NC1195 meeting
March 7-8, 2017, Kansas City, MO

Attendees: John Sawyer (Iowa State Univ.), Will Horwath (Univ. of California-Davis), Jeanette Norton (Utah State Univ.), Fabian Fernandez (Univ. of Minnesota), Marshall McDaniel (Iowa State Univ.), Sue Blodgett (Iowa State Univ.), Ann Russell (Iowa State Univ.), Peter Scharf (Univ. of Missouri), Rhae Drijber (Univ. of Nebraska), Sindhu Jagadamma (Univ. of Tennessee), Xiaofei Li (Univ. of Mississippi)

Minutes of the 2017 meeting were approved.

Administrative advisors report

Nancy Cavallaro, NIFA update via phone conferencing and presentation

Nancy discussed the strategic goals from FY 2018-2022. “Nitrogen is still big", she said. A task force is set on Ag and Rural prosperity and part of that will include promoting energy independence and growth. Budget includes: AFRI funding $700M (authorized in 2008 Farm Bill), Research & Education $800,000, Extension $475,000, Integrated $36,000, Total $1,350,000. Cannot report much on BNRE, but it will stay pretty much the same. Focus on sustainable agroecosystems: nutrient management, chemical contaminants, soil health & microbiomes, ecosystem services and ag management, bioenergy and multifunctional landscapes. Three intra-agency collaborations: INFEWS, Signals in the Soil, and Carbon Cycle.

State reports

<u>Sindhu Jagadamma (Univ. of TN)</u>

Effect of cover cropping on soil nitrogen transformations in corn-soybean production systems

We initiated a project to investigate the role cover crops play in maintaining the health of Tennessee soils. We use an existing field trial that was started in 2013 on a corn-soybean system at the University of Tennessee’s Research and Education Center in Milan, TN. This experiment includes several single and multi-species cover crop treatments, such as wheat, cereal rye, cereal rye plus hairy vetch, cereal rye plus crimson clover, and the USDA-NRCS recommended soil health mixture (combination of cereal rye, oats, purple top turnips, daikon radish, crimson clover and hairy vetch) as well as a cover crop free control. It was found that NRCS’s soil health mixture outperformed other treatments on soybean yield after 3 years of study. It was also found that soil inorganic N (potassium chloride-extractable NH_4^++NO_3^-) varied significantly across the treatments. Combination of cereal rye and hairy vetch showed statistically higher inorganic N compared to the single species cereal rye and no cover control, and the values from the other treatments were in between. Since soil inorganic N level does not accurately represent the plant available N, we determined potentially mineralizable N (PMN) based on a 7-day aerobic incubation experiment, which accounts for the N that become available throughout the growing season. Soil PMN varied significantly across the cover crop treatments. Multi-species mixture and double species cereal rye + crimson clover treatments showed the highest, and the cover crop free control showed the lowest PMN. Regardless of the treatments, PMN values were 2.3 to 2.5 times higher than the soil inorganic N, which confirms previous findings that fertilizer recommendation based on soil inorganic N levels most often leads to over fertilization of the crops.

Xiaofei Li (Univ. of MS)

Developing Economically Optimal N Rate Recommendations

Overarching objectives: a) looking at Economically Optimal Variable-rate N fertilizer, b) putting unprofitable areas out of production. Specifically, Dr. Li would like to quantify N responses and interactions with different growing factors, develop optimal N rate algorithms, VRA-N decision tools for growers. Used varying coefficient models to look at site-specific crop yield response with variables like soil texture, WHC, SOM, pH, elevation, slope. Used farmer-collected yield, N rate, seeding rate to determine N recommendations. Data analysis skills he brings to the table: Econometrics (multivariate techniques), GIS data, R programming.

