AUBURN
UNIVERSITY
BIOSYSTEMS ENGINEERING

SOIL MOISTURE

Lab One

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Introduction

Soil moisture content is important for plant growth. Different crops need to meet different soil moisture contents in order to achieve optimal growth. Plants must have access to water, but soils cannot be overly waterlogged either. Soils that cannot access water and oxygen will die- soils without moisture will stop growing and die. Plants that are waterlogged have too much exposure to water and cannot access oxygen necessary for growth. Different irrigation techniques have been used to quantify the efficiency of the relationship between soil, plants, and the water used to irrigate the crops. Flood irrigation, furrow irrigation, sprinkler irrigation, center pivot irrigation and drip irrigation are the different methods that are typically used in order to apply water to different plots.

The soil properties that are to be calculated as a result of collecting soul samples from irrigated and non-irrigated cotton rotation plots are gravimetric soil moisture content (dry basis), porosity, and the disturbed bulk density of the soil sample collected from the specific treatment plot assigned. For this assignment, cotton in a non-irrigated plot under treatment 8 (H2) was analyzed. The irrigated plot, H1, was analyzed by a different student, and data was exchanged in order to compare similarities and differences.

Objectives

The first objective for this lab assignment is to observe how a programmable semi-permanent sprinkler irrigation and soil moisture monitoring system in operation at the Auburn University cotton rotation. The second objective for the lab assignment is to determine the texture, soil moisture, porosity, and bulk density of the soil sample collected from the cotton rotation plot assigned during class. The last objective for the lab was to estimate the volume of water needed to bring a 16-ounce fresh sample of the soil to field capacity.

Methods

Soil samples from each of the plots were harvested before the lab was conducted. An *in-situ* sample was also taken by Dr. Dougherty as a baseline sample for comparison. The sample used for this lab was from a non-irrigated plot receiving *Treatment 8* from *cotton 0-80-60 a winter legume (0-0-0)*. Using a grate, the soil was sifted to remove large organic particulates such as rocks, sticks, worms, and litter in order to conduct accurate tests. Going outside to avoid dropping soil in the lab, a feel test was conducted. The soil was felt, wetted to conduct a ribboning test, and then saturated in order to determine how to classify the soil type assigned. The feel method was also conducted in order to determine the estimated moisture content in a range of percentages of the assigned soil sample.

In order to meet the objectives specified above, the mass of a 50mL sample of the soil was measured. An aluminum tare was labeled and weighed before use. Using a graduated cylinder, 50mL of the sifted soil was measured in the labeled tare on a scale in order to collect the mass of a 50mL volumetric sample of the soil. After recording the mass of the moist soil in its tare, the labeled tare and soil sample were placed into a drying oven set to 105 degrees Celsius for three days. The aluminum tare and dried soil were then weighed again, and the new figures were recorded to conduct the calculations specified in the objectives above.

Results & Discussion

Bulk Density, Moisture Content, & Porosity

Table 1: bulk density, moisture content, and porosity

	Bulk Density (g/cm^3)	Moisture Content *dry basis* (%)	Moisture Content *volumetric basis* (%)	Porosity (%)
H1	0.749	25.3	-	71.7
H2	0.842	21.0	17.7	68.7

For this lab, the soil cores were left intact and were not removed. This demonstrates that the bulk density calculated was a "disturbed" value. Bulk density was calculated by dividing the mass of dry soil by the 50mL volume of soil taken from the original soil sample after being sifted. The bulk density for the non-irrigated soil, H2, was calculated as 0.842 g/cm^3. This illustrated how many grams of soil were present in the volumetric sample of 50 cubic centimeters of air, water, and dry soil.

Two different values for moisture content were calculated. The moisture content (dry basis) of the soil compared the amount of water dried out of the soil and divided it by the amount of dry soil left over after evaporation and drying. The moisture content on a volumetric basis divided the amount of water extracted from the soil sample via drying and divided it to the total 50mL volume of the extracted soil sample. After calculations, the moisture content (dry basis) of the non-irrigated soil H2 was 21.0%. The moisture content (volumetric basis) of 50mL of the non-irrigated soil H2 was 17.7%, while the moisture content on a volumetric basis of 473mL of non-irrigated soil H2 was 25.9%.

