Final Report Conservation Innovation Grant

National CIG Program –69-3A75-12-192-Ranjith Udawatta

Report/Project Period: September 24, 2012 to August 31, 2016

Project Number: 69-3A75-12-192-Ranjith Udawatta

Date Awarded: September 24, 2012

Title: Multipurpose Cover Crop and Conservation Practices for a Sustainable Agricultural System to Improve Soil Health, Environmental Quality, and Farm Productivity.

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NON-TECHNICAL SUMMARY

Row crop agriculture is often scrutinized for negative impacts on the environment and ecosystem services. These include degradation of water quality, soil health, land productivity, and farm economics. There is a strong direct relationship between agricultural water pollution and hypoxia in the Gulf of Mexico. Cover crops are believed to improve water quality, soil quality, land productivity and farm economics and thereby helping provide numerous ecosystem services.

Little cover crop research or demonstrations exist in Missouri. While there is interest in cover crop use and their benefits, adoption is very low in the U.S. and particularly among Missouri farmers. The overall goal of the project was to quantify ecosystem benefits of adoption of cover crops on Missouri corn-soybean rotations. Additionally the project planned to promote adoption of cover crops though a program funded by Missouri Department of Natural Resources.

This proposal established eight small watersheds to quantify water, soil, land productivity, and economic benefits of cover crops (Fig. 1). Our team consisted of farmers, university faculty, and federal and state agency personnel and private individuals who worked together to ensuring success of this project. Results indicated significant reduction in runoff volume, sediment, and nutrient losses from watersheds with cover crops as compared to watersheds without cover crops. Soil quality changes were not significant during the initial two years. However, watersheds with cover crops indicated greater enzyme activities during the fourth year. Phospholipid fatty acid (PLFA) concentrations were significantly greater with continuous ground cover as compared to exposed soils. Greater PLFA is an indication of diverse soil microbial communities that help promote efficient nutrient cycling, degradation of chemicals, and carbon sequestration. Land productivity increased on watershed with cover crops. Our study also showed improvements in

crop yields in 2014 following a cover crop (Fig. 2). However, weather conditions in Midwest are variable and we experienced both droughts and floods during our study. In 2012 because of drought and in 2015 because of excess soil wetness planting was limited and where planting was done, plants were severely stressed. Thus, our study had only one year out of three where plant growth and development could be compared. This highlights the need for additional studies to acquire more years of information to quantify the benefits of cover crops on crop yields. Economic benefits of cover crops were noticed after three years of cover crops. In our study, we have found that integration of cover crops has increased farm income in 2014. Yields were increased by 10% on the fields with cover crops. While the use of cover crops added about $100 per acre additional cost, the additional yield from cover crops was offset this additional cost. Cover crop costs decreased in 2015 by 6% while the yields on the fields with cover crops were ~10% higher than the fields without the cover crops.

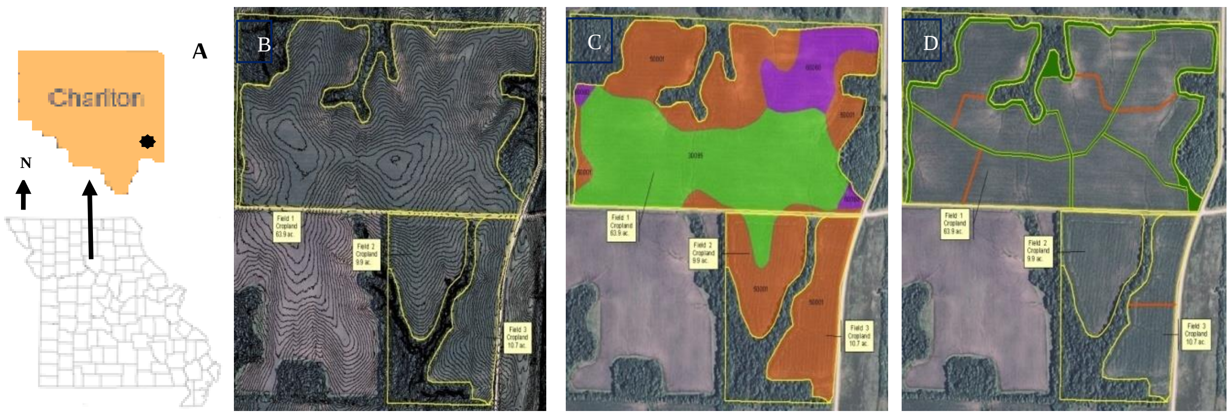


Fig. 1. Maps showing: (a) Approximate location of the Chariton County Soil Health Conservation Farm in Chariton County, Missouri, (b) One-ft interval contour lines of the farm, (c) Major soil distribution (Armstrong loam, Grundy silt loam, and Bevier silty clay loam) and (d) 12 demonstration watersheds to evaluate soil health, water quality, and production benefits.

Fig. 2. 2014 corn yields at the Soil Health Farm for cover crop and no-cover crop areas.

The second major goal of increased adoption of cover crops was accomplished by the financial support from the Missouri Department of Natural Resources. Fifty farmers in Chariton County have adopted cover crops in theirs farms with 1584 acres.

As proposed the project has established a demonstration farm to demonstrate ecosystem benefits of cover crops and several demonstration were conducted at this farm. The study also quantified ecosystem benefits of cover crops and these information and data were disseminated through peer-reviewed journal publications, conference abstracts and poster presentations, thesis, workshops, seminars, websites, and popular magazine articles.

