Crop and Soil Management Systems for Water Quality Protection and Agricultural Sustainability

Traditional nitrogen (N) fertilizer management schemes for U.S. corn production systems have resulted in low N use efficiency (NUE), reduced water quality, and considerable public debate regarding N use in crop production. Hence, alternative N management strategies, that improve NUE and protect water quality, are needed to sustain corn-based farming. The key to balancing tradeoffs amongst yield, profit, and water quality protection is to achieve synchronized N supply vs. demand, and in so doing, account for spatial and temporal variability in N supply and demand. This project will develop alternative strategies by using remote sensing techniques to direct in-season variable N applications to areas needing N when the crop can most efficiently utilize N. To accomplish this goal we will first develop protocols for using active sensors to accurately assess canopy N status. Then we will develop sensor algorithms that translate sensor data into corrective N applications. Finally, we will develop a decision aid that integrates sensor output with other data including weather and spatial information on soil properties to make more appropriate N applications under ever-changing soil and weather conditions. We expect NUE can be enhanced using this responsive strategy for corn N management. In the foregoing strategies, we endeavor to synchronize N supply to meet crop demand. During parts of the season (especially fall), N supply through mineralization exceeds crop demand. To address this part of N synchronization, we will develop cropping systems that utilize winter cereals to remove residual soil N and protect groundwater quality.

Objective 1: Develop procedures, using active sensor measurements of crop N status to make variable rate in-season N applications to improve N use efficiency, optimize profitability, and protect water resources.

Objective 2: Develop cropping schemes and management strategies using winter cereals to remove excess N from the soil system.

Need for Research

The Western Corn Belt and Central Great Plains are major production areas for corn, soybean, sorghum, wheat, and forage. For production of these crops to be efficient, nutrients, especially nitrogen (N), must be added to the natural system to replace N removed through crop harvest and other natural and management related processes. However, at times during the growing season crop demand may exceed N availability and crop yield is likely reduced. Other times, N availability may exceed crop demand, resulting in environmental degradation. For greatest efficiency, the addition of N should occur in the quantity and at the time to equal crop demand. Unfortunately, traditional N management schemes have resulted in over application of N. These applications often occur at a time convenient for the farmer, but not synchronized to crop demand. These practices result in low nitrogen use efficiency (NUE) and subsequent economic losses as well as environmental degradation (ground and surface water contamination and release of greenhouse gases to the atmosphere). Spatially variable landscapes and soils and weather variation are additional major causes for low NUE in traditional N management schemes in the region. To adjust management for effects of soil and weather variability on plant N nutrition and to improve N management, more complete understanding and new techniques are needed. Active sensors that can remotely assess crop N status, N decision aids that use sensor or other spatial data along with soil and weather factors affecting plant N status, are needed to make appropriate in-season N applications to synchronize N supply with crop demand. Additionally, research is needed to identify productive cropping schemes that remove excess nitrate from the soil system when N supply exceeds crop demand. Planned research will provide producers with technologies that better synchronize crop N demand with N supply and as a result improve NUE and protect water and air quality. Our assumption is that if NUE is improved for these new technology vs. traditional N management, more N will be captured by the crop and less will be available in the soil system to potentially degrade the environment through either leaching or gaseous losses.

Producers will benefit through more efficient management of inputs, regulatory agencies will benefit by having a wider array of effective practices to offer land managers as they partner to achieve environmental protection goals, and society will benefit through improved soil, air, and water quality.

This project will produce procedures for use of active crop canopy sensors to detect N status, decision aids to use sensor output to guide fertilizer N application, and improved cropping schemes for better management of N in crop production systems.

Customers of the research include producers, consultants, extension educators, regulatory agency personnel, and other scientists. Much of the research will be conducted on farmer’s fields and results will be shared with consultants, extension personnel, and other scientists.

Soil Management Practices for Dryland and Irrigated Cropping Systems

Soil performs essential functions such as providing a medium for plant growth, storing and purifying water, supplying nutrients for plant growth, and affecting air quality through interactions with the atmosphere. Soil management affects how well soils perform these essential functions, which is complicated by soil spatial variability. The goal of this project is to develop approaches for mapping spatial variability, delineate spatially variable fields for efficient application of inputs, and will determine how residue management affects soil function. Soil N and C impacts the environment through their effects on water and air quality. Research will be conducted to improve our understanding of soil N and C dynamics. This information will be used to develop a N index for assessing management effects on water quality, develop an algorithm for in-season application of N fertilizer, and improve residue management for C sequestration. Tools for assessing soil management effects on soil functions are lacking. This study will implement an assessment tool, the Soil Management Assessment Framework (SMAF), using datasets from diverse research projects. The SMAF will be improved by developing scoring curves for additional soil indicators. Use of corn stover for ethanol production has been proposed. This study will determine the impact stover removal has on soil function and develop recommendations for determining the amount of stover that can be diverted to ethanol production without impairing soil function. Products resulting from this study will contribute to improved soil management that maintains or improves the soil functions needed for sustainable soil use.

