

Reading the frontier: A year in our journals

By Aaron Lee M. Daigh

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A year of reading across SSSA journals revealed unexpected connections among diverse studies of soil processes, measurement, and scale. In this President's column, Aaron Daigh explores common themes that surfaced and

what they suggest about the future of soil science.

An enjoyable consequence of writing “[President’s Picks](#)” series featuring SSSA research this year is that I regained the habit of consistently reading through all of our journals’ tables of contents and their abstracts just for fun. This allowed me to learn things I might not have found in my previous years’ normal routine. I started the series as a way to celebrate research in our journals, especially work that warranted rereading and changed a perspective I previously held. By late summer, I had accumulated enough research picks that I started to reread them back-to-back rather than as separate, isolated monthly choices. The papers range from molecular interactions on mineral surfaces to 15-m-deep vadose zones and Martian regolith simulants. On the surface and spaced out in time, one might not expect them to have much in common. However, several ideas appeared repeatedly, which inspired me to dedicate this month’s column to them.

[One of the things I have always liked about this discipline is that we work across scales that differ by many orders of magnitude, in landscapes with histories that cannot be reproduced exactly, and with materials that change while we are trying to characterize them.](#) We still have to simplify those systems enough to make measurements, test hypotheses, and build useful and informative models. However, I think one incredibly interesting part is determining when those simplifications remain appropriate and

when they begin to limit interpretation. Quite a few of this year's research picks provided new insights into this issue.

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History, sequence, and state

Not surprisingly, the clearest pattern was in studies where a soil process or observation depended strongly on what that soil recently experienced—its own history. Li et al. (2026) showed that antecedent rainfall and repeated freeze–thaw cycles had opposite effects on subsequent wind erosion in an Aeolian sandy soil. Rainfall strengthened the soil surface and formed a protective crust, whereas repeated freeze–thaw weakened the soil and progressively increased wind erosion through the tested cycles. O'Donnell et al. (2026) demonstrated the importance of prior conditions over a much longer period while reconstructing more than 80 years of sediment

accumulation in an agricultural wetland. Their sediment record reflected interacting land-use transitions and episodic climate events rather than simple, gradual accumulation through time.

