MEASURING SOIL AGGREGATION
(ON-FARM PROTOCOL)

Introduction

Aggregates are small pellets in the soil which look like soil filled with tapioca, couscous, or cheese curds of different sizes. These pellets are small microbial towns made from soil minerals (i.e. sand, silt and clay) and organic matter held together by fungal hyphae and fungal and bacterial glues and waxes. Pores, which may be air- or water-filled, exist between the soil minerals and organic matter. When aggregates are water stable, these towns are protected and soil organisms can live and grow near their food sources (i.e. organic matter). Soil organisms, such as fungi, make substances like glomalin which form a coating on the surface of soil aggregates to keep them stable.

Materials

Aluminum foil or wax paper
Brushes to clean sieves (paint brushes)
Dishwashing liquid soap (low foam, sodium based, and/or nonionic surfactant)
Dust mask and other personal protective equipment for high dust
Glue gun (optional)
Glue sticks (optional)
Mesh screen, plastic (2-mm opening, standard window screen)
Mesh screen, plastic (1-mm opening, small insect screen or no-see-ums screen)
Muffin cups or a leak- and oven-proof container about 2 inches (5 cm) wide
Muffin tin (optional)
Oven
Paper/newspaper/Kraft paper/butcher paper
Permanent marker
Plastic bags/vials/jars to hold aggregates
Plastic cup/vial/small bowl/small Tupperware no more than 1-2 inches (2.5-5 cm) wide
PVC or rigid, plastic pipe [1-2 inches (2.5-5 cm) outer diameter, 0.9-1.9 inches (2.3-4.8 cm) inner diameter)
Saw or pipe cutter
Scale or balance, kitchen or food scale may be used
Soil samples
Spray bottle and/or condiment squeeze bottle
Stir stick/rubber scraper/knife/spoon
Water (Distilled preferred but tap is okay)
Water-insoluble glue
Work gloves

Methods

Air Drying the Soil:

1. Spread soil sample (at least a ½ cup or 100 ml) out in a single layer on newspaper or Kraft paper to air dry (i.e. dry at room temperature).
2. Remove any rocks or pebbles larger than 0.5 inch or 1.5 cm.
3. Manually break apart any large clods by gently kneading or massaging with your fingers.
4. Repeat Step 3 daily for 5 to 10 days until the soil is dry.
5. To determine if the soil is dry, weigh the soil or a subsample of soil using a scale, record the weight, dry for 24 hours, and weigh again. If the weight does not change, then the soil is dry. Dry longer if needed.
6. After drying, the sample can be stored in a plastic bag or jar at room temperature until ready to use.

Making the Sieves:

7. Take the pipe and cut it into 2-3 inch or 5-7.5 cm pieces. The pieces should be at least 2 inches (5 cm) high – similar in height, but it is not necessary to cut them all to exactly the same height.
8. Cut the 2- and 1-mm mesh screens into 2.5 inch or 6 cm squares (**Figures 1-2**).
9. Lay out a strip of aluminum foil or wax paper big enough to hold mesh squares equal to the number of sieves you wish to make with a little extra for a pile of glue.
10. Lay out squares of mesh on the foil or wax paper – an equal number of 2- and 1-mm squares from Step 8.
11. Make a pile of glue on the foil or wax paper.
12. Generously coat the edge one end of each pipe piece from Step 7 with glue by dipping and rotating the edge in the glue pile. Optional: Use the glue gun to put glue on the edge of one end of pipe.
13. Immediately place the glue coated edge of pipe down on the mesh – one pipe per each mesh (**Figure 3**).
14. Place a book or weight on top of the PVC pieces to make a good seal with the glue (**Figure 4**).
15. Allow the glue to dry overnight, remove the weight and carefully remove the mesh on the pipe from the foil or wax paper. Add more glue if needed. You now have sieves with two sizes of mesh – 2-mm and 1-mm. Label the sieves with permanent marker as 2 mm or 1 mm, respectively. Cut the mesh to remove edges. (**Figure 5**)
16. Weigh each of the sieves and write the weights with a permanent marker on the side of each sieve.

