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Aggregate stability kit for soil quality assessments

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Abstract

Aggregate stability affects soil strength and, therefore, the soil's ability to transmit liquids and gases, which are important functions for crop production and ecosystem health. Because aggregate stability is an indicator of vital soil functions, it can be used to assess soil quality. For soil quality assessments, there is a need for a quantitative field method for measuring aggregate stability that is simple to perform, low cost, and available for routine assessments by land managers. A method is presented that follows the commonly used or standard single-sieve wet-sieving method for aggregate stability. A combination of manual sieving and drying apparatus is constructed from a trunk-style tackle box. Sieves are constructed from a 60-mesh screen and PVC reducing adapters. The method requires manual sieving, 30 cycles per minute (0.5 cycles/s) for 3 min. Percent water aggregate stabilities from the proposed manual sieving technique were not significantly different from aggregate stabilities obtained from the mechanical wet sieving technique. The proposed low cost method was able to distinguish differences in aggregate stability caused by differences in soil type and land use. This low cost method provides a tool that can be used in conjunction with other measurements to assess relative differences in soil quality.

Keywords: Aggregate stability; Method; Soil management; Soil quality

1. Introduction

Aggregation is a product of interactions of the soil microbial community, mineral and organic components, the composition of the above-ground plant community, and what

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has happened to the ecosystem in the past (Kemper and Koch, 1966; Tisdall and Oades, 1982; Goldberg et al., 1988). It is also a temporal variable property (Lehrsch and Jolley, 1992; Scott et al., 1994) that is affected by soil use and management (Angers et al., 1993; Tate, 1995; Dalal and Bridge, 1996). Soil aggregates and their stability have a strong influence on physical properties such as infiltration (hydraulic characteristics), aeration, soil strength, erosion, and the soil's ability to transmit liquids, solutes, gases, and heat (Topp et al., 1996). Thus, aggregate stability can provide key information about the capacity of soil to function, which defines soil quality. Boehm and Anderson (1997) have demonstrated that aggregate size and stability can indicate change in soil quality as a result of soil management.

Indicators of soil quality are measurable soil properties that influence the capacity of the soil to perform specific functions. Indicators should be easily measured and verifiable, sensitive to variations in soil management, have a relatively low sampling error (Carter et al., 1997), and be available for use by consultants, farmers or land managers (Karlen et al., 1997). However, there is no established quantitative low cost method for measuring water-stable aggregate that is available for everyone to use. Emerson (1967) developed a method of classifying aggregates based on subjective observations. Arshad et al. (1996) presents a method for measuring the water stability of

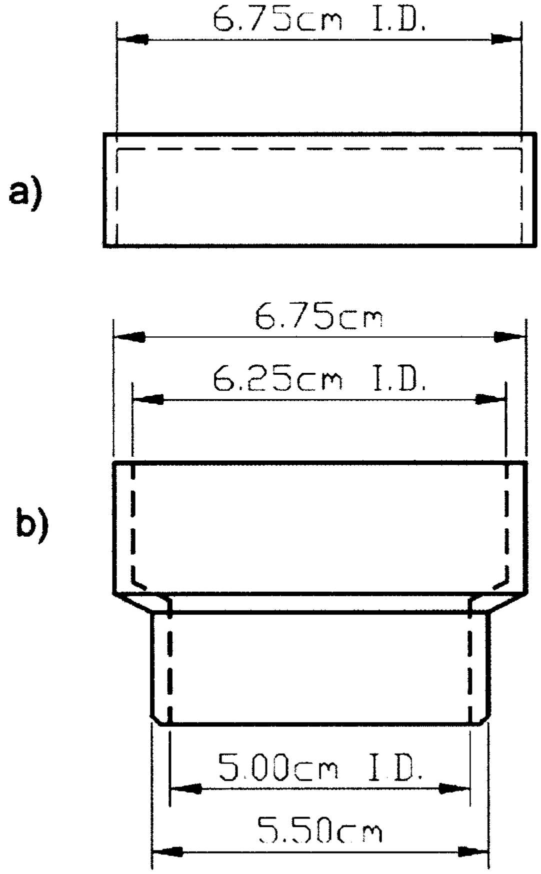

Fig. 1. Diagram of constructed 0.25-mm opening sieves: (a) lid made from Skippy jar lids and nylon cloth; (b) sieves made from 0.25-mm opening brass screen cut and glued to bottom of male PVC reducing adapter.

