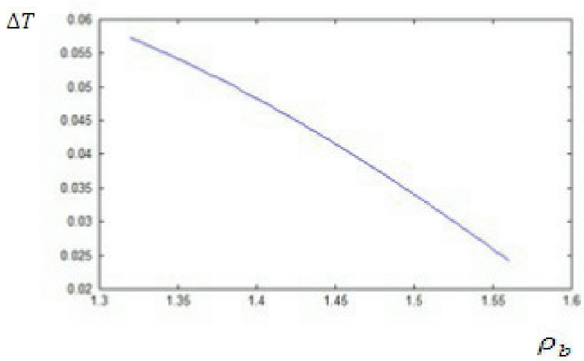

Fig1.2:temperature-Bulk density retrogression,When A_0 =1

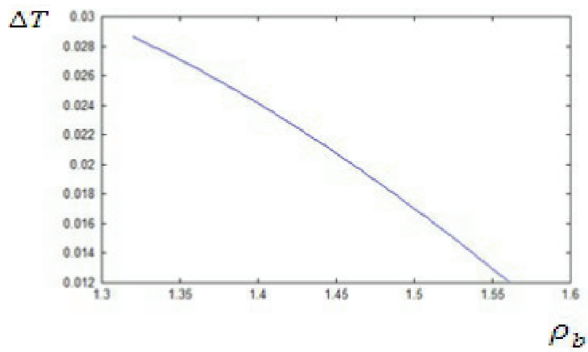

Fig1.3:temperature-Bulk density retrogression,When A_0 =0.5

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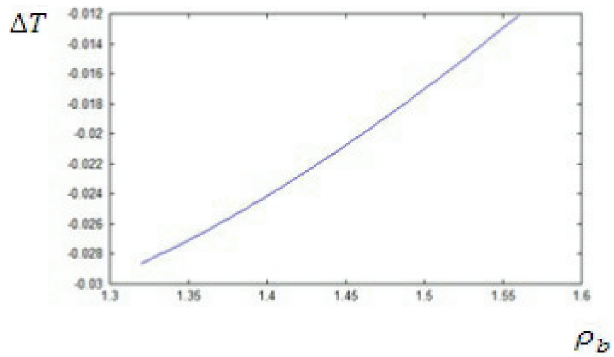

Fig1.4:temperature-Bulk density retrogression,When A_0 =-1

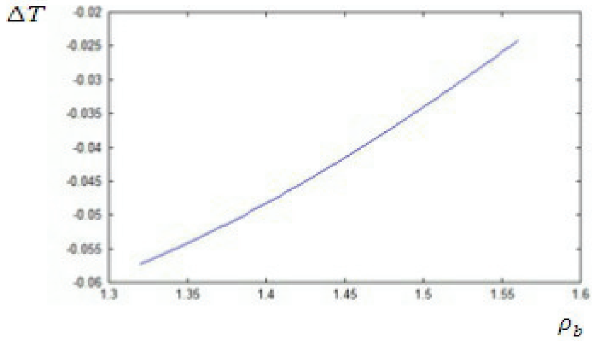

Fig1.5:temperature vs Bulk density retrogression,When A_0 =-0.5

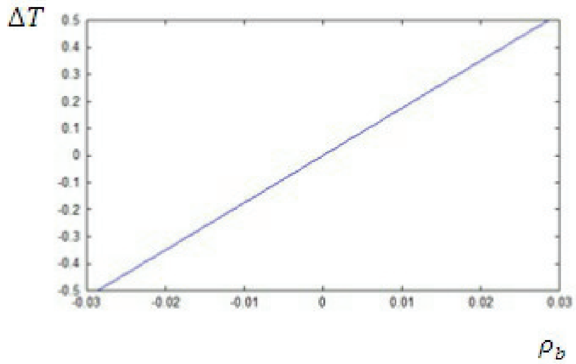

Fig1.6:temperature vs Annual temp. Amplitude progression, when A_0 =1.32

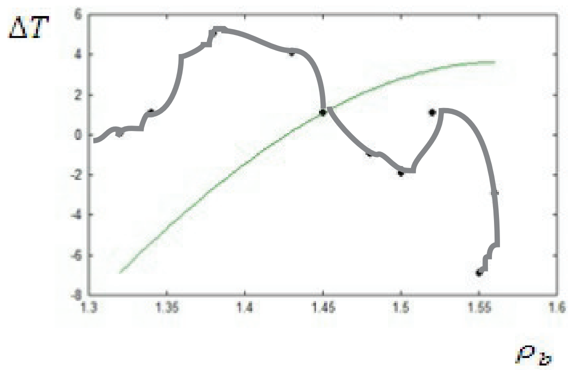

Fig1.7:temperature vs soil bulk density progression in Abaji L.G.A, When 120 ≤ A_0 ≥ 130. Experimental and theoretical graph shown above