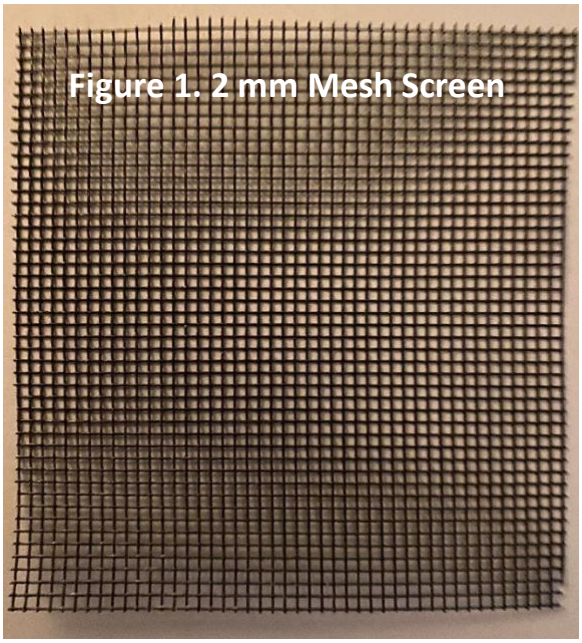
Figure 1. 2 mm Mesh Screen

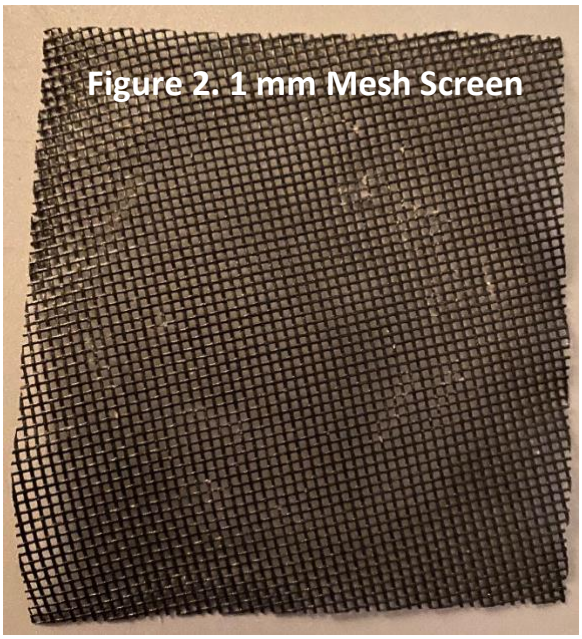
Figure 2. 1 mm Mesh Screen

Figure 3. Gluing mesh to PVC pipe on foil

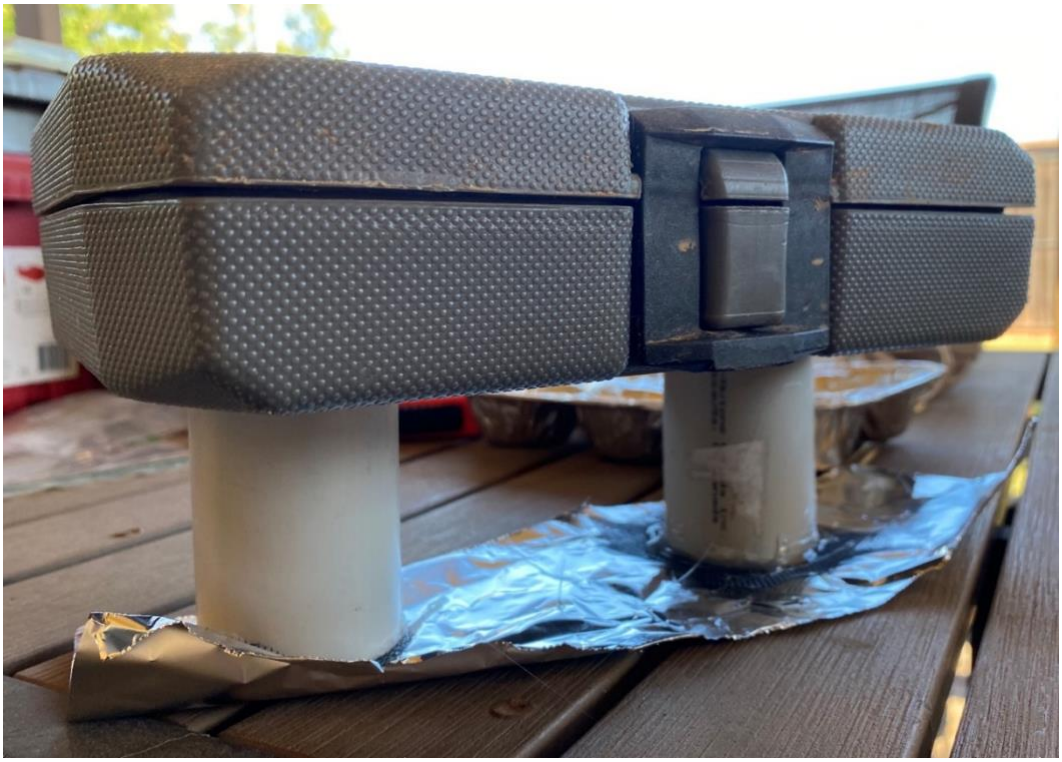

Figure 4. Weight used to seal PVC pipe to mesh while drying.