0 20 50 cm

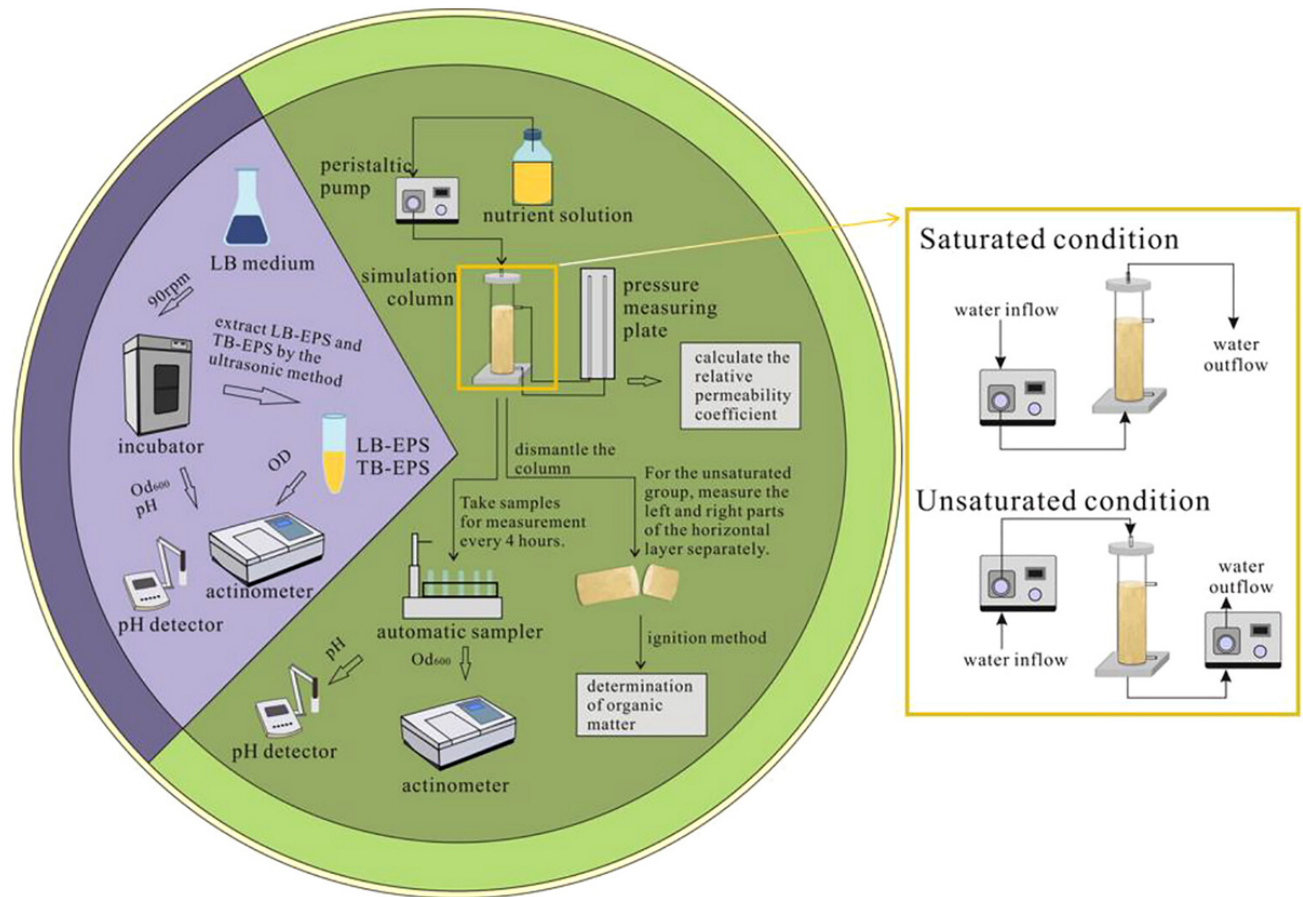


Li et al. (2026) showed that antecedent rainfall and repeated freeze–thaw cycles had opposite effects on subsequent wind erosion in an Aeolian sandy soil. This figure, taken from the paper, shows 0 rainfall intensity followed by various levels of rainfall intensity with some following wind erosion.

The August and September Picks examined related effects in deep soil and biogeochemical processes. Sedaghatdoost and Mohanty (2026) sampled as deep as 15 m in the Gulf Coastal Plains and found a deep vadose zone that was much more biogeochemically active than the common assumption of conservative transport below the root zone would suggest. Wetting and drying altered iron redox chemistry and, through its coupling with phosphate sorption, allowed the deep soil to shift from a phosphorus sink to a phosphorus source depending on recent hydrological conditions. Huang et al. (2026) likewise found that the frequency of wetting and drying changed microbial processing of dissolved organic matter in lake–wetland soils, including aromatic compounds usually considered relatively resistant to degradation. The authors proposed that repeated cycling disrupted aggregates and exposed carbon that had previously been physically protected.

Chen et al. (2026) showed another form of history dependence while examining microbial clogging under variably saturated flow relevant to managed aquifer recharge. The hydraulic response to microbial clogging did not decline monotonically toward one fixed conductivity, but passed through a rapid decline, a partial rebound and readjustment, and eventually a long–term dynamic equilibrium. Moderately unsaturated conditions also promoted more microbial growth and extracellular polymeric substance (EPS) accumulation than fully saturated conditions, while the clogging itself was vertically stratified, with bacterial cells dominating the aerobic near–surface zone and EPS occluding micropores below. Cramer et al. (2026) used

neutron and X-ray imaging to document a related change around microplastics, where water initially moved more slowly through water-repellent zones and later bypassed them through preferential pathways. In both studies, the measured response developed over time and could not be explained solely from the initial condition.



Chen et al. (2026) showed another form of history dependence while examining microbial clogging under variably saturated flow relevant to managed aquifer recharge. This illustration shows the experimental setup comprised an inflow/outflow system, a simulated column, a peristaltic pump, a piezometer panel, and a collection device.

Two other Picks considered related issues through modeling approaches. Mair et al. (2025) modeled root water uptake and showed that the influence of rhizodeposits depended on the intensity, timing, and frequency of atmospheric boundary conditions.

