Project Title: Influence of cover crops on nutrient dynamics and stratification in an established no-till wheat-sorghum-soybean cropping system.

Principle Investigators:

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Introduction/Justification:

The opportunity for this research comes during a time of continued scrutiny of agriculture's contribution to ground and surface water contamination and the production of greenhouse gases (CO_2, CH_4 and N_2O) that are linked to climate change and necessitates studies that examine long-term effects of management decisions. Examples of the decisions facing scrutiny include the rate of nitrogen (N) fertilizer applied and the use of cover crops for their mitigation potential in no-till systems. The response of an agro-ecosystem to a management change is a culmination of rapid and slow changes during several years. Thus, accurately interpreting the impact of management decisions requires long-term studies that look at cumulative responses over time.

Nutrient stratification is an expected cumulative response in a long-term no-till system. Native prairie ecosystems have considerable nutrient stratification because of the translocation of nutrients from the soil profile into above ground plant tissue and the subsequent senescence and decay of the plant material on the soil surface (Groves et al., 2007). The translocation of nutrients by deep-rooted plants prevents nutrients from leaching below the rooting zone. This can prevent N leaching losses and degradation of ground water. No-till cropping systems that incorporate deep-rooted crop species and/or cover crops in the rotation mimic the prairie. The plant roots function like a pump moving nutrients from the soil to the above ground plant tissue and the decaying tissue on the soil surface enhances nutrient stratification (Chen and Weil, 2010; Smith et al, 2007). Root growth has been observed to proliferate in zones with high nutrient availability. The mulch layer in no-till systems moderates soil temperatures and maintains adequate soil moisture, supporting root growth and nutrient uptake throughout most of the growing season. The challenge of nutrient stratification in a no-till cropping system is the potential for increasing near-surface phosphorous (P), resulting in greater losses of dissolved P (organic and inorganic) with runoff water (Groves et al., 2007, Smith et al., 2007).

In our study, crop yield responses to N rates with and without cover crops in a no-till system already have revealed some interesting patterns. Sorghum planted after some cover crops, has demonstrated greater fertilizer use efficiency at low and intermediate nitrogen application rates in three of the five harvest years (Figure 1 a and b).

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Figure 1a. Sorghum yield response to preceding cover crop and nitrogen fertilizer in 2009 and 2010.

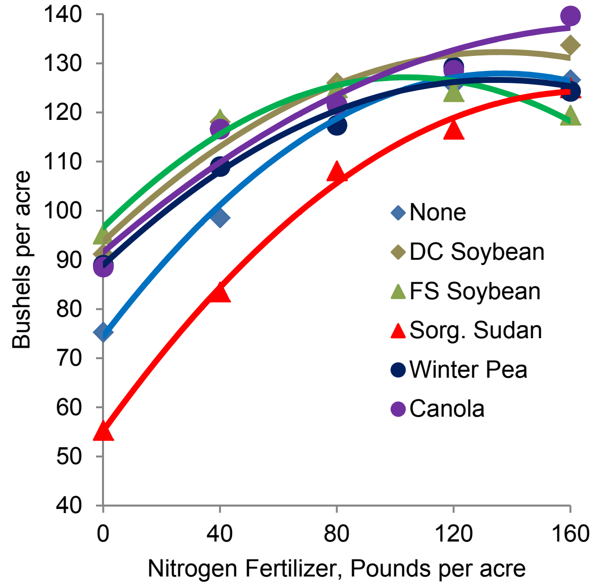
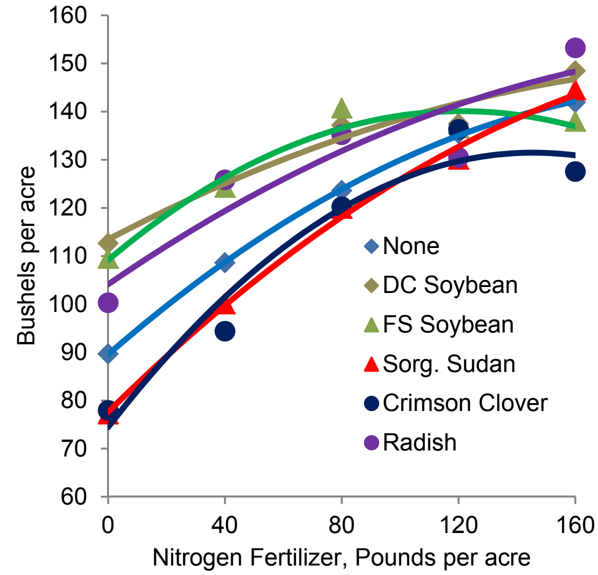