PODUCER PARTICIPATION AND PROMOTE ADOPTION OF COVER CROP PRACTICES

Funding from the Missouri Department Natural Resources for the Cover Crop Pilot Project promoted adoption of cover crops in Chariton County. During the period between 2013 and 2015, 50 landowners/farmers participated with 1584 acres enrolled in the program and $225,000 obligated for incentive payments. The average cost of seed was about $20 per acre. The incentive payment for the practice is set at $75 per acre. This incentive payment covered seed cost, nutrient management costs, setting and calibrating drills, as well as the cost to make modifications to equipment to plant into the mat of covers. Each cooperator can enroll in a maximum of 40 acres.

The program consisted of two levels of participation for cooperators. Cooperators participating in Level 1 were eligible for an annual incentive payment for three years of cooperation. The cooperator must implement no-till practices for 3 years, implement nutrient management for 3 years, establish cover crops for three consecutive years, and implement at minimum a two-crop type rotation such as corn-soybean. The cover crops may be a single species following corn or soybeans, but cannot be the same species two consecutive years. In one year of Level 1 you must plant a minimum of 2 cover crop species.

Cooperators in Level 2 were eligible for an annual incentive payment for four years of cooperation. The cooperator must implement no-till practices for four years, nutrient management for four years, a conservation crop rotation that includes 3 distinct full season crops and includes 3 crop types, as well as a minimum of 2 species of cover crops following wheat. One of which must be a legume and must be at least 50% of the mixture.

Additionally, two or three meetings were annually held at the NRCS office in Keytesville to determine management decisions such as fertilizers, spraying, and planting crops and cover crops at the farm. NRCS, landowners, farmers, and facility operators and suppliers attended these meetings.

PROFESSIONAL DEVELOPMENT

1. This project supported the investigators, graduate students, and technicians to give conference presentations in 2013, 2014, 2015, and 2016.
2. The PI attended the CIG showcase at the Soil Water Conservation Conference 2016 in Louisville, Kentucky.
3. Undergraduate students were involved in field and laboratory activities for field instrumentation, sampling, and sample analysis.

GRADUATE STUDENT TRAINING ACTIVITIES

Three graduate students completed MS thesis projects quantifying changes in soil physical properties, probiotics, and soil microbial properties as influenced by cover crops.

Name, Department	Period	Thesis Title	Current Position
Marcello Goyzueta Soil, Environmental and Atmospheric Sciences (SEAS)	January 2013 to May 2015	Cover Crops: An Alternative Practice to Improve Soil Physical Properties and Soil Water Dynamics	FAO-Bolivia
Ahsan Mir Rajper SEAS	August 2013 to July 2015	Assessing the Role of Probiotics for the Enhancement of Soil Quality Under Cover Crops	PhD Student, University of Alberta, Canada.
James VeVerka SEAS	January 2013 to July 2015	Cover Crop Practices in Missouri Claypan Soils and Their Influences on Selected Soil Health Indicators	USDA-NRCS, Iowa

DISSEMINATION OF RESULTS AND INFORMATION:

Peer-reviewed journal publications, conference abstracts and poster presentations, thesis, workshops, seminars, websites, and popular magazine articles were used to disseminate research findings and information to wider audience.

PUBLICATIONS:

Peer-reviewed publications

Rajper, A.M., R.P. Udawatta, R.J. Kremer, C-Ho Lin, and S. Jose. 2016. Assessing the role of probiotics on soil microbial biomass, communities structure and enzyme activity. Agroforestry Systems DOI 10.1007/s10457-016-9895-1

Svoma, B.M., and C.J. Gantzer. 2016. Regional climatological probabilities to increase success and reduce risk in rain-fed cover crop management. J. Soil Water Conservation. 71:377- 384 Doi:10.2489/jswc.71.6.377.

Sougata Bardhan, S., R.P. Udawatta, S. Jose, C.J. Gantzer, C. Bobryk. 2017. Impact of Three Year Crop Rotation and Cover Crops on Soil Microbiological Properties in a Central Missouri Farm. Agricultural and Environmental Letters (In Review).

VeVerka, J.S., R.P. Udawatta, and R.J. Kremer. 2017. Soil quality and cover crops on corn-soybean watersheds during drought years. Applied Soil Ecology (In Review).

Weerasekara, C.S., R.P. Udawatta, C.J. Gantzer, K.S. Veum, S. Jose, and R.J. Kremer. 2017. Effects of cover crops on soil quality: Emphasis on chemical and biological parameters. Communication in Plant and Soil (In Review).

In Preparation

Cai, Z., R.P. Udawatta, L. Godsey, C.J. Gantzer, and S. Jose. 2017. An Economic Analysis of Cover Crops for a Missouri Corn and Soybean Rotation

Udawatta, R.P., C.J. Gantzer, and S. Jose. 2016. Water quality benefits of cover crops on corn/soybean watersheds in the claypan soils.

Abstracts/posters

Weerasekera, C.S., R.P. Udawatta, C.J. Gantzer, K.S. Veum, and S. Jose. 2016. Effects of cover crops on soil biological and chemical parameters. Abstracts 2016 ASA, CSSA, and SSSA International Annual Meetings. Tucson, Arizona. November 6-10, 2016. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 5585 Guilford Road, Madison, Wisconsin 53711-1086.

Udawatta, R.P., C.J. Gantzer, and S. Jose. 2016. Water quality benefits of cover crops on corn/soybean watersheds in the claypan soils. Soil Water Conservation Society. 945 SW Ankeny Rd, Ankeny, IA 50023. 71st Annual Soil and Water Conservation Society Conference. Managing Great River Landscapes. Abstract Book. July 24-27, 2016. Galt House Hotel. Louisville, KY.

Godsey, L.D., R.P. Udawatta, and C.J. Gantzer. 2016. Estimating the costs and returns for cover crops on a Missouri corn and soybean rotation. Soil Water Conservation Society. 945 SW Ankeny Rd, Ankeny, IA 50023. 71st Annual Soil and Water Conservation Society Conference. Managing Great River Landscapes. Abstract Book. July 24-27, 2016. Galt House Hotel. Louisville, KY.

