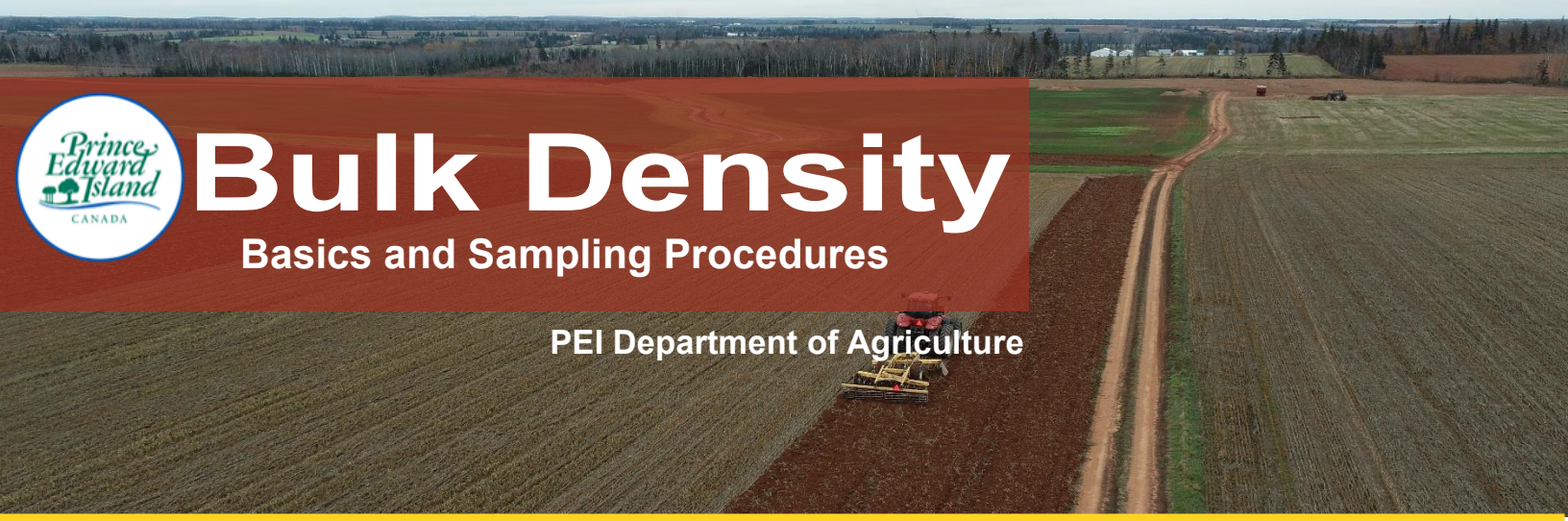

Bulk Density

Basics and Sampling Procedures

PEI Department of Agriculture

Soil Conservation **V1 | July 2025**

Bulk density is defined as the mass of dry soil per given volume. Bulk density is a determinant of soil compaction, soil density, and soil health. A compacted or denser soil has more soil particles in the same volume than a loose soil. Hence, the higher the bulk density value, the greater the soil is compacted or "dense." This means that there is less water and air-filled pore space within the soil, which can lead to limiting factors for plant growth and root movement and growth, as illustrated in Figure 1.

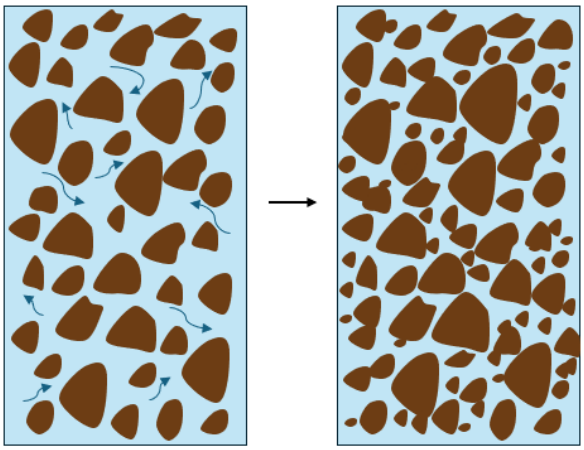

Figure 1. Illustration of loose vs compacted Soil in relation to differences in pore spaces and airflow.