Porosity was measured by determining the total void space and then dividing the entirety of the void space by the volume of the sample of soil that was dried. Void space is the summation of the volume of air and water in the soil sample being analyzed. The porosity of the 50mL "disturbed" sample of soil was measured at 68.72%. The intact porosity of the soil could be determined by adding the 122.9g of water in the intact sample to the 199.8 g of air in the intact sample. Dividing this by the total volume of the intact sample, 473mL, the intact porosity was determined at 68.22% which is indeterminately smaller than the 68.72% porosity calculated in the disturbed sample. Calculations for porosity are demonstrated below in the appendix.

The results found for the H1 irrigated plot were calculated separately by student Adam Behr and can be seen above in **Table 1**.

Gravimetric vs Feel Moisture Determination

Table 2: Gravimetric data calculations

Sample #	Volume (mL)	Tare (g)	Tare & Soil (g)	Dry Soil (g)	Water (g)	MC dry basis (%)
H2	50	4.24	55.20	46.34	42.10	21

Gravimetric methods are used to determine the moisture content of soils via calculating the mass of water in a soil sample by noting the mass of a soil sample before and after oven drying. Moisture content (dry basis) compares the weight of water extracted from the soil to the weight of the dry soil. All of the calculations for moisture content, bulk density, and porosity were based on the calculations from the gravimetric determination method. Using a 50mL sample weighed and dried in a 4.24g tare, the combined mass of the sifted soil and tare was 55.2g. After drying in the oven at 105 degrees Celsius, the tare and dried soil weighed 46.34g. This meant that the mass of the dry soil weighed 42.1g and the mass of the water that had been in the soil was 8.86g.

This can be compared directly to the feel method because the feel method used visual and manual methods of determining the moisture of a particular sample by seeing how much water or dampness displayed by squeezing the clump of soil in a hand. This demonstrated that the water content of the soil as a different entity than the soil particles themselves. Because the H2 soil sample was saturated and clayey, it was difficult to use the feel test to determine the moisture content. Through the feel test, it was determined that the available soil moisture content as a result of available water capacity of the sandy clay loam sample was between 50% and 70%. However, the textbook volumetric moisture content of sandy clay loams is supposed to fall within 20% to 32%. This means that the feel method was supposed to have yielded a 25% to 50% soil moisture availability as a result of the available water capacity of the sandy clay loam sample.

Soil moisture Determination Methods

Soil moisture can be determined in various ways. The method that was used in this lab was soil probing/soil sampling. By comparing the soil's texture and using gravimetric drying methods, the actual soil moisture was determined. This method is easier to conduct because most analyzing soil moisture have access to tares, an oven for drying, and some sort of scale for weighing. In order to determine the volumetric-based moisture content from the weight-based moisture content, the total volume of the sample of the soil being analyzed is necessary to complete the calculations. The other four methods, were not used in this lab. Tensiometers, electrical resistance blocks, neutron probes, and dielectric soil moisture sensors encompass four other ways to measure soil moisture content.

Tensiometers measure soil moisture tension by inserting a porous cup into the soil while a vacuum gauge on the other end of a long plastic tube reads the soil moisture tension of the soil sample.

Electrical resistance blocks also read soil moisture tension. Two electrodes that are embedded in a gypsum mixture detect changes in electrical resistance and or conductance as water content on the block of gypsum changes.

Neutron probes work by inserting probes containing tubes full of radioactive sources and detectors in soil. Neutrons are emitted by the radioactive substance, and turn into slower neutrons and hydrogen atoms present in the water located in the soil. The neutron probes measure soil moisture content by looking at the amount of soul neutrons associated with the soil moisture content.

Dielectric soil moisture sensors measure electric properties in the soil based on their moisture contents. Calculations can be performed to convert the data from dielectric sensor information to tangible soil moisture content figures.

