Procedures and Protocols for Field Data and Sample Collection

Rapid Carbon Assessment Project

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For questions/clarifications contact:

Skye Wills

402-314-5659

Skye.wills@lin.usda.gov

Ellis Benham

402-437-5132

ellis.benham@lin.usda.gov

National Soil Survey Center

USDA-NRCS

100 Centennial Mall No., Rm. 152

Lincoln, NE 68508

Table of Contents

Section	Page Number
Major Steps in Rapid C Data Collection	**3**
Step #1: Navigate to Rapid C Location	**4**
Step #2: Verify Soil Group and Land Use	**5**
Step #3: Layout Plot	**8**
Step #4: Document Land Cover/Use on the plot	**11**
How to use an Angle Gauge	14
First 4 "in" Trees	15
Use a Clinometer to Determine Tree Height	15
Step #5: Pedon Data and Sample Collection	**18**
Sample collection Decision Rules	19
Bulk Density Method Decision Flow Chart (also a pdf)	20
Bulk Density Methods	21
Step #6: Label, Transport and Store Samples	**23**
Appendix A: Bulk Density Methods	**24**
Appendix B: Sampling Decision Rule Examples	**35**

Major Steps in Rapid C Data Collection

1. Navigate to Rapid C Location
2. Verify Soil Group and Land Use
3. Layout Plot
4. Document Land Cover/Use
5. Pedon Data and Sample Collection (at each point)
    A. Pedon descriptions
    B. Bulk Density Sample
    C. VNIR Sample
6. Transport and Store Samples in Field Office Lab
7. Field Lab Processing and Procedures
    A. Weigh moist sample
    B. VNIR on field moist samples
    C. Dry and process samples
    D. VNIR on air dry samples
    E. Archive center pedon
8. Quality Assurance and Quality Control
    A. Calculate bulk density on a subset of samples
    B. Send flagged samples to NSSC-SSL in Lincoln
9. Data Transfer.

Step #1: Navigate to Rapid C Location

- This sample location has been selected because it falls in a particular soil group and land use/cover (Cropland, Rangeland, Pastureland, Forest land or Wetland).
- The permissions for access to this land should have been confirmed in the planning phase.
- Use maps and GPS to find the general area then navigate to the point with a GPS unit. The level of accuracy is not critical, we expect that you will be within 30m of the actual coordinates. Set your GPS unit to use WGS84 as the datum.
- The sample point can be moved within the same land use and map unit component to avoid unsafe conditions or extreme disturbance (for instance a borrow pit or other new construction).
  - Move the point to the nearest location (within the same delineation or within 100m across delineations) that meets the soil group and land cover/use requirements
  - If the point cannot be reasonably moved, it should be rejected.
  - The sample location can also be rejected through step #2 and #3.

If a location is rejected,

- Someone within the MO will then need to plan to visit another location from that group and land use/cover combination in the future. This should be coordinated with all RCA leads for your MO. When that is accomplished will depend on your schedule and the locations. This is logistically challenging, but important to meeting the overall goals of the project.

Step #2: Verify Soil Group and Land Use

- Identify target land use: The target land use was assigned using a nearby National Resource Inventory (NRI) point. RaCA sites have been assigned for Cropland, CRP, Forest land, Pastureland, Rangeland and Wetland. There are some land uses that can be difficult to distinguish (for example: Pasture land vs. Rangeland or Rangeland vs. Forest land). In these cases, use your best judgment, if the point could conceivably be described as the target (see precise definitions below), accept it. If you accept the point, be certain to include all the vegetation as it exists on the plot (for example, describe both grass and tree species on a cedar/juniper invaded rangeland).

  The following terms were taken from the 2007 NRI Glossary of Key Terms (http://www.nrcs.usda.gov/technical/NRI/2007/glossary.html)

  Land cover/use. A term that includes categories of land cover and categories of land use. Land cover is the vegetation or other kind of material that covers the land surface. Land use is the purpose of human activity on the land; it is usually, but not always, related to land cover. The NRI uses the term land cover/use to identify categories that account for all the surface area of the United States.

  Cropland. A *Land cover/use* category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland comprises land in row crops or close-grown crops and also other cultivated cropland, for example, hay land or pastureland that is in a rotation with row or close-grown crops. Noncultivated cropland includes permanent hay land and horticultural cropland.

  Conservation Reserve Program (CRP) land. A *Land cover/use* category that includes land under a CRP contract. [***Conservation Reserve Program (CRP).*** A federal program established under the Food Security Act of 1985 to assist private landowners to convert highly Erodible cropland to vegetative cover for 10 years.]

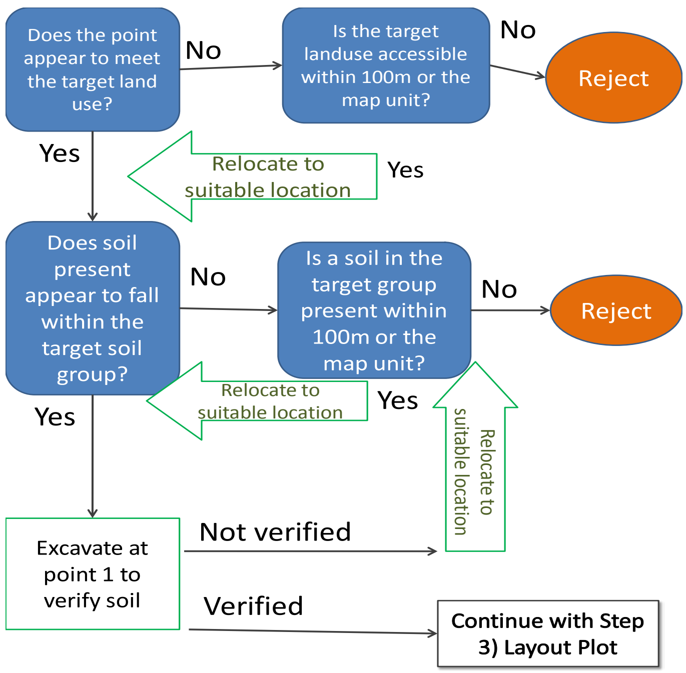
  Forest land. A *Land cover/use* category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cut over forest or abandoned farmland) and not currently developed for no forest use. Ten percent stocked, when viewed from a vertical direction, equates to an areal canopy cover of leaves and branches of 25 percent or greater. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide.

Pastureland. A *Land cover/use* category of land managed primarily for the production of introduced forage plants for livestock grazing. Pastureland cover may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments: fertilization, weed control, reseeding or renovation, and control of grazing. For the NRI, includes land that has a vegetative cover of grasses, legumes, and/or forbs, regardless of whether or not it is being grazed by livestock.

Rangeland. A *Land cover/use* category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.

Wetlands. Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. (Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. U.S. Department of the Interior, Fish and Wildlife Service.)

- Identify target soil group: series (components)
    - Assess visually
    - Confirm with excavation (if you cannot reject the target soil through your excavation and sampling, accept it)
- Use decision tree to either accept or reject the point



- If the point is rejected, move the point to the nearest location (within the same delineation or within 250m across delineations) that meets the soil group and land cover/use requirements
- If the correct component/group cannot be found, then you can sample the dominant component in that 250m radius area. Be sure to record the actual soil series believed to be present, but do not update the site ID.
- If sampling is not possible, and no replacement points are reasonable follow the guidelines in: RaCA Guidance Bulletin_Alter Site location.docx on the Rapic Carbon Sharepoint site.

Step #3: Layout Plot

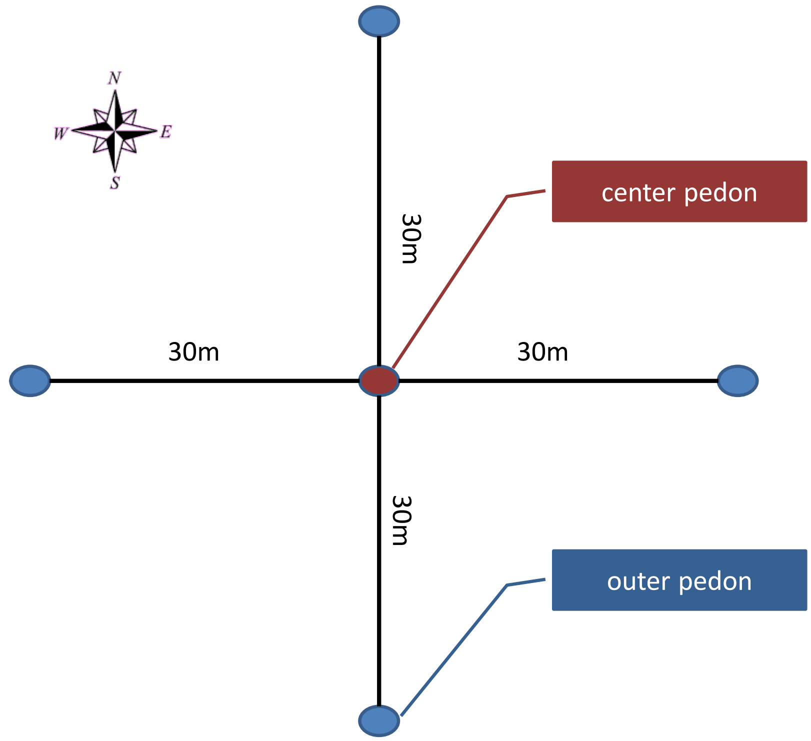
- Rapid C Assessment Sampling occurs in a nested or clustered design.
- A center point/pedon is a located at the Rapid C Site Location
- Outer points/pedons are clustered around the central pedon according to the following procedure. Their location is recorded as azimuth and distance from the center point.