VeVerka, J.S., R.P. Udawatta, and R.J. Kremer. 2016. Soil quality and cover crops on corn-soybean watersheds during drought years. Soil Water Conservation Society. 945 SW Ankeny Rd, Ankeny, IA 50023. 71st Annual Soil and Water Conservation Society Conference. Managing Great River Landscapes. Abstract Book. July 24-27, 2016. Galt House Hotel. Louisville, KY.

Rajper, A., R.P. Udawatta, R.J. Kremer, C.H. Lin, and S. Jose. 2015. Assessing the role of probiotics on soil quality under cover crops in field and greenhouse studies. Agroforestry as a Catalyst for On-farm Conservation and Diversification. 14th North American Agroforestry Conference, June 1-3, 2015, Ames, Iowa, USA.

Ahsan M. Rajper, A.M., R.P. Udawatta, R.J. Kremer, C-H Lin, and S. Jose. 2014. Effects of probiotics on soil microbial community and biomass under cover crops. Abstracts 2014 ASA, CSSA, and SSSA International Annual Meetings. Long Beach, CA. November 2-5, 2014. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 5585 Guilford Road, Madison, Wisconsin 53711-1086.

Chandrasoma, J.M., R.P. Udawatta, S.H. Anderson, and C.J. Gantzer. 2014. Measured and HYDRUS-simulated water infiltration within areas under conservation buffers and corn/soybean management. 69th Soil and Water Conservation Society International Conference "Making Waves in Conservation" Abstracts, 27-30 July, Lombard, Illinois.

Adhikari, P., R.P. Udawatta, and S.H Anderson. 2014. Soil thermal properties under prairies, conservation buffers and corn/soybean management systems. 69th Soil and Water Conservation Society International Conference "Making Waves in Conservation" Abstracts, 27-30 July, Lombard, Illinois.

Goyzueta, M., R.P. Udawatta, C.J. Gantzer, and S.H. Anderson. 2014. Cover crops, an alternative practice to improve soil physical properties and soil-water dynamics on Missouri claypan soils. 69th Soil and Water Conservation Society International Conference "Making Waves in Conservation" Abstracts, 27-30 July, Lombard, Illinois.

Gantzer, C.J., R.P. Udawatta, and T. Reinbott. 2014. Cover crops, native pollinator species field borders, and riparian buffers for environmental quality. 69th Soil and Water Conservation Society International Conference "Making Waves in Conservation" Abstracts, 27-30 July, Lombard, Illinois.

Udawatta, R.P. 2014. Role of cover crops in improving water quality and other environmental measures. MU cover crop research and extension symposium. January 14, 2014. Hampton Inn, Columbia, MO.

Titus, Y., and R.P. Udawatta. 2013. The Missouri Soil Health demonstration Farm. Missouri Natural Resources Conference to educate general public and natural resource professionals on ecosystem benefits of cover crop practices. Jan. 31, 2013

MS Thesis Graduate Students:

The following three thesis were completed during the project period.

Goyzueta, M. 2015. Cover Crops: An Alternative Practice to Improve Soil Physical Properties and Soil Water Dynamics. MS Thesis, University of Missouri.

Ahsan Mir Rajper, A.M. 2015. Assessing the Role of Probiotics for the Enhancement of Soil Quality Under Cover Crops. MS Thesis, University of Missouri.

VeVerka, J. 2015. Cover Crop Practices in Missouri Claypan Soils and Their Influences on Selected Soil Health Indicators. MS Thesis, University of Missouri.

Popular magazine Articles

Houghton, D. 2016. Seeking soil services: local demonstration farm studies long-term benefits of cover crops. America's New Bounty, The Furrow, The farmer's Walk. 121: 28-29.

Webpage

In-Between Crops--Integrated cover crops study wins Conservation Innovation Grant 2013. On the College of Agriculture Food and Natural Resources website of University of Missouri to promote cover crop management among landowners, agency personnel, and academia. http://cafnrnews.com/2013/03/the-in-between-crops/

WORKSHOPS, SEMINARS AND SYMPOSIUMS

A workshop titled "*Ecosystem Services of Cover Crops*" for producers and agency personnel on August 3, 2016. The worship consisted of field demonstrations at the Chariton County Soil Water Conservation District Soil Health Demonstration Farm in the morning. The lecture session consisted of the following five presentations on cover crops, soil health, cover crop practices in Missouri, cover crop economics, and trends with cover crops at the Knights of Columbus Hall, Salisbury in the afternoon.

1. Carbonomics: The Wonderful Economy of the Soil by Keith Berns, Green Cover Seed

2. Evolution of Missouri Soil and Water Conservation Program Cover Crop Practice by Jim Plassmeyer, Soil & Water Conservation Program, Missouri Department of Natural Resources

3. Cover Crops, Evaluation and Early Research Results by Tim Reinbott, Director Field Operations, MO-AES Field Operations

4. Trends with Cover Crops across the Corn Belt by Rob Myers, Regional Director - Extension Programs North Central Sustainable Agriculture Research and Education (SARE)

5. Do Cover Crops pay? MO Cover Crop Economic Case Studies by Lauren Cartwright, Agricultural Economist/Resource Conservationist at USDA-NRCS

All presentations were uploaded to a Box site of University of Missouri and opened for input and discussions to all attendees and speakers.

The workshop was well attended with over 85 attendees. Attendees include landowners, farmers, NRCS, Missouri Department of Conservation, Missouri Department of Natural Resources and University of Missouri.

