SOIL AGGREGATE STABILITY BY WET SIEVING

A Practical Guide for Comparing Crop Management Practices

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International Maize and Wheat Improvement Center

Acknowledgements
This material was developed under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and partly funded by 'Desarrollo sustentable con el productor', part of 'Modernización Sustentable de la Agricultura Tradicional', supported by SAGARPA. This series is based on contributions and materials from A. Castellanos-Navarrete, A. Chocobar, R. A. Cox, S. Fonteyne, B. Govaerts, N. Jespers, F. Kienle, K. D. Sayre, N. Verhulst.

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Soil aggregate stability by wet sieving

1. Introduction

Soils are subjected to spatial and temporal alterations of aggregates and pores caused by natural (pedogenesis) and anthropogenic (management) factors (Lal and Shukla, 2004). In fact, soil aggregate distribution is a static measure that, to provide information on dynamic changes, has to be repeated over time. A practical alternative is to undertake measures on soil stability. Structural stability is often measured as the stability of soil fragments exposed to stresses (Díaz-Zorita et al., 2002). Of particular importance is the ability of the soil to retain its arrangement of solid and void spaces during rainfall or irrigation events. Soil structure can collapse: (i) by direct impact of raindrops that break surface soil aggregates and result in soil surface crusts; and (ii) by spontaneous slaking through breakdown of soil aggregates during rapid wetting both at the soil surface (contributing to soil crust formation) and within the soil (resulting in soil compaction) (Arshad and Mermut, 1988; FAO, 2003; Lal and Shukla, 2004). In both cases, the break-down of aggregates into small particles leads to clogging of soil pores forming surface seals, reducing the hydraulic conductivity of the soil (Lal and Shukla, 2004). This problem is worse in arid and semi-arid regions due to the rapid drying of the soil. Degradation at the soil surface and at the sub-soil results in reduced rainfall water infiltration into the soil, and thus increased incidence of runoff and soil erosion, leading to low water use efficiency. In other words, the erodibility of the soil increases as aggregate stability decreases (Kemper and Rosenau, 1986). Aggregate collapse also influences solute transport processes in the soil as well as resistance to penetration by roots and shoots in seedbeds (Rathore et al., 1983; Schneider and Gupta, 1985; Nasr and Selles, 1995; Diaz-Zorita et al., 2002).

Wet sieving has been proposed as a methodology to study aggregate stability against water erosion (Yoder, 1936; Kemper, 1966; Kemper and Rosenau, 1986). In this method, cyclically submerging and sieving soil in water emulates the natural stresses involved in the entry of water into soil aggregates. Since disruption strongly varies by moisture content of samples (Beare and Bruce, 1993; Márquez et al., 2004), two sample pre-treatments have been proposed: slaked and capillary-wetted pre-treatments. Direct immersion of dry soil in water at atmospheric air pressures causes a great disruption of aggregates into smaller aggregates and primary particles. Weak aggregates are disrupted as a consequence of the sudden release of internal air, displaced by water (Panabokker and Quirk, 1957; Cambardella and Elliott, 1993; Gale et al., 2000). If the purpose of the aggregate analysis is related to infiltration rates of flooded soils or the formation of soil crusts, immersion of air-dry soil is probably the best procedure. Capillary-wetted pre-treatment fits better for analysis of soil stability under rain fed conditions and when soil under the surface is also studied. A much smaller and gradual degree of disruption occurs when soils are slowly wetted (e.g., through an aerosol) because the bonding is still sufficiently strong to hold most of the primary particles together in aggregates (Kemper and Rosenau, 1986). For pre-treatment, distilled water must be used since salt can cause changes in the ionic status and stability of soils, except in the case of sodic soils (Shainberg et al., 1981). Results can be expressed as mean weight diameter (MWD) (van Bavel, 1949) or as aggregate percentage.