Bulk density is often measured in g/cm^3 (mass/volume). It is calculated by dividing the dry mass of the soil collected by the total volume of the soil collected. In general, loose soils rich in organic matter will have a much lower bulk density and offer better growing conditions for root penetration. Sandy soils often exhibit much higher bulk density due to their reduced total pore space. Typical ranges for sandy soil types (such as those typically found on PEI) range in bulk density from 1.1 to 1.8 g/cm^3 (Table 1). The table below provides a general relationship of ideal bulk density values based on soil texture, highlighting bulk densities that may affect or restrict root growth.

Table 1. General relationship of bulk density to root growth based on soil texture.

Soil texture	Ideal bulk densities (g/cm^3)	Bulk densities that may affect root growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
sands, loamy sands	< 1.60	1.69	>1.80
Sandy loams, loams	< 1.40	1.63	>1.80
Sandy clay loams, loams, clay loams	<1.40	1.60	>1.75
Silts, silt loams	<1.30	1.60	>1.75
Silt loams, silty clay loams	<1.40	1.55	>1.65
Sandy clays, silty clay loams, some clay loams (35–45% clay)	<1.10	1.49	<1.58
Clays (>45% clay)	<1.10	1.39	>1.47

Source: (USDA Natural Resources Conservation Service, Natural Resources Conservation Service, 2008)

Bulk Density Sampling

Bulk density can vary across different locations within a field, both over time and at the smallest spatial scales. In intensively used agricultural fields, these changes can occur extremely rapidly due to

variations in soil moisture levels, organic matter accumulation, and soil composition. Therefore, when assessing bulk density, it is essential to collect samples using recommended density sampling rings and follow prescribed sampling protocols to ensure accurate results.

Bulk Density Sampling Procedure:

1. Gently clear any above-ground plant tissue from the soil surface, avoiding disturbance.
2. Place the ring flush to the soil surface.
3. Using the hammer, gently pound the ring into the soil until its top is level with the field surface. The beveled edge of the ring should be the edge used to penetrate into the soil surface.
4. Dig into the soil beside the ring with a spade or small shovel to easily reach its bottom.
5. Brace the soil within the ring with the spade/shovel while gently removing it. If soil is very dry, ensure no soil is lost during removal.
6. Gently skim excess soil from the top and bottom of the ring, ensuring it's flush with the edges.
7. Place ring covers on both ends and store in a labeled plastic bag.
8. Submit labeled soil sample bags to PEI Analytical Laboratories (PEIAL) for analysis with a completed soil sample submission form (available on the PEIAL website or at the lab reception desk).

Sample Drop off / Sample Kit Pickup location:

PEI Analytical Laboratories (PEIAL)
BioCommons Park,
23 Innovation Way,
Charlottetown, PE C1E 0B7.

Bulk Density Sampling Kit

Bulk density sampling kits are available for loan from the PEIAL. Each kit contains the following tools (Figure 2):

- Sampling ring (7.2 cm in diameter, 7.6 cm in height)
- 2 plastic ring covers
- Plastic soil sample bag

A kit will be required for each sample to be collected. A ring hammer will accompany the sampling kit(s).