Procedure for locating pedons

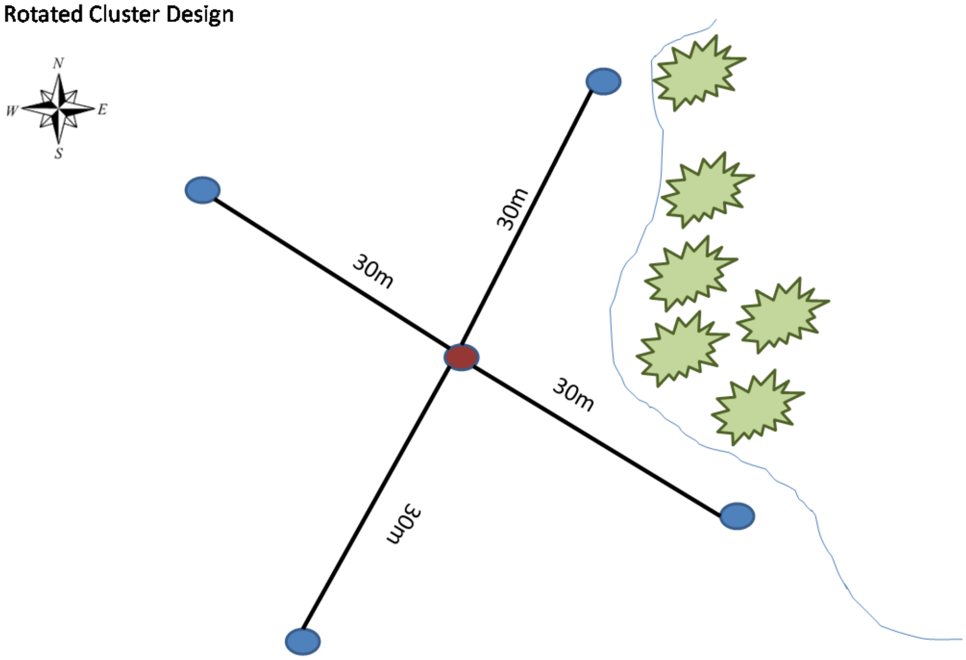
- This procedure assumes that the center point (pedon) has been located and the soil group and land use have been confirmed.
- Determine whether a standard or modified cluster will be necessary by asking:
  - What is the minimum distance from the center point to soils that would fall in another group, an alternate land cover or use, or access impediments (such as a property line)?
    - Min > 30m: use standard cluster
    - Min < 30m: Assess the direction of suitable locations
  - On what portion of a 360^{o} circle radiation from the center point do these restrictions occur?
    - < 25%: use standard cluster distance and rotate directions (Rotated Cluster Design)
    - > 25 %: move central pedon towards the center of the polygon
      - Use original pedon as outer pedon (Shifted Cluster Design)
      - If this fails use chain or other design (Chain Design)
      - If 5 suitable points cannot be located at the current location – **REJECT the location.**
- If a point is rejected after excavation, it can be moved 1 – 10m in any direction to avoid resetting the entire plot. Record the new azimuth and distance from the center point.

NOTE: Outer pedons are acceptable under three circumstances: 1) the target soil is present, 2) a similar (to the center pedon) soil is present or 3) another soil in the target group is present. Use your best judgment to determine if a pedon meets one of these criteria.

Standard Cluster Design



Rotated Cluster Design

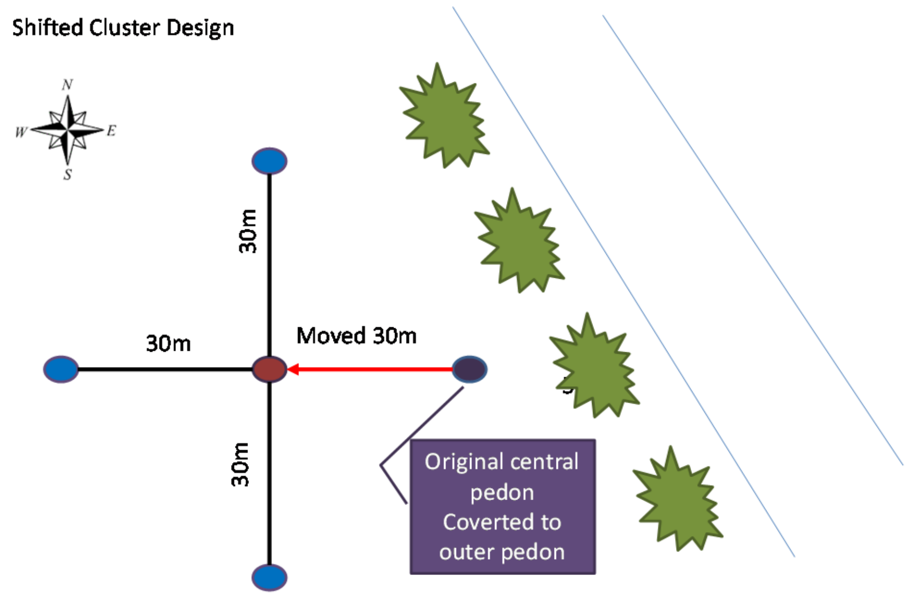


After a layout is Determined

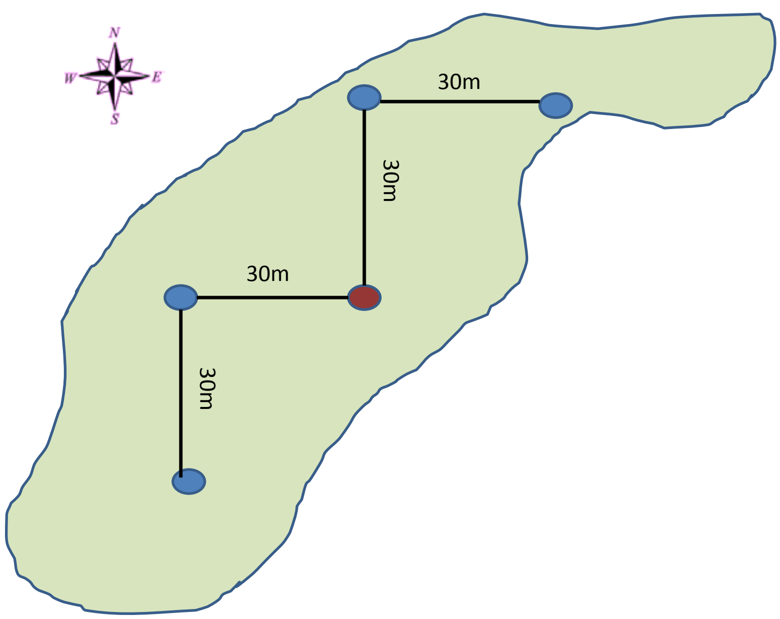
- Record type of plot
- Record location of center pedon
- Flag and record location of outer pedons (azimuth and distance to center point).

