DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Agriculture and Natural Resources

FSA2229

Aggregate Stability as an Indicator of Soil Health

Grant Bennett
Program Associate,
Crop Soil & Environmental Sciences

Dr. Kristofor R. Brye
University Professor,
Applied Soil Physics and Pedology

Shelby Lebeau
Environmental Science Lab Coordinator/Instructor

Dr. Mike Daniels
Distinguished Professor,
Extension Soil and Water Conservation

Sophie Sward
Graduate Student,
Crop Soil & Environmental Sciences

James M. Burke
Program Associate,
Crop Soil & Environmental Sciences

Arkansas Is Our Campus

Visit our website at:
https://www.uaex.uada.edu

Introduction

Soil health has been gaining interest among producers and researchers in recent years. The trend can largely be attributed to rising input costs that threaten the profitability of agricultural operations in the mid-Southern United States. Implementing management practices that prioritize improving soil health can reduce those input costs.

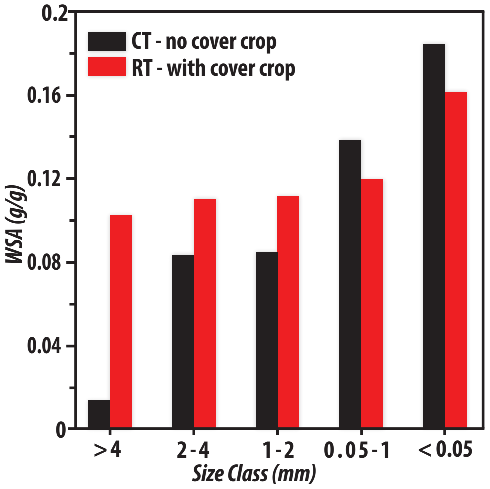
Soil health encompasses physical, chemical and biological indicators. Improving soil physical structure can positively impact all three facets of soil health indicators, including aggregate stability.

"Aggregate stability" describes a soil aggregate's (i.e., peds) ability to resist being broken apart by outside forces, such as raindrop impact. Improving aggregate stability not only strengthens soil structure, it also improves nutrient cycling, air and water flow and water storage, providing habitat for essential soil microbes as well.

Soil Aggregate Formation

Soil aggregates are groups of soil particles bound together by biological and chemical attraction (NRCS, 2017). Biologically, microbial by-products, such as glomalin, released in the soil act as a type of glue that keeps soil particles bound to one another. Plant roots act as a system of threads that bind particles together, while root exudates act as another glue-like adhesive (Shedekar, 2018). Chemically, soil particles are also bound together via flocculation of soil colloids (i.e., clays) with polyvalent cations and in the presence of iron oxides, organic matter and/or carbonates.

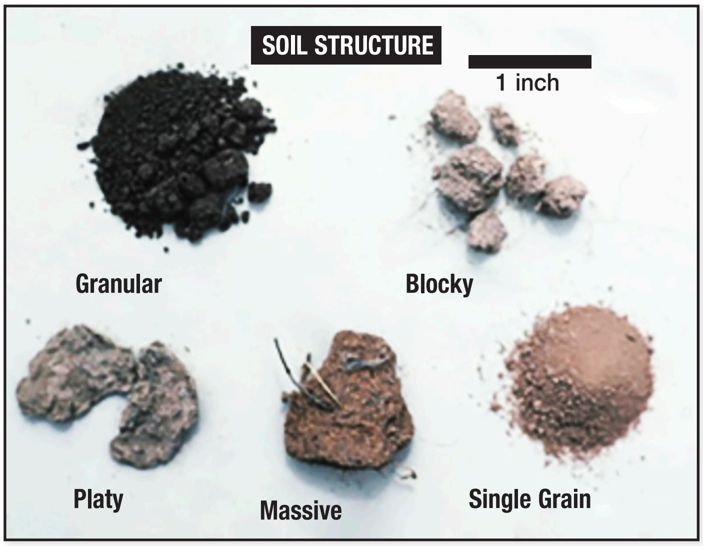
Figure 1: Mean water-stable aggregate (WSA) concentrations among aggregate size classes.