1–2 mm aggregates without using a mechanical wet-sieving machine, but does not correct for sand content above 1 mm.

The most common method for measuring aggregate stability in water is wet sieving (Kemper and Rosenau, 1986; Angers and Mehuys, 1993). A frequently used wet-sieving test is the single-sieve method proposed by Kemper and Koch (1966), and later modified by Kemper and Rosenau (1986). The objective of this paper is to present a low cost modified version of this method that does not require the use of a mechanized wet-sieving machine and can be easily constructed from locally purchased materials. The manual versus the mechanized wet-sieving technique was compared, and the proposed method is demonstrated on different soil types and land uses for soil quality assessments.

2. Construction of aggregate stability kit

Eight 0.25-mm opening sieves were constructed from a 60-mesh brass screen (0.25-mm openings), cut and mounted on the bottom (smaller end) of 5.08-cm male PVC reducing adapters (Fig. 1b) using PVC cement, epoxy, or other thick glue. A trunk-style tackle box (34 × 20 × 15 cm) was used for wet-sieving a set of eight sieves (Figs. 1b and 2b) and used as a drying chamber (Fig. 2e). The inside tray of the tackle box was removed. Six 6-cm diameter holes were drilled through the top of the tackle

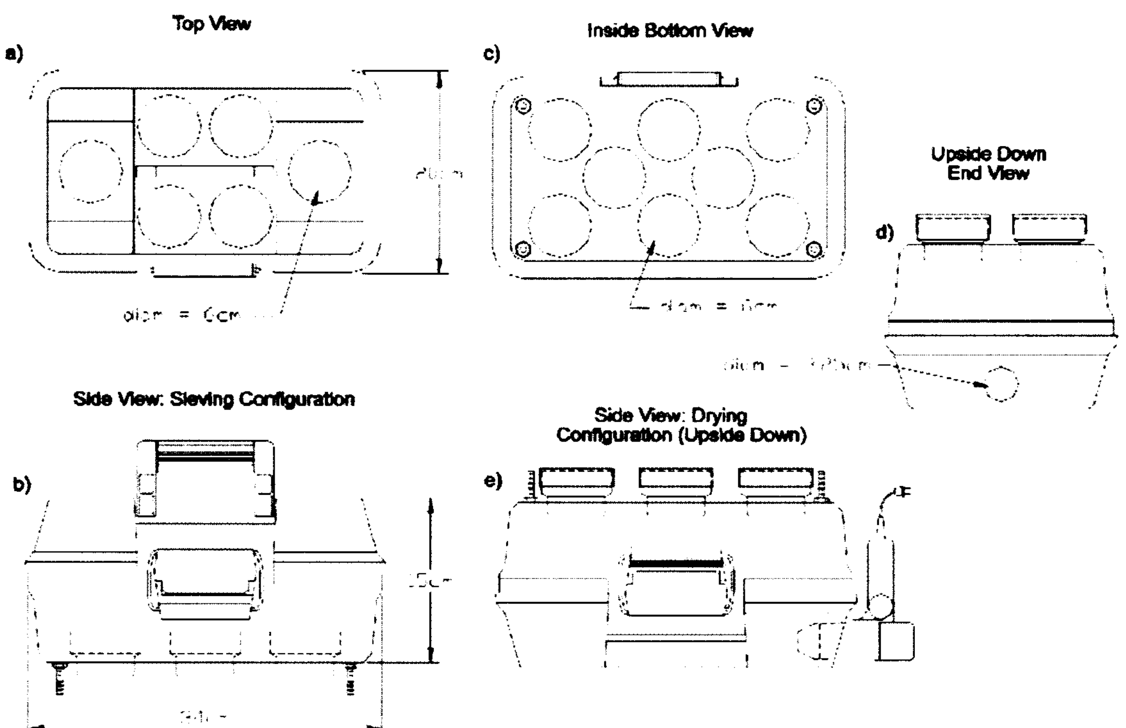

Fig. 2. Diagram of constructed combination sieving and drying apparatus: (a) six 6-cm viewing holes in top of trunk-style tackle box; (b) side view of sieving configuration with sieves; (c) inside bottom view of tackle box showing eight 6-cm sieve holders; (d) upside-down end view of tackle box showing insertion hole for hair-dryer; (e) side view of tackle box showing drying configuration with sieves and hair dryer.