Count exposed soil at 25 meter marks along tape as its being laid out (record in Step #4)

Shifted Cluster Design



Chain Cluster Design – version 1



Step #4: Document Land Cover/Use on the plot

Photograph the plot from various angles

- At a minimum:
  - Straight down over point 1, out towards each outer point
  - Any vegetation that needs to be identified
    - A broad photo depicting the role the plant plays in the community (growth form, etc.)
    - A close-up of the flower or seedhead
    - A close-up of the leaves
    - Specifically for Trees – trunk bark and leaves (including attachment to branch)
- Keep notes about photo files and/or use a repeated pattern
- Label files with standard format
  - CxxyyLzzPatnn.jpg
  - Where:
    - CxxyyLzz = RaCA site ID
      - xx = MO number
      - yy = statistical group # for MO
      - L = land use
      - zz = Plot # within the group
    - P = a constant, indicating the file is a photograph
    - a = Pedon # within plot
    - t = type: d = down, n = north, e = east, s = south, w = west, v = vegetation, u = undefined
    - nn = number (multiple images)

Record Data on plot form:

- **User Site ID:** Use local convention OR repeat the RaCA site ID
- **Plot layout**: determined in step #3
- **Soil Group ID**: record target soil group (provided/attached to x,y point)
- **Soil Survey Office**
- **RaCA site ID:** record ID of x,y for the center point of of site/plot
- **Offset azimuth:** if center point is moved, record the direction moved
- **Offset distance:** if center point is moved, record the distance (best approximation, may be paced or determined from map if greater than 50 m)
- **Latitude and Longitude:** Use GPS to record lat/long at the final location of point 1
- **Ecological Site Name and ID** – correlated to soil component
- **State Phase Name and ID –** determined using ecological site description

- **Community Phase Name and ID** – use ecological site description to determine; record whatever level of information is available or you're comfortable identifying
- **Land Cover** : does not necessarily match land use; use best match from selected options from Earth_Cover_Kind_Level_One in NASIS. Only a subset of the allowable choices in NASIS are used here. Here are some definitions that may be helpful.
  - Earth_Cover_Kind_Level_One - The natural or artificial material that is observed to cover a portion of the earth's surface. It is determined (at least conceptually) as a vertical projection downward. Level one of a hierarchical system. (1992 NRI Instructions)
  - Crop cover - The full cycle, including land preparation and post-harvest residue cover of annual or perennial herbaceous plants that are cultivated or harvested, or both, for the production of food, feed, oil, and fiber other than wood, and excluding hay and pasture.
  - Grass/herbaceous cover - Non-woody vegetative cover composed of annual or perennial grasses, grass-like plants (sedges/rushes), forbs (including alfalfa and clovers), lichens, mosses, and ferns (>75% grass, grass-like, forb cover).
  - Shrub cover - Vegetative cover composed of multi-stemmed and single-stemmed woody plants that attain a mature height of less than four meters (>50% shrub canopy cover).
  - Tree cover - Vegetative cover recognized as woody plants which usually have one perennial stem, a definitely formed crown of foliage, and a mature height of at least four meters (including ornamentals and Christmas trees), (>25% tree canopy cover).

% Exposed Soils: This is related to erodibility; the idea is to capture the amount of surface that is susceptible to soil erosion

- As you are laying your outer points:
  1. Walk the length of the tape
  2. At each meter mark from 5m to 30m note if soil surface is covered by live vegetation, dead vegetation or rock and count all points with exposed soil surface (bare)
  3. Sum the number of points that are bare along tape to each outer point
  4. Sum the 4 exposed (bare) soil counts to get an average % bare ground.

- **Drained?:** is the site artificially drained: Yes or No

- **Distance to disturbance:** record the distance to any acute disturbance that might impact the distribution of soil carbon on the plot (water trough, trail etc.)
- **Disturbance type:** describe the disturbance from the previous entry (you're encouraged to use a common terminology within your MO that will allow later retrieval of results by common disturbance types. There is limited space on the form and in the database. Please limit the description to less than 50 characters.

<u>Forested</u>

- **Plantation:** is the forest planted (plantation) answer: yes/no,
  - If yes, is it **bedded** (surface topology altered by mounding): yes/no
  - **stage** (how far through the typical time of stand rotation; not necessarily maturity or size): early (0 – 25%); mid, 26 – 75%; late, 76 – 100%

Dominant Species Information: List the dominant species (up to 6 by % composition or presence)

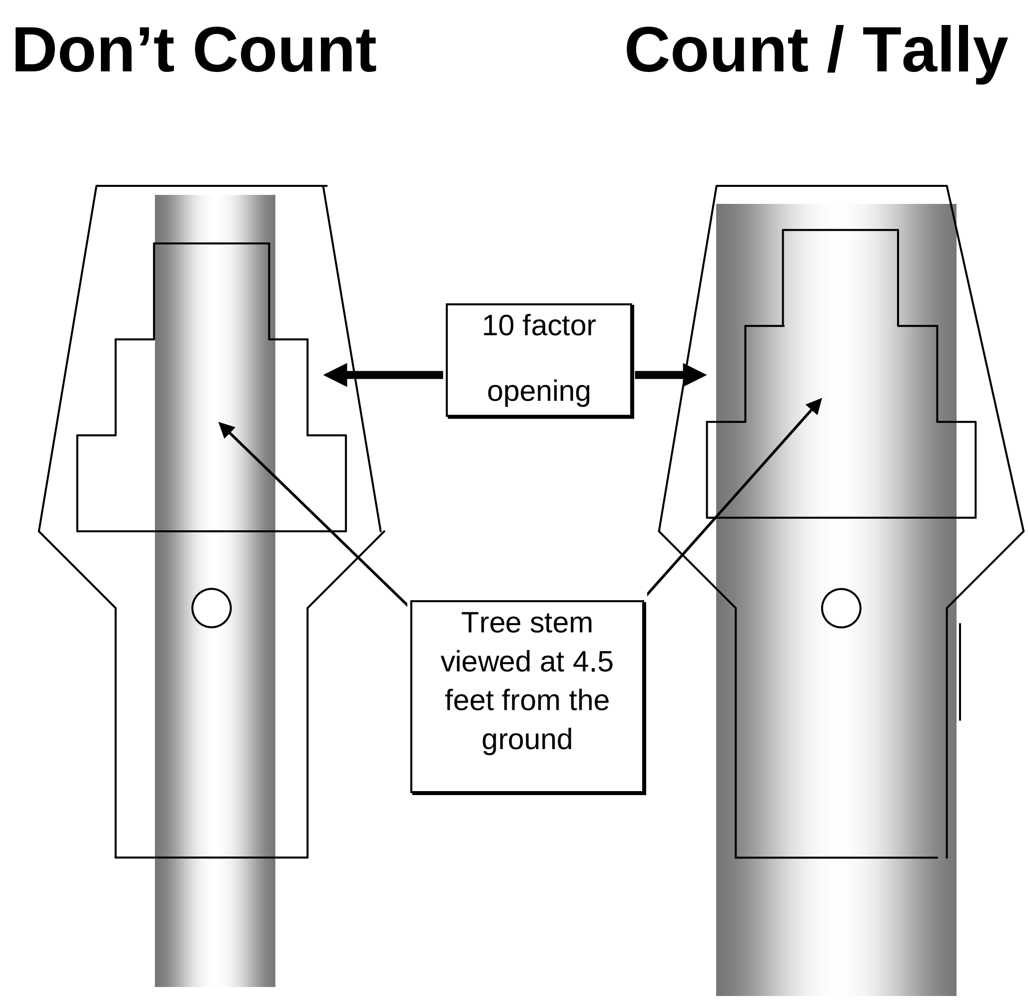
- **Canopy position**: overstory or understory
  - Trees – overstory – branches are part of the top canopy
  - Grasses, forbs, shrubs are not considered part of the canopy
- **National Plant Symbol:** This can be entered later when you have access to the NRCS plant database
- **Local plant name:** include common name, or scientific name if known
- **Order of Dominance**: rank species from most (1) to least (6) common by total weight. This does not need to be precise, just a general approximation of what's on the plot

Basal Area Information: Use Angle Gauge (specific instructions on next page) or prism to record the number of trees counted or tallied in a variable plot

First 4 "IN" trees: Begin counting looking north and turning clockwise. For the first 4 trees that are tallied or counted as "in", record diameter at breast height (DBH) and Height (specific instructions on following pages)

How to Use an Angle Gauge (CRUZ-ALL)

Locate your plot point and mark with a flag or stick. Using an angle gauge, site on live trees (no shrubs) 4 1/2 feet above the ground that are at least 4 inches in diameter. **Distance of the tree from the plot center does not matter.** Begin facing N. Straddle the marked point and rotate the angle gauge 360 degrees (NOTE: this procedure differs from that used to tally trees with a prism). The angle gauge should be kept at a proper distance (25 inches) from the eye when making inventory determinations. As you turn, record each tree that completely fills or more than fills the 10-factor opening of the gauge. See examples below.



First 4 Trees

- These measurements are recorded for the first four trees tallied or counted as "in" using the angle gauge or prism

DBH – Diameter at Breast Height (Diameter in inches at 4.5 ft)

There are three ways that you can measure DBH.

Option 1) Use a tape with diameter inches to measure around the tree at breast height (4.5ft. above the ground), record as DBH.