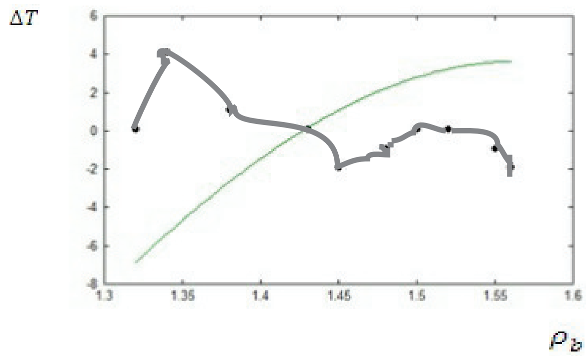

Fig1.8:temperature vs soil bulk density progression in Bwari L.G.A, When -120 ≤ A_0 ≥ 130. Experimental and theoretical graph shown above

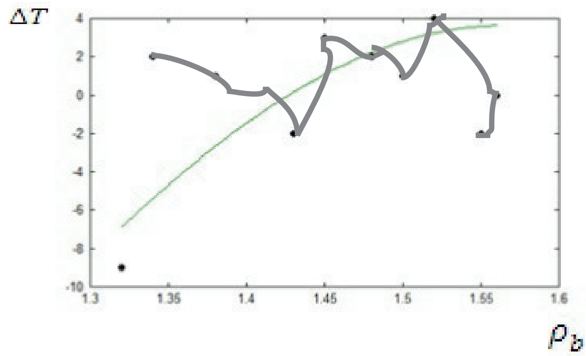

Fig1.9:temperature vs soil bulk density progression in Garki L.G.A,When 120 ≤ A_0 ≥ 130. Experimental and and theoretical graph shown

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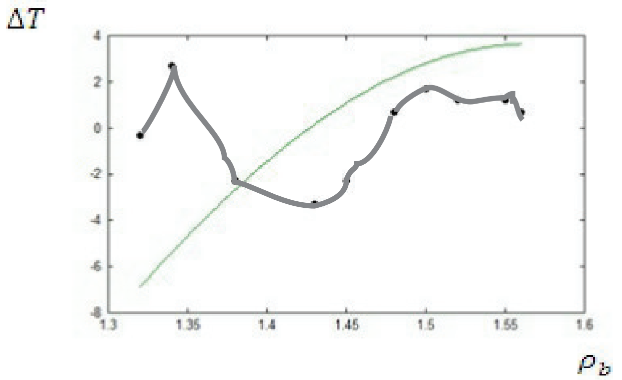

Fig1.10:temperature vs soil bulk density progression in Gwagwalada L.G.A, when -120 ≤ A_0 ≥ 130. Experimental and theoretical graph shown

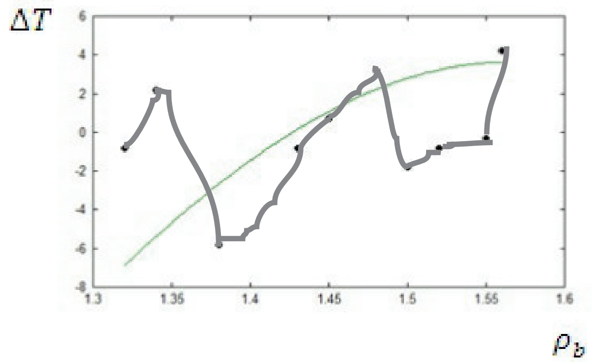

Fig1.11: temperature vs soil bulk density progression in Kuje L.G.A,When -120 ≤ A_0 ≥ 130. Experimental and theoretical graph shown above

The soil moisture progression per day as shown in Figure (1.1A,B) is in agreement with past research work. (12,13, 14,15) The longer the days, the greater the soil moisture and the bulk density of the soil. The results revealed that the effect of the soil type. The organic contents and the compactive energy on the dry density affect the porosity of the soil. It is also evident (from figure 1.1C&D) that as soil moisture increased from air-dry state, maximum soil temperature increased to a maximum value of dry density called optimum water content. The compacting energy used 9.4% for all the locations except Abaji which was at 14.2% and decrease after that point. Beyond the optimum values, the maximum soil temperature decreases with increasing value of moisture content to lower optimum value at 21% moisture. The decrease in maximum temperature is due to the fact that addition of water to dry soil expels some soil air and increases the thermal contact between the soil particles. This results shows a large increase in thermal conductivity, k and a small increase in the volumetric heat capacity. The overall result is an increase in the thermal diffusivity. Figure1.2-1.5 shows the effects of temperature deviations on the soil bulk density. First (in figure1.2) when the annual amplitude of the surface soil temperature is unity, the graph shows that a negative relationship. The same occurrence happened when the annual amplitude of the surface soil temperature is 0.5(as shown in figure 1.3). The amplitude of the surface soil temperature was made -1 and -0.5 as shown in figure 1.4 and 1.5 respectively. Positive relation between the temperature deviations and the bulk density was noticed which simply means that the susceptibility for compaction is more visible at the negative annual amplitude of the surface soil temperature. In figure 1.6, the bulk density was rather constant to observe the variations between the temperature deviations and annual amplitude of the surface soil temperature. It results shows a linear relationship between them. Figure 1.7- 1.11 is the main analysis of the temperature deviation curve which was derived in equation (ii) above. Generally, the temperature deviations in the practical values have an irregular sinusoidal shape. The theoretical graph is the parabolic curve which had intersects with the irregular sinusoidal graph. Figure 1.7- 1.11 has two major advantages (i) it predicts the annual amplitude of the surface soil temperature of a region (ii) It predicts the presence of soil compaction. Figure 1.7 has one point of intersection which gave an annual amplitude of the surface soil temperature (?16oC).The amplitude of the practical value is higher than the theoretical amplitude; therefore it shows the presence of soil compaction in Abaji L.G.A. Figure 1.8 also has one point of intersection and annual amplitude of the surface soil temperature (?0.5 oC). The amplitude of the practical value is higher than the theoretical amplitude, therefore it shows the presence of soil compaction in Bwari L.G.A. Figure 1.9 has six points of intersection which gave the following annual amplitude of the surface soil temperatures(?-116 oC,-25 oC,11 oC,33 oC,50 oC and 53 oC).The average is therefore ?9 oC. The amplitude of the practical value is higher than the theoretical amplitude, therefore it shows the presence of soil compaction in Garki L.G.A. Figure 1.10 has one point of intersection which gave an annual amplitude of the surface soil temperature (?-46oC).The amplitude of the practical value is lower than the theoretical amplitude, therefore it shows that there is a negligible presence of soil compaction in Gwagwalada L.G.A. Figure 1.11 has four points of intersection which gave the following annual amplitude of the surface soil temperatures(?-58 oC,-27oC,40 oC,56 oC). The average is therefore ?16 oC. The amplitude of the practical value is higher than the theoretical amplitude, therefore it shows the presence of soil compaction in kuje L.G.A.