Figure 1b. Sorghum yield response to preceding cover crop and nitrogen fertilizer 2013.



GreenSeeker NVDI data collected from pre-heading sorghum supports the conclusion that nitrogen uptake differs depending on N rate as well as cover crop type (Figure 2 a and b).

Figure 2a. Sorghum CNVDI response to preceding cover crop and nitrogen fertilizer in 2009 and 2010.

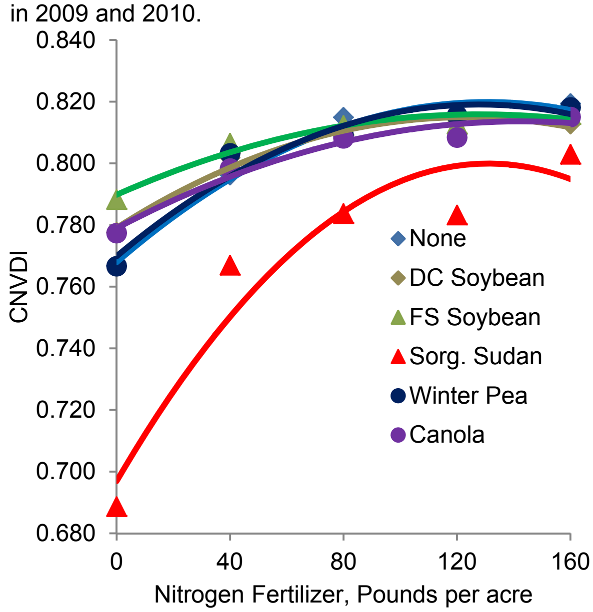
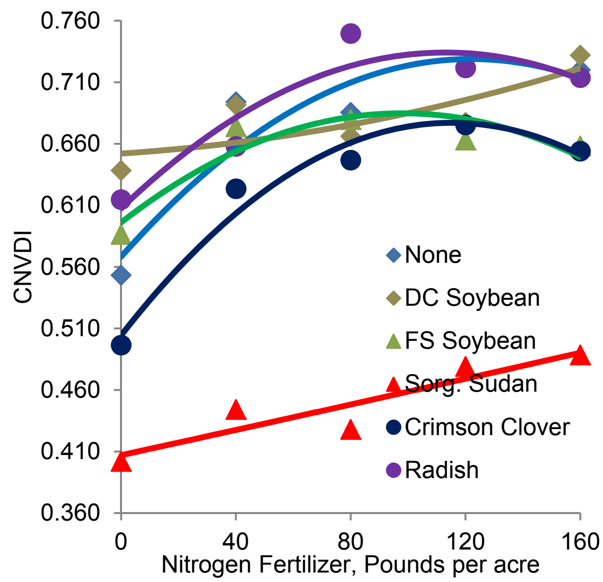


Figure 2b. Sorghum CNVDI response to preceding cover crop and nitrogen fertilizer 2013.



In 2012, with both the heat and soil moisture stresses, the presence of cover crops in the rotation ahead of sorghum affected sorghum, wheat and soybean yields (Figure 3 a

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b c). The effect of cover crop species on yields of the grain crops in different phases of the rotation was not consistent.

Figure 3a. 2012 Sorghum Yield Response to Cover Crop.

