2018 Research Results

USDA

AREA 4 SCD Cooperative Research Farm

United States Department of Agriculture

USDA-ARS Northern Great Plains Research Laboratory

February 26-27, 2019

"Farming and Ranching for the Bottom Line" Conference

Bismarck State College National Energy Center of Excellence

Area 4 SCD Cooperative Research Farm & Northern Great Plains Research laboratory

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The scientists of the Northern Great Plains Research Laboratory have included in this publication research from the Area 4 SCD Cooperative Research Farm, the USDA-ARS Northern Great Plains Research Lab, and North Dakota State University. The Area 4 SCD Cooperative Research Farm data was created thanks to cooperative agreement between the Northern Great Plains Research Laboratory and Burleigh County SCD, Cedar SCD, Emmons County SCD, Kidder County SCD, Logan County SCD, McIntosh County SCD, Morton County SCD, Oliver County SCD, Sheridan County SCD, South McLean County SCD, Stutsman County SCD, and West McLean County SCD, which are the North Dakota Area IV Soil Conservation Districts. **The preliminary results of this report cannot be published or reproduced without permission of the scientists involved.**

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Message from the Research Leader

This year marked the 35th year of the Area 4 SCD Cooperative Research Farm which reflects the strong collaborative commitment of the Area 4 SCDs to agricultural research. Original goals of the Area 4 Farm Research Advisory Committee included:

- . Conducting research on field-sized plots
- . Developing management systems that conserve soil and water resources
- . Improve water conservation and soil erosion control technology
- . Promote the adoption and use of research findings
- . Present research information in understandable terms
- . Identify research needs through the advisory committee and agricultural community.

While the specific research being conducted has changed over time, these themes have continued to provide guidance for research on the Area 4 Farm, and more broadly, the research conducted at the Northern Great Plains Research Laboratory (NGPRL). Input from the Area 4 Research Advisory Committee and the NGPRL Customer Focus Group plays a critical role in identifying research needs. With this input, our research has expanded to not only development of management systems that conserve soil and water sources, but toward systems that improve these and other environmental resources while also increasing productivity and economic viability.

The 2018 issue of the Research Results annual report is one way we aim to present the findings of our research in understandable terms and to promote their adoption and use. We hope that you enjoy this issue.

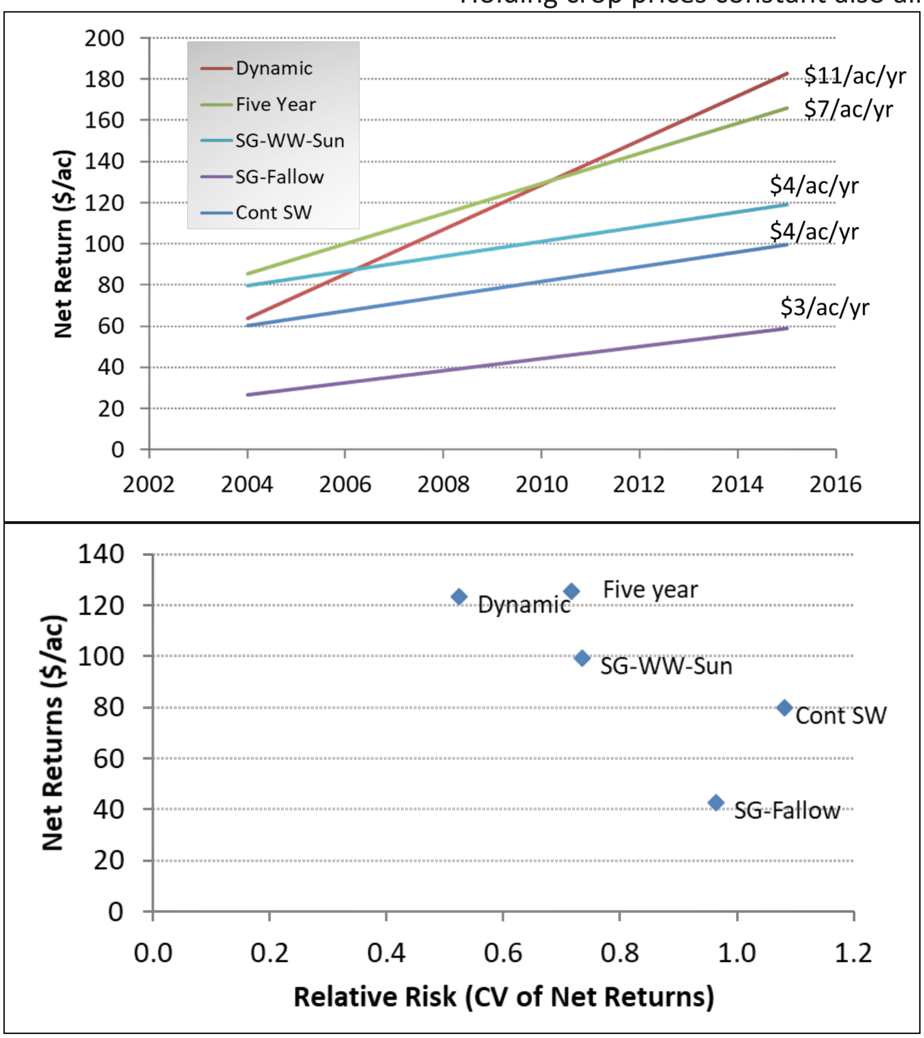
Northern Great Plains Research Laboratory Staff, Mandan, ND – 2018

Crop diversity effects on productivity and economics

Drs. David Archer, Mark Liebig, Don Tanaka, and Krishna Pokharel

Increasing crop diversity by adding more crops to a rotation has been proposed to increase sustainability of crop production. With use of no-till in the northern Great Plains and improvements in crop varieties, the potential for growing more crops has increased in the region. But, if diverse rotations are to be truly sustainable they need to be economically viable. The combination of no-till and increased crop diversity can help improve soils, for example increasing soil organic carbon, which can increase productivity over the long-term. Diverse crop rotations can help break disease and pest cycles and help improve nutrient cycling. These effects can help increase yield and reduce production costs, increasing profitability. Also, as with any investment, diversifying can help reduce economic risk by "not putting all of your eggs in one basket".

