NC-1178 Report, June 27 and 28, 2016

Long-term tillage and crop rotation and corn residue management effects on yield and soil parameters

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Study Description

The objective of this project is to establish coordinated field studies to determine the short-term and long-term impacts of different tillage, crop rotation, and corn residue removal rates on soil health and productivity. These studies established as long-term studies since 2002 and 2008, respectively at the Iowa State University Research and Demonstration Farms at different locations across the state.

Under the long-term tillage and crop rotation study five tillage systems include: no-till (NT), strip-tillage (ST), chisel plow (CP), deep rip (DR), and moldboard plow (MP) and the three crop rotations include two with soybean: Corn-soybean (C-S), Corn-corn-soybean (C-C-S) and a continuous corn (C-C) system. The experiment design for all sites was the same; a complete randomized block design with tillage as the main treatment and crop rotation as the sub-plot treatment with four replications. The C-C system was added to the experiment in 2008 after the 2007 crop year. Each plot size is 30 ft wide (12 rows) and 90 ft. long for the corn and soybean rotation systems (C-C-S and C-S) and 30 ft wide and 60 ft. long for the continuous corn (C-C) system. Corn and soybean yields were determined from the center 4 and 6 rows of each plot, respectively. These experiments implemented at seven Iowa State University Research and Demonstration Farms representing different soil types and climate conditions.

Under the residue removal study, the main treatment is tillage practice (no-till and chisel plow), which was split into three different corn residue removal rates (0, 50, and 100%), The N rates were the split-split treatments, varying from none to 250 lb N/acre in spring of 2009. Soil measurements were conducted in August and September, which includes soil C, N, P, K, bulk density, water infiltration, residue cover, microbial biomass, and weekly carbon dioxide (CO_2) and nitrous oxide (N_2O) gas field measurements. After harvest, crop measurements included grain yield, and N, P, and K uptake. Laboratory analyses for various soil and agronomic parameters were conducted such as, soil carbon analysis, plant carbon analysis, nutrients analyses, lab incubation studies, aggregate stability analysis, and data management and analysis.

Accomplishments/Outputs

During the growing season of 2015, several presentations of the preliminary findings of these studies were presented to local farmers and agronomists in the state. These workshops were organized by Extension as part of the annual Extension and education program. Yield data collected from these studies analyzed to cover yield response and economic returns to the stated treatments in these studies. The impact of soil management practices on certain soil health parameters was highlighted as well. Training sessions, PowerPoint presentations, and educational materials were presented during these events. In addition to field days, initial findings of this research were shared with other colleagues and agricultural professionals through newsletter articles, American Society of Agronomy (ASA) annual meetings, refereed journal articles, presentation at the regional committee meeting, and presentation to extension educators and other agricultural professionals during various events such as the Integrated Crop Management (ICM) conference in Iowa in 2015. The ICM conference is organized annually and approximately 1,000 agricultural professionals attended the conference.

Outcomes/Impacts

The analysis of 14 years of data on the effect of long-term tillage and crop rotation on corn and soybean yield and economic returns showed an interesting trend across the state of Iowa. Corn yield and economic return showed significant variability across the state as affected by soil type and climate conditions. Economic return showed a significant advantage for NT over conventional tillage systems where input cost was $15-25/ha less with NT compared to conventional tillage systems. Also the results reveal a significant decline in corn yield with continuous corn compared to corn following soybean rotation. The soybean yield in the same study shows no significant differences in yield regardless of tillage or crop rotation. However, economic return for soybean across all tillage systems and locations was 5% greater with C-C-S compared to C-S rotation.

Under the residue removal study, we continue the documentation of residue removal under different residue removal rate, tillage systems, and N rate effects on yield and soil parameters. Generally, residue removal affected soil temperature, where soil temperature increased as removal rate increased. This change was reflected in corn yield response, where greater yield observed especially with CP. Also, a significant change in residue carbon and total N potential input was reduced as the level of corn residue removal increased. Along with that carbon budget was affected by residue removal, tillage systems, and N rate. Yield variability over the years affected by weather variability for all residue removal treatments with slight advantage for corn yield in wet cold areas with increased residue removal.

Publications

Al-Kaisi, M., S.V. Archontoulis, and D. Kwaw-Mensah. 2016. Soybean spatiotemporal yield and economic variability as affected by tillage and crop rotation. Agron. J. 108 (3): 1-14.

Al-Kaisi, M., S.V. Archontoulis, D. Kwaw-Mensah, F. Miguez. 2015. Tillage and crop rotation effects on corn agronomic response and economic return at seven Iowa Locations. Agron. J. 107:1411-1424.

Guzman, J. and **Al-Kaisi, M.** 2014. Residue removal and management practices effects on soil environment and carbon budget. Soil Sci. Soc. Am. J. 78: 609-623.

Guzman, J.G., M. Al-Kaisi, and T. Parkin. 2015. Greenhouse Gas Emissions Dynamics as Influenced by Corn Residue Removal in Continuous Corn System. Soil Sci. Soc. Am. J. 79:612–625. doi:10.2136/sssaj2014.07.0298

External Funding:

This project was supported through funding from the Agronomy Endowment at the Department of Agronomy at Iowa State University from 2008 to present in the amount of **$215,000**. This funding made it possible to support graduate student and other research needs.

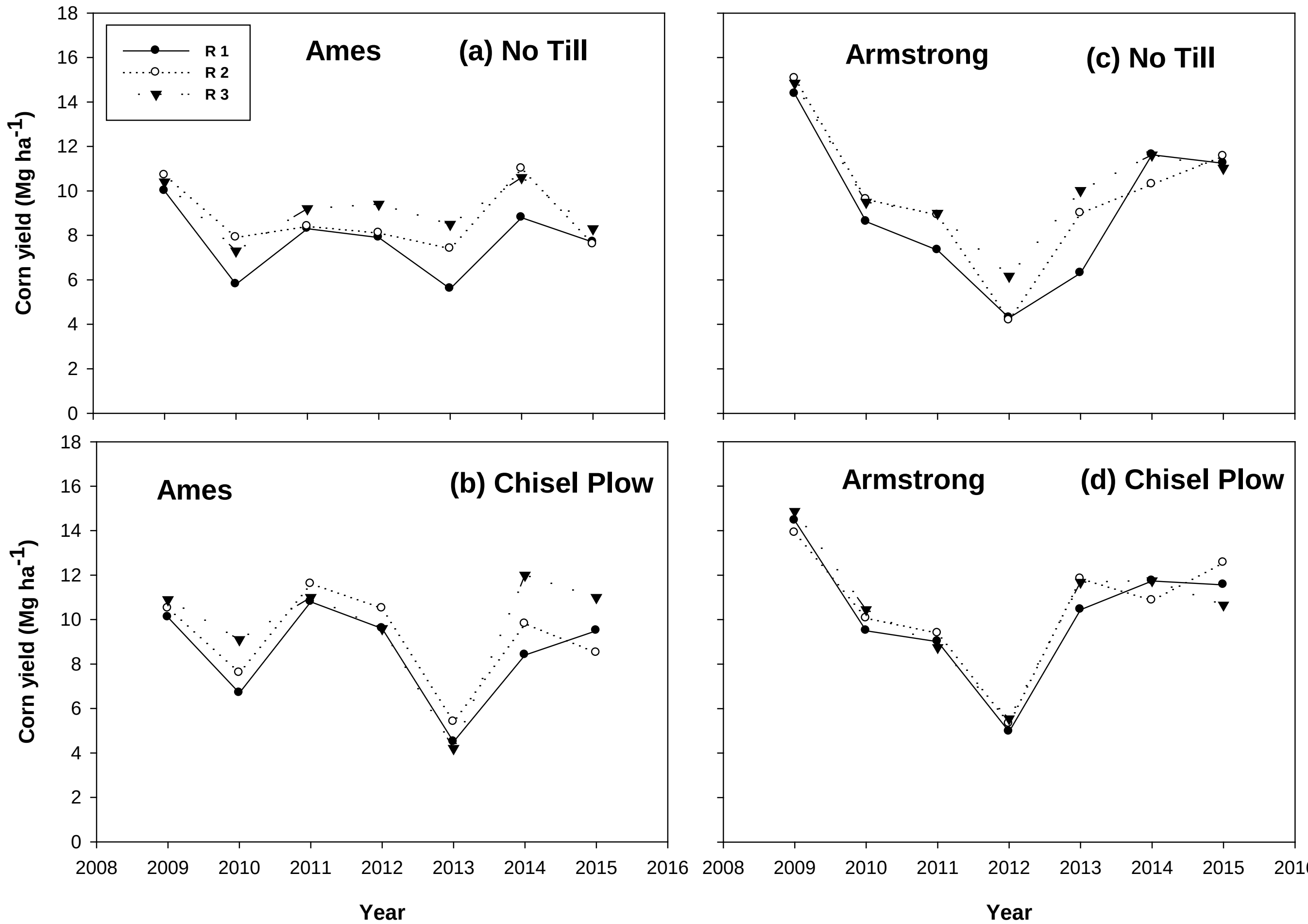

Figure 1. Seven years of continuous corn yields in no tillage and chisel plow at 186 kg N ha^{-1}, with three corn residue removal treatments R 1, R 2, and R3, where R 1 = No residue removal, R 2= 50% residue removal and R 3= Full residue removal. Yield drop in 2012 at both sites due to statewide drought. Yield drop in Ames in 2013 was the result of wind and severe hail damage.

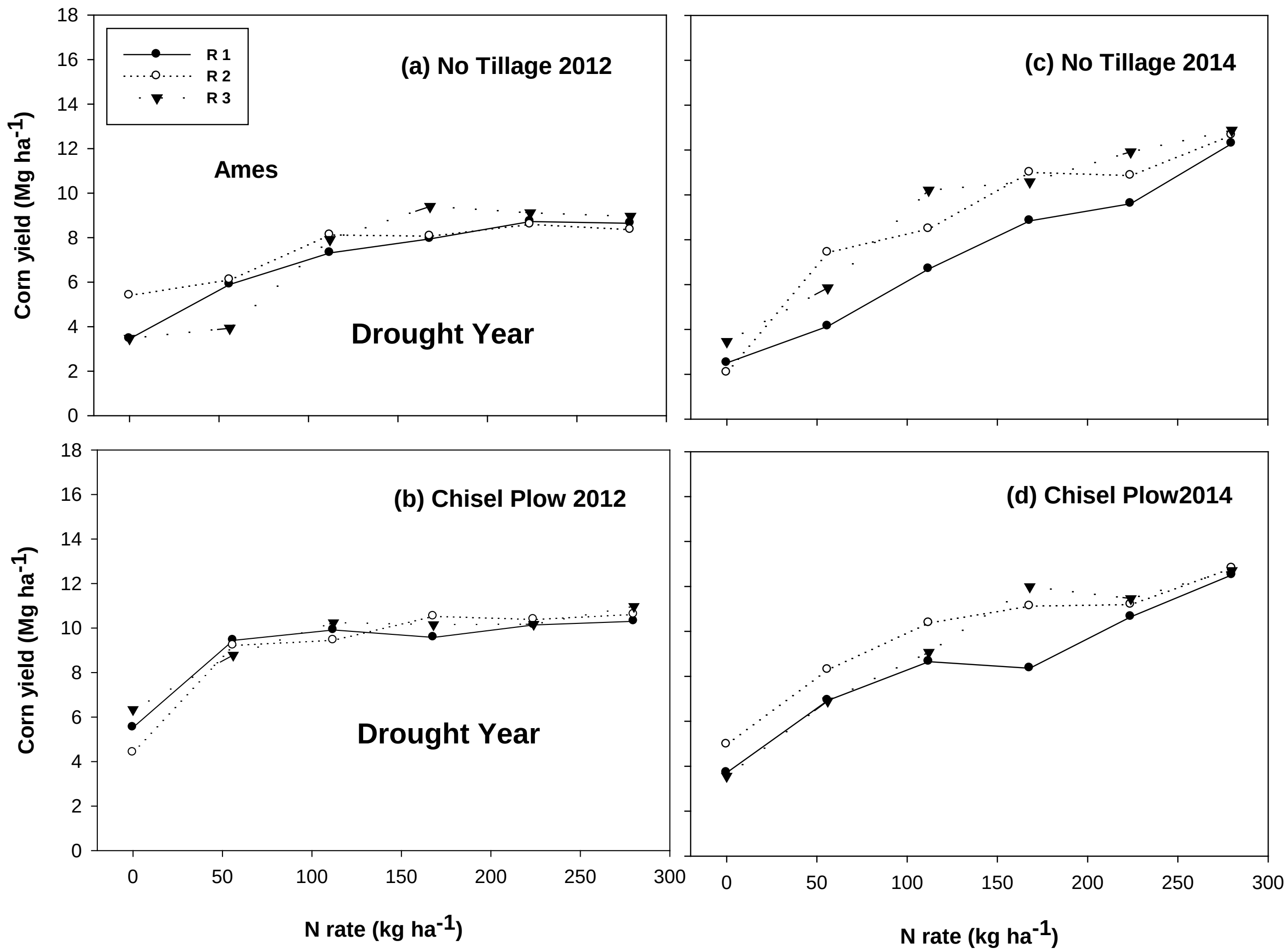

Figure 2. Corn yields in no till and chisel plow with three corn residue removal treatments R 1, R 2, and R3, and six N rates (0, 56, 112, 168, 224, and 280 kg N ha^{-1}) where R 1 = No residue removal, R 2= 50% residue removal and R 3= Full residue removal.

