Bulk Density Protocol

Purpose

To measure the soil bulk density of each horizon in your soil profile.

Overview

Students obtain a soil sample in the field using a container with a measured volume. The soil is weighed, dried, and weighed again to determine the dry mass and water content of the soil sample. Dry soil samples are then sieved and the mass and volume of the rocks or other material >2 mm in the sample are also measured. Students use the Bulk Density data sheet to calculate the soil bulk density by subtracting the mass and volume of the rocks from the dry mass and volume of the soil sample. The procedure is done three times for each horizon. The dry, sieved soil <2 mm is then stored for additional analyses.

Student Outcomes

Students will learn laboratory techniques to determine bulk density and mathematical formulas to calculate soil particle density. Students will learn about relationships among bulk density, soil particle density and porosity.

Science Concepts

Physical Sciences

Objects have observable properties.

Earth and Space Sciences

Earth materials are solid rocks, water and gases of the atmosphere.

Soils have properties such as color, texture, structure, consistence, density, pH, moisture, and heat that support the growth of many types of plants.

Soils consist of minerals, organic material, air, and water.

Water circulates through soil changing its properties.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct an investigation.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Communicate procedures and explanations.

Time

2-3 50-minute class periods

Level

Middle and Secondary

Frequency

Once for each soil profile

After collecting and preparing the samples, the soil can be used for other analyses at a future time.

Materials and Tools

Balance

Metal sampling cans or other containers (enough for three per horizon) *

Permanent marker

Wood block

Hammer

Nail

Pencil or pen

Trowel, shovel, or other digging device

Bucket or container to carry cans and equipment to and from field

Drying oven

Graduated cylinder

Water

Sieve

Paper to catch sieved soil (paper plate, plain white paper, other…)

Sealable plastic bag to store sample

Bulk Density Data Sheet

**Variations:*

Metal sampling cans, such as those used in the Soil Gravimetric Moisture protocol can be used for bulk density sampling. Containers other than sample cans can also be used to obtain soil samples. These should be thin walled (so as not to compress the soil), and have a known volume. Possible materials may include thin walled pvc pipe or other pipe, or other types of cans (such as those used for tuna fish, cat food, etc...). Do not use glass or other materials that may break or be easily deformed. As long as volume can be calculated for the container, and it can be completely filled with soil, it is acceptable to have both ends open (such as would occur if using a pvc pipe)

Preparation

Collect required equipment.

Calibrate the balance to 0.0 g.

Determine the mass of each can *without the top on* and mark the value clearly somewhere on the bottom part of the can.

Punch a small hole at the bottom of each can using the nail and hammer.

Preheat oven for drying sample.

Prerequisites

Soil Field Characterization Protocol

Bulk Density Introduction

Soil bulk density is a measurement of how tightly packed or dense the soil is. It is determined by measuring the mass of dry soil in a unit of volume (g/mL or Mg/m^3). How dense the soil sample is depends on the structure (shape) of the soil peds, how many spaces (pores) are in the sample, how tightly they are packed, and also the composition of the solid material. Soils made of minerals (sand, silt, and clay) will have a different bulk density than soils made of organic material. In general the bulk density of soils can range from 0.5 g/mL or less in soils with many spaces (such as organic soils), to as high as 2.0 g/mL or greater in very compact horizons.

