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Linking Soil and Water Quality with Crop Performance across a Continuum of Tillage and Management Strategies: Enhancing Sustainability through Soil-Health-Promoting-Practices: Years Two and Three.

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Abstract

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1. Scope of Work–2015 and 2016

In 2015 and 2016, research and extension activities continued on this project. The Neely-Kinyon Long-Term Agroecological Research (LTAR) Experiment entered its 19th year in 2016, reaching another milestone of significant impact; along with the other comparator sites, the USDA-ARS Organic Water Quality (OWQ) site, Boone, Iowa, having six years of production; and the Organic Reduced-Tillage (ORT) site, Boone, Iowa, ending ten years of research. Research continued at each site on the effect of organic system approaches on crop yields, weed management, soil quality, soil microbial community structure, nitrate leaching (OWQ), and economic performance. The following parameters were also measured: Grain (corn, soybean and oats), hay (alfalfa) and straw (oat) biomass and yields; Pest (aphids, bean leaf beetles, stink bugs, corn borer, earworms and soybean cyst nematodes) and beneficial insect population density and richness; Weed population density and response to organic treatments; Grain quality in terms of nutrient content and appearance; Soil quality indicators, including soil carbon sequestration and nutrient (C and N) cycling; soil chemical measurements, including macro- and micro-nutrients; soil physical measurements, including bulk density and aggregate stability; and Microbial community structure; Costs of production, including fuel, labor, pesticides, and fertilization; and Economic returns. The agronomic aspects were under the management of Dr. Delate and her lab, while the soil quality aspects were managed by Dr. Cambardella and Matt Bakker. Ann Johanns, ISU Extension specialist, continued with the economic aspects. Various labs at ISU (soils, plant disease, food-science) were utilized for specific analyses.

Partnerships with Adair County Extension and organic farmers throughout the state strengthened the impact of this work.

2. Project Summary

Comparisons across the three research sites, with histories ranging from 5- to 19-years-old, allowed for an examination of the effects of crop rotation history (short vs. longer) and system (organic vs. conventional) on weed management, crop productivity, soil quality and soil microbial communities. The Neely-Kinyon Long-Term Agroecological Research (LTAR) experiment was started in 1998 to examine suitable crop rotations that provide high yields, grain quality, and adequate soil fertility during the 3-yr transition to organic and following certification. Using identical crop varieties in both conventional corn-soybean (C-S) and organic three- and four-year crop rotation systems, organic corn yields following two years of alfalfa (C-S-O/A-A) have been statistically equivalent to conventional corn, averaging 162 bu/acre over the long term, compared to conventional corn provided 120-145 lb/acre of synthetic nitrogen, which averaged 169 bu/acre. Organic soybean yields, averaging 49 bu/acre, have been similar or greater than conventional soybean yields at 47 bu/acre. The organic oat 13-yr average was 97 bu/acre compared to the county average of 63 bu/acre. The organic alfalfa 13-yr average was 4 tons/acre compared to county average of 3.5 tons/acre. Over all years, despite lower yields in times of excess rain and loss of N from composted manure fertilization, organic returns have averaged twice those of conventional returns. Organic corn was selling for $8.25/bu in December 2016 and organic feed-grade soybeans were $18.50/bu compared to $3.52/bu and $9.64/bu for conventional corn and soybean, respectively. The weather in 2015 and 2016 was extremely challenging, with 10 inches above normal rainfall in June 2015 and drought in 2016. As a result of these extreme weather conditions and late planting, weed management and yields were affected in all plots, pointing out the need for constant on-site management and timeliness in planting, rotary hoeing and cultivation for weed control for successful organic yields.

Overall, weed populations were higher in the organic corn plots compared to the conventional corn plots. In the soybean plots in 2015 and corn plots in 2016, there were, however, no differences in broadleaf weed populations between the organic and the conventional plots. Greater weed populations in organic plots could be attributed to wet fields in spring, which created poor conditions, leading to a delay between planting and the first rotary-hoeing in corn and soybean crops. For good weed management in organic crops, the first rotary-hoeing should occur within 2–3 days after planting. The highest organic corn yield has consistently occurred in the longest C-S-O/A-A rotation, but in 2015, the 3-yer rotation (C-S-O/A) fields had the greatest yields, averaging 115 bu/acre. In 2016, the previous pattern returned, with greatest yields in the 4-year rotation, at 166 bu/acre. Organic corn yields in this rotation were significantly greater than conventional yields, at 135 bu/acre, which had equivalent yields to the organic rotation with corn grown twice in three years (C-S-C-O/A). In 2015, soybean yields averaged 54 bu/acre in both organic and conventional systems which received multiple herbicides. In 2016, conventional plots yielded 56 bu/acre, while the only equivalent organic yield, at 49 bu/acre, occurred in the 4-year rotation plots, due to lack of early weed management in organic plots.

At the Organic Reduced-Tillage (ORT) site, Boone, Iowa, poor weather affected yields both years of the project, with organic soybean yields averaging 42 bu/acre in the no-till (rolled/crimped rye) vs. 31 bu/acre in the mowed rye plots in 2015. In 2016, drought affected emergence and soybeans were chopped for livestock feed, averaging 10,803 lb/acre. Crop rotation sequence did not affect yields either year. Oatlage yields averaged 16,461 lb/acre in 2015. In 2016, oat grain yield averaged 113 bu/acre, which was a higher yield than in recent years, suggesting the combination of an earlier planting date (March 22 vs. April 1 in 2015) and more supportive weather led to increased yields. Weeds developed rapidly in the excessive spring/summer rains, and consisted of annuals (primarily foxtail and lambsquarter) and perennials (thistles, clover and bromegrass), with less weed coverage in no-till soybean plots (33%) compared to 40% in mowed plots, with no differences based on rotational history or 2015 tillage systems. A new roller system will be trialed in the future to determine if a deeper rye mulch layer will prevent high weed populations.

At the Organic Water Quality site, corn and soybean yields were equivalent between conventional and organic plots in 2015, averaging 144 bu/acre and 51 bu/acre, respectively, and in 2016, averaging 200 bu/acre and 52 bu/acre, respectively. Oat yields averaged 105 bu/acre in 2015, an excellent yield, given the wet weather, and 85 bu/acre in 2016. Alfalfa plots yielded 2.18 tons/acre in 2015, and 3.05 tons/acre in 2016. Although there was no significant difference in soybean cyst nematode populations between conventional and organic plots, averaging 830 eggs per 100 cc of soil, the conventional soybean plots harbored 2.5 times as many nematode eggs as the organic plots. Pest and beneficial insects were equivalent between systems in 2015 and 2016. Subsurface drainage water nitrate-N loss for a 3-year period at the OWQ site from the conventionally managed C-S system (79.2 kgN/ha) was nearly twice as much as from the organically managed C-S-O/A-A (39.9 kgN/ha). The pasture system (16.5 kgN ha^{-1}) lost the least amount of N over the 3 years.

At the LTAR site, soil quality was consistently higher in the organic rotations relative to the conventionally managed corn-soybean rotation from 2012 to 2016. In 2015 and 2016, soil quality the organic soils had more microbial biomass C and N, higher P, K, Mg and Ca concentrations, and lower soil acidity than conventional soils. The long-term 4-yr organic rotation had more microbial biomass C and stable macroaggregates than the 3-yr organic rotation in the fall of 2016 which suggests the extra year of alfalfa enhances soil structural stabilization and microbial activity. Soil quality enhancement was particularly evident for labile soil C and N pools, such as N mineralization potential and particulate organic matter, which are critical for maintenance of N fertility and efficient carbon cycling in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with cation exchange capacity (CEC).

In the soil microbial community structure analysis of LTAR soils, data suggested that bacterial communities in the organic soil differed from conventional soils. Since the organic soils were shown to have significantly higher microbial biomass C and N and more biologically active organic matter than the conventional soil, this suggests that organic management provides a rich resource of food for the soil microbes, which fuels microbial growth, and subsequently increases microbial biomass.

At the ORT site, the impact of no-tillage was exemplified by stable macroaggregates comprising a greater proportion of the total soil mass in the no-till soil compared with the mowed treatment. Macroaggregation is an integral indicator of soil dynamic change, where enhancement is also related to changes in soil structural stability, water infiltration and storage, and carbon storage.

3. Technical Report

Introduction

Management of soil organic matter (SOM) to enhance soil quality and supply crop nutrients is a key determinant of successful farming. This involves balancing two ecological processes: mineralization of carbon (C) and nitrogen (N) in SOM for short-term crop uptake, and sequestering C and N in SOM pools for long-term maintenance of soil quality, including structure and fertility. The latter has important implications for regional and global C and N budgets, including water quality and C storage in soils. Cover crops and crop rotations with perennial legumes have been shown to be effective at preventing erosion and minimizing nitrate-N leaching. Within the agricultural community, however, there exists a conundrum related to tillage and soil health. Tillage is used to modify soil conditions for the purpose of nurturing crops by providing a suitable environment for seed germination and root development, while concomitantly suppressing weeds, controlling soil erosion and maintaining adequate soil moisture. While herbicides are used to manage weeds without soil disturbance, issues of weed resistance and non-target effects have led many to investigate alternative practices that include some form of tillage while employing other practices to ensure soil and water quality. Our hypothesis is that farming systems using integrated methods of tillage, crop rotation, and cover cropping to promote soil health and productivity, suppress competitors, and minimize the impact on beneficial organisms and their environment will accrue long-term economic and environmental benefits. By evaluating across a continuum of experimental sites with different cropping histories and management practices, we will: 1) Identify cropping systems that maximize yields, increase profitability, limit pests, especially weed populations, and promote soil health, while minimizing nutrient loss and fostering carbon sequestration; 2) Determine effects of cropping systems with different management histories on soil health, water quality and soil microbial community structure and function related to nutrient cycling and carbon sequestration; 3) Enhance conservation, environmental, energy and economic outcomes on farms by developing systems-based IPM/BMP guidelines to suppress weeds, augment biological controls, and improve soil health; and 4) Develop and demonstrate educational tools to promote soil conserving practices for producers, extension personnel, NRCS, and other agricultural professionals that include technology transfer techniques of workshops, field days and webinars, utilizing a farmer-centered approach. We will identify key practices related to extended crop rotations, cover cropping, and strategic tillage, which will aid in promoting soil and water quality, along with maintaining weed populations below economic thresholds, to ensure optimal yields and profitability.