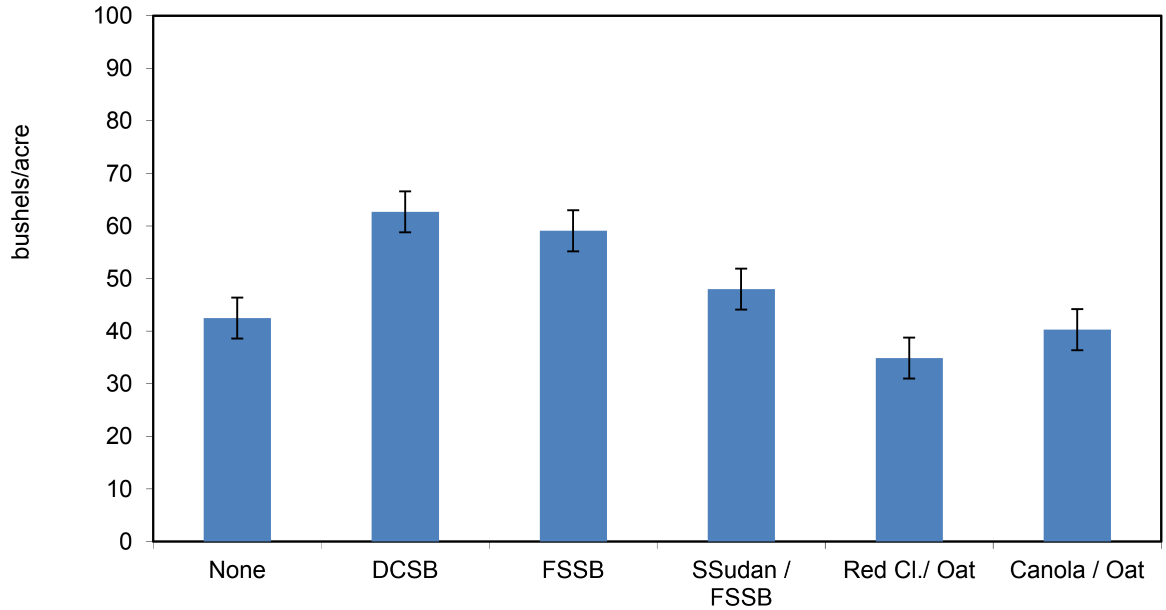


Figure 3b. 2012 Wheat Yield.

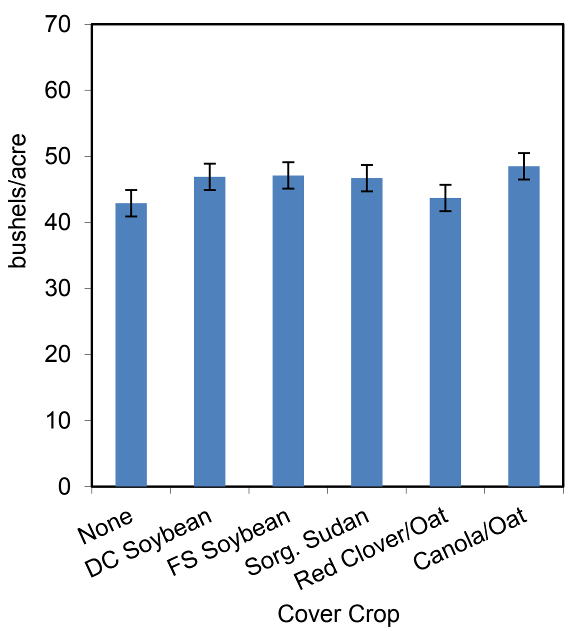
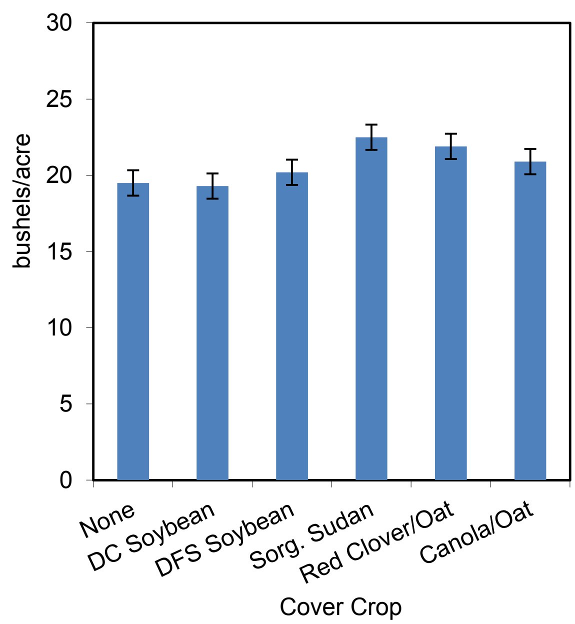