Rhae Drijber (Univ. of NE)

Bacteria Communities in Corn Cropping Systems

The Nebraska project will build on our prior NC1195 research goals as well as research being funded through a USDA-ARS specific cooperative agreement (Drijber, R. (PI). Soil Microbial Community Structure, Dept of Agriculture-ARS, $100,000 (2014-2019) and the CERES Trust (Drijber, R. (PI). Organic Soil Matter w/ Cover Crops, Ceres Trust, $180,000 (2014-2017). Our overall goal is to enhance our fundamental knowledge of the underlying microbial processes controlling soil C and N cycling, with particular attention to the role factors such as soil, climate and cropping system management have on nutrient supply to crops, soil quality/health, and N losses via greenhouse gases and leaching. Microbial processes form the core of C and N cycling in soils; thus, they are central to the main goal of our national project which is to understand how the interactions of soil, climate, cropping system and N fertilization practices impact NUE and lead to improved N rate and management recommendations for growers. The Nebraska project is centered on three main research themes:

1. Management of crop residues via tillage and/or stover removal: impacts on soil quality.
2. Carbon sequestration in maize cropping systems: a microbial perspective.
3. Optimum N rate for maize cropping systems: consequences of the extremes.

Theme 1: Management of crop residues via tillage and/or stover removal: impacts on soil quality. Our goal is to determine the impact of residue management practices on microbial processes affecting soil quality, particularly the active soil C and N pools, and how that impacts crop yield, NUE, long-term C sequestration and overall soil quality. This research will primarily be conducted at two USDA-ARS long-term field sites as part of a USDA-ARS specific cooperative agreement in collaboration with USDA scientists Brian Wienhold and Virginia Jin and a third site funded by the CERES Trust. The first site located near the UNL/ARS Agronomy Complex near Mead NE is a corn stover removal study (REAP) where the whole-plot factor is the tillage treatment (no-till vs disk) and the sub-plot treatment is the amount of stover removal (none, half, all) with six replications. A second site located in Lincoln NE is a long-term tillage and corn-soybean crop rotation at Roger's Memorial Farm (RMF). The experiment is a randomized complete block (six replications) with six tillage treatments. Subplot treatments are continuous corn, continuous soybean, and a 2-year soybean-corn rotation with each phase present each year. This site was intensively sampled in 2015 prior to conversion of the site all to NT in 2016. The third site is located on organically certified land near Mead NE and consists of an organic cover crop/crop rotation study for soil organic matter building and weed management. Our objective is to evaluate two soil quality assessment tools, the Haney Soil Health Test (HSHT) and Soil Management Assessment Framework (SMAF), both developed by USDA-ARS, for their ability to differentiate among various long-term managements. A major goal is to determine whether these tests allow producers to gauge and track their progress when using different indicators of soil health.

Theme 2: Carbon sequestration in maize cropping systems: a microbial perspective. This study is part of UNL's Carbon Sequestration Project (http://csp.unl.edu/public/) and is a continuation of Anita Wingeyer's PhD project (Wingeyer, 2011) testing the hypothesis that deep incorporation of maize residues plus fertilizer N using fall conservationist deep tillage (FCDT) will expose more maize residues to physical and chemical stabilization mechanisms leading to increased SOM accumulation compared to previous no-till. Deep incorporation of maize residues plus fertilizer N using FCDT exposed more maize residues to physical and chemical stabilization mechanisms leading to increased SOM accumulation compared to previous no-till. Thus, FCDT creates over time a positive balance of soil C and N accrual through an enhanced soil-residue interface in these soils (Wingeyer et al., 2012). The focus of this next phase of work is to characterize the microbial community changes resulting from FCDT over a period of several years. Preliminary data indicates enhanced contributions of FAME biomarkers for saprophytic and arbuscular mycorrhizal fungi. Thus, FCDT led to a fungal dominated soil community that may promote plant residue stabilization deep into the soil profile in this continuous maize cropping system. A second component to this work will address the dilemma of negative soil C balance in some maize-soybean cropping systems (Dobermann et al., 2005) compared to continuous maize through a temporal analysis of soil microbial community shifts over a period of several years. This work will focus primarily on the CSP site although other sites may be brought in for comparison purposes.