To avoid miscalculations, it is also important to avoid the inclusion of primary textural particles (i.e., sand, gravel, etc.) or products from processes different than fragmentation (e.g., abrasion) (Diaz-Zorita et al., 2002). Gravel and coarse sand in samples can be calculated through the sand correction procedure in which samples are subjected to chemical dispersion through immersion in Na-hexametaphosphate (HMP) (Diaz-Zorita et al., 2002). Chemical dispersion is based primarily on the concept of particle repulsion, as a result of elevation of the particle zeta potential. This process is usually accomplished by saturating the exchange complex with sodium (Gee and Bauder, 1986).

2. Materials and Equipment

- Shovel
- Large rectangular sampling boxes or paper bags
- Marker, and labels if boxes are used
- 8 mm sieve for sample preparation
- Sieves with openings of 4.00, 2.00, 1.00, 0.50, 0.25 and 0.053 mm
- Distilled water (approximately 5 l per sample)
- Atomizer
- Metal trays of known weight
- Bottle with spray nozzle (wash bottle)
- Weighing scales
- Stopwatch
- Datasheet and pencil

3. Procedure

3.1 Field sampling

Field sampling for soil structure studies must be undertaken carefully to avoid structure disruptions which will distort results. When making comparisons between different management practices, all samples should be collected on the same day (i.e., observed variability in soil structure of soils which have similar water content may be a result of different management practices). Samples should be obtained using a shovel to avoid compression and disturbance of the sample (which occurs when using an auger) and ensure minimum wall surface area to volume ratio to decrease the risk of compaction. Only the part of the sample not touch by the shovel may be used. Avoid any activities, such as hammering the shovel, which can result in sample disruption. Then samples are placed in rigid large sampling boxes or paper bags that have been appropriately labeled. Avoid layering the samples as this would cause compression of soil. Prior to analysis, samples should be stored in a controlled environment (i.e., constant temperature and humidity).

3.2 Sample preparation

After field sampling, air-dry samples at room temperature for a few hours and then gently break large clods (>5 cm) along natural planes of weakness into natural aggregates. The samples are then air-dried for 2 weeks before being passed through an 8 mm sieve to remove coarse plant residues, roots and any stones >8 mm. Take a sub-sample of 20 g (or 40 g for the alternative wet sieving method detailed below) for further analysis. Thoroughly mix the sample before taking the sub-sample to ensure you obtain a representative sub-sample.

3.3 Measurement

For each sieve, a marked tray is required to contain the soil fractions after sieving and during drying. For the capillary-wetted pre-treatment, the soil sub-sample is moistened with an atomizer after pouring onto the sieves (Figure 1). For the slaking pre-treatment, the samples are placed in a metal tray and immersed in distilled water for 30 min (take care to not point the spray nozzle directly at the sample as doing so may break down aggregates).

The sieves are stacked on top of each other, starting with the sieve with the largest diameter on top and the smallest below (i.e., 4.00, 2.00, 1.00, 0.50, 0.25 and 0.053 mm) (Figure 2). Pour the soil sample onto the top sieve, cleaning the tray with the wash bottle if necessary without pointing the water directly at the sample. The sieves are then immersed and moved up and down over a vertical distance of 3.5 cm and a rate of 35 strokes min^{-1} for 1 minute (Figure 3). After sieving, each sieve is cleaned into a marked tray using the wash bottle. The soil is then oven-dried at 105°C (Figure 4) and weighed.

Each fraction is corrected for the presence of sand and coarse fragments: fractions are shaken for 18 h with 5% sodium hexametaphosphate (1:3 soil:liquid ratio). Then the weight retained on respective size screens is determined by passing the fraction through the same sieve it was retained upon during the first sieving. The sand and coarse fragments retained on the sieve are carefully washed with water to ensure that all dispersed particles pass through the sieve and only sand or course fragments stay behind. Tap water can be used since salt content of the water can no longer affect aggregation at this stage. The sieve is cleaned into a marked tray using the wash bottle The soil is then oven-dried at 105°C (Figure 4) and weighed.
To facilitate calculations, it is convenient to use the same marked tray for the first sieving and the sand correction. The retained weight is then subtracted from the original weight of that fraction.