Materials and Methods

The Neely-Kinyon Long-Term Agroecological Research Site

The Neely-Kinyon LTAR site was established in 1998 to study the long-term effects of organic production in Iowa. Treatments at the LTAR site, replicated four times in a completely randomized design, include the following rotations: conventional Corn-Soybean (C-S), organic Corn-Soybean-Oats/Alfalfa (C-S-O/A), organic Corn-Soybean-Oats/Alfalfa-Alfalfa (C-S-O/A-A) and organic Corn-Soybean-Corn-Oats/Alfalfa (C-SB-C-O/A). Oat/alfalfa plots were field cultivated on March 30, 2016, and 'Saber' oats were underseeded with 'Viking 370HD' alfalfa (Albert Lea Seed, Albert Lea, MN) at a rate of 90 lbs/acre and 15 lb/acre, respectively. Plots were cultipacked on March 30 after planting. Following harvest of the organic corn plots in 2015, winter rye was no-till drilled at a rate of 75 lb/acre on November 4, 2015.

Conventional corn plots were injected with 32% UAN on May 6, 2016, at 140 lb N/acre, disked on May 6 and field cultivated on May 19. Chicken manure (S.W. Iowa Egg Cooperative, Massena, IA) was applied to organic corn plots at a rate of 6.9 tons/acre on March 28 in the organic C-S-O/A and C-S-O/A-A plots, and at a reduced rate of 2.9 tons/acre in the C-S-C-O/A plots on the same day. Corn and soybean variety selection and planting methods in 2016 were as follows: Viking 0.24-02N corn was planted at a depth of 2.5 in. as untreated seed at a rate of 35,000 seeds/acre in the organic and conventional plots, on May 20, 2016. Conventional soybean plots were disked on May 6 and field cultivated on May 19. Viking 0.2399AT 12N soybeans were planted at a depth of 2 in. in organic and conventional plots at a rate of 175,000 seeds/acre on May 20, 2016. Conventional corn plots were sprayed on May 21, 2016, with Dual II™ at 3/4 pt/acre. Conventional corn plots were cultivated on June 16 to deal with weed problems. Conventional soybeans received applications of Sonic™ at 3.5 oz/acre, Round-up™ at 32oz/acre, and Sharpen™ at 1.5 oz/acre. Conventional soybean plots were cultivated on June 16 and 28 to deal with weeds still emerging after herbicides. On June 30, plots were sprayed with Cadet™ at 0.6 oz/acre, crop oil at 1 gal/100 gal water/acre, and AMS at 2.7 lb/acre to control remaining weeds.

The alfalfa and compost that was applied in the organic corn plots were plowed under on April 11, 2016. Plots were disked on May 6 and field cultivated on May 19. Organic corn plots were rotary-hoed on June 1 and row-cultivated on June 9 and 16, which was a rotary-hoeing less than in 2013, which had optimal weed management.

Rye was disked twice in organic soybean plots on May 6, and field cultivated on May 19, before soybean planting on May 20. Organic soybean plots were rotary hoed on June 1 and June 7, and row-cultivated on June 11, June 16, and June 28. The length of time between planting and the first rotary hoeing (12 days) was damaging to weed management, so considerable time was invested in "walking" each organic soybean plot for large weeds above the canopy on July 28, August 10 and August 17. There was a problem of weeds in conventional plots in 2016, even after repeated herbicide applications, but these were not "walked" in keeping with the protocol of herbicide applications only in conventional plots.

Corn and soybean stands were counted on June 21, and weeds were counted within square meter quadrats at three randomly selected areas within a plot. Corn stalk nitrate samples were collected on September 18 from three randomly selected plants in each plot. Soybean cyst nematode sampling occurred in all soybean plots on October 3 by All crop and soil analyses were conducted at the Iowa State University Soil and Plant Analysis Laboratory, Ames, IA, and nematode analysis was conducted at the ISU Plant Disease Clinic (Ames, IA).

Alfalfa was baled on June 3, July 8, and August 16. Oat grain was harvested on July 13. Corn and soybean plots were harvested on October 18 and 20, respectively. Grain samples were collected from each corn and soybean plot for grain quality analysis, which was conducted at the ISU Grain Quality Laboratory, Ames, IA.

Results and Discussion

The weather in 2016 was again challenging, but May weather allowed an early planting date, which helped with yields. As a result of rainy weather conditions in June, weed management in organic plots suffered. Corn stands were similar between organic and conventional systems, averaging

36,062 plants/acre (Table 1). Soybean plant populations also were similar between systems, averaging 106,833 plants/acre (Table 2). Grass weed populations were highest in the organic C-S-O/A-A corn plots, averaging 20 weeds/m^2, and were similar in the C-S-O/A and C-S-O/A-A plots, at 11 weeds/m^2. All organic plots had significantly greater grass weed populations than conventional plots, which had no grass weeds at the time of the sampling (Table 1). Broadleaf weeds, which averaged 5 weeds/m^2 were similar in both conventional and organic plots. In the soybean plots, the organic plots averaged 12 grass weeds/m^2, compared to <1 weed/m^2 in conventional plots (Table 2). Broadleaf weeds were greater in organic plots, averaging 2 weeds/m^2 compared to <1 weed/m^2 in conventional soybean plots. Weeds in organic fields could be attributed to a delay of 12 days between planting and the first rotary hoeing in corn and soybean plots. For good weed management in organic crops, the first rotary hoeing should occur within 2–3 days after planting. Corn stalk nitrate levels were statistically greater in conventional corn, at 1,945 ppm nitrate-N, compared to 470 ppm nitrate-N in the organic corn, signifying luxury application in conventional plots, and below recommended levels in the organic corn (Table 3). Yields, however, did not correspond to stalk nitrate levels, as the organic corn in the C-S-O/A-A rotation, at 166 bu/acre, performed better than the conventional corn, at 135 bu/acre (Table 3). There were no soybean cyst nematodes detected in any plots in 2016 (Table 4).

Oat yields were impacted by wet weather, with yields of 58 bu/acre in the three-year rotation, and 63 bu/acre in the four-year rotation (Table 5). Alfalfa yields were excellent, at 5.4 tons/acre over the entire season, similar to the 4.6 tons/acre yields in 2014 and 2015. The June harvest was the highest, with the August cutting suffering from dry weather. Oat and alfalfa baleage in the O/A plots averaged 1.47 tons/acre.

Organic corn varieties were changed in 2016 and corn was planted earlier–on a date more like the early years of the LTAR experiment, when corn was always planted in mid- to late-May. As a result of these factors, and timely rains, organic corn yield in the C-S-O/A-A plots (166 bu/acre) was statistically greater than the conventional corn yield, which averaged 135 bu/acre (Table 3). The other organic corn yields were statistically similar to the conventional corn yield, but numerically higher, at 151 bu/acre in the three-year rotation, and 136 bu/acre in the rotation with the reduced rate of compost (C-S-C-O/A).

Despite insufficient mechanical weed management in organic soybean plots due to weather impacting field operations, the subsequent high weed populations in the organic soybeans were managed through manual removal ("walking") and yields were high, averaging 45 bu/acre over both organic systems, with the four-year rotation statistically equivalent to the conventional soybean yield. The conventional system, which received multiple herbicides, averaged 56 bu/acre, and the organic C-S-O/A-A soybean yield was equivalent at 49 bu/acre (Table 4). There were no soybean cyst nematodes detected in any plots in 2016 (Table 4).

If crops were sold as certified organic, as they were in previous years (and can continue to be, since the fields are certified every year), premium organic corn prices would have brought in $1,328/acre in the C-S-O/A-A rotation, compared to $482/acre for conventional corn. Organic soybeans could have sold for $882/acre in the same rotation, compared to $550/acre for conventional soybeans.

Organic corn grain quality was exceptionally high in 2016. Protein levels were equal to conventional corn, at 8.7% (Table 3). The longer period between corn crops in the organic system lent an additional 0.50% in protein content, as evidenced by the 8.2% protein in the corn-intensive C-S-C-O/A rotation. Corn density was greater in the organic system, at 1.3%. Moisture was lower, averaging 18% in the organic C-S-C-O/A corn at harvest, compared to the other organic rotations and the conventional corn (18.6%). Corn starch was nearly equivalent in both systems, averaging 73%, with the C-S-C-O/A higher at 73.6%. Corn oil content was greater, at 3.6%, in corn from the organic system, compared to 3.5% in the conventional corn.

Soybean moisture levels were not different between systems, averaging 13% (Table 4). Protein levels were equivalent between systems, at 35%. Soybean carbohydrate levels averaged 23%. Oil levels (19%) and fiber content (5%) were also similar across all rotations. Soybean insect pest levels were low in 2016, with stained soybeans averaging 1.8% across all rotations, and no difference between conventional and organic soybeans (Table 4).

Soil Quality and Microbial Community Methods

Field and laboratory studies were employed to examine the effect of different cropping histories and management strategies at the LTAR on soil quality parameters including organic matter, carbon sequestration, soil microbial biomass and microbial community structure and function, using DNA extraction, amplification, and analysis to provide characteristic profiles that reflect microbial differences, and water quantity/quality. For soil quality analysis, five randomly-located soil cores (0-15 cm) were removed from each LTAR plot in 2015 and 2016 after harvest but before any tillage operations. The cores were mixed together to produce one composite sample from each plot.

LTAR Soil Quality Summary

Soil quality was higher in the organic rotations relative to the conventionally managed corn-soybean rotation in the fall of 2016 (Table 37). The organic soils had more microbial biomass C and N, higher P, K, Mg and Ca concentrations, and lower soil acidity than conventional soils (Table 3). The long-term 4-yr organic rotation had more microbial biomass C and stable macroaggregates than the 3-yr organic rotation in the fall of 2016 which suggests the extra year of alfalfa enhances soil structural stabilization and microbial activity. Soil quality enhancement was particularly evident for labile soil C and N pools, such as N mineralization potential and particulate organic matter, which are critical for maintenance of N fertility and efficient carbon cycling in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with cation exchange capacity (CEC).