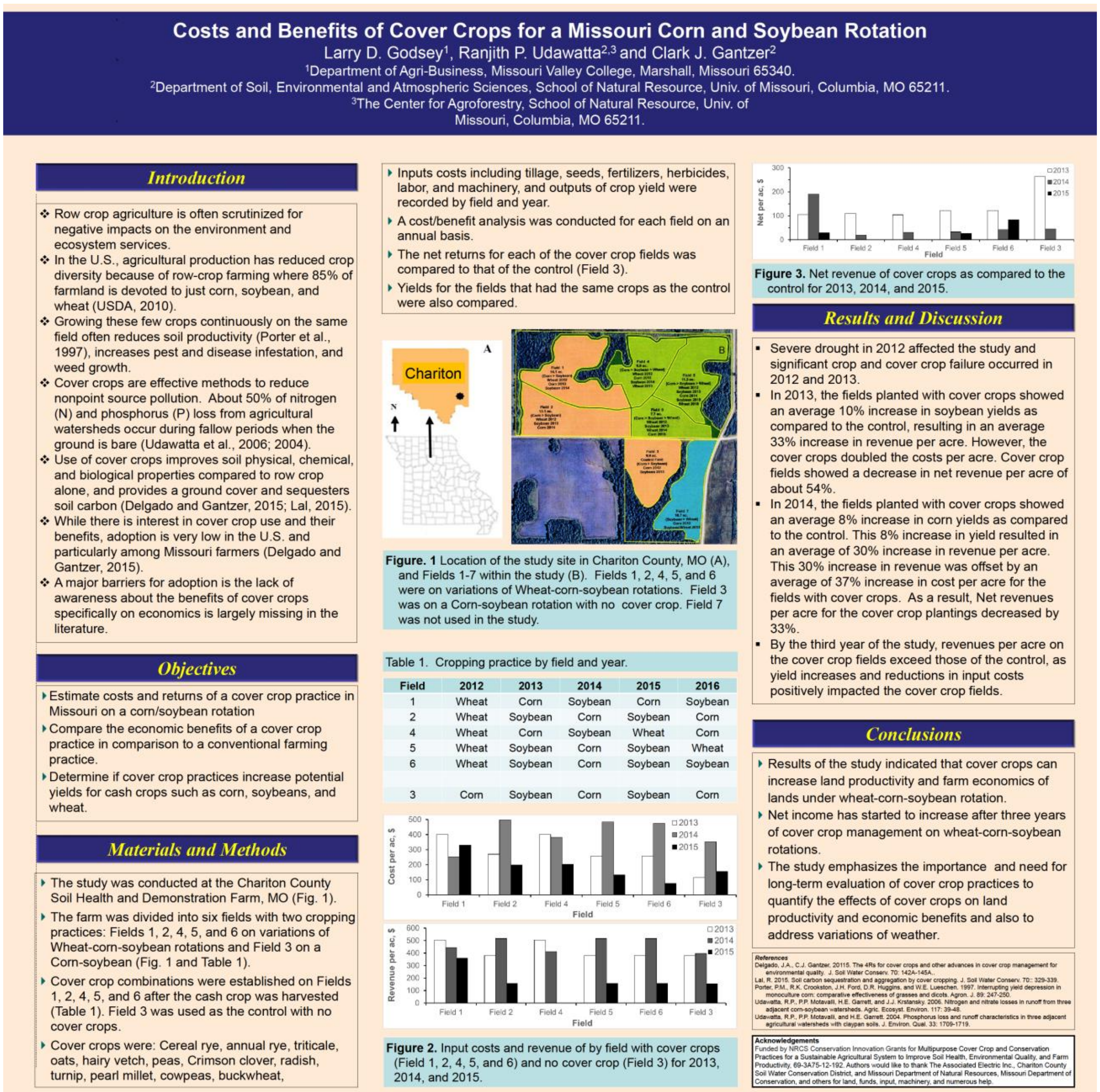
Figure 1. Field demonstrations at the Chariton County Soil Water Conservation District Soil Health Demonstration Farm in the morning (left) and the lecture session at the Knights of Columbus Hall, Salisbury in the afternoon (right) for the Ecosystem Services of Cover Crops workshop on August 03, 2016.

Ranjith Udawatta and David Hammer organized a symposium entitled "*Soil Health for Conservation, Sustainable Productivity, and Ecosystem Benefits*" at the 2013 Missouri Natural Resources Conference. Eight professionals gave oral presentations at the meeting and the session was well received with over 80 attendees. January 30 - February 1, 2013, Tan-Tar-A Resort, Osage Beach, MO. The symposium emphasized importance of soil quality/health and cover crop management on ecosystem benefits.

Ranjith Udawatta organized a symposium entitled *"Flood Recovery and Establishment of Flood Resilient Ecosystems"* at the 2012 Missouri Natural Resources Conference. Six professionals gave oral presentations at the meeting and the session was well received with over 280 attendees. February 1-3, 2012, Tan-Tar-A Resort, Osage Beach, MO. The symposium emphasized importance of soil quality/health and cover crop management on ecosystem benefits.

CHANGES AND PROBLEMS:

The field experiment was impacted by the drought of 2012 and spring rains of 2015 and thus the data collection. As the project continued, we have collected water, soil, crop yield, and economic data for subsequent years to quantify ecosystem services of cover crops. The study also emphasized the importance of long-term monitoring dues to variations associated with weather, management, and soil types. For example, based on three years (2012-2015) of data, it is not possible to determine the precise impact of cover crops on crop yields and farm economics.