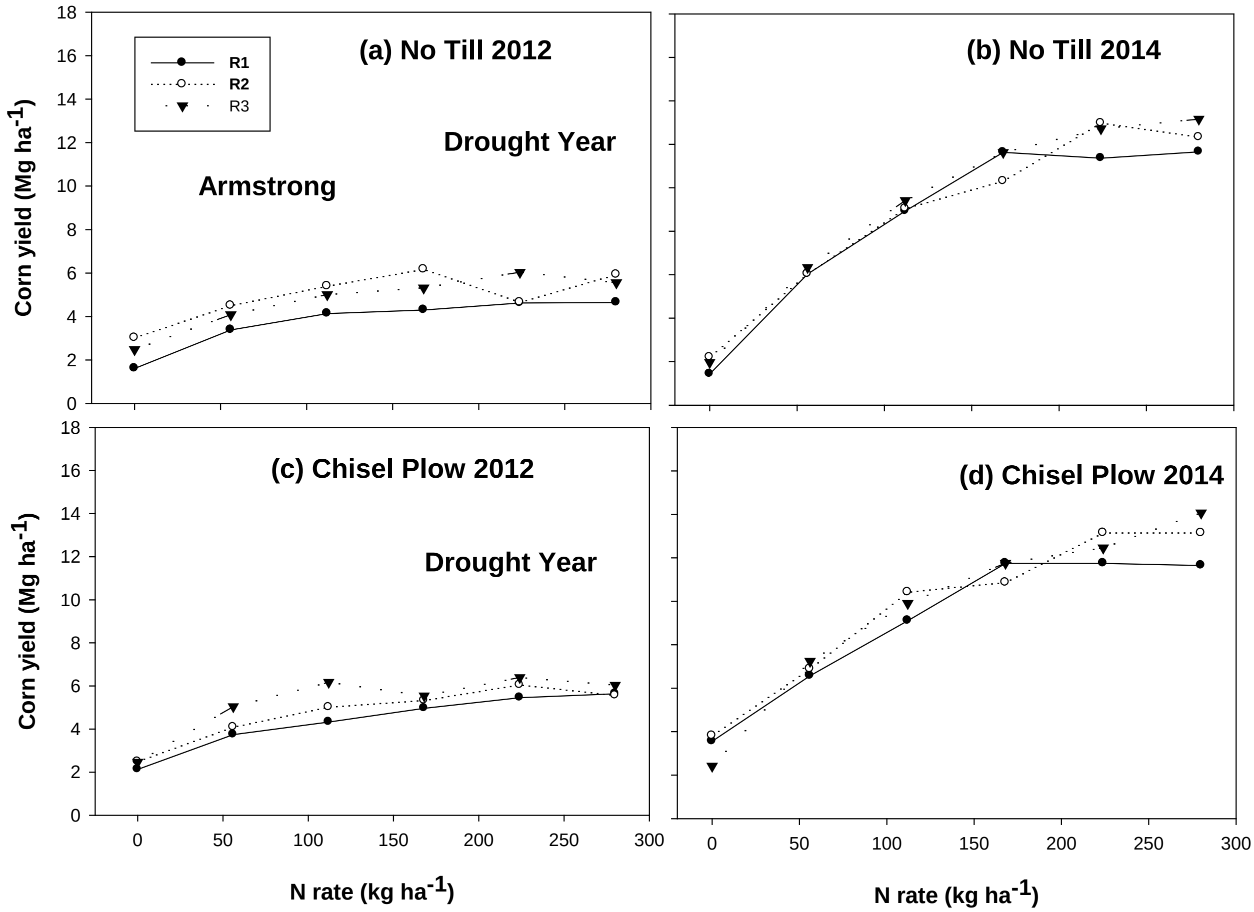

Figure 3. Corn yields in no till and chisel plow with three corn residue removal treatments R 1, R 2, and R3, and six N rates (0, 56, 112, 168, 224, and 280 kg N ha^{-1}) where R 1 = No residue removal, R 2= 50% residue removal and R 3= Full residue removal.

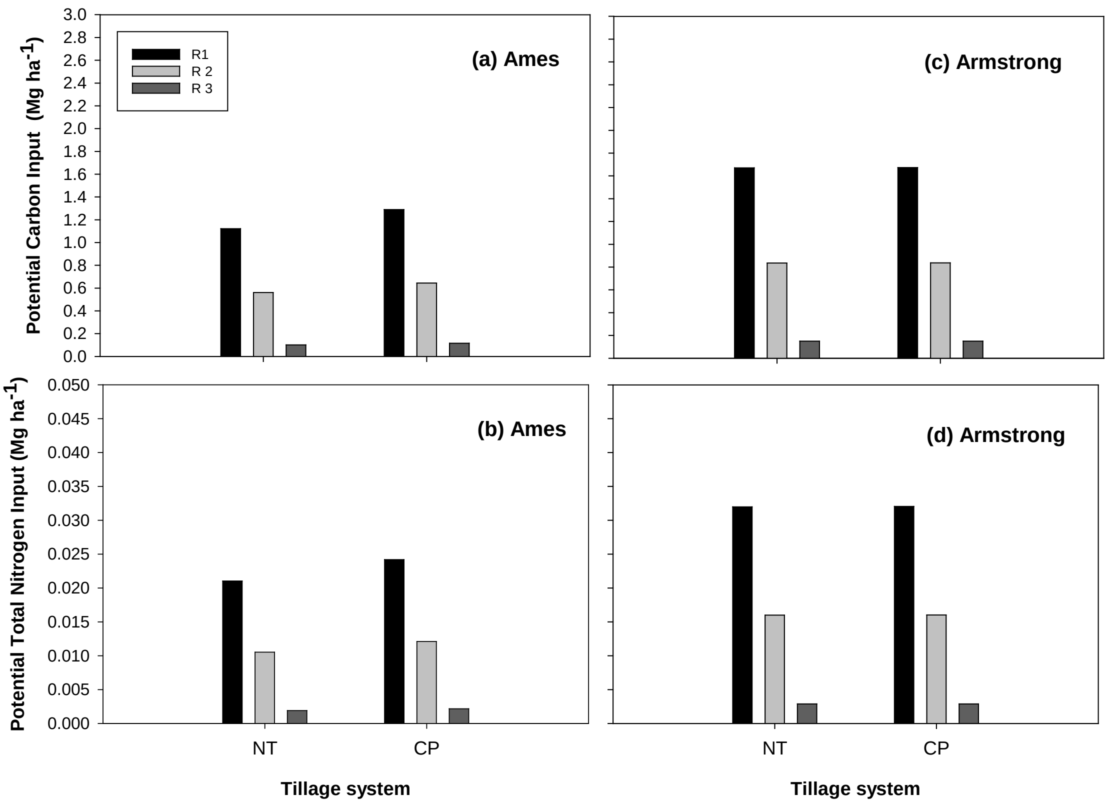

Figure 4. Potential Carbon and Total Nitrogen Input from three rates of residue removal (no residue removal, 50% residue removal and full residue removal) in a continuous corn study in Ames and Armstrong where R 1 = No residue removal, R 2= 50% residue removal and R 3= Full residue removal.

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NC-1178 Annual State Report

Year: 2015-16

Institution: University of Wisconsin-Madison

Committee Representative: Francisco J. Arriaga, Dept. of Soil Science

Activities

Research efforts have been in a transition period to a new 2-year Hatch project, entitled "Enhancing Productivity and Environmental Stewardship of Dairy Forage Systems with Cover Crops and No-tillage." A graduate student working towards a M.S. degree began on September 2015 as a member of this project. The objectives of this study are to: 1) determine the impact of using a cereal rye as a cover crop and no-tillage on sediment and phosphorus losses from corn silage production fields, 2) link soil health to water quality and crop productivity, and 3) identify drivers and barriers for adoption of cover crop use by farmers using questionnaires. Several extension presentations have been given this reporting cycle using data from this work.

Summary of Results

Rainfall simulations were performed in June 2016 to compare runoff, sediment and phosphorus losses between the different management systems. Initial data indicates that alfalfa had the lowest amount of runoff, followed by no-tillage with a cover crop after a 3 inch/hour simulated event (Figure 1). No-tillage without the cover crop had lower runoff amounts than either chisel/finisher system. Including a cover crop with a chisel/finisher tillage system didn't reduce runoff. Total runoff amounts were 0.75, 2.0, 2.1, 1.6 and 1.4 inches for the alfalfa, chisel/finisher with no cover, chisel/finisher with cover crop, no-tillage with no cover and no-tillage with cover crop, respectively. In other words, tillage increased runoff water losses by 30% relative to no-tillage, while cover crops decreased tillage between 5% and 12%. Total sediment losses followed a similar pattern (Figure 2), but including a cover crop in the system reduced sediment losses more dramatically. We continue laboratory analysis to determine losses of different phosphorus fractions and other assessments of soil properties.

Relevant Publications

No peer-reviewed publications during this cycle.

Additional Outcomes

Research project highlighted during the Agronomy/Soils Field Day at the Arlington Agricultural Research Station held on August 30, 2016. This field day targets farmers, crop consultants, Land and Water Conservation districts, and other agricultural practitioners, with an attendance of 250+ participants. Data has also been used in other field days and extension/outreach presentations, with a total of 200+ participants.

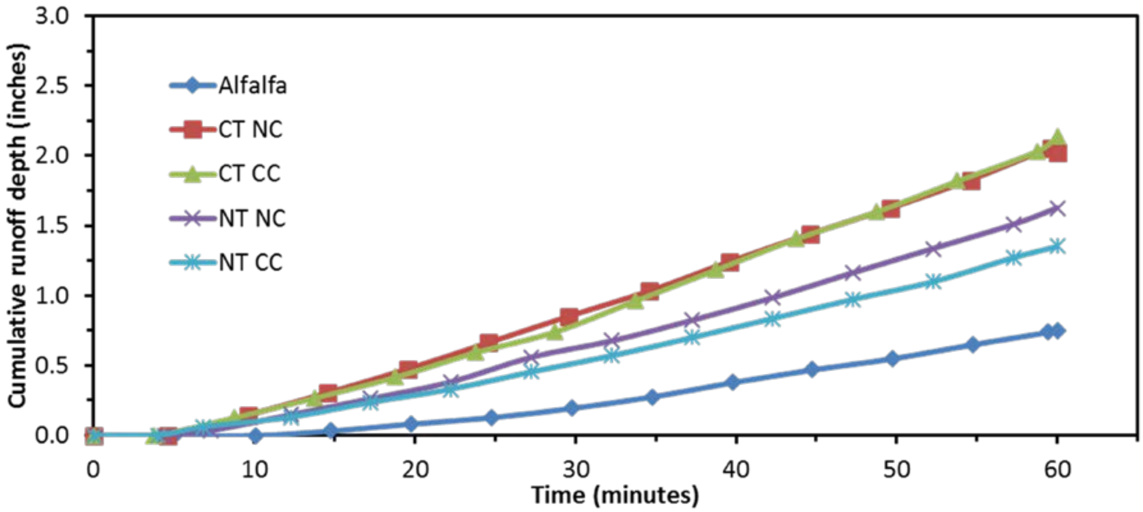


Figure 1. Cumulative runoff produced during a 60-minute simulated rainfall event at a 3 inch/hour rate (30-year return period). CT - chisel/finisher tillage; NT - no-tillage; NC - no cover crop; CC - cereal rye as a cover crop.