Table 1
Classification and site location of soils used for aggregate stability determinations

Soil series	Classification	Site location
Belen	Clayey over loamy, smectitic, calcareous, thermic Vertic Torrifluvents	Dona Ana county, NM
Capac	Fine-loamy, mixed, mesic Aeric Endoaqualfs	Ingham county, MI
Cullen	Very-fine, kaolinitic, thermic Typic Hapludults	Charlotte county, VA
Harrisburg	Coarse-loamy, mixed, thermic Typic Petrocalcids	Dona Ana county, NM
Kalamazoo	Fine-loamy, mixed, mesic Typic Hapludalfs	Kalamazoo county, MI
Philomath	Clayey, smectitic, mesic, shallow Vertic Haploxerolls	Benton county, OR
Plainfield	Mixed, mesic, Typic Udipsamments	Waushara county, WI
Zilwaukee	Fine, mixed, calcareous, mesic Typic Endoaquolls	Saginaw county, MI

box (Fig. 2a). These holes allow for viewing of the sieves while wet sieving. Eight 6-cm diameter holes were drilled into the bottom of the tackle box in the pattern as shown in Fig. 2c. These holes hold the sieves, both for wet sieving (Fig. 2b) and drying (Fig. 2e). A 3.25-cm diameter hole is drilled into the center of the top half of one end of the tackle box (Fig. 2d) for insertion of a 400-W hair dryer (Fig. 2e). A 2.54-cm rubber grommet can be used to line the 3.25-cm hole to create a good seal when the hair dryer is inserted. Four 0.64-cm holes were drilled in each inside bottom corner of the tackle box (Fig. 2c). Four 3.8-cm-long bolts (0.64 cm diameter) were inserted through the holes (from inside the tackle box) and bolted from the outside (Fig. 2b). These bolts act as a support stand to give clearance for the sieves when positioned in the 6-cm holes inside the tackle box (Fig. 2b). Total cost to build the kit is about US$25.00.

3. Soils

The method is designed for use on all soil types where aggregate stability is a concern. Surface soils were collected from different parts of the United States and varied in soil texture and land use (Table 1). Two of the eight soils are arid soils (Belen and Harrisburg soils). Soil samples were collected from the 0–7.6-cm depth and allowed to air-dry (48 h) if they were moist. The samples were gently passed through a 2-mm sieve to remove gravel. Almost all of the soil was gently pushed through the sieve. The sieved material was thoroughly mixed before taking subsamples for aggregate stability determinations.

4. Method

Each of the eight 0.25-mm sieves were placed on the scale and weight recorded. About 10 g of sieved soil was placed in the 0.25-mm sieve and total weight recorded (sieve plus soil weight). A section of terry cloth was saturated with deionized or distilled water and laid flat on an impermeable surface (table top). The 0.25-mm sieves containing the soil were placed on the saturated cloth, allowing the soil to wet up through capillary action for 5 min. After wetting, the 0.25-mm sieves were placed in the inside bottom of the tackle box, in 6-cm diameter holes, and tackle-box lid closed. The tackle box, containing the sieves, is lowered into a tub of deionized or distilled water. The water temperature should be at or near the temperature of the soil. While observing through the viewing holes on the top of the tackle box, the sieves were immersed so that the water surface was just above the soil sample. The tackle box was moved up and down in the water through a vertical distance of about 1.5 cm at the rate of 30 cycles per minute (one cycle is an up and down stroke of 1.5 cm in length) for 3 min (0.5 cycles/s). Other specifications can be used, but it must be consistent throughout the measurements. Kemper and Rosenau (1986) used 36 cycles per minute for 3 min through a vertical distance of 1.3 cm. Care was taken to make sure the aggregates remained immersed in water on the upstroke. After wet sieving, the sieves containing the aggregates were placed on a dry piece of terry cloth, which absorbed the excess water from the aggregates. The empty tackle-box was closed and placed upside-down and a 400-W hair dryer inserted through the 3.25-cm side hole (Fig. 2e). The sieves, containing the aggregates, were placed in the 6-cm holes on the inverted tackle box (Fig. 2e). The hair-dryer was turned on and aggregates allowed to dry. To prevent any soil particles from blowing out of the sieves, it may be necessary to place a cover over the top of the sieves (Fig. 1a). From our experience, lids have not been necessary. Covers were constructed from 6.75 cm (I.D.) plastic lids (Skippy peanut butter jar lids). The inside portion was cut out and lined with nylon cloth (Fig. 1a). Instead of using the electric hair dryer, aggregates in the sieves can be air-dried. After drying, the weight of each sieve plus aggregates was recorded. To determine the amount of sand, the sieves containing aggregates were immersed in 10 g l^{-1} calgon solution (dispersant) for 5 min, moving the sieves up and down periodically. The sieves were rinsed by passing a jet of water (i.e., faucet, squirt bottle) through the sieves until only primary particles > 0.25 mm remained. The sieves were placed on a section of dry terry cloth to remove excess water and then placed on the inverted tackle box for drying as described above. After drying, the weight of the sieve plus sand was recorded.