Fields at the Area 4 Research Farm have been managed for many years using no-till and with five different crop rotations. This provided an opportunity to see if more diverse rotations do indeed increase productivity and economic viability over the long-term. Rotations included small grain-fallow (SG-Fallow), continuous spring wheat (Cont SW), small grain-winter wheat-sunflower (SG-WW-Sun), field pea-corn-soybean-spring wheat-winter wheat (Five Year), and a dynamic rotation where crop choices were made each year (Dynamic). The dynamic rotation included at least six crops each year and has included alfalfa since 2009. Comparisons were made between these systems for 2004-2015.



Comparing the productivity of individual crops is difficult since the same crops are not grown in each rotation. However, spring wheat yields were compared across all rotations since it was grown in most rotations in most years. On average, there were no significant differences in spring wheat yields between the rotations, except that yields were higher in the SG-Fallow rotation than the other rotations. This was expected since a crop is only grown every other year in this rotation, thereby taking advantage of increased soil water during the fallow phase. Looking at trends in spring wheat yield over time, there were no significant trends over time and no differences in trends between rotations.

Another way to look at productivity is in terms of the value of crops produced or gross returns. This allows for comparisons across all crop in each rotation. Holding crop prices constant also allows us to see if there were any increases in productivity over time, independent of changing market conditions. Comparing average gross returns over the period, productivity was significantly lower with SG-Fallow than for any other rotation. There were no significant trends in productivity over time.

Looking at production costs, total production costs were lower for SG-Fallow than for any of the other rotations. Cost showed significant increases over time for Cont SW and SG-WW-Sun, increasing at about $5 per acre per year. This was independent of changes in input prices, meaning that increases in input use in these rotations was necessary to maintain productivity. This is an indication that these rotations may be becoming less sustainable. There were no significant trends in costs for the other rotations.

Comparing average profitability of each rotation, the SG-Fallow rotation had significantly lower net returns than the Dynamic and Five Year rotations. Although differences between other rotations were not statistically significant, there was a general trend of decreasing net returns with decreasing crop diversity, with the Dynamic and Five Year rotations having highest returns, followed by SG-WW-Sun, Cont SW, and SG-Fallow. (Figure 1). Also, economic risk was compared for each rotation in terms of the variation in net returns over time as a proportion of average net returns (e.g., a measure of relative risk for each rotation). Relative risk showed a general pattern of decreasing risk with increasing crop diversity. That means that more diverse rotations tended to be more profitable and less risky than rotations with lower crop diversity (Figure 1).

Looking at profitability, there were no statistically significant trends for any of the rotations. However, there was some indication that differences may be emerging. Profitability for the more diverse Dynamic and Five Year rotations appeared to be increasing more rapidly, at $11 and $7 per acre per year, than less diverse crop rotations (Figure 2), showing potential long-term benefits of these more diverse rotations.

Overall, this research was unique in providing field-scale evidence that more diverse rotations can increase economic returns and reduce economic risks in this region, and that these benefits may increase over time.

Archer, D.W., M.A. Liebig, D.L. Tanaka, and K.P. Pokharel. 2018. Crop diversity effects on productivity and economics: A Northern Great Plains case study. Renewable Agriculture and Food Systems 1-8. https://doi.org/10.1017/S1742170518000261.

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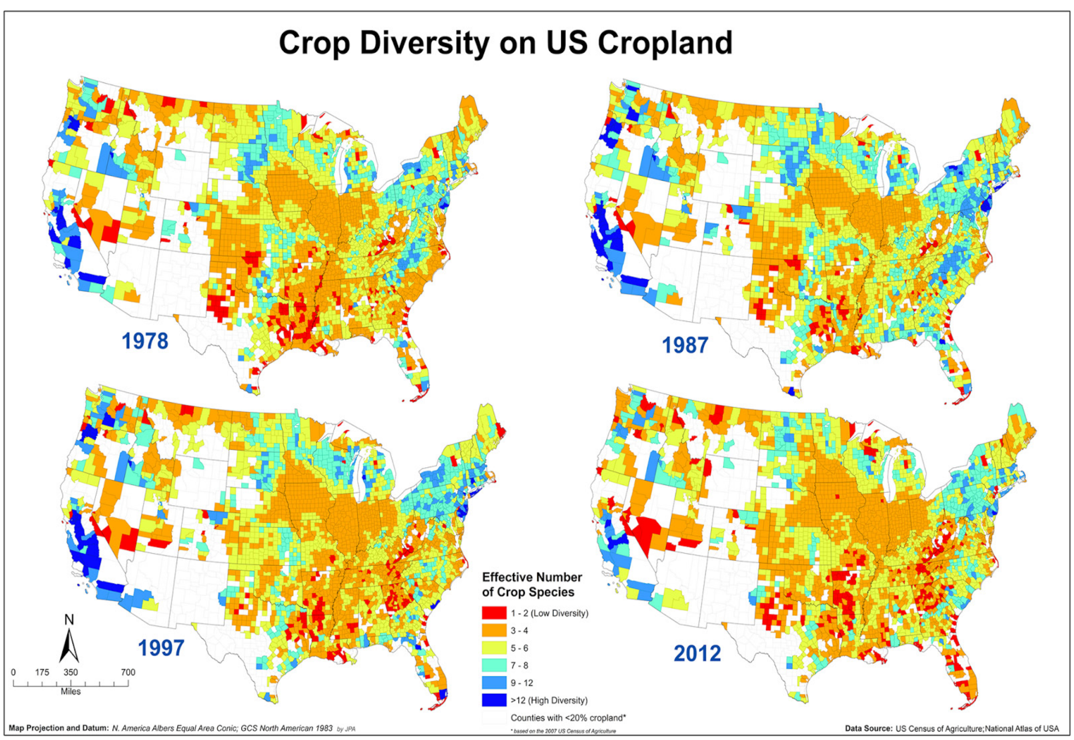