*Theme 3: Optimum N rate for maize cropping systems: consequences of the extremes.*Maize-based cropping systems cover over 39 million ha in the US and represent an enormous stock of soil organic carbon (SOC). However, SOC balances in maize systems may be positive, negative, or neutral (Adviento-Borbe et al., 2007; Khan et al., 2007). Research led by Michael Castellano (NC1195 member and collaborator) on soils across Iowa concluded that when comparing the agronomic optimum N rate to an excessive N rate there were no differences between SOC amount, SOM C/N ratios, or microbial biomass (Brown et al., 2014). This is contrary to findings from research in Nebraska and elsewhere where N rate had a significant impact on soil microbial biomass and community structure, particularly AMF biomass in the soil (Jeske, 2012; Segal, 2014; Tresesder, 2008). The question is whether these decreases in soil fungal biomass over the long-term lead to changes in aggregate size distribution and stability, and thus changes in SOC storage. A second component of this research is to better understand the impact of N fertilizers on AMF biomass in the soil given its important role in nutrient uptake, particularly under high yield (Grigera et al., 2007). These questions will be addressed using a number of long-term maize sites across Nebraska and Iowa. The sites in Nebraska include (a) a long-term crop rotation study (CRS) that was established in 1984 and has been under continuous no-till since 2006; (b) the dryland maize N rate trial at Concord, NE; and (c) an irrigated maize N rate trial at Clay Center. All sites have a range of N fertilizer rates and most include continuous maize and maize-soybean in rotation.

Basic soil properties (total C & N, pH, EC, plant available nutrients, etc.), including analyses specific to SMAF & HSHT; soil microbial biomass and community structure using fatty acid profiling; fungal to bacterial ratios; aggregate size distribution and stability; particulate organic matter and oxidizable soluble carbon; N mineralization, soil enzymes related to C and N cycling; AMF colonization of roots and soils.

Publications and presentations; training of graduate students and undergraduates; evaluation of two soil quality indices, the HSHT and SMAF for relevance to Nebraska producers; fundamental knowledge on the role microorganisms play in soil quality, C sequestration and NUE. Overall advancement of the science on how we can optimize maize cropping systems for high yield and resource sustainability without sacrificing profitability.

Greater awareness of the biological underpinnings of soil quality as related to how we manage our soils. There is increasing interest among producers in Nebraska on monitoring the quality of their soils and understanding the role that biology plays in improving or maintaining soil quality. This is seen as increased use of cover crops, alternative and more intensive crop rotations and incorporation of livestock into the system. Providing farmers with reliable indices to monitor or gauge their soil quality status and progress is foremost. Presentations focusing on these aspects will be given to audiences such as the NE Business Association, Crop Consultant Clinics, Basic Soils School (I am speaking Jan 28, 2016), and various other appropriate venues.

<u>Fabian Fernandez (Univ. of MN)</u>

N response trials: Does splitting application affect yield or N dynamics?

Historically in Minnesota, anhydrous ammonia was the primary source of nitrogen used by farmers. In recent years, urea has become the primary nitrogen source due to market pressures, safety, and regulations. While urea can be an excellent source of nitrogen when applied close to planting time, this source is not as reliable for fall applications as anhydrous ammonia because it has greater potential for nitrification, and eventually, loss to the environment if soil conditions are right. Our current Best Management Practices (BMPs) for southcentral Minnesota do not include urea as an acceptable source for fall applications, but it is acceptable for southwestern, west-central, and northwestern Minnesota. The reason for this difference is that in southcentral Minnesota, due primarily to more precipitation in the spring, the potential for nitrogen loss is greater than in the other parts of the state. Several large coops that serve southcentral Minnesota have recently stop supplying anhydrous ammonia (an acceptable source for fall application), but continue to provide nitrogen for fall applications, now using urea. This is very concerning because of the potential for nitrogen loss and the fact that this switch in the supply comes at a time when regulations are being drafted (and scrutiny intensifying) for fall nitrogen applications. In addition, for the other regions of the state where fall urea is acceptable, I have been receiving reports that fall urea applications have not been as effective in the last several years. This is likely due to a consistent trend for wetter springs.