Soil Microbial Community Analysis

This study used high-throughput amplicon sequencing of 16S rRNA gene fragments to assess differences in soil bacterial community composition at the LTAR site. More than 11,000 distinct bacterial taxa in soils were observed at this field site, with the soil in organic plots having a different bacterial community structure different compared to conventional plots. Over two years, when contrasting the bulk soil microbiomes associated with long-term field management under organic and conventional paradigms, changes in the abundance of functional genes related to the cycling of greenhouse gases were evident (Fig. 3). Particulate methane monooxygenase genes were more frequent in soil under organic management, while soluble methane monooxygenase genes were more frequent in soil under conventional management in one of two years. Clade II nitrous oxide reductase genes were significantly less frequent in soils under second year alfalfa compared to soils under corn. There were also significant changes in bulk soil prokaryote (2 out of 2 years) and fungal (1 out of 2 years) community structure in response to agricultural management. A large portion of the soil microbial community responded to agricultural management, with 27-29% (between years) of abundant bacterial taxa differing significantly in relative abundance between land management paradigms. Among the most consistent outcomes with large effect sizes were enrichment of operational taxonomic units (OTUs) belonging to *Acidobacteria* Subgroup 6, *Microvirga*, *Planctomyces*, and *Verrucomicrobiaceae* under organic management, and enrichment of OTUs belonging to *Chthoniobacterales*, *Planctomyces*, *Sphingomonas*, and *Thaumarchaeota* under conventional management. Structural changes in soil microbiomes accompanied changes in soil edaphic properties, including bulk density, pH, and nitrogen status. Deliberate management of soil microbiomes may enhance provision of ecosystem services.

Economic Analysis

Over all years, despite lower yields in times of excess rain and loss of N from composted manure fertilization, organic returns have averaged twice those of conventional returns (Fig. 1). Organic corn was selling for $8.25/bu in December 2016 and organic feed-grade soybeans were $18.50/bu compared to $3.52/bu and $9.64 for conventional corn and soybean, respectively. Feed-grade oats are $6.50bu and feed-grade wheat is $12.25/bu.

Organic Reduced-Tillage (ORT) Site

Rye was drilled at 130 lb/acre on September 28, 2015, in the eight oat/alfalfa plots going to organic soybeans in Spring 2016. Eight other plots were planted to oats/alfalfa at previous rates in Spring 2016 in order to continue a soil-building rotation for certified organic status. The rye was rolled/crimped on June 6. A new system of drilling soybeans into the stubble was attempted due to an Iowa farmer's success with this method in 2015. Soybeans (Viking 0.2399AT12N, Albert Lea Seed, MN) were drilled into the crushed mulch at a rate of 80 lb/acre, immediately following rolling the rye. Oats and alfalfa were drilled together on March 22, 2016, at a rate of 2 bu/acre (Saber oats, Albert Lea Seed, MN) and 15 lb/acre alfalfa (Viking 370HD, Albert Lea Seed, MN).

No differences were found between treatments in rye biomass (Table 6). Cover crop biomass was numerically higher in Rotation 2 (Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean) plots that had rolled/crimped rye in 2015 ("Rolled") at 5,299 lb/acre and numerically lower in Rotation 1 (Wheat-Rye-Soybeans-Oats-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa)-Rolled plots. Total carbon was numerically higher in Rotation 2 plots that had mowed rye in 2015 ("Mowed") at 44.64%, and numerically lower in Rotation 2-Rolled plots at 44.21% (Table 7). Total nitrogen was equal in Rotation 1 and 2-Rolled and Mowed plots at 1.23%. Oat yields averaged 113 bu/acre in 2016, which was a higher yield than in recent years, suggesting the combination of an earlier planting date (March 22 vs. April 1 in 2015) and more supportive weather led to increased yields.

While there were no significant differences in oat grain yield between treatments (Table 8), yield in Rotation 1-Mowed plots was numerically higher at 136 bu/acre and Rotation 2-Mowed plots had numerically lower yields at 91 bu/acre. Oat grain moisture was numerically higher in Rotation 2-Mowed plots at 19.90% and numerically lower in Rotation 1-Mowed plots at 18.40%.

The farm experienced a severe drought and less than 10% of the soybeans emerged through the thick rye mulch. Soybeans were re-drilled at the same rate on June 22, but the drought continued, and emergence was only slightly improved. On July 6, soybeans were re-planted using a 4-row 30-inch planter that opened a slot where soybeans could emerge. Emergence was good following the rains that finally came, but it was too late for a fully mature soybean crop to develop. While there were no significant differences, soybean plant height was numerically higher in Rotation 2 (Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean)-Mowed plots at 67 cm and numerically lower in Rotation 1 (Wheat-Rye-Soybeans-Oats-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa)-Mowed plots at 60 cm (Table 9). Soybean cyst nematode showed only numerical differences with Rotation 2-Mowed plots higher at 333 eggs/100cc of soil, and Rotation 1-Rolled plots lower, with no SCN eggs recovered (Table 10).

Insect populations were low overall, with no differences among treatments. Bean leaf beetles averaged 4 beetles/plot; aphids and whiteflies averaged 1 insect/plot; corn rootworms averaged 4 beetles/plot; and thrips averaged 2 thrips/plot (Table 11). Beneficial insects were equivalent among treatments with nabids, spiders, and minute pirate bugs averaging 1 insect/plot (Table 12). Soybeans were chopped for livestock feed on September 13, with soybean biomass weighed in a weigh wagon. Chopped soybean biomass yield at harvest was equivalent between treatments, averaging 10,803 lb/acre (Table 13). Again there appeared to be greater yields in the Rotation 2 plots, averaging 11,778 lb/acre compared to 9,830 lb/acre in Rotation 1 plots. One of the differences between Rotation 1 and 2 was the addition of composted animal manure on the 2013 corn crop and a crop of oat/alfalfa the previous year (2015) in Rotation 2 plots, which could have led to greater soil fertility in those plots. Regarding soybean plant nutrients, there was no difference between treatments, but Rolled plots were numerically higher at 42.75% carbon compared to Mowed plots at 42.63%. Plant nitrogen was numerically higher in Mowed plots within Rotation 2 at 3.07% and numerically lower in Rolled plots at 2.57%.

Organic Water Quality (OWQ) Site

Thirty plots were established in May 2011 within a 25-ha field at the Agronomy and Ag Engineering Farm that was maintained as organic alfalfa from 2007 to 2011. Tile drains, flow barriers and sump pumps were installed at the site in July 2011. Sump pits were equipped with water meters, sump pumps, sump basins, distribution pipes and water sampling devices in October 2011. In November 2011, conduit and transmission lines for the data loggers were installed and a permanent weather station was also installed at the field site. Tile drain sampling began on December 1, 2011, and continued every week. Drain flow did not cease in 2011 and 2012 due to a warm winter. Crop rotations began in 2012 and included corn and soybean in the conventional treatment, an organic pasture with grass and legumes, and all crops in an organic corn, soybean, oats, and alfalfa rotation. Plots were maintained as organic through the use of compost fertilization, mechanical tillage for weeding, and naturally-based insect management products. Despite the lack of rain and extreme heat in the first year of production, organic yields were statistically equivalent to conventional corn and soybean yields. Every year since 2012 has included weather extremes, with flooding occurring over multiple periods in 2015 and drought during the 2016 season. In 2015, the organic oat/alfalfa plots had the greatest amount of biomass N (5%) compared to 2.3% in the organic pasture and 3.4% in the alfalfa plots (Table 14). Biomass carbon levels were similar at 42%. On May 28, pasture biomass was greater at 2,214 lb/acre than alfalfa biomass (1,851 lb/acre). Weeds were low in cover cropped plots of oat/alfalfa, alfalfa and pasture (Table 15), but higher levels (86 lb/acre) were observed in alfalfa plots compared to pasture plots (<1 weed/acre). On June 9, corn plant populations were equivalent between organic and conventional plots, averaging 46,210 plants/acre (Table 16). Grass weeds were greater in the organic corn plots, while broadleaf weed populations were similar (Table 16). Soybean plant populations were also equivalent between organic and conventional plots, averaging 160,175 plants/acre (Table 17). Similar to corn plots, grass weeds were greater in the organic plots, while broadleaf weed populations were equivalent between systems. At the end of the month (6/30/15), after rotary hoeing and cultivations, corn stands were still similar between systems, averaging 47,000 plants/acre (Table 18). Grass weed populations remained higher in organic corn plots, but broadleaf weeds were equivalent in conventional and organic plots. Soybean populations also remained high after cultivation (Table 19), with equivalent populations (161,235 plants/acre as an overall average). Similar to earlier populations, grass weeds remained higher in organic plots and broadleaf weeds were equivalent between systems. Soil nitrate levels were lower in the conventional corn plots, at 2.4 ppm NO_3-N, compared to 4.8 ppm in the conventional plots on August 3 (Table 20). There was no difference in the amount of stained soybeans between plots (Table 21), averaging 1% stained, signifying low levels of bean leaf beetles in both systems. Key insect pests were similar between systems (Table 22), with no significant differences in bean leaf beetle, thrips, corn rootworm populations, although there were 56% more thrips found on conventional soybean plants compared to organic plants. Key beneficial insects, including minute pirate bugs and spiders, were also similar between conventional and organic plots. Other minor insects, such as caterpillars and tarnished plant bugs, were in low numbers and equivalent between systems (Table 23). Corn stalk nitrate at the end of the season was equivalent between systems, averaging 3,360 ppm NO_3-N (Table 24). Corn and soybean yields were equivalent between conventional and organic plots, averaging 144 bu/acre and 51 bu/acre, respectively (Table 25). Oat yields averaged 105 bu/acre (Table 26) and alfalfa yields were 2.18 tons/acre (Table 27), a reduced yield due to flooding in June. At the last alfalfa harvest (October 16), there was 0.73 ton/acre harvested from alfalfa plots and 0.23 tons/acre from oat/alfalfa plots (Table 28). Although there was no significant difference in soybean cyst nematode populations between conventional and organic plots (Table 29), averaging 830 eggs per 100 cc of soil, the conventional soybean plots harbored 2.5 times as many nematode eggs as the organic plots. Organic corn had greater protein levels, at 8%, compared to 7.5% in the conventional corn (Table 30), while starch levels were higher in the conventional plots. All grain quality components were equivalent between conventional and organic soybeans (Table 31), with protein levels averaging 35%.

