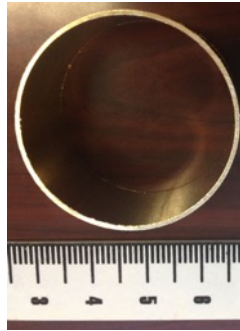
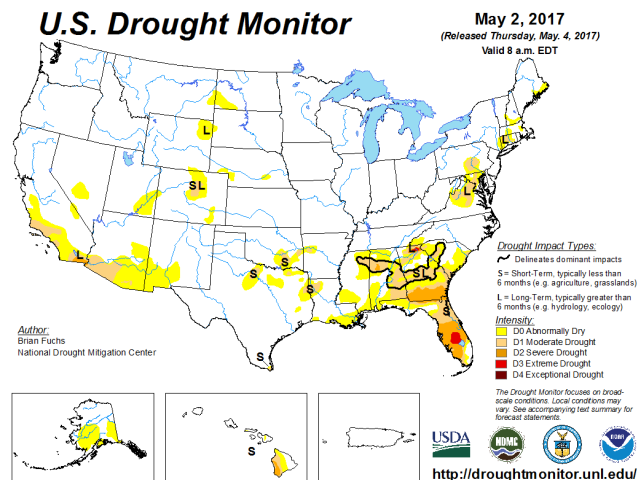


CoCoRaHS Soil Moisture Monitoring



Why Soil Moisture?

The 0-2" soil samples have the potential to be used in calibration-validation effort by the National Aeronautics and Space Administration's (NASA) Soil Moisture Active-Passive Satellite (SMAP). The 7-9" samples are suitable for aiding in the drought monitoring process, which is an operation lead by the United States Department of Agriculture (USDA). This is also a great opportunity to play outside, get your hands dirty, and learn something!



Getting Equipped:

CoCoRaHS will be providing soil moisture measurement kits for the cost of \$50.00. These kits include a brass ring for soil coring (1), a graduated cylinder (2), and a CoCoRaHS scale (3).

To obtain these materials please request via email (peter@cocorahs.org), or via phone (970-491-8545).

1. Brass Ring: 2" (50.8 mm) height 3.125" (79.4 mm) diameter



Item available separately from [onlinemetals.com](http://www.onlinemetals.com)

http://www.onlinemetals.com/merchant.cfm?pid=22612&step=4&showunits=inches&id=84&top_cat=79

Once on this webpage select the "Create a Custom Size" tab. In the box labeled "Length – Inches:" select 2. This should bring the listed cost/piece to \$6.38 before shipping and handling.

2. Graduated Cylinder (250 mL)



Item available separately at [https://www.amazon.com/SEOH-Graduated-Cylinder-Borosilicate-](https://www.amazon.com/SEOH-Graduated-Cylinder-Borosilicate-Capacity/dp/B00JG30QJW/ref=sr_1_1?ie=UTF8&qid=1490386967&sr=8-1&keywords=graduated+cylinder+250ml)

[Capacity/dp/B00JG30QJW/ref=sr_1_1?ie=UTF8&qid=1490386967&sr=8-1&keywords=graduated+cylinder+250ml](https://www.amazon.com/SEOH-Graduated-Cylinder-Borosilicate-Capacity/dp/B00JG30QJW/ref=sr_1_1?ie=UTF8&qid=1490386967&sr=8-1&keywords=graduated+cylinder+250ml)

3. CoCoRaHS metric scale



Item available separately at www.weatheryourway.com

Soil moisture measurements also include a short list of household items. These include the following:

1. Pad, paper, and pencil/pen
2. Ruler
3. Level, or straight edge
4. Trowel
5. Tin foil, cookie sheet, or pot pie holder
6. Oven (toaster oven okay)
7. Sharpie (or similar labeling device)
8. Rag or paper towel
9. Shovel
10. Bucket scoop, or similar flat surface
11. Sandwich bag
12. Wood block (large enough to cover cylinder)
13. Water bottle
14. Gloves (optional)
15. Masking Tape (optional)

If you do not have any of the necessary household materials please specify what you are missing when contacting CoCoRaHS. We can do your shopping for you, charging the extra cost of the materials only.