Based on these needs, I developed a plan to understand and address this issue and I was successful in securing funds to establish a research project across the state evaluating urea and urea enhancers comparing timing of application and placement method. I have been deliberate in targeting extension-education efforts using the data collected (and being collected) to address the dos and don’ts of urea application. These efforts are rising awareness and providing research-based information to allow farmers and crop advisors make informed decisions. I have talked about the findings in winter meetings, field days, and blogs and podcasts. If warranted, once I have sufficient data from these studies, I will work with other nutrient management specialists to revise our current BMPs to reflect current findings.

The results of what is being learned are preliminary as this is an ongoing study. Urea applications in the fall in the south-central part of the state is showing consistently reduced yields relative to spring applications. This is similar to what we have seen in the past and what is reflected in the current BMPs for Minnesota. In other parts of the state, specially the southwest and west central part of the state, there are several situations where fall urea applications reduced yield relative to spring applications. However, these results are not as consistent as in the south central part of the state. The study also showed that using a nitrification inhibitor in the fall might not be sufficient to minimize nitrogen loss. A sub-surface band application of urea might be better than a broadcast and incorporated application regardless of the time of application (fall or spring), but results are not extremely consistent at this moment.

<u>Peter Scharf (Univ. of MO)</u>

NC1195 Report 2018

The Scharf Group evaluated three N-related management aspects: i) cover crops and N, ii) N and ear row number, and iii) Preplant N vs. sensor-based sidedress. Rye and wheat contributed to yield drag, but rye+turnip did not when terminated earlier. Popup fertilizer N (10 lbs N/ac) did not increase yields, but an extra 50 lbs N at sidedress(in addition to 100 lbs N/ac) did increase about 10 bu/ac. Ultimately, the larger rye penalty came from lower N status. Sensor-based N management (at V7) decreased N_2O emissions by nearly 50%.

<u>Anne Russell (IA State Univ.)</u>

N Cycling Model For Agroecosystems

Use of a user-friendly N model is essential for education and outreach. This model is a) highly aggregated, b) based on data from IA soils and crops, c) economic information on ISU extension website, d) used teaching modules for an Introductory Ecology course at ISU last Fall. Teaching goals are to i) Understand that by the Law of Conservation of Mass, matter is neither created nor destroyed. This allows us to balance element budgets. ii) Learn how to test hypotheses about the effects of management on N cycling in agricultural system. This includes questions about cropping system, N fertilizer addition, tilled vs no-till, cover crops and riparian buffer strips. iii) Gain an understanding of how local management can influence soil health, and local and regional water and air pollution. Continued development on the model is needed in order for creation of more scaffolding to ease use for students.

<u>Jeanette Norton (UT State Univ.)</u>

Nitrogen Source Effects on Organisms, Functional Genes and Processes

Improved understanding of nitrogen (N) cycling in agroecosystems is essential for increasing N use efficiency and sustainable food production. Availability of N from organic sources to crops is the result of the enzymatic processes that comprise N mineralization, immobilization and nitrification. Small field plot experiments in silage corn were conducted in Utah comparing ammonium/urea fertilizers (ammonium sulfate at 100 and 200 lbs. N/acre AS100 and AS200) to composted steer manure. Ammonia oxidizing bacteria (AOB) were more responsive than ammonia oxidizing archaea (AOA) to ammonium fertilizer in both field and laboratory. AOA were responsible for a higher proportion of nitrification under low ammonium levels. The relative contribution of AOA to nitrification increased with increasing temperature and their activity had a higher temperature optimum than AOB. N fertilizers strongly stimulated the rates of potential nitrite oxidation. We determined nitrogen use efficiency (NUE) under contrasting N treatments over a period of five years by the difference method. We found that the inorganic N treatments of AS100 and AS200 had higher yields as compared to compost. N uptake was the highest in AS200 followed by AS100 and then compost. The AS fertilizer treatments had the highest NUE (61%) overall versus compost (14%). Increases in soil organic N under compost suggested that the majority of the N not recovered in the crop remained in the soil.