In 2016, corn and soybean yields were equivalent between conventional and organic plots (Table 32). Oat yields were decreased from 2015 levels, at 85 bu/acre, but alfalfa yields were greater, at 3 tons/acre. Soybean cyst nematode populations were again equivalent between systems, averaging 1,228 eggs/100 cc of soil, with numerically greater numbers in conventional plots (Table 33). Pest and beneficial insects were again equivalent between systems in 2016 (Table 34), with bean leaf beetle populations higher than 2015 levels, averaging 39 BLBs in 20 sweeps. Thrips levels were lower, averaging 1 insect per 20 sweeps, while whiteflies were greater than in 2015, averaging 18 insects per 20 sweeps. Soybean grain quality was high in 2016, with no differences in all quality components between systems (Table 35). Protein levels averaged 35% and oil averaged 18%. Corn grain quality was also good, with no differences between systems, and protein levels averaging 8.7% (Table 36). Oil averaged 4.5% and starch levels averaged 71%.

Previous results showed that subsurface drainage water nitrate-N loss for a 3-year period from the conventionally managed C-S system (79.2 kgN/ha) was nearly twice as much as from the organically managed C-S-O/A-A (39.9 kgN/ha). The pasture system (16.5 kgN ha^{-1}) lost the least amount of N over the 3 years.

<u>Outreach</u> efforts included annual Field Days, webinars, conference and classroom presentations, and publications (see Publications and Outreach below). **Outcomes** will include greater producer knowledge and skills related to cover cropping and other methods to increase soil and water quality while enhancing farm profitability and mitigating climate change through carbon-sequestering practices.

EXTENSION/OUTREACH HIGHLIGHTS FOR PI

- Continued to establish the Iowa State University Organic Ag. Program as an internationally recognized program through invited presentations across the U.S.

- Presented research results to 2,309 participants through 33 research and extension presentations in Iowa and other states

- Updated organic training modules, which are available as DVDs for purchase, for the "Organic Agriculture: Theory and Practice" 16-week course as an Adobe Connect™ archives for Extension staff and producer clientele

- Organized and held the Sixteenth Annual Iowa Organic Conference on November 13-14, in partnership with the University of Iowa Office of Sustainability, focusing on organic production, policy, and marketing, which included coordination of 20 speakers; and location and assistance with preparation of an all-organic meal for 210 participants.

- Prepared research summaries for the Neely-Kinyon Farm Field Day and Focus Group on August 23, 2016, addressing LTAR and organic grain, hay, vegetable and integrated crop-livestock research

- Worked with the Iowa Organic Association and Practical Farmers of Iowa in presenting research at Field Days on June 28 and June 30 for 132 producers and agency staff

- Worked with the USDA Natural Resources Conservation Service in preparing and offering a national webinar on October 4 on "Tillage and Residue Management in Organic Systems" for 166 agency staff and the public

- Research and extension results from the Organic Ag. Program were presented as invited talks at nine out-of-state venues

- Led the Extension Alternative Ag Team in meetings related to organizing website content and coordination with the Leopold Center for Sustainable Agriculture for the Alternative Ag website: http://www.extension.iastate.edu/alternativeag/

- Wrote research grant proposals with significant Extension component with multi-state partners, including a new organic breeding project for the NIFA-OREI program, at the invitation of corn breeder, Thomas Lubberstedt (Agronomy, ISU); continued managing grants totaling $1,690,673, to expand organic research and extension activities and support students during this period

- Responded to 78 phone calls and e-mails from producers and agricultural professionals related to questions on sustainable/organic agriculture practices, certification and other Extension information

- Responded to 7 calls from media related to questions on sustainable/organic agriculture that resulted in several press releases

- Extended research results to producers, agricultural professionals and consumers through publication of 4 Extension reports posted on the ISU Research Farms website, the ISU Organic Ag website, and/or on the national eOrganic webpage

- Distributed over 50 copies of the Organic Agriculture Series and other Extension hand-outs on organic agriculture

- Continued development of my Iowa State University ***Organic Agriculture*** webpage with relevant research and policy issues

- Continued responding to requests for organic information outside of Iowa and writing/receiving grants to enhance program

Invited Research and Extension/Outreach Presentations:

***Invited presentations**
****Conference keynote speaker**

Date	Location	Title	Audience Number
*January 8	Minnesota Organic Conference, St. Cloud, MN	Organic No-Till for the Midwest	92
*January 20	Organic Ag Research Symposium, Eco-Farm Conference, Monterrey, CA	Long-Term Effects of Organic Management on Weed Populations	45
**January 30	New Jersey Organic Conference Northeast Organic Farming Assoc., Red Hook, NJ	Mainstreaming Organic Agriculture	290
*February 18	Canadian Organic Conference Winnipeg, Manitoba, Canada	Use of Cover Crops and Green Manures in Organic Production	155
**February 19	Canadian Organic Conference Winnipeg, Manitoba, Canada	The Role of Biodiversity in Organic Systems	206
*February 23	Southwestern Community College Horticulture Class, Creston, IA	Organic Fruit and Vegetable Production	10

February 27	MOSES Organic Conference, La Crosse,WI	Improving Conservation through Reduced Tillage and Cover-Crop-Based Rotations in Organic Production (poster presentation)	75
March 2	Wallace Foundation for Rural Research and Development, Lewis, IA	Organic Research at the Neely-Kinyon Farm	28
*March 10	Organic Trade Association Conference, ExpoWest, Anaheim, CA	Impacts of Organic Farming on Climate Change	178
*March 12	Organic Valley Producer Meeting, Decorah, IA	Organic Yields, Economics and Ecosyst Services	35
*April 6	Consumer Federation of America Annual Conference, Washington, D.C.	Food Policy and Environmental Protection	62
April 21	Extension Alternative Ag Meeting, Ames, IA	Update on ISU Organic Ag Programs	6
*April 22	Iowa Academy of Sciences, Des Moines, IA	Organic Agriculture and Environmental Benefits	65
May 5	State Soil Conservation Committee Des Moines, IA	Organic No-Till Vegetable Production	22
*May 23	Organic Trade Association Organic Confluences Conference, Washington, D.C.	Environmental Benefits of Organic Agriculture	73
*June 7	USDA-NIFA Organic Research And Extension Initiative Panel, Washington, D.C.	Organic Ag in Iowa Update	15
*June 15	PFI Field Day, Sammons Farm, Churdan, IA	Organic No-Till for Soybean Production	80
*June 28	Iowa Organic Association Field Day, Ames, IA	Organic No-Till and Water Quality in Organic Systems	40
*June 30	PFI Field Day, Petersen's Farm, Kno IA	Economics of Organic Production	52

August 23	Neely-Kinyon Field Day, Greenfield, IA	Overview of Organic Experiments: LTAR, Organic No-Till and Integrated Crop-Livestock	55
August 23	Integrated Crop-Livestock Focus Gro Greenfield, IA	Integrated Crop-Livestock Opportunities and Constraints	10
*October 4	USDA-NRCS National Webinar, NR(Des Moines, IA	Tillage and Residue Management In Organic Systems	166
**October 7	Oklahoma Organic Conference, Oklahoma City, OK	Mainstreaming Organic Agriculture	62
October 15	World Food Prize Youth Institute, Dupont Pioneer, Johnston, IA	Overview of Iowa State University Ag Programs	12
October 18	USDA-NIFA-OREI PD Workshop Washington, D.C.	Integrated Crop-Livestock Systems	28
*October 28	Iowa Organic Association Board Meeting, Ames, IA	ISU Organic Ag Programs	6
November 4	Iowa Public Radio, Ames, IA	16th Annual Iowa Organic Conference	
*November 7	American Society of Agronomy Meet Phoenix, AZ	Practitioners' Perspectives on How Orga Rules Meet the Challenge of Sustainability.	120
November 13	Iowa Organic Conference, Iowa City, IA	Introduction to the Farmer-Mentor Session	55
November 14	Iowa Organic Conference, Iowa City, IA	Introduction to the 2015 Iowa Organic Conference	210
November 14	Iowa Organic Conference, Iowa City, IA	Organic No-Till Update	38

November 29	Hort 530 Class, Dept. of Horticulture, Iowa State University, Ames, IA	Agroecological Research	6
November 30	Iowa Organic Advisory Board Meeting, Des Moines, IA	The 16th Annual Iowa Organic Conferer	12

Total: 33 presentations
Audience: 2,309 participants

Refereed Publications:

Delate, K., S. Canali, R. Turnbull, R. Tan and L. Colombo. 2016. Participatory Organic Research in the U.S. and Italy: Across a Continuum of Farmer–Researcher Partnerships. Renewable Agriculture and Food Systems, p. 1-18. Available at: DOI: https://doi.org.10.1017/S1742170516000247

Reeve, J.R., L.A. Hoagland, J.J. Villalba, P.M. Carr, A. Atucha, C. Cambardella, D.R. Davis, K. Delate. 2016. Organic Farming, Soil Health, and Food Quality: Considering Possible Links. Advances in Agronomy 137:319-368.

Published Abstracts

Delate, K., and C. Cambardella. 2016. Improving Conservation through Reduced Tillage and Cover-Crop-Based Rotations in Organic Production. Organic Research Forum, Midwest Organic Conference (MOSES), February 26-27, 2016, LaCrosse, WI.