Percent water-stable aggregates (% of soil > 0.25 mm) was calculated as (weight of sieve plus dry aggregates − weight of sieve plus dry sand) ÷ (weight of sieve plus air-dried soil − weight of sieve plus dry sand) × 100 (Kemper and Koch, 1966).

5. Laboratory wet-sieving method

The manual-sieving method was compared to the mechanized-sieving method. The same procedure for sample preparation and pretreatment as described above were used for the mechanized-sieving method except for the mechanical sieving apparatus and sieves (Kemper and Rosenau, 1986, pp. 429–430). The mechanical sieving apparatus holds eight single 0.25-mm opening sieves (3.6 cm diameter) with stainless steel screens. Stroke length was adjusted to 1.5 cm. Cycles were adjusted to about 30 per minute for 3 min. Sieve loading rates in the 3.6 cm diameter sieves of the mechanical method were held constant by reducing the mass of soil to about 7 g. After the wet-sieving and sand correction procedures, sieves containing aggregates or sand were dried in an oven at 60°C. All other procedural steps were conducted as described in the proposed low cost method.

6. Results and discussion

For the assessment of soil quality, aggregate stability tests should be developed to maximize sensitivity to soil changes as a result of management. Aggregates greater than 0.25 mm are considered macroaggregates, which are affected more readily by soil use and management than microaggregates, < 0.25 mm (Tisdall, 1996). Within the macroaggregate size range, the 1–2 mm size fraction is commonly used to determined aggregate stability (Kemper and Rosenau, 1986; Angers and Mehuys, 1993; Arshad et al., 1996). However, Gijsman (1996) has shown greater sensitivity to management-induced treatment differences by determining the stability of a larger size range of macroaggregates (0.25–2.0 mm). For greater sensitivity and ease of use, our proposed method determines the percentage of water-stable macroaggregates in the 0.25–2.0 mm size range, corrected for sand (> 0.25 mm).

The amount of soil or loading rate on the sieve can affect the amount that falls through during the wet-sieving process. Beare and Bruce (1993) reported that a loading rate of 0.66 g cm^{-2} gave reproducible results. This rate was confirmed in independent tests using the procedure described here (unpublished data). The single-sieve standard method (Kemper and Rosenau, 1986) uses a loading rate of 0.40 g cm^2. Our method uses a loading rate of 0.51 g cm^2. The higher loading rate was chosen to increase the amount of soil analyzed and improve ease of measurement by the user. Lower loading rates can be used, but it must be consistent throughout the measurements.

The method of wetting or pretreatment of the sample greatly affects the stability of aggregates (Kemper and Rosenau, 1986; Beare and Bruce, 1993). Wetting air-dry soil through capillary action to near saturation is used in our low cost method to standardize this procedure. Beare and Bruce (1993) have shown that wetting of air-dried soil tended to emphasize differences in macroaggregation. The stability of macroaggregates depends on management (Tisdall, 1996). Better sensitivity to changes in soil function as a result of management may be an advantage to wetting air-dried soil.

The proposed aggregate stability method was measured on split samples from six soils of varying texture (Table 1). Percent water-stable aggregates (WSA) varied significantly between the six soil types. In general, % WSA increased as the clay content of the soils increased. This is consistent with the results reported by Kemper and Koch (1966).