Organic farming systems receive amendments to maintain soil fertility and supply nutrients for plant growth. However, there is little information about the response of soil N cycling function and functional genes to different quality of organic amendments. Our study investigated the effect of organic fertilizers (control, compost, and manure), and their interaction with cover crops (millet, buckwheat, and black turtle bean) on soil enzyme activities, N transformation rates and functional gene abundance under an organic system. In the organic farming system, abundances of functional genes for mineralization were increased by organic N fertilizer and these abundances were significantly correlated with corresponding enzyme activity. Organic N fertilizers had a stronger effect than cover crop type on soil function and functional gene abundance. Soil enzyme activities related to mineralization were increased by both compost and manure, but there was little difference between these. Nitrification potential, nitrite oxidation potential, and denitrification potential in the manure treatment were significantly higher than those in the control and compost treatments, indicating application of manure had a higher N loss potential than compost application in this system.

William Horwath (Univ. CA - Davis)

Soil Respiration and Oxidizable C to Predict N Mineralization

Mineralizable carbon (C) is respired upon the rewetting of dried soil, and has been proposed as a metric of soil health, but the metric still lacks a standardized protocol and validation. A standardized protocol is an essential first step in quality control needed for a robust soil test. The development of commercially viable soil health testing focused on biological properties is needed for improving the sustainability of our agricultural production systems. The burst of respiration on rewetting of air-dried soil, commonly referred to as “the Birch effect”, hereafter referred to as ‘mineralizable C’, is a potentially valuable tool in helping growers better understand the role of soil microbial biomass in their soils. Mineralizable C has been proposed as an important metric of overall health and quality of a soil. We examined numerous sources of laboratory variability associated with mineralizable C, with the overall goal of understanding the influence of each source variability to determine whether this test is robust enough for adoption by the soil test industry.

Our analysis included soil from eight studies on 72 agricultural cropland sites from across the United States. In addition to traditional soil measurements, mineralizable C was measured using permutations of soil processing and rewetting protocols (n = 1142 individual observations) to determine the sources of variation associated with these procedures (sieve size, water content, direction of rewetting). Additionally, selected studies were used to determine the analytical and inter-laboratory variability associated with measurements of mineralizable C.

Similar to other soil measurements, mineralizable C has multiple sources of variability: spatial, temporal and analytical. Mineralizable C had a twofold to 20-fold greater inter-laboratory variability than other commonly used soil tests, leading to a high degree of uncertainty associated with the interpretation of results. Procedural differences—such as sieve size and the method of rewetting—significantly influenced measurements of mineralizable C and underscore the need for the development of a standardized and universally adopted protocol. Capillary rewetting consistently suppressed mineralizable C relative to rewetting with a specific amount of water and is therefore is not a recommended approach. However, the sensitivity of mineralizable C to changes in management did not differ among incubation intervals of 6, 24, and 72 h. However, our findings show these sources of variability are soil-specific and may be a substantial hurdle to a repeatable measurement of mineralizable C and to its utility as a robust soil health metric. We used a conservative Type II ANOVA to determine effect sizes, suggesting that the potentially confounding effects are even greater when more liberal analyses are performed. Several in situ studies of respiration have found that samples sizes of up to 75 separate samples are needed to achieve 95% confidence in values ±10% of a population mean to account for these multiple sources of variability. In our study, the analytical variability is exemplified in the lack of statistical differences at the 95% confidence level between the means of 25% WHC (284.0 mg CO_2–C kg^{-1} soil) and 50% WHC (444.2 mg CO_2–C kg^{-1} soil) in soils sampled from one site, despite a 56% increase in mean mineralizable C measured. While these procedural effects may influence inter-laboratory variability, there was also a considerable amount of analytical variability associated with mineralizable C measurements within a laboratory that is highly dependent on soil type. In a commercial setting, this analytical variability can result in unreliable and/or inconsistent recommendations when using a single measurement. If additional analytical replicates were to be suggested, this would increase the cost of analysis and may serve as a financial barrier for growers.