Liu et al. (2026) examined fingering flow, where infiltrating water can self-organize into fast, narrow pathways even in a uniform porous medium without pre-existing macropores, and an optimality-based active region model in which hydraulic conductivity depends on flux rather than saturation alone. Both papers are great demonstrations of how fixed soil properties alone are incomplete and insufficient to explain the response.

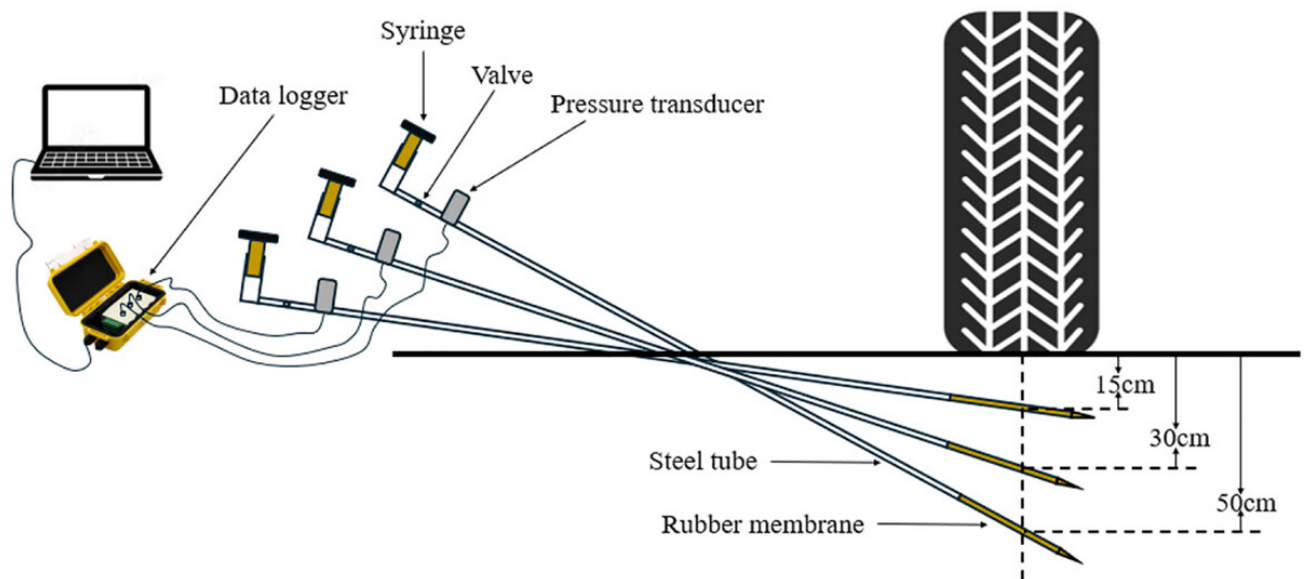
We have always known that soils change, but I think these papers do a great job of describing how sequence, frequency, and prior state are essential in what governs the outcomes of soil processes. In other words, this means a measurement at a single time may not contain all the information needed to understand a subsequent response.

The measure is not the mechanism

My March Pick, by Widanagamage and Patrignani (2026), compared laboratory- and field-determined soil water retention curves in a well-aggregated tallgrass prairie soil. The field measurements did not necessarily provide a better representation of the wet end of the curve, where sensor measurement frequency and equilibration lag affected what could be measured under strong aggregation and nonequilibrium flow. I particularly like that result because it demonstrates and reminds us that each measurement is produced using an instrument, a protocol, a sampling interval, and a scale. Those choices affect the observation and the context of our interpretations whether we acknowledge them explicitly or not.