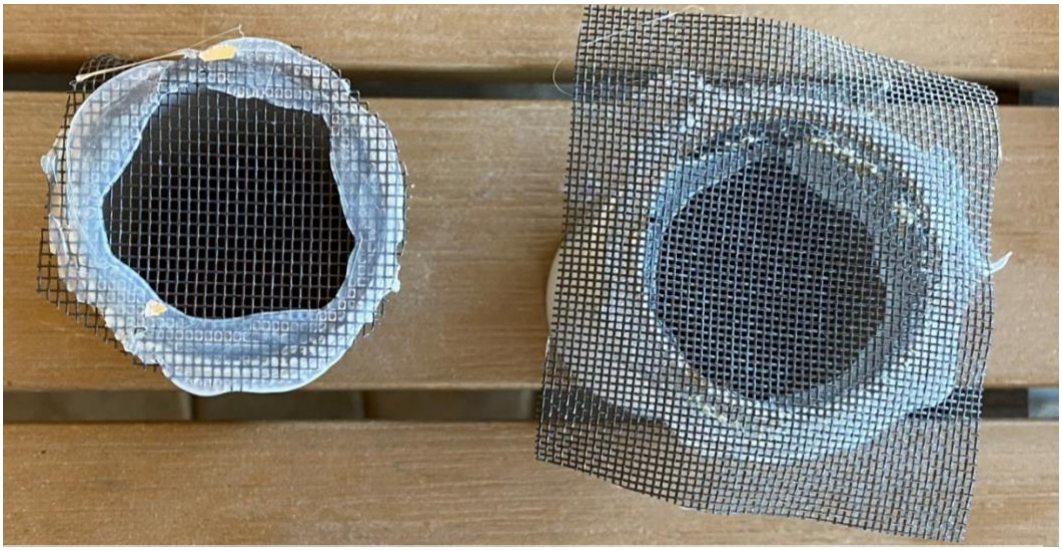

Figure 5. Mesh glued to PVC pipe and cut to the size of the pipe.

Dry Sieving to Collect Aggregates:

17. Cut pieces of paper – 2 per soil sample – into 8-inch (20-cm) squares. Optional: Use small bowls/cups/Tupperware rather than pieces of paper if these containers will hold the sieves from Step 16 while allowing room for manual shaking up and down and a little side to side (i.e. dry sieving) and does not weigh near the weight limit of the scale.
18. Place a piece of paper or dry sieving container from Step 17 on the scale and add a 2-mm sieve from Step 16 mesh-side down on the paper. Weigh and record the weight or tare the scale.
19. Add air-dried soil from Step 6 into the 2-mm mesh sieve to form a thin (0.25 inch or 5 mm) layer on top of the mesh (**Figure 6)**. Weigh and record the weight.
20. Carefully remove the paper with the 2-mm mesh sieve with soil in it from the scale.
21. Shake the 2-mm sieve manually until the smaller particles stop passing through the mesh. The soil on the paper contains aggregates and particles less than 2-mm in size (**Figure 7**).
22. Weigh the 2-mm sieve with the remaining soil (**Figure 8)**, record the weight, and dispose of the material on the 2-mm sieve. Optional: Do not dispose of the soil and particles on the 2 mm mesh if you want to test the aggregate stability of aggregates and particles larger than 2 mm. Set the 2-mm sieve from this step aside until wet sieving steps.
23. Place the other piece of paper or dry sieving container from Step 17 on the scale, weigh and record. Add the 1-mm sieve from Step 16 on top of it mesh-side down, weigh and record.
24. Bend the paper from Step 21 to create a funnel and pour the aggregates and particles less than 2-mm in size into the 1-mm sieve (**Figure 9**). Weigh and record the weight.
25. Carefully remove the paper with the 1-mm sieve and aggregates and particles less than 2-mm in size from the scale.
26. Shake the 1-mm sieve manually until the smaller particles stop passing through the mesh. The soil on the paper contains aggregates and particles less than 1-mm in size.
27. Carefully move the paper containing aggregates and particles less than 1-mm in size from Step 26 onto the scale, weigh, record the weight, and dispose of the soil.
28. Weigh the 1-mm sieve from Step 26 which contains aggregates and particles 1-2 mm in size (i.e. passed through the 2-mm mesh and collected on the 1-mm mesh). Record the weight and begin the wet-sieving process or transfer the material on the sieve into plastic bags/vials/jars to save for later.

Figure 6. Soil placed on 2-mm sieve.

Figure 7. Soil passed through 2-mm sieve.

Figure 8. Soil left in 2mm sieve after shaking

Figure 9. Soil passed through 2-mm sieve was placed on 1-mm mesh.

Wet Sieving to Measure Aggregate Stability:

29. Label, weigh and record the weights of four muffin cups or leak- and oven-proof containers per soil sample for wet sieving. These muffin cups/containers should be wide enough to hold the sieves created in Steps about 2 inches (5 cm) wide and low enough to manually move the sieves up and down (i.e. wet sieving). Each muffin cup/container should be labeled CR, UA, SA, or CM to indicate the aggregate fraction collected in the muffin cup/container such as after capillary rewetting (CR) in Step 34, unstable aggregates (UA) from Step 37, stable aggregates (SA) from Step 40, or the coarse material (CM) from Step 41, respectively.
30. If you removed the dry 1-2 mm aggregates and particles from the 1-mm sieve in Step 28, gently pour them back into the sieve, weigh, and record. If you did not remove them, then proceed to step 31.
31. Place the 1-mm sieve containing the 1-2 mm aggregates and particles from Step 28 or Step 30 into the muffin cup/container from Step 29 labeled CR, weigh and record.
32. Carefully remove the muffin cup containing the 1-mm sieve and 1-2 mm aggregates and particles from the scale and place the muffin cup in a muffin tin/pan or container to support it during wet sieving if needed. Note: If a leak- and oven-proof container is used rather than a muffin cup, this container is removed from the scale and move to Step 33 (**Figure 10**).
33. Make sure the sieve is resting flat on the bottom of the muffin cup/container.
34. Add water (preferably distilled water) around the outside of the sieve using the spray/squeeze bottle or a cup with a spout so the water will wick under the sieve and into the aggregates by capillary action (i.e. capillary rewetting). Do not add or pour the water into the sieve or over the aggregates. If the water does not wick under the sieve, then lift one side of the sieve up gently just to start the water wicking. Let it incubate for 5 minutes (**Figure 11**).
35. During the 5-minute incubation in Step 34, place the other three muffin cups from Step 29 into the muffin tin/pan. Note: If other leak- and oven-proof containers are used than muffin cups, there is no reason to use a muffin tin/pan for drying.
36. After the incubation in Step 34, transfer the 1-mm sieve into another muffin cup/container from Step 29 labeled UA and filled about ¾ full of water (preferably distilled water). Make sure the water is about a 0.5 inch or 1.5 cm above the aggregates on the mesh.
37. Gently move the sieve up and down while keeping the aggregates and mesh submerged in water and repeat this process 50 times over a two-minute period. (Hint: Use the beat from the song “Staying Alive” or “Another One Bits the Dust” to establish the perfect rhythm.)
38. Unstable aggregates will break up as the sieve is moved up and down and the soil particles inside the unstable aggregates will pass through the mesh and collect on the bottom of the muffin cup/container (**Figure 12**).
39. Remove the sieve from the water. The aggregates that stay on the mesh are water stable but there might also be sand or other debris (i.e. coarse material) on the mesh which are not aggregates.
40. Add water (either tap or distilled water) plus a small drop of liquid soap to another muffin cup/container from Step 29 labeled SA. The muffin cup/container should be about ¾ full of the water plus liquid soap so the water will be about 0.5 inch or 1.5 cm above the aggregates on the mesh – like the height of water in Step 35 (**Figure 12**).
41. Place the sieve from Step 38 in the muffin cup from Step 39 and shake and move the sieve up and down to break up the aggregates for five minutes. If needed, gently break up the aggregates on the mesh using a stir stick/knife/spoon while the mesh is submerged. In this step, the stable aggregates from Step 38 should break apart with the soil particles that were inside these aggregate passing through the mesh and the coarse material staying on the mesh (**Figure 13**).
42. Use the spray/squeeze bottle to rinse the coarse material off the mesh into the muffin cup/container from Step 29 labeled CM.
43. Place the muffin pan or four leak-proof, oven-safe containers from Steps 29-42 into an oven at 250°F (100°C) for 12-24 hours to evaporate the water and oven-dry the soil particles (**Figure 14-15**).

44. Weigh the material in each muffin cup or container separately and record the weights.

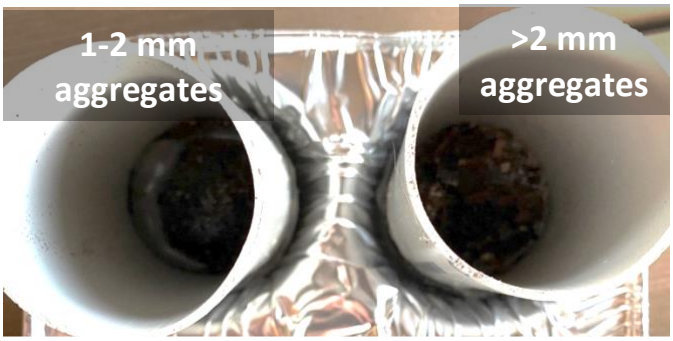

Figure 10. Soil aggregates and particles collected on mesh in sieves by dry sieving where the >2 mm aggregates were on top of the 2-mm mesh in the 2-mm sieve (right) and the 1-2 mm aggregates passed through the 2-mm mesh and were collected on the 1-mm mesh.

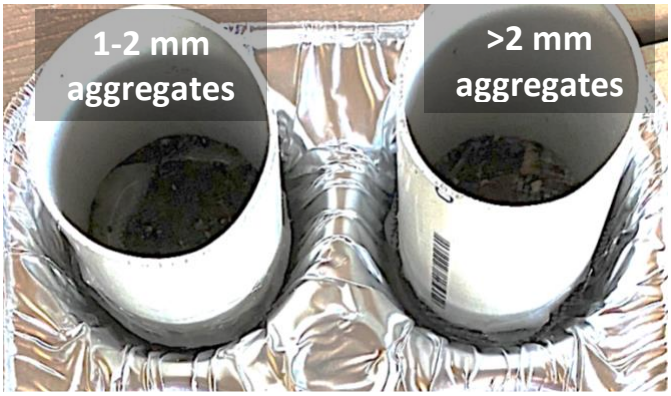

Figure 11. Water added around the outside of the sieve the muffin cup to wet aggregates and particles by capillary action.

