On-Farm Research
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What's the value of soil health for nutrient management in Virginia?

Alan Franzluebbers
USDA-Agricultural Research Service
3218 Williams Hall
NCSU Campus Box 7620
Raleigh NC 27695

Tel: 919-515-1973
Email: alan.franzluebbers@usda.gov

Soil health

Soil health refers to how well soil performs the functions that it naturally can do (or what we expect it to do for us). This may mean how well soil absorbs heavy precipitation rather than becoming sealed and causing excessive runoff. It may also mean how productive the soil can be with minimal inputs rather than simply growing a few, small undesirable plants. It might also reveal how biologically active the soil is, such that nutrients are slowly transformed from an organic to inorganic state to allow a steady supply of nutrients for plant growth throughout the year.

Indeed, when conservation agricultural management practices have been deployed for at least a few years, the condition of soil often improves. This results in progressive development of:

- greater water infiltration, less runoff, little evidence of erosion, and no standing water in the field
- greater soil water storage that can be realized with a few more growing days to avert plant wilting during drought conditions
- visible evidence of earthworms coming to the soil surface after heavy rainfall events
- surface soil that breaks apart in the hand into crumbles rather than forming clods
- darkened soil near the surface in response to organic matter accumulation
- vigorous crop growth following precipitation and little evidence of nutrient deficiency, particularly nitrogen (N)

Nutrient management

So, what do these improvements in soil health have to do with nutrient management? We've been long told that to produce a top corn crop, 1 to 1.2 pounds of N fertilizer are needed per bushel of grain expected. This recommendation certainly accounts for most of the total N demand by the corn crop, which can be estimated more accurately as 1.4 pounds of N per bushel of grain. The difference in N is assumed provided by the soil itself via organic matter mineralization and residual inorganic N. As an example, a 200 bu/acre corn grain yield would require 280 lb N/acre and a fertilizer N recommendation of 1 lb N/bu leaves a deficit assumed supplied by soil (i.e. 280 lb N/acre needed by corn – 200 lb N/acre supplied by fertilizer = 80 lb N/acre supplied by soil).

Research supporting this synthesis and overall recommendations

A total of 99 field trials were conducted in 2017 and 2018 in Virginia, North Carolina, and South Carolina. Sites in Virginia were from the Shenandoah Valley (n=6), the Piedmont (n=2), and the Coastal Plain (n=5). Sites in South Carolina were from the Coastal Plain (n=8). Sites in North Carolina were from the Appalachians (n=5), the Piedmont (n=43), and the Coastal Plain (n=31). In each field, 16 plots of 15' x 25' were assigned to four sidedress N rates (0, 50, 100, and 150 lb N/acre as urea with stabilizer in 2017 and 0, 80, 160, and 240 lb N/acre as ESN smart nitrogen in 2018). Soil was sampled in spring prior to the growing season or shortly after planting in four separate blocks at depths of 0-4", 4-8", and 8-12" (8-12" depth in 2017 only). Corn grain yield was determined from hand harvest of 12' 8" of row after reaching physiological maturity. Grain was shelled, dried in an oven, and adjusted to 15.5% moisture. Yield was regressed upon sidedress N rate to determine the economically optimum N fertilizer rate using either (a) a non-linear equation (preferred, but only if logical), (b) a linear equation (if non-linear equation was illogical), or (c) mean value across N rates (if linear slope was negative). Cost-to-value threshold to determine economically optimum N rate was low (5 lb grain/lb N), medium (10 lb grain/lb N), high (15 lb grain/lb N), and very high (20 lb grain/lb N). This was equivalent to fertilizer cost of $0.50 / lb N and grain value of $5.60 / bu (low), fertilizer cost of $0.75 / lb N and grain value of $4.20 / bu (medium), fertilizer cost of $0.94 / lb N and grain value of $3.50 / bu (high), and fertilizer cost of $1.00 / lb N and grain value of $2.80 / bu (very high). Detailed economic analyses can be found in the open access article at: https://doi.org/10.1002/agj2.20213.

Soil health conditions of these fields were assessed with a variety of soil organic matter fractions and routine soil chemical analyses. Detailed soil and grain yield responses to sidedress N rate can be found in the open access article at: https://doi.org/10.1002/agj2.20094.

These studies were preceded by additional field trials from more direct collaboration with key Virginia DCR Soil and Water Conservation employees, Jeff Cline, Alec Lipscomb, and Robert Shoemaker. A total of 47 strip trials were from the Shenandoah Valley (n=20), Virginia Piedmont (n=4), NC Appalachians (n=3), NC Piedmont (n=11), and NC Coastal Plain (n=9). Details of this study can be found in the open access article at: https://doi.org/10.2136/sssaj2018.01.0029.