Delate, K. and F. Thicke. 2016. Practitioners' Perspectives on How Organic Rules Meet the Challenge of Sustainability. American Society of Agronomy Annual Conference, November 7, 2016, Phoenix, AZ. Available at: https://scisoc.confex.com/scisoc/2016am/webprogram/Paper102109.html

Nichols, K.A., J.W. Moyer, K. Delate, and B. Heins. 2016. Integrating Crops and Livestock in a Systems-Based Approach to Enhance Organic Farm Stability, Safety and Resilience - Rodale Institute Study. American Society of Agronomy Annual Conference, November 8, 2016, Phoenix, AZ: https://scisoc.confex.com/scisoc/2016am/webprogram/Paper102979.html

Phillips, H., B. Heins, P. Pagliari, K. Delate, R. Turnbull, A. Shaw, J. Moyer, and K. Nichols. 2016. Integrating Crops and Livestock in a Systems Approach to Enhance Organic Farm Stability, Safety and Resilience. Organic Research Forum, Midwest Organic Conference (MOSES), February 26-27, 2016, LaCrosse, WI.

Books and Chapters in Books:

Nair, A. and K. Delate. 2016. Composting, Crop Rotation, and Cover Crop Practices in Organic Vegetable Production. In: D. Nandwani (ed.), Organic Farming for Sustainable Agriculture, Sustainable Development and Biodiversity 9: pp. 231-257, Springer International Publishing Switzerland. Available at: DOI 10.1007/978-3-319-26803-3_11

Contributions to Print Media (newsletters, trade journals, Extension pubs):

Extension Publications

Editor-Reviewed Publications:

Delate, K., and A. Nair. 2016. Crop Rotations, Composting, and Cover Crops for Organic Vegetable Production, HORT 3052, Iowa State University Extension and Outreach, ISU, Ames, IA. 12 pp. Available at: https://store.extension.iastate.edu/FileDownload.ashx?FileID=3603

Delate, K., R. Breach, and R. Johnson. 2016. Comparison of Organic and Conventional Crops at the Neely-Kinyon Long-Term Agroecological Research Site, 2015. Organic Agriculture Website. Iowa State University, Ames, IA: http://extension.agron.iastate.edu/organicag/researchreports/nk15ltar.pdf

Delate, K., R. Breach, and R. Johnson. 2016. Effect of Organic Soil Fertility and Fungicide Treatments on Yield and Pest Management, Neely-Kinyon-2015 http://extension.agron.iastate.edu/organicag/researchreports/nk15soyfertility.pdf

Delate, K., R. Breach, and R. Johnson. 2016. Evaluation of Organic Pest Management Treatments for Bean Leaf Beetle and Soybean Aphid, Neely-Kinyon-2015: http://extension.agron.iastate.edu/organicag/researchreports/nk15blb.pdf

Delate, K., M. Rees, and R. Johnson. 2016. Evaluation of Organic Varieties and Organic Popcorn Varieties and Fertilization Southeast Research Farm, 2015: http://extension.agron.iastate.edu/organicag/researchreports/crawf15soybeanpopcorn.pdf

Delate, K., Phillips, H., B. Heins, P. Pagliari, K. Delate, R. Turnbull, A. Shaw, J. Moyer, and K. Nichols. 2016. Integrating Crops and Livestock in a Systems Approach to Enhance Organic Farm Stability, Safety and Resilience. USDA-NIFA-OREI Project Directors Workshop Proceedings, October 18, 2016, USDA-NIFA, Washington, D.C.

Heins, B., K. Delate, and H. Phillips. 2016. Research Looks at Integrating Crops and Livestock to Enhance Organic Farm Resilience. Organic Broadcaster November/December 2016 Issue. Available at: https://mosesorganic.org/integrating-crops-livestock/

Press Releases related to organic Research and Extension:

Iowa Organic Conference Highlights Perennials and Their Benefits, Sept. 30, 2016. Iowa State University Extension and Outreach, ISU, Ames, IA: http://www.extension.iastate.edu/article/iowa-organic-conference-highlights-perennials-and-their-benefits

Farmer-Mentor Roundtables at Iowa Organic Conference. October 24, 2016. Iowa State University Extension and Outreach, ISU, Ames, IA: http://www.extension.iastate.edu/article/farmer-mentor-roundtables-highlight-iowa-organic-conference

Delate, K. 2016. Integrating livestock provides benefits in climate-smart agriculture. May 16, 2016. Iowa State University Extension and Outreach, ISU, Ames, IA: http://www.extension.iastate.edu/article/integrating-livestock-provides-benefits-climate-smart-agriculture

Videos/Webcasts:
"Tillage and Residue Management in Organic Systems", USDA-NRCS National Webinar, October 4, 2016, USDA-NRCS, Des Moines, IA. Available at: http://www.conservationwebinars.net/webinars/residue-and-tillage-management-in-organic-farming-systems-central-states

Website Development/Expansion

- Developed information/reports, and updated Alternative Ag Web Portal with Extension Alternative Ag Team: http://www.extension.iastate.edu/alternativeag/
- Supplied information/reports to: ISU "Organic Agriculture" website http://extension.agron.iastate.edu/organicag/
- Supplied information/helped develop the 16th Annual Iowa Organic Conference website: https://sustainability.uiowa.edu/2016-iowa-organic-conference/
- Organic Ag webpage: Main page viewing averaging 6,623 views in 2016, with 81% new viewers
- E-Organics/e-Xtension (No-Till Organic Wiki)
- ISU Horticulture and Agronomy Webpages

Contributions to other forms of media:
Many websites carried information about the Iowa Organic Conference and research projects in 2016 (selected press examples below). I provided information/interviews for seven media outlets that published news reports on the 16th Annual Iowa Organic Conference in the following media:

Conference Boosts Iowa Organic Farming. The Daily Iowan. Nov. 15, 2016, Iowa City, IA. Available at: http://daily-iowan.com/2016/11/14/ui-conference-boosts-iowa-organic-farming/

Iowa Organic Conference-2016. Leopold Center for Sustainable Agriculture, Ames, IA:
http://leopold.iastate.edu/iowa-organic-conference-2016

Iowa Organic Conference is November 13-14. Globe Gazette.
http://globegazette.com/business/annual-iowa-organic-conference-is-nov/article_67274f43-a435-5fa7-bdfc-5bb8f718fa17.html

Farmer-Mentor Roundtables at Iowa Organic Conference. Morning Ag Clips:
https://www.morningagclips.com/farmer-mentor-roundtables-at-conference/

On Twitter: Iowa Organic Conference:
https://twitter.com/UIsustainable/status/798241937081978884

Cooperative Efforts

Target audiences for this research primarily include organic farmers, but conventional farmers with an interest in transitioning to organic production are also included. Agricultural professionals, including those in ISU Extension, USDA-ARS National Lab for Ag and the Environment, USDA–NRCS, and USDA-Resource, Conservation and Development staff, have participated in trainings and conferences related to this project. On-farm trials have been conducted with Practical Farmers of Iowa farmer-cooperators. We have also partnered with the Iowa Dept. of Ag. and Land Stewardship (IDALS) Organic Program in hosting the Annual Iowa Organic Conference each year, where results from this project and other organic research are presented.

Resources Leveraged

Results from this project have been used as background and supporting evidence for other organic research that examines the effects of organic practices (compost, cover crops, crop rotations, no-tillage) on yields, soil quality and water quality in farming systems. These include the following grants that have been awarded to the research team of Delate, Cambardella and Bakker:

1. CERES Foundation: "Improving Organic No-Till Systems for Enhanced Soil Quality and Weed Management in Organic Vegetable and Grain/Forage Systems": 2013-2016: $176,000
2. USDA, Cooperative State Research, Education & Extension Service (CSREES), Organic Research and Extension Initiative & Water Quality Programs, "Enhancing Farmland Water Quality and Availability through Soil-Building Crop Rotations and Organic Practices," 2009-2016: $599,142.
3. USDA-NIFA: "Developing Robotic Technologies for In-Situ Automatic Intra-Row Weed Control in Vegetable Production Systems" (PIs: L. Tang, K. Delate): 2013-2016: $78,578 (KD portion)
4. USDA-NIFA-OREI: "Integrating Crops and Livestock in a Systems Approach to Enhance Organic Farm Stability, Safety and Resilience": with Univ. Minnesota and Rodale Institute: 2014-2018: $1.9 million

Table 1. Corn plant and weed populations, LTAR experiment, Neely-Kinyon Farm, 6/21/16.

Treatment	Plant populations (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	36,583	0.00c	4.50
Org. C-SB-O/A	35,583	9.67b	6.67
Org. C-SB-O/A-A	36,250	20.00a	4.50
Org. C-SB-C-O/A	35,833	13.17b	4.83
$LSD_{0.05}$	NS[y]	0.35	NS
p value ($\alpha = 0.05$)	0.8383	<.0001*	0.4244

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 2. Soybean plant and weed populations, LTAR experiment, Neely-Kinyon Farm, 6/21/16.

Treatment	Plant populations (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	111,333	0.17b	0.42b
Org. C-SB-O/A	102,667	9.67a	1.42ab
Org. C-SB-O/A-A	106,500	13.25a	2.58a
$LSD_{0.05}$	NS[y]	7.00	0.55
p value ($\alpha = 0.05$)	0.5771	0.0004*	0.0346*

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 3. Corn yield, stalk nitrate, and grain quality analysis in the LTAR experiment, Neely-Kinyon Farm, 2016.

Treatment	Bu/acre	Stalk NO_3^--N (mg/kg)	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol yield (gal/bu)
Conventional C-SB[x]	135.38b[y]	1,945[y]	18.78a	8.75a	3.45b	72.95b	1.29c	2.82b
Org. C-SB-O/A	150.45b	648b	18.40a	8.75a	3.58a	73.25ab	1.31a	2.82b
Org. C-SB-O/A-A	166.04a	706b	18.58a	8.70a	3.58a	73.33ab	1.31a	2.83b
Org. C-SB-C-O/A	136.13b	54.5b	17.63b	8.23b	3.58a	73.60a	1.30b	2.85a
$LSD_{0.05}$	0.067	82.3	0.69	0.23	0.02	0.25	0.0024	0.0068
p value (α = 0.05)	0.0030*	0.0249*	0.0008*	0.0048*	0.0471*	0.0313*	0.0002*	0.0013*

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 4. Soybean yield, soybean cyst nematodes, and grain quality analysis, LTAR experiment, Neely-Kinyon Farm, 2016.

