Better Long-term Management Enhances Soil C and N Stocks

Traditional practices, such as conventional tillage with crop–fallow, have reduced dryland soil carbon and nitrogen over the last several decades by 30 to 50% of their original levels in the northern Great Plains. Improved management practices are needed to restore carbon and nitrogen levels and sustain soil quality and productivity.

In a study in the September–October 2015 issue of Agronomy Journal, researchers report the 30-year effect of tillage and cropping sequence combinations on dryland soil carbon and nitrogen and crop yield in the northern Great Plains. Specifically, they found that reduced tillage with continuous cropping increased soil carbon and nitrogen storage by 12 to 98% compared with traditional practices after 30 years.

Moreover, although soil carbon and nitrogen storage decreased from original levels in all treatments, reduced tillage with continuous cropping resulted in minimal losses. Continuous cropping also increased annualized mean crop grain yield by 23 to 30% compared with crop–fallow. Higher tillage intensity, however, increased available soil nitrogen, such as ammonium- and nitrate-nitrogen.

This long-term study in the northern Great Plains shows that improved management practices, such as no-till or reduced tillage with continuous cropping, can sequester soil carbon and nitrogen, enhance crop yields, and sustain long-term soil fertility compared with the traditional practices of the region.


Wheat Nitrous Oxide Emissions Vary Year to Year

The Intergovernmental Panel on Climate Change (IPCC) estimates that 1.25% of the nitrogen fertilizer applied to crops is lost as nitrous oxide (N₂O). Yet no data for winter wheat production in the U.S. southern Great Plains is included in this estimate. Winter wheat production in this area represents 8.5 million ha.

To fill this knowledge gap, a study in the September–October 2015 issue of Agronomy Journal determined the effects of nitrogen (N) fertilizer rate on N₂O emissions from a dryland, winter wheat–summer fallow system in the southern Great Plains.

What the researchers found is that cumulative emissions of N₂O varied year to year and were influenced by environment and N rate. In plots that received N fertilizer, nitrous oxide emissions were typically highest following the N application, as well as toward the end of the summer fallow period, when summer rainfall and temperatures were conducive to N₂O production.

Some plots that historically received high N fertilizer each year went unfertilized in 2012 and 2013, producing N₂O emissions equivalent to the mid-range of the fertilized treatments. Annual cumulative emissions ranged from 0.009 to 0.024 kg N₂O per kg N applied, with an average of 0.015 kg N₂O per kg N applied, illustrating the variability in N₂O emissions.


Reduced-till continuous cropping system with crop residue (left) and conventional till crop–fallow system with no residue (right). Photo by Upendra Sainju.

Reduced-till continuous cropping system with crop residue (left) and conventional till crop–fallow system with no residue (right). Photo by Tracy Wilson.

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Determining Soil Ice Contents with Thermo-Time Domain Reflectometry

In cold regions, freezing and thawing of soils affects buildings, roads, and airports, causing structural damage in some cases. Monitoring frozen soils is therefore important; however, while liquid water can be accurately estimated using Time Domain Reflectometry (TDR), determining ice content has been difficult.

In a recent study in the August 2015 issue of *Vadose Zone Journal*, scientists identified the optimal heat pulse to use with a Thermo-TDR (T-TDR) probe to determine the thermal properties and ice contents of frozen soil. Optimum heating is important because if ice melts during heat pulse measurements, thermal properties are incorrectly estimated.

The T-TDR probe consists of two thermocouple temperature sensors and one heating element. To test it, the researchers filled columns with sand, silt loam, and silty-clay loam soils at three soil water contents and performed measurements at five temperatures between 0 and –15°C. Soil volumetric heat capacity, thermal diffusivity, and ice content were then determined and compared with modeled values.

Modeled and measured volumetric heat capacities corresponded well at all temperatures, except for –2°C and –5°C. In soils colder than –5°C, T-TDR successfully measured ice content changes. But between –5 and 0°C, ice content could not be measured because the heat pulse melted some of the ice. It was possible, though, to estimate ice content at these temperatures as the difference between the total water content and the T-TDR-measured liquid water content.

Overall, the authors showed that T-TDR can effectively measure soil ice contents when melting is minimized by optimal heat application, further expanding our ability to monitor partially frozen, partially saturated soils.

Adapted from Tian, Z., J. Heitman, R. Horton, and T. Ren. 2015. Determining soil ice contents during freezing and thawing with thermo-time domain reflectometry. Vadose Zone J. 14(8). View the full article online at http://dx.doi.org/doi:10.2136/vzj2014.12.0179

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Wetting and Drying of Soil beneath a Snowpack in California's Southern Sierra Nevada

Under current climate conditions and future scenarios, the partitioning of snowmelt into surface runoff, evapotranspiration, and, especially, groundwater recharge, is growing increasingly important. In the August 2015 issue of *Vadose Zone Journal*, a research team used direct observations of the subsurface under snowpack to understand the movement of snow meltwater into the unfrozen soil below.

The study took place in the Providence Creek headwaters of the Southern Sierra Mountains, part of the NSF-funded Critical Zone Observatory (CZO) network. Snowmelt in the Sierra Mountains has also gained significance because of the severe drought gripping the western United States.

The team measured snow depth, soil water content, and temperature at two elevations, on slopes facing different directions, and under different canopy conditions from 2009 to 2011. Soil water content was observed at 30-minute time intervals at four depths.

The scientists found that soil water at the 10-cm depth was most influenced by snowmelt infiltration at most locations, although in some locations, soil was wetter at 30, 60, and 90 cm. While soil water content at individual depths is important, however, the vertical gradients in soil moisture content and persistence are the keys to determining groundwater recharge, say the authors.

The study also found that wetting pulses from infiltrating snowmelt generally reached deeper depths at lower elevations than higher ones. But, overall, wetting and drying dynamics in the top one meter of soil showed high spatial variability, highlighting the importance of deploying instrumentation at multiple locations to most accurately capture groundwater recharge mechanisms.


A Heat-Pulse Sensor for Water Content Measurement

Soil water content is a fundamental variable, required for characterizing and monitoring soil conditions in agricultural and natural systems. It is also widely used for studying related processes in ecological, geo-hydrological, and environmental sciences. Measuring soil water content, however, is not straightforward, posing a pressing need for sensors that can provide accurate data from *in situ* measurements.

In the July–August 2015 issue of the *Soil Science Society of America Journal*, researchers report on a newly developed heat-pulse sensor, constructed using thick-walled stainless-steel tubing for the probes. The rigid probes are resistant to deflection during installation and allow the sensor to accurately measure volumetric water content across a wide range of soils.

The researchers tested the new heat-pulse sensor in different soil textures and water content levels and found that the volumetric water content is accurately measured without bias and with an accuracy of ±1.4%. The investigators also found that soil-specific calibration is not required to achieve this level of accuracy, provided that bulk density and soil-specific heat are known, making this sensor applicable for a wide range of soils.

Given the simplicity of this method and its measurement capabilities, this newly designed heat-pulse sensor with rigid probes provides for an alternative measurement option to consider when requiring accurate *in situ* soil water content data.

High-Resolution Soil CO₂ Study Finds Complexity in Shallow Soil Layer

Soil CO₂ production rates and fluxes vary with time and depth. The shallow near-surface soil layer is important for myriad soil processes, yet knowledge of dynamic CO₂ concentrations and fluxes in this complex zone is limited.

In the July–August 2015 issue of the Soil Science Society of America Journal, researchers report a high-resolution CO₂ study where a concentration gradient method was used to determine CO₂ production and effluxes in shallow layers of a bare soil. The CO₂ concentration dynamics were continuously measured at 13 depths in the 0- to 200-mm soil layer, along with the continuous soil surface CO₂ emissions determined by surface chambers.

Using the millimeter-scale resolution, the team identified a concave distribution of CO₂ concentration in the 0- to 33-mm soil layer and reported 90% of CO₂ was produced from the 0- to 50-mm soil layer. Soil production from most soil layers can be well described by a soil temperature function and further partly explained by soil water content, with a contrasting pattern of soil water content response found in surface and deep layers. The team also reported contrasting diurnal patterns of CO₂ concentration and flux in response to soil temperature between surface and deep layers.

These novel findings suggest the necessity of intensive CO₂ concentration measurements for capturing the complexity of soil CO₂ production and transport near the surface. Fluxes of CO₂ from gradient and chamber methods had good agreement at multiple time scales, indicating the power of the gradient method in estimating surface soil CO₂ effluxes and production.


Use of 3D-Printing Technologies to Reproduce Soil Structure

The processes that form porous media, such as soils, lead to highly heterogeneous 3D structures, forcing scientists to adopt models for reproducing the reality. Impressive insights into soil physics were recently provided by X-ray computed microtomography (X-ray µCT), for example, which allows microscopic visualization of complex soil pore architectures.

Indeed, the study of pore-scale processes with digital imaging and modeling has expanded enormously in recent years. In contrast, the integration of X-ray µCT with 3D printing technology is still in its infancy.

In a study in the July–August 2015 issue of the Soil Science Society of America Journal, researchers combined X-ray µCT with a 3D multi-jet printer to reproduce the structures of a silty-loam soil at the original scale with a resolution of 80 µm. The goal was to test the hydraulic properties of the soil-like prototypes.

The team found that the prototypes were similar to the original samples in terms of total porosity and pore shape. However, pore connectivity was reduced due to technical limitations during the printing process.

Encouraging results were also obtained for hydraulic conductivity: Measurements, which were successfully conducted on most samples, showed a positive correlation with experimental data. Reproducing soil macrostructure at the actual scale with 3D printing technology is therefore possible, widening opportunities for research studies and technological applications, such as bioreactor design and development.


Three-dimensional representations of a large soil sample resulting from X-ray computed microtomography (microCT) analysis and 3D-printed copies.
U.S. Soil Saturated Hydraulic Conductivity Data to Inform Models

The ability of soils to conduct water is measured by the soil hydraulic conductivity value, or Ksat. It is difficult to imagine a soil water–related modeling project in which Ksat is not an influential soil parameter. Ksat measurements are time- and labor-consuming, and estimation of Ksat from readily available data is commonly needed.

In the July–August 2015 issue of the *Soil Science Society of America Journal*, researchers report that they have found a treasure trove of data on Ksat of U.S. soils in non-digitized reports dating back 40 years or less. Digitizing them led to creation of the largest nationwide Ksat database. The application of a machine-learning algorithm showed that one can obtain a reasonably accurate Ksat estimate by knowing to which of 12 USDA particle size distribution classes and to which of two bulk density classes the soil belongs. The proposed estimation of Ksat from textural class and bulk density has the advantage of utility in data-poor environments and large-scale projects.


Rice Cutgrass Increases Denitrification in Agricultural Drainage Environments

Removal of excess nitrogen in agricultural runoff can be enhanced by constructing vegetated wetlands but is cost prohibitive. Maintaining vegetation in low-gradient ditches may serve as a low-cost feasible alternative, but a better understanding of nitrogen cycling in vegetated ditches, particularly the role of denitrification in N removal, is needed.

In the July–August 2015 issue of the *Journal of Environmental Quality*, USDA-ARS and University of Arkansas researchers report on an experiment where denitrification rates were compared during experimental runoff events conducted in outdoor mesocosms maintained under different emergent vegetation treatments.

The team found that all treatments retained greater than 60% of nitrate during runoff, but rice cutgrass, a common wetland grass species, converted dissolved nitrate in runoff water to nitrogen gas at rates 30 times higher than observed for agricultural ditch environments planted with cattails or without plants. Results indicate that ditches planted with cutgrass have the potential to permanently remove >50% of nitrogen captured from agricultural runoff.

Given the drainage density of agricultural ditches, this study suggests that establishing rice cutgrass in ditches as a widespread conservation practice may contribute significantly to reductions in nitrate export from the Lower Mississippi River Basin. This practice has the potential to significantly reduce nutrient impacts to the Gulf of Mexico.


Heavy Rainfall Impacts on Drinking Water Quality

Organic matter (OM) removal from source waters is a key process involved in the production of clean, safe drinking water in industrialized countries. The concentration of OM, which is a key determinant of the “water quality” of the resource, is highly influenced by short-term variations in weather conditions. Rainfall events often result in impaired water quality due to flushing of OM from the catchment to the water.

In the July–August 2015 issue of the *Journal of Environmental Quality*, researchers report on results from targeted sampling regimes in the UK and France aimed at understanding the impact of rainfall events on final drinking water quality. As OM that persists through the water treatment process can produce potentially harmful by-products, such as trihalomethanes (THMs), e.g. chloroform, during the disinfection stage, the research assessed how readily such compounds are formed following a large rainfall event compared with baseline conditions.

While the rainfall event dramatically increased the concentration of OM, on a per-unit basis this OM had the same propensity for THMs formation as the OM in the...
water prior to the rainfall. This information will be useful for water companies when managing the performance of water treatment plants during periods of poor source water quality.


Some Trace Contaminants Survive Sludge Digestion

A wide variety of trace contaminants make their way into municipal wastewater systems. Some are degraded during wastewater treatment, some remain in effluents, and some partition to sludge. This wastewater sludge is then treated before being used in land application; two common treatment processes in North America are aerobic and anaerobic digestion.

In a study in the July–August 2015 issue of the Journal of Environmental Quality, researchers investigated the presence of trace contaminants in sludge, along with changes in their concentrations after aerobic or anaerobic digestion and dewatering. The contaminants included polybrominated diphenyl ether (PBDE) flame retardants, pharmaceuticals, synthetic musk fragrances, and other personal care product components.

Personal care product components of triclosan and triclocarban, the musk fragrance galaxolide, and PBDE congener 209 were the contaminants detected most frequently and at the highest concentrations, up to 30 parts per million. Some contaminants also appeared to degrade during aerobic digestion while accumulating during anaerobic digestion.

These results indicate that aerobic digestion can potentially reduce levels of some trace contaminants during sludge treatment. However, anaerobic digestion allows energy to be recovered from treated biosolids in the form of combustible gases. It also retains the nutrient and soil conditioning value of biosolids for land application uses. To help engineers and scientists weigh the costs and benefits of these different sludge treatment processes, more information is needed on the environmental effects of trace contaminants in biosolids.


Redesigning Reed Canarygrass as a Bioenergy Feedstock

Perennial grasses are excellent candidates for bioenergy feedstock production, especially long-lived grasses with broad adaptation, such as reed canarygrass. However, 40 years of breeding reed canarygrass for use in pastures has resulted in cultivars with severely modified alkaloid profiles, making them acceptable to livestock but less acceptable for bioenergy.

Wild germplasm with high alkaloid concentrations therefore represents the best source of germplasm to develop dedicated cultivars for bioenergy feedstock production. In a study in the September–October 2015 issue of Crop Science, researchers report on field studies that document genetic variation for numerous biomass quality traits within a population of wild reed canarygrass accessions.

The team demonstrated that desired improvements in biomass quality—which will, in turn, improve conversion efficiency—will require a focused effort on a small number of biomass quality traits in the breeding program. For example, a thermo-chemical conversion platform, designed to produce heat or pyrolysis products, would require high biomass yield, low ash, and a high energy content.

A fermentation platform for producing liquid transportation fuels, on the other hand, would require high biomass yield and low lignin. Numerous wild accessions were superior to existing cultivars in biomass yield and quality, indicating that breeding dedicated cultivars for energy production is feasible.

Adapted from Casler, M.D., J.H. Cherney, E.C. Brummer, and B.S. Dien. 2015. Designing selection criteria for use of reed canarygrass as a bioenergy feedstock. Crop Sci. 55(5). View the full article online at http://dx.doi.org/doi:10.2135/cropsci2015.03.0142

Aeration tanks for aerobic breakdown of wastewater sludge. Photo courtesy of Flickr/ Gary Gzik.
Physiological Traits to Enhance Cowpea Drought Tolerance

Cowpea is a very important food crop, especially in the more arid regions of the world. However, it is vulnerable to drought, and there is still ambiguity about the response of several key physiological properties to soil drying. An international group was organized to examine two specific traits that could potentially increase drought tolerance: initiation of stomatal closure early in the soil-drying cycle and tolerance of symbiotic nitrogen fixation activity to soil drying. To give breath to the investigation, 10 genotypes were studied based on their performance in field trials.

The results of this study, reported in the September–October 2015 issue of *Crop Science*, showed large divergence in the response to soil drying among the 10 genotypes. Cultivar CB46 was found to begin closing stomata at the highest soil water content, making it especially desirable for the driest environments. Nitrogen fixation in Mouride, IT97K-566-6, and Suvita 2 was especially tolerant of soil drying, more so that previously observed in any grain legume. These results can now be used in cultivar selections for current cropping systems and for future breeding efforts.


Chickpea Germplasm Offers Large Variation in Root Traits

Chickpea is often cultivated on residual soil moisture, making terminal drought stress a major cause of yield loss. A deep and prolific root system is an important trait for ameliorating this loss in chickpea yields and enhancing the crop’s adaptability to drought.

In a study in the September–October 2015 issue of *Crop Science*, researchers report on the diversity in root traits in the reference set of chickpea germplasm. In the research, the genetic variability of root traits in 35-day-old plants was assessed using a cylindrical culture system in two post-rainy seasons.

The scientists uncovered large and useful genetic variability in root dry weight, shoot dry weight, root-length density, and root-to-total-plant dry-weight ratio. They also found moderate to high broad-sense heritability, indicating the possibility of using this variability in breeding and selection for stress tolerance. A few top accessions have been identified for each trait or combination of traits that can be readily used in breeding.

Accessions originating in the Mediterranean region and western Asia were found to possess the best root-length densities and root dry weights, emphasizing the importance of these germplasm accessions for superior root traits. Overall, the study identified 23 superior accessions with a combination of desirable root traits for widening the parental base for future drought tolerance breeding efforts.


Ten cowpea genotypes were studied for two specific traits that could potentially increase drought tolerance.

A few contrasting accessions for rooting depth in the reference set of chickpea germplasm.
SafeAssign Increases Student Awareness of Plagiarism in Writing

Plagiarism in student writing is a widespread concern among university instructors, regardless of academic program or student level. Several plagiarism detection software programs have been used to identify plagiarism and deter students from plagiarizing, but have resulted in mixed success. Moreover, use of these programs to teach students to identify potential plagiarism in their own writing has not been well documented.

In volume 44 of Natural Sciences Education, researchers report on use of the plagiarism detection software, SafeAssign, as an instructional tool in an undergraduate scientific writing class. They found that use of the program by students increased their awareness of plagiarism during the writing process. SafeAssign also increased students’ confidence in their writing. However, it did not reduce the average percent of matching text from the first draft to the final submission.

Overall, the study shows that deploying plagiarism detection software as teaching tools may be beneficial in the writing process when coupled with appropriate instruction and support from the instructor.


Labile Organic Carbon in Coastal Wetland Soils of the Mississippi River Deltaic Plain

The Mississippi River deltaic plain (MRDP) coastal wetlands represent one of most complex and anthropogenically altered coastal ecosystems in the world. These wetlands have been subjected to a significant loss, primarily as a result of subsidence in the MRDP plus a similar rate of eustatic sea level rise. Sediment inputs and organic matter accretion has been considered as the two most important factors for the stability of these wetlands. The MRDP wetland soils contain variable amounts of organic carbon (C) due to different net C inputs as affected by primary productivity, specific hydrological condition, and coastal influence. Understanding different organic C fractions in these wetland soils is particularly important to predict and manage the movement and transformation of these C sources in this highly dynamic region and their contribution to the northern Gulf of Mexico hypoxia.

Along an increasing salinity gradient toward the ocean, the MRDP coastal wetland ecosystem changes from the bottomland forest swamp to the freshwater, brackish, and saline marshes. Among these different wetland ecosystems, freshwater and brackish marsh soils contain higher labile organic C (LOC) than saline marsh and forest swamp soils. The trend is highly correlated to total organic C contents of these soils and consistent with the soil/sediment C accumulation rates in these wetlands.

Different methods of the LOC characterization for these wetlands yield varying results. In general, LOC estimated by aerobic incubation as well as salt and cold water extractions is generally less than 0.5% of soil organic C (SOC). Hot water extraction and especially acid hydrolysis yield much higher LOC estimates (1.2–3.5% and 13–43% of SOC, respectively) than those by aerobic mineralization, cold water, and salt extractions. There are generally close correlations among LOC values determined by aerobic incubation, could water, and salt extractions. These results are supported by their similar relations to SOC functionality. While carboxyl C (mainly organic acids) was the primary contributor to the LOC determined by cold water and salt extractions, aerobic mineralization includes the positive contribution of both carboxyl C and O/N-alkyl C (polysaccharides, amino acids, and proteins). On the other hand, the LOC measured by hot water extraction captures carbonyl C (mainly ketonic and aldehyde compounds), whereas slowly releasing organic C by acid hydrolysis includes the contribution of alkyl C (aliphatics) besides O/N-alkyl C. The positive contribution of alkyl C in these MRDP soils to AHC is different from that reported for upland soils.

The LOC in freshwater marsh soils facilitates a much higher denitrification potential than the saline and forest swamp soils. However, the presence of phenolic aldehydes and ketones in the SOC of these wetland systems could inhibit the denitrification. Clay sediments and cations from
the Mississippi river diversion and seawater intrusion likely exert an integrated effect on the lability of soil organic matter (SOM) in these wetlands. While clay sediment additions reduce LOC degradation as evident by lowered CO₂ emissions, both divalent Ca²⁺ and monovalent K⁺ are found to enhance the retention of dissolved organic matter (DOM) although the magnitude of these effects varies with specific wetland soils. Research evidence also suggests the occurrence of selective degradation of syringyl structures of lignin structure over guaiacyl in both bulk SOM and DOM in the MRDP wetlands. In addition, the DOM degradation by photochemical process likely enhances its lability and contribution to the northern Gulf of Mexico hypoxia.


Bioavailability and Preservation of Organic Phosphorus in Freshwater Sediments and Its Role in Lake Eutrophication

Eutrophication is a primary water quality issue for most of the freshwater in the world. Thousands of lakes around the world have been impacted by eutrophication, which results in ecological and environmental concerns such as increasing biomass of phytoplankton and macrophyte, algal blooming, oxygen depletion, fish dying, poor water taste, and odor. The process of eutrophication would increase the rate of supply and accumulation of organic matter in a lake. Organic P (Po) is an important component of natural organic matter. Taken the case study of Lake Dianchi in southwestern China, in this work, Dr. Yuanrong Zhu and his colleagues are trying to answer if the increased rate of supply and accumulation of Po would accelerate eutrophication of lakes, or if the preservation of Po in lake sediments would increase the loading of bioavailable phosphorus, and even restore the eutrophic lakes.

Lake Dianchi in southwestern China. Photo courtesy of Wikimedia Commons/Emitchan.

Lake Dianchi is the representative eutrophic lake in southwestern China. This chapter presents and discusses the species and bioavailability of Po in the freshwater sediments and their role in lake eutrophication. Enzymatic hydrolysis, a novel biochemical approach, has been applied to characterize Po compounds and their bioavailability in sediments. The bioavailable Po forms include labile monester P, diester P, and phytate-like P. Correlation analysis revealed that the hydrolysable Po was significantly correlated to total organic carbon in the sediments, implying that eutrophication led to the accumulation of the potential bioavailable Po in the sediments. The bioavailable inorganic P (e.g., Fe/Al-P) would be transferred to Po in the history of eutrophication. Thus, bioavailable Po would be key factor to support and maintain eutrophic status for eutrophic lakes longer even after external sources of P have been controlled. The observations and insight derived from this chapter are helpful in better understanding of the biological cycles of sediments Po in freshwater lakes and their contribution in lake eutrophication.


Correction

We would like to make three corrections to the article “The Hunt for Antibiotics in Soil,” which appeared on pages 4–9 of the July 2015 issue of CSA News magazine: (i) Slava Epstein was incorrectly identified as being affiliated with Northeastern’s Antimicrobial Discovery Center; (ii) Selman Waksman was incorrectly identified as the only soil microbiologist to win the Nobel Prize when in fact several soil scientists (including soil microbiologists) shared the Nobel Prize in 2007 as part of a team of scientists that wrote the Intergovernmental Panel on Climate Change report; and (iii) we failed to mention that Waksman was on staff at Rutgers University when he won the Nobel Prize in 1952. We regret the errors and omissions.