Option 2) Use a tape with inches to measure the circumference around the tree at 4.5 ft. above the ground. Calculate diameter from circumference: DBH = circumference / 3.14

Option 3) Use a "Biltmore" stick to determine diameter at breast height (DBF)

- Observe the tree at 4.5ft.
- Keeping the stick 25 in from your eye and within your line of sight, line up the stick so that zero begins on the edge of the tree trunk
- Read the outer measurement for the other edge of the tree trunk

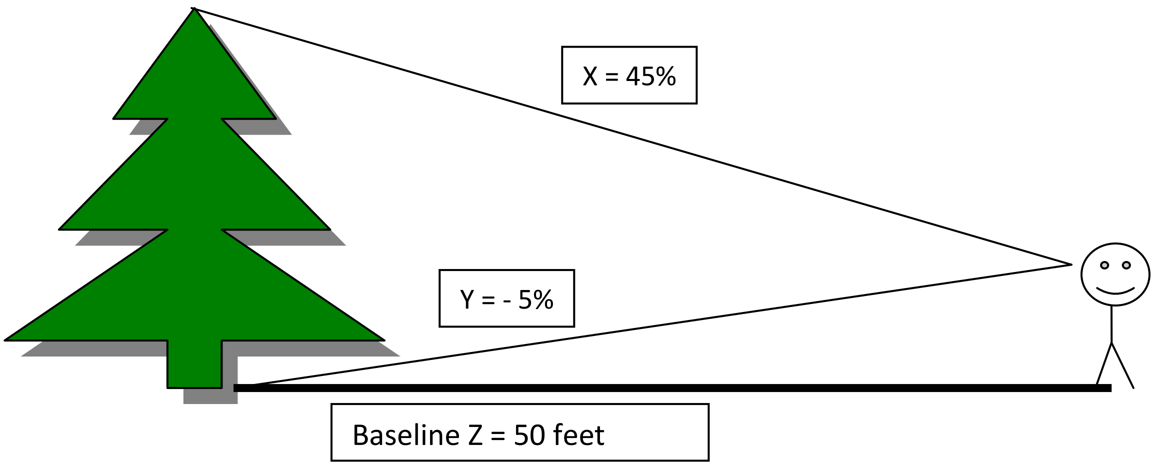
-

Use a Clinometer to Determine Tree Height (recorded in feet)

1. Walk away from the base of the tree a known distance (pace or measure)
2. Use % scale measurement on the clinometer; note the reading at the top (uppermost) and base (bottommost) portion of the tree.
3. Calculate the height:
    a. If the bottom number is negative:
        i. Add the absolutes
           height = (top%/100 + bottom%/100) * distance
    b. If the bottom number is positive
        i. Subtract the bottom
           Height = (top% /100 - bottom%/100) * distance
4. Rules of thumb:
    a. If you are 50 feet from the tree
        i. Divide by 2: (Top% - Bottom%) / 2
    b. If you are 100 feet from the tree
        i. Just subtract the % readings: Top%-Bottom%

Level Ground

- Back away from the tree until you can see both the base and top of the tree
    - o Z this is called the baseline
    - o (50 feet is typical, this can be paced or measured)
- Sight the top of the tree and read the % scale (X%)
- Sight the bottom of the tree and read the % scale (Y%)
- Add the bottom reading from the top (use absolute values) and multiply by the baseline distance
    - o ((X%+Y%)/100)*(baseline distance) *(At 50 ft simply divide the sum of the sightings by 2)*
    - o ((45% + 5%)/100)*50 = 25 feet tall

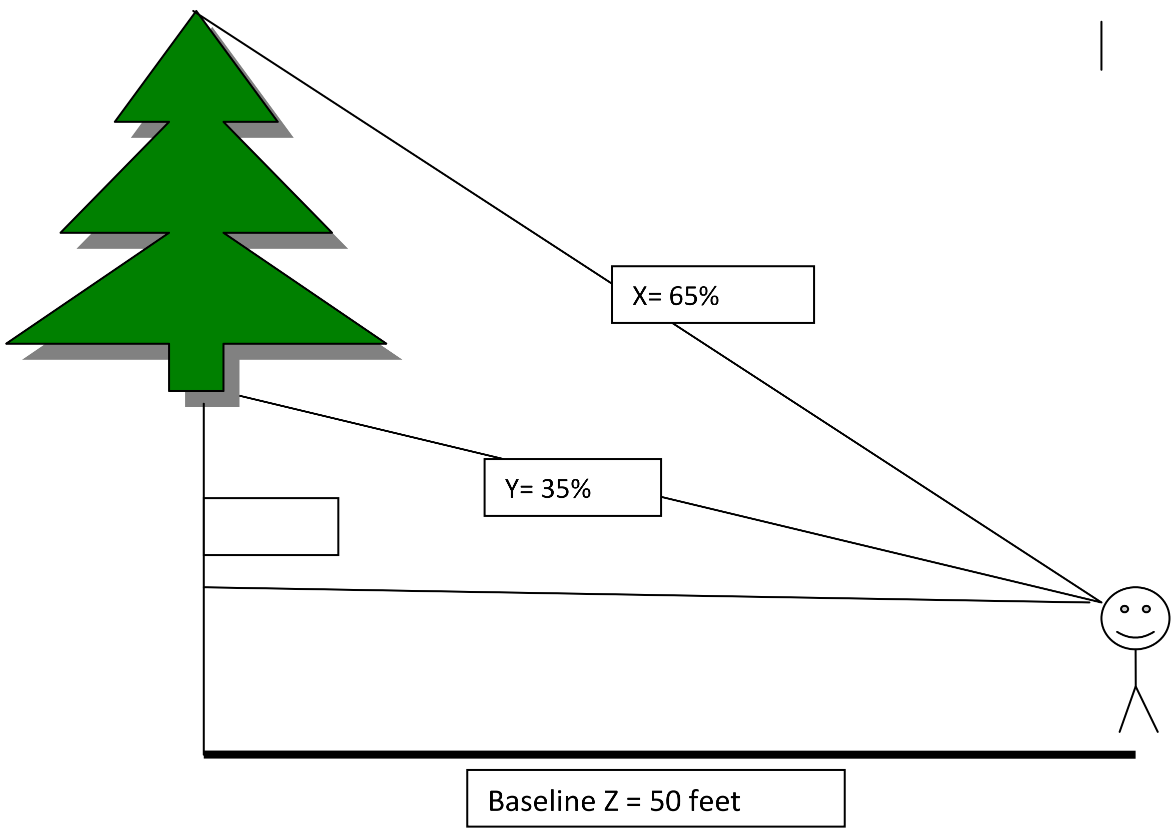


Clinometer Height Measurement

Sloping ground

Move to a distance where you can see both the bottom and top of the tree

When eye level is below the tree



- Sight the top of the tree (X%)
- Sight the bottom of the tree (Y%)
- Subtract the bottom reading from the top (use absolute values) and multiply by the baseline distance
    - (X%-Y%)/100 *(baseline distance) *(At 50 ft simply divide the sum of the sightings by 2)*
    - ((65% - 35%)/100)*50 = 15 feet tall

Step #5: Pedon Data and Sample Collection __________

Pedon Descriptions: All pedon descriptions will be uploaded to NASIS from Pedon PC (can use form in the field http://soils.usda.gov/technical/forms/BASICPEDNFRM4.XLS)

******Consider the special sampling instructions for mineral surface horizons. Describe layers that will be sampled separately, 0 – 5 cm, as a separate horizon**

> **For the center pedon**: Use the linked form or Pedon PC to do a description to the depth necessary to ID the soil. Data can be entered in Pedon PC in the office
>
> **For the outer pedons:** Use an abbreviated form with the minimum data (horizon nomenclature, depths, color, texture, redox features, structure – where possible), the standard form, or Pedon PC to do descriptions to the depth necessary sample the soil (1m or a restrictive layer). Data can be entered in pedon PC and NASIS in the office.

General Sampling Guidelines:

A. Dig a pit to 50 cm or to the depth of a restrictive layer, whichever is less. Use probe, hydraulic probe or auger to sample from 50 – 100 cm. Note the name of the soil identified on the bulk density form “Soil name as sampled”.
B. Up to the top 5 cm of the mineral soil will be described and sampled as a layer: all other samples will be collected by genetic horizons.
C. Determine bulk density sampling procedure using decision rules and flow chart for all horizons within 50 cm – collect sample for Db and carbon
D. For horizons from 50 – 100 cm, collect sample for carbon only, can be done with auger or probe.
E. Collect samples, carefully labeling bag with the rapid carbon site number, the point/pedon number and the horizon nomenclature and depths.

Sampling decision rules for Bulk Density (Db) and Soil Carbon

All horizons will have a representative sample collected for carbon (either the horizon itself or as part of a similar adjacent horizon). In horizons sampled for Db, that sample will be used later for carbon determination (you only need 1 sample per horizon). For the horizons that cannot be sampled for Db, their Db will be estimated from an adjacent horizon or a pedotransfer function. Shallow horizons can be sampled separately when the soil scientist deems it necessary for an accurate measurement of soil carbon stocks.