Kogler and Nordt (2026) examined a related issue at a different scale. Along a Texas Vertisol climosequence, gilgai microhighs and microlows separated by only a few meters differed systematically in their organic and inorganic carbon stocks, and that meter-scale variability obscured the broader relationship with precipitation that might

otherwise appear at regional scales. Freiberg and Arai (2026) examined the issue at molecular scales by showing that the configuration of functional groups in six carboxylic acids, rather than concentration alone, strongly influenced how effectively the acids dissolved hydroxyapatite. Ayetan et al. (2026) found a comparable depth-dependent response in soil compaction, where lower tire inflation pressure substantially reduced stress in the upper profile while stresses at depth remained strongly influenced by total wheel load and soil structural condition. Kiaika et al. (2026) showed a similar issue when scaling soil processes into global models. The effects of soil macroporosity were suppressed when precipitation and hydraulic properties were averaged across large model grid cells but became much more apparent when subgrid variability was represented. In each case, a number, setting, or measurement provided useful information, but did not by itself describe the full reality of what governed the system.



Ayetan et al. (2026) found a comparable depth-dependent response in soil compaction, where lower tire inflation pressure substantially reduced stress in the upper profile while stresses at depth remained strongly influenced by total wheel load and soil structural condition. This illustration, taken from the paper, shows bolling probes set up for stress measurement.

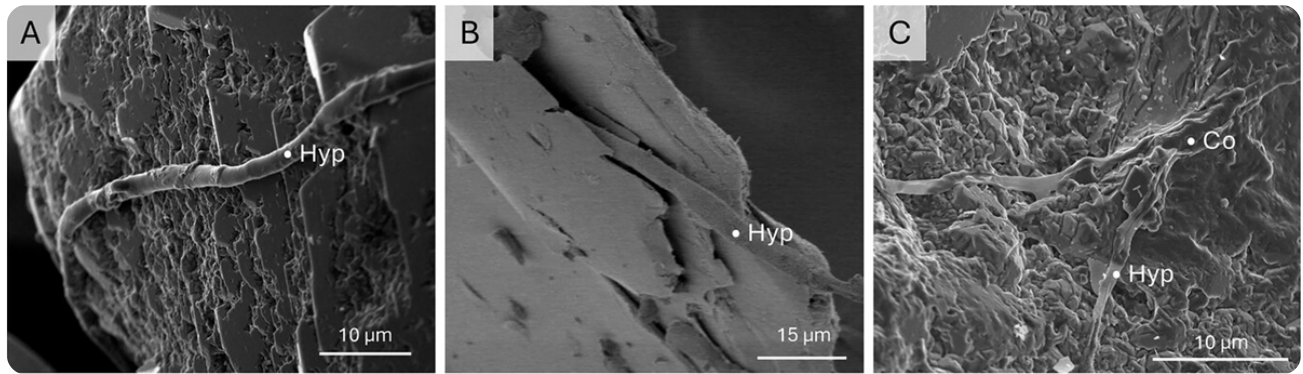
I probably noticed this theme among the Picks because my own group has spent a fair amount of time examining similar issues. This year, we published our perspectives on distinguishing comparative soil health benchmarking from mechanistic prediction, how soil health is a nonequilibrium flow problem, and how limitations arise when emerging contaminants are studied as single species even though environmental exposures occur as complex mixtures (Daigh et al., 2026a, 2026b; Daigh, 2026a). We also published a paper reconsidering how we define soil and which process-based states should be included in that definition (Daigh, 2026b). Obviously, those papers were not part of my President's Picks, but they probably help give some insight or explain why I selected several of the Picks discussed here.

There is nothing inherently wrong with reducing a complicated system to a useful number for the strict purpose of benchmarking. We use field capacity, wilting point, carbon stocks, soil health scores, weathering indices, and many other abstractions because they let us compare, communicate, and make efficient decisions. Problems arise when those abstractions are applied as a predictive means outside the conditions and context for which its relationship to the governing process has been established. The papers above examine that issue at different scales, but each helps remind us to ask what information a number represents and what information it does not. That seems especially important now as more of our measurements are aggregated into large datasets, remote products, decision-support tools, and models used beyond the context where the measurements were made.

Defining the scope of soil science

The April and October Picks addressed research involving Martian and lunar regolith simulants. Coker et al. (2026) evaluated thermal treatment, aqueous leaching, and biological reduction for removing perchlorate from a Martian regolith simulant, a remediation problem directly relevant to potential extraterrestrial crop production. Fackrell et al. (2026) showed that commonly used lunar and Martian regolith simulants contained Earth-derived microorganisms and that some sterilization methods altered the material. Their furnace treatments, for example, collapsed smectite and dehydrated gypsum in simulants containing hydrated phases, while packed autoclave bins could retain viable organisms in their centers where compaction limited steam penetration. If preparation or sterilization alters the analog material, that effect becomes part of the experimental design and interpretation.