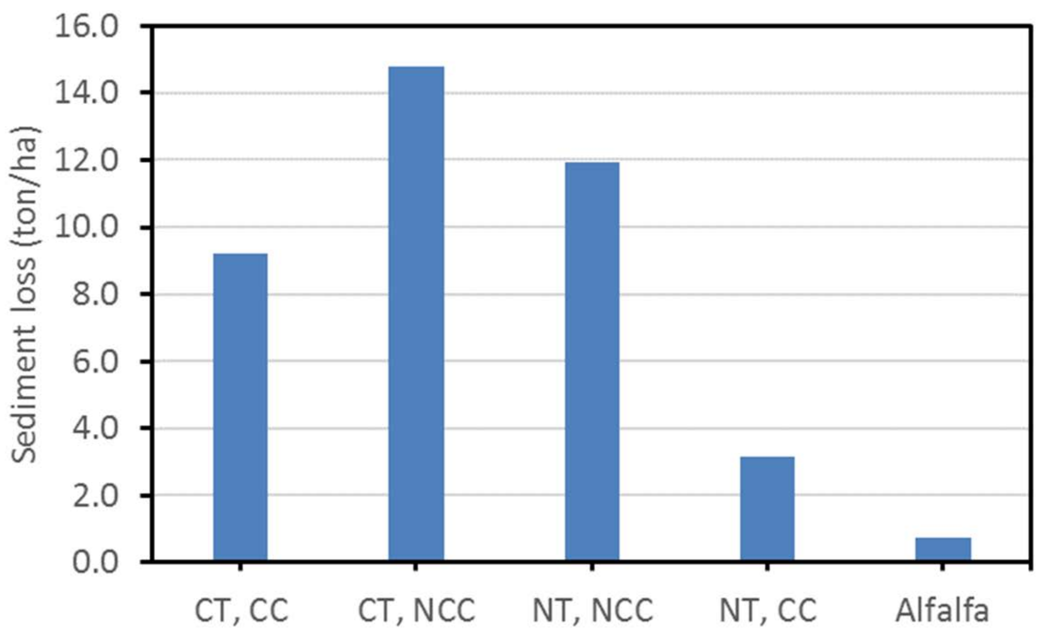


Figure 2. Total sediment losses after a 60-minute simulated rainfall event at a 3 inch/hour rate (30-year return period). CT - chisel/finisher tillage; NT - no-tillage; NC - no cover crop; CC - cereal rye as a cover crop.

NC-1178 Report, June 27 and 28, 2016

Impacts of corn residue grazing on soil properties under irrigated conditions

Humberto Blanco, Associate Professor

Department of Agronomy and Horticulture, University of Nebraska-Lincoln

STUDY DESCRIPTION

The objective of this project is to evaluate the impact of corn residue grazing on soil compaction, wind and water erosion risks, structural quality, fertility, and microbial community and their relations with corn-soybean yield on an irrigated no-till corn-soybean production system. Farm scale studies are being conducted at multiple locations across precipitation gradient in Nebraska. Important accomplishments and outcomes from study near Mead, NE are discussed in this report.

To assess the impacts of long term (16 yr) corn residue grazing on soil properties, an experiment was established in 1997 on a 36 ha of irrigated cropland managed at the Agricultural Research and Development Center of the University of Nebraska-Lincoln located near Mead, NE. The soil is a Tomek silt loam (0 to 2% slope). The experiment had three treatments: 1) fall/winter grazing (November through January), 2) spring grazing (February to the middle of April), and 3) control (no grazing) replicated twice. Grazing treatments were applied using stocker cattle (227- 318 kg). Fall grazing treatment had stocking rate of 4.4 to 6.2 AUM ha^{-1} (1997-2015). From 1997-1999, spring grazing treatment had a stocking rate of 3.7 to 5.2 AUM ha^{-1}. Beginning in 2000, the stocking rate for spring grazing treatment was modified to 9.3 to 13.0 AUM ha^{-1}.

In situ measurements of cone index and intact soil cores were collected in spring 2015 from 0 to 5, 5 to 10, 10 to 15, 15 to 20 cm to determine soil compaction. Bulk soil samples were collected from 0 to 5 and 5 to 10 cm to analyze wet aggregate stability, dry aggregate strength, soil organic C, particulate organic matter (POM), macro-nutrients, and microbial properties using standard protocols. Corn and soybean yields were determined by harvesting 0.16 to 0.26 ha of area per treatment per replicate each year.

SUMMARY OF RESULTS

Soil compaction and structural quality

Fall grazing did not increase cone index at any soil depth relative to control (no grazing; Fig. 1). Figure 1 shows that cone index under fall grazing was similar to control at the 0 to 5 cm and the 5 to 10 cm soil depth and lower by 0.7 times at the 10 to 15 cm and 15 to 20 cm soil depth than control. The results suggest that long-term corn residue grazing by cattle during fall/winter (November-January) did not compact the soil. Spring grazing caused significant increase in cone index compared to control (Fig. 1). Figure 1 shows that cone index under spring grazing was 3.4 times higher at the 0 to 5 cm, 2.0 times higher at 5 to 10 cm, 1.5 times higher at the 10 to 15 cm, and 1.3 times higher at 15 to 20 cm than control. The spring grazing treatment of our experiment was specifically designed to portray the worst-case scenario of grazing using high stocking rates (9.3 to 13.0 AUM ha^{-1}) than often recommended. In addition, soils are often thawed, muddy and have soil temperature above freezing point during mid-February to April which makes soil more prone to compaction. The results of our study indicate that corn residue grazing in spring at stocking rates of 9.3 to 13.0 AUM ha^{-1} can increase soil compaction risks. The values of cone index (1.2 to 1.5 MPa) were, however, below the threshold level of 2.0 MPa to inhibit the plant root growth. We therefore conclude that even spring grazing had no effect on soil properties of biological significance.

Unlike cone index results, grazing treatments did not affect soil bulk density and wet aggregate stability. Fall grazing had no effect on dry aggregate strength of 2-4.75 mm and 1-2 mm soil aggregates while spring grazing increased the strength of 2-4.75 mm aggregates by 2 times (Fig. 2). The results suggest that long term corn residue grazing have no or minimal impact on soil structural quality.

Soil fertility and microbial properties

Grazing treatments did not affect particulate organic matter, total organic C concentration, and soil organic C stocks (Table 1). Even though differences of organic C were not significant among grazing treatments, but the numerical values tended to be higher in grazed plots compared with control at the 0 to 10 cm soil depth. The trend for increase in soil C fractions and stocks can be due to addition of cattle manure into the soil as reported in other long term studies. Grazing treatments had no effect on soil macro-nutrients and chemical properties except for calcium and sulphur concentration at the 0 to 10 cm soil depth (Table 2.) While not significant, concentration of other nutrients tended to be higher under spring grazing compared to the control except for phosphorus.

Grazing treatments had no significant effect on soil microbial community structure except for actinomycetes (Table 3). Even though differences of soil microbial community structure were not significant among treatments, the numerical values tended to be higher in grazed plots compared with control at the 0 to 10 cm soil depth. The input of cattle dung and urine can act as source of readily available C substrate, which can affect the microbial activity and composition of microbial community. The results suggest that long term corn residue grazing has none or slightly positive impact on soil fertility and microbial properties.

Correlation among different soil properties and corn-soybean yield as influenced by cattle grazing of corn residues

Fall grazing improved soybean (4.4 metric ton/ha; $p < 0.01$) and corn yields (12.7 metric ton/ha; $p= 0.07$) relative to control, while spring grazing increased soybean yields (4.3 metric ton/ha; $P = 0.07$) but had no impact on corn yield (12.5 metric ton/ha; $p = 0.27$) in this 16-yr experiment. Among the measured soil properties, corn yield was not related to any of the measured soil properties. For example, changes in cone index (p=0.89) did not effected the corn yield. Such relation is expected as grazing did not increased cone index value more than the critical levels to limit the plant growth.

Soybean yield was positively correlated (p =0.09) with aurbuscular mycorrhizal fungi (AMF) and it tended to increase with increase in actinomycetes community (p=0.16). Presence of AMF and actinomycetes have been reported to enhance the efficiency of nitrogen fixing bacteria by improving infection rate and impacting the mineral nutrition of host plant. Improved availability of nutrients to soybean could be a plausible reason for increased soybean yields in our experiment.

Accomplishments/Outputs

Important findings of this research are being disseminated among livestock producers, extension educators, and other agricultural professionals. A seminar was given in Department of Agronomy and Horticulture, UNL in spring 2016 highlighting the impact of cattle grazing on various soil properties. A summary of research findings has been submitted to Nebraska Beef Cattle Reports which will be published in 2017. An abstract has been submitted to American Society of Agronomy (ASA) for annual meeting of 2016. In addition, based on the results, a manuscript entitled 'Impacts of Long-Term Corn Residue Grazing on Soil Properties under Irrigated Conditions' is under preparation.

Outcomes/Impacts

Grazing corn residues under irrigated no-till system in eastern Nebraska for 16 yr showed no or small effects on soil properties. The grazing of corn residue in fall showed no impact on soil compaction, soil structural quality but had slightly positive impact on soil fertility, soil microbial properties and corn-soybean yields. Spring grazing treatment in our study increased cone index (indicator of soil compaction) and strength of 2-4.75 mm dry soil aggregates relative to control. However, the level of compaction was below the critical level (cone index < 2 MPa) to cause significant crop yield losses. Thus, spring grazing of corn residues showed no effect on corn yield while soybean yields were improved relative to control.

The results of this study have large implications for the development of integrated crop-livestock systems in the region. Our findings suggest that grazing of corn residues may not have large detrimental effects on soil properties even in the long term under the conditions of this study. Overall, grazing of corn residues under no-till corn–soybean systems at the stocking rates targeted to remove 10 to 20 % of residue can provide additional feed for livestock in this region.

Publications:

Rakkar, M.K., H. Blanco, M. E. Drewnoski, J. C. MacDonald, T. J. Klopfenstein. 2017. Effect of Long-Term Corn Residue Grazing on Soil Properties. Nebraska Beef Report. (Under review)

External Funding:

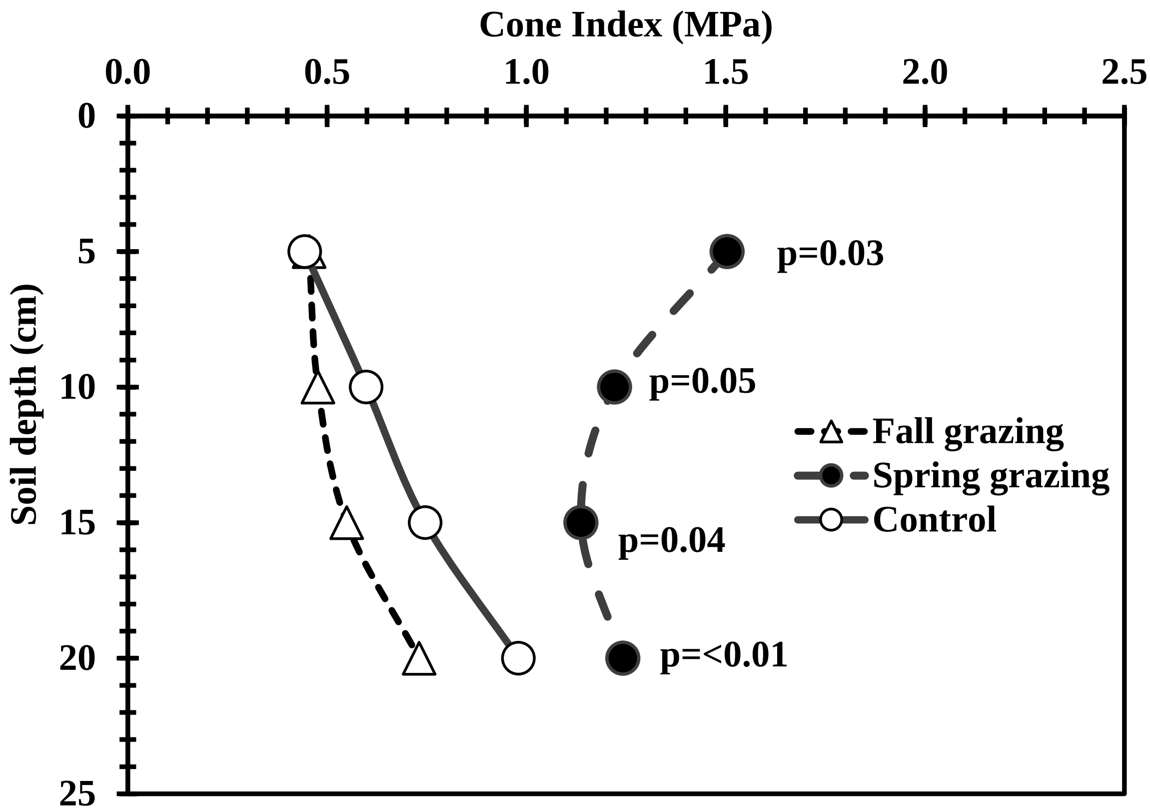
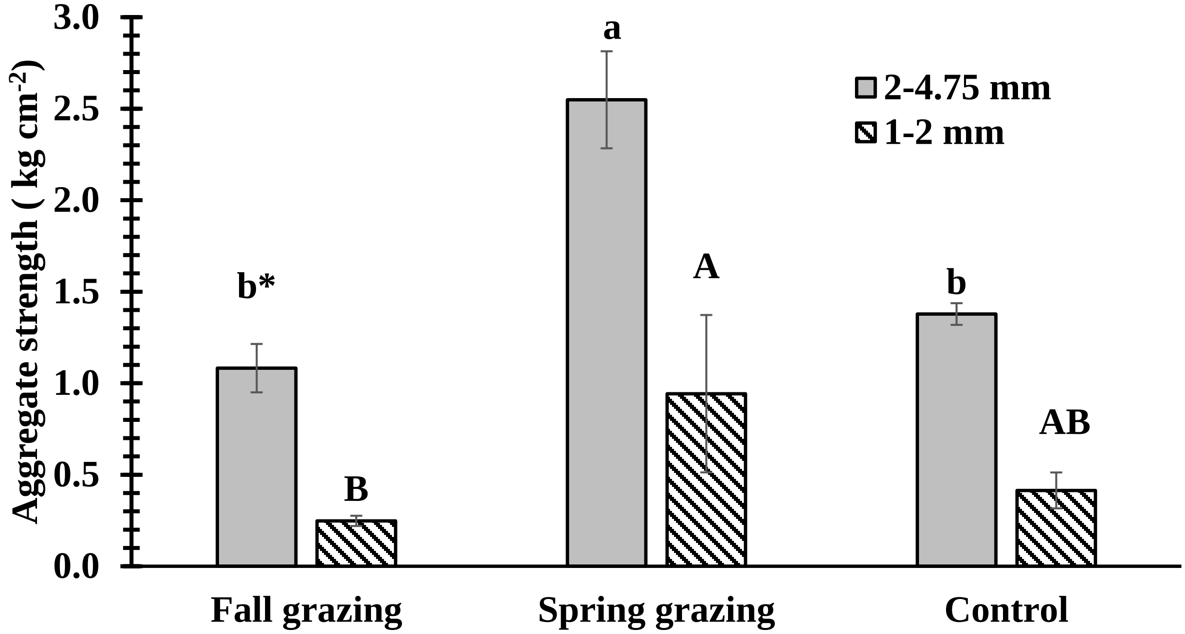