Figure 3c. 2012 Soybean Yield.



Preliminary research quantifying season long N_2O emissions from the 80 kg ha^{-1} nitrogen rate and non-legume cover crops suggests that cover crops may play an important role in reducing N_2O-N loss from the system. Figure 4 displays the

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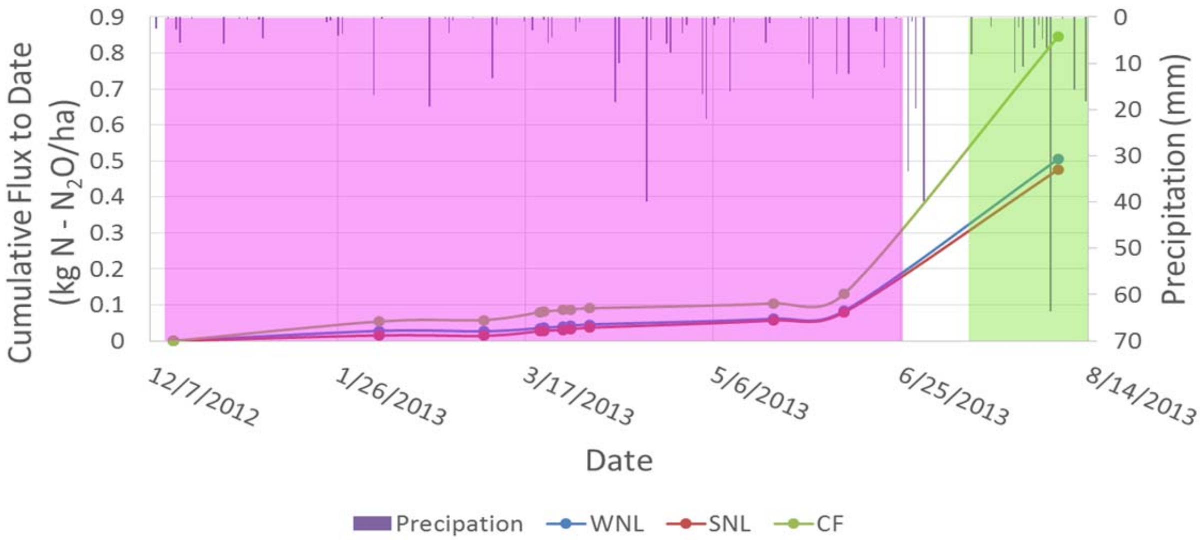
cumulative nitrous oxide flux in winter wheat (2012; purple shaded box) followed by 2013 summer non-legume (green shaded box) cover crop. The chemical fallow treatment has significantly higher cumulative nitrous oxide flux (P=0.05; LSD 0.1 = 0.37).

Figure 4. Cumulative nitrous oxide flux in winter wheat and cover crops.