5.0 Conclusion

Soils in Abuja display some degree of compaction except for Gwagwalada that showed negligible compaction. Garki location produced the highest compaction at 14cm depth. The highest annual amplitude of the surface soil temperatures was noticed in Kuje and the lowest in Bwari.

Appreciation

This work is self-funded. We appreciate Mrs. Jennifer Emetere for editing the script. We appreciate the Head of Physics Department of the above named institution

References

1. Adelabu, J. S. and Uno, E. (2004): Effect of soil Moisture and Soil Diffusivity Zuma JPAS 6: 58 - 61.

2. Amacher, Michael C.; O'Neill, Katherine P. 2004. Assessing soil compaction on Forest Inventory & Analysis phase 3 field plots using a pocket penetrometer. Research Paper RMRS-RP-46WWW. Fort Collins, CO:U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 7 p.

3. Adelabu, J. S. and Uno, E. (2005): Soil Compaction Causes and consequences. Zuma, JSPAS 7: 56-59

4. Al Nakshabandi G. and H. Kohnke(1965) Thermal Conductivity and Diffusivity of Soil as Related to Moisture Tension and other Physical Properties, Agric. Meteorol. 2,271-279

5. Carter Smith (1997): Assessing the compaction susceptibility of South African Forestry soil. Tillage Research 43: 335 - 354.

6. Cary J. W. (1965): Water flux in moist soil. Thermal versus suction Gradients. Soil Sc. 168 - 175.

7. Ellis, C I (1980). Soil compaction at low moisture content - field trials in Sudan. 7th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Accra, Ghana, 1-7 June 1980

8. Fredlund, D.G., Gitirana Jr., G.(2005); Unsaturated Soil Mechanics as a Series of Partial Differential Equations. Proceedings of International Conference on Problematic Soils, 25-27 May 2005,Eastern Mediterranean University, Famagusta, N. Cyprus pp 1-28

9. Gupta V.R ,, Jangid R.A (2011):The Effect of Bulk Density on Emission Behaviour of Soil at Microwave Frequencies.Int. Journal of Microwave Sc. and Tech,Vol 2011,Article ID 160129, pp 1-6

10. Hillel, D. 1982. Introduction to soil physics. Academic Press, San Diego, CA.

11. Hilf, J. W. (1956), An Investigation of Pore Water Pressures in Compacted Cohesive Soils, Technical Memorandum 654, U. S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

12. Herrick, J.E.; Jones, T.L. 2002. A dynamic cone penetrometer for measuring soil penetration resistance. Soil Science Society Of America Journal 66:1320-1324.

13. Kumar, C. P., Arora, Manohar, Singh, Digamber, Mittal, Sanjay, Srivastava, S. L. and Rao, P. R. (1999). Variation of Soil Moisture Characteristics in a Part of Hindon River Catchment, Case Study Report No. CS(AR)-4, National Institute of Hydrology, Roorkee, 1998-99, 61 p.

14. Taylor, H.M.; Gardner, H.B. 1962. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. Soil Science 96:153-156.

15. Willem W. Verstraeten , Frank Veroustraete and Jan Feyen (2008); Assessment of Evapotranspiration and Soil Moisture Content Across Different Scales of Observation, Sensors 8, 70-117

16. Yuanshi Gong, Qiaohong Cao and Zongjia Sun (2003): The effects of soil bulk density, clay content and temperature on soil water content measurement using time-domain reflectometry . Hydrol. Process. 17, 3601-3614

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