Fig. 1. Soil-depth distribution of cone index for the 0 to 20 cm depth affected by cattle grazing of corn residues after 16 yr under irrigated no-till system on a Tomek silt loam in eastern Nebraska. The *p*-values are reported for each depth interval



* different lower case letters on bars represent significant differences among 2-4.75 mm aggregates and different uppercase letters represent significant differences among 1-2 mm aggregates between three treatments.

Fig. 2. Aggregate strength of 2-4.75 mm and 1-2 mm aggregates averaged across depth as affected by 16 yr of corn residue grazing of a Tomek silt loam in eastern Nebraska. Error bars correspond to standard deviation

Table 1. Impact of 16-yr of corn residue grazing on particulate organic matter and total organic carbon averaged across two soil depths (0-5 and 5-10 cm) of a Tomek silt loam in eastern Nebraska.

Treatment	**Particulate organic matter (mg g^{-1})**		**Total organic C**	**Soil C stock**
	0.5 mm	**0.053 µm**	**g kg^{-1}**	**Mg ha^{-1}**
Fall grazing	1.73 ± 1.06[†]	10.3 ± 4.45	2.02 ± 0.47	1.38 ± 0.24
Spring grazing	1.72 ± 0.90	12.6 ± 4.30	1.94 ± 0.48	1.40 ± 0.27
Control	1.10 ± 0.27	9.87 ± 3.95	1.67 ± 0.52	1.15 ± 0.32
***p*-value**	0.26	0.32	0.27	0.15

† Mean±Standard deviation

Table 2. Impact of 16-yr of corn residue grazing on soil fertility and related soil chemical properties averaged across two soil depths

Treatment	**pH**	**Nitrate-N**	**Available P**	**Exchangeable K**	**Exchangeable Ca**	**Exchangeable Mg**	**S**
		--mg kg^{-1}	----------	----------	----------	----------	----------
Fall grazing	6.3 ± 0.4[†]	5.6 ± 2.0	14.3 ± 7.5	354.9 ± 72.8	2337 ± 250b[#]	352.1 ± 73.0	10.6 ± 1.7b
Spring grazing	6.4 ± 0.4	8.1 ± 5.4	18.5 ± 13.1	398.4 ± 90.9	3009 ± 477a	499.0 ± 139.9	12.9 ± 2.5a
Control	6.7 ± 0.5	4.2 ± 2.2	22.8 ± 18.4	354.3 ± 58.6	2685 ± 481a	417.3 ± 157.0	9.3 ± 1.7c
***p*-value**	0.47	0.16	0.70	0.37	0.09	0.20	0.02

(0-5 and 5-10 cm) of a Tomek silt loam in eastern Nebraska.

[†]Mean ± Standard deviation
[#]Means followed by different letters in a column indicate significant differences among treatments

Table 3. Impact of 16-yr of corn residue grazing on soil microbial community averaged across two soil depths (0-5 and 5-10 cm) of a Tomek silt loam in eastern Nebraska.

Treatment	**Total FAMEs** ‡	**Bacteria and Actinomycetes**	**Actinomycetes**	**MicroEukaryote**	**Arbuscular mycorrhiza**	**Saprophytic fungi**
	nmol g^{-1}					
Fall grazing	74.8 ± 33.1†	38.6 ± 15.3	4.32 ± 2.10a#	2.28 ± 1.35	5.28 ± 2.10	4.01 ± 2.78
Spring grazing	76.2 ± 22.7	39.1 ± 10.3	4.21 ± 1.46a	2.10 ± 0.74	5.62 ± 1.95	4.21 ± 1.97
Control	62.9 ± 24.8	32.3 ± 11.9	3.32 ± 1.40b	1.97 ± 0.69	5.04 ± 1.58	3.12 ± 1.78
***p*-value**	0.12	0.12	0.06	0.48	0.73	0.18

† Mean±Standard deviation

‡Total fatty acid methyl esters computed as sum of PLFAs (i14:0, i15:0, a15:0, 15:0, i16:0, 10Me16:0, i17:0, a17:0, cy17:0, 17:0, br18, 10Me17:0, 18:1v7, 10Me18:0 and cy19:0)

Means followed by different letters in a column indicate significant differences among treatment

Relevant Publications:

1. Blanco-Canqui, H., A.L. Stalker, R. Rasby, T.M. Shaver, M.E. Drewnoski, S. van Donk, and L.C. Kibet. 2016. Does cattle grazing and baling of corn residue cause runoff losses of sediment, carbon, and nutrients? Soil Sci. Soc. Am. J. 80:168-177.
2. Kibet, L., H. Blanco-Canqui, R.B. Mitchell, and W.H. Schacht. 2016. Root biomass and soil carbon response to growing perennial grasses for bioenergy. Energy, Sustainability and Society 6:1 DOI 10.1186/s13705-015-0065-5.
3. Parlak, M., and H. Blanco-Canqui.2015. Soil losses due to potato harvesting: a case study in western Turkey. Soil Use and Management. 31:525-527.
4. Blanco-Canqui, H., T. M. Shaver, J.L. Lindquist, C.A. Shapiro, R.W. Elmore, C.A. Francis, and G.W. Hergert. 2015. Cover crops and ecosystem services: Insights from studies in temperate soils. Agron. J. 107:2449–2474.
5. Parlak, M., C. Palta, S. Yokus, H. Blanco-Canqui, and D.A. Carkaci, 2016. Soil losses due to carrot harvesting in south central Turkey. Catena 140:24-30.
6. Stalker, A., H. Blanco-Canqui, J. Gigax, A. McGee, T. Shaver, and S. van Donk. 2015. Corn residue stocking rate affects cattle performance but not subsequent grain yield. J. Animal Sci. 93:4977-4983.

NC-1178 Annual State Report

Year: 2016

Institution: North Dakota State University
Committee Representative: Larry Cihacek

Activities:

Activity 1: A site established in 2008 was evaluated for the effects of biomass removal on changes in soil organic C and soil properties. The sites are an irrigated continuous corn and corn-soybean rotation under no-till management at the Oakes Research Site near Oakes, North Dakota on a loamy fine sand soil. Corn residue was removed using a plot forage chopper by removing the corn residue from none, one-third, two-thirds or all of the rows in the plots. Aggregate stability, wind erodible fraction, penetrability, bulk density, water infiltration, SOC change and N mineralization potential were evaluated after a 5-year period. In addition, soil samples were collected to a depth of 1 m for SOC analysis at this site. This activity was completed in late 2015.

Activity 2: Recent railcar shortages in the northern Great Plains has resulted in increases in distillers by-products stockpiles and causes issues with storage and disposal of materials before they become unusable. One potential for disposal is to land apply the by-products on cropland and utilize the nutrients they contain as plant nutrients. Distiller's grains by-products were obtained from three ethanol plants within a 60 mile radius of Fargo, ND to determine their plant nutrient values and the variation in values over a 24-week period. The products included dry distillers grains (DDGs), wet distillers grains (WDGs) and condensed distillers solubles (CDSs). The materials were sampled weekly for eight weeks and monthly for another four months. The materials were analyzed for moisture content (dry matter content), and total N, P, K, S, Ca, Mg, Na, Fe, Zn, Cu, and Mn. Materials within a class of materials (DDGs, WDGs, CDSs) had significant differences in moisture content which influenced nutrient contents. Differences in nutrient content also varied from plant to plant and over the 24 week time period mainly due to the nutrient quality of the corn feed stocks. This activity is continuing through 2016.

Activity 3: Integrated crop-livestock systems research at the North Dakota State University Dickinson Research Extension Center is evaluating seasonal soil nitrogen fertility within an integrated crop and livestock production system. The 5-year diverse crop rotation is: sunflower (SF) - hard red spring wheat (HRSW) - fall seeded winter triticale-hairy vetch (THV; spring harvested for hay)/spring seeded 7-species cover crop (CC) - Corn (C) (85-90 day var.) - field pea-barley intercrop (PBY). The HRSW and SF are harvested as cash crops and the PBY, C, and CC are harvested by grazing cattle. In the system, yearling beef steers graze the PBY and C before feedlot entry and after weaning, gestating beef cows graze the CC. All crops are managed with no-tillage. Since rotation establishment, four crop years have been harvested from the crop rotation. Seasonal soil nitrogen status (NO_3-N, NH_4-N, NO_3-N + NH_4-N) was monitored throughout the 2014 and 2015 growing seasons from June through October in 3 replicated field plot areas within 10.6 ha crop fields with a focus on the continuous and rotational spring wheat crops. In each sampled plot area, 6 – 20.3 cm x 0.61 m aluminum irrigation pipes were pressed into the soil as enclosures to restrict root access to soil nitrogen. Soil samples were at approximately 2-week intervals from both inside and outside the enclosures. The crop rotation N values were also compared to triple replicated perennial native grassland plot areas dominated by native grass species. NH_4-N and NO_3-N showed similar trends across the 2014 and 2015 growing seasons. However, when soil testing these fields for fertility recommendations we have seen a decline in N rate recommendations in spite of increasing yields. This activity is continuing through 2016.

Impacts:

1. Knowledge of corn stover removal effects on soil physical properties of fragile soils helps farmers make rational decisions about utilizing the stover for livestock feed or biofuels.
2. Byproducts of ethanol production can not only be utilized for animal feed but also can be utilized as a source of plant nutrients for field crops.
3. Utilization of a diverse crop rotation system can enhance soil N cycling and lower fertilizer requirements than a monoculture system.

Summary of Results:

<u>Activity 1:</u>

For continuous corn:

1. Wind erodible fraction (<0.84mm) increased with increased residue removal.
2. Field moist water stable aggregate fraction decreased with increase in residue removal.
3. Water infiltration rate decreased with increased residue removal.
4. Apparent soil penetration resistance increased.
5. Little effect on SOC changes and N mineralization were observed.

For corn-soybean rotation, corn phase:

1. Water infiltration rate decreased with increased residue removal.
2. Apparent increase in soil penetration resistance.
3. The magnitude of SOC change decreased.
4. N mineralization did not appear to be affected by residue removal.

For corn-soybean rotation, soybean phase:

1. Air-dry water stable aggregates decreased with increased residue removal.
2. Apparent soil penetration resistance slightly increased.
3. SOC change appeared to decrease with residue removal, but changes were small and not significant.