Additional research that includes legume cover crops and a range of N rates is needed to more fully understand the role of cover crops in managing and mitigating N_20 losses. The overall nitrogen use efficiency, including an accounting of N_2O losses, can then be determined. Soil profile nutrient characterization is needed to understand how different cover crops and N rates applied during the sorghum phase may be effecting P, K and pH stratification. It is plausible that plants in the high N rate treatment are transporting high amounts of P and K from the soil profile, enhancing the nutrient stratification gradient. The comprehensive quantification of NUE, N_2O losses and nutrient stratification in a cropping system with different cover crops and N rates provide improved understanding of no-till cropping systems and opportunities to optimize fertilizer use efficiency and minimize environmental impacts.

Project Goals and Objectives:
The goal of the proposed project is to addresses the priority area **"Better understanding of no-till related to fertilization practices."** Specifically this project will examine nitrogen use efficiency (NUE) and nutrient and pH stratification in sorghum phase of a wheat/cover crop – sorghum – soybean cropping system converted to no-till in 2007.

The specific project objectives and hypotheses are:

1. Determine how legacy effects of legume and non-legume summer and winter cover crops proceeding sorghum, impact NUE, yield and N_2O production in the sorghum phase of the rotation.

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2. Characterize influence of cover crops on P, K, and pH stratification in the soil profile after eight years of no-till.

To accomplish the research objectives, yield, plant, soil and gas samples will be collected during the 2014 and 2015 growing seasons from the sorghum phase of the rotation.

Procedures:

A. Field Experiments – Since the 2007 cropping season, the Cropping Systems Research Group in the Department of Agronomy at Kansas State University (PI Roozeboom) has maintained a 4-hectare no-till cropping system study at the Kansas State University Department of Agronomy field research unit located approximately 8 km south of Manhattan, Kansas on a Wymore silty clay loam soil (fine, smectitic, mesic Aquertic Argiudoll; 39˚11'N 96˚35'W (Figure 5).

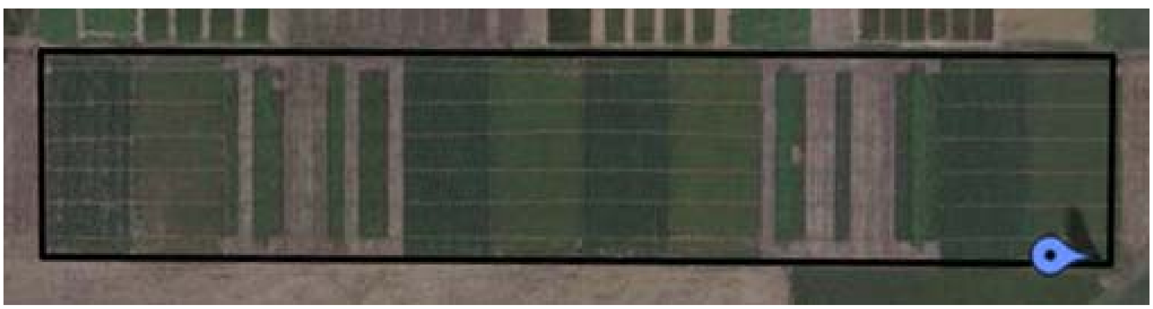

Figure 5. Google Map image of site (http://goo.gl/maps/dALwD).

The study consists of all phases of a three-year wheat/cover crop – sorghum – soybean rotation containing six different treatments imposed between wheat harvest and sorghum planting:

1. Chemical fallow check – sprayed at least twice between wheat harvest and frost to control weeds and volunteer wheat.
2. Double-crop soybean check – soybeans planted as soon as possible after wheat harvest and harvested for grain.
3. A summer non-legume (currently sorghum-sudan grass) – planted as soon as possible after wheat harvest and terminated with roller/crimper at boot to early heading (typically early to mid-September).
4. A summer legume (currently late-maturing soybeans) – planted as soon as possible after wheat harvest and terminated with roller/crimper at early pod set (typically early to mid-September).
5. A winter non-legume (currently tillage radishes) – planted in mid to late August, depending on soil surface moisture conditions, and terminated by

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freezing temperatures during winter. Often has had one or two herbicide applications before planting to control weeds and volunteer wheat.