Sample Collection Decision Rules*

Use Db Methods Flow Chart to Determine Appropriate Db Sampling Method

<u>For Soils with < 50 cm of O material</u>

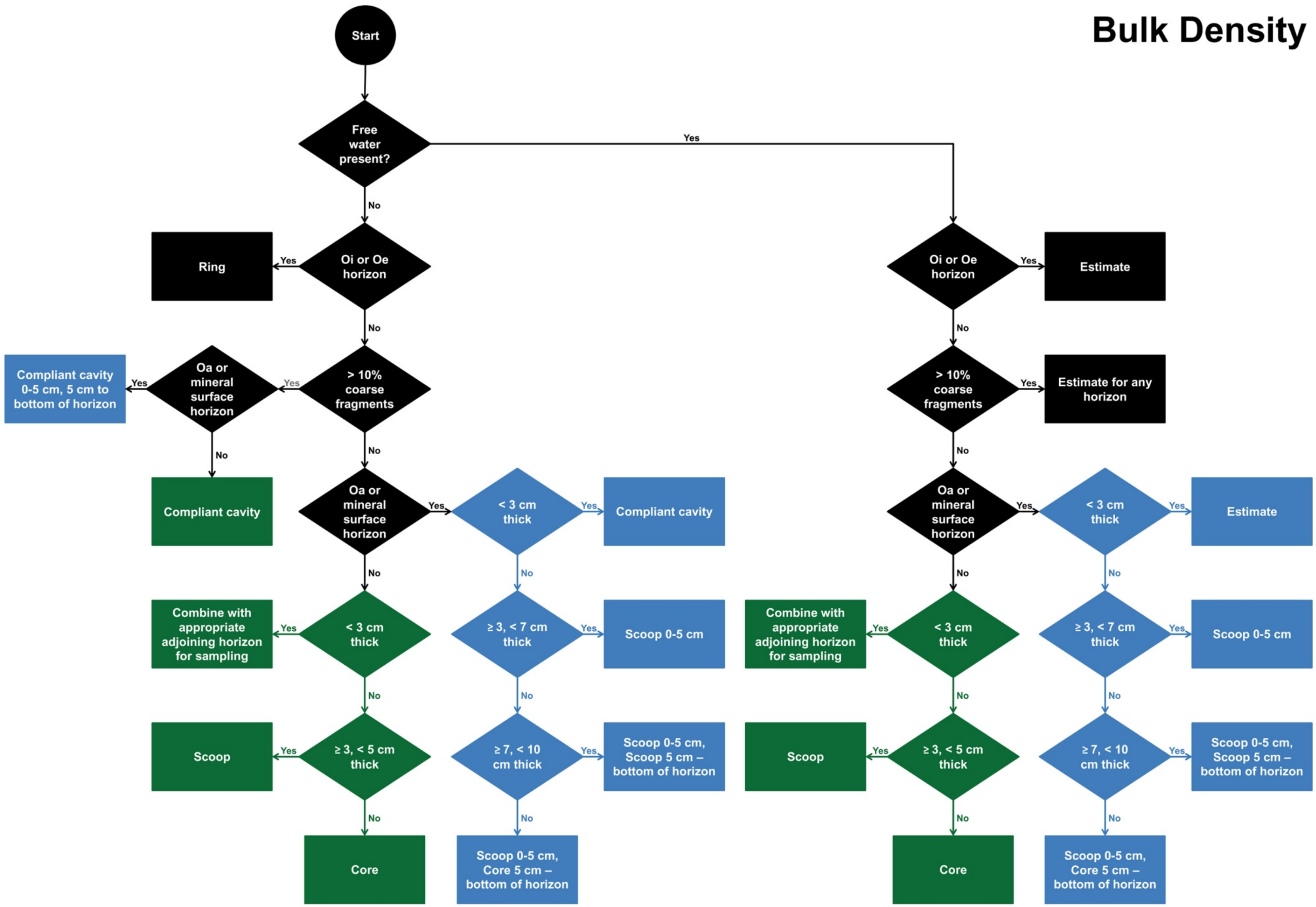
1. **O horizons above mineral material**
    a. Collect samples for Db and VNIR from surface to top of mineral material or 50 cm (whichever is shallowest) by genetic horizon
2. **Horizons at mineral surface** (upper most mineral horizon – could be at 0 cm or just below an O horizon). Choose one of the following options to sample for Db and VNIR:
    a. <u>Mineral surface horizon <3 cm thick</u>
        i. Collect sample of surface horizon **.**
        ii. Collect sample from bottom of surface horizon to 5 cm
    b. <u>Mineral surface horizon 3 – 5 cm thick</u>
        i. Collect sample of surface horizon
        ii. Collect sample from bottom of surface horizon by genetic horizon (no artificial break at 5 cm)
    c. <u>Mineral surface horizon 6- 7 cm thick</u>
        i. Collect sample of upper 5 cm of horizon (for example, 0 – 5 cm)
        ii. Do not sample bottom 1 or 2 cm of horizon (for example, 6 -7) the Db and VNIR of the upper 5cm will be applied to the entire horizon
    d. <u>Mineral surface horizon >7 cm thick</u>
        i. Collect sample from the upper 5 cm as a separate layer (for example, 0 - 5 cm
        ii. Collect sample from 5 cm to the bottom of the surface horizon(fore example, 5 – 8 cm)

3. **Other Mineral horizons entirely above 50 cm:**
    a. Collect samples by genetic horizon for Db and VNIR
4. **For horizons that occur at 50 cm (choose one):**
    a. Collect one sample for entire horizon for bulk density and VNIR (for example, in a horizon at depths 43 – 61cm -- collect one sample for Db and VNIR)

    or

    b. Split horizon at 50 cm and collect Db for upper portion (for example, 43 – 50cm sampled for Db and VNIR, 50 – 61 cm sampled for VNIR only)
5. **For horizons that occur entirely below 50 cm:**
    a. Collect samples by genetic horizon for VNIR only

***see Appendix B for Sample Decision Rules Examples**


Bulk Density
Start
Free water present?
Yes
No
Oi or Oe horizon
Yes
Ring
No
> 10% coarse fragments
Yes
Oa or mineral surface horizon
Yes
Compliant cavity 0-5 cm, 5 cm to bottom of horizon
No
Compliant cavity
No
Oa or mineral surface horizon
Yes
< 3 cm thick
Yes
Compliant cavity
No
≥ 3, < 7 cm thick
Yes
Scoop 0-5 cm
No
≥ 7, < 10 cm thick
Yes
Scoop 0-5 cm, Scoop 5 cm – bottom of horizon
No
Scoop 0-5 cm, Core 5 cm – bottom of horizon
No
< 3 cm thick
Yes
Combine with appropriate adjoining horizon for sampling
No
≥ 3, < 5 cm thick
Yes
Scoop
No
Core
Oi or Oe horizon
Yes
Estimate
No
> 10% coarse fragments
Yes
Estimate for any horizon
No
Oa or mineral surface horizon
Yes
< 3 cm thick
Yes
Estimate
No
≥ 3, < 7 cm thick
Yes
Scoop 0-5 cm
No
≥ 7, < 10 cm thick
Yes
Scoop 0-5 cm, Scoop 5 cm – bottom of horizon
No
Scoop 0-5 cm, Core 5 cm – bottom of horizon
No
< 3 cm thick
Yes
Combine with appropriate adjoining horizon for sampling
No
≥ 3, < 5 cm thick
Yes
Scoop
No
Core

Bulk Density (Db) Data and Sample Collection (choose method with flow-chart, page 18)

1. As Samples are collected fill out the "Bulk Density Information" form (field names are underlined)
    a. Record horizon designation and the upper and lower boundary for the horizon from which the sample was taken (the entire horizon may not have been sampled, but the results will be applied to the entire horizon)
    b. Record Bulk Density Method Used
    c. Record Information in the appropriate spaces for the method used

Bulk Density Methods (see Appendix A for full Db procedures)

2. **Soil Scoop**
    a. For Horizons 5 cm thick
        i. Line up the top of the scoop with the horizon surface
        ii. Prepare pit face so that there is flat wall and surface.
        iii. Insert into side of pit wall until back is flush with pit face
        iv. Cut vertically in front of scoop edge then remove scoop
        v. Trim material extending over the edge of the scoop (use angle to trim to avoid disrupting the sample)
        vi. Record <u>Variable Volume Core / Scoop 1st depth – 4th depth</u> as 0.
    b. For Horizons <5 cm thick
        i. Line up the bottom of the scoop with the bottom of the horizon
        ii. Prepare pit face so that there is flat wall and surface.
        iii. Insert into side of pit wall until back is flush with pit face
        iv. Cut vertically in front of scoop edge then remove scoop
        v. Trim material extending over the edge of the scoop (use angle to trim to avoid disrupting the sample)
        vi. Measure the distance from the top of the scoop to the top of the sampled soil in 4 representative places
        vii. Record as : <u>Variable Volume Core / Scoop 1st – 4th depth</u>

3. **Compliant Cavity**
    a. Place foam donut on ground and cover with rigid ring (130 mm inside diameter). Mount the assembly on the soil surface by securely driving threaded rods (being careful not to damage the threads) into the ground through holes in ring and by tightening ring with wing nuts.
    b. Line cavity with ½ mil plastic. Fill cavity to the upper surface of the rigid ring with millet. Strike off excess millet with a straight edge and return excess to storage container.
    c. Remove plastic film and millet. Measure the volume of millet in the graduated cylinder. This volume (Vd) is the measurement of cavity

volume prior to excavation (dead space). Record this as Initial Vol on the form to the nearest 5 ml.

d. Excavate soil from inside the cylindrical form to required depth, place in a labeled bag, and seal. Line the cavity with ½ mil plastic film. Fill the cavity with millet to the top of the rigid ring. Strike off excess millet. Measure the volume of millet. This is the Final Vol on the form to the nearest 5 ml.