Examining farmers’ wllingness to grow and allocate land for oilseed Ccops for biofuel production

Dr. Dave Archer

The demand for sustainable and secure sources of renewable energy has risen due to higher transportation costs, environmental issues and national security concerns. Numerous countries are searching for renewable and secure sources of energy that reduce greenhouse gas emissions caused by fossil fuels. In particular, a number of initiatives within the airline industry are taking place to enhance the production and use of biofuels. Oilseed crops such as camelina, carinata, and canola have good properties for bio-based jet fuel. Examining alternative sources for biofuels is important to meet the potential demand for biofuel, particularly for the airline industry.

While there are several crops that could be used for producing biofuels, understanding if farmers would grow these crops is crucial for market development. Studying the technical feasibility of oilseed crops in connection to biofuel production is not enough. Production of bio-jet fuel from oilseeds will not be successful unless farmers are willing to grow them.

Research was conducted to determine farmers' willingness to adopt and allocate land for growing non-food oilseeds as bio-energy crops across the western US. The research also focused on identifying factors that increase or decrease willingness to growing these crops.

A mail survey was conducted in three regions of the western US from randomly selected wheat farmers located in 11 states in the western US. This study examined the willingness of farmers to adopt and allocate land for oilseed crops for bio-jet fuel production. From an economic standpoint, farmers decide to introduce oilseed crops in their farming systems when they believe that the expected profit from the new crop is higher than the expected profit without the new crop. At the same time, farmers' who are willing to adopt also consider how much land to allocate for the new crop. During adoption and land allocation decisions, different factors also affect farmers' willingness to grow bioenergy crops.

Results indicated that 58% of sampled farmers were willing to adopt oilseeds as bio-energy crops under favorable contracts, and were willing to grow oilseed crops initially on 160 acres. This compares to previous research showing 61 and 44% of farmers surveyed would be willing to grow annual and perennial bioenergy crops, respectively. Furthermore, these farmers indicated they would be willing to allocate on average 122 and 97 acres for annual and perennial bioenergy crop production, respectively.

Several factors had a significant positive effect on likelihood of adoption. Likelihood of adoption was 21% higher for farmers who had previous experience growing oilseeds, 8.8% higher for self-identified first-adopters, 18% higher if an oilseed crushing facility was nearby, 9% higher for farmers who use no-till, and 6% higher for farmers having a college degree. Conversely, likelihood of adoption was 16.5% lower for risk-averse farmers and 36% less for female farmers compared to male farmers. Also, more experienced farmers were less likely to adopt oilseeds, with a 0.34% decrease for each additional year of experience.

Similarly, the initial area that farmers were willing to allocate to oilseed production was significantly influence by several factors. Reliance on farm income had a positive impact of oilseed adoption, with a 1% increase in the portion of household income coming from farming increasing the allocation of land to oilseed crops by 1.4 acres. Also, although female producers were less likely to adopt oilseeds, if they did adopt oilseeds, they would be willing to initially devote a larger area to oilseed production, 3.4 more acres than male farmers. Factors having a significant negative impact on the initial land allocated to oilseeds included crop-share land rents, the relative profitability of wheat compared to oilseeds, and livestock ownership.

Recommendations to increase the development of oilseeds as a bioenergy crop should consider the above factors. To increase the adoption and supply of oilseed crops for biofuel production, results suggest the following.

• Availability of nearby crushing facilities are important. Nearby availability of crushing facilities increases the chance of market establishment for oilseed crops.

• Farmers with oilseed production experience have a positive influence on the adoption process. This may help to create a conducive environment where experienced oilseed producers can share their experience with other farmers.

• When assessing adoption, consideration of land tenure arrangements should be considered. Land rented on a crop-share basis was less likely to be allocated to oilseed production. Involve land owners earlier on in the process to get their buy-in.

• Increasing the profit of oilseed varieties (discovering good varieties, price support etc.) could lessen the opportunity costs of switching to oilseed production. Hence more land could be converted for oilseed production as the opportunity cost of growing oilseeds is reduced.

• A potential supply for oilseed crops for biofuel and bio-jet fuel production is possible, but barriers to market establishment still need to be overcome.

Further research is needed to conduct similar studies in other areas. It is also recommended to determine what favorable contracts for farmers should consist of. A favorable contract is different for different farmers, as well as between farmers and bio-refineries. In this study, willingness to grow oilseed crops were treated as one activity. But there are different types of oilseed crops which are suited to different locations. Further research is then recommended to identify which oilseeds would be optimal for different locations.