Soil aggregates can be divided into two general size categories, micro- (< 0.25 mm in diameter) and macroaggregates (> 0.25 mm in diameter (Figure 1). Micro- and macroaggregates serve different purposes in the soil but are both vital to soil functioning and overall soil health. Microaggregates are generally more stable than macroaggregates and better able to resist being broken up by soil disturbances. Both forms store soil organic carbon (SOC), but macroaggregates store more easily accessible SOC that soil microbes can use as a food source. Microaggregates store SOC contained in soil organic matter (SOM) and are protected from microbial decomposition. The main sources of microaggregation in soil are organo-mineral complexes (OMC), which are formed by SOM combining with minerals in soil (Quan et al., 2020). Organo-mineral complexes are another binding agent for soil particles that promote aggregate stability when subjected to mechanical- or water-induced disruption. While microaggregates are more resistant to disruption, microaggregates are formed inside macroaggregates. Therefore, if macroaggregates are broken apart before microaggregates can form, the long-term storage of SOC and SOM may be compromised (Starr, 2024).

The arrangement of micro- and macroaggregates in a soil determines the soil structure (Figure 2). The surface layer of healthy, undisturbed soil typically has a granular structure, with rounded macroaggregates made up of smaller microaggregates. In contrast, a degraded soil surface may become crusted, platy or even lack structure altogether (NRCS, 2017).

Figure 2: Common soil structure types: granular, blocky, platy, massive, single grain (NRCS, 2017).



Factors Influencing Soil Aggregates

The presence of clay and SOM enhances aggregate stability because both carry a net or partial negative charge, respectively. Soil organic matter, specifically, is considered the most critical component of aggregate stability, as the formation of microaggregates occurs partially because of clay particles binding to organic molecules (Arel et al., 2022). Polyvalent cations, such as calcium (Ca^{2+}) and magnesium (Mg^{2+}), act as bridging agents, binding negatively charged particles together and helping to provide integrity to soil aggregates (Wuddivira & Camps-Roach, 2007). Unlike cations such as Ca^{2+} and Mg^{2+}, excess sodium ions (Na^{+}) present in soil contribute to the dispersion of clay particles rather than flocculation. This dispersion happens because the positively charged Na^{+} ions take up space on cation exchange sites, but do not have charges that are strong enough to bind clay particles together.

Additionally, climatic conditions impact aggregate formation and stability. In Arkansas specifically, the warm, humid climate, coupled with disruption from tillage, increases crop residue contact with soil, promoting accelerated SOM decomposition. Subsequently, Arkansas soils often contain low SOM levels (<2.5%), which reduce the availability of negative charges for polyvalent cations to flocculate soil colloids and reduce the presence of microaggregates. Subsequently, Arkansas soils often contain low SOM levels, which reduce the availability of negative charges for polyvalent cations to flocculate soil colloids and reduce the formation of microaggregates.

Soil texture heavily influences soil aggregates. Specifically, the presence of clay particles in soil contribute to aggregation because of the ability of clay to bind particles together better than silt or sand. However, soils containing large concentrations of 2:1 clays are prone to shrinking and swelling during the wetting and drying process. This shrink-swell cycle can result in disaggregation due to the movement of clay particles. Also, dry clay soils that are rapidly hydrated are more prone to bursting apart due to air being trapped within and the pressure of the air and water, leading to a breaking point.

Soil pH also influences soil aggregation, as pH plays a part in chemical and biological soil functions that also influence aggregate stability. For instance, increasing soil pH is shown to increase microbial activity which promotes plant growth and increased SOM concentrations.

Additionally, as soil becomes more alkaline, flocculation of clay particles and formation of larger soil aggregates occur (Arel et al., 2022; Lebeau et al., 2024).

Soil's ability to form stable aggregates that resist disintegration is necessary for soil to carry out functions that support plant, animal and microbial life. Management practices that do not promote aggregate formation and SOM accumulation often result in production limitations that can only be remedied with increased inputs, which in turn increase costs.

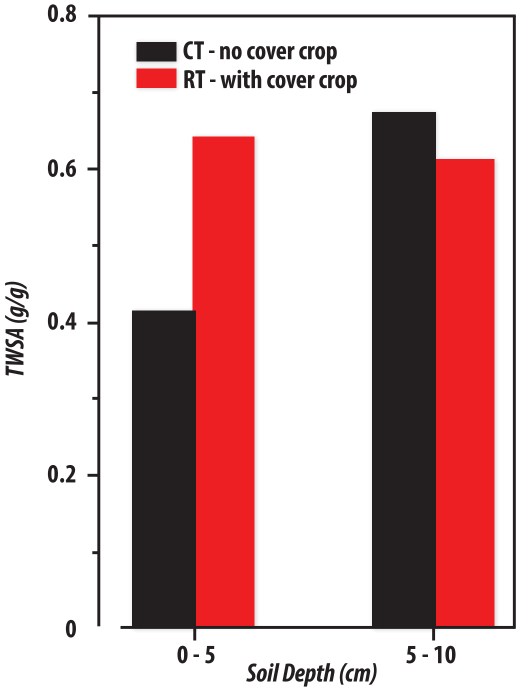
Production Constraints

Conventional management practices such as routine tillage in the Lower Mississippi River Valley, while useful for seedbed preparation and weed control, have been shown to contribute to soil degradation over time (Figure 3) (Fanning et al., 2025; Arel et al., 2022; Lebeau et al., 2024).