Activity 2:

1. The CDS materials contained 25.3-29.1 % dry matter (D.M.), 0.95-1.24 % nitrogen (N), 0.39-0.43 % phosphorus (P), 0.59-0.62 % potassium (K), and 0.32-0.45 % sulfur (S) and smaller quantities of other plant nutrients.
2. The WDG materials contained 31.4-52.0 % D.M., 1.45-2.39 % N, 0.25-0.41 % P, 0.33-0.55 % K, and 0.31-0.34 % S.
3. The DDG materials contained 84.6-85.3 % D.M., 3.78-3.81 % N, 0.72-0.77 % P, 0.97-1.04 % K, and 0.61-0.89 % S.
4. The differences within each material appear to be primarily due to the water (or D.M.) content.
5. The nutrient contents of the CDS products showed the most variation over the time of sampling. The WDG and DDG products were relatively uniform in nutrient content over the sampling period.

Activity 3:

1. Mineral N is tending to be higher throughout the growing season in the rotation spring wheat than in the continuous spring wheat.
2. Soil test based N requirements are decreasing with time for both systems
3. Wheat yields appear to be increasing in the rotation system.
4. N cycling in the rotation system appears to be increasing over the continuous wheat system.
5. Crop diversity appears to be enhancing soil health and soil productivity.

Relevant Publications:

Chatterjee, A., K. Cooper, A. Klaustermeier, R. Awale, and L. J. Cihacek. 2016. Does crop species diversity influence soil carbon and nitrogen pools? Agronomy J. 108:427-432.

Olson, K. R., M. Al-Kaisi, R. Lal, and L. Cihacek. 2016. Impact of soil erosion on soil organic carbon stocks. J. Soil Water Cons. 71(3):61A-67A.

Additional Outcomes:

(e.g. sponsored events, collaborations, grants, others)

Theses Completed:

Kraft, E. A. 2014. Summarizing regional research data contributing to the U.S. Rapid Carbon assessment in the northern Great Plains. M. S. Thesis. Natural Resources Management. NDSU. (Final draft submitted in 2016).

Sanders, D. 2015. Corn stover removal effects on soil properties in North Dakota. M. S. Thesis. Natural Resources Management. NDSU.

Bhomik, A. 2016. Greenhouse gas emission and soil quality in long term integrated and reduced tillage organic systems. Ph. D. Soil Science, NDSU.

2016 Multi-State (NC-1178) Project Annual Report

Evaluating the effect of conservation management practices on soil carbon dynamics in degraded lands of Southern Guam

Mohammad H. Golabi, Soil Scientist

College of Natural and Applied Sciences, University of Guam.

Project Background:

Guam is composed primarily of limestone rock to the north and red volcanic clay soils in the south. The red volcanic soils in the south are severely eroded and locally are referred to as badlands. These barren sites are exposed to overland flow, wind and rain causing severe soil erosion and producing massive amount of sedimentation in the downstream rivers and shorelines of southern Guam. This massive siltation not only damage the marine environment downstream and effect fisheries in the south but also effect fresh flow of rivers which are the main sources of fresh water for residential consumption in southern Guam. Furthermore, soil erosion is the cause of soil fertility depletion, it damages soil structure, and it reduces the 'effective' rooting depth (Lal, 2003). These degradation processes have also produced acidic soils which are high in iron and aluminum oxides that remain in the soil composition therefore making it difficult to sustain crop productivity on these soils.

In addition, the adverse impacts of accelerated soil erosion on carbon (C) dynamics an emission of carbon dioxide (CO_2 into the atmosphere also deserve to be studied(Lal, 2003). Transfer and redistribution of soil organic carbon (SOC) caused by soil erosion may also have an impact on the global C budget (Lal, 2003).

The challenge facing soil and agricultural scientists is therefore to develop restoration strategies to improve the current conditions on these soils and avoid further environmental and financial constraints to the island's ecosystem that not only has already affected water resources but will have a major impact on already unsustainable agricultural productivity that mostly depend on these lands. Furthermore, the extent of soil erosion, and its impact on soil C dynamics, and the potential of erosion management (conservation) to sequester C by mitigating the accelerated sedimentation (Lal, 2003) are among the challenges of soil and environmental scientists not only in Guam but around the world.

Toward this end, we have designed an integrated conservation farming technique to study the effect of different farming management on soil quality and productivity while evaluating the techniques on controlling soil erosion and reducing sedimentation. The aforementioned management strategy also includes biochar application for soil quality improvement and for increasing the carbon storage capacity of the soils under study. The later practice (biochar application) is also expected to reduce the CO_2 emission into the atmosphere via carbon sequestration process.

Biochar is a solid substance made from the heating of biomass (e.g., coconut husk, Vetiver grass, tree branches) at high temperatures and low levels of oxygen called pyrolysis. The biochar is basically composed of carbon with some ash that contains NPK. Biochar is also known to improve the fertility of soils by raising the soil cation exchange capacity (CEC) while maintaining the carbon storage capacity of the soil. When the CEC is high, the soil is able to hold more cation nutrients, which are otherwise lost via leaching. It is reported (Butnan, et.al. 2015) that liming is also an important co-beneficial aspects of biochar application on similar soils in the tropics. Biochar application effectively reduces the negative effects of Aluminum toxicity and other elements such as Mn (Butnan, et.al. 2015).

Biochar is very stable and by adding it to the soils is tantamount to carbon sequestration that helps reduce carbon dioxide emission which is linked to global warming. For this reason, this study is therefore in line with the government's intention to reduce CO_2 emission as well as conserving energy.

This study include trial plots where growth performance of selected crops (Maize) will be evaluated based on farming method that are practiced on field plots designed for this purpose. The specific farming techniques evaluated in this project are as the following:

a) No-Till (NT) or zero tillage

b) Reduced tillage (RT)

c) Conventional Tillage (CT)

d) Conventional Tillage with Biochar application (CT/BC)

These regimes represent a wide range of practices that are being evaluated as conservation and restoration techniques. These practices are also evaluated based on the amount of crop residue that is removed from the soil surface following each harvest. In this experiment, the crop resides on the no-till (NT) plots are bush cut and left on the surface following the harvest. The crop residue is gradually decayed and broken down as organic mulch covering the rows hence protecting the soil surface from the water erosion. The crop residue from the reduced tillage (RT) plots is also treated the same way until just before the next planting phase. At planting, the remaining residue on reduced till (RT) plots is incorporated into the soil surface for bed preparation. Crop residue from both conventional tillage (CT) and conventional with biochar (CT/BC) are removed to the ground and soil surface is left completely bare and exposed to weather conditions until next planting. In addition, soil quality improvement will be evaluated based on the farming techniques practiced. In this regard, specific attention will be focused on the plots where biochar is applied. Soil quality improvement therefore will be evaluated based on the amount of biochar added to the soil composition.

In summary, this project is aimed at developing an efficient and feasible program that will be set in place to improve the quality of the red volcanic soils in southern Guam using soil enhancer, the biochar, in addition to conservation farming techniques described above. Also, a proper understanding of soil conditions and nutrient deficiencies will be evaluated by running a comprehensive soil testing and analysis prior to the application of Biochar.

Output:

The results from 2015 data pertaining to the conservation practices (NT, RT, and CT, CT/SH, CT/BC) are shown in Figures 1. As shown (Fig. 1), the carbon content was the highest under the No-tillage (NT) practice. It is believed that high carbon content under No-till plot was due to ‘no disturbances’ to the soil surface during the study period. On the reduced till (RT) plots the percent carbon content also remained high next to the No-till plots mainly due to the reduced disturbances as compared to conventional tillage practices. On the other hand, it was shown that the percent carbon content in the conventional tilled (CT) plots were the lowest for all sampling events while the carbon content of conventional tilled soils with sunnhemp rotation (CT/SH) was higher mainly due to the green manure effect that added organic matter as well as carbon to soil as the result of sunnhemp biomass production and its incorporation into the soil after the harvest. Same trend have been observed in the previous years (Golabi, 2015) with NT showing the highest amount of carbon content compared to the other treatments under study. This study showed that the soil organic matters as well as soil organic carbon content are all affected by the tillage treatments applied on these soils.

Also, as indicated, the carbon content of the soil was considerably higher in the lower depths regardless of the tillage treatment however; the overall carbon content of the soil under CT is generally lower due to continuous disturbances on the soil surface and within the tillage depth (Golabi, 2015). This could be due to oxidation of soil carbon as the result of exposure to the air following each tillage practice.

Furthermore the data illustrate that the carbon content of the soil near the surface is less than 2% for all treatment regardless of the tillage practices. This could be due to the fact that the carbon sequestration potential is inadequate near the soil surface due to oxidation process. On the other hand, the carbon content of the soil is higher at depths below the 8 inch. This may indicate that the amount of carbon loss at the deeper depth is the lowest due to fewer disturbances and more stability conditions at the lower soil matrix (Golabi, 2015).

As indicated earlier, replacing sunnhemp with biochar starting on 2016 maintained and/or improved the crop yield as shown in Figure 2. However, the amount of CO_2 released from the biochar plots was lower during the active plant growth than before planting. This showed an opposite trend as compared to the other treatments where the CO_2 released was higher during the active growth than before planting. This could be due to the boost of microbial activities caused by the initial biochar application before planting. However, during the active plant growth, the organic carbon and/or the CO_2 generated by microbial activities might have been tied up as the biochar was incorporated further into the soil during active growth period.

Impacts:

This study is intended to evaluate the effect of conservation tillage practices on soil quality improvement on these severely eroded and acidic soils of southern Guam. The study also evaluates the impact of Biochar application not only as soil amendment but also as a technique for storing soil carbon content known as carbon sequestration.   The conservation practices as evaluated here is expected to have a major impact on the island's water resources hence fishing and marine resources due to soil erosion control techniques implemented in this study. The results of this study also point to the fact that agricultural sustainability hence food security can be attainable if the aforementioned techniques are implemented in Guam and other neighboring islands in the western Pacific. Furthermore, the application of biochar as soil amendment is also expected to preserve soil organic carbon thus reducing the amount of CO_2 release due to the oxidation process.

The preliminary results from the study have so far indicated that tillage systems may affect the soil carbon storage capacity and/or the amount of carbon loss due to the level of disturbances and/or amount of residue removal from the soil surface. The study also showed that the conservation farming practices such as No-till can potentially increase carbon sequestration in the soil as disturbances within the plow layers are reduced to minimum and/or to zero.

The results of this ongoing experiment will provide knowledge based techniques for sustainable agricultural practices applicable to the island's climate conditions and resources available to farmers in this and other islands of Micronesia. The result of this study will also contribute to the overall scientific efforts in understanding the role of agriculture in soil carbon dynamic, and the ways in which this may reduce atmospheric carbon dioxide if the aforementioned techniques implemented to a much larger extend.

Public Education/Outreach:

This study will provide information pertaining to soil degradation as relates to the local conditions of the island tropical climate following the removal of crop residue from the soil surface following the harvest. The results of the study will also provide information pertaining to carbon loss due to disturbances that occur during the tilling processes prior to planting. The study will also provide information pertaining to carbon storage and carbon sequestration potential of the soils under conservation farming practices adoptable to the local conditions of the island's tropical climate. Application of biochar as soil amendment to these severely eroded soils of southern Guam may prove to be a viable option toward sustainable agricultural practices in this and other islands of Micronesia.

In order to disseminate the findings of the project, occasional field demonstration have been conducted at the Branch Stations at Ija in southern Guam. The effect of Biochar application as well as soil conservation practices and land rehabilitation techniques have been showcased during these field demonstrations. These field demonstrations will provide excellent opportunities for informal and formal transfer of research results to farmers/ranchers and forest land managers. The Ija station is located in southern Guam where research results can be visually observed during the field demonstrations. Results from the research plots will also be disseminated through traditional extension publications such as brochures, bulletins, newspaper articles, as well as referee journal publications. The aforementioned extension activities will be conducted with collaboration with extension faculty/personnel.

Keywords: Conservation tillage, residue removal, Biochar, Compost, Degraded soils, Badlands, Volcanic clay soils, Pyrolysis.

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1. Butnan Somchai, Jonathan L. Deenik, Banyong Toomsan, Michael J. Antal, and Patma Vityakon. 2015. Biochar characteristics and application rates affecting corn growth and properties of soils contrasting in texture and mineralogy. Geoderma 237-238, pp 105-116.

2. **Golabi, Mohammad H.**, (2015). Soil carbon content evaluation as affected by conservation practices and crop residue removal from the oxide rich, highly weathered, soils of southern Guam. *Presented at the:* Multi-State (NC 1178) Project Report Meetings. Held at the Columbus, Ohio during June 23-24, 2015.

3. Lal, R. 2003. Soil erosion and the global carbon budget. Environment International 29 (2003) 437–450. Available at: www.sciencedirect.com

Publications/Disseminations:

Conference/Meeting Presentations

1. ***Role of Conservation Practices on Reducing the net Soil Carbon loss – A human-Biosphere Interaction and Climate Change***. Mohammad H. Golabi*, and Clancy Iyekar. College of Natural and Applied Sciences, University of Guam. The 23rd Pacific Science Congress (13-17 June, 2016), Taipei, Taiwan.