Weldensie T. Embaye, Jason S. Bergtold, David Archer, Cornelia Flora, Graciela C. Andrango, Marting Odening, Jeroen Buysse Examining farmers' willingness to grow and allocate land for oilseed crops for biofuel production Energy Economics 71 (2018) 311–320

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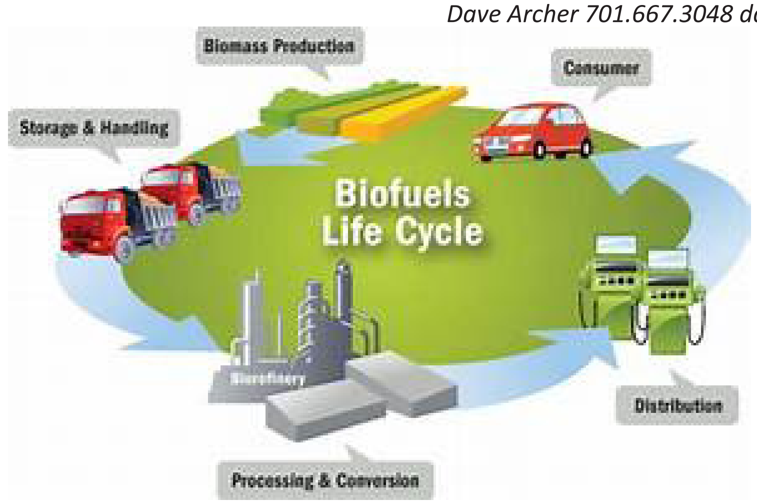

Digital image processing for classification and quantification of cover crop flowers

Subhashree N Srinivasagan, S. Sunoj, and C. Igathinathane, NDSU Agricultural and Biosystems Engineering. Jose G Franco and David W Archer, NGPRL, USDA-ARS, Rachel E Mallinger, Department of Entomology and Nematology, University of Florida

Agricultural intensification is cited as one the causes of biodiversity loss since it deals with a majority of the arable terrestrial landscape. With this intensification in agriculture, there is concrete evidence for the global decrease in insect pollinators. Among the insect pollinators, bees are considered valuable for maintaining pollination services in agriculture. Reduction in bees is prevalent in the Great Plains Region of the United States, where agriculture is dependent on the bee for pollination. One of the basic solutions is to incorporate flowering plants such as cover crops in the crop rotation. This method is widely adopted as it possesses multiple agronomical and social-economic benefits. Cover

Fig. 1. Cover crops species considered for the bee pollinator study at USDA-ARS, Mandan.

Crop floral traits, such as color, shape, size, and shape, influence the pollinators visitation rate and affect plant pollination.

A bee pollination study was conducted by the USDA-ARS Red River Valley, Fargo, and Northern Great Plains Research Laboratory (NGPRL), Mandan to assess the attraction of the bees towards to the

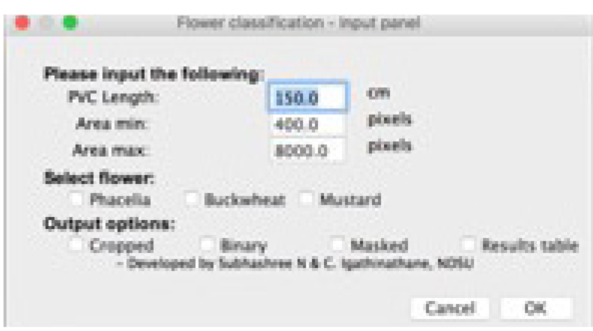

Fig. 2. Front panel of the developed plugin.

cover crop species considered. The experimental plot was located at the NGPRL in Mandan. Bee pollinator discrimination based on their floral traits among three different flower species (Phacelia, Buckwheat, and Mustard; Fig. 1) was studied in a bee visitation

Fig. 3. Equipment used for image acquisition.

research plot containing four main plots, each containing 16 subplots.

In these studies, several measurements were made manually to characterize the floral traits. Manual counting and area measurement using a ruler or thread to determine floral size is tedious, time-consuming, and subjective to errors. Hence, an image processing method was proposed as a better alternative for

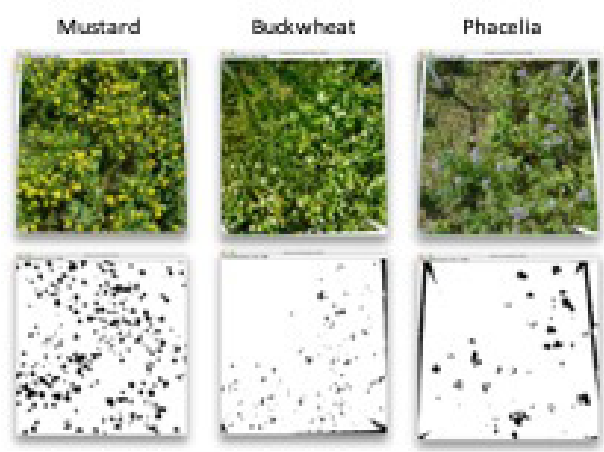

Fig. 4. Conversion of RGB to binary image through pre-processing and thresholding techniques.

flower classification and quantification in terms of floral count, average floral area, and percent floral coverage. An open source image analysis software (ImageJ) was used to develop the user-coded plugin specifically for this application (Fig. 2). A color DSLR camera and custom designed frame (1.5 m × 1.5 m) with legs were used in the test plots

Fig. 5. Flower quantification results (object count and floral percentage) displayed in log window

for capturing the inflorescence images (Fig.3). The images were captured weekly for a duration of about three months (June – August 2017), a total of 192 sample images (4 main plots × 16 subplots × 3 replications) were captured in a visit.