Each of the other four methods are very efficient and effective in reading soil moisture content for growers. The other methods utilize more complex processes and more expensive instrumentation in order to conduct soil moisture content tests. Large-scale farms, researchers, and corporations can afford the tools used to conduct these tests. If gravimetric tests are performed, tensiometers, electrical resistance blocks, neutron dielectric soil moisture sensors should be used to confirm data results.

Theoretical Porosity & Field Capacity (Part II)

For the soil sample to reach its theoretical field capacity, the volumetric moisture content of the 16-ounce sample of soil had to be between 20% and 32%. Based on the 50mL sample, however, the volumetric moisture content of the 16-ounce sample was 17.7%. This means that there was an 8.3% availability of water in the soil to reach field capacity. By multiplying 8.3% by the total volume of the soil, the amount water necessary for the soil to reach field capacity. This amount came out to 39.36 mL of water that needed to be added to the sample to reach field capacity After drainage, the total amount of excess water that drained from the cup was around 6mL, demonstrating that there was not an overly excessive amount of water that needed to be drained for the soil sample to fill its pore space and reach its true field capacity.

The theoretical porosity of a cubical array of perfectly shaped spherical particles can be calculated by looking at the volume of a sphere inside of the volume of a cube. By subtracting the volume of the sphere from the volume of the cube and dividing this figure over the total volume of the cube, the porosity equation is modeled. The volume of the cube and sphere model subtracted from one another models the concept of void space while the total volume of the cube models the total volume of the sample collected and analyzed.

In a perfectly theorized cube-sphere scenario, the porosity would be 48.64%. Both the porosities for the irrigated and non-irrigated soil samples from Treatment 8 were higher than the theoretical value of perfectly spherical soil samples stacked on top of each other within a perfectly cubical volume.

Appendix (Calculations, Attached Lab Assignment, Part II- Porosity & Field Capacity)

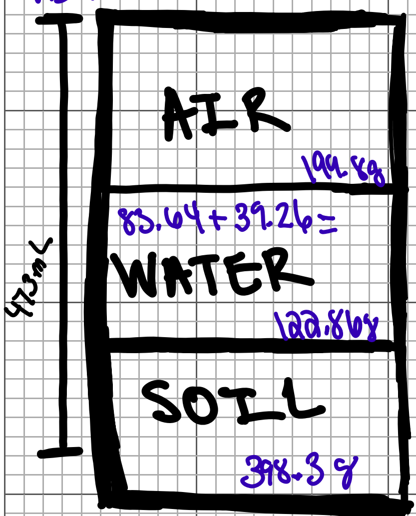
Calculations and supplemental materials are attached to this sheet.

Rowe, Rosia | Lab 1 Calculations | 09/05/2018 | 1

$398.3 \times 0.21 = 83.64$ (H_2O)
$473 \times 0.083 = 39.26$

$473 \times 0.842 = 398.3$ (dry soil)

$473 - 150.3 - 122.9 = 199.8$ (dry air)



Moisture content (dry basis):

$$MC_{db} = \frac{\text{water}}{\text{dry soil}} = \frac{8.86}{42.10} \times 100 = 21\%$$

$\frac{398.3\,g}{2.65\,g} = 150.3\,mL$

$\boxed{MC_{dB} = 21\%}$

bulk density:

$$BD = \frac{\text{dry soil}}{\text{volume}} = \frac{42.10}{50} = 0.8420\ g/cm^3$$

$\boxed{BD = 0.8420\ g/cm^3}$

$$\text{Porosity}(\%) = \frac{\text{void space}}{50} = \frac{25.25 + 8.86\ (mL)}{50\ mL} \times 100$$