2. *UOG-CLASS Conference, (March 8, 2016), University of Guam, Magilao, Guam*
   Can a UOG Green Movement slow down the Global Warming? What is the role of 'Carby Carbon in all of this? Mohammad H. Golabi, Soil Scientist, University of Guam

3. ***Evaluating the role of Conservation Practices on reducing the net Carbon loss from the Soil in order to lower the CO_2 concentration in the Atmosphere.*** Mohammad H. Golabi, and Clancy Iyekar. Presented at the International Youth Forum on Soil and Water Conservation (IYFSWC) that was held at Nanchang Institute of Technology, Nanchang, China. October 16-18, 2015.

4. ***Evaluating the effect of long-term conservation practices on Soil Carbon Dynamics as relates to Climate Change.*** Mohammad H. Golabi, and Clancy Iyekar. Presented at the *"Building Resilient Island Communities"*. 2015 UOG, Island Sustainability Conference that was held in Tumon, Guam during 15-16 April of 2015.

5. ***Evaluating the role of Conservation Practices on reducing the net Carbon loss from the Soil in order to lower the CO_2 concentration in the Atmosphere.*** Golabi, Mohammad H., and Clancy Iyekar. (2015). *In the proceedings of:* The International Youth Forum on Soil and Water Conservation (IYFSWC) that was held at Nanchang Institute of Technology, Nanchang, China, during 16-18 of October, 2015.

6. ***Soil carbon content evaluation as affected by conservation practices and crop residue removal from the oxide rich, highly weathered, soils of southern Guam.*** Golabi, Mohammad H., and Clancy Iyekar. (2015). Presented at the*:* Multi-State (NC 1178) Project Report Meetings. Held at the Columbus, Ohio during June 23-24, 2015.

Related Newspaper Articles

1. **Golabi, M. H**., 2015. Reducing carbon dioxide emissions. Tuesday April 14, 2015. Vol. 47, No. 72, Hagatna, Guam

2. **Golabi, M. H.**, 2015. Soils can affect global warming. Thursday, May 28. Vol. 47, No. 115. Hagatna, Guam

3. **Golabi, M. H.**, 2015. Soils and global warming. Tuesday, June 30, 2015. Hagatna, Guam

Scope of Impact: Local, Regional, International

Source of Funding: Multi-State (NC 1178)

Duration: 2014 – 2019?

Topic: Effect of residue removal on Soil Carbon content.

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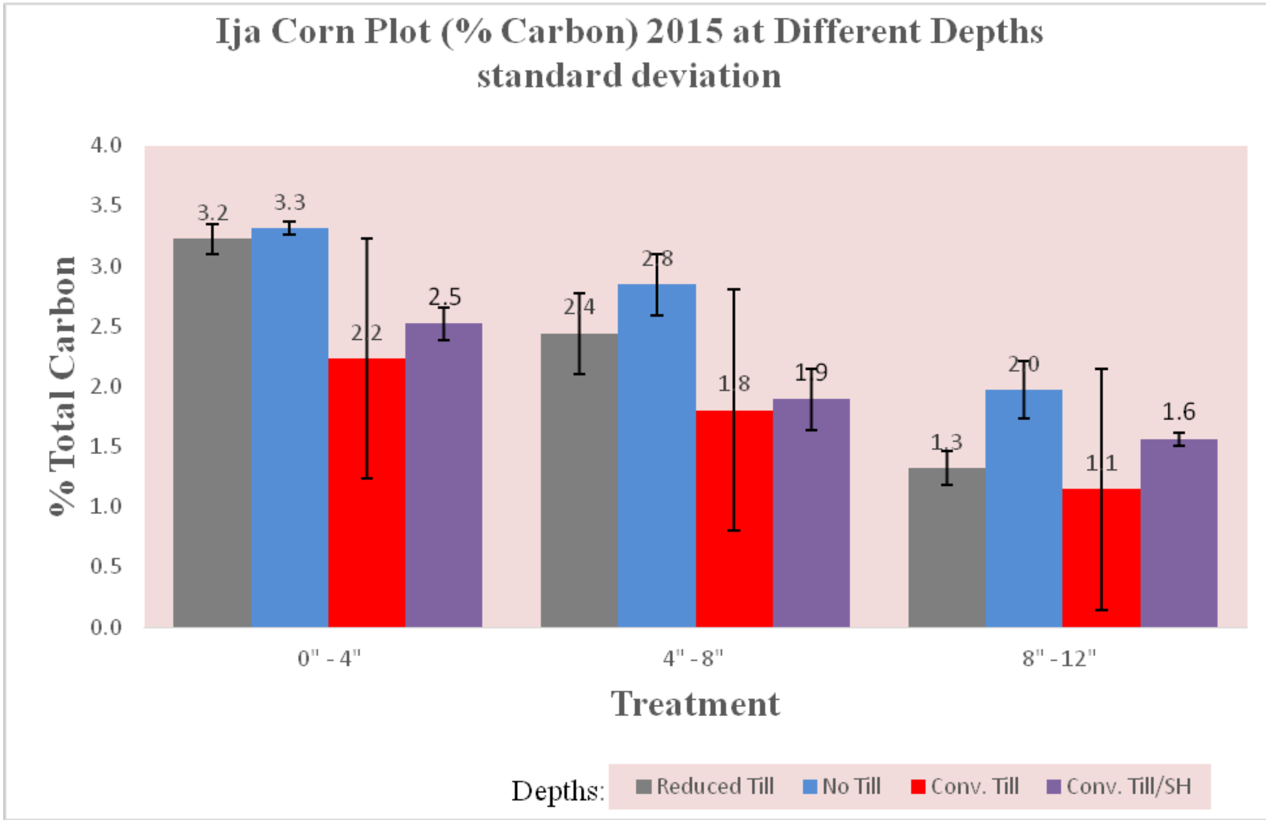

Figure 1.: Showing percent Carbon conten of the soil at diferent depth under diferent treatment (conservation tillage practices).

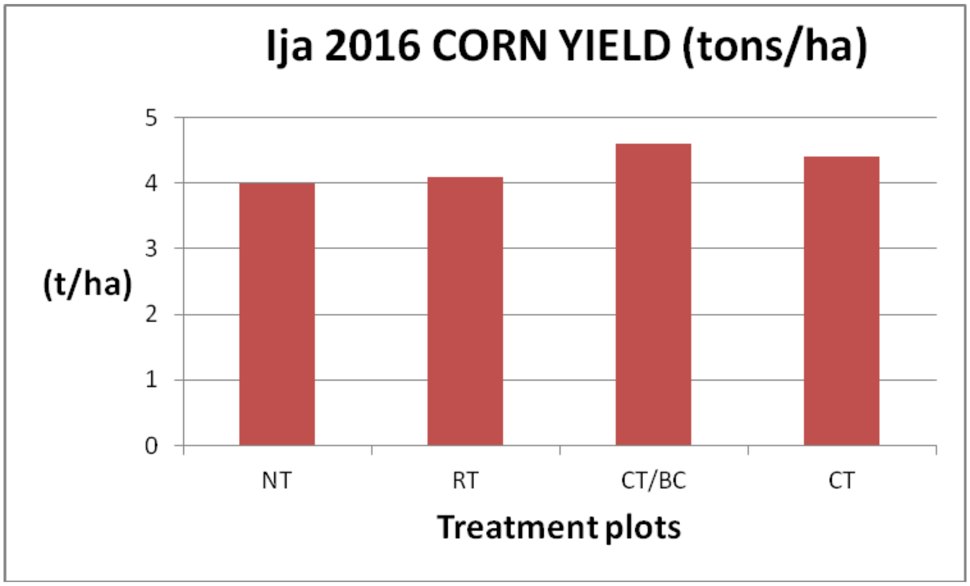

Figure 2.: Showing the corn yield for 2016 harvest

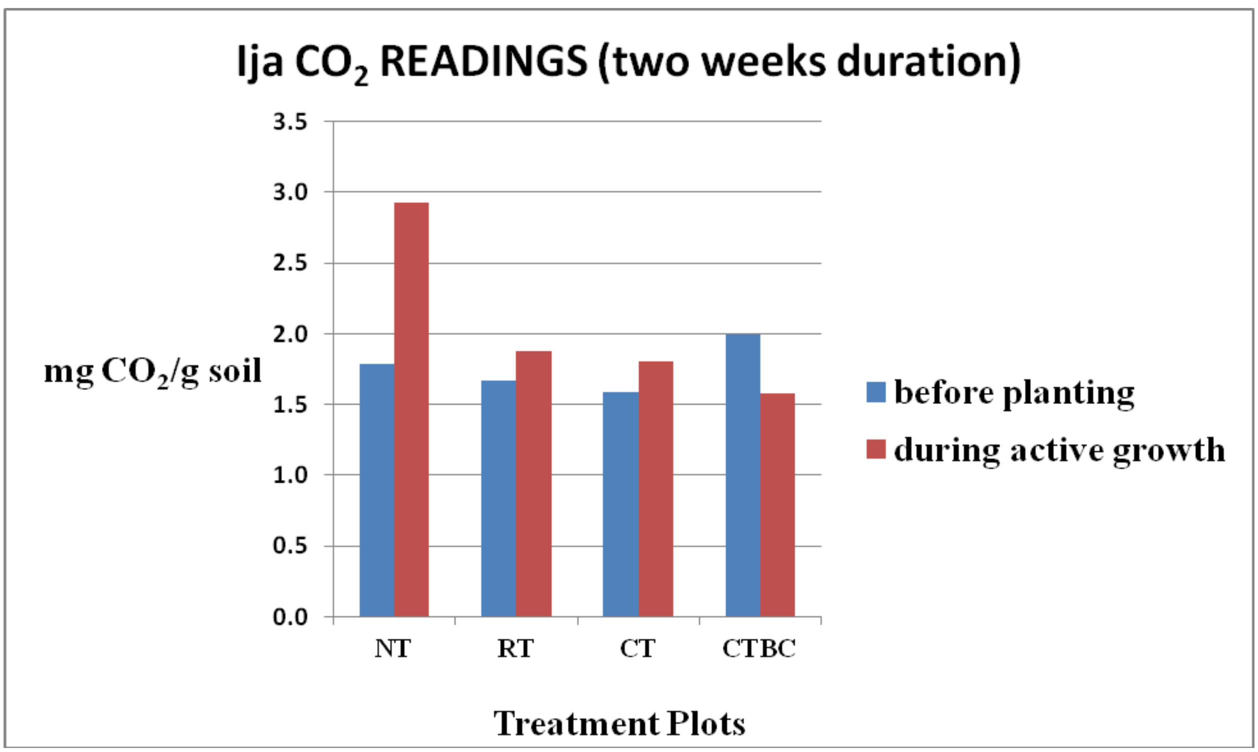

Figure 3.: Showing the amount of CO_2 emision from the treatment plots before and during the active crop growth.

2016 NC-1178 Annual State Report

Effects of residue and cover crop on soil physical and hydrological properties under corn and soybean rotation in South Dakota

Kopila Subedi-Chalise and Sandeep Kumar
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Study Description

Corn residue are widely used for biofuel production. In 2020 it is estimated that use of corn biomass as biofuel production will reach up to 112 million of dry ton (NAS, 2009). Similarly by 2030 the quantity will increase up to 256 million dry tons (DOE 2011). This excessive use of crop residue may fulfill the aim of U.S for being independent in fossil fuel production but it impacts in long term productivity of soil including soil physical, chemical and biological properties (Blanco-Canqui and Lal, 2007). It is important to find a solution, where U.S can meet its goals for biofuel production without impacting soil quality and productivity. To meet this goal, it is essential to identify the quantity of residue can be harvested sustainably. Also, it is important to find some substitutes, which mitigate negative effects of removing corn residue. Thus, in this study two residue removal treatments (high residue removal and low residue removal) were incorporated with cover crops and without cover crops treatments. Cover crops are used as substitutes to protect soil quality.

Rational: The rationale behind this study was, in South Dakota the rate of corn residue removal rate is increasing for biofuels. Many scientific research studies were conducted to determine the sustainable residue removal rate, the rate varies from 25% to 50%. Due to short-term economic benefit of corn residue removal, farmers remove high rate of residue without understanding long impact of residue removal. Also, farmers are not aware about substitutes such as cover crops which can mitigate impacts of high residue removal. Thus, this study aims to assess the impacts of corn residue and cover crops on soil quality indicators.

Study site. This experimental site is located in Brookings, SD. Residue removal treatments were implemented in 2000 with no-till corn and soybean rotation. In late fall, 2005 residue removal treatments were split and cover crops treatments were integrated. Individual plots of 30 by 30 m were split into 15 by 30 m after cover crop was integrated. The low residue removal (LRR) treatment consisted of harvesting only the corn grain, leaving all other plant materials on the soil surface, and the high residue removal treatment (HRR) consisted of cutting the stalks 0.15 m from the ground and removing all portion above 0.15 m of the plant. For cover crop treatment winter lentils [*Lens culinaris* Medik. Variety Morton] were broadcast into soybean at the end of R6 and slender wheatgrass were broadcast into corn at tasseling.