Objective 1: Determine the role of spatial variability in affecting management outcomes in dryland and irrigated systems.

a. Develop sensors for in-season nutrient management.
b. Determine management zones for efficient use of inputs.
c. Residue management to maintain or enhance critical soil functions.

Objective 2: Improve understanding of N and C dynamics in cropping and tillage systems commonly used in the Western Corn Belt and Central Great Plains.

a. N index – Assist NRCS efforts to develop a N index for identifying BMP's that minimize N losses in runoff and leaching.
b. Develop an algorithm for in-season N management.
c. Soil C dynamics to enhance C sequestration.

Objective 3: Implement and expand the Soil Management Assessment Framework (SMAF)

a. Develop additional scoring curves for the SMAF.
b. Implement the SMAF.

Objective 4: Determine the impact residue removal for biofuel production has on the soil resource.

Need for Research

The Western Corn Belt and Central Great Plains are major production areas for corn, soybean, sorghum, wheat, and forage. Confined livestock feeding operations and biofuel production are major consumers for crops produced in this region. Spatial variability in soil properties and highly variable weather (precipitation and temperature) complicate management for crop production. Decision support tools, improved understanding of the role mineralization and residual soil N play in plant nutrition, and approaches for sampling soils to account for spatial variability are needed to improve soil nutrient management. Decision aids, assessment tools, and a better understanding of the role crop residue management plays in C dynamics are needed to conserve soils and improve or maintain critical soil functions, especially in areas where crop residue may be used as feedstock for biofuel production. A better understanding of the effect management has on the flux of greenhouse gases between soils and the atmosphere is also needed.

Producers will benefit through more efficient management of inputs, regulatory agencies will benefit through more accurate assessment of management practices, and society will benefit through improved soil, air, and water quality.

This project will produce decision aids, sensors, and assessment tools for managing inputs associated with production agriculture. We will enhance existing soil management assessment tools for use by producers, consultants, and regulatory agencies. We will provide recommendations for producers and the ethanol industry regarding harvest and management of crops and crop residue for biofuel production.

Producers, consultants, extension educators, regulatory agency personnel, and other scientists are customers of this research. Much of the research will be conducted on farmer's fields and results will be shared with consultants, extension personnel, other scientists, and agencies such as NRCS and DOE. Other aspects of the research will involve validation and improvement of existing assessment tools and will involve personnel from regulatory agencies and other scientists.

Environmentally Sound Manure Management for Reduction of Health-Related Microorganisms and Odor

Need for Research: Livestock production has become more concentrated, which increases the risk for manure-related environmental pollution (i.e., pathogens, nutrient mobilization, greenhouse gases, ammonia emissions, and odors). Typically, animal manure is stockpiled and/or treated and then land-applied in order to deal with the large amounts of manure that are produced by animal feeding operations. Land-applied manure is nutrient-rich, and thus, serves as a valuable renewable resource for crop production that can be substituted for synthetic fertilizers. However, manure also contains microorganisms, some pathogenic. Manure-borne pathogens may pose a threat to human and animal health due to accidental ingestion, inhalation, or transmission to water sources, food crops, or inanimate objects that come in contact with animals and humans. The activities of most microorganisms in manure are largely unknown, but are responsible for manure decomposition that can result in unwanted odor and gas emissions. The lack of basic information on manure microbial processes and the potential for pathogen dissemination and nutrient losses during manure storage, treatment, and application hampers research efforts focused on assessing and controlling emissions from confined animal production facilities and land application areas.

Objectives

(1) Define the critical environmental (temperature and moisture content) and biological factors (manure content/composition and nutrient content) affecting emissions of odor compounds, greenhouse gases, and ammonia from beef cattle feedlot surfaces.

(2) Measure the effects of critical environmental and biological factors (Objective 1) on transport of N, P, and indicator microorganisms from beef cattle feedlot surfaces.

(3) Determine the potential for emissions of pathogenic, fecal indicator microorganisms, nutrient and odor compounds in wastewater, soil and air during and after spray wastewater application.

(4) Evaluate alternative treatment technologies such as constructed wetlands, cattle feedlot runoff systems, and water treatment technologies to reduce or eliminate the occurrence, transmission, or persistence of manure-borne pathogens and excessive nutrients (N and P) and other constituents (biological oxygen demand, pH, and total suspended solids).

Products & Customers of Research: Producers, rural communities impacted by manure emissions, other scientists, federal and state agencies, public health officials, and the general public will benefit from this program by utilizing information on the critical control factors regulating pathogen occurrence and fate, odor production, and excessive nutrient transport in manure-impacted environments. This information is vital for the development of management tools and technologies for reducing the environmental impacts of modern livestock production.

Improved manure storage, treatment, and application procedures are the anticipated products of this research. Better manure storage, treatment, and application practices will produce: (i), safer water, air, and food supplies, (ii) reduced emissions of volatile N, odor compounds, and greenhouse gases, (iii) reduced synthetic fertilizer use, and (iv) reduced nutrient transport in runoff.