*The volume is the measurement of excavated soil and dead space. The difference between the two millet volumes (Final Vol – Initial Vol) is the volume of excavated soil.

4. Ring Excavation

a. Place a 25.4 cm diameter plastic ring on the soil surface.
b. Drive three sharpened rods into the soil, equally spaced around the outside of the ring. Drive the rods at a distance from the ring such that the washers under the wing nuts on the pins just touch the top surface of the ring. Press the ring down lightly, and tighten the wing nuts enough to prevent the ring from shifting.
c. Line the ring with the ½ mil plastic, fill with millet, and strike off the excess above the upper surface of the ring. Pour the millet in the ring into the graduated cylinder and measure its volume. You may have more than one cylinder full. Record the total millet volume as Initial Vol to the nearest 5 ml.
d. Excavate soil to the desired depth. Place the soil in a labeled bag and seal it.
e. Line the ring with the ½ mil plastic, fill with millet, and strike off the excess above the upper surface of the ring. Pour the millet in the ring into the graduated cylinder and measure its volume. You may have more than one cylinder full. Record the total millet volume as Final Vol to the nearest 5 ml.

5. Soil Cores

a. Variable volume core (VVC) refers to a partially filled core, the volume of the sample will vary depending on the sample. Constant volume core (CVC) refers to a core that is completely filled and will have the same volume of sample every time it is filled.
b. Record core length (VVC Len) and diameter (VVC Diam), to the nearest tenth of a cm (one decimal place), above point one on the Bulk Density Information Form. The measurements should be checked periodically, after maintenance (edge sharpening) or at any time damage occurs to the core.
c. Prepare flat surface, either horizontal or vertical, at required depth in sampling pit.

d. Press or drive core sampler into soil. If a hammer is required, place a wood block on top of the core tube before striking it. Strike squarely on wood block.
e. Remove the core from the soil by digging out beside it and cutting the soil in front of the core cutting edge so excess soil in front of the core is still attached.
f. Trim protruding soil flush with ends of cylinder.
g. If the core is full, Record the diameter and length under "CVC / hydraulic probe"
h. If the core is not full, place a straight edge across the top of the core and measure and record the depth from the straight edge to the soil surface in four representative locations Variable Volume Core / Scoop 1st depth – 4th depth to the nearest tenth of a cm.
i. Place the entire soil sample in a labeled bag and seal air-tight.
    i. Minimum Label:
        1. RCA Pedon ID (RCA Site ID – pedon number)
        2. Layer/sample Sequence
        3. Horizon Designation
        4. Horizon/Layer Depths

    For example, the surface sample (Ap) from the first point/pedon of site C0101C01 should have the following on the label:

    C0101C01 – 1
    1
    Ap
    0 – 5 cm

Step # 6: Label, Transport and Store Samples in Field Office Lab

Place the entire soil sample in a labeled bag and seal air-tight.

Minimum Label:
1. RCA Pedon ID (RCA Site ID – pedon number)
2. Layer/sample Sequence
3. Horizon Designation
4. Horizon/Layer Depths

For example, the surface sample (Ap) from the first point/pedon of site C0101C01 should have the following on the label:

C0101C01 – 1
1
Ap
0 – 5 cm

This step will be carried out according to the logistical constraints of each MO and field office lab. The goal is to store samples at the field moisture content (as sampled) until they can be weighed. The total soil weight will be used to determine bulk density and field moisture content is important for interpreting those results.

Appendix A: Bulk Density (Db) Methods

Soil Scoop

Modified for Rapid Carbon Assessment

Application

Bulk density by the scoop method offers the opportunity to obtain bulk density information without the expense incurred to obtain water retention. The sides of the scoop can be used as a gauge for collecting a standard 0-5 cm surface sample for bulk density. Field-state bulk density by the scoop method is particularly useful if the soil layers are at or above field capacity and/or the soils have low extensibility (shrink-swell) and do not exhibit desiccation cracks even if below field capacity.

Summary of Method

A metal scoop is pressed or driven into the soil. The scoop is removed, extracting a sample of known volume. The moist sample weight is recorded. The sample is then dried in an oven and weighed.

Interferences

Rock fragments and large roots in the soil interfere with sample collection. Dry or hard soils often shatter when the scoop is hammered into the soil. Pressing the scoop into the soil reduces the risk of shattering the sample. If soil cracks are present, select the sampling area so that crack space is representative of the sample, if possible. If this is not possible, make measurements between the cracks and determine the aerial percentage of total cracks or of cracks in specimen.

Safety

Be careful when using an oven. Avoid touching hot surfaces and materials. Follow standard field and laboratory safety precautions.

Equipment

1. Four mil 15.2 X 22.9 cm air-tight plastic bags
2. Marking pen to label bags
3. Electronic balance, ±0. 1-g sensitivity.
4. Sieve, No. 10 (2 mm-openings)
5. Metal scoop – the base is 10 cm X 10 cm. The sides are 5 cm high. The material is 1.59 mm steel, folded to shape. A 3.17 mm steel plate is welded to the back to strengthen the scoop if it is hammered into the soil. The cutting edge of the bottom and sides is sharpened from the outside.
6. Wood block
7. Hammer
8. Weighing pan, aluminum, 50.8 mm diameter, 15.9 mm depth
9. Oven, 110 ±5 °C
10. First-aid kit

Reagents

None.

Procedure

1 Prepare flat vertical surface, at required depth in sampling pit. The sampling area must be excavated to the top of the layer to be sampled, with the top of the layer relatively smooth. Record scoop volume.
2 Press or drive scoop into soil. Use a wood block against the back of the scoop if driving with a hammer or pressing with a jack. Maintain horizontal travel as the scoop advances into the soil. The sides of the scoop can be used as a gauge. Cut the soil along the front of the scoop after the scoop has been pushed into the soil to the full 10 cm distance. If the layer sampled is less than the full 5 cm height of the walls, place a straight edge across the top of the scoop and measure and record the distance from the straight edge to the soil surface in four representative locations. Remove the sample from the scoop, and place in air-tight labeled bag for transport to laboratory.
3 At the laboratory, weigh the bag on a balance tared with a similar bag.
4 Air dry the core. Break it up for faster drying.
5 Weigh the air dry sample.
6 Crush the fine earth portion of the air dry sample and pass it through a 2 mm sieve. Weigh the sieved sample.
7 Weigh the coarse fragments, determine their density, and discard.
8 Tare a weighing pan on a balance. Add ~50 g of air dry soil to it. Record the soil weight.
9 Dry the weighing pan of air dry soil in oven at 110 °C until weight is constant.
10 Remove the pan from the oven, and weigh as soon as it is cool on a balance tared with a weighing pan.

Calculations

ODW = ADW/(ADS/ODS)

Db = ODW/[SV - (RF/PD)]

Where:

ODW = Oven-dry weight of the <2 mm fraction
ADW = Air dry weight of the <2 mm fraction
ADS = Air dry weight of the sub-sample
ODS = Oven dry weight of the sub-sample

Db = Bulk density of <2-mm fabric at sampled field water state (g cm^{-3})
RF = Weight of rock fragments
SV = Soil volume – is scoop volume for 5 cm thick sample. It is scoop volume – 100*(avg of four measurements from soil surface to scoop top) if scoop is not full.
PD = Density of rock fragments

Compliant Cavity

After Grossman and Reinsch (2002) and Soil Survey Staff (2004)

Modified for Rapid Carbon Assessment

Application

Compliant cavity method (Grossman and Reinsch, 2002) is useful for fragile cultivated near-surface layers or layers with appreciable amounts of coarse fragments. This method has the important advantage that it is not necessary to flatten the ground surface or remove irregularities, i.e., the surficial zone is usually not altered (Grossman and Reinsch, 2002). The procedure described herein is after Grossman and Reinsch (2002) and the Soil Survey Staff (2004, method 3B3a), modified for the Rapid Carbon Assessment project.

Summary of Method

By this procedure, the cavity volume on the zone surface is lined with thin plastic and small rounded objects are added to a datum level. Soil is quantitatively excavated in a cylindrical form to the required depth. The difference between the initial volume and that after excavation is the sample volume. The excavated soil is dried in an oven and then weighed. A correction is made for the weight and volume of rock fragments.

Interferences

Bulk density by compliant cavity can not be determined if free water is present in the hole.

Safety

Be careful when using an oven. Avoid touching hot surfaces and materials. Follow standard laboratory and field safety precautions.