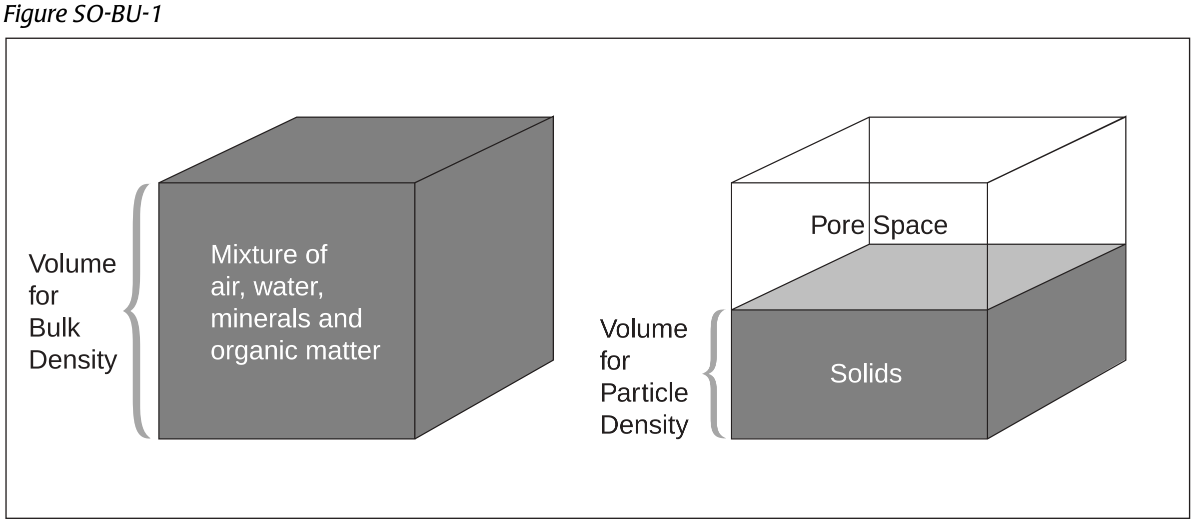
Knowing the bulk density of a soil is important for many reasons. Bulk density indicates how tightly soil particles are packed together and if it will be difficult or easy for roots to grow or shovels to penetrate into and through a soil horizon. Bulk density is also used in converting between mass and volume for a soil sample. If we know the mass of a soil sample, we can calculate its volume by dividing the sample mass by the bulk density of the soil. If we know the volume of a soil sample, we can determine its mass by multiplying the sample volume by the bulk density of the soil.

When we determine bulk density of a soil sample, we are usually interested in the density of the soil material (<2 mm) itself because this is the part of the horizon that is most important in soil processes such as heat, water, and nutrient exchange. We are able to correct for the part of the sample that is made up of rocks (or coarse fragments) by subtracting the calculated density of the rocks from the density of the total sample as is shown in the following equation:

$$\frac{\text{Mass of dry soil (g)}}{\text{Volume of dry soil (mL)}} - \frac{\text{Mass of Rocks (g)}}{\text{Volume of Rocks (mL)}} = \text{Bulk Density (g/mL or Mg/m}^3\text{)}$$

Particle density is similar to bulk density, but it includes only the mass of the solid (mineral and organic) portion of the soil and excludes the spaces where air and water are found. In other words, the particle density of the soil is its mass in a given volume after it has been compressed. (For instructions on calculating particle density, see the *GLOBE Particle Density Protocol*). If we

Figure SO-BU-1



have data for both bulk density and particle density, we can also derive information about the porosity (the proportion of the soil volume that is pore spaces) of a sample. This helps us to determine how much air or water can be stored or moved through the soil, how fast water and heat will be moved through the soil, potential for flooding or drought, and other important soil properties. (For instructions on calculating porosity, see the *Looking at the Data Section* and the GLOBE *Particle Density Protocol)*.

Teacher Support

To calculate bulk density, we measure the mass of a given volume of dry soil, including the air spaces, but excluding materials larger than soil (such as rocks or any material greater than 2.0 mm, which is the upper limit of sand size particles). See description of *Particle Size Distribution* in *Welcome* for the Soil Characterization chapter. A metal can or other container is pushed into the soil to obtain a sample with a specific volume, and then the soil is dried in order to obtain the dry mass of the soil in that volume. After weighing, the dry sample is sieved and rocks or other material greater than 2 mm is separated. The >2 mm material is weighed in order to determine its mass, and its volume is derived by displacement in water.

The can used for sampling must be weighed before bringing it into the field so that its mass can be subtracted from the total mass of the can and soil once it is brought back to the lab and dried. It is important to have a hole at the bottom of the can, or both ends removed, in order to allow air to escape and soil to completely fill the container, as well as to be able to identify when the container has completely filled the volume. A dried sample of soil is used in this protocol to ensure that all measurements are starting at the same moisture content so that they can be easily compared. When the students bring the soil sample back from the field, they measure the moist mass of the soil before drying. Although this information is not used in the bulk density calculation, it is important to determine the moisture content of the soil when it was sampled which will provide additional information for scientists looking at the data.

There are many potential sources of error in this protocol. Taking 3 replicate samples for bulk density for each horizon helps to minimize this error. Some of these errors may occur if the sampling container was not completely filled with soil, if the sampling container was too thick and compressed the soil, if the sampling container became badly deformed during placement in the soil, if the soil was not completely dry, or if the rocks were not completely removed.