6. A winter legume (currently crimson clover) – planted in mid to late August, depending on soil surface moisture conditions, and terminated chemically in late April, typically three to four weeks before sorghum planting. Often has had one or two herbicide applications before planting to control weeds and volunteer wheat.

Each cover crop and check treatment (6 m x 70 m) is subdivided into subplots (6 m x 14 m) receiving five different nitrogen fertilizer rates (0, 45, 90, 135 and 180 kg N ha^{-1}) applied within 30 days of sorghum emergence using a flat-coulter liquid fertilizer applicator to inject nitrogen fertilizer (32-0-0 UAN) below the residue layer. Nitrogen application rates are designed to characterize sorghum response to fertilizer nitrogen at yields up to 10 Mg ha^{-1}. For this project we will focus on three N rates:

1. 0 kg N ha^{-1} – No supplemental N added to the sorghum crop. There may be residual N from the wheat crop and/or N fixed by the legume cover crops
2. 90 kg N ha^{-1} – Nitrogen addition expected to minimize any N limitation while still detecting nitrogen contributions for the cover crops.
3. 180 kg N ha^{-1} – Nitrogen addition expected to compensate for any N limitations and maximize sorghum yield.

The ongoing nature of the rotations has allowed medium to long-term effects to accumulate over time, including changes in the soil profile nutrient characteristics, organic matter content and physical and biological characteristics. The fallow treatments were first imposed during the 2007 growing season. Therefore, sampling during the sorghum phase (Objective 1 below) or immediately after sorghum harvest (Objective 2 below) will be applied to plots that have had fallow treatments imposed three times in the context of 2 ⅔ cycles of the full rotation in 2014 and a full three cycles in 2015.

B. Sampling relative to Objective 1, NUE, Yield and nitrous oxide (N_2O) fluxes – The design of the experiment allows for an accurate estimate of nitrogen contribution to the sorghum crop following termination of each cover crop and the ability to determine in season plant N uptake at multiple times during the growing season using GreenSeeker® (Trimble Navigation Ltd., Sunnyvale, CA) NVDI, N_2O fluxes for each cover crop by N rate combination, NUE and residual soil nitrogen concentrations at the end of the growing season.

During the sorghum phase of the rotation the following parameters will be

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measured or calculated to provide an accurate estimate of yield, nitrogen uptake and agronomic use efficiency, and N_2O losses:

1. Total biomass yield and N content
2. Grain yield and N content
3. Nitrogen Use Efficiency (kg kg^{-1}) = Grain weight / N supplied.
   N supplied is the fertilizer N applied + N supplied in the soil.
   N supplied by the soil is estimated by Total N in plant for 0-N plot.
4. Nitrogen Utilization Efficiency (kg kg^{-1}) = Grain weight / Total N in plant.
5. Nitrogen Uptake Efficiency (%) = (Total N in plant / N supplied) x 100.
6. Nitrogen Recovery (%) = [N uptake (fertilized plot) –N uptake (0-N plot)] / [N applied] ×100.
7. Nitrogen Harvest Index (%) = (Grain N content / N total in plant) x 100.
8. Nitrous oxide fluxes will be quantified beginning with the proceeding cover crops and following through sorghum harvest using a static chamber based methodology according to the USDA GraceNet protocol (Parkin and Venterea, 2010) and analyzed by gas chromatography. The graduate student supported by this project will be responsible for samples collection and data analysis. Sample analysis will be supported by other funding sources and results will be reported to all funding sources.

C. Sampling relative to Objective 2, Nutrient Stratification – Soil profile nutrients (N, P and K) and pH will be quantified by collecting soil cores to a depth of 60 cm from all 0, 90 and 180 kg N ha^{-1} plots after sorghum harvest and dividing the cores into the following depth increments:

   1. 0-5 cm
   2. 5-10 cm
   3. 10-15 cm
   4. 15-30 cm
   5. 30-60 cm

   The sampling depth and increments described above have been used successfully to detect and characterize nutrient stratification on no-till systems (Smith et al., 2007).