A sequence of image pre-processing and thresholding techniques was employed for the segmentation of flowers from the background (soil and plant material separation) inside the sample frame. The segmented flowers (mustard, buckwheat, and phacelia) from the background in the form of a binary image (black and white) was used for further analysis (Fig. 4).Flower quantification was performed on the binary image containing the extracted flowers and the results were displayed in the log window (Fig. 5).

Flower classification was executed using the color thresholding techniques. The successful classification of buckwheat and phacelia present in the same in the same image is demonstrated in Figure 6.

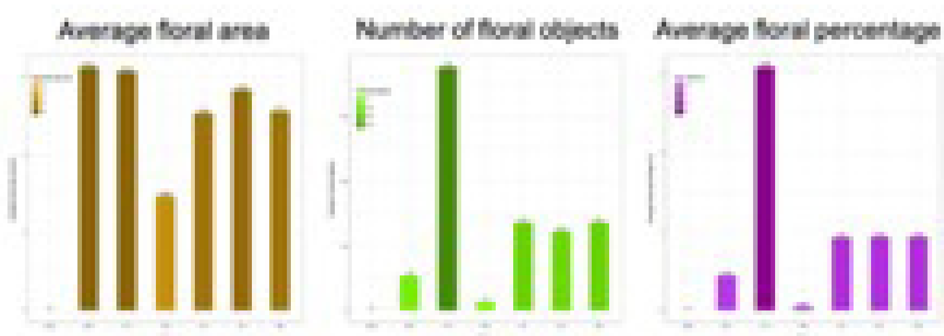

Fig. 7. Flower quantification results

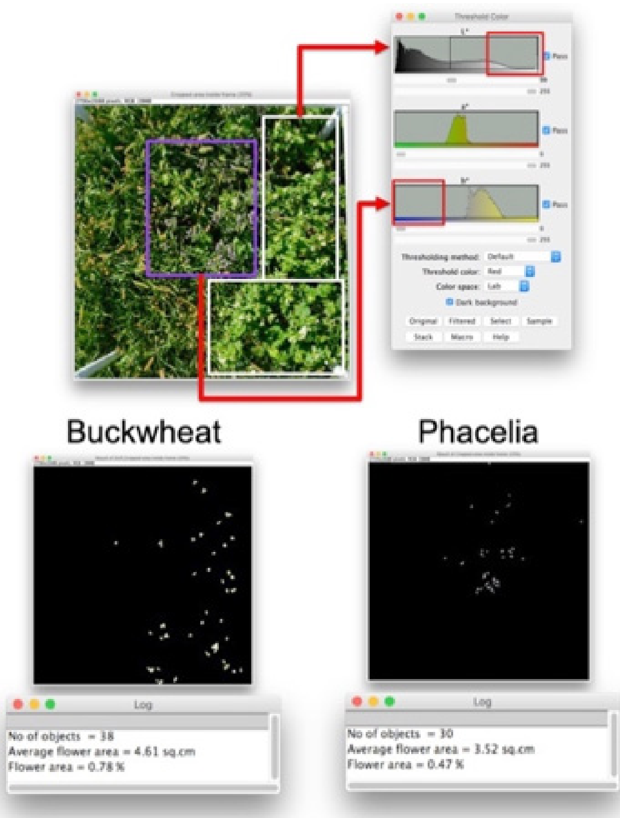

Fig. 6. Flower classification results – buckwheat and phacelia

Based on preliminary analysis it can be concluded that successful classification of flower species and quantification of floral count, floral area, and floral cover percentage was achieved with the developed plugin (Fig. 2).

Maximum floral count for phacelia was observed during the third week after planting. The floral cover percentage followed a similar pattern as the floral object count (Fig. 7).

A significant reduction in time was also achieved – manual counting of 196 objects required about 3 minutes, while the developed plugin required only 5 seconds.

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Sunflower plant-stand count, spatial distribution, and vigor analysis from UAV images using ImageJ

S. Sunoj, Drs. C. Igathinathane, J. P. Flores, NDSU Agricultural and Biosystems Engineering, Drs. D. Archer and J. Hendrickson, NGPRL, USDA-ARS

Plant-stand count, spatial distribution, and vigor are some of the important measures of the early season as it helps to (i) determine whether the target plant population was achieved, (ii) evaluate planter performance on seed placement and spacing, and (iii) obtain emergence growth characteristics of planted seeds. Evaluating these measures by field scouting is a common practice; however, it is time-consuming, painstaking, and only a partial field area can be covered. Use of unmanned aerial vehicle (UAV) images is currently replacing some of the field scouting methods as they are quick, easy, and can cover the entire field.