Helpful Hints

- Review the bulk density field and lab protocol with your students.
- Discuss what mass and volume are and how they affect density.
- Review different ways to determine the volume of the can.
- Discuss the possible errors that could occur in this measurement such as:
  1. the soil was not completely dry,
  2 the rocks were not completely removed
  3. the sampling can was not completely filled with soil
  4 the sampling container was badly deformed during placement in the soil
  5. other sampling errors
- When performing your soil profile description, look carefully at the color and other properties of the soil to see if there are differences that might affect the bulk density

Questions for Further Investigation

What are the different ways to determine the can volume?

Why do you put a hole in the can?

What happens to the sample if the can is dented?

What human activities could change the bulk density of the soil?

What natural changes could alter the bulk density of a horizon?

How long might it take to alter the bulk density?

How does bulk density affect the types of vegetation that can grow on a soil?

How does bulk density affect the amount of roots in a horizon?

How does soil texture affect the bulk density of a horizon?

How does soil structure affect the bulk density of a horizon?

How would the bulk density value be different if the rocks were not removed from the sample?

Soil Bulk Density
Field and Lab Guide

Task

To obtain three Bulk Density measurements for each of the horizons in the soil profile

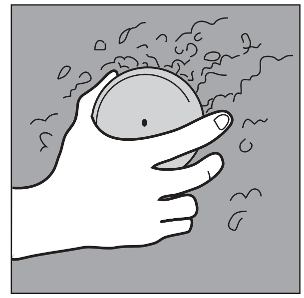
What You Need

- ❑ Balance
- ❑ Sampling cans or other containers (enough for three per horizon plus a few extra, in case some of the cans get bent)
- ❑ Permanent marker
- ❑ Wood block
- ❑ Hammer
- ❑ Nail
- ❑ Pencil or pen
- ❑ Sealable plastic bags, jars, or other containers to store samples and extra soil
- ❑ Drying oven
- ❑ Bucket or container to carry cans and equipment to and from field
- ❑ Graduated cylinder
- ❑ Water
- ❑ #10 Sieve (2 mm mesh openings)
- ❑ Rubber gloves
- ❑ Paper to catch sieved soil (paper plate, plain white paper, other…)
- ❑ Rolling pin, hammer, or other utensil for crushing peds and separating particles
- ❑ Trowel, shovel, or other digging device
- ❑ *Bulk Density Data Sheet*

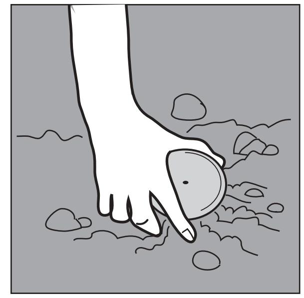
In the Classroom Before Sampling

1. Collect required equipment.
2. Calibrate the balance to 0.0 g.
3. Determine the mass of each can **without the top on** and mark the value clearly somewhere **on the bottom** part of the can.
4. Punch a small hole at the bottom of each can using the nail and hammer.
5. Preheat the oven to 105˚ C for drying the sample when you bring it back from the field.

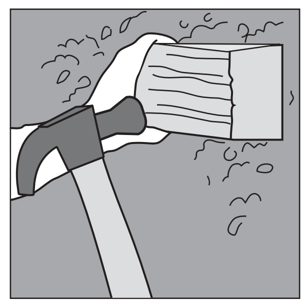
In the Field



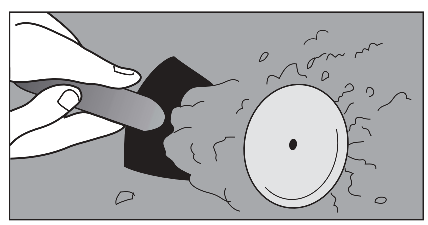
1. Label each sampling container on the bottom part of the container (not the lid) with the site name, sample number, horizon number, top depth, bottom depth, and date The mass of the empty can should already be on the bottom of the container.



2. For each horizon in your soil profile, push a can with a known volume into the side of the horizon. If necessary, wet the soil first so that the can will go in easily. Stop when you can see some of the soil poking through the small hole in the bottom of the can.
   Note: If you do not have a pit or other exposed soil profile you can take the bulk density of the soil surface.
   a. Choose three locations close to where you performed your soil characterization protocol and remove vegetation and other material from the soil surface.
   b. At each location, push a can with a known volume into the surface of the soil. If necessary, wet the soil so that the can will go in easily. Stop when you can see some soil poking through the small hole in the bottom of the can.