Equipment

1 Fabricated Plexiglass rings, 9 mm thick, 130 mm inside diameter, and >200 mm outside diameter. Make three 16 mm diameter holes that are 10 mm from the outer edge of ring. Position holes equidistant apart.
2 Make 50 mm thick foam rings from flexible polyurethane with an "Initial Load Displacement" of 15 to 18 kg. Foam rings have the same inside diameter as the Plexiglass rings.
3 Use wing nuts and three, 380 mm long, 10 to 13 mm diameter, threaded rods to mount and position the compliant cavity. Sharpen the rods. Place two regular nuts at the end of threaded rod to increase the area of surface struck.
4 Plastic film, ½ mil, 380 mm to 460 mm wide
5 Four mil 15.2 X 22.9 cm air-tight plastic bags
6 Millet grain
7 Funnel, plastic, 25.4 cm
8 Marking pen to label bags
9 Graduated cylinder, plastic, 1000 mL
10 Kitchen knife, small
11 Scissors, small, to cut fine roots
12 Hacksaw blade to cut large roots
13 Straight edge, at least 15 cm long
14 Weights for plastic film
15 Clothespins. If wind, use clothespins for corners of plastic film.
16 Hard rubber or plastic mallet
17 Weighing pan, aluminum, 50.8 mm diameter, 15.9 mm depth
18 Sieve, square-hole, 10 mesh, 2 mm
19 Oven, 110 ±5 °C.
20 First-aid kit

Procedure

1 Place ring of plastic foam on ground and cover with rigid ring (130 mm inside diameter). Mount the assembly on the soil surface by securely driving threaded rods into the ground through holes in ring and by tightening ring with wing nuts.
2 Line cavity with ½ mil plastic. Fill cavity to the upper surface of the rigid ring with millet. Strike off excess millet with a straight edge.
3 Remove plastic film and millet. Measure the volume of millet in the graduated cylinder (nearest 5 ml). This volume (Vd) is the measurement of cavity volume prior to excavation (dead space).
4 Excavate soil quantitatively and in a cylindrical form to required depth, place in a labeled bag, and seal. Line the cavity with ½ mil plastic film. Fill the cavity with millet to the top of the rigid ring. Strike off excess millet. Measure the volume of millet (nearest 5 ml). This volume (Vf) is the measurement of excavated soil and dead space. The difference between the two millet volumes (Vf - Vd) is the volume of excavated soil (Ve).
5 At the laboratory, weigh the bag on a balance tared with a similar bag.
6 Air dry the sample. Break it up for faster drying.
7 Weigh the air dry sample.
8 Crush the fine earth portion of the air dry sample and pass it through a 2 mm sieve.

Weigh the sieved sample.

9 Weigh the coarse fragments, determine their density, and discard.

10 Tare a weighing pan on a balance. Add ~50 g of air dry soil to it. Record the soil weight.

11 Dry the weighing pan of air dry soil in oven at 110 °C until weight is constant.

12 Remove the pan from the oven, and weigh as soon as it is cool on a balance tared with a weighing pan.

13 Compute bulk density. Weight of macroscopic vegetal material (g cm^{-3}) also may be reported.

Calculations

Ve = Vf - Vd

where:

Ve = Excavation volume of whole soil
Vf = Millet volume measurement of excavated soil and dead space (cc)
Vd = Millet volume measurement of dead space (cc)

ODW = ADW/(ADS/ODS)

where:

ODW = Oven-dry weight of <2 mm soil (g)
ADW = Air dry weight of the <2 mm fraction
ADS = Air dry weight of the sub-sample
ODS = Oven dry weight of the sub-sample

Db = ODW/[Ve - (RF/PD)]

where:

Db = density of <2-mm fabric at sampled field water state (g cm^{-3})
ODW = Oven-dry weight of <2-mm soil (g)
Ve = Excavation volume of whole soil (cm^{-3})
RF = Weight of rock fragments
PD = Density of rock fragments

Report

Bulk density is reported to the nearest 0.01 g cm^{-3} (g cc^{-1}).

Ring Excavation

After Grossman and Reinsch (2002) Soil Survey Staff (2004)
Modified for the Rapid Carbon Assessment Project

Application

Ring excavation (Grossman and Reinsch, 2002) is a robust, simple, and rapid procedure that is good where local variability is large. The diameter can range down to 15 cm and upwards to 30 cm or more. It is not necessary to excavate from the whole area within the ring. A limit of 2 cm on the minimum thickness of the sample should be considered. The procedure described herein is after Grossman and Reinsch (2002) and the Soil Survey Staff (2004, method 3B4a), modified for the Rapid Carbon Assessment project.

Summary of Method

A 25.3 cm ID ring is placed on the ground and fastened with three pins driven into the soil. The ring is lined with ½ mil plastic and filled to the upper ring surface with small spherical objects. The volume of the filler material is determined. The soil is excavated to the desired depth, and the cavity is again lined with plastic film and filled to the upper ring surface. The volume of the filler material is again determined. The change in volume is calculated. This is the volume of soil excavated. The excavated soil is weighed field moist and air dry, and the air-dry/oven-dry ratio is calculated. If rock fragments are present, the weight and volume of >2-mm material in sample are corrected and bulk density computed. Bulk density of soil is reported in g cm^{-3}.

Interferences

The method can not be used if free water is present in the excavated hole.

Safety

Be careful when using an oven. Avoid touching hot surfaces and materials. Follow standard field and laboratory safety precautions.

Equipment

1 Four mil 15.2 X 22.9 cm air-tight plastic bags
2 Marking pen to label bags
3 Electronic balance, ±0.1-g sensitivity
4 Weighing pan, aluminum, 50.8 mm diameter, 15.9 mm depth
5 Plastic cylinder, 25.3 cm diameter, 4.4 cm high
6 Steel pins, sharpened, 38 cm long, with wing nuts and washers
7 Plastic film, ½ mil, 458 mm wide
8 Millet grain
9 Graduated cylinder, plastic, 1000 ml
10 Straight edged tool or ruler at least 30 cm long
11 Plastic funnel, 25.4 cm diameter
12 Hand digging equipment
13 Sieve, No. 10 (2 mm-openings)
14 Oven, 110 ±5 °C
15 First-aid kit

Reagents

None.

Procedure

1 Place a 25.4 cm diameter plastic ring on the soil surface.
2 Drive three sharpened rods into the soil, equally spaced around the outside of the ring. Drive the rods at a distance from the ring such that the washers under the wing nuts on the pins just touch the top surface of the ring. Press the ring down lightly, and tighten the wing nuts enough to prevent the ring from shifting.
3 Line the ring with the ½ mil plastic, fill with millet, and strike off the excess above the upper surface of the ring. Pour the millet in the ring into the graduated cylinder and measure its volume (nearest 5 ml). You may have more than one cylinder full.
4 Excavate soil to the desired depth. Place the soil in a labeled bag and seal it.
5 Line the ring with the ½ mil plastic, fill with millet, and strike off the excess above the upper surface of the ring. Pour the millet in the ring into the graduated cylinder and measure its volume (nearest 5 ml). You may have more than one cylinder full.
6 Calculate the change in volume on removal of the soil (Ve).
7 At the laboratory, weigh the bag on a balance tared with a similar bag.
8 Air dry the sample. Break it up for faster drying.
9 Weigh the air dry sample.
10 Crush the fine earth portion of the air dry sample and pass it through a 2 mm sieve. Weigh the sieved sample.
11 Weigh the coarse fragments, determine their density, and discard.
12 Tare a weighing pan on a balance. Add ~50 g of air dry soil to it. Record the soil weight.
13 Dry the weighing pan of air dry soil in oven at 110 °C until weight is constant.
14 Remove the pan from the oven, and weigh as soon as it is cool on a balance tared with a weighing pan.
15 Compute bulk density. Weight of macroscopic vegetal material (g cm^{-3}) also may be reported.

Calculations

ODW = ADW/(ADS/ODS)

where:

ODW = Oven-dry weight of <2 mm soil (g)
ADW = Air dry weight of the <2 mm fraction
ADS = Air dry weight of the sub-sample
ODS = Oven dry weight of the sub-sample

Db = ODW/[Ve - (RF/PD)]

where:

Db = density of <2-mm fabric at sampled field water state (g cm^{-3})
ODW = Oven-dry weight of <2-mm soil (g)
Ve = Excavation volume of whole soil (cm^{-3})
RF = Weight of rock fragments
PD = Density of rock fragments

Report

Bulk density is reported to the nearest 0.01 g cm^{-3} (g cc^{-1}).

Soil Cores

After Soil Survey Staff (2004)
Modified for Rapid Carbon Assessment Project

Application

Bulk density by the core method offers the opportunity to obtain bulk density information without the expense incurred to obtain water retention. Field-state bulk density by the core method is particularly useful if the soil layers are at or above field capacity and/or the soils have low extensibility (shrink-swell) and do not exhibit desiccation cracks even if below field capacity. This method is not intended for weak or loose soil material, or material with an appreciable amount of coarse fragments. The procedure described herein is after the Soil Survey Staff (2004, method 3B6a), modified for the Rapid Carbon Assessment project.

