SOIL AGGREGATE ANALYSIS
(Kemper and Koch, 1966; Nichols and Toro, in review; Wright and Upadhyaya, 1998)

Introduction

Several methods exist for separating aggregates from soil and determining the percentage of water stable aggregates (WSA). We use the methods described below for the following reasons:

1. Soil samples are air-dried to a constant weight to make sure samples from all treatments are at the same moisture content.

2. Samples are dry sieved by hand to collect aggregate size classes one size class at a time rather than using a rotary sieve or sieve shaker with stacked sieves. This will reduce mechanical shearing of aggregates and keeps larger aggregates from impacting and breaking up smaller aggregates.

3. Collecting each size class individually allows for each size class to be wet sieved or analyzed individually.

DRY SIEVING TO COLLECT AGGREGATES

Materials

Balance
Brushes to clean sieves
Dust mask or other personal protective equipment
Large roll of kraft paper (brown paper) or newspapers
Plastic bags, tubes, or jars to hold aggregates
Sharpie or labels
Stainless steel or brass sieves of the appropriate sizes
Work gloves

Method

1. Lay the soil samples out on brown paper or newspaper and leave them until dry. Paper can also be used to cover the samples to prevent contamination. Drying times vary depending on how wet the samples were when taken and ambient humidity. If needed, the samples may be gently broken up by hand along natural fracture lines. This procedure may be repeated during the first few days of drying, but do not force the soil to break apart. Most samples will be dry within one week. To make sure that they samples are dry, check to see if the weights change with further drying. To do this, make the following measurements: 1. weigh a subset of three to five samples from the various treatments when you think that they are dry; 2. leave these samples to dry either by incubating overnight (at least 8 hours) at room
temperature or drying on a slide warmer or in an oven at less than 40°C for at least 2 hours; and 3. weigh the samples again and compare weights.

2. Dry soil may be weighed at this point for a total soil weight (WT) or the sum of the weights in each aggregate size class may be used for the WT value.

3. Air-dried soil is gently poured onto a sieve with a screen size matching the largest sized aggregates in a size class. The soil should be added to the sieve until all the sample is used or soil just covers the entire screen, whichever comes first. If a large amount of soil is being sieved, you may have to repeat the sieving process until the whole sample is completed.

4. The sieve is held in one hand above a piece of brown paper or newspaper and tapped with the other hand (use work gloves to protect hands and mask and other personal protective equipment to protect from dust) at least 25 times for very small samples and up to 150 or more times for samples that cover the entire screen* (Fig. 1A and 1B). Soil aggregates and particles smaller than the mesh screen will pass through and be collected on the paper below.

5. Gently pour the material on the paper into a sieve with a screen size matching the smallest aggregates in the size class and repeat step 3 (Fig. 1B).

6. Gently pour the aggregates collected on top of the screen into a plastic bag, tube, or jar for storage (Fig. 1C) and repeat steps 3-4 on the material that has passed through the screen.

7. Repeat step 3-5 until all the aggregate size classes of interest are collected**.

8. Repeat steps 2-6 until all of the soil has been sieved. You can combine aggregates of the same size class and sample together even if they were sieved in different repeated fractions.

9. Weigh the total amount of aggregates in each size class (WA). Use these values plus the total sample weight (WT) value described in step 1 and the proportion of the aggregate weight that is in the coarse fraction (i.e. the average coarse material weight (Wc) divided by original wet sieved sample weight (Wo) from the wet sieving process and multiplied by WA) to calculate the proportion of the total sample that is in each aggregate size class (Pawi).

\[
P_{awi} = \frac{W_A - \left(\frac{W_c}{W_o}\right) * W_A}{W_T}
\]

where \(P_{awi}\) = proportion of aggregate weight for each size class \(i\); \(W_A\) = weight of total material in each size class \(i\); \(W_c\) = weight of coarse material in size \(i\) as measured after weight sieving; \(W_o\) = weight of aggregates placed on the sieve prior to wet sieving size \(i\); \(W_T\) = total sample weight.

* The number of taps required should be the same for all the treatments and all the aggregate size classes in an experiment. Large samples will require more taps than small samples, while larger mesh screens may require fewer taps than fine mesh screens. Therefore, you may want to check the number of taps required to get the material from the largest samples to pass through each screen (i.e. visually observe no or very few particles passing through the screen) for all the aggregate sizes you are measuring and adjust accordingly.