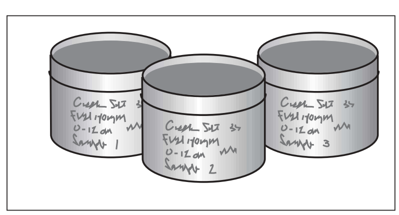
3. If it is difficult to push the can into the soil, place a piece of wood over the can and hit the wood with the hammer. This spreads the force of the hammer blow to all edges of the can at once and minimizes denting the can.
   Note: Dents can change the volume of the can and may compact the soil sample, which could affect the results! If the can becomes very dented, discard it and try to get another sample.



4. Using a trowel or shovel, dig around the can to remove it and the soil surrounding it. Trim the soil from around the can until it is flat against the edges of the can so that the volume of the soil is the same as the volume of the can.

5. Cover the labeled can with the lid or other cover before you take it to the classroom.

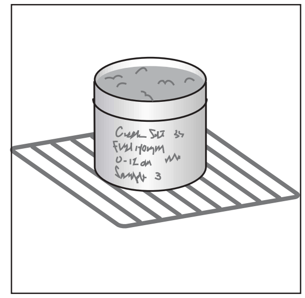
6. Repeat this procedure so that you have three bulk density samples for each horizon in your profile



In the Classroom After Sampling

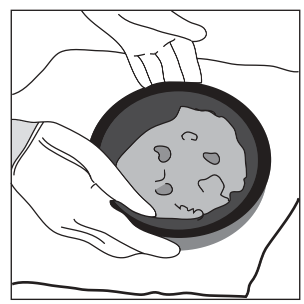
1. Remove the top of the can, weigh each sample in its can, and record this as the moist mass on the *Bulk Density Data Work Sheet.*

2. Place the samples in the soil drying oven until the soils are dry. (See the *Gravimetric Soil Moisture Protocol* for instructions on drying soils)

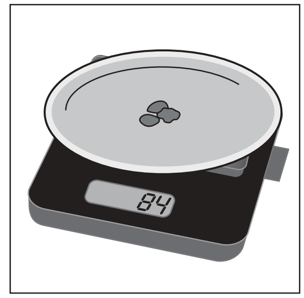


3. Once the soils are dry, weigh each dry bulk density sample in its container and record this as the dry mass on the *Bulk Density Data Work Sheet.*

4. Place a sieve (#10, 2 mm mesh) on a large piece of paper (such as newspaper) and pour one sample into the sieve. Put on rubber gloves to avoid contaminating your sample with acids from your skin.

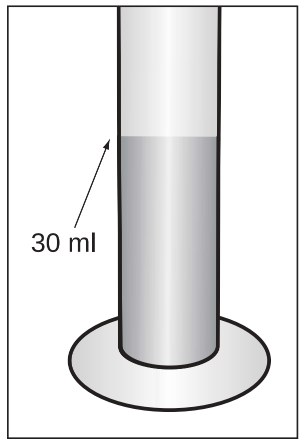


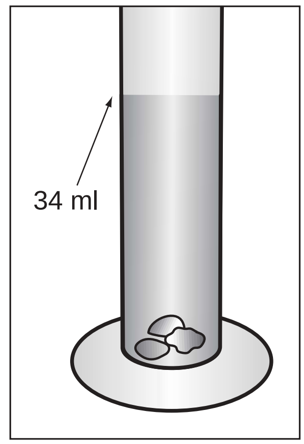
5. Carefully push the dried soil material through the mesh onto the paper. Be careful not to bend the wire mesh by forcing the soil through. Rocks will stay on top of the sieve. (If no sieve is available, carefully remove the rocks by hand.) Save the sieved soil from each sample for the other lab analyses.



6. If rocks are present, use the following procedure to determine the volume of the rocks.
   a. Weigh the rocks that are left on top of the sieve and record this mass on the *Bulk Density Data Work Sheet*.
   b. Place 30 mL of water in a 100 mL graduated cylinder, and gently place the rocks in the water. Read the level of the water after all the rocks have been added and record this value and the original volume of water on the *Bulk Density Data Work Sheet*.

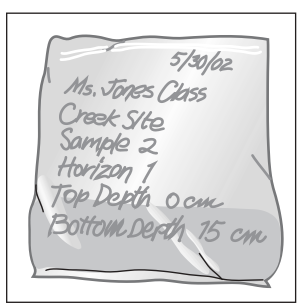
Note: As you add the rocks, if the volume of the water comes close to 100 mL, record the increase in volume, empty the cylinder and repeat the procedure for the remaining rocks. In this case, you must record the sum of the water volumes with the rocks and the sum of the water volumes without the rocks.