Treatment	Bu/acre	Nematodes (eggs/100 cc soil)	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbs (%)	Stained soybeans (%)
Conventional C-SB[x]	55.77a[y]	0	13.07	35.05	18.55	4.83	23.60	1.35
Org. C-SB-O/A	41.33b	0	13.30	35.13	18.60	4.83	23.50	2.28
Org. C-SB-O/A-A	48.90ab	0	13.50	35.10	18.68	4.80	23.43	1.90
$LSD_{0.05}$	5.01	--	NS	NS	NS	NS	NS	NS
p value (α = 0.05)	0.0221*	--	0.1425	0.9652	0.4777	0.6224	0.5969	0.3657

[x] Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 5. Oat and alfalfa harvests in the LTAR experiment, Neely-Kinyon Farm, 2016.

Treatment	Oats (bu/acre)	Alfalfa (tons/acre)
Org. C-SB-O/A[x]	57.96	
Org. C-SB-O/A-A	62.74	5.42
Org. C-SB-C-O/A	49.72	
$LSD_{0.05}$		
p value (α = 0.05)		

[x]Org.= Organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 6. Rye and weed biomass in the cover crop, ORT experiment, Agronomy Farm, 5/24/16.

Rotation	Soybean treatment in 2015	Rye dry weight (lb/acre)	Weed dry weight (lb/acre)
1[x]	Rolled rye	4,540	8.45
1	Mowed	4,988	38.09
2	Rolled	5,162	136.34
2	Mowed	5,132	130.53
$LSD_{0.05}$		NS[y]	NS
p value (α=0.05)		0.7208	0.7248

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 7. Nutritional analysis of rye cover crop in the ORT experiment, Agronomy Farm, 5/24/16.

Rotation	Soybean treatment in 2015	C (%)	N (%)
1[x]	Rolled rye	44.62	1.33
1	Mowed	44.62	1.13
2	Rolled	44.21	1.27
2	Mowed	44.64	1.19
$LSD_{0.05}$		NS	NS
p value (α=0.05)		0.0952	0.1460

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybean-Oat/Alfalfa-Soybean; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 8. Oat yield in the ORT experiment, Agronomy Farm, 7/15/16.

Rotation	Soybean treatment in 2015	Yield (bu/ac)	Moisture (%)
1[x]	Rolled rye	117.27	19.23
1	Mowed	136.27	18.40
2	Rolled	109.01	19.30
2	Mowed	90.90	19.90
$LSD_{0.05}$		NS	NS
p value (α=0.05)		0.4395	0.5060

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean Oat/Alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 9. Soybean height in the ORT experiment, Agronomy Farm, 9/10/16.

Rotation	Soybean treatment in 2015	Height (cm)
1[x]	Rolled rye	60.96
1	Mowed	59.94
2	Rolled	60.20
2	Mowed	66.55
$LSD_{0.05}$		NS
p value (α=0.05)		0.1255

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa.
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 10. Soybean cyst nematode populations in the ORT experiment, Agronomy Farm, 9/10/16.

Rotation	Soybean treatment in 2015	Eggs/100 cc of soil
1[x]	Rolled rye	0.00
1	Mowed	50.00
2	Rolled	100.00
2	Mowed	333.33
$LSD_{0.05}$		NS
p value (α=0.05)		0.1447

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 11. Soybean pest insect populations in the ORT experiment, Agronomy Farm, 9/10/16 (number per 20 sweeps per plot).

Rotation	Soybean treatment in 2015	Aphids	Bean leaf beetle	Thrips	Corn rootworm
1[x]	Rolled rye	0.50	2.50	2.50	3.00
1	Mowed	0.00	7.00	3.00	2.00
2	Rolled	0.67	2.00	0.33	5.00
2	Mowed	1.50	3.50	2.00	6.50
$LSD_{0.05}$		NS	NS	NS	NS
p value (α=0.05)		0.3501	0.3664	0.3984	0.7806

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa.

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 12. Soybean beneficial insect populations in the ORT experiment, Agronomy Farm, 9/10/16 (number per 20 sweeps per plot).

Rotation	Soybean treatment in 2015	Minute pirate bug	Spider	Nabid
1[x]	Rolled rye	1.50	0.00	0.00
1	Mowed	0.00	0.00	0.00
2	Rolled	0.33	0.33	0.00
2	Mowed	0.00	1.00	1.00
$LSD_{0.05}$		NS	NS	NS
p value (α=0.05)		0.1430	0.6461	0.4789

[x]Rotation 1=Wheat-Rye-Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa.

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 13. Soybean biomass harvested in the ORT experiment, Agronomy Farm, 9/14/16.

Rotation	Soybean treatment in 2015	Yield (lb/acre)	Total C (%)	Total N (%)
1[x]	Rolled rye	9583.20	--	--
1	Mowed	10076.88	--	--
2	Rolled	10260.80	42.75	2.57
2	Mowed	13290.64	42.63	3.07
$LSD_{0.05}$		NS	NS	NS
p value (α=0.05)		0.4247	0.8604	0.4113

[x]Rotation 1=Wheat-Rye- Soybean-Oat-Hairy Vetch-Corn-Oat/Alfalfa-Soybeans-Oat/Alfalfa-Soybeans; Rotation 2=Wheat-Hairy Vetch-Corn-Oats-Rye-Soybeans-Oat/Alfalfa-Corn-Soybean-Oat/Alfalfa. [y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 14. Nutrient analysis of plant biomass at OWQ experiment, Agronomy Farm, 5/28/2015.

System-Crop	Total Carbon (%)	Total Nitrogen (%)
Organic C-S-O/A-A[x], Organic Alfalfa	42.12	3.34b [y]
Organic C-S-O/A-A, Organic Oat/Alfalfa	41.30	4.69a
Organic Pasture	41.69	2.26c
$LSD_{0.05}$	NS	0.9274
p value (α = 0.05)	0.0643	<.0001[*]

[x]C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 15. Biomass components in the OWQ experiment, Agronomy Farm, 5/28/2015.

System	Crop	Grass dry weight (lb/acre)	Legume dry weight (lb/acre)	Oat dry weight (lb/acre)	Alfalfa dry weight (lb/acre)	Forb dry weight (lb/acre)	Weed dry weight (lb/acre)
Organic C-S-O/A-A[x]	Organic Alfalfa	192.10	-	-	1851.36	-	86.11
	Organic Oat/Alfalfa	-	-	515.56	2.27	-	15.07
Organic Pasture	Mixed species	1673.83	540.81	-	-	2.47	0.70

[x]C= corn, S=soybean, O=oat, A=alfalfa

Table 16. Stand and weed populations in corn plots in OWQ experiment, Agronomy Farm, 6/9/2015.

System	Crop	Stand (plants/acre)	Grass (plants/m^2)	Broadleaf (plants/m^2)
Organic C-S-O/A-A[x]	Organic corn	45,130	11.67a[y]	3.00
Conventional C/S	Corn	47,290	0.43b	2.71
$LSD_{0.05}$		NS	2.7433	NS
p value ($\alpha = 0.05$)		0.0877	0.0121*	0.8575

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 17. Stand and weed populations in soybean plots in OWQ experiment, Agronomy Farm, 6/9/2015.

System	Crop	Stand (plants/acre)	Grass (plants/m^2)	Broadleaf (plants/m^2)
Organic C-S-O/A-A[x]	Organic soybean	164,600	11.53a[y]	2.33
Conventional C/S	Soybean	155,750	0.88b	0.75
$LSD_{0.05}$		NS	4.3863	NS
p value (α = 0.05)		0.4538	0.0020*	0.2134

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 18. Stand and weed populations in corn plots in OWQ experiment, Agronomy Farm, 6/30/2015.

System	Crop	Stand (plants/acre)	Grass (plants/m^2)	Broadleaf (plants/m^2)
Organic C-S-O/A-A[x]	Organic corn	47,270	20.60a[y]	7.07
Conventional C/S	Corn	46,730	0.60b	5.53
$LSD_{0.05}$		NS	16.115	NS
p value (α = 0.05)		0.6231	<.0001*	0.4477

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 19. Stand and weed populations in soybean plots in OWQ experiment, Agronomy Farm, 6/30/2015.

System	Crop	Stand (plants/acre)	Grass (plants/m^2)	Broadleaf (plants/m^2)
Organic C-S-O/A-A[x]	Organic soybean	157,800	9.00a[y]	3.07
Conventional C/S	Soybean	164,670	2.87b	5.53
		NS	1.0334	NS
p value ($\alpha = 0.05$)		0.4922	0.0202*	0.1578 NS

[x] C= corn, S=soybean, O=oat, A=alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 20. Soil nitrate levels in corn plots, OWQ experiment, Agronomy Farm, 8/3/2015.

Treatment	NO_3^--N (mg/kg)
Organic C-S-O/A-A[x]	4.78±0.69a[y]
Conventional C/S	2.40±0.69b
$LSD_{0.05}$	0.15
Interaction p value ($\alpha = 0.05$)	0.0396*

[x] C= corn, S=soybean, O=oat, A=alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 21. Soybean staining in the OWQ experiment, Agronomy Farm, 8/18/2015.

Treatment	Stained soybeans (%)
Organic C-S-O/A-A[x]	1.03
Conventional C/S	0.89
$LSD_{0.05}$	NS
p value (α = 0.05)	0.4772

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 22. Key soybean pest and beneficial insects in OWQ experiment, Agronomy Farm, 8/20/2015 (number per 20 sweeps).