Integrating soil health with nutrient management

Indicators of soil health are used to simplify the complex processes and properties of soil so that we can track progress of management. Best indicators are those that (1) can be related to a specific soil function, (2) are as universally relevant as possible so that a variety of management conditions can be evaluated in the same region, as well as across the many diverse ecoregions and soil types around the world, (3) are simple, yet robust in discerning ecosystem relevant effects, and (4) are cost effective.

Soil-test biological activity (STBA) measures the capacity of soil to breathe. Just like humans, the breath of soil indicates the metabolic condition of soil organisms. A soil breathing at a low level might be like a person resting or sleeping. A soil breathing at a high level might be like walking vigorously, bicycling, or even running. And just like people, soil metabolic activity requires energy. The food for soil is fundamentally organic carbon, which can be supplied by plant roots and residues, livestock manures, compost, and residual organic matter in soil. The more we feed the soil, the more the soil can do for us. An important aspect of a well-fed soil with high STBA is the mineralization of organic matter into inorganic N, aka net N mineralization.

In field trials across the Carolinas and Virginia, corn grain production was optimized under the soil and climatic conditions of each trial with a different level of supplemental N fertilizer that was dependent on the level of STBA. That is because STBA is highly associated with net N mineralization. ***Therefore, the natural soil supply of N varies based on soil health condition, as indicated by soil-test biological activity (STBA).***

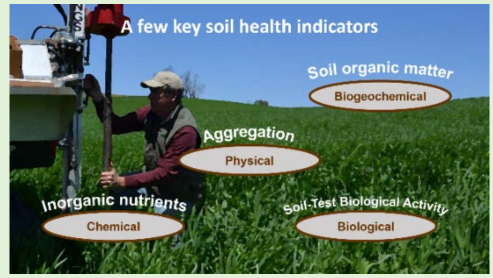
Across 99 field trials conducted in 2017 and 2018, an increasing level of STBA led to progressively greater economic return compared with the current N recommendation system in Virginia. This greater economic return was more dramatic when the cost of N fertilizer was high or the value of corn grain was low [i.e. integrated as the cost-to-value threshold (CVT)].

Marginal economic return ($/acre) using STBA as a soil health test to determine N fertilizer recommendation for corn as compared with current N recommendation system in Virginia.

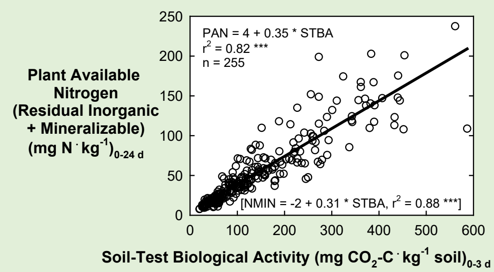
	Cost-to-Value Threshold (lb grain/lb N)			
Soil-Test Biological Activity (STBA)	5	10	15	20
Very Low (0-125 mg/kg/3d)	+2.22	−6.85	−0.52	+7.77
Low (125-250 mg/kg/3d)	+2.47	−0.40	+6.18	+15.18
Medium (250-375 mg/kg/3d)	+2.72	+6.05	+12.89	+22.59
High (375-500 mg/kg/3d)	+2.97	+12.50	+19.59	+30.00
Very High (>500 mg/kg/3d)	+3.23	+18.96	+26.30	+37.41

Visualization of concepts

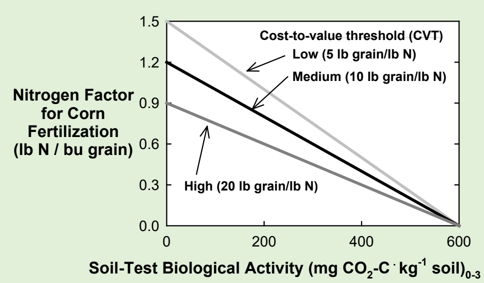
Soil health can be indicated by key soil properties and processes that relate closely to the functioning of soil. Soil-test biological activity reflects (a) the capacity of soil to supply nutrients via decomposition of organic matter that releases inorganic nutrients for plant uptake, (b) the manipulation of soil particles into water-stable aggregates, and (c) potentially the overall storage of nutrients in organic form, as well as soil microbial biomass and diversity.



Net N mineralization is highly associated with the level of soil-test biological activity (STBA). The linear association reveals the influence of soil microbial activity on the release of inorganic N that becomes available for plant uptake.



The N factor for corn production is often assumed to be 1 to 1.2 lb N / bu grain, but data from these field trials suggest the N factor to optimize economic return will depend on the supply of soil N mineralization, as indicated by soil-test biological activity.



The following observations were from 26 field trials with yield ≥190 bu/acre (CVT=10 lb grain/lb N). In sites with low STBA, there was no difference in fertilizer N recommended, yield, or economic return compared with the current Virginia system. However, when STBA was medium or greater, N fertilizer was reduced by 41 lb N/acre, yield was reduced by only 4 bu/acre, and economic return was $13.45 greater compared with the current Virginia system. ***Improved soil health can lead to greater economic return from optimized N fertilizer recommendation!***