Costs and Benefits of Cover Crops for a Missouri Corn and Soybean Rotation

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[1]Department of Agri-Business, Missouri Valley College, Marshall, Missouri 65340.
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Introduction

- Row crop agriculture is often scrutinized for negative impacts on the environment and ecosystem services.
- In the U.S., agricultural production has reduced crop diversity because of row-crop farming where 85% of farmland is devoted to just corn, soybean, and wheat (USDA, 2010).
- Growing these few crops continuously on the same field often reduces soil productivity (Porter et al., 1997), increases pest and disease infestation, and weed growth.
- Cover crops are effective methods to reduce nonpoint source pollution. About 50% of nitrogen (N) and phosphorus (P) loss from agricultural watersheds occur during fallow periods when the ground is bare (Udawatta et al., 2006; 2004).
- Use of cover crops improves soil physical, chemical, and biological properties compared to row crop alone, and provides a ground cover and sequesters soil carbon (Delgado and Gantzer, 2015; Lal, 2015).
- While there is interest in cover crop use and their benefits, adoption is very low in the U.S. and particularly among Missouri farmers (Delgado and Gantzer, 2015).
- A major barriers for adoption is the lack of awareness about the benefits of cover crops specifically on economics is largely missing in the literature.

Objectives

- Estimate costs and returns of a cover crop practice in Missouri on a corn/soybean rotation
- Compare the economic benefits of a cover crop practice in comparison to a conventional farming practice.
- Determine if cover crop practices increase potential yields for cash crops such as corn, soybeans, and wheat.

Materials and Methods

- The study was conducted at the Chariton County Soil Health and Demonstration Farm, MO (Fig. 1).
- The farm was divided into six fields with two cropping practices: Fields 1, 2, 4, 5, and 6 on variations of Wheat-corn-soybean rotations and Field 3 on a Corn-soybean (Fig. 1 and Table 1).
- Cover crop combinations were established on Fields 1, 2, 4, 5, and 6 after the cash crop was harvested (Table 1). Field 3 was used as the control with no cover crops.
- Cover crops were: Cereal rye, annual rye, triticale, oats, hairy vetch, peas, Crimson clover, radish, turnip, pearl millet, cowpeas, buckwheat,
- Inputs costs including tillage, seeds, fertilizers, herbicides, labor, and machinery, and outputs of crop yield were recorded by field and year.
- A cost/benefit analysis was conducted for each field on an annual basis.
- The net returns for each of the cover crop fields was compared to that of the control (Field 3).
- Yields for the fields that had the same crops as the control were also compared.

Figure. 1 Location of the study site in Chariton County, MO (A), and Fields 1-7 within the study (B). Fields 1, 2, 4, 5, and 6 were on variations of Wheat-corn-soybean rotations. Field 3 was on a Corn-soybean rotation with no cover crop. Field 7 was not used in the study.

Table 1. Cropping practice by field and year.

Field	2012	2013	2014	2015	2016
1	Wheat	Corn	Soybean	Corn	Soybean
2	Wheat	Soybean	Corn	Soybean	Corn
4	Wheat	Corn	Soybean	Wheat	Corn
5	Wheat	Soybean	Corn	Soybean	Wheat
6	Wheat	Soybean	Corn	Soybean	Soybean
3	Corn	Soybean	Corn	Soybean	Corn

Figure 2. Input costs and revenue of by field with cover crops (Field 1, 2, 4, 5, and 6) and no cover crop (Field 3) for 2013, 2014, and 2015.

Figure 3. Net revenue of cover crops as compared to the control for 2013, 2014, and 2015.

Results and Discussion

- Severe drought in 2012 affected the study and significant crop and cover crop failure occurred in 2012 and 2013.
- In 2013, the fields planted with cover crops showed an average 10% increase in soybean yields as compared to the control, resulting in an average 33% increase in revenue per acre. However, the cover crops doubled the costs per acre. Cover crop fields showed a decrease in net revenue per acre of about 54%.
- In 2014, the fields planted with cover crops showed an average 8% increase in corn yields as compared to the control. This 8% increase in yield resulted in an average of 30% increase in revenue per acre. This 30% increase in revenue was offset by an average of 37% increase in cost per acre for the fields with cover crops. As a result, Net revenues per acre for the cover crop plantings decreased by 33%.
- By the third year of the study, revenues per acre on the cover crop fields exceed those of the control, as yield increases and reductions in input costs positively impacted the cover crop fields.

Conclusions

- Results of the study indicated that cover crops can increase land productivity and farm economics of lands under wheat-corn-soybean rotation.
- Net income has started to increase after three years of cover crop management on wheat-corn-soybean rotations.
- The study emphasizes the importance and need for long-term evaluation of cover crop practices to quantify the effects of cover crops on land productivity and economic benefits and also to address variations of weather.

References
Delgado, J.A., C.J. Gantzer. 20115. The 4Rs for cover crops and other advances in cover crop management for environmental quality. J. Soil Water Conserv. 70: 142A-145A.,
Lal, R. 2015. Soil carbon sequestration and aggregation by cover cropping. J. Soil Water Conserv. 70:: 329-339.
Porter, P.M., R.K. Crookston, J.H. Ford, D.R. Huggins, and W.E. Lueschen. 1997. Interrupting yield depression in monoculture corn: comparative effectiveness of grasses and dicots. Agron. J. 89: 247-250.
Udawatta, R.P., P.P. Motavalli, H.E. Garrett, and J.J. Krstansky. 2006. Nitrogen and nitrate losses in runoff from three adjacent corn-soybean watersheds. Agric. Ecosyst. Environ. 117: 39-48.
Udawatta, R.P., P.P. Motavalli, and H.E. Garrett. 2004. Phosphorus loss and runoff characteristics in three adjacent agricultural watersheds with claypan soils. J. Environ. Qual. 33: 1709-1719.

Acknowledgements
Funded by NRCS Conservation Innovation Grants for Multipurpose Cover Crop and Conservation Practices for a Sustainable Agricultural System to Improve Soil Health, Environmental Quality, and Farm Productivity, 69-3A75-12-192. Authors would like to thank The Associated Electric Inc., Chariton County Soil Water Conservation District, and Missouri Department of Natural Resources, Missouri Department of Conservation, and others for land, funds, input, machinery, and numerous help.