Classifying Your Soil (optional, but recommended):

Before beginning to measure soil moisture, estimate your soil type using the field soil texture test from the Colorado Master Gardener Program. Knowing your soil type gives you an idea of what your soil sample should weight when it is dried. Sandy soils are heavier when dried because they have less pore space (pockets of air). This also means sandy soils likely won't hold as much water when wet. Clay-heavy soils will be lighter when dry because clay has more pore space. Here is a breakdown of the expected dry weight range for each CoCoRaHS soil type option:

Soil Type	Expected Dry Weight (grams)
Sand	320-410
Loamy Sand	310-400
Sandy Loam	305-390
Loam	285-345
Silt Loam	265-350
Sandy Clay Loam	265-390
Clay Loam	265-350
Silty Clay Loam	250-345
Sandy Clay	250-380
Clay	250-330
Silty Clay	250-330

Estimation of Soil Type by Master Gardener Field Test (optional, but recommended):

1. Go to your measurement site with a trowel when conditions have been wet, or bring a water bottle with some water to wet soils if dry.
2. Dig out a sample of roughly golf ball size from the top two inches of soil and then follow the flow chart instructions below (from Figure 5.4 of the "Estimating Soil Texture" printout to determine soil type).

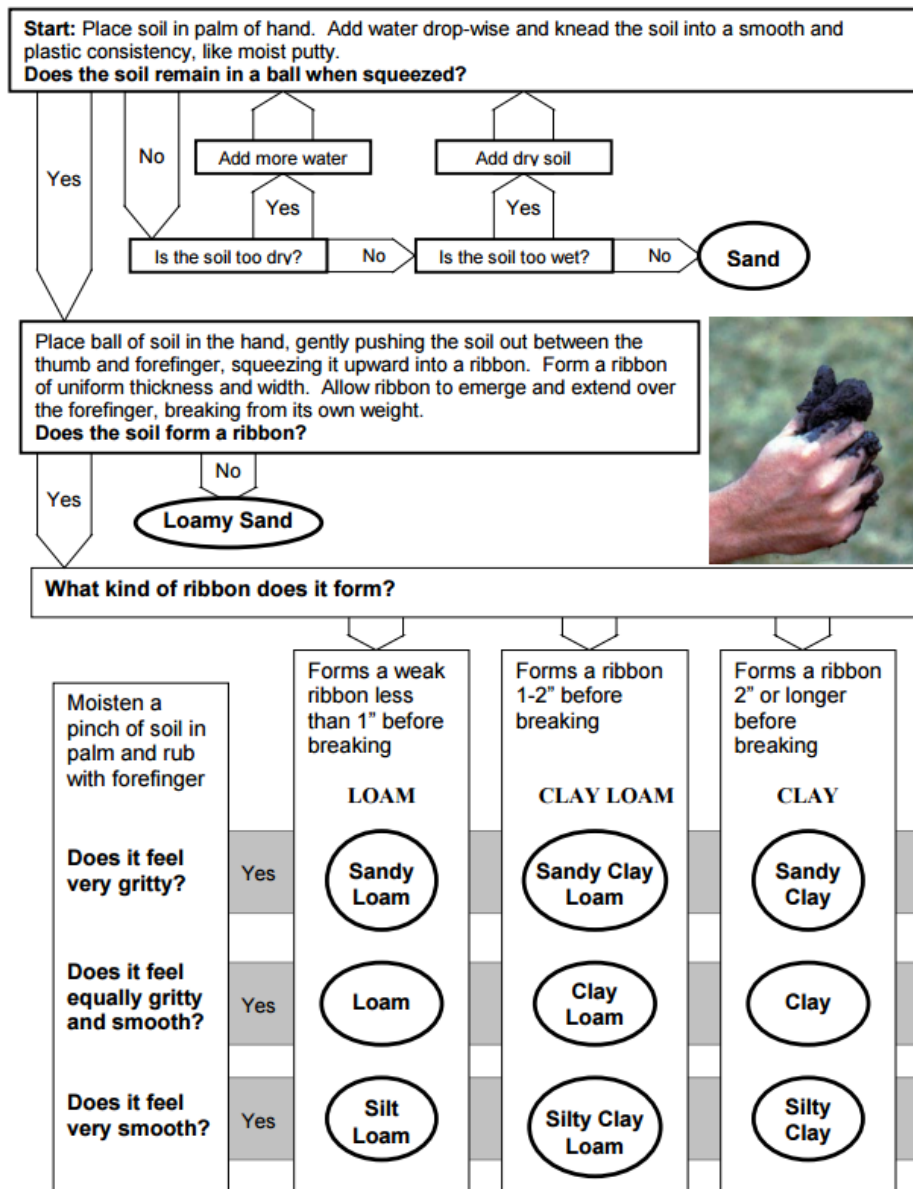


Chart courtesy of CSU Master Gardener: www.ext.colostate.edu/mg/gardennotes/214.pdf