Physical soil degradation can lead to low SOM, increased erosion, reduced water infiltration, increased water runoff, low water holding capacity, surface crusting, compaction and nutrient loss via runoff.

Any tillage practice will inevitably break apart soil aggregates. However, the frequency and depth of tillage influence long-term effects. Frequent tillage that penetrates deep into the soil profile breaks up aggregates throughout nearly the entire rooting depth of crops and does not give the soil adequate time to re-form stable aggregates. Additionally, leaving the soil fallow between growing seasons contributes to erosion, as there is no vegetative cover protecting the soil surface. Increasing oxygen presence and soil-to-crop residue contact via tillage create ideal conditions for rapid SOM decomposition, especially in warm, humid climates that favor microbial activity, such as that of the LMRV.

Figure 3: Mean total water stable aggregates (TWSA) at 0-5 and 5-10cm (or 0-2 and 2-4inch) depths in conventional till without cover crop and reduced till with cover crop treatments.



Tilled soil that is left fallow between growing seasons is exposed to wind and precipitation that can cause soil with poor structure to break apart. Upon disintegration, the soil particles are either lost via wind and water movement, or clog soil pores. Clogged pores lead to surface crust during and after precipitation or irrigation events, preventing water from infiltrating the soil. Instead, water runs off the field carrying sediment and nutrients with it.

Additionally, lack of infiltration due to crusting deprives crops of necessary moisture. To remedy crusting, further tillage is often necessary, followed by irrigation to supplement plants with the moisture they missed from the previous rainfall.

Compaction is a major concern for producers in the LMRV. Compacted soil restricts the movement of air, water and plant roots, preventing crops from accessing nutrients and moisture held lower in the soil profile.

Tillage is often used to alleviate compacted soil, but poorly aggregated soil will settle back into the compacted state after further equipment passes through the field.

Growers sometimes use further inputs to alleviate the physical degradation of the soil. But as fuel, labor and equipment costs continue to rise, this is becoming increasingly unfeasible for most producers.

Conservation Management

Conservation management can help alleviate production constraints caused by soil degradation. The NRCS identifies four principles of soil health: minimizing disturbance, maximizing living roots, maximizing soil cover and maximizing biodiversity.

Reduced tillage involves tilling soil only when necessary and at shallower depths. This affects aggregates near the surface and allows more time for micro- and macroaggregate formation. Additions of organic soil amendments, such as biochar, poultry litter and/or manure, contribute to SOM accumulation and benefit soil microorganisms, which can result in enhanced aggregation (Hanauer et al., 2019).

The continuous presence of aboveground vegetation protects the soil surface from erosion and keeps living roots, which help bind aggregates, in the ground.

Producers can provide continuous soil-surface protection by planting cover crops in the fall. Cover crops not only protect the soil surface, but also contribute to SOM, suppress weeds and insects and limit water and nutrient runoff and leaching (Roberts et al., 2018).

Improving soil physical structure through increasing aggregate stability can help maximize biodiversity, which is a biological indicator of soil health. Reducing soil disturbance and increasing SOM provides beneficial soil microbes with the habitat and food source they need, and aids in necessary soil functions such as nutrient cycling.

Aggregate Stability Measurement

The most common method of quantifying aggregate stability is wet sieving. Wet-sieve analysis involves multiple, stacked sieves, with mesh count gradually increasing from top to bottom. The sieves are submerged in water and mechanically agitated (Figure 4).

Soil peds are placed on the top sieve, which has the largest holes in the mesh, and the mechanical arm begins to raise and lower the sieve nest. Disaggregation begins due to the movement of the sieves in the water, along with the sudden influx of water into the dry peds, which creates pressure from the trapped air and water, resulting in soil breaking apart or "slaking." Aggregates remaining on top of each sieve are collected and dried. The mass in each size class is determined to calculate water-stable

Figure 4: Wet-sieve apparatus that utilizes five sieves of gradually increasing mesh count that are submerged in water and mechanically agitated by raising and lowering continuously.

aggregate concentration by size class to total WSA concentration. This indicates the aggregates' ability to resist disintegration (Elliott, 1986). Measuring aggregate stability using the wet sieve method helps determine the proportion of aggregates that remain intact after being subjected to mechanical and hydraulic forces.