** The number and sizes of aggregate size classes collected depends on the objective of the experiment. For measuring glomalin, previous experiments have demonstrated that a 1-2 mm size class is most appropriate. If erosion, especially wind erosion, is a factor in your
experiment, larger aggregate size classes may be collected. You may also want to collect a microaggregate size class < 0.25 mm. We typically collect 3 to 7 aggregate size classes ranging from 9.5 to 0.053 mm.

Figure 1. Soil is placed in a sieve with a screen size matching either the largest or smallest aggregates in a size class. The sieve is tapped a standard number of times to pass material smaller than the screen size through the screen and onto the brown paper (A). The material which passed through the screen is transferred from the brown paper onto the next smallest screen (B). Aggregates collected on top of the screen are transferred into plastic bags, tubes, or jars for storage (C).
## Dry Sieved Aggregate Distribution Data and Calculations

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<th>Agg size</th>
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### Column ID Description of data or calculation in column

**ID** Information about sample

**Agg size** Aggregate size class description

**Weight** Total weight of aggregates in a size class

**Proportion sand weight from WSA** Ave coarse weight (from WSA data sheet) ÷ Ave original weight (from WSA data sheet)

**Proportion agg weight from WSA** [Ave original weight (from WSA data sheet) - Ave coarse weight (from WSA data sheet)] ÷ Ave original weight (from WSA data sheet)

**Proportion sand** (Weight * Proportion sand weight from WSA) ÷ Total weigh of soil sample (or sum of aggregate weights)

**Proportion agg** (Weight * Proportion agg weight from WSA) ÷ Total weigh of soil sample (or sum of aggregate weights)

**Proportion total sum** Proportion sand + Proportion agg

**Proportion total calc** Weight ÷ Total weigh of soil sample (or sum of aggregate weights)

**Summed total** Sum for all four aggregate size classes of (Proportion total sum)
WET SIEVING TO MEASURE WATER STABLE AGGREGATION (WSA)  
(Kemper and Koch, 1966; Kemper and Chepil, 1965)

Materials
Stainless steel or bass sieves of the appropriate sizes  
Equipment to mechanically submerge sieves in water for a five minute period  
Slide warmer or oven to dry samples  
Weigh boats  
Balance

Method

1. Pre-weigh and label weigh boats to transfer aggregates and coarse material into for drying. [The same weigh boat may be used for both the aggregates (collected after wet sieving, step 5) and the coarse material (collected after treating with sodium hexametaphosphate, step ), but pre-weighing the boats will allow you to subtract the boat weight from the air-dried samples without having to remove the samples to tare the boat.]

2. Transfer 1-4* g of air-dried soil in each aggregate size classes into sieves with a screen size ¼ of the size of the smallest aggregates in the size class. For example, if you are sieving 1 to 2 mm aggregates, use a screen with mesh openings of 0.25 mm (¼ of 1 mm). The screens are placed in the pre-weighed weigh boats to collect dust that passes through the screen during weighing and for capillary rewetting (Step 3).

3. Samples are capillary rewetted from underneath by adding Milli-Q (or double distilled) water to the outside of the sieve in the weigh boat and allowing water to wick up from underneath.

4. Incubate on bench top for 10 min.

5. Place sieves into an apparatus described by Kemper and Koch (1966) for mechanical wet sieving. Sieves are moved up and down in a column of water at a rate of approx. 40 cycles per minute for 5 min. The bottom of the sieve is never allowed to break the surface of the water.

6. Material collected on the sieve was washed gently into pre-weighed weigh boats, dried at 70 to 90 °C, and weighed.

7. The coarse material was removed by adding 0.5% sodium hexametaphosphate and shaking periodically (3 to 4 times) over a 5 min period to disrupt the aggregates

8. The disrupted aggregates are washed through a screen matching the smallest aggregate size in the class using forced water. For smaller aggregate sizes, a rubber policeman or
similar device may be used help break up aggregates and push them through the screen. The coarse material is collected on the screen, washed into pre-weighed weigh boats, dried between 70 to 90 °C, weighed, and subtracted from the amount of aggregates collected after wet sieving

9. The formula for calculating the percentage WSA for each size class is:

\[
WSA_i = \left( \frac{W_o - W_c}{W_o} \right) \times 100
\]  

(3)

where \( WSA_i \) = water stable aggregation for each size class \( i \); \( W_o \) = weight of material on the sieve after wet sieving size \( i \); \( W_c \) = weight of coarse material in size \( i \); \( W_o \) = weight of aggregates placed on the sieve prior to wet sieving size \( i \).