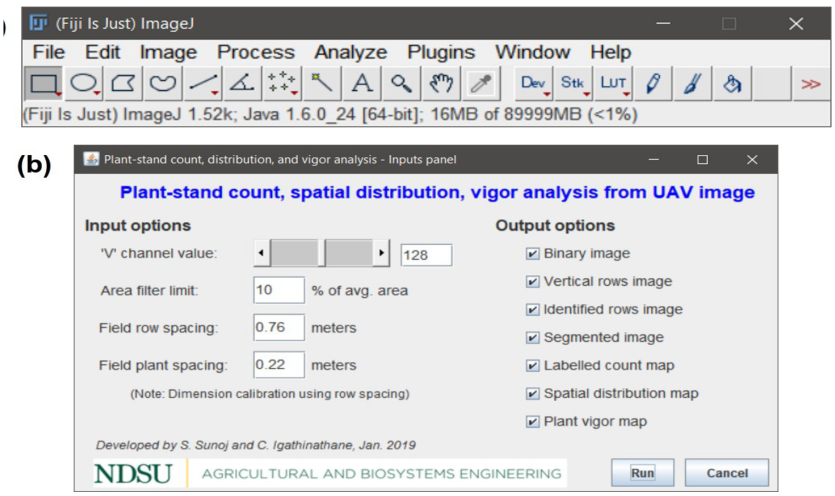

Fig. 1. The open-source and free Fiji software and the front panel of the developed plugin. (a) The simple interface of the Fiji software (Ver. ImageJ 1.52k; Java 1.6.0_24); (b) The front panel of the developed plugin with various input and output options.

To analyze the UAV image data, some commercial software exists. However, a simple, open-source and free software-based solution, and a consolidated method that worked with minimum user input requirements is not available. The basic commercial software itself is expensive and should carry an annual subscription (e.g., ≈$99/month), and to perform specific tasks, the user has to purchase additional analysis packages (e.g., stand count, plant health, weed mapping).

Most of the reported studies have included computationally intensive algorithms, such as Hough transform and machine learning methods, in which it is difficult for the user to comprehend the process (algorithm) involved in the application (black-box approach) and oftentimes users have no control on some of the program parameters. Also, the users have to upload the image to a cloud platform to perform the analysis, which gets into the "data-security" issues.

To resolve these issues, we proposed to use an open-source platform to develop a plugin with a suite of output options with minimal user inputs. The user-coded plugin was developed using Fiji (Fiji is just ImageJ, open-source image processing software; Fig. 1a) in Java that performed plant-stand count, spatial distribution, and vigor (foliage growth) from UAV images. The plugin starts with a custom-designed front panel (Fig. 1b) that had four generic inputs and seven output options. The user can choose the required options and the plugin starts processing the selected region of the input image when the 'Run' button was clicked. Such user-developed plugins will ensure data security, as the user can perform the analysis in-house, rather than uploading the image to any cloud based services.

The plugin performs several operations in the background and produces outputs in the form of images and textual data. The novelty of this research was that all the processing operations were developed from scratch using the "profile analysis" of the image pixels. The profile analysis is a simple procedure available in almost all the image processing software. In profile analysis, the number of white pixels along the individual vertical column in a binary image was counted and analyzed. Algorithms using geometrical principles were used to analyze the profile data and decipher various features to obtain the necessary outputs.

The sunflower experimental trial field from Carrington Research and Extension Center (47.52175° N, −99.11488° W) was used in this study. The images were captured when sunflower plants were in V2 and V4 stages. The UAV image used in this study

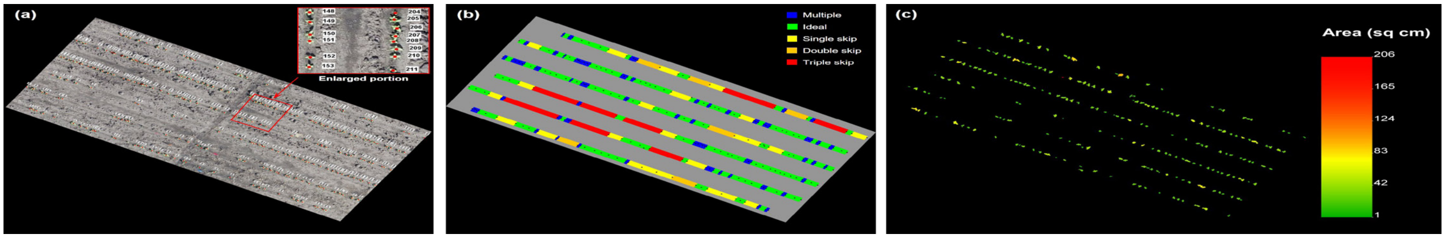

Fig. 2. Few outputs from the developed ImageJ plugin using the inclined field image as input. (a) Row-wise sequentially counted plants; (b) Plant spatial distribution map classified into five spacing classes – multiple, ideal, single skip, double skip, and triple skip; and (c) Plant vigor map with the legend indicating plants' projected area in cm2.

was obtained using a DJI Phantom 4 Pro has flown at an altitude of 12.2 m (≈40′) above the field. The built-in DJI's flight operation software produced a flight plan once the field was delineated using the polygon selection tool. The front and side overlap of each image was fixed as 80 %. The flight plan produced about 230 images, which was stitched using Pix4Dmapper Pro software. The resolution of the stitched image was ≈0.00331 m/pixel.

The plugin read the UAV image as an input, irrespective of planting pattern and plant rows inclination, and produced outputs plant-stand count, spacing distribution, and vigor for the selected portion of the field (Fig. 2).