Conclusions

Strengthening soil aggregate stability is central to improving the physical and subsequent chemical and biological functioning of agricultural soils, particularly in regions like the LMRV, where degradation and rising input costs challenge long-term productivity. By understanding how aggregates form, the factors that influence their stability and the consequences of management decisions that disrupt soil structure, producers can make informed choices that support resilient soils. Conservation practices that adhere to the aforementioned principles of soil health offer practical, cost-effective pathways to enhance aggregation while reducing dependency on expensive inputs. Ultimately, improving aggregate stability not only enhances soil health but also contributes to more sustainable and profitable agricultural systems for Arkansas producers.

References

Arel, C., Brye, K.R., Fryer, M., & Daniels, M. (2022). *Cover crop effects on near-surface soil aggregate stability in the southern Mississippi valley loess* (MLRA 134). Agricultural Sciences, 13:741-757.

Elliott, E.T. (1986). *Aggregate structure and carbon, nitrogen, and phosphorus in native and cultivated soils.* Soil Science Society of America Journal, 50:627-633.

Fanning, C., Brye, K.R., Daniels, M., Roberts, T.L., Fernandes, S., & Wood, L. (2025). *Cover-crop effects on near-surface soil physical properties, infiltration, and nematodes over time in the Lower Mississippi River Valley*. Agrosystems, Geosciences & Environment, 8(70119).

Hanauer, A., Weidhuner, A., Kazakevicius, A., & Sadeghpour, A. (2019). *Soil aggregation and aggregate stability*. Southern Illinois University. [Fact sheet]. Retrieved from: https://projects.sare.org/media/pdf/A/g/g/Aggregation-Factsheet.pdf.

Lebeau, S.G., Brye, K.R., Daniels, M., & Wood, L.S. (2024). *Cover crop and wheel-track effects on soil properties under cotton production in eastern Arkansas*. Agrosystems, Geosciences & Environment, 7(20549).

Natural Resource Conservation Service (NRCS). United Stated Department of Agriculture. (2017). *Rangeland soil quality - aggregate stability*. [Web]. Retrieved from: https://www.nrcs.usda.gov/sites/default/files/2022-12/Rangeland_Soil_Quality_Aggregate_Stability_2.pdf.

Quan, G., Fan, Q., Sun, J., Cui, L., Wang, H., Gao, B., & Yan, J. (2020). *Characteristics of organo-mineral complexes in contaminated soils with long-term biochar application*. Journal of Hazardous Materials, 384(121265).

Roberts, T., Ortel, C., Hoegenauer, K., Wright, H., & Durre, T. (2018). *Understanding cover crops*. University of Arkansas Division of Agriculture. [Fact sheet]. Retrieved from: https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/horticulture/FSA-2156.pdf.

Shedekar, V. (2018). *Soil aggregate stability – a soil health physical indicator*. Ohio State University Extension. [Web]. Retrieved from: https://agcrops.osu.edu/newsletter/corn-newsletter/2018-02/soil-aggregate-stability-%E2%80%93-soil-health-physical-indicator.

Starr, L. (2024). *Soil health spotlight: soil structure and aggregation*. Agronomy eUpdates. Kansas State University. [Web]. Retrieved from: https://eupdate.agronomy.ksu.edu/article/soil-health-spotlight-soil-structure-and-aggregation-372-3.

Wuddivira, M.N., & Camps-Roach, G. (2007). *Effects of organic matter and calcium on soil structural stability*. European Journal of Soil Science, 58:722-727.

GRANT BENNETT is a program associate in the department of Crop, Soil & Environmental Sciences with the University of Arkansas System Division of Agriculture Cooperative Extension, Little Rock. **DR. KRISTOFOR R. BRYE** is a university professor in applied soil physics and pedology. **SHELBY LEBEAU** is an environmental science lab coordinator/instructor. **DR. MIKE DANIELS** is a distinguished professor with Extension Soil and Water Conservation. All three are located at the University of Arkansas in Fayetteville. **SOPHIE SWARD** is a graduate student and **JAMES BURKE** is a program associate both in the department of Crop, Soil & Environmental Sciences with the University of Arkansas System Division of Agriculture Cooperative Extension, Little Rock.

FSA2229-PD-1-2026