Soil Quality and Cover Crops on Corn-soybean Watersheds during Drought Years

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Introduction

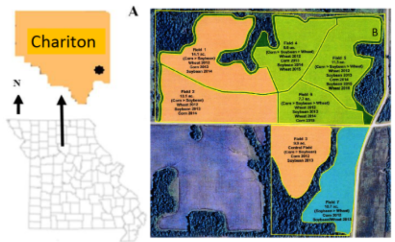
- The concept of soil health is defined as the ability of soil to maintain biological activity and encourage animal and plant health (Doran and Parkin, 1994).
- Concerns of soil degradation and the increasing awareness of the value of soil resources have strengthened the interest in soil health or soil quality investigations.
- Soil microbial activities can respond rapidly to short- and long-term climatic and weather variations, reflecting changing environmental conditions (Doran and Parkin, 1996).
- Cover crops can be defined as a living vegetative ground cover maintained seasonally or permanently.
- A variety of benefits to soil ecosystems are attributed to cover crop practices.
- The benefits of cover crops need to be firmly established to reinforce their environmental and economic value in comparison to their fixed cost.
- A wealth of soil biological assessments is reported in the literature, yet few have investigated cover cropping combined with tillage practices on marginal claypan soils in the central United States.

Objective

- The objectives of the study were to determine the effects of cover crops, depth and landscape position under no-till and rotational planting management on biological soil health parameters

Materials and Methods

- The study site was Chariton County Soil Health and Demonstration Farm, MO (Fig. 1A).
- Two Conservation (CS) and two Conventional watersheds (CV) with Armstrong loam (Fine, smectitic, mesic Aquertic Hapludalfs) were used for the study (Fig. 1C and 2).
- Cover crops grown on Conservation watersheds (CS) were: winter peas, cowpeas, hairy vetch, buckwheat, radishes, crimson clover, sorghum sudan, oats, turnips, sunflower, annual rye, sunhemp, cereal rye, sweet clover and triticale.
- Nine locations were sampled within four watersheds at depths of 0-10 cm, 10-20 cm and 20-30 cm. Nine locations are: Upper, middle (backslope), and lower (footslope) positions with three replicated positions.
- Soil C and N were determined by LECO method.
- Water stable aggregates were determined by wet sieving method (Table 1).
- Soil enzymes include: β-glucosidase, glucosaminidase, and fluorescein diacetate hydrolase (FDA) and dehydrogenase (Table 1).



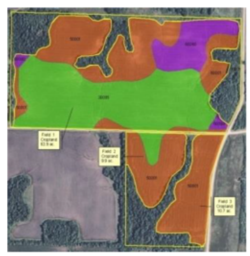


Fig. 1. Study site Location in Chariton County, MO (A), cover crop and crop establishment guide (B), major soil distribution (Armstrong loam brown, Grundy silt loam green, and Bevier silty clay loam purple; C).

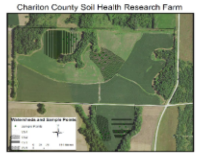


Fig. 2. Soil sampling locations, transects and landscape positions within watersheds..

Table 1. Standard soil analyses procedures.

Parameter	Units	Reference
Water stable aggregates	%	Angers et al. 2007
β-glucosidase	μg p-nitrophenol released g^{-1} dry soil h^{-1}	Dick et al. 1996
Glucosaminidase	μg p-nitrophenol released g^{-1} soil h^{-1}	Parham and Deng 2000
Fluorescein diacetate (FDA)	μg fluorescein released g^{-1} dry soil h^{-1}	Dick et al. 1996
Dehydrogenase	μg TPF released g^{-1} dry soil h^{-1}	Pepper et al. 1995

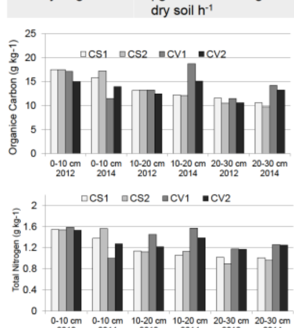


Fig. 3. Soil organic carbon and nitrogen for conservation and conventional watersheds for two sampling depths and years.

Results and Discussion

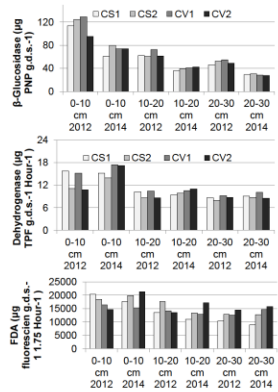


Fig. 4. β-Glucosidase, dehydrogenase, and FDA activities by conservation and conventional watersheds by sampling year and depth at the Chariton Farm.

- Surface OC values ranged from 15 g kg^{-1} to 18 g kg^{-1}, with lower depths having 11 g kg^{-1} to 14 g kg^{-1}(Fig. 3).
- For conventional watersheds, TN values ranged from 1.21 g kg^{-1} to 1.51 g kg^{-1} mid and lower depths, with conservation watershed TN values ranging from 0.93 g kg^{-1} to 1.12 g kg^{-1} for similar depths (Fig. 3).
- WSA results were mixed across watersheds, with significant changes identified for watershed*depth ($p<0.01$) and watershed*landscape ($p<0.05$) interactions.
- Soil enzyme activities responses were mixed across watersheds for duration, soil depth and landscape position. Glucosidase activity significantly decreased between sampling events. Dehydrogenase and FDA activities were similar between sampling events within a depth (Fig. 4).