3. Repeat the process for soil of 7-9" depth.

Site Requirements:

1. Flat locations are best. Moisture may be lower than representative of average at the top of mounds or hills, and higher than representative of average in dips or valleys.
2. Your dig site does not have to be barren, but surface vegetation should be pulled before taking a core sample.
3. Just as in siting a rain gauge, take soil moisture measurements as far away from houses and large trees as practically possible. A horizontal distance of more than two times the height of the obstruction is preferential.

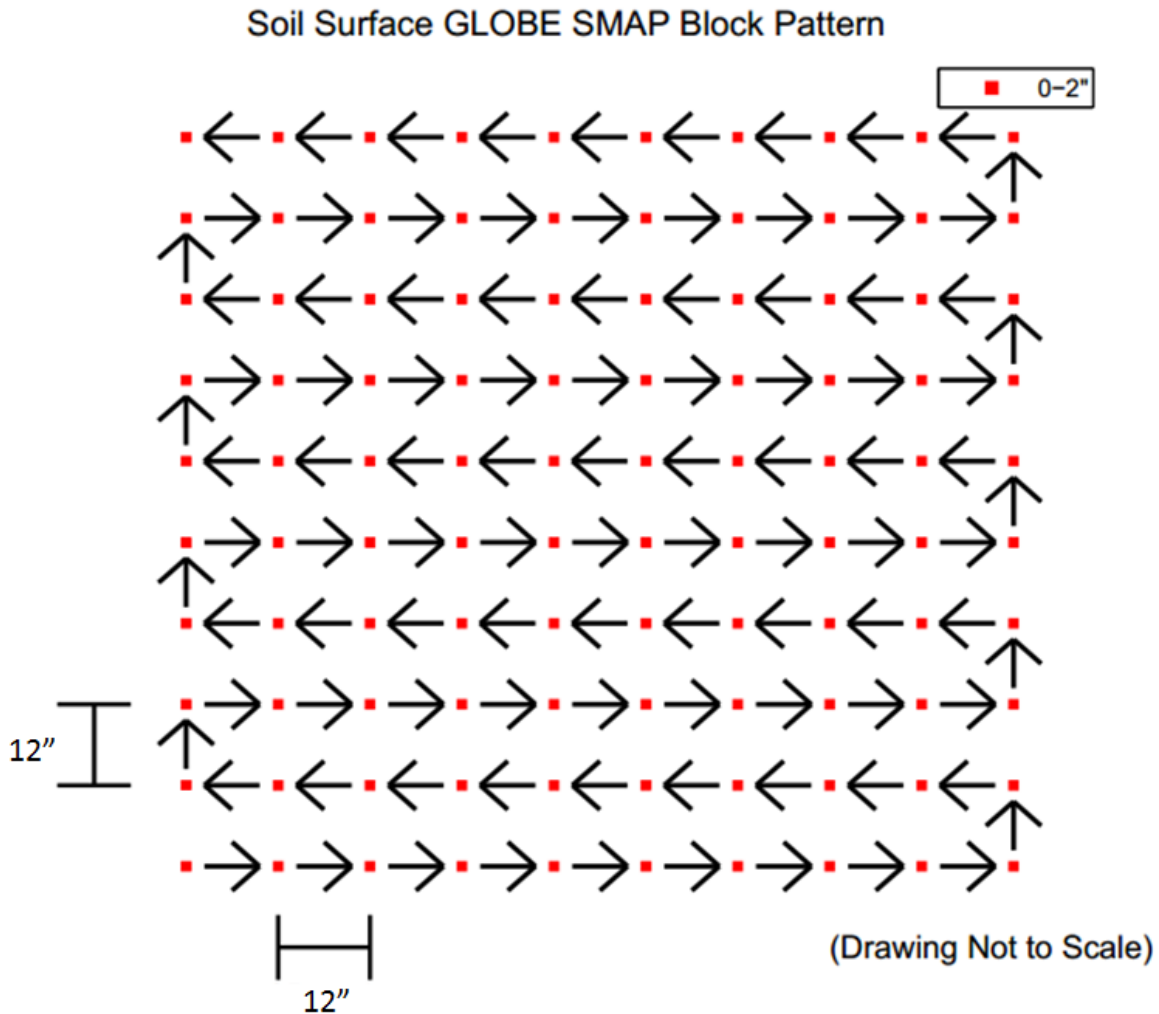
Sampling Depths:

1. 0-2"
2. 7-9"

Sampling Patterns:

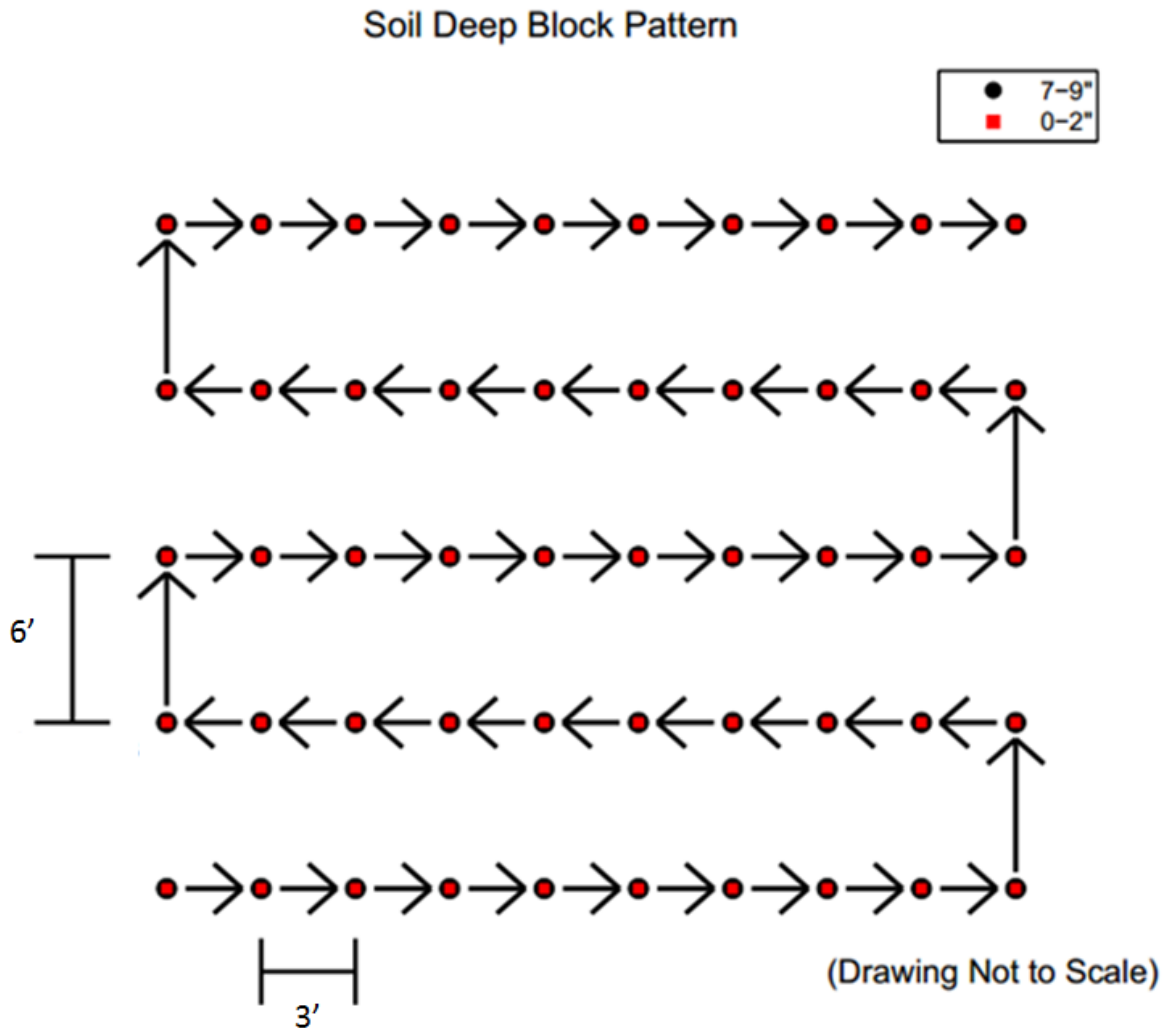
You will have considerable leeway to choose how and where samples are taken. An example will be given below of how to report 0-2" soil samples only, and how to report at both 0-2", and 7-9" depths.