D. <u>Technology Transfer</u> – The cropping system detail in this study is representative of similar no-till cropping systems in the Great Plains and the research findings will be representative of what producers utilizing no-till and cover crops are experiencing or could experience if they transition from a tillage based cropping system. The project findings and study site will be utilized in K-State Research

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and Extension programs including producer field days, professional development training for county agents, NRCS staff and certified crop advisors, and winter Extension meetings. Research findings will also be disseminated annually by multiple methods including handouts for the above describe programs, e-newsletters and websites maintained by the principle investigators (PIs). Furthermore, the data generated by this project will be presented at professional meetings such as the American Society of Agronomy and included in conference proceedings. The M.S. student supported by this project will prepare a thesis that details the research findings and included an outreach product such as an extension publication. The PIs will work with the graduate student to develop at least one peer reviewed publication and one extension publication.

Duration of the Project:

This two year project will be conducted from June 1, 2014 to May 31, 2016.

Expected Outputs and Outcomes:

This project will provide for a comprehensive characterization of the study treatments, allowing for the determination of difference in nutrient and pH stratification following the transition to an established no-till cropping system as well as a detailed examination of nitrogen use efficiency. This research will also provide an improved understanding of N_2O emissions in response to a range of nitrogen rates following different fallow management options including cover crops, double cropped soybeans and chemical fallow in a wheat/cover crop – sorghum - soybean rotation. Secondary outcomes include improved fertilizer and cover crop management recommendations that maximize producer profits, reduce phosphorous and nitrogen loss, including N_2O – a critical greenhouse gas, and improve soil health.

Project outputs will include graduate student training, M.S. thesis, Extension presentations, and research and extension publications. Additionally the project PIs will prepare annual reports detailing research progress, findings and technology transfer.

References:

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Grove, J.H., R.C. Ward, and R.R. Weil. 2007. Nutrient stratification in no-till soils. Leading Edge 6:374–381.

Parkin, T.B. and R.T. Venterea. 2010. Sampling Protocols. Chapter 3. Chamber-Based Trace Gas Flux Measurements. IN Sampling Protocols. R.F. Follett, editor. P. 3-1 to 3-39.

Smith, D.R., E.A.Warnemuende, C. Huang, and G.C. Heathman. 2007. How does the first year tilling a long-term no-tillage field impact soluble nutrient losses in runoff? Soil and Tillage Research. 95: 11-18.

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Project Budget:
Total: $60,000 ($30,000/year for 2 years). These funds will be used to support a graduate student, material, supply, and analytical costs associated with the proposed plant and soils research, and travel to the field site (year 1 and 2) and a professional meeting (year 2). The project graduate student will be responsible for the collections of the greenhouse gas samples outlined in this proposal. Analysis fees for the greenhouse gas samples will be supported through funds from existing sponsored projects and Regional Research Funds.

Proposed Budget Summary	**Year 1**	**Year 2**	**Totals**
A. Salaries and Wages:			
Graduate Student(s) - MS	$22371	$22371	$44742
B. Fringe Benefits (5.9% for graduate students)	$1320	$1320	$2640
C. Travel (Mileage to and from the field site in both years and funds for the graduate student to attend a professional meeting in year two to present research results.)	$400	$1200	$1600
D. Other Direct Costs			
Material and Supplies (Seed, fertilizer, chemicals, and fuel for plots. Expendable research supplies for plant and soil sample collection and processing.)	$1000	$200	$1200
Other - Contractual Services (Soil Testing Lab - Cost calculated based on the established fee schedule for Plant and Soil analysis)	$4909	$4909	$9818
E. Total Amount of This Request	$30,000	$30,000	$60,000