Audience

Data from this research was shared with various research professionals, producers and students. In addition, results from this study was presented at various professional meetings.

Accomplishments/Outputs

- To observe soil quality indicators intact soil cores (5 cm diam. × 5 cm length) were collected in 2015 from 0-5 cm and 5-15 cm depth. Intact cores were used to measure soil water retention, pore size distribution and bulk density. Infiltration rates were measured using double –ring infiltrometer. The soil penetration was measured using the Eijkelkamp-type hand penetrometer. Soil organic carbon, TN, pH and EC were measured. Only few parameters are discussed is this report.
- Data from this study site was used to develop a USDA grant which got funded in 2014.

Outcome/Impacts

- This study helps to convince farmers that it is important to observe long-term impact of residue removal in order to protect long-term agricultural benefits. This study also concludes that residues and cover crops significantly improve soil properties.
- Preliminary data is presented below in Table 1 showed that low residue removal improves soil properties by increasing soil organic carbon, soil nitrogen, water infiltration rate and reducing compaction.

Table 1: Soil organic carbon and total nitrogen impacted by residue removal (Low residue removal, LRR and high residue removal, HRR) and cover crop (with cover crop and without cover crop treatment)

Treatment	**SOC**		**TN**	
	0-5 cm	**5-15 cm**	**0-5 cm**	**5-15 cm**
	--------------------g kg^{-1}	-----------------		
Residue removal				
LRR	27.8[a]	22.0[a]	2.23[a]	1.81[a]
HRR	23.1[b]	20.4[b]	1.94[b]	1.71[b]
Cover Crop				
Yes	25.8[a]	21.2[a]	2.11[a]	1.77[a]
No	25.1[a]	21.2[a]	2.05[a]	1.75[a]
	Analysis of Variance *(P>F)*			
Residue (R)	<0.001	0.007	<0.01	0.03
Cover Crop (C)	0.46	0.99	0.31	0.96
R × C	0.01	0.02	0.1	0.04

Data on SOC and TN for the 0-5 and 5-15 cm depths are shown in Table 1. Residue removal treatment impact soil organic carbon (SOC) for both depths. However, cover crop did not impact SOC for both depths. The LRR (27.8 g kg^{-1}) increased SOC by 20.3% as compared to HRR (23.1 g kg^{-1}) for depth 0-5cm. Similarly, for depth 5-15cm SOC for LRR (22 g kg^{-1}) increased by 8% as compared to HRR (20.4 g kg^{-1}) treatment. In general, cover crop increased SOC as compared to the plots with no cover crops but they were not statistically significant. However, the interaction between residue and cover crops on SOC are statistically significant (P< 0.03) for both depths.

Similarly, residue removal treatment impact total nitrogen (TN) for both depths. The LRR treatment (2.23 g kg-^{1}) has 15% higher TN compared with HRR (1.94 g kg-^{1}) treatment for first depth. For second depth, LRR (1.81 g kg-^{1}) treatment has 5% higher TN as compared with HRR (1.71 g kg-^{1}) treatment. The accumulation of TN was higher with cover crop treatments but they were not statistically significant. However, the interaction between residue and cover crops are statistically significant (P< 0.05) for both depths.

Table 2: Infiltration rate affected by different levels of residue removal; low residue removal (LRR) and high residue removal (HRR) and cover crop treatments.

Treatment	**Infiltration rate**
	------mm hr^{-1}------
Residue removal	
LRR	97.58^{a}
HRR	54.0^{b}
Cover Crop	
Yes	94.41^{a}
No	57.16^{b}
	Analysis of Variance *(P>F)*
Residue (R)	0.001
Cover Crop (C)	0.004
R × C	0.136

Data represented in Table 2 shows that residue removal and cover crop both impact on water infiltration rate. Infiltration rate decreased significantly with HRR treatment. In LRR treatment infiltration rate was 97.58 mm hr^{-1} which was, 80% higher compared with HRR (54 mm hr^{-1}) treatment. Similarly, the presence of cover crop increase the water infiltration rate. Infiltration rate with yes cover crop (94.41 mm hr-^{1}) treatment was 65% higher.

Table 3: Bulk density affected by different levels of residue removal; low residue removal (LRR) and high residue removal (HRR) and cover crop treatments

	Bulk density	
	0-5 cm	5-15 cm
	--------------------g cm^{-3}-----------------	
Residue removal		
HRR	1.38^{a}	1.41^{a}
LRR	1.30^{b}	1.38^{a}
Cover Crop		
Yes	1.35^{a}	1.41^{a}

No	1.33[a]	1.39[a]
	Analysis of Variance *(P>F)*	
Residue (R)	0.37	0.26
Cover Crop (C)	0.64	0.35
R × C	0.61	0.68

The higher SOC in LRR treatment has decreased soil bulk density (Table 3) and increased the water infiltration in this treatment compared to that in HRR. Low residue removal adds higher carbon in to the soil and improve soil properties. An ongoing research will evaluate the impacts of residue removal on soil microbial activity.

Publications

Subedi, K.*, Wegner, B., Sandhu S., Ozlu E., and Kumar, S. (2015). Impact of crop residue and cover crop on water infiltration.

External Funding

USDA project funded in 2014 will help in analyzing additional data related to crop water use and water use efficiency.

NC 1178

Annual Report 2016

The Ohio State University

PI: Rattan Lal
GRA: Chris Eidson

On-going field experiments started in 2004 on crop residue management were continued during 2015 for three sites in Ohio at Coshocton, South Charleston, and Hoytville. The experiment at Coshocton had two sets of plots: initiated in 2004 and 2011. The data presented below are for the Coshocton site only. This site has been discontinued and the data reported herein are the last sampling and measurements.

Crop Yield

Total biomass and grain yields decreased with increase in the amount of residue retention (Tables 1 and 2). The average corn stover yield ranged from 5.9 Mg/ha for 100% residue retention to 8.9 Mg/ha for 0% residue retention. The average reduction in stover yields, compared with that for the complete residue removal, was 13.5, 18.0, 24.0, 33.8 and 29.2% for 25, 50, 75, 100 and 200% residue retention respectively (Table 1).

The trend in corn grain yield was similar to that of the stover yield (Table 2). The average corn grain yield (15.5% moisture content) ranged from 6.3 Mg/ha for 200% retention to 10.1 Mg/ha for 0% residue retention. In comparison with the control treatment based on 0% residue retention, reduction in corn grain yield was 3.0, 9.9, 6.9, 14.9 and 37.6% for 25, 50, 75, 100 and 200% residue retention treatment, respectively.

It is important to establish the cause-effect relationship between corn production (grain and stover yields) and residue retention. To begin with, statistically total biomass and grain yields did not differ among residue retention treatments for the 2004 experiment. However, the data had a consistent trend of decrease in yield with increase in the rate of residue retention. For the 2011 site, however, total biomass yield was significantly lower for 100% and 200% residue retention compared with the 0% retention treatment. Further, the grain yield was significantly lower for 200% residue retention compared with 0% residue retention treatment. The least value of the harvest index (ratio of the grain: total biomass yields) was also observed for the 200% residue retention treatment (Table 3). Similar to the previous years, poor stand establishment because of the residue accumulation in front of the seed drill is ne of the important engineering issues that must be addressed. Regardless of the statistical significance of the differences in corn production, there is definitely a trend of decrease in biomass and grain yields with increase in the amount of residue retention. This trend may be attributed to both biotic and abiotic factors. While biotic factors are those related to the incidence of pest and pathogens, abiotic factors include residue-induced changes in soil temperature and moisture regimes and differences in soil properties, soil health and soil functionality.

Amount and distribution of rainfall during spring (at the seedling stage) along with soil moisture and temperature regimes can impact crop establishment and growth. Sub-optimal soil temperatures (<20°C at 0-5cm soil depth) and poor aeration (<10% air-filled pores) can adversely affect crop growth. With above normal rains and cooler temperatures during the spring of 2015 (April-May), inhibited seedling growth and further aggravated the incidence of pests (e.g., slugs) and pathogens. Residue retention can also impact soil properties: chemical, physical and biological. Further, the least value of the harvest index also signifies that soil and micro-climatic conditions inhibited the transfer of photosynthates from biomass to the grains. Thus, understanding changes in soil properties is relevant to understanding the yield trends in relation to residue retention.

Soil Properties and Residue Retention

There were no differences in soil p^H which was close to neutral and ranged from 6.7 to 7.1 for 0-20cm depth. In comparison, soil electrical conductivity (EC) generally increased with increase in residue retention. For 0 to 10 cm depth, electrical conductivity for the 2004 site at Coshocton was 0.47, 0.51, 0.28, 0.91, 0.66 and 0.70 ds/m for 0-10cm depth compared with 0.21, 0.25, 0.23, 0.41, 0.27, and 0.32 ds/m for 10-20 cm depth for 0, 25, 50, 75, 100 and 200% residue retention treatments respectively (Table 4). These values are low compared with a critical value of 5 ds/m beyond which corn yield may decline. Yet, the relative values of EC (the last column in Table 4) indicate increase by 35% at 100% residue and 50% at 200% residue retention treatments. Does this mean increase in salt concentration in the surface layer because of residue retention? These trends need to be checked, and additional information is needed.

The data on soil organic carbon (SOC) stocks, presented in Table 5, show an interesting trend with increase in residue retention. Indeed, increase in residue retention increased the SOC stock in 0-20 cm depth. The SOC stock, sampled in the fall 2015, was 30.0, 32.1, 34.3, 35.1, 38.2, and 38.3 MgC/ha for 0, 25, 50, 75, 100 and 200% residue retention treatments, respectively. Thus, the SOC stock in 0-20 cm depth increased by 7, 11, 12, 13 and 13% compared with that in the control with 0% residue retention.

The average rate of increase in SOC stock over 11 year period, compared with that of the control with 0% residue retention, was 191, 391, 464, 745, 755 kgC/ha×yr for 25, 50, 75, 100 and 200% residue retention, respectively (Table 5). These rates are consistent with those published in the literature for Ohio and the Midwestern region.

Relevant Publications

Beniston JW, Shipitalo M, Lal R, Dayton EA, Hopkins DW, Jones FS, Joynes A, Dungait JAJ.(2015) Carbon and macronutrient loss during accelerated erosion from different tillage and residue management systems. European Journal of Soil Science 66: 218-225 DOI: 10.1111/ejss.12205.

Lal, R. 2015. A System Approach to Conservation Agriculture. Journal of Soil and Water Conservation 70(4):82A-88A

Lal, R. 2015. Sequestering carbon and increasing productivity by conservation agriculture. J. Soil Water Conserv. 70(3):55A-62A

Lal, R. 2015. Soil carbon sequestration and aggregation by cover cropping. J. Soil Water Conserv. 70:329-339.

Lal, R. 2015. Assessment and Management of Soil Carbon Sequestration. In R.K. Rattan et al. (Eds) Soil Science: An Intoriductoin" Indian Soc. Soil Sci., New Delhi, India, pp.405-424.

Lal, R. 2015. Soil Carbon. In S. Nortcliff (Ed) "Task Force: Soil Matters" Catena Verlag, 64-69.

Table 1. Effects of residue retention on dry corn stover yields at Coshocton in 2015

Residue Retention (%)	Stover Yield (Mg/ha)			Relative
	2004 Site	2011 Site	Average	
0	8.4	9.3	8.9	100
25	7.8	7.5	7.7	86.5
50	7.1	7.5	7.3	82.0
75	7.5	6.0	6.8	76.0
100	6.4	5.4	5.9	66.2
200	7.4	5.1	6.3	70.8

Table 2. Effects of residue retention on corn grain yield (15.5% moisture) at Coshocton in 2015.

Residue Retention (%)	Grain Yield (Mg/ha)			Relative
	2004 Site	2011 Site	Average	
0	9.0	10.7	10.1	100
25	10.0	9.6	9.8	97.0
50	9.6	8.6	9.1	90.1
75	9.8	8.9	9.4	93.1
100	9.7	7.5	8.6	85.1
200	7.4	5.1	6.3	62.4

Table 3. Effects of residue retention on harvest index of corn for the Coshocton site in 2015.

Residue Retention (%)	Harvest Index (%)			Relative
	2004 Site	2011 Site	Average	
0	53	52	52.5	100
25	56	56	56.0	107
50	58	54	56.0	107
75	57	62	59.5	113
100	60	58	59.0	112
200	50	49	49.5	94

Table 4. Effects of residue retention treatments on soil electrical conductivity in 2015.