Surface Only Measurements (GLOBE SMAP Block Pattern):



Take all soil moisture measurements one foot (or 30 centimeters) apart continuing in a line for a series of ten samples. On the 11th measurement move perpendicular to the previous measurement and continue so on in a snake-like pattern. You may deviate slightly from your sampling site in this idealized model in order to avoid rocks and root clusters. One red dot represents one day of sampling.

Surface and Root Zone Measurements (Soil Deep Block Pattern):



Take one soil core at 0-2" depth. Dig a hole down to 7" depth with a shovel. You will have to remove much more soil in order to take these deeper measurements, so measurements from one observation to the next will be farther apart. A distance of one yard (or one meter) is recommended. On one side of the hole that goes to 7" dig an elongated section. This will make removing your root zone soil core much easier. Once you have removed the 7-9" core, fill the hole you have dug back in as much as possible. Take your next nine samples in a line perpendicular to the elongated hole that was dug to reach 7". Take these samples each one yard apart (or one meter). On the 11th sample, move two yards in a direction perpendicular to your previous line of measurements and parallel to the elongated holes that have been dug to 7". Continue on in a snake-like pattern. You may deviate from this pattern slightly to avoid rocks and root clusters. One dot represents one day of sampling.

*****NOTE OF CAUTION*****

Taking root zone measurements is hard work. Digging down to the root zone may involve considerable force if soils are dry or heavy. Cramps, blisters, and general soreness are possible from this endeavor. Furthermore, some soil types may stick to your brass ring. Please use caution in separating the soil from the ring. Use of sharp objects such as knives is not recommended. This activity is recommended only for those in strong physical condition. Proceed with caution.

Soil Coring:

1. Bring your pencil, paper, ruler, level (straight edge), brass ring, bucket scoop (or similar thin, flat surface), scale, sandwich bag, sharpie, masking tape, hammer, wooden block, and trowel to your selected dig site.
2. Weigh the bag that will be used to hold your soil core. This weight can be subtracted when weighing the sample.
3. Remove surface vegetation from your dig site. You only need to do this right where you are digging. You do not need to clear a large area around the dig site. One square foot ($\sim 10 \text{ dm}^2$) is enough.
4. Place the brass ring on a flat portion of soil, and twist it into the ground a bit to clearly designate a core site. If the soil is soft, continue to push; you may be able to push the ring in with your hand.
5. Put the wood block on top of the brass ring, and then hammer it into the ground until the block is flat against the surface.
6. Using the trowel, excavate the soil surrounding one half of your brass ring down to the depth of the bottom of your sample. Make sure you have excavated enough area to lay the bucket scoop flat in the pit.
7. Slide your soil core contained by the brass ring horizontally over the surface of the bucket scoop. Be careful not to lose any of your soil core through of the bottom of the ring, especially if soils are dry.
8. Slide the soil core into your sandwich bag.
9. Break up the soil core, and remove any rocks larger than a pea, and any roots larger than a q-tip.
10. Squirt some water from your water bottle into your graduated cylinder, and measure that volume.
11. Now drop the rocks and roots you removed into the graduated cylinder and read the volume again. The difference in volume between these two measurements is equal to the volume of rocks and roots removed, and should be subtracted from your container volume when determining the sample's dry density and volumetric water content.
12. Weigh your soil sample. Record it. Be sure to tare (subtract) the weight of the bag.
13. Label your sample with the date, time, volume of rocks and roots removed, and depth of measurement. You may prefer doing this with masking tape, and a sharpie or pen to avoid marking directly on the bag.