The manual sieving method (using the modified tackle box) was compared to the mechanized sieving technique (Table 2). Comparison of methods on the six soils showed no significant difference in % WSA, indicating no difference in techniques. The average coefficient of variation (CV) for the manual and mechanized method was 5.4% and 4.6% for % WSA corrected for sand, respectively (Table 2). Slightly higher CVs were obtained for the coarse textured soils compared to the finer textured soils. This is consistent with Kemper and Koch (1966) who obtained an average CV of 4.0% for coarse-textured soils and an average CV of 1.2% on fine-textured soils. Using the

Table 2
Comparison of percent water stable aggregates (WSA) > 0.25 mm from the mechanized wet-sieving and manual wet-sieving methods

Soil Series	Textural class	*n*	Sieving method	WSA (%)	CV (%)	Corrected for sand	
						WSA (%)	CV (%)
Philomath	Silty clay loam	4	Manual	94 (4.1)[a]	4.4	88 (4.2)	4.7
		4	Mechanized	96 (2.3)	2.4	88 (2.1)	2.4
Cullen	Clay loam	4	Manual	78 (3.8)	4.8	69 (3.4)	4.8
		4	Mechanized	81 (3.3)	4.1	70 (3.3)	4.8
Belen	Sandy clay loam	4	Manual	60 (1.8)	3.0	56 (1.9)	3.4
		4	Mechanized	57 (4.3)	7.5	53 (4.4)	8.3
Capac	Loam	4	Manual	71 (1.8)	2.6	61 (2.0)	3.2
		4	Mechanized	76 (1.5)	2.0	62 (1.0)	1.6
Plainfield	Sandy loam	4	Manual	80 (4.1)	6.1	40 (3.3)	9.0
		4	Mechanized	85 (1.5)	1.8	41 (2.6)	6.4
Harrisburg	Loamy sand	4	Manual	52 (6.6)	12.7	32 (2.4)	7.5
		4	Mechanized	66 (2.9)	4.4	33 (1.4)	4.3

[a]Numbers in parentheses are standard deviations.

standard WSA test, Amezketa et al. (1996) obtained CVs of < 5% with four replicates. This CV was considered to indicate that the test was both precise and reproducible. The low CVs obtained in our study suggest that our low cost method, when performed correctly, can also give precise and reproducible results.

When reporting % WSA, a correction for sand is commonly performed. This is because individual sand grains may act as aggregates and contribute to the amount of water-stable aggregates (Kemper and Koch, 1966). The % WSA in Table 2 are higher before correction for sand, indicating that sand (> 0.25 mm) is contributing to the total amount of stable aggregates, which confirms the need to correct for sand. As expected, the effect is more pronounced in the coarse-textured than in the fine-textured soils (Table 2).

Percent water-stable aggregates were determined using the proposed method on three soil types across two land uses (Table 3). Again, greater % WSA were obtained as the clay content increased. Significantly greater % WSA were obtained on the forest sites

Table 3
Percent water stable aggregates (% of soil > 0.25 mm) using field method; comparison on a range of soil textures across two land uses

Soil series	Textural class	Land use	Water stable[a] aggregates (%)	Coefficient of variation (%)
Zilwaukee	Silty clay	Forest	87.7 (86.6–88.8)[b]	1.5
		Cultivated	72.7 (67.7–77.7)	8.4
Capac	Loam	Forest	59.3 (56.8–61.8)	5.2
		Cultivated	35.3 (32.5–38.0)	9.4
Kalamazoo	Sandy loam	Forest	54.8 (51.7–57.9)	6.9
		Cultivated	39.3 (36.5–42.1)	8.4

[a]Percent water stable aggregates corrected for sand (% of soil > 0.25 mm).
[b]Numbers in parentheses are 90% confidence intervals.

than on the cultivated sites on the same soil type. This is consistent with other studies showing greater aggregate stabilities on uncultivated or virgin soils than on cultivated soils (Panabokke and Quirk, 1957; Haynes and Swift, 1990; Golchin et al., 1995). This indicates that this proposed low cost method can distinguish changes in % WSA that are caused by differences in land use and management. Soil quality indicators should be able to detect changes in soil functions as a result of management.

7. Conclusions

The aggregate stability kit can be constructed and performed by any land manager or consultant without the use of expensive lab equipment. There was no difference in aggregate stability results when the manual sieving technique, in the low cost method, was compared to the mechanical wet-sieving technique. This low cost method can distinguish differences in aggregate stability resulting from differences in soil type and land use. When performed to the specifications presented here, this low cost aggregate stability kit can provide a low cost, reliable, and sensitive tool that can be used in conjunction with other measurement to assess relative changes in soil quality.

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