Figure 12. Soil passed through the mesh after capillary rewetting (top) and water-stable aggregates on the mesh after wetting sieving (bottom) for 1-2 mm (left) and >2 mm aggregates (right).

Figure 13. Soil particles in unstable aggregates passed through the mesh (top) and water-stable aggregates were broken up to collect coarse material (bottom) for 1-2 mm (left) and >2 mm aggregates (right).

Figure 13. Unstable aggregates passed through the mesh

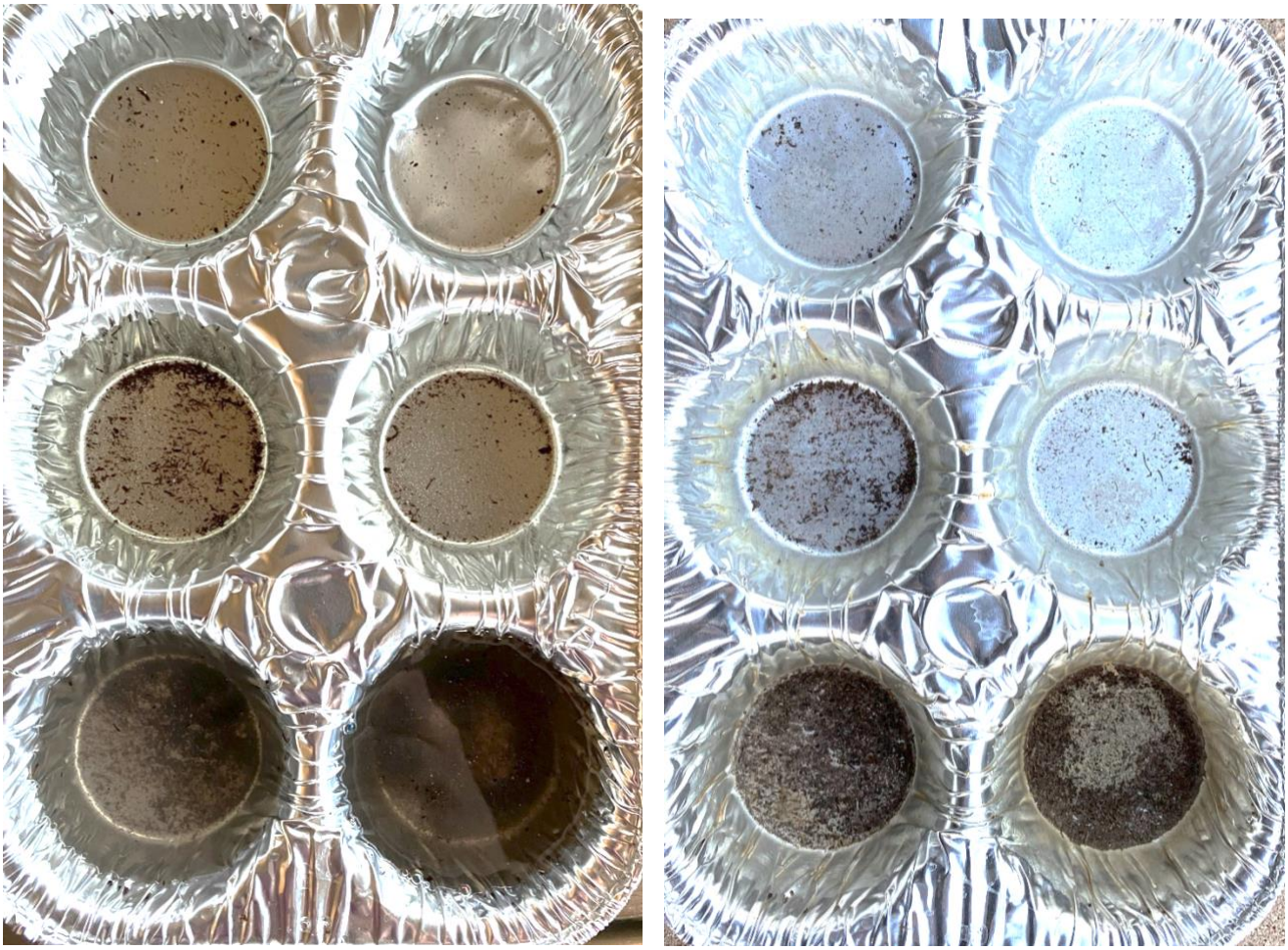

Figure 14. The soil particles in the top muffin cups are particles passed through the mesh during the capillary rewetting process, the unstable aggregates passed through the mesh during wet sieving in the middle, and on the bottom water-stable aggregates broken up to pass through the mesh before (left) and after (right) drying in an oven for 1-2 mm (left) and >2 mm aggregates (right).

Figure 15. Coarse material sand, roots, etc. collected by dry sieving that is the same size as the aggregates and need to be separated from the measurements of aggregates before drying for 1-2 mm (left) and >2 mm aggregates (right).