14. Clean off your trowel with a dry rag or paper towel to avoid sample cross-contamination.
15. (Optional) Now it's time to get your 7-9" depth sample. Dig down to 7". These measurements should be taken directly below where you took your 0-2" measurements. Be conscientious of how far you've dug. You can use the ruler to measure the depth, and a level, or just a straight edge, to make sure the ruler is lined up perpendicular to the ground. Once you have dug out soil to 7" depth repeat steps 5-14 for your deeper sample. Be careful of debris falling into the hole from nearer the surface. You want to make sure 7-9" soil cores are actually representative of undisturbed soils at depth.

The Drying Process:

1. Have the following materials on hand: pencil and paper, drying surface (ie tin foil, cookie sheet, pot pie holder), and scale.
2. Set and your oven to 210-215 F.
3. Weigh the drying surface you wish to place your soil sample on, so that this weight can be subtracted in your calculation.
4. Carefully pour your soil sample from the sandwich bag onto the drying surface, and spread it out. If you are using tin foil, fold up the corners before pouring the soil to avoid mass loss. You may dry more than one sample at the same time.
5. (Optional) Weigh your sample again before placing it in the oven. This weigh-in is designed to corroborate your field measurement, but on a consistent, flat surface such as a counter top. Think of it as a sanity check. If the sample has changed in weight by a few grams or less it is likely due to evaporation and not a scale error during the soil coring process.
6. Place the soil sample in the oven, and wait!
7. Let the soil dry for 2-12 hours. Note: The drying time needed will be dependent on soil wetness and soil type. You may be able to do this step more quickly if you remove the soil occasionally to check the weight. Once there has been no measurable evaporation for at least half an hour you may proceed. After getting to know your soil you may gain some intuition for how long the drying process takes.
8. Once the soil weight no longer changes over at least one half hour period it is done.

A Note on Drying:

Some soil samples may exude some odor. Once again, this is going to be dependent on soil wetness, and soil type. If you're uncomfortable drying these samples in your oven, you may consider a toaster oven as a suitable alternative. You may dry samples in a cheap toaster oven that is plugged in outside or in a garage.

The Data Entry Form:

My Data Entry : Soil Moisture Report Form

The screenshot shows a web form titled "Soil Moisture Report Form" with a "Submit Data" and "Reset" button at the top right. The form contains the following sections and fields:

- Station Information:**
 - Station Number: CO-LR-1107
 - Station Name: Fort Collins 4.5 WNW
- Observation Date and Time:**
 - Observation Date: 4/6/2017 (marked with a red asterisk and a help icon)
 - Observation Time: AM (marked with a red asterisk and a help icon)
- Observation Notes:** A text area for notes, marked with a red asterisk and a help icon.
- Information about where the sample was taken:**
 - Distance from previous sample in meters: 0.3 (marked with a red asterisk)
 - Is the land irrigated? Yes No
 - Did you begin a new row? Yes No
- Soil Samples Table:**

Depth	Soil Type	Weight Before Drying (grams)	Volume of Rocks and Roots Removed(cm3)	Weight After Drying (grams)
0-2"	Sandy Clay	<input type="text"/>	<input type="text"/>	<input type="text"/>
7-9"	Sandy Clay Loam	<input type="text"/>	<input type="text"/>	<input type="text"/>


Numbered callouts (1-10) point to the following fields:

- Observation Date
- Observation Time
- Observation Notes
- Distance from previous sample in meters
- Is the land irrigated?
- Did you begin a new row?
- Soil Type for 0-2" depth
- Weight Before Drying (grams) for 0-2" depth
- Volume of Rocks and Roots Removed(cm3) for 0-2" depth
- Weight After Drying (grams) for 0-2" depth

1. Observation Date: Enter the date in which soil samples were removed from the ground.
2. Observation Time: Enter the time in which soil samples were removed from the ground.
3. Observation Notes (optional): Enter any relevant comments you wish to include about the condition of your soils, or your soil monitoring experience.
4. Distance from previous sample in meters: Provide the distance between your current soil core site and your previous soil core site to the nearest tenth of a meter. If you are following the SMAP Block Pattern (page seven), and spacing the measurements one foot apart, please enter "0.3." If you are following the Deep Block Pattern (page eight), and spacing the measurements three feet apart, please enter "1.0." If this is your first measurement, please enter a zero in this field.
5. Is the land irrigated? If the plot where your cores were taken is irrigated, check the radio button labeled "Yes." If not, please select "No."
6. Did you begin a new row? Consult the figure above containing the block pattern you are using to take soil cores (see pages seven and eight for details). If you began a new row, select "Yes." If not, select "No." If this is your first measurement, please select "Yes."
7. Soil Type: Enter the soil types you determined for the 0-2" depth, and the 7-9" depth in the boxes of the corresponding rows. If you did not estimate a soil type, or did not take a measurement at the specified depth, please leave this blank.