Palma et al. (2026) examined a terrestrial environment that may serve as an analog for Martian regolith. Their work on James Ross Island in Antarctica described cold, arid, salt-rich soils that are weakly weathered, including evidence of possible dry permafrost and complications in applying the Chemical Index of Alteration where sodium enrichment depresses the index. I find studies like this fascinating because they test familiar pedological methods under environmental conditions that differ markedly from those in which those methods are most often applied. In some cases, the methods remain useful, while in others, the environmental conditions indicate limitations or require modified interpretation. Along a related frontier, Morris et al. (2026) approached the boundaries of soil science from the microscopic direction, reviewing how fungi physically and chemically interact with minerals and how difficult it remains to connect those interactions across scales. They also considered how fungal weathering features and biominerals could serve as potential biosignatures when interpreting extraterrestrial materials.



Morris et al. (2026) reviewed how fungi physically and chemically interact with minerals and how difficult it remains to connect those interactions across scales. This figure, taken from the paper, shows fungal-rock interactions observed using scanning electron microscopy.

I have also been thinking about the physical scope of soil science for many years. My own paper this year proposed that a process-based definition of soil should include zero-states, active layers, and what I'm coining as págousols (i.e., soil formed from ice parent materials; aka volatile minerals), which would classify many celestial bodies in the icy outer solar system within an expanded process-based definition of soil (Daigh, 2026b). If we define soil primarily by where it occurs on Earth, the scope is relatively straightforward but artificially truncated. If we define it by the active physical, chemical, and/or biological gradients (what Hans Jenny referred to as external potentials) that have the possibility to transform a parent material (being refractory or volatile minerals), the scope becomes broader and requires more fundamental and explicit criteria. The work by Coker, Fackrell, Palma, and others applies soil-science questions to planetary and planetary-analog materials and provides examples in which those criteria can be considered.

I do not think soil science needs to establish a final scope quickly, and I would also be cautious about any definition claiming to be "complete." The important issue is that [when](#)

soil science concepts are applied to unfamiliar materials and environments, the applicability of familiar categories and methods must be tested rather than assumed. This work also creates opportunities for collaboration with planetary science, astrobiology, geochemistry, engineering, and plant science while retaining the pedology, physics, chemistry, and biology required to interpret these materials as soil scientists. Broadening the scope of the discipline does not require reducing its reliance on those foundational areas.

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Patterns across this year's President's Picks

Taken together, these Picks do not point to a single new theory or coordinated research agenda. Instead, they show investigators working on very different problems while testing assumptions that are often simplified in standard descriptions. A deep vadose zone exhibits substantial biogeochemical activity, antecedent wetting and drying affect subsequent responses, meter-scale microtopography can obscure regional carbon relationships, and regolith simulants can contain terrestrial microorganisms and be mineralogically altered during sterilization. In each case,

examining the system in greater detail identified conditions under which a common assumption or simplified representation was incomplete.

This relates to something I wrote about in my [July president's column](#) regarding the depth problem in soil science. [Our discipline is at its best when we accumulate cautious and consistent evidence across many soils, sites, seasons, scales, and decades. That caution should include periodically testing the quantities, boundary conditions, indices, and assumptions that have become standard practice.](#) This applies to students and early-career researchers, but also to those of us who have worked in the field long enough to have developed our own familiar approaches. A parameter that is routinely fixed, an index that is widely accepted, or a spatial scale that has become standard may be entirely appropriate... BUT, it is still worth knowing the conditions under which it remains appropriate.

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The President's Picks were intended to give additional visibility to excellent work in our journals. Reading them together also gave me a broader view of the research questions being pursued across our Society. Our members are examining history dependence, measurement assumptions, scale, and soil processes in planetary and planetary-analog environments, along with many other questions that did not fit the patterns discussed here. Some have immediate applications and others are fundamental. Both are important parts of an active scientific discipline, and I have enjoyed having a reason each month to read more of that work.

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