Residue Retention (%)	Electrical Conductivity (ds/m)			Relative
	0-10 cm	10-20 cm	Average	
0	0.47	0.21	0.34	100
25	0.51	0.25	0.38	112
50	0.28	0.23	0.26	76
75	0.91	0.41	0.66	194
100	0.66	0.27	0.46	135
200	0.70	0.31	0.51	150

Table 5. Effects of residue retention on SOC stock and rate of increase in 0-20 cm depth for experiments started in 2004 at Coshocton in 2015.

Residue Retention (%)	SOC Stock		Rate of Change (kgC/ha×yr)
	MgC/ha	Relative	
0	30.0	100	-
25	32.1	107	191
50	34.3	114	391
75	35.1	117	464
100	38.2	127	745
200	38.3	128	755

NC-1178 Annual State Report

Year: 2016
Institution: Illinois
Committee Representative: K. R. Olson

Activities: In 2009, an existing corn-soybean rotation under 3 tillage treatments (no-till, chisel plow (conservation tillage), and moldboard plow) and with and without cover crops was modified. After harvest in 2009 was a corn year the corn stover will be removed from 3 replications of each tillage and cover crop treatment. The stover was also removed in 2011 and will be removed in 2013. The other three replications of each tillage and cover crop treatment was left with the residue. Starting in 2009, the soybean plant population and yields are provided in Tables 1 and 2. The effects residue retention on SOC stocks are shown in Table 3.

Table 1. Soybean and Corn Plant Population of Tillage Plots with and without Cover Crops and with and without Corn Residue Removal at Dixon Springs, Illinois (metric)

Year	2010 Soybean	2012	
		X 1000 pts/ha	
Treatment with cover crops and without residue removal			2 year average
NT	225a	168a	197a
CP	226a	126a	176a
MP	255a	96b	176a
Treatment with cover crops and with residue removal			2 year average
NT	227a	166a	197a
CP	231a	124ab	178a
MP	263a	96b	180a
Treatment without cover crops and without residue removal			2 year average
NT	235a	170a	203a
CP	236a	128a	182a
MP	238a	100b	169b
Treatment without cover crops and with residue removal			2 year average
NT	237a	170a	204a
CP	241a	132a	187a
MP	235a	98b	167b

+Values with and without residue removal in the same tillage treatment and with cover crop or the same tillage treatment and without cover crop and in the same year followed by the same letter are not significantly different at the 0.05 probability level.

Year	2011	2013	
	Corn		
	X 1000 pts/ha		
Treatment with cover crops and without residue removal			2 year average
NT	74a	72a	73a
CP	73a	74a	74a
MP	60b	70a	65a
Treatment with cover crops and with residue removal			
NT	81a	74a	78a
CP	76ab	76a	76a
MP	68b	72a	70a
Treatment without cover crops and without residue removal			
NT	76a	70	73a
CP	78a	68a	73a
MP	70a	74a	72a
Treatment without cover crops and with residue removal			
NT	76a	72a	74a
CP	66b	68a	67a
MP	71ab	70a	71a

+Values with and without residue removal in the same tillage treatment and with cover crop or the same tillage treatment and without cover crop and in the same year followed by the same letter are not significantly different at the 0.05 probability level.

Table 2. Soybean and Corn Yield of Tillage Plots with and without Cover Crops and with and without Corn Residue Removal at Dixon Springs, Illinois (metric)

Year	2010	2012	
	Soybean		
	Mg/ha		
Treatment with cover crops and without residue removal			2 year average
NT	2.94a	2.87a	2.91a
CP	2.79a	2.16a	2.48a
MP	2.88a	1.71a	2.30a

Treatment with cover crops and with residue removal			2 year average
NT	2.38b	2.67a	2.52a
CP	2.53a	2.06a	2.30a
MP	2.96a	1.81a	2.39a

Treatment without cover crops and without residue removal			2 year average
NT	2.85a	2.65a	2.75a
CP	2.53a	1.96a	2.25a
MP	2.75b	1.82a	2.29a

Treatment without cover crops and with residue removal			2 year average
NT	2.70a	2.55a	2.63a
CP	2.67a	2.04a	2.75a
MP	2.18a	1.92a	2.05a

+Values with and without cover crop in the same tillage treatment and year followed by the same letter are not significantly different at the 0.05 probability level.

Year	2011 Corn	2013	
		Mg/ha	
Treatment with cover crops and without residue removal			**2 year average**
NT	6.65a	11.2	8.9
CP	6.17a	11.1a	8.6
MP	5.91a	10.9a	8.4
Treatment with cover crops and with residue removal			**2 year average**
NT	5.64a	11.6a	8.6
CP	7.66b	11.4a	9.5
MP	7.10b	11.2a	9.2
Treatment without cover crops and without residue removal			**2 year average**
NT	6.70a	10.9a	8.8
CP	5.84c	10.6a	8.2
MP	7.70b	10.4a	9.1
Treatment without cover crops and with residue removal			**2 year average**
NT	5.63a	11.1a	8.37
CP	7.24b	10.8a	9.02
MP	7.00b	10.9a	8.95

+Values with and without cover crop in the same tillage treatment and year followed by the same letter are not significantly different at the 0.05 probability level.

Table 3. Residue versus Residue Removal on SOC stocks of 3 tillage treatments.

Reside Removal by Tillage Treatments	Depth	Average of all treatments (baseline) June 2009 SOC	Average of all treatments June 2013 SOC	SOC change	SOC effect	Rate of change
	Cm	Mt C/ha /layer	Mt C/ha /layer	Mt/ha /layer	%	Mt C/ha /layer/yr
No tillage						
Removal	0-75cm	45.4a	53.7a	8.3	18	2.1
Residue	0-75cm	46.9a	58.3a	11.4	24	2.9
C gain/loss	0.75cm	1.5	**4.6**			
Chisel plow						
Removal	0-75cm	38.9a	43.4a	4.5	11	1.1
Residue	0-75cm	38.4a	46.5a	8.1	21	2.0
C gain/loss	0.75cm	-0.5	**3.2**			
Moldboard plow						
Removal	0-75cm	37.4a	44.9a	7.5	20	1.9
Residue	0-75cm	34.2a	42.5a	8.3	24	2.1
C gain/loss	0.75cm	-3.2	**-2.5**			

* For each tillage treatment and year, means with and without residue removal means followed by the sale letter are not significantly different at the P=0.05 probability level. Mt= metric tons

Refereed journal articles:

Olson, K.R., M. M. Al-Kaisi, R. Lal and L. Cihacek. 2016. Soil erosion and landscape considerations in determining soil organic carbon stocks: review and analysis. J. of Soil and Water Conservation 71 (3): 61A-67A.

Olson, K.R., L W Morton and D. Spiedel. 2016. Little River Drainage District conversion of the Big Swamp to agricultural land. J. Soil Water Conservation 71: (2): 37A-43A.

Olson, K.R. L W Morton and D. Spiedel. 2016. Impact of Little River Drainage District Diversion on Missouri Big Swamp and St. Francis River drainage. J. Soil Water Conservation 71: (1): 13A-19A.

Morton, L.W. and K.R. Olson 2016. St. Johns Bayou and levee and drainage district attempt to mitigate internal flooding. J. Soil Water Conservation 71: (4): 75A-82A.

Olson, K.R. J. Matthews, L W Morton and J. Sloan. 2015. Impact of levee breaches, flooding and land scouring on soil productivity. J. Soil Water Conservation 70: (1):5A-11A.

Olson, K.R. and L W Morton. 2015. Slurry trenches and relief wells installed to strengthen Ohio and Mississippi river levee systems J. Soil Water Conservation 70(4): 77A-81A.

Accomplishments and Impacts

Soil erosion and agricultural land unit management affect SOC stock of sloping agricultural land units along with the attendant changes in SOC sequestration, storage, retention, and loss. It is imperative to recognize that water and wind erosion processes of transport and deposition of SOC enriched-sediments within a landscape unit contribute to redistribution of SOC stock, in particular within the upland agricultural land unit boundaries, water bodies beyond those land units, or into the atmosphere. Redistribution of SOC because of soil erosion process neither constitutes nor is equivalent to SOC sequestration, which involves the dynamic interactions between soil, plant, and atmospheric CO_2 within the designated unit. The absence of such dynamics leads to the conclusion that soil erosion is a destructive process altering and changing soil C stocks (organic and inorganic) causing the loss of significant amount of relatively stable SOC that has been retained in the soil system for millennia, and adversely affecting net primary productivity and use efficiency of inputs. The selection of agricultural land unit and its position for study and determining SOC stock can affect the results and their interpretations. An eroding land unit will underreport the SOC stock, a depositional agricultural land unit will overestimate the SOC stock, while an agricultural mixed landscape (combined eroding and depositional) land unit can have a different and an uncertain SOC distribution outcome because of losses by decomposition, leaching, and runoff.

2016 Kansas Report - NC-1178
DeAnn R. Presley

Project Title: Sustainability and profitability of residue removal for biofuel use in a water-limited region.

Study description
A corn residue removal research project began in 2009 at three sites. One site was discontinued after 2011, but the other two locations are still active research sites. Residue removal studies continue on two sets of plots with 0, 25, 50, 75, and 100% stover removal levels. One plot is in eastern Kansas, and the other is an irrigated site in western Kansas. Crop grain yield is measured annually and soil organic C and bulk density are measured every other year in odd years.

Thus far, there have been few instances where crop residue removal has been detrimental to corn yields. In fact, removal has led to increased crop yields at the irrigated Colby site, where irrigation is used to double the natural precipitation each year. Corn yields are high, thus residue production has been high, and removal led to increased crop yields at Colby in this high-yielding environment, until 2015 when the 0% removal was the highest yielding treatment, though not significantly different. At the rainfed Ottawa site, differences in crop yields were observed in 2009, 2010, and 2015. In 2015, 0% removal was significantly lower yielding than all other treatments. Soil data is not included in this research report as the samples and data are still being analyzed.

Accomplishments/Outputs
The results from this long-term project are regularly used by Dr. DeAnn Presley in extension presentations on the subject of soil health and management, including non-technical extension media such as the weekly eUpdate published by the Department of Agronomy at Kansas State University. One such recent document is availalable at: ksu.ag/29ARvs0

Outcomes/Impacts
It is our hope that these findings will help producers make informed decisions concerning the management of agricultural land in the future. In particular, decisions concerning the harvesting of crop residues for bioenergy feedstock need to be made with caution. Further dissemination of these results is essential to shed light upon the impacts of crop residue removal on agriculture and the environment.

Publications during reporting period:
Book chapter:

Wills, SA, CO Williams, MC Duniway, J Veenstra, C Seybold, D Presley. 2017. Human Land Use and Soil Change. IN LT West, MJ Singer and AE Hartemink (eds). The Soils of the USA. Springer International Publishing, Switzerland, ISBN 978-3-319-41870-4.

External funding:
None at this time.

Table 1. Corn yields, 2009-2015. Letters denote statistical differences among treatments within each site year ($p<0.05$).

		Yield (ton/ha)					
		Site		Site		Site	
Time	Removal Level	Colby		Hugoton		Ottawa	
2009	0%	13.11	b	11.10	a	7.49	bc
	25%	16.48	ab	11.94	a	6.32	c
	50%	17.86	a	11.87	a	7.96	ab
	75%	18.14	a	12.54	a	8.08	ab
	100%	17.32	a	10.50	a	9.43	a
2010	0%	13.48	ab	15.80	a	4.41	c
	25%	12.59	b	15.15	a	4.40	c
	50%	14.41	ab	16.81	a	4.59	bc
	75%	15.89	a	16.09	a	5.56	a
	100%	15.72	a	15.53	a	5.33	ab
2011	0%	6.73	a	12.22	a	0.88	a
	25%	8.81	a	10.83	a	1.05	a
	50%	9.42	a	13.00	a	1.23	a
	75%	8.91	a	10.76	a	1.58	a
	100%	9.99	a	14.07	a	1.40	a
2012	0%	9.61	b			1.27	a
	25%	10.06	ab			1.59	a
	50%	11.01	ab			1.52	a
	75%	12.45	a			1.22	a
	100%	12.31	ab			1.72	a
2013	0%	12.33	b			9.22	a
	25%	13.98	ab			9.02	a
	50%	12.68	b			9.35	a
	75%	14.88	a			9.89	a
	100%	14.67	a			9.45	a
2014	0%	11.32	b			7.96	a
	25%	12.86	ab			7.84	a
	50%	11.79	b			8.85	a
	75%	14.14	a			8.46	a
	100%	14.01	a			9.86	a
2015	0%	14.7	a			6.77	b
	25%	13.1	a			8.14	a
	50%	13.3	a			8.71	a
	75%	13.0	a			8.53	a
	100%	13.3	a			8.32	a