Rotation	Aphids	Bean leaf beetles	Thrips	Corn rootworm	Minute pirate bugs	Spiders	Total beneficial insects
Organic C-S-O/A-A[x]	13.00	1.00	29.60	4.40	7.80	2.00	13.8
Conventional C/S	11.60	3.20	52.40	6.00	9.40	2.00	17.2
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	--

Table 23. Other pest and beneficial insects in OWQ experiment, Agronomy Farm, 8/20/2015 (number per 20 sweeps).

Rotation	Caterpillar	Nabids	White flies	Grasshoppers	Green lacewings	Leafhoppers	Tarnished plant bugs	Wasps
Organic C-S-O/A-A[x]	0.40	0.60	2.40	0.60	0.60	0.60	3.60	0.00
Conventional C/S	0.20	1.40	2.80	1.00	0.00	0.00	1.00	0.00
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	--

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 24. Corn stalk nitrate levels in the OWQ experiment, Agronomy Farm, 9/18/2015.

Treatment	$NO_3^{-}N$ (mg/kg)
Organic C-S-O/A-A[x]	3634.00
Conventional C/S	3086.00
$LSD_{0.05}$	NS
p value ($\alpha = 0.05$)	0.3770

[x] C= corn, S=soybean, O=oat, A=alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 25. Corn and soybean yields in the OWQ experiment, Agronomy Farm, 10/16/2015.

Treatment	Corn yield (bu/acre)	Soybean yield (bu/acre)
Organic C-S-O/A-A[x]	140.06	51.41
Conventional C/S	148.16	51.24
$LSD_{0.05}$	NS	NS
p value (α=0.05)	0.0655	0.9789

[x] C= corn, S=soybean, O=oat, A=alfalfa
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 26. Oat yield in the OWQ experiment, Agronomy Farm, 10/16/2015.

Treatment	Yield (bu/ac)
Organic C-S-O/A-A[x]	104.65
Conventional C/S	--
$LSD_{0.05}$	--
p value (α=0.05)	--

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 27. Alfalfa yield in the OWQ experiment, Agronomy Farm, 2015.

Treatment	Yield (tons/acre)
Organic C-S-O/A-A[x]	2.18
Conventional C/S	--
$LSD_{0.05}$	--
p value (α=0.05)	--

Table 28. Alfalfa yield by treatment in the OWQ experiment, Agronomy Farm, 10/16/2015.

Treatment	Yield (ton/acre)
Alfalfa only	0.73a
O/A	0.23b
$LSD_{0.05}$	0.24295
p value (α=0.05)	0.0006*

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 29. Soybean cyst nematodes in the OWQ experiment, Agronomy Farm, 10/22/2015.

Treatment	Eggs per cc
Organic C-S-O/A-A[x]	480.00
Conventional C/S	1180.00
$LSD_{0.05}$	NS
p value (α = 0.05)	0.4657

[x] C= corn, S=soybean, O=oat, A=alfalfa

[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 30. Corn grain quality in the OWQ experiment, Agronomy Farm, 11/5/2015.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol yield (gal/bu)
Organic C-S-O/A-A[x]	14.88	8.00a[y]	4.26	72.06b[y]	1.24	2.81b[y]
Conventional C/S	15.08	7.52b	4.6	72.68a	1.24	2.84a
$LSD_{0.05}$	NS	0.23379	NS	0.23413	NS	0.00537
p value ($\alpha = 0.05$)	0.5187	0.0020*	0.656	0.0060*	0.4535	0.0158*

[x] C=corn, S=soybeans, O=oats, A=alfalfa

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ (Fisher's Protected LSD Test).

Table 31. Soybean grain quality in the OWQ experiment, Agronomy Farm, 11/27/2015.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbos (%)	Sum (%)
Organic C-S-O/A-A[x]	9.98	34.96	19.64	4.70	22.70	54.60
Conventional C/S	9.26	34.96	19.56	4.72	22.76	54.52
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
p value ($\alpha = 0.05$)	0.1226	1.0000	0.8615	0.7924	0.9169	0.9018

[x] C=corn, S=soybeans, O=oats, A=alfalfa

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ (Fisher's Protected LSD Test).

Table 32. Corn, soybean, oat and alfalfa yields in the OWQ experiment, Agronomy Farm, 2016.

Treatment	Corn yield (bu/acre)	Soybean yield (bu/acre)	Oat yield (bu/acre)	Straw yield (tons/acre)	Alfalfa harvest date	Alfalfa yield (tons/acre)
Organic	196.40	53.98	85.0	1.10	6/8	1.58
Conventional	203.80	49.38			7/5	0.42
p value (α=0.05)	0.2130	0.3414			8/19	0.57
					9/21	0.47
					Average	0.76
					Seasonal total	3.05

Table 33. Soybean cyst nematode count in the OWQ experiment, Agronomy Farm, 9/10/16.

Treatment	Eggs/100 cc
Organic	1176.00
Conventional	1280.00
$LSD_{0.05}$	NS
p value (α=0.05)	0.9272

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 34. Pest and beneficial insects, OWQ experiment, Agronomy Farm, 9/10/16.

Treatment	Ant	Bean leaf beetle	Corn rootworm	Cricket	Flea beetles	Syrphid fly	Robber fly	White fly	Other fly	Minute pirate bug
Organic	0.63	38.63	4.50	0.13	0.75	0.13	0.38	19.38	0.75	1.50
Conven-tional	0.00	39.00	3.50	0.00	0.00	0.00	0.50	17.50	0.50	2.00
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
p value (α=0.05)	0.2889	0.9845	0.7886	0.6454	0.1894	0.6454	0.7791	0.8974	0.8171	0.6666

Treatment	Moth	Spider	Stinkbug	Soldier bug	Tarnished plant bug	Thrips
Organic	0.38	1.00	0.38	0.88	0.50	0.75
Conventional	0.00	0.50	0.50	0.50	1.50	0.00
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
p value (α=0.05)	0.3559	0.5960	0.7791	0.5787	0.2547	0.2856

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 35. Soybean grain quality analysis in the OWQ experiment, Agronomy Farm, 2016.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbohydrates (%)	Sum (%)
Organic	12.54	35.26	18.18	4.84	23.72	53.44
Conventional	12.64	34.60	18.54	486	24.00	53.14
$LSD_{0.05}$	NS	NS	0.21	NS	NS	NS
p value (α=0.05)	0.8801	0.1339	0.0005*	0.6811	0.4356	0.4553

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 36. Corn grain quality analysis in the OWQ experiment, Agronomy Farm, 2016.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol yield (gal/bu)
Organic	16.00	8.76	4.62	71.04	1.27	2.77
Conventional	15.92	8.56	4.54	71.44	1.27	2.79
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
p value (α=0.05)	0.8739	0.4422	0.2907	0.2441	0.2774	0.2861

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 37. Neely-Kinyon LTAR Soil Quality Fall 2016 (depth 0-15 cm).

	SOC gkg^{-1}	TN gkg^{-1}	pomC gkg^{-1}	pomN gkg^{-1}	mbc $mgkg^{-1}$	mbn $mgkg^{-1}$	pminN $mgkg^{-1}$	no3N $mgkg^{-1}$	P $mgkg^{-1}$	K $mgkg^{-1}$	Mg $mgkg^{-1}$	Ca $mgkg^{-1}$	Ec µS cm^{-1}	ph	Aggs %	bd gcm^{-3}
Conv C-S	22.7b	2.3b	2.75b	0.23c	285c	15.4b	36.6b	10.7a	22.9c	252b	358c	3368b	161b	6.11c	23.1b	1.18
Organic C-S-O/A	24.5a	2.5a	3.62a	0.33a	334b	19.8ab	47.6a	10.5a	110.2a	357a	434ab	4271a	211a	7.19a	23.1b	1.16
Organic C-S-O/A-A	24.3a	2.6a	3.60a	0.34a	369a	20.5a	50.0a	11.6a	77.8ab	288b	428b	4157a	214a	6.93b	29.5a	1.16
Organic C-S-C-O/A	24.0ab	2.6a	3.11b	0.29b	343b	20.7a	46.4a	9.8a	45.0bc	254b	493a	4045a	200a	7.00b	30.8a	1.18
Lsd $_{0.05}$	*1.4*	*0.1*	*0.41*	*0.040*	*32*	*4.8*	*4.2*	*NS*	*35.6*	*37.5*	*60*	*243*	*36*	*0.13*	*5.4*	*NS*

[x] C=corn, S=soybeans, O=oats, A=alfalfa

[y] Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ (Fisher's Protected LSD Test).

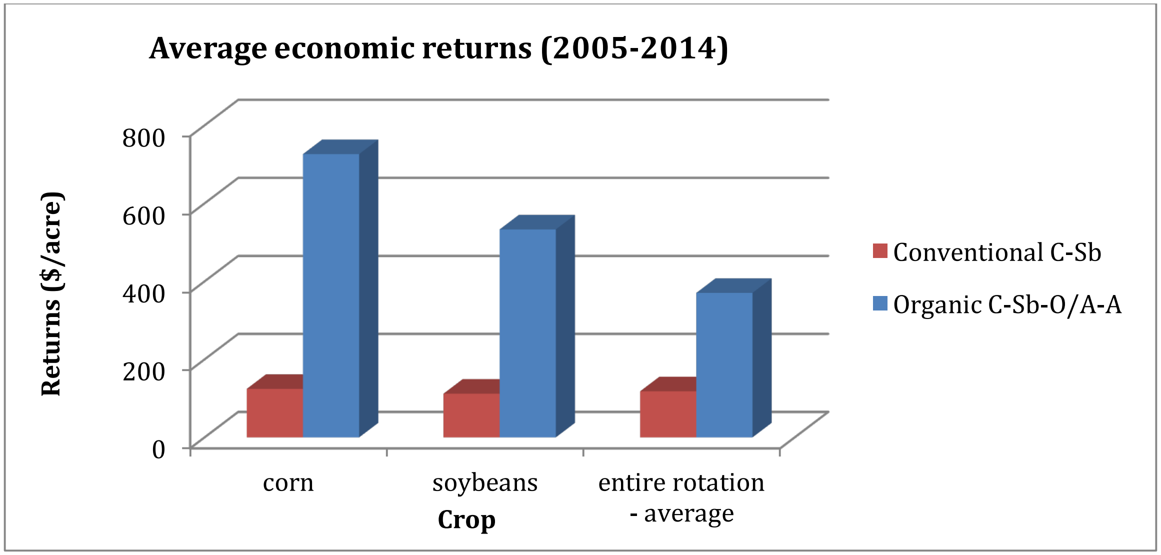

Figure 1. Economic Analysis of average returns from conventional corn and soybean versus organic C-S-O/A, 2005–2014, LTAR site, Greenfield, IA.