<u>John Sawyer (IA State Univ.)</u>

Winter Cereal Rye Cover Crop and Corn Nitrogen Response

Understanding the soil supply of crop available nitrogen for corn production is critical for furthering our knowledge of corn nitrogen fertilization needs, refinement of fertilization guidelines, and improvement in fertilizer nitrogen use efficiency. This research will provide a greater fundamental knowledge of the processes controlling soil carbon and nitrogen cycling, with particular attention to the role of factors such as soil, climate and cropping systems on the soil nitrogen supplied to crops and nitrogen loss from soils. In addition, this research will allow a reassessment of current nitrogen rate guidelines for corn and provide new decision-aid tools, such as mechanistic process-based modelling and in-season active corn canopy sensing, to help understand plant response to nitrogen, nitrogen use efficiency, corn fertilization requirement across landscapes, and methods to adjust seasonal nitrogen fertilization. Information gained from the project will be disseminated through scientific journals and meetings; extension and outreach meetings for crop advisers, agency personnel, and farmers; and development or refinement of extension educational materials and decision-aid tools that will be deployed through internet and mobile platforms.

<u>Marshall McDaniel (IA State Univ.)</u>

Back to the 90's: NC1195 Data

Soil tests in general have served a critical role in the field of soil fertility for over half a century, and have helped to increase crop productivity and promote more efficient use of fertilizers on farms. However, N soil tests have limitations and chemical extraction tests have not predicted well the potentially mineralizable N supplied to corn over a growing season. Thus, these tests often do not accurately predict a corn's yield response to fertilizer N. We explored 30 soil tests for their individual and combined ability to predict corn response to N application in 56 site-years across the Midwest USA (1995-1998 over NE, WI IL, and MN). Corn responses to N varied significantly, with 59% showing a significant yield response to N (RN) and surprisingly 41% showed no response to N (many with manure history). We sub-divided the 41% non-responsive sites into two categories – non-responsive, high-yielding (NRHY) and non-responsive, low-yielding (NRLY). A 14 day aerobic incubation (O2I) best predicted whether or not soils responded to N ($P = 0.035$). Using machine learning, a combination of the O2I and an 8-minute 2 M KCl extraction best predicted N response category – where O2I < 35 mg N/kg was responsive, and an 8-minute 2 M KCl extraction was able to resolve whether corn in the non-responsive soil was NRHY or NRLY (high-yielding soils had >10 mg N/kg). Our results highlight the potential need for a combination of two or more N soil tests in order to enhance prediction of corn response to N application. Using this multi-test approach, agronomists can obtain optimal yields in soils that respond to N application, and reduce over-application of fertilizer N in non-responsive soils.

Use of past project datasets

- Marshall McDaniel is working on the "old" 1995-1998 NC218 dataset. Goal is to talk with group about 1st draft of publication in March 2019.

- Xiaofei Li now also has NC218 data and will look into economics of the 56 site-year data.

Data and publication development

- Answer question of "Are non-responsive sites decreasing over time?" Or in other words, is corn becoming more and more reliant on N over the decades it has been grown in the NC Midwest? This would require a literature search (including 'gray' literature and extension documents). See Sebilo (2013).

Next meeting March 5-6, 2018 at Fairfield Inn and Suites, Kansas City, MO

Leadership

Leadership for 2019 is:
Marshall McDaniel, Chair;
Ann Russell, secretary,
Sindhu Jagadamma*, member-at-large.

*Sindhu Jagadamma was elected as member-at-large and will make arrangements for next year's meeting.