Conclusions

- Seasonal and annual climatic extremes, primarily precipitation patterns, during the study period impacted cover crop establishment whereby these conditions were reflected in soil enzymatic and water stable aggregate responses. The variability observed regarding carbon and nitrogen data may be attributed to no-till practices, minimizing the amount of residue introduced into the soil surface.
- Study findings reinforce the importance of the frequency and timing of sample collection for estimating microbial processes influenced by dynamic C and N cycling.

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Water quality benefits of cover crops on corn/soybean watersheds in the claypan soils

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INTRODUCTION

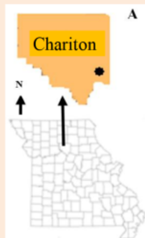
- There is a strong consensus that the cause of the Gulf's hypoxic zone is attributed to nutrients coming from the watershed of the Mississippi River Basin.
- Recent estimates suggest that 43% of the N and 27% of the P flux to the Gulf originate in Mississippi River Basin and come primarily from agricultural runoff (Aulenbach et al., 2007).
- Cover crops are effective methods to reduce nonpoint source pollution. Use of cover crops improves soil physical, chemical, and biological properties compared to row crop alone, and provides a ground cover and sequesters soil carbon (Delgado and Gantzer, 2015; Lal, 2015) thus help improve quality of runoff water.
- About 50% of nitrogen (N) and phosphorus (P) loss from agricultural watersheds occur during fallow periods when the ground is bare (Udawatta et al., 2004; 2006).
- While there is interest in cover crop use and their benefits, adoption is very low in the U.S. and particularly among Missouri farmers (Delgado and Gantzer, 2015).
- A major barriers for adoption is the lack of awareness about the benefits of cover crops specifically, on environmental and economical benefits.

OBJECTIVES

1. Quantify runoff, sediment, and nutrient losses from watersheds.
2. Establish and compare effectiveness of cover crops on runoff water from row crop watersheds.

MATERIALS AND METHODS

- The study was conducted at the Chariton County Soil Health and Demonstration Farm, MO (Fig. 1A).
- The farm was divided into eight watersheds.
- Cover crop combinations were established on watersheds 1-6 (Fig. 1B). Watersheds 7 and 8 served as controls, with no cover crops.
- Cover crops were: Cereal rye, annual rye, triticale, oats, hairy vetch, peas, Crimson clover, radish, turnip, pearl millet, cowpeas, buckwheat,
- Watersheds were instrumented with approach sections, 3-ft flumes, flow meters, water samplers, and batteries (Fig. 1D).
- Water samples were collected after each runoff event and analyzed for sediment and nutrients (Table 2).



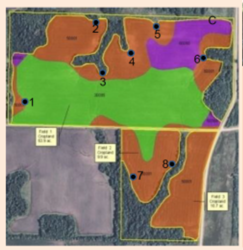


Fig. 1. Study site Location in Chariton County, MO (A), cover crop and crop establishment guide (B), major soil distribution (Armstrong loam brown, Grundy silt loam green, and Bevier silty clay loam purple), watershed sampling locations (●), number (C) and sampler assembly (D).

Table 1. Standard Water Quality Analysis Methods.

Parameter	Analytical Method	Detection Limit	Units
TN	Pritzlaff, 1999a; Lachat Quickchem Automated Ion Analyzer (method 10-107-04-1-C)	0.0003	mg L^{-1}
NO_3^--N	Pritzlaff, 1999b; Lachat Quickchem Automated Ion Analyzer (method 10-107-05-1-B)	0.0003	mg L^{-1}
TP	Liao and Marten, 2000; Lachat Quickchem Automated Ion Analyzer (method 10-115-01-1-F)	0.7	µg L^{-1}
Ortho-P	Prokopy, 2000; Lachat Quickchem Automated Ion Analyzer (method 10-115-01-1-B)	0.7	µg L^{-1}
TSS	APHA, 1992 (Method 2540D)	0.001	mg L^{-1}

Table 2. Watershed management

Watershed	2012	2013	2014	2015	2016
1	Wheat	Soybean	Corn	Soybean	Corn
2 and 3	Wheat	Corn	Soybean	Corn	Soybean
4 and 5	Wheat	Corn	Soybean	Wheat	Corn
6	Wheat	Soybean	Corn	Soybean	Wheat
7 and 8	Corn	Soybean	Corn	Soybean	Corn

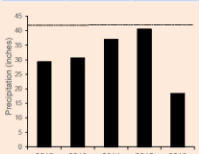
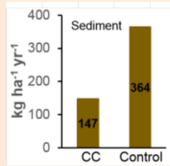


Fig. 2. Annual precipitation (bars) and 30-year mean (horizontal line) for the Linnaeus Center, Linn County. 2016 precipitation is from January 1 to July 20.

RESULTS AND DISCUSSION



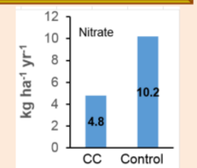
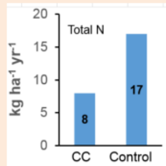
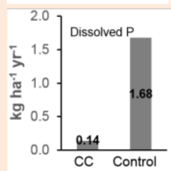
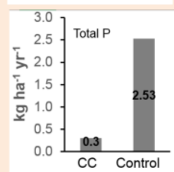


Fig. 3. Effects of cover crops (CC) on sediment, nitrate, total nitrogen, dissolved phosphorus and total phosphorus losses from wheat-corn-soybean rotational watersheds at the Chariton County Soil Haelth and Demonstration Farm







- **Severe drought in 2012 affected the study and significant crop and cover crop failure occurred in 2012 and 2013 (Fig. 2).**
- **Results indicated that cover crop practices has helped reduce sediment, nitrate, total nitrogen, dissolved phosphorus, and total phosphorus losses from agricultural watersheds with wheat-corn-soybean rotation.**
- **Differences in precipitation during the study also influenced water quality from these watersheds.**
- **Some events were not sampled due to erosion (under cutting) and soil accumulation. Soil burms created by erosion, in front of the flume, prevented runoff water entering the flume.**
- **Several large events during the study caused significant sediment and nutrient losses on all watersheds.**
- **Results of the study also suggest that long-term monitoring is needed to address variations associated with weather, crop, and management.**