7. Transfer the rock-free dry soil from the paper under the sieve into clean dry plastic bags or containers. Seal the containers, and label them the same way that they were labeled in the field (horizon number, top and bottom depth, date, site name, site location, etc.). This soil can now be used for the other lab analyses.

8. Store these samples in a safe, dry place until they are used.



Bulk Density
Data Sheet

(Record all of this information on the GLOBE *Bulk Density Data Entry Page*)

NOTE: All measurements are done without the top of the can!!

Date of sample collection: Year ________ Month ________ Day ________

Site: ________:

Horizon Number: ________, Horizon Depth: Top ________cm, Bottom ________cm

Sample Number 1

A. Container volume: ________ mL

B. Container mass: ________ g

C. Wet mass of sample: ________ g

D. Dry mass of sample: ________ g

E. Mass of rocks: ________ g

F. Volume of water without rocks: ________ mL

G. Volume of water and rocks: ________ mL

Sample Number 2

A. Container volume: ________ mL

B. Container mass: ________ g

C. Wet mass of sample: ________ g

D. Dry mass of sample: ________ g

E. Mass of rocks: ________ g

F. Volume of water without rocks: ________ mL

G. Volume of water and rocks: ________ mL

Sample Number 3

A. Container volume: ________ mL

B. Container mass: ________ g

C. Wet mass of sample: ________ g

D. Dry mass of sample: ________ g

E. Mass of rocks: ________ g

F. Volume of water without rocks: ________ mL

G. Volume of water and rocks: ________ mL

Bulk Density Protocol–Looking at the Data

Are the data reasonable?

Typical bulk density values for soils average around 1.3 g/mL (or Mg/m^3) for mineral particles. However, they can be as high as 2.0 g/mL (Mg/m^3) for very dense horizons, and as low as 0.5 g/mL (Mg/m^3) or lower for highly organic soils.

The bulk density of the soil (corrected for rocks) is calculated using the following equation.

$$\frac{\text{Mass of dry soil (g)}}{\text{Volume of dry soil (mL)}} - \frac{\text{Mass of Rocks (g)}}{\text{Volume of Rocks (mL)}} = \text{Bulk Density (g/mL or Mg/m}^3\text{)}$$

To calculate the bulk density of your soil sample, use the information from the *Soil Bulk Density Data Sheet* to fill in information on the *Soil Bulk Density Calculation Sheet:*

Table SO-BU-1: Soil Bulk Density Calculation Sheet

		Sample Number		
		1	2	3
A	Container volume (mL)			
B	Container mass (g)			
C	Dry mass of soil + can (g)			
D	**Mass of dry soil (g) = C-B**			
E	**Uncorrected Bulk Density (g/mL) = D/A**			
F	Volume of water without rocks (mL)			
G	Volume of water with rocks (mL)			
H	**Volume of rocks (mL) = G-F**			
I	Mass of rocks (g)			
J	**Density of rocks (g/mL) = I/H**			
K	**Corrected Bulk Density g/mL = C-F**			

What were the results of your data?

- If your bulk density was <1.0, it has a very low density and may have a high content of organic matter. In order to identify organic matter, look for a dark color and the presence of roots. Many times, soil horizons on the surface are high in organic matter.

- If your bulk density was near 2.0 or greater, it appears to be a very dense soil. Soils can be dense if they have been compacted and do not have high organic matter content, which is common in surface soils where people are walking or machinery has compressed the soil. Soils with massive or single grained structure will have higher densities than soils with good granular or blocky structure. The texture of the soil can also affect the bulk density. In general, sandy soils have a higher bulk density than clayey or silty soils with good structure.

Note: If the bulk densities of your soil do not seem to be consistent with the other properties of the same horizon (color, structure, texture, depth in the profile, root content), then there may be an error in your measurement. Check your methodology and calculations to see where an error may have occurred.

What do people look for in these data?

Many people use information about soil bulk density, particle density, and porosity. Scientists, Engineers, Farmers and other professionals use bulk density to estimate how tightly packed the soil components are in each horizon.

Calculating Soil Porosity

This technique, as well as an example of student research using porosity data, is explained in the *Looking at the Data* section of the *Particle Density Protocol*.