* For aggregate size classes that contain aggregates >0.6 mm (i.e. 1 or 2 mm), use 4 g. If the smallest size is >0.120mm and <0.6 mm (i.e. 0.25 mm) use 2 g. If the smallest size is <0.120 mm (i.e. 0.25-0.053 mm), use 1 g. Less soil for the smaller aggregate sizes prevents clogging the fine mesh sieves.

Notes:
1. It is recommended to run at least three duplicate samples from the same soil. If your equipment only allows you to run eight samples at a time, you may want to use four duplicate samples to limit confusion.
2. Values for duplicate samples from the same soil should have a standard error (SE) of the mean of <2%. Some values, especially for larger aggregate size classes, may have a SE up to 5%.
3. WSA values may be combined with the total weights of the dry sieved aggregates to calculate a stability index (SI) for the whole soil. A normalized stability index (NSI) also may be measured on soil aggregates as described by Six et al. (2000). The equations for SI calculated from the WSA values measured from Kemper and Koch (1966) is

The formula for calculation of the stability index (SI) is

\[
SI = \left[ \sum_{i} \left( I \times P_{ai} \times (WSA_i \div 100) \right) \right] \div n
\]  

(4)

where SI = stability index; \( n \) = the number of the aggregate size classes; \( I = n \) and decreases by an increment of 1 from the largest to the smallest aggregate sizes class; \( P_{ai} \) = proportion of aggregate weight for each size class \( i \); \( WSA_i \) = water stable aggregation for each size class \( i \).
Figure 2. Small (2.54 cm diameter) sieves of the appropriate (i.e. ¼ the smallest aggregate size in the class) screen size are placed in pre-weighed weigh boats, the appropriate amount (i.e. 1 to 4 g based on aggregate size class) of aggregates are placed in the sieve, and capillary rewetted by wicking (A). After incubating for 10 min, the screens are placed in an apparatus for mechanical wet sieving (i.e. moving up and down in a column of water) for 5 min (B).

Figure 3. Homemade sieves may be used when wet sieving soil aggregates. Mesh is glued to the bottom of rigid tubing using water-insoluble glue (A). A rubber washer placed on the tubing acts as a lip allowing the sieve to be moved up and down a column of water by a mechanical apparatus (Fig. 2B) (B).
**Water Stable Aggregation (WSA) Data and Calculations**

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**Column ID**

- **ID**: Description of data or calculation in column
- **Agg. size**: Information about sample
- **Sieve ID**: Aggregate size class description
- **Orig. stab. sample wght (g)**: ID on sieve used for WSA
- **Ave orig. wght**: Weight of sample in sieve for WSA
- **Boat wght**: Average weight of duplicate samples in sieves for WSA
- **Dried agg. wght + boat**: Weight of pre-weighed weigh boat
- **Dried agg. wght**: Weight of material left on sieve after wet sieving and drying at 70-90°C and without tarring the weigh boat
- **Agg. wght**: (Dried aggreg weight + boat) – (Boat weight)
Dried coarse wght + boat
Weight of material left on sieve after treating dried aggregates with sodium hexametaphosphate, washing disrupted aggregates through the sieve and drying at 70-90°C and without tarring the weigh boat

Coarse wght
(Dried Nahexa coarse material weight + boat) – (Boat weight)

Ave coarse wght
Average weight of coarse material from duplicate WSA samples

Propor. coarse
(Ave coarse weight) ÷ (Ave original weight)

Propor. aggreg
[(Ave original weight) - (Ave coarse weight)] ÷ (Ave original weight)

WSA
[(Aggreg weight) – (Coarse material wght)] ÷ (Original stability sample wght (g))

Ave
Average WSA values for duplicate samples

SE
Standard Error of WSA values for duplicate samples