Figure 1. Remoistened soil samples.

Figure 2. Stack of sieves.

Figure 3. Immersion of the stack of sieves in distilled water.

4. Alternative wet sieving method

If you do not dispose of the small sieves described in the method above, the 20 cm sieves used for dry sieving can be used. This method is more labor intensive and a little less accurate.

Extra materials required (Figure 5)

- Flat bottomed bowls (washbasins) of ±30 cm in diameter and ±8 cm in height
- Bottle with spray nozzle (wash bottle), to clean the sieves
- Large measuring cylinder
- measuring cup
- 20 cm diameter sieves with a mesh size of 4.00, 2.00, 0.250 and 0.053 mm
- Large metal trays

The trays that will be used to dry the samples in the oven should be weighed prior to sample processing. A representative 40 g sub-sample is obtained and placed in a 4 mm sieve in a washbasin, which is filled until the water is about 1.5 cm under the upper ring of the sieve. The soil sample is equally distributed across the sieve and left to soak for 5 minutes. During waiting, the floating organic residues have to be removed from the water. Thereafter, sieve the sample for 2 minutes. Do this by moving the sieve smoothly up and down under a small angle (± 3.5 cm vertical distance). The soil should come above the water surface with every movement, but maintain a slight angle to avoid air under the mesh. Carefully wash the sides and the bottom of the sieve with distilled water above the next sieve placed in a washbasin. Wash the material retained on the sieve into a marked tray.

Place the 2 mm sieve in the next washbasin and transfer all the water and soil from the previous washbasin into the sieve. You can use the bottle of distilled water to wash all the soil out of the first washbasin into the sieve, taking care not to point the water

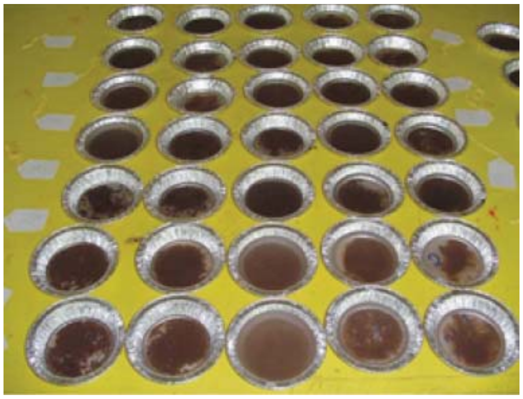

Figure 4. Soil samples after wet-sieving to be dried in the oven.

Figure 5: Setup for the alternative sieving method.

directly to the soil. The sieving process is repeated and the sieve cleaned into a marked, weighed tray. The process is then repeated for the 0.250 mm and 0.053 mm sieves, and the remaining <0.053 mm fraction is also poured into a tray. If this fraction is too large to fit into a tray, take a sub-sample. The sub-sample is taken with a measuring cup, while continuously stirring to make sure all the material is suspended. The tray with the sub-sample of the <0.053 mm fraction is weighed. The remaining quantity of the <0.053 mm fraction is measured in the measuring cylinder in order to be able to calculate the total <0.053 mm fraction later. The trays are placed in an oven at 105°C for 18–24 hours until they are completely dry.

Sand correction is performed in the same way as explained above for the other wet sieving method.