Calculating the Percentages of Dry Sieved and Water-Stable Aggregates

45. The equations below are used to calculate the percentage of dry-sieved aggregates which are greater than (>) 2 mm, 1-2 mm, and less than (<)1 mm in size.

Basic equation:

$$\%\ Dry\ sieved\ aggregates\ of\ size\ x = (Weight\ of\ dry\ sieved\ aggregates\ of\ size\ x\ \div Total\ weight\ of\ soil\ sieved) \times 100$$

Detailed equation from the processes described above:

$$\%\ Dry\ sieved\ aggregates > 2\ mm = [\{(Step\ 22\ weight\ of\ soil\ on\ top\ of\ 2mm\ mesh) - (Step\ 16\ weight\ of\ 2mm\ sieve)\} \div \{(Step\ 19\ weight\ of\ soil\ sample\ plus\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve) - (Step\ 18\ weight\ of\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve)\}] \times 100$$

$$\%\ Dry\ sieved\ 1-2\ mm\ aggregates = [\{(Step\ 24\ weight\ of\ soil\ aggregates\ and\ particles\ on\ top\ of\ 1mm\ mesh\ plus\ paper\ or\ dry\ sieving\ container\ and\ 1mm\ sieve) - (Step\ 23\ weight\ of\ paper\ or\ dry\ sieving\ container\ and\ 1mm\ sieve)\} \div \{(Step\ 19\ weight\ of\ soil\ sample\ plus\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve) - (Step\ 18\ weight\ of\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve)\}] \times 100$$

$$\%\ Dry\ sieved\ aggregates < 1\ mm = [\{(Step\ 27\ weight\ of\ paper\ or\ drying\ sieving\ container\ and\ soil\ aggregates\ or\ particles\ passed\ through\ the\ 1mm\ mesh) - (Step\ 23\ weight\ of\ paper\ or\ dry\ sieving\ container\ alone)\} \div \{(Step\ 19\ weight\ of\ soil\ sample\ plus\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve) - (Step\ 18\ weight\ of\ paper\ or\ dry\ sieving\ container\ and\ 2mm\ sieve)\}] \times 100$$

46. The equation below is used to calculate the percentage of water-stable aggregates which are 1-2 mm in size.

Basic equation:

$$\%\ Water\ stable\ aggregates\ of\ size\ x = (Weight\ of\ stable\ aggregates\ remaining\ on\ mesh\ of\ the\ smallest\ of\ size\ x\ after\ wet\ sieving\ and\ removing\ coarse\ material \div Total\ weight\ of\ aggregates\ of\ size\ x\ collected\ by\ dry\ sieving) \times 100$$

Detailed equation from the processes described above:

$$\%\ Water-stable\ 1-2\ mm\ aggregates = [\{(Step\ 44\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'SA' - (Step\ 29\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'SA')\} \div \{(Step\ 28\ or\ Step\ 30\ weight\ of\ 1-2\ mm\ dry\ sieved\ soil\ aggregates\ in\ 1mm\ sieve) - (Step\ 16\ weight\ of\ 1mm\ sieve)\}] \times 100$$

47. To check the calculation for the percentage of water-stable aggregates which are 1-2 mm in size from Step 46, use the following equation.

Basic equation:

$$\%\ Water\ stable\ aggregates\ of\ size\ x = [(Total\ weight\ of\ aggregrates\ of\ size\ x\ collected\ by\ dry\ sieving - Weight\ of\ soil\ collected\ after\ capillary\ rewetting - Weight\ of\ unstable\ aggregates\ of\ size\ x - Weight\ of\ coarse\ material\ of\ size\ x) \div Total\ weight\ of\ aggregates\ of\ size\ x\ collected\ by\ dry\ sieving] \times 100$$

Detailed equation from the processes described above:

$$\%\ Water\ stable\ 1-2\ mm\ aggregates = [\{\{(Step\ 28\ or\ Step\ 30\ weight\ of\ 1-2\ mm\ dry\ sieved\ soil\ aggregates\ in\ the\ 1mm\ sieve) - (Step\ 16\ weight\ of\ 1mm\ sieve)\} - \{(Step\ 44\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'CR' \{-(Step\ 29\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'CR')\} - \{(Step\ 44\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'UA') - (Step\ 29\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'UA')\} - \{(Step\ 44\ weight\ of\ muffing\ cup\ or\ wet\ sieving\ container\ labeled\ 'CM') - (Step\ 29\ weight\ of\ muffin\ cup\ or\ wet\ sieving\ container\ labeled\ 'CM')\}\} \div \{(Step\ 28\ or\ Step\ 30\ weight\ of\ 1 - 2\ mm\ dry\ sieved\ soil\ aggregates\ in\ 1mm\ sieve) - (Step\ 16\ weight\ of\ 1mm\ sieve)\}] \times 100$$

Template of a table to record the weights and assist in calculations of the percentages of dry sieved aggregates greater than 2 mm, 1-2 mm, and less than 1mm in size and of water-stable 1-2 mm aggregates