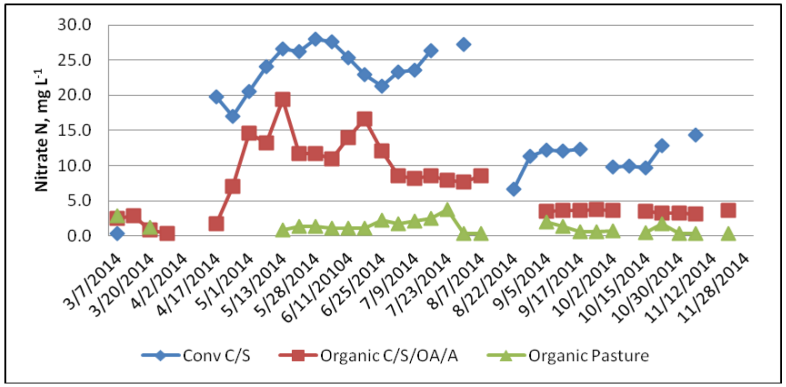

Fig. 2. Flow-weighted subsurface drainage water NO_3-N concentrations from OWQ site (from Cambardella et al., 2015).

Cambardella, C.A., K. Delate, and D.B. Jaynes. 2015. Water quality in organic systems. Sustainable Agriculture Research 4(3): http://www.ccsenet.org/journal/index.php/sar/article/view/50106

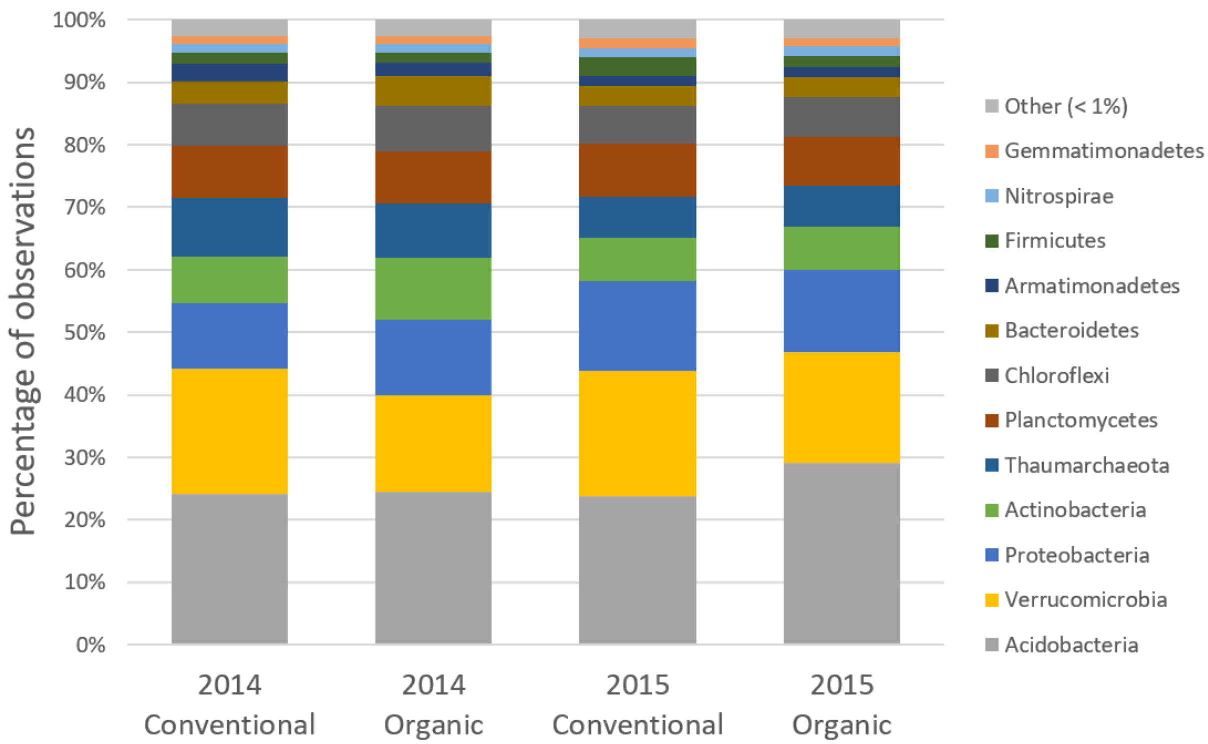

Figure 3. Bulk soil prokaryote community structure, at the rank of phylum. Shown are mean values across LTAR replicate plots and across crop species. Phyla present at < 1% mean relative abundance are grouped as 'Other'.

11. Budget Report – All funds were expended for this project.

Leopold Center for Sustainable Agriculture
Proposed Budget for ISU Grants
X Project Budget   ___ Subcontract Budget   (Check one)

	Year 1 2015-2016 Leopold Center Requested Funds
Salaries/Hourly	183
Payroll Benefits	3
Equipment > $5,000	
Travel – Domestic	10,450.01
Travel – Foreign	
Student Tuition	
Supplies & Materials	
Ag & Vet Supplies	5,792.92
Lab & Research Supplies	
Other Supplies	

Subcontracts (Attach separate budget for each)	
1. USDA-ARS	$26,100
2.	
3.	
4.	
Total Subcontracts	26,100*
Other Direct Costs	
Telecommunication Charges	1,454.19
Computer Usage	
Printing/Copying	349.31
Honoraria/Services	4,527.85
Postage	
Other	78
Total Other Direct Costs	6,060.04
TOTAL DIRECT COSTS	49,938

_x_ Project Budget **__ Subcontract Budget** **(Check one)**

AMENDED JAN 6, 2016

Refer to instructions on the back of this form. A separate budget is required for each project year.

Year 2

2016-2017

Leopold Center

	Requested Funds
Salaries/Hourly	
Payroll Benefits	
Equipment > $5,000	
Travel – Domestic	9,000
Travel – Foreign	
Student Tuition	
Supplies & Materials	
Ag & Vet Supplies	3,788
Lab & Research Supplies	
Other Supplies	
Subcontracts (Attach separate budget for each)	
1. USDA-ARS	*$30,000
2.	
3.	
4.	
Total Subcontracts	30000

Other Direct Costs	
Telecommunication Charges	1,000
Computer Usage	
Printing/Copying	1,000
Honoraria/Services	5,000
Postage	150
Other	0
Total Other Direct Costs	7150
TOTAL DIRECT COSTS	49,938

Salary and wages: Will be paid off other grants or in Services below.

Travel: Travel to field sites (state truck expense) and reimbursable lunch costs of the student employees; additional travel to field days and conferences to present findings =$9,000

Supplies and Materials: Costs of field supplies including flags, stakes, seed and compost; Costs of University farm services, including planting, cultivating, and harvesting = $3,788

Telecommunication: telecommunication costs for field research and Extension activities = $1,000

Printing/copying: Field Day and conference printing charges = $1,000

Postage: postage for Extension mailings = $150

Honoraria/Services: Costs of outside farm services, including pest management; website maintenance; costs of local labor in Greenfield, IA = $5, Subcontract (USDA-ARS): Costs to cover soil, plant and water quality analysis = $30,000; with a request and approval to move $10,000 from 2016 supply funds into 2016 salary funds. (see Amended Statement below)

USDA STATEMENT OF WORK: AMENDED December 14, 2015

Performance Period: February 1, 2015 – January 30, 2017

Approach: The long-term goal of this project is to encourage transition to more ecologically-diverse methods of farming that preserve soil health and water quality. Three established experiments will be utilized in this project, each with a unique crop rotation and management history that will support comparisons across a continuum of conditions: 1) The Long-Term Agroecological Research (LTAR) Experiment, established in 1998 in Greenfield, Iowa, a long-term site comparing certified organic and conventional farming systems 2) the USDA-ARS Organic Water Quality (OWQ) site, Boone, Iowa, a new experiment, comparing transitioning organic and conventional crop rotations and pasture systems; and 3) the Organic Reduced-Tillage (ORT) site, Boone, Iowa, in its sixth year comparing different cover crops and reduced tillage options.

ARS Agrees to: Design soil, plant and water sampling protocols; Collect surface soil cores in the fall after harvest in 2015 and 2016 at LTAR, OWQ and ORT to assess soil quality and water samples every week from the OWQ from March 1, 2015 - April 30, 2017 to assess water quality; Collect aboveground biomass samples from all crops in 2015 and 2016 in order to assess crop biomass C and N inputs at OWQ site; Process soil, plant and water samples and conduct laboratory analysis. Collect soil CO_2 flux data during the growing season in 2015 and 2016 at OWQ site; Soil microbial community structure will be evaluated for the LTAR and OWQ sites in 2015 and the OWQ site only in 2016. Water quality will be evaluated at the OWQ site only; Summarize, run statistical analysis and interpret soil quality, microbial ecology, and water data.

ARS Deliverables: ARS will provide soil quality data for the LTAR, OWQ and ORT sites; water quality data for the OWQ site; and microbial community structure and function data for the LTAR and OWQ sites.

Timeline of ARS Research Activities, March 1 2015 – April 30 2017.

	2015, 2016, 2017			
Quarter	**1st**	**2nd**	**3rd**	**4th**
Soil quality (LTAR, OWQ, ORT) and microbial diversity measurements			x	x

(LTAR and OWQ 2015 and OWQ 2016)				
Water quality measurements (OWQ)	x	x	x	x
Soil CO_2 Flux measurements		x	x	
Plant biomass collection & analysis		x	x	x
Nutrient budget development (all sites)				x
Evaluation and data analysis and report writing			x	x