8. Weight before Drying: Please enter the weight of your soil sample before drying. Make sure the row in which your total is entered is the row designated for the depth of your sample. If you did not take a measurement at the specified depth, please leave this blank.
9. Volume of Rocks and Roots Removed: Please enter the volume of rocks and roots removed from your sample. Make sure the row in which your total is entered is the row designated for the depth of your sample. If you did not take a measurement at the specified depth, please leave this blank.
10. Weight after Drying: Please enter the weight of your soil sample after drying. Make sure the row in which your total is entered is the row designated for the depth of your sample. If you did not take a measurement at the specified depth, please leave this blank.

Reviewing Your Submission:

Soil Moisture Report Edit 						
Station Number	CO-LR-1107		Observation Date	4/11/2017		
Station Name	Fort Collins 4.5 WNW		Observation Time	7:00 AM		
Submitted	4/11/2017 12:02 PM		Is Soil Irrigated	False		
Is Sample Part Of New Row	False		Meters From Previous Sample	0.3		
Depth	Pre-Dry Weight	Dry Weight	Volume Removed (g/cm ³)	Dry Density (g/cm ³)	Volumetric Water Content(%)	Soil Type
0-2"	344	311	11.4	1.29	13.77	Sandy Clay
7-9"	372	356	1.0	1.42	06.40	Sandy Clay Loam
Notes						
				1	2	
It is drier than usual for this time of year. We did receive two tenths of an inch last week, but it was not enough moisture to penetrate to the 7-9" zone.						

After submitting your report you will receive a notification that the report has been saved, and you will have the opportunity to review the entry. If any information does not appear to be correct, please click on "Edit" in the upper right-hand corner to change the submission.

You will notice that two new fields on the report have shown up even though you did not fill them out. Do not be alarmed. The "Dry Density" and "Volumetric Water Content" fields are information that the website calculates based on the information you have provided. Here's what they mean:

1. Dry Density: Your soil's dry density is equal to the mass of the soil and air pocket space once water has been evaporated from the sample. Here's how it is calculated:

$$\text{Dry Density} = \frac{\text{Mass of Dried Sample}}{[\text{Volume of Brass Cylinder} - \text{Volume of Rocks and Roots Removed}]}$$

2. Volumetric Water Content: This number tells us the percentage of your soil sample (in volume) that was actually just water. This number is heavily dependent on soil type, but with enough observations you'll start to get a feel for what range of numbers to expect when soils are wet, and when soils are dry. Here's how it's calculated:

$$\text{Volumetric Water Content} = \frac{[\text{Mass of Water Evaporated}]}{[\text{Volume of Brass Ring} - \text{Volume of Rocks and Roots Removed}]}$$

This number is multiplied by 100 to express it as a percent rather than a ratio.

Measurement Intervals:

Because measuring volumetric water content is much more time-intensive than a precipitation measurement, we do not have a required measurement schedule at this time. Furthermore, it is not recommended that you take soil cores any more frequently than once a week. Measurements are also not recommended when soil freezes, and or when snow cover exists. The value of soil core measurements maximizes during the growing season. Here are several recommendations for measurement schedules you are welcome to try:

1. Synchronize your measurements with NASA's SMAP flyover schedule. Details can be found at http://smap_op.apps.nsidc.org/
2. Take a weekly, biweekly, or even monthly measurement at a time that is most convenient
3. Try measuring soil moisture before a large storm, and for several days following the storm
4. Try more frequent measurements when your area is descending into, or recovering from drought
5. It is not recommended that soil moisture measurements be taken at night. Hours during the middle of the day with intense sunlight should likewise be avoided unless that corresponds to the SMAP flyover schedule. Morning and evening observations are preferred.

Questions or Concerns:

Please direct your questions to info@cocorahs.org, or peter.goble@colostate.edu