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Key to Soil Resiliency: Understanding Soil Aggregate Stability

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Aggregate stability is an important physical property of soil and a key soil health indicator. It reflects soil resiliency against natural eroding agents like water, air, and human activity. This allows the soil to maintain structure despite being under various environmental stressors. Soil aggregates are clusters of soil particles that are stuck together by various binding materials such as soil organic matter (especially soil organic carbon), clay, and microbial adhesive agents. Stable soil aggregates can lead to a well-structured soil environment that promotes plant growth, water infiltration, nutrient storage, and eventually increases agricultural productivity (Figure 1).

The Role of Soil Aggregate Stability in Soil Health

Soil aggregates act as the building blocks of soil health. By being clumped together (aggregated), soil particles and aggregates create pore spaces that allow plant roots, air, and water to move freely. Pore spaces also become a hub for nutrients and carbon to be stored in, supporting carbon sequestration (locking away carbon dioxide within the soil). Additionally, beneficial soil microbes reside in the protected microclimate present in tiny pores (known as 'micropores') within soil aggregates; this protects them from desiccation under stressful soil conditions like extreme temperatures and drought, which is predominant in desert ecosystems of the Southwest. Furthermore, stable aggregates are also essential in helping protect the soil from erosion (the particles are tightly held together), compaction (maintains essential pore spaces), and nutrient loss (sequestering carbon and nutrients).

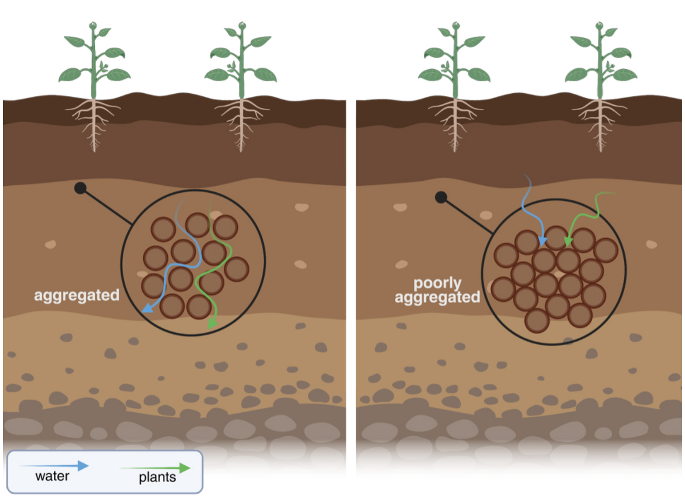

Figure 1. Water and plant roots move more easily through well-aggregated soil but can get "stuck" in poorly aggregated soil.

Erosion Resistance: Stable aggregates reduce the risk of erosion, preventing soil particles from being dislodged and carried away by water, wind, or human activity. This is especially important in regions like Arizona, where sudden, intense rainfall can cause flash flooding and topsoil loss. Wind is a dominant eroding effect (Arizona Geological Survey, n.d.).

Water Infiltration and Storage: When water is infiltrated into the soil through the pore spaces created by soil aggregates, it reduces runoff and increases water storage and availability to plants. Soils with high aggregate stability are also better equipped to handle extreme weather conditions such as heavy rainfall or drought (Moebius-Clune et al., 2017). In Arizona, even small amounts of rainfall can cause flooding when the soil is highly compacted. Thus, flooding can indicate poor soil aggregation. This is because compacted soil lacks the intricate network of pore spaces that well-aggregated soils provide (USDA NRCS, n.d.).

Carbon Sequestration: Soil aggregates play a key role in carbon storage and sequestration. Soil organic carbon is essential for healthy soils (Aswin & Sanyal, 2025) and can be trapped within tiny pore spaces (micropores) in well-aggregated soil. This prevents it from being released into the atmosphere as carbon dioxide (CO2). This process contributes to carbon sequestration, which is a vital part of mitigating climate change and creating environmental resilience (Six et al., 2004). In the desert Southwest, soil is often prone to wind erosion due to a lack of binding materials such as soil organic carbon. Under high soil temperature and high ambient temperature, the rate of microbial decomposition of soil organic carbon is higher, and therefore it is essential to build soil aggregates to preserve soil organic carbon building towards a healthier soil ecosystem.

Nutrient Cycling: Microbes break down organic matter in the soil, which helps release essential, plant-available nutrients like nitrogen and phosphorus. Soil aggregates provide the habitat for microbes to thrive and proliferate. Often soil aggregates trap soil organic matter in spaces inaccessible to microbes, therefore slowing the decomposition of organic matter, which ensures a steady supply of nutrients to plants over time (Bronick & Lal, 2005).

Monitoring and Assessment

To understand soil health and to aid in decision-making for land management, soil aggregate stability is an essential factor to monitor. There are several methods to assess aggregate stability that include:

Visual Observation: Farmers can look at soil and determine if it is well-aggregated by deciding if it has a crumbly texture, which would indicate strong aggregation. If the soil is more compact or powdery, this indicates poor aggregation (Bronick & Lal, 2005).

Wet Aggregate Stability (Slake Test): This analysis evaluates the proportion of stable and unstable aggregates within the soil. The method involves placing a soil sample into a sieve that is on an oscillating apparatus; this video explains the test: https://shorturl.at/ZxPcB. Then, the soil is subjected to a standardized erosion activity, and the soil's resiliency is measured against it (Garcia et al., 2022). The value ranges from 0-1, where 0 means no aggregation and 1 represents perfect aggregation or no erosion.

Management Practices

To improve soil aggregate stability, sustainable agricultural practices should be implemented that strengthen soil structure and promote soil organic matter build-up (Figure 2). Some effective management practices include:

Conservation tillage: Tillage physically disrupts the soil, breaking up soil aggregates and deteriorating soil structure. Practicing conservation tillage by either) minimizing mechanical disturbance, leaving at least 30% of the soil surface with crop residue, or b) adopting no-till practices, which avoids any disturbance to the soil. These are two different methods for preserving soil aggregate stability (Busari et al., 2015). Both practices also reduce the risk of soil compaction.

Figure 2. Plant roots growing through soil aggregates. Nutrients are stored within the clumps, making it easier for the plant to access them. (Photo: Authors)

Planting cover crops: Cover cropping instead of fallowing can be an effective way to reduce erosion and protect the soil beneath. The roots of cover crops can help soils stay aggregated and protect against eroding forces, such as wind and water.

Conclusion

Soil aggregate stability is a key soil health indicator that influences erosion prevention, water infiltration, and plant growth. By adopting monitoring techniques like the wet aggregate stability test and implementing sustainable farming practices, soil resilience is bound to improve. These efforts are becoming increasingly critical in arid places like Arizona, where soil water storage and soil erosion preservation are essential in agricultural sustainability.

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