$\boxed{\text{Porosity} = 68.72\%}$

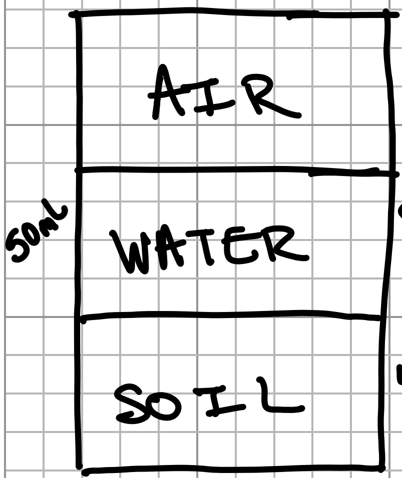
$$\text{Volumetric moisture content} = \frac{\text{water}}{\text{volume}} = \frac{8.86\,mL}{50\,mL} = 17.7\%$$

$\boxed{MC_{va} = 17.7\%}$

$\frac{122.9}{473} \times 100 = 25.9\% \sim 26\% \rightarrow 26 - 17.7 =$ $\boxed{8.3\%\ H_2O\text{ vol basis}}$

Soil is 8.3% MC_{va} → NEEDS 20% – 32%.

$\boxed{\text{Target: } 26\%}$



25.25

+

$8.86 \times 1\,cm^3 = 8.86\,mL$

+

$42.10g \times \frac{1\,cm^3}{2.65g} = 15.89\,mL$

$\overline{\quad 50 \quad}$

H_2O to add: $473 \times 0.083 = 39.26\,mL$

adding 39.26 mL will bring the soil sample up to field capacity

BSEN 4210 Lab 1 – Soil moisture
Lab report due: two weeks (100 pts.)
Report format: see sample report on course web page (under lab assignments)

Objectives:

1. Observe a programmable semi-permanent sprinkler irrigation and soil moisture monitoring system in operation at the Auburn University cotton rotation (Rainbird controller information on class web page).
2. Determine the texture, soil moisture, porosity, and bulk density of two soil samples from assigned cotton rotation plots.
3. Estimate the volume of water needed to bring a 16 oz. fresh sample of your soil to field capacity.

Part I: Cotton rotation soil moisture evaluation

a. During our visit to the cotton rotation site, you and your team mate will grab two soil samples at 4-6" depth (one irrigated and one non-irrigated) for your assigned treatment plot (Table 1). While at the site, estimate the texture of the soil sample (print out Lab 1 soils data from class web page) and the percent available moisture for each sample based on feel and appearance (print out USDA - Estimating soil moisture… from class web page).

b. After visiting the cotton rotation site, determine the gravimetric soil moisture content (dry basis), porosity, and disturbed bulk density for your two bagged and dated soil samples. Record total weight and volume of wet soil sample in Corley basement lab. Weight samples and tares individually before and after oven drying at 105ºC. Calculations for MC, porosity, and bulk density are given in class. Procedures to determine gravimetric soil moisture are provided below.

Table 1. Cotton rotation plots for soil moisture study ($_1$-irrigated, $_2$-non-irrigated plot)

Treatment #	Description	Student (#)
1	Cotton 0-80-60 (no winter legume)	A_1 / A_2 (1)
2	Cotton 0-0-0 (winter legume 0-80-60)	B_1 / B_2 (2)
3	Cotton 0-40-30 (winter legume 0-40-30)	C_1 / C_2 (3)
4	Cotton 0-80-60 (winter legume 0-40-30) Corn 0-0-0 (winter legume 0-40-30)	D_1 / D_2 (4)
5	Cotton 120-80-60 (winter legume 0-40-30) Corn 120-0-0 (winter legume 0-40-30)	E_1 / E_2 (5)*
6	Same as #1	F_1/F_2 (6)
7	Same as #4	G_1/G_2 (7)
8	Cotton 0-80-60 (winter legume 0-0-0)	H_1/H_2 (8)
9	Same as #5	
10	Cotton 0-80-60 (winter legume 0-80-60) Corn 0-0-0 (wheat or rye 60-0-0) Soybean 0-0-0	I_1/I_2 (9)
11	Same as #10	
12	Same as #10	
13	Cotton 120-80-60 (no winter legume)	J_1 / J_2 (10)

*In-situ core sample also taken

Data sheet:

Student name: Rosia Rowe
Soil sample: Treatment 8 (H_2)
Location of sample: Plot H
Antecedent moisture condition: non-irrigated 2.8
Estimated textural class: sandy clay loam
Estimated moisture content (feel method): 50% - 75%
Crop currently in plot Cotton

Student name: Adam Behr
Soil sample: Treatment 8 H_1
Location of sample: Plot H
Antecedent moisture condition: irrigated 2.8
Estimated textural class: sandy loam
Estimated moisture content (feel method): 25 - 50%
Crop currently in plot Cotton

<u>Soil moisture determination procedures: gravimetric method</u>

1. Label tares on bottom using A_1, A_2, B_1, B_2, etc.
2. Remove organic matter and rocks from your sample and estimate textural class.
3. Using entire sample, estimate soil moisture using "feel test".
4. Using a graduated cylinder, determine the exact volume of two (2) fresh soil samples (approximately 50 mL each).
5. Using aluminum drying tares, determine the exact weight of fresh soil samples.
6. Place fresh soil samples in drying oven at 105ºC for at least 24 hours.
7. Record dry weight of samples to determine MC (percent, dry basis).

Gravimetric:

Sample #	Vol. mL	Tare g	Tare+soil (wet) g	Tare+soil (dry) g	Dry soil g	Water g	MC % (db)
H_1	50						
H_2	50	4.24	55.20	46.34	42.10	8.86	21.0
In-situ	136.2	7.23	232.97	189.37	182.14	43.60	23.93

<u>Discussion</u>: The following questions should be answered in your lab report:

1. What is the dry bulk density of your soil samples? [Note: we are calculating a "disturbed" bulk density, since we did not remove intact soil cores].
2. What is the moisture content (dry basis) of each soil sample?
3. Can this result be compared directly with results from the feel method? If so, how?
4. What is the estimated total porosity of each soil sample?
5. Is this higher or lower than intact soil porosity?
6. Based on the web handout "Measuring Water Sources", what are four methods used to determine soil moisture? Give a brief assessment of their application in irrigation.
7. How is the procedure for determination of volumetric soil moisture different from the gravimetric procedure you used in lab?
8. What piece of information is needed to convert from weight-based MC to volumetric-based MC?

Part II: Theoretical porosity and field capacity

a. What volume of water is needed to bring 16 oz. (→ 473 mL) of your fresh soil sample to approximate field capacity? Show all calculations. How close was your estimate to the actual amount of water needed to initiate free drainage of water?

= 199.8

.398 x .21 = 122.86

.842 x 473 = 398.3

$\frac{298.3g}{2.65g} = 150.3mL$

Air = 473 − 150.3 − 122.9 = 198.8

$\frac{122.9}{473} = 25.9\%$

↳ mcvol

Need 20% to 32% to reach field capacity

$\boxed{\text{avg} = 26}$

moisture content (volumetric) = 17.7%

Target − current = avail. % MC

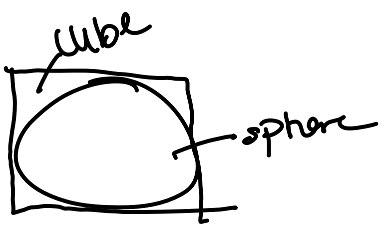
26 − 17.7 = 8.3%

473 X 0.083 = 39.26 mL

need 39.26 mL to initiate free drainage

b. Determine the theoretical porosity of a cubical array of perfectly spherical particles (round soil particles lined up on top of each other). Show all calculations.

$$\text{Porosity} = \frac{\text{void space}}{\text{volume}} = \frac{\text{volume air} + \text{volume } H_2O}{\text{total volume (vol air)}}$$



$$V_c = bwh = (2x)(2x)(2x) = (2r)(2r)(2r)$$

$$V_s = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi r^3$$

$$= \frac{8r^3 - \frac{4}{3}\pi r^3}{8r^3} = \frac{\cancel{r^3}(8 - \frac{4}{3}\pi)}{\cancel{r^3}(8)} = \frac{8 - \frac{4}{3}\pi}{8}$$

$$\frac{8 - 4.1887}{8} \times 100 = 47.64\%$$