IN-FIELD MEASUREMENT OF SOIL HEALTH AND SUSTAINABILITY (June 2012)

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Background

Agriculture is challenged to develop soil management practices that economically provide sufficient food and fiber yet maintain environmental sustainability and conserve the quality of essential soil, water, and air resources.

Strategies for sustainable management include:
Conservation of soil organic matter
Minimizing soil erosion
Balancing production with environmental needs
Better use of renewable resources.

Tools for Measuring SQ & Health for Sustainable Management

Our research has developed tools and approaches, accessible to both agricultural specialists and producers, to assess soil health and the sustainability of agricultural management practices. Development of the soil quality test kit, tools for on-farm assessment of sustainability, and interpretive guidelines have aided research/organization/farmer partnerships in areas of *Nutrient Management* and development of *Sustainable Soil Management Systems*. We are also developing methods for assessing biological soil properties using equipment and techniques available to non-specialists, and developing and assessing a simple tool for on-farm assessment of sustainability as discussed by Doran (2005).

The USDA Soil Quality Test Kit provides tools and approaches for in-field assessment of soil health and sustainability by scientists, conservationists, and producers. Commercially marketed by Gemplers, the kit is a valuable resource to agricultural professionals and teachers and over 650 test kits have been marketed to date. Over 10,000 copies of the USDA Soil Quality Test Kit Manual and Interpretive Guide (USDA, 2001) were printed and distributed to field staff, agricultural professionals, and producers since 1999. Copies are also available in English or Spanish on the Internet.

While the USDA soil quality test kit is very useful to scientists, consultants, and conservationists it is generally too involved for practical use by farmers. Consequently, a soil health 'Vest' and a field calibrated probe for soil electrical conductivity are currently under development by Gempler's and Hanna Instruments for use by consultants, producers, and educators. This Soil Health Vest is the culmination of many years of work in USDA and is produced under the REAP@ trademark by the Renewing Earth and Its People Foundation co-founded by John and Janet Doran (www.reapfund.org).

The REAP soil health test vest is affordable and easy to use and measures the basic soil properties needed to assess soil quality for sustainable management. This vest also greatly facilitates specialists working directly with producers in the field. In many cases the producer can use this equipment themselves for quick evaluations of questions that arise in the field. This enables decisions to be made in the field while circumstances are fresh in their mind rather than waiting days or weeks for a laboratory analysis on a soil sample. If a 'quick' test identifies that a problem may exist, the farmer can submit a sample to a testing lab for a certified verification of the preliminary field test. A listing of the components of the soil quality vest and their relationship to indicators of sustainability is given below.

Table 1- Strategies for sustainable management as assessed by indicators of SQ & Health in the REAP Soil Health Test Vest.

SUSTAINABILITY STRATEGY	SOIL HEALTH 'VEST' INDICATOR
CONSERVE SOIL ORGANIC MATTER *through* Increases with reduced tillage, plant and animal manures, and increased soil cover where C inputs > or = C outputs	**Illinois SOM COLOR CHART** Field comparison of OM over time and between management systems **RING** for measuring **SOIL BULK DENSITY** for accurate C & N measurements
MINIMIZE SOIL EROSION *through* Conservation tillage and increased residue protective cover	**VISUAL** (gullies, rills, dust, etc.) **&** **RING/ROD** for measuring **WATER INFILTRATION,** **POTENTIAL RUNOFF,** **& COMPACTION**
BALANCE **PRODUCTION & ENVIRONMENT** *through* conservation and integrated management systems that optimize tillage, residue, water, and chemicals Synchronizing N and P with crop needs during year	**NITRATE &** **PHOSPHATE TEST STRIPS** for soil and water **RING & TROWEL** for soil compaction/plant rooting/**WFPS** **SOIL EC PROBE** for nutrient balance/losses
BETTER USE OF **RENEWABLE RESOURCES** *through* less fossil fuels and petrochemicals, renewable resources & biodiversity (crop rotations, legumes, manures, integrated pest management)	**SOIL EC/TEMP. PROBE** For optimal biological range and potential NO_3 leaching losses **pH TEST STRIP -** Soil acidification with inefficient N use Soil and water **NITRATE** levels **SOIL RESPIRATION** (Mineralization)

After Kleinschmit (2003)

Figure 1. REAP Soil Health Vest and small Aluminum ring (2.9”x 5”) with many uses

Soil Bulk Density & WFPS

Soil Compaction

Water Infiltration

Water-holding Capacity

3-hour Soil Respiration

Incubated at field Temperature

Potential N Mineralization

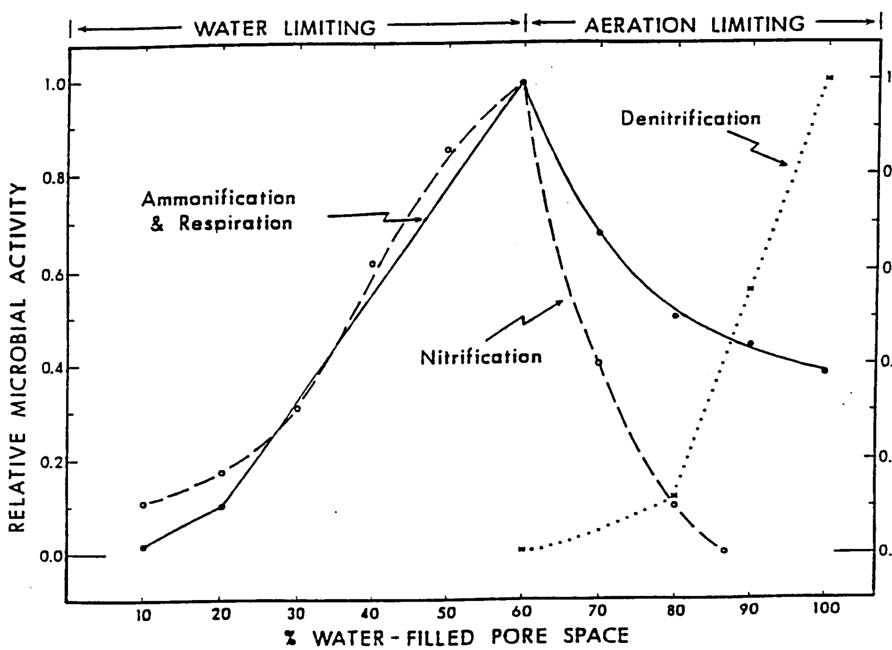

Figure 2. Aerobic & Anaerobic microbial processes and % WFPS (Parkin, Doran, Franco-Vizcaino 1996)

The ability to measure soil bulk density using the aluminum ring allows calculation of soil water-filled pore space and determination of the relative proportion of aerobic and anaerobic processes such as nitrification and denitrification.

Soil electrical conductivity (EC) is an easily measured yet reliable indicator of soil health and biological activity and can serve as a quick indicator of plant available nitrate-N. In general, an EC range of 0 to 1 units (dS m^{-1}) indicates good soil health but values between 1 and 2 or higher result in reduced growth of salt sensitive plants and disruption of the microbial processes of nitrification and denitrification (Smith and Doran, 1996). Soil EC can also be used to estimate soil nitrate-N levels in low lime soils (pH < 7.2).

Rapid estimator of Soil Nitrate-N

(low lime soils, pH < 7.2)

140 X (EC - background*, dS/m) = ppm Nitrate-N

Late Spring Nitrate-N Test for
non-limited corn yield

(Early June, top 30 cm soil, corn 30 cm tall 4-6 leaves)
EC differential: of 0.18 units (25 ppm nitrate-N) in fertilized corn or
0.11 units (16 ppm nitrate-N) with recent manure or after established alfalfa.

Nitrate loss after heavy rain and water logging
If soil EC is 0.01, the Nitrate-N content is < 1.4 ppm

* background EC = Soil Nitrate-N analysis / 140 ppm per dS/m EC

We have identified that a soil electrical conductivity value above 1 salt unit (1 deci Siemen per meter) can result in increased loss of fertilizer and available nitrogen as the potent greenhouse gas nitrous oxide. Increased greenhouse gas emission to the atmosphere can negate remediation of global warming that is offset by increases in soil organic matter levels with reduced tillage management. Nitrous oxide production from nitrification, an aerobic process (60% WFPS), is inhibited by soil EC values greater than 1 but production from denitrification, an anaerobic process (90% WFPS), is increased by soil EC values above 0.8.

Soil Electrical Conductivity (EC):

Indicator of Soil Health and activity of Plants, Microorganisms, and Nematodes;

Range of units (dS/m) in wet soil:

0 to 1 units: best soil health

1 to 2 units: Caution, problem for:

- **Sensitive plants** (e.g. bean, cowpea, pepper, orchardgrass, berseem clover, and potatoes)
- **Nitrogen bacteria** (more Nitrous Oxide evolved offsets benefits of tie-up of atmospheric CO_2 in SOM; 1 N_2O = 300 CO_2)
- **Plant parasitic nematodes** (may have a selective advantage at EC>1)

Soil electrical conductivity (EC) is also useful for estimating N-mineralization during the growing season. We have demonstrated the potential for using measurement of soil electrical conductivity for estimating growing season N mineralization and the effectiveness of cover crops in recovering available nitrogen from manure and fertilizer.

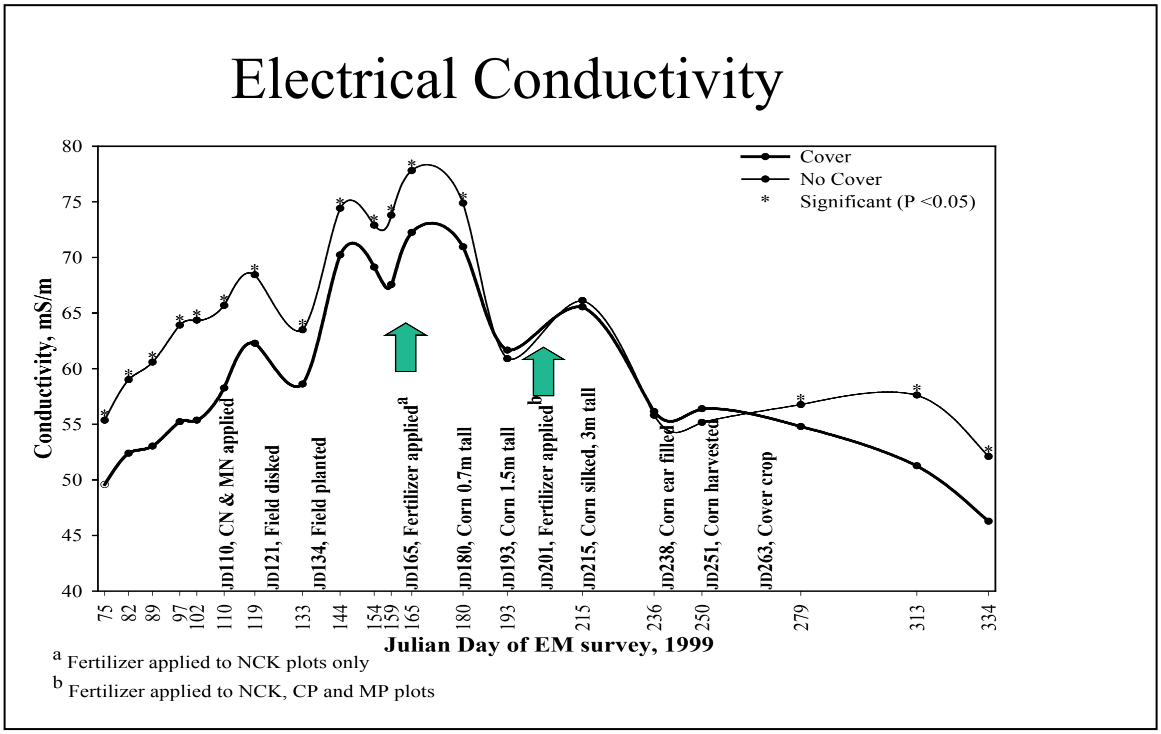

Figure 2. Comparison of growing season soil electrical conductivity with and without a rye cover crop. (After Eigenberg et al., 2002)

Soil EC is also useful in rapidly making late spring estimates of available nitrogen and in determining the potential for loss of environmentally important forms of N as nitrous oxide to the atmosphere or as soluble nitrate in surface and groundwater. Assessment of EC as a tool for managing soil spatial variability within a field and its potential as a 'scouting tool' for determining association with plant disease and nematode infestations needs further evaluation.

Conclusion

Soil quality assessment is a valuable tool for determining the sustainability of land management systems. In the near future farmers will be able to use soil electrical conductivity to assess the nutrient and soil conditions for plant growth each time they pass through a field with a tractor at planting, during cultivations, and at harvest. Until such technologies are fully available to farmers, the REAP soil health test vest can provide simple field assessments by producers for making on-the-go decisions to help determine the sustainability of their management practices.

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