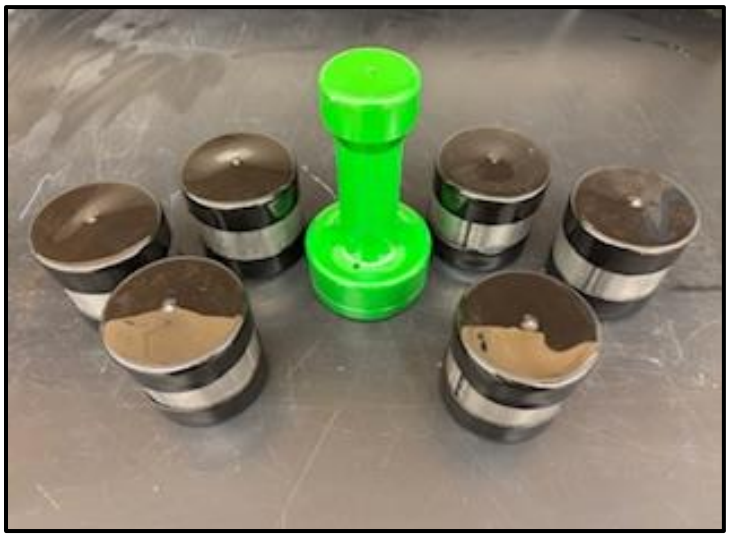

Figure 2. Bulk density sampling kits available for loan at PEIAL.

Other equipment that will be necessary to bring with you while sampling includes:

- A pocketknife
- A spade/small shovel
- A GPS or phone (to point reference soil sample locations)
- Permanent marker for labelling

Other Sampling Considerations

To maximize efficiency, bulk density samples can be collected concurrently with other soil samples (e.g. nutrient and soil health), which often occurs in early or late fall depending on the planted crop. For forage or long-term pasture, samples can be taken anytime throughout the season, provided there is sufficient soil moisture to facilitate sampling. For fields in annual crop production, soil sampling within the same cropping year should occur in early spring (prior to planting) or late fall (post-harvest).

Optimal bulk density sample timing is when soils are sufficiently moist but not fully saturated. Saturated soils will make core sampling more difficult and produce inaccurate results if soils are waterlogged and slick. In contrast, very dry soils also complicate sampling, as the soil may fall out of the core during removal from the ground surface.

When taking core samples, it is extremely important that the soil surface on both the top and bottom of the core is flush with the ends of the sampling rings. Excess soil beyond the ring's edge, or an insufficient amount, will affect the accuracy of the bulk density value by altering the total weight.

Areas within the field that are not representative of the majority should be sampled separately (e.g., field lane ways/compacted areas, tops of knolls/hills, bottoms or edges of fields, wet areas).

The number of sampling points per field is determined by the total field size, management practices, cropping history, and yield potential. A general rule of thumb is to collect a bulk density sample at the same location as each nutrient soil sample. While this can vary, typically a minimum of 1-2 cores per acre would be necessary, with at least 10-15 cores per field location.

The sampling depth for bulk density should be within the crop's immediate root zone. This depth can vary by crop but should be approximately 6-8 inches as a minimum. PEIAL sampling rings are approximately 3 inches in height and can be used twice within the same hole to reach a minimum depth of 6 inches.

Resources:

Dalhousie University. 2024. Bulk density Determination- Core Method (Standard Operating Procedure).

Food and Agriculture Organization of the United Nations. 2023. Standard operating procedure for soil bulk density: Cylinder method. Available online at: https://openknowledge.fao.org/server/api/core/bitstreams/deed7688-a43e-4532-962f-d48768bd61c4/content

M.R. Carter and E. G. Gregorich. 2008. Soil Sampling and Methods of Analysis. Second Edition. Published CRC Press, 1224 pps.

United States Department of Agriculture. 2001. Soil Quality Test Kit Guide. Available online at: https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20Quality%20Test%20Kit%20Guide.pdf

USDA Natural Resources Conservation Service. (2008). Soil quality Indicators: Bulk density. In *United States Department of Agriculture USDA* (pp. 123–141). United States Department of Agriculture, Natural Resources Conservation Service. https://www.nrcs.usda.gov/sites/default/files/2022-10/nrcs142p2_051591.pdf

For more information on collecting bulk density soil samples, please contact:

Sophia Oku- Agronomic Extension Specialist by email to sioku@gov.pe.ca

Kyra Stiles- Nutrient Management Specialist by email to kstiles@gov.pe.ca