5. Calculations

$$MWD = \sum_{i=1}^{n} \langle d \rangle_i \, w_i$$

Where:

MWD = mean weight diameter (mm)

d = mean diameter of each size fraction size *i* (mm) (e.g., soil found in 1.00 mm sieve has 2.00 mm as maximum diameter and 1.00 mm as minimum diameter. Thus, mean weight diameter for such sieve is 1.50 mm).

w = proportion of total sample weight (g) – sand and coarse fragments weight (g) occurring in the size fraction *i*

n = number of size fractions

6. Worked Example

Soil sample 2041-Ia was sieved with sieves of 4.00, 2.00, 0.250 and 0.053 mm. The different fractions were placed into numbered, weighed trays and dried in an oven at 105°C for 24 hours. The following data were obtained:

Sample	Sieve (mm)	Plate No.	Weight plate (g)	Weight plate + Sub-sample <53 µm (g)	Rest volume <53 µm (l)	Dry weight Plate + soil (g)
2041-Ia	4.00	133	15.77	-	-	15.87
	2.00	132	15.86	-	-	15.89
	0.250	131	16.01	-	-	32.25
	0.053	130	15.98	-	-	35.02
	0	129	15.73	455.68	1.250	16.47

After drying, the weight of the fractions was calculated by subtracting the weight of the tray from the total weight of the tray + soil. For example, for the fraction smaller than 0.250 mm and larger than 0.053 mm:

35.02 - 15.98 = 19.04 g

The weight in the tray of the fraction smaller than 0.053 was calculated similarly and then the total weight of the <0.053 mm fractions was calculated. After sieving, 439.95 g of the remaining water was poured into a tray, while the remainder was measured to be 1.250 l and discarded. Because the amount of soil in the water is very small, we can simplify the calculation and state that the weight of the discarded water was 1,250 g. After drying, 0.74 g of soil remained in the tray, so the ratio of soil to water is:

0.74 g/439.95 g = 0.001682

This ratio allows us to calculate the total fraction <0.053 mm:

(1250 g + 439.95 g) * 0.001682 = 2.843 g

After this the total weight of the soil in the sample (36.18 g) and the proportion of each weight fraction could be calculated. In this example, the sand correction is omitted. For example, for the fraction smaller than 0.053 mm:

2.843 g/ 36.18 g = 0.07432

Thereafter the mean weight diameter of the soil sample could be calculated according to the formula:

$$MWD = \sum_{i=1}^{n} \langle d \rangle_i \, w_i$$

$$= (6\times0.002614)+(3\times0.0007843)+(1.125\times0.4245)+(0.1515\times0.4977)+(0.0265\times0.07432)=0.57 \text{ mm}$$

Data Sheet – Wet Sieving (Small sieves)

Sampling date: ……../………/……….. Experiment: ____________________________

Measurement date: ……../………/……….. Page: ……../………

Sample	Total sample weight (g)	Sieve (mm)	Plate No.	Weight plate (g)	Dry weight plate + soil (g)
		4			
		2			
		1			
		0.5			
		0.250			
		0.053			
		4			
		2			
		1			
		0.5			
		0.250			
		0.053			
		4			
		2			
		1			
		0.5			
		0.250			
		0.053			
		4			
		2			
		1			
		0.5			
		0.250			
		0.053			
		4			
		2			
		1			
		0.5			
		0.250			
		0.053			

Data Sheet – Wet Sieving (20 cm sieves)

Sampling date: ……../………/………..

Experiment: ____________________________

Measurement date: ……../………/………..

Page: ……../………

Sample	Sieve (mm)	Plate No.	Weight plate (g)	Weight plate + sub-sample <53 µm (g)	Rest volume <53 µm (g)	Dry weight plate + soil (g)
	4			-	-	
	2			-	-	
	0.250			-	-	
	0.053			-	-	
	0			-	-	
	4			-	-	
	2			-	-	
	0.250			-	-	
	0.053			-	-	
	4			-	-	
	2			-	-	
	0.5			-	-	
	0.250			-	-	
	0.053			-	-	
	0			-	-	
	4			-	-	
	2			-	-	
	0.250			-	-	
	0.053			-	-	
	0			-	-	
	4			-	-	
	2			-	-	
	0.250			-	-	
	0.053			-	-	
	0			-	-	
	4			-	-	
	2			-	-	
	0.250			-	-	
	0.053			-	-	
	0			-	-	

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