Summary of Method

A metal cylinder is pressed or driven into the soil. The cylinder is removed, extracting a sample of known volume. The moist sample weight is recorded. The sample is then dried in an oven and weighed.

Interferences

During the coring process, compaction of the sample is a common problem. Compression can be observed by comparing the soil elevation inside the cylinder with the original soil surface outside the cylinder. If compression is excessive, the soil core may not be a valid sample for analysis. Rock fragments in the soil interfere with core collection. Dry or hard soils often shatter when the cylinder is hammered into the soil. Pressing the cylinder into the soil reduces the risk of shattering the sample. If soil cracks are present, select the sampling area so that crack space is representative of the sample, if possible. If this is not possible, make measurements between the cracks and determine the aerial percentage of total cracks or of cracks in specimen.

Safety

Be careful when using oven or microwave. Avoid touching hot surfaces and materials. Follow standard field and laboratory safety precautions.

Equipment

11 Four mil 15.2 X 22.9 cm air-tight plastic bags
12 Marking pen to label bags
13 Electronic balance, ±0.1-g sensitivity
14 Sieve, No. 10 (2 mm-openings)
15 Weighing pan, aluminum, 50.8 mm diameter, 15.9 mm depth
16 Steel core ring, 7.6 cm ID, 7.6 cm long, 1.6 mm thick wall
17 Wood block
18 Hammer
19 Oven, 110 ±5 °C
20 First-aid kit

Procedure

11 Prepare flat surface, either horizontal or vertical, at required depth in sampling pit. Record the core dimensions.
12 Press or drive core sampler into soil. If a hammer is required, place a wood block on top of the core tube before striking it. Remove the core from the soil by digging out beside it and cutting the soil in front of the core cutting edge so excess soil in front of the core is still attached. Trim protruding soil flush with ends of cylinder. If the core is not full, place a straight edge across the top of the core and measure and record the distance from the straight edge to the soil surface in four representative locations. Place the soil sample in a labeled bag and seal air-tight.
13 At the laboratory, weigh the bag on a balance tared with a similar bag.
14 Air dry the core. Break it up for faster drying.
15 Weigh the air dry sample.
16 Crush the fine earth portion of the air dry sample and pass it through a 2 mm sieve. Weigh the sieved sample.
17 Weigh the coarse fragments, determine their density, and discard.
18 Tare a weighing pan on a balance. Add ~50 g of air dry soil to it. Record the soil weight.
19 Dry the weighing pan of air dry soil in oven at 110 °C until weight is constant.
20 Remove the pan from the oven, and weigh as soon as it is cool on a balance tared with a weighing pan.

Calculations

ODW = ADW/(ADS/ODS)

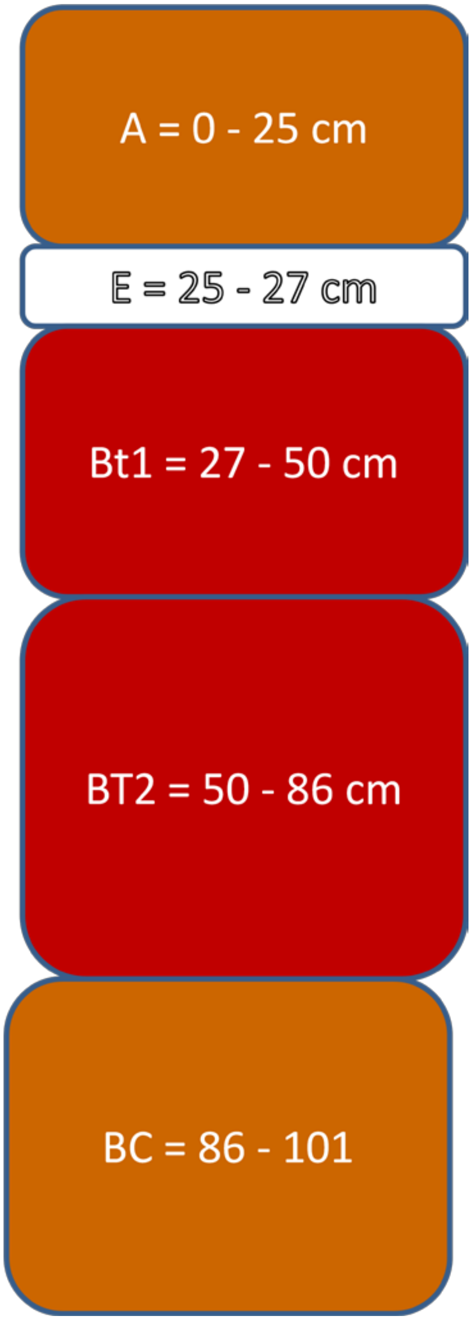
Db = ODW/[SV - (RF/PD)]

where:

ODW = Oven-dry weight of the <2 mm fraction
ADW = Air dry weight of the <2 mm fraction
ADS = Air dry weight of the sub-sample
ODS = Oven dry weight of the sub-sample

Db = Bulk density of <2-mm fabric at sampled field water state (g cm^{-3})
RF = Weight of rock fragments
SV = Soil volume – is core volume if the core is full. If not, calculate (avg of four measurements from core end to soil (in cm))*(pi*core radius in cm squared) and subtract the resulting value from the core volume.
PD = Density of rock fragments

Appendix B: Sampling Decision Rule Examples



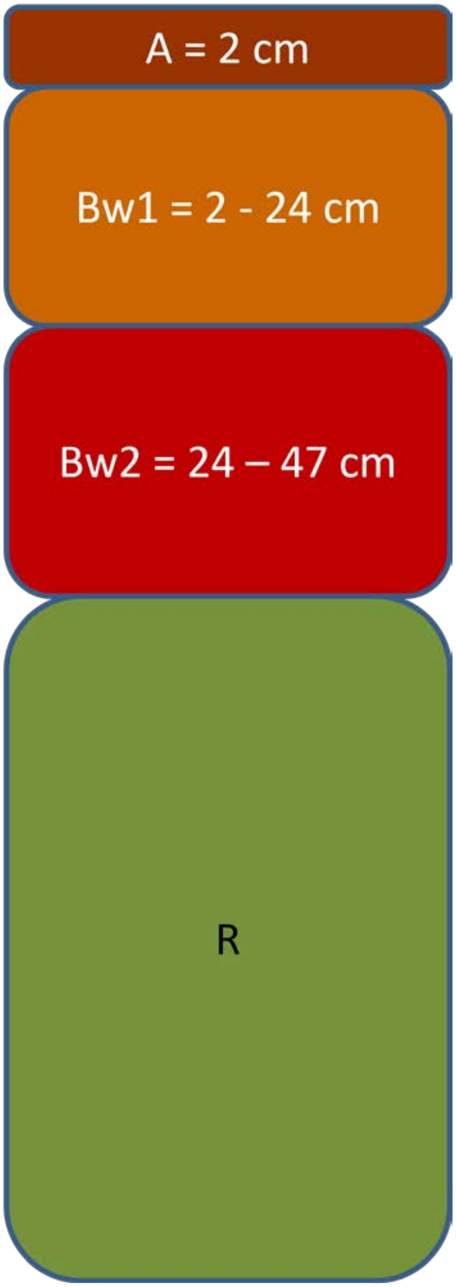
Samples

Bulk Density and Carbon

- **A1 – 0-5cm**
- **A2 – 5 – 25cm**
- **E and Bt1 – 25 – 50cm**

Carbon Only

- **Bt2 – 50 – 86 cm**
- **BC – 86 – 100 cm**



Samples

Bulk Density and Carbon

- **A: 0-2cm**
-
- **Bw1a: 5 – 24cm**
- **Bw1b: 24 – 47cm**

Samples

<u>Alternative 1</u>

Bulk Density and Carbon

- **A: 0 - 5cm**
- **Bt1: 7 – 14cm**
- **Btk1: 14 – 35cm**
- **Btk2: 35 – 81cm**

Carbon Only

- **BC : 81 – 100 cm**

<u>Alternative 2</u>

Bulk Density and Carbon

- **A: 0 - 5cm**
- **Bt1: 7 – 14cm**
- **Btk1: 14 – 35cm**
- **Btk2: 35 – 50cm**

Carbon Only

- **Btk3: 50 - 81 cm**
- **BC : 81 – 100 cm**

Samples

Bulk Density and Carbon

- **Oa: 0 – 4cm**
- **A1: 4 – 9 cm**
- **A and E: 9 – 15cm**
- **Bhs: 15 – 27cm**
- **Bs: 27 – 53 cm**

Carbon Only

- **C: – 53 – 100 cm**