Conclusions

- **Cover crops significantly reduced sediment and nutrient losses from corn-soybean watersheds in northern Missouri.**
- **Monitoring should be extended: During the study precipitation was below normal and suggests the need for long-term monitoring to quantify effects of cover crops on water quality. This will help account for variabilities associated with weather conditions combined with crop rotation.**

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EFFECTS OF COVER CROPS ON SOIL BIOLOGICAL AND CHEMICAL QUALITY PARAMETERS

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Introduction

- Human abuse of soil resources has caused disappearance of several earlier civilization
- Farming practices have caused the rate of soil loss to be greater than the rate of soil formation (Amundson et al., 2015)
- Better agricultural management practices that sustain soils are required to conserve soil resources (Montgomery, 2007)
- Cover crops (CC) provide numerous environmental benefits while enhancing the sustainability of corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) production systems (Delgado and Gantzer, 2015)
- Benefits of CC include;
    - Reduced soil erosion and nutrient loss via leaching or runoff, weed suppression, carbon sequestration, integrated pest management, soil moisture conservation, reduced non-point source pollution
- Soil physical, chemical, and biological properties are improved by CC because of increased organic C content, cation exchange capacity, aggregate stability and water infiltration (Dabney et al., 2001)
- Soil enzymes such as β-glucosidase, β-glucosaminidase, and fluorescein diacetate (FDA) hydrolase are considered good indicators of soil biological quality (Dick, 1994; Karlen et al., 1997, Gregorich et al., 2006)

Objectives

- Evaluate the aboveground biomass production of hairy vetch (*Vicia villosa* Roth.) and cereal rye (*Secale cereale*) cover crops
- Determine the changes of soil chemical and biological properties including total C, N, and P contents and soil enzyme activities of CC grown Menfro silt loam, Mexico silt loam, and sand under two irrigation methods

Methods

Location

- University of Missouri-Columbia green house complex; March - May 2016

Experimental Design

- Randomized complete block design (RCBD)

Method

- 4 seeds were seeded into each pot
- Irrigation water amount was calculated using bulk density and plant available water content of each soil
- CC were harvested at 6, 9, and 12 weeks after seeding

		Irrigation Methods			
		Full volume of water		Half volume of water	
Soil type	Menfro silt loam	HV Rep=4	CR Rep=4	HV Rep=4	CR Rep=4
	Mexico silt loam	HV Rep=4	CR Rep=4	HV Rep=4	CR Rep=4
	Sand	HV Rep=4	CR Rep=4	HV Rep=4	CR Rep=4

Table 1. Treatment combinations applied in the experiment, where HV= Hairy vetch and CR= Cereal rye

Results and Discussion

- Menfro silt loam resulted the highest aboveground biomass for hairy vetch while Mexico silt loam had the highest biomass yield for cereal rye (Fig. 2)
- CC type and water treatment were not significant for the three enzymes and total C, N, and P
- β-glucosidase activity was significantly increased as 21.5% for Mexico silt loam, 27% for Menfro silt loam, and 45% for sand at the end of the study period (Fig. 3)
- Total C, N, and P amounts were significantly decreased with time (Fig. 4)

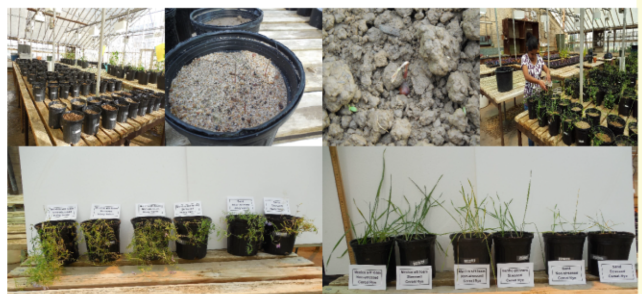

Figure 1. Growth of Hairy vetch and Cereal rye in Mexico silt loam, Menfro silt loam, and sand under stressed and non-stressed conditions at six weeks after planting

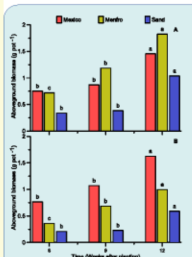

Figure 2. Mean aboveground biomass yield of (A) hairy vetch and (B) cereal rye in Mexico silt loam, Menfro silt loam, and Sand. Different letters denote significant differences among treatments at α ≤ 0.05.

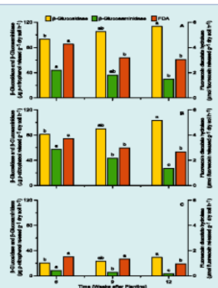

Figure 3. Changes of β-glucosidase, β-glucosaminidase, and fluorescein diacetate (FDA) hydrolase activities in (A) Mexico silt loam, (B) Menfro silt loam, and (C) Sand with time. Different letters denote significant differences among treatments at α ≤ 0.05.

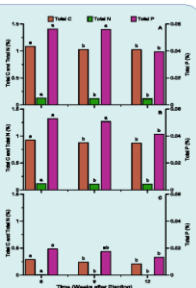

Figure 4. Changes of total C, total N, and total P contents in (A) Mexico silt loam, (B) Menfro silt loam, and (C) Sand with time. Different letters denote significant differences among treatments at α ≤ 0.05.

Conclusions and Suggestions

- Enzyme activities and total C, N, and P contents decreased with time in all soil types with the exception of β-glucosidase
- Long-term studies conducted for the above soil types are required for making better management decisions when using CC for improving soil productivity and row crop yield

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