	Weight (ounces or grams)
Step 16 – 2-mm sieve	
Step 16 – 1-mm sieve	
Step 18 – 2-mm sieve plus paper/dry sieving container	
Step 19 – Total soil sample to be sieved, 2-mm sieve, and paper/dry sieving container	
Step 22- Soil on top of 2-mm mesh after dry sieving soil with the 2-mm sieve plus 2-mm sieve	
Step 23 – paper/dry sieving container alone	
Step 23 – 1-mm sieve plus paper/dry sieving container	
Step 24 – 1-mm sieve plus paper/dry sieving container and soil aggregates and particles less than 2 mm passed through the 2-mm sieve	
Step 27 – Paper/dry sieving container and soil particles less than 1 mm passed through the 1-mm sieve	
Step 28 – 1-mm sieve containing the 1-2 mm aggregates from dry sieving soil and collected from soil passed through the 2-mm mesh in the 2-mm sieve and resting on top of the 1-mm mesh in the 1-mm sieve	
Step 29 – Muffin cup or leak- and oven-proof container labeled ‘CR’ for soil passed through the mesh after capillary rewetting	
Step 29 – Muffin cup or leak- and oven-proof container labeled ‘UA’ for unstable aggregates passed through the mesh after wet sieving	
Step 29 – Muffin cup or leak- and oven-proof container labeled ‘SA’ for stable aggregates passed through the mesh after breaking up the aggregates on the mesh	
Step 29 – Muffin cup or leak- and oven-proof container labeled ‘CM’ for sand, roots, etc. rinsed off the mesh after the stable aggregates are broken up and passed through the mesh	
Step 30 (optional) – 1-mm sieve containing 1-2 mm aggregates from Step 28 which were return to the 1-mm sieve	
Step 31 – Muffin cup or leak- and oven-proof container, 1-mm sieve and dry sieved 1-2 aggregates	
Step 44 – Muffin cup or leak- and oven-proof container labeled ‘CR’ for soil passed through the mesh after capillary rewetting and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled ‘UA’ for unstable aggregates passed through the mesh after wet sieving and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled ‘SA’ for stable aggregates passed through the mesh after breaking up the aggregates on the mesh and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled ‘CM’ for sand, roots, etc. rinsed off mesh after stable aggregates broken up and passed through mesh and oven dried	

Optional Processes

Measuring the Percentages of Dry and Wet Sieved Aggregates of Other Sizes:

1. The 2-mm aggregates were already separated by the *Dry Sieving to Collect Soil Aggregates* process. To measure the water stability of the aggregates greater than 2 mm, the *Wet Sieving to Measure Aggregate Stability* process was modified as follows:
    a. The aggregates greater than 2 mm were collected in Step 22.
    b. In Steps 30 and 31, rather than using the 1-2 mm aggregates collected in Step 28 being used, the >2-mm aggregates from Step 22 were used.
    c. In every step from 32-44 replace, the text '1-2 mm' with '>2 mm' and every '1-mm sieve' with '2-mm sieve'.
    d. Use the table below as a template for the data to collect.
    e. The basic and detailed equations outlined in Step 46 would be used to calculate the percentage of water-stable aggregates greater than 2 mm.
2. Additional aggregate sizes may be collected and water stability tested by repeating Steps 17-44 using different mesh or wire with different sized openings where any text indicating '2' mm as the largest size of aggregates will be replaced by the largest size in the range for size *x* and '1' mm as the smallest size of aggregates will be replaced by the smallest size in the range for size *x*.

Template of a table to record the weights and assist in optional calculations of the percentages of water-stable aggregates greater than 2 mm after dry sieving

	Weight (ounces or grams)
Step 16 – 2-mm sieve	
Step 22- Soil on top of 2-mm mesh after dry sieving soil with the 2-mm sieve plus 2-mm sieve	
Step 29 – Muffin cup or leak- and oven-proof container labeled 'CR' for soil passed through the mesh after capillary rewetting	
Step 29 – Muffin cup or leak- and oven-proof container labeled 'UA' for unstable aggregates passed through the mesh after wet sieving	
Step 29 – Muffin cup or leak- and oven-proof container labeled 'SA' for stable aggregates passed through the mesh after breaking up the aggregates on the mesh	
Step 29 – Muffin cup or leak- and oven-proof container labeled 'CM' for sand, roots, etc. rinsed off the mesh after the stable aggregates are broken up and passed through the mesh	
Step 31 – Muffin cup or leak- and oven-proof container, 2-mm sieve and dry sieved aggregates greater than 2 mm	
Step 44 – Muffin cup or leak- and oven-proof container labeled 'CR' for soil passed through the mesh after capillary rewetting and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled 'UA' for unstable aggregates passed through the mesh after wet sieving and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled 'SA' for stable aggregates passed through the mesh after breaking up the aggregates on the mesh and oven dried	
Step 44 – Muffin cup or leak- and oven-proof container labeled 'CM' for sand, roots, etc. rinsed off mesh after stable aggregates broken up and passed through mesh and oven dried	

Observing aggregate stability:

3. If you do not want to quantify aggregate stability and/or wish to immediately demonstrate aggregate stability, then follow the procedure below:
   a. Make the sieves using the process described above and air dry the soil as described if possible.
   b. Dry sieve the soil to collect the aggregates as described in the Dry Sieving Aggregates process, but because this process is entirely about observations, you do not need to weigh the sieves, containers, or soil.
   c. After Step 28, rather than going on to the Wet pour about 20 of the dry sieved 1-2 mm aggregates from the 1 mm sieve or storage into a small clean container -ideally clear, with a flat bottom and about 1-2 inches (2.5-5 cm) wide and tall.
   d. Gently add water by pouring it down the side of the container to cover the aggregates. Do not add the water over the aggregates.
   e. Observe if the aggregates remain intact and the clarity of the water.
   f. Estimate the amount of aggregates that remain intact by observing the aggregates through the bottom of the cup/container and comparing to the pictures in **Figure 16**.

Figure 16. The 1-2 mm aggregates in the picture on the left were 14% water stable while those in the center were 47% stable and on the right were 93% stable.

Observations/What's Happening

1. Aggregate size is based on the width of the openings in the mesh and measured in mm (i.e. millimeters or 1 inch divided into about 25 pieces).
2. Note the amounts of soil greater than 2 mm, 1-2 mm and less than 1 mm in size during the dry sieving process.
3. Note the amount of soil which is at the bottom of the cup after capillary rewetting and after each step in the wet sieving process sieving.
4. Note the clarity of the water during the capillary rewetting and sieving steps.
5. Note if there is a lot of sand, roots, or organic debris in the dry sieved aggregate fractions - >2, 1-2, and <1 aggregates as this impacts the percentages of these dry-sieved fractions in soil and the amount of coarse material collected in Steps 41-44.
6. Note that the percentages are based on weight and not on number. This may be an issue if the aggregates contain a lot of sand or organic matter. Because sand is heavier, the percentage of dry sieved aggregates and water-stable aggregation may be over-estimated particularly with fine sand. Organic matter does not weigh much and could result in an under estimation of aggregation.
7. Soil aggregates in soil with a lot of clay, some of the aggregates are formed by chemical interactions between clay minerals where clay minerals bind to each other or the formation of organo-mineral complexes where clay minerals bind to organic matter. These aggregates are usually smaller than 1 mm.

8. The 1-2 mm aggregate size class is targeted because research indicates this size class is most impacted by biological processes.
9. Soil aggregates are formed and stabilized by biological, physical, chemical and geological processes.
10. Soil porosity is primarily the open space between soil aggregates with the sizes of aggregates defining the sizes of the pores and the openings between the pores.
11. When the aggregates are water-stable and do not easily fall apart during wet-dry cycles (i.e. following precipitation events – rain, snow or irrigation), the fine particles inside the aggregates are not released to clog the pore space.
12. When pore space is clogged, soil functions decline including gas exchange, water infiltration, water retention, nutrient cycling, and root and biological growth.
13. The maintenance water-stable soil aggregates are critical to soil health.
14. Compare aggregate stability to the dry aggregate weight/percentage.

Tips & Tricks

1. A craft glue gun and glue sticks may be used to attach the mesh to the pipe pieces. This glue dries quickly but may not be strong enough to keep the mesh attached well to allow the sieves to be reused, but it is easy to repair.
2. If the mesh separates from the pipe, it may be reglued or replaced with a new mesh.
3. If the mesh develops holes, it can be removed from the pipe and replaced.
4. To prevent accidental spillage in steps 20, 25, and 27 when removing the paper squares with the sieves containing soil particles and aggregates, use a small bowl/cup/Tupperware for dry sieving rather than paper. It's important to make sure that whatever container you use fits on the scale, is not too heavy for the maximum weight limit and is for shaking the sieve.
5. All the paper used for air drying and dry sieving may be reused for other samples if it is not stained, has no soil particles attached to it, or is torn.
6. The aluminum foil or wax paper used in making the sieves may be reused if it is not torn and can be laid flat.
7. All sieves, containers, and other supplies such as utensils, brushes, etc. from the dry and wet sieving processes may be reused.
8. When oven drying after wet sieving, it will be helpful to place the muffin cups in a muffin tin/pan if they aren't in there already. If other containers are used, they should be placed on a cookie sheet to prevent accidental spillages.
9. Create a table to record the weight and assist in the equations – a template is provided above.
10. The Making the Sieves process can occur before collecting and air drying the soil.
11. It is best if the soil is air dried prior to dry or wet sieving especially if percentages are calculated. Air drying may not be possible particularly if the optional *Observing Soil Aggregation* protocol below is done.
12. The four processes – *Air Drying Soil, Making Sieves, Dry Sieving to Collect Soil Aggregates*, and *Wet Sieving to Measure Aggregate Stability* – do not need to be completed immediately one after the other – air-dried soil and dry-sieved aggregates may be stored for weeks, month, or years if they are stored at room temperature and protected from artificial compression or breakage.

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