The new approaches developed and included in the plugin are the following:

i. Image preprocessing – Conversion of color image to a binary image using YUV color space by adjusting only the V channel (new approach).

ii. Planting pattern determination – The plugin also determines automatically the planting pattern (lengthwise or widthwise) from the input UAV images. No studies so far have reported this planting pattern determination.

iii. Plant rows orientation determination – A simple and less computationally intensive method using profile was developed, unlike Hough transform.

iv. Crop rows identification – A fully automatic crop rows identification method was developed that tested successfully (e.g., row length of ≈100 m).

v. Plant clusters segmentation – Using the sideways profile, i.e., perpendicular to vertical rows, the clusters were resolved into the individual plant.

vi. Plant-stand count – Plants were counted row wise and sequentially labelled with resolved clusters (Fig. 2a).

vii. Plant spatial distribution – Inter-plant distance between plant centroids were calculated and the spacing was classified into five classes – multiple, ideal, single skip, double skip, and triple skip (Fig. 2b).

viii. Plant vigor analysis – Based on the projected area of the plant, a color-coded vigor map was generated to display the crop growth and health (Fig. 2c).

The plugin was validated using a few sections of plots cropped from the stitched image (≈45 m2 area). The visual count from the images served as the reference for comparison with the plugin count. Conclusions based on preliminary results indicate that the plugin can count the plants with an accuracy of ≥95 %. The CPU time taken to perform the analysis was ≈55 s in a Windows computer (Windows 10, 8 GB RAM, Intel i5 Processor, 2.20 GHz processor speed). The performance of the plugin is expected to be similar in any computer of with the same accuracy, provided the input image quality was good. Being an open source application, the plugin and the image data can remain within the users' control, thus ensuring data security.

Disclaimer: Mention of company or trade names of products is for description only and does not imply any endorsement by NDSU and/or USDA, as similar products will also be suitable for the purpose

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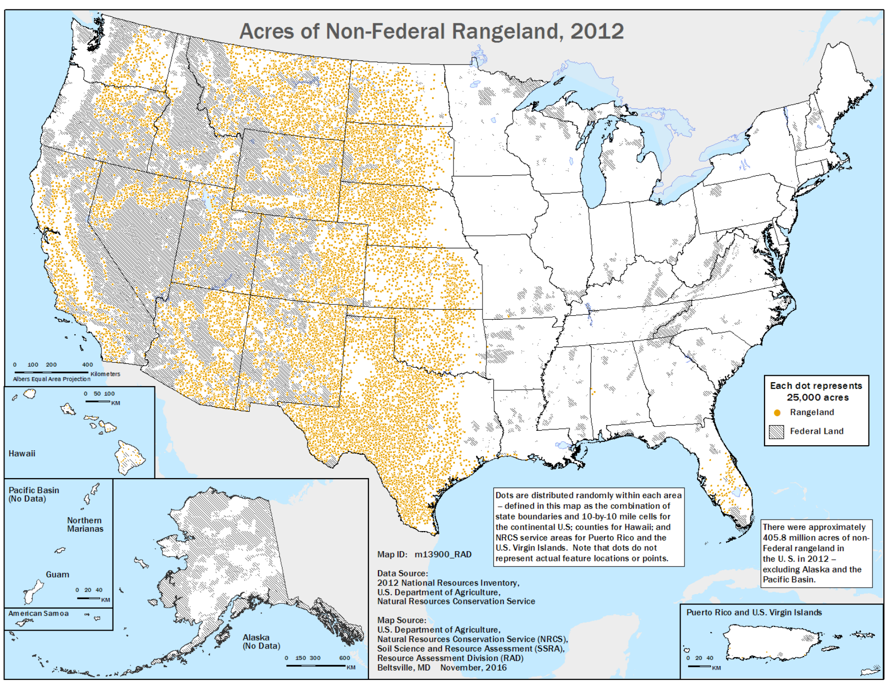
2018 National Resources Inventory (NRI) rangeland resource assessment

Dr. David Toledo

The 2018 National Resources Inventory (NRI) Rangeland Resource Assessment was recently released. This is the third NRI rangeland resource assessment; earlier reports were released in 2010 and 2014.

Dr. David Toledo, NGPRL Range Scientist, participated in the interagency group (ARS, NRCS, Department of Interior, Bureau of Land Management, U.S. Geological Survey, and the Forest Service) that worked together to develop field data collection protocols and data elements that could be used for national inventories.

The NRI survey program is scientifically based, employing recognized statistical sampling methods. The findings focus on key issues in rangeland science, including rangeland health, non-native plant species,



Acres of Non-Federal Rangeland, 2012. NRI rangeland on-site data has been collected in 17 western states from North Dakota to Texas and west. Rangeland NRI estimates of nearly 406 million acres of rangeland.

non-native and native invasive plant species, bare ground, inter-canopy gaps and soil surface aggregate stability. NRI rangeland data collected in 2004-2010 and 2011-2015 are used to provide estimates of change in rangeland conditions.

NRI is a statistical survey of land use and natural resource conditions and trends on U.S. lands. Data is continually collected from preselected spots representing hundreds of thousands of acres across the country including rangeland, cropland, and many Bureau of Land Management landscapes. With the assistance of a global positioning system (GPS), data collectors navigate to sample locations and collect on-site data.

Although NRI reports vary depending upon the land being studied, rangeland reports are focused primarily on key issues like rangeland health, non-native plant species, non-native and native invasive plant species, bare ground, inter-canopy gaps and soil surface aggregate stability.

Rangeland is defined by the NRI as a land cover/use category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland.

This includes areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied.

Rangeland data collected according to these protocols provide information that can be used to assess current conditions, and in the future as sites are revisited, data collected with these protocols will provide the basis for determining changes in rangeland conditions.

Lessard, V., Spaeth, K., Fults, G., Talbot, C., Metz, L., Pyke, D., Herrick, J.E., Toledo, D.N., Goslee, S.C., Krueger, T., Musser, K. 2018. 2018 National Resources Inventory (NRI) Rangeland Resource Assessment. Government Publication/ Report. https://www.nrcs.usda.gov/wps/portal/nrcs/main/ national/technical/nra/nri/

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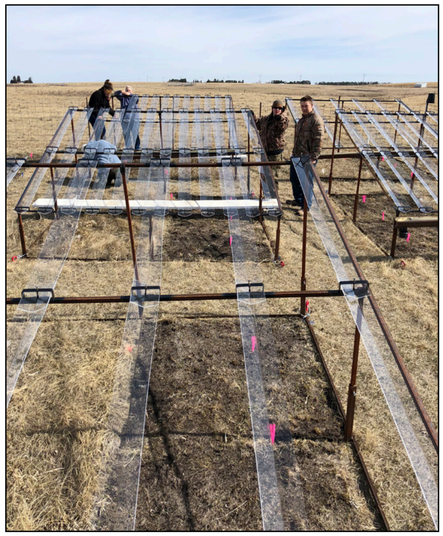
Effect of cool-season invasive grasses on pollinators and wildlife species

Dr. David Toledo



Kentucky bluegrass (Poa pratensis) and/or smooth bromegrass (Bromus inermis) invasion in the northern mixed grass prairie has been rapid and wide spread. Plant foliar cover and plant biodiversity data from the USDA-ARS Northern Great Plains Research Laboratory, near Mandan suggest that Kentucky bluegrass now covers between 3 and 54% of the pastures sampled and as cover of Kentucky bluegrass increases plant species richness decreases. These data also show how, despite decreases in native species richness and overall biodiversity at a plot scale, at the landscape scale we still see the presence of 140 different native species. Suggesting that management that maintains higher levels of diversity is still within the realm of possibilities.

Data collected by Bob Patton at the NDSU Central Grasslands Research Extension Center between 1988 and 2014 also show an increase of Kentucky bluegrass and smooth bromegrass. These data also show the effect of grazing intensity of these two grasses and the effects of grazing on plant species richness. These data suggest that moderate to heavy grazing of pastures invaded by K. bluegrass and smooth brome can provide an advantage for maintaining species diversity. However, depending on how heavy the grazing, the overall production of heavily grazed pastures might be negatively affected. This stresses the importance of having clearly defined management objectives that weigh the pros and cons of potential management actions.

Despite accelerated expansion, the consequences of Kentucky bluegrass and/or smooth bromegrass on other ecosystem processes remain largely unknown. A review of current available literature suggests that K. bluegrass invasion may have negative effects to ecosystem services, including declines in native pollinators and loss of habitat for wildlife species.

Although most pollinators do not use Kentucky bluegrass directly, the association between Kentucky bluegrass and loss of native plant diversity suggests Kentucky bluegrass may be indirectly affecting pollinators. Diverse vegetation supports a variety of pollinators, providing pollination services necessary for many plants to reproduce and/or produce a crop. Research suggests that plant invasions and loss of native habitat can have a negative effect on pollinator diversity. However, specifics about pollinator types lost because of Kentucky bluegrass and the impacts of these losses is still not well understood.

In terms of wildlife habitat, one of the most important factor associated with population changes of grassland obligate species is loss of native habitat. Loss in vegetative composition and structure favors generalist species that can tolerate a more homogeneous habitat. While bluegrass and bromegrass can be of some value, little information exists on the effects of these grasses on vegetation composition and structure for wildlife.

Current research being performed at the NDSU CGREC, aims to address some of our knowledge deficiencies regarding impacts of invasion of bluegrass and smooth brome on pollinators and wildlife species. Additionally, this new research also aims to address ways to manage this invasion using natural disturbances such as fire and grazing combined with novel management approaches such as patch burn grazing. At the USDA-ARS NGPRL, there is also ongoing research aimed at determining the effects of burning and drought on plant composition and forage value of bluegrass invaded areas.

In terms of expanding our possibilities to adapt to change and apply precautionary measures while this new research bears results, maintaining a broad suit of native forage species that are adapted to site specific conditions will likely yield the greatest long term benefits in terms of livestock production and the sustainability of the rangelands ecosystems.

**An earlier version of this article appeared in the Spring 2018 newsletter of the NDSU Central Grasslands Research and Extension Center.*

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Cover crop plantings can benefit managed or wild bees, but not both?

Drs. Jose G. Franco, USDA-ARS Research Ecologist, Rachel Mallinger, Entomologist, University of Florida and Jarrad Prasifka, USDA-ARS Research Entomologist

Fig. 1. Bumble bee (Bombus spp.) visiting phacelia, honey bee (Apis mellifera L.) visiting buckwheat, and a native wild bee visiting sunflower in research plots in Mandan, ND (photos credit, Jose Franco).

The flower-rich grasslands of the Northern Great Plains (NGP) have historically been a primary place for managed honey bee hives to spend the summer. This provides them with adequate forage to recover from the stresses related to pollination services and the transport process. As a result, the NGP region contributes most of the honey produced in the United States. North Dakota alone produces 23% of the nations' honey, making it a multimillion-dollar industry for the state (USDA, 2017).

North Dakota also has a species-rich native wild bee community and grows many crops that benefit from insect pollination including sunflowers, buckwheat, dry edible beans, canola and other oilseeds. Rising demand and prices for biofuels, as well as advancements in plant breeding and changes in climate patterns that have increased the suitability of the region for crops not historically grown here, have resulