<u>Project Report of NREC Project</u>

Impacts of Manure and Inorganic Fertilizer on Soil Fertility, Water Quality, and Crop Yield in South Dakota

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Summary. The experimental site for SDSU soil fertility project is located at the Southeast Research Farm of the South Dakota State University located at Beresford, and Brookings Felt farm, South Dakota. The experimental sites were established in 2003 at Beresford and 2008 at Brookings to assess the influences of manure and inorganic fertilizer on the long-term corn (*Zea mays* L.)-soybean (*Glycine max*. L.) rotation. Crop rotation now is proposed to be corn-soybean-spring wheat. The experimental site has 24 plots with 4.6 to 20 m dimensions into complete randomized block design. The study treatments include: three manure rates [low manure (LM), manure application based on the phosphorous requirement; medium manure (MM), manure application based on nitrogen requirement; high manure (HM), two times prescribed nitrogen rate], two chemical fertilizer rates [medium fertilizer (MF), recommended inorganic fertilizer rate; high rate of the fertilizer (HF)], and control (CK, without any manure or fertilizer application). The manure was applied in the spring in a manual application and incorporated by disk at 6-cm deep for 1 to 3 days before planting at either site. South Dakota Agricultural Laboratories analyzed manure of the study. Fertilizer treatments for 190 kg ha^{-1} yield goal for corn in 2018 and no fertilizer application was done for soybean in 2019 for both sites.

Data showed that high manure compared to the high fertilizer treatments increased soil microbial community (total PLFA was 2715 ng g^{-1} soil in HF compared to 1315 ng PLFA-C g^{-1} soil in control treatment), porosity and water retention. In general, manure application increased the carbon fractions and β-glucosidase enzyme activity as compared to the control for 0-10 cm, indicating the carbon stability and carbon cycling in the manure applied system. Carbon and nitrogen fractions increased with the higher manure application for first two depths (22.5 and 17.1 µg C g^{-1} soil), but were not affected by fertilization; however, only cold water soluble organic nitrogen (CWN) was increased by medium fertilizer treatment as compared to the control for 0-10 cm depth, whereas, both medium and high fertilizer treatments increased the CWN by 121% and 86%, respectively, for 10-20 cm soil depth. Overall soil health was higher under manure applications when compared to inorganic fertilization. However, risks for nutrient transport away from the field were also high when manure applications exceeded recommend rates based on soil phosphorus. For C pools in 2018 and 2019, results also showed that all manure and inorganic fertilizer significantly increased active C at 10-20 cm depth compared to CK. Treatments that included manure had significantly higher C mineralization than inorganic fertilized treatments and CK at 0-10 cm. The manure treatments also had higher dissolved organic C and N than inorganic fertilized treatments at both sites. Particulate organic C and N also increased by manure at both depths compared to inorganic fertilized and CK at both sites. Carbon management index increased by manure at both depths compared to inorganic fertilizer at Brookings. The results demonstrate that manure can increase C and N compared to inorganic fertilized and unfertilized treatments.

The present study will help in assessing the impacts of incorporating the cover crops in enhancing the soil health and water quality under corn-soybean-spring wheat rotation managed with different manure and fertilizer treatments.

The spring wheat was introduced into the corn-soybean rotation in 2020 spring and cover crops will be added in the rotation in 2020 fall at the Brookings and Beresford sites. The introduction of the spring wheat and cover crops into the rotation is to diversify crop rotation and increase year around soil coverage, and target nutrient scavenging.

Study Objectives.

The primary goal of this project is to provide information to producers on the optimum rates of inorganic fertilizer and manure for enhancing soil fertility and crop yields without losing extra N and P losses. The specific objectives of the project are to:

1. Assess the impacts of manure and inorganic fertilizer applications under corn-soybean-spring wheat-cover crop rotation on soil P fractions (organic and inorganic) at two sites (Beresford and Brookings).
2. Assess the impacts of manure and inorganic fertilizer applications on soil health indicators (microbial carbon, enzymes, phospholipid fatty acids, water retention and storage, porosity, and water infiltration rate).
3. Assess the impacts of manure and inorganic fertilizer applications on N loss via leaching, NH_3 volatilization, N_2O emissions, and N retention in plant and soil pools.
4. Assess the impacts of manure and inorganic fertilizer applications on crop growth parameters, nutrients in plants, and N use efficiency.

Methods

Soil samples were collected before planting in 2020 at both sites to determine the nutrient status and to apply manure and fertilizer to the treatments. Spring wheat was planted at both sites and calculated manure and fertilizers were applied based on the treatment requirement. Soil samples were collected from 0-5 and 5-15 cm depths in 4 replicates and mixed together to make a composite sample for each plot in June 2020 to analyze selected soil health indicators. Detailed tasks are mentioned below for 2020.

Task 1. To determine soil phosphorus fractions.

Impacts of manure and inorganic fertilizer applications under corn-soybean-spring wheat-cover crop rotation on soil P fractions (organic and inorganic) at two sites (Beresford and Brookings). Soil samples were collected from 0-5 cm (surface), and 5-15 cm (sub surface) depth from each plot in June 2020 (during spring wheat). Samplings are also scheduled after the harvest of spring wheat (Sep, 2020) and during cover crop (Nov-Dec, 2020) at both the sites.Total P concentration will be determined ($HClO_4$–HNO_3 digestion). Phosphorus fractions (labile, moderately labile and non-labile) will be determined using the fractionation procedure. Both organic and inorganic P levels will be determined by measuring with $NaHCO_3$, NaOH and HCl extracts. The residual P content will be determined by subtracting the amount of extracted P from the total P content. Microbial biomass P will be determined by the fumigation-extraction method. Soil P stock will be calculated for each soil depth. In addition, P concentrations in leaves and grain, as well as P accumulation in total aboveground biomass will also be measured at crop harvest.

Task 2. To Assess Soil Health

Impacts of manure and inorganic fertilizer applications on soil health indicators such as C and N fractions, enzyme activities, microbial community structure (MCS), and physical and hydrological properties. Soil samples at 0-5 and 5-15 cm depths were taken from each plot for the two sites (Beresford and Brookings). Collected soil samples are stored in a cooler, transported to the lab and stored at 4°C for soil enzyme activities and microbial biomass analysis and at -20 °C for MCS analysis. Part of a sample has been air-dried and ground to pass through a 2-mm sieve for further analysis. Soil organic C and total N concentrations will be determined by combustion using a C and N analyzer after grinding the soil to 0.1 mm. Microbial biomass C (MBC) and (MBN) N, active C (AC), water-soluble C (WSOC) and N (WSON) will be also determined. While the content of MBC and MBN will be analyzed using the fumigation-extraction method, AC in soils will be measured using the permanganate oxidizable C. Water-soluble C and WSON will be determined using a distilled water in a soil/solution ratio of 1:10. Enzyme assays will follow standard protocols with sample incubation at 37°C for a fixed time period in a specific buffer pH range, with the needed substrate. Arylamidase enzyme catalyzes the hydrolysis of an N-terminal amino acid from arylamides; dehydrogenase enzyme plays an essential role in the initial stages of soil organic matter oxidation; β-glucosidase enzyme is involved in the hydrolysis of cellobiose and amidohydrolases (L-asparaginase, L-glutaminase, and urease) are widely distributed in nature, and have been detected in plants, animals, and microorganisms. All the enzymes' results will be expressed on moisture-free basis. Moisture will be determined from loss in weight following drying at 105°C for 48 h. Phospholipid fatty acid (PLFA) analysis will be used to assess the composition of MCS. Briefly, phospholipids will be separated from neutral lipids and glycolipids in silica gel columns. Fatty acid methyl esters will be created through mild acid methanolysis. The PLFA methyl esters will be analyzed on an Agilent gas chromatography. The sum of all PLFAs will be used to estimate total microbial biomass. Different bacteria biomarkers will be identified and summation of the bacterial sum included gram positive bacteria, gram negative bacteria and actinomycetes. Similarly, total fungal biomass included saprophytic biomarkers and an arbuscular mycorrhizal fungi associated biomarker. The fungal/bacterial ratio will calculated by dividing the fungal sum by the bacterial sum. Soil protein (glomalin) content will be determined by using BCA assay. Water scout sensors are installed to record soil moisture, soil temperature and matric potential at Beresford site.

Task 3. Soil nitrogen losses assessment

To assess the impacts of manure and inorganic fertilizer applications under corn-soybean-spring wheat-cover crop rotation on N loss via leaching, NH_3 volatilization, N_2O emissions, and N retention in plant and soil. Runoff and denitrification will be minimal because of the flat fields. Water samples from the two fields will be collected using suction lysimeters, which will be installed and fixed at 1.0 m depth. The samples will be collected 3–6 times per year for measuring N leaching. NH_3 volatilization from the two fields will be measured using a continuous ventilation method. Briefly, PVC collectors with a phosphoglycerol-soaked sponge as an absorbent will be used and the NH_4–N in the sponge will be extracted and measured using a spectrophotometer. Soil N_2O emissions will be measured using a static chamber method. Soil samples will be collected for measuring the NO_3-N and NH_4-N contents using the KCl extraction method. Plant dried samples will be ground to pass through a 0.5 mm sieve and will be digested with H_2SO_4-H_2O_2 to measure N level in the plant.

Task 4. To Assess Crop growth and yield

To assess the impact of manure and inorganic fertilizer applications under corn-soybean-spring wheat-cover crop rotation on crop growth parameters (crop height, different crop growth stages, crop yield, 1000 grain weight), nutrients in plants, and N use efficiency, agronomic N use efficiency and physiological N use efficiency. Collected plant samples will be dried at 70ºC and ground to pass a 20-mesh sieve for measuring nutrients levels. Nutrient uptake will be calculated based on the per cent nutrient in gran/straw and dry matter content of grain/straw. The N use efficiency will be calculated as a ratio of (N uptake by the crop on N treated plots - N uptake by the crop on the control) to the total N applied. The agronomic N use efficiency will be determined by dividing (the yield in N treated plot - the yield in control plot) by the rate of applied N. The physiological N use efficiency for grain will be calculated by dividing the sun-dried grain weight from all plant harvest by the total N accumulation at maturity. The physiological N-use efficiency for biomass will be calculated by dividing the plant matter accumulation at maturity by the total N accumulation at maturity.

Changes in project or personnel. One MS Student (Asmita Gautam) and two partially budgeted postdoctoral researchers (Abagandura Gandura and Udayakumar Sekaran) worked under this project in 2019. Jemila Chellappa joined in the project in February 2020.

Products/Publications/Presentations.

- Gautam, A., Jose Guzman, Péter Kovács and Sandeep Kumar. 2020. Manure and inorganic fertilization impacts on soil nutrients, aggregate stability, organic carbon and nitrogen in different aggregate fractions. Archives of Agronomy and Soil Science. (Under review)
- Gautam, A., Udayakumar Sekaran, Jose Guzman, Péter Kovács, Jose Gonzalez and Sandeep Kumar. 2020. Responses of soil microbial community structure and enzymatic activities to long-term application of mineral fertilizer and beef manure. Environmental and Sustainability Indicators.(Submitted)
- Gautam, A. MS student. (Graduated Fall 2019). Long-term impacts of manure and inorganic fertilization on soil physical, chemical, and biological properties. MS Thesis.
- Gautam, A., Jose Guzman, Sandeep Kumar, Peter Kovacs and Peter Sexton. 2019. Long-Term Impacts of Manure Application and Inorganic Fertilization on Soil Health in South Dakota. Poster presentation at Soil Science Society of America Annual Meeting in San Diego, CA.
- Abagandura, O.G., Butail, P.B., Mahal, N.K., Gautam, A., Kumar, S. 2019. Carbon and Nitrogen Pools As Affected By Long-Term Manure and Synthetic Fertilizer Application in Corn and Soybean Rotation. Oral presentation at 2019 ASA-CSSA-SSSA International Annual Meeting, Nov. 10-13, San Antonio, Texas.
- Gautam, A., Guzman, J.G., Peter Kovacs, P., Sexton, P, and Kumar, S. 2019. Long-Term Impacts of Manure Application and Inorganic Fertilization on Soil Aggregate Stability, Soil Organic Carbon and Nitrogen in Different Aggregate Factions in South Dakota. Oral presentation at 2019 ASA-CSSA-SSSA International Annual Meeting, Nov. 10-13, San Antonio, Texas.
- Gautam, A., Sekaran, U., Guzman, J.G., Peter Kovacs, P., Kumar, S., and Sexton, P. 2019. Long-Term Impacts of Manure Application and Inorganic Fertilization on Microbial Properties in South Dakota. Poster with 5-minute Rapid presentation at 2019 ASA-CSSA-SSSA International Annual Meeting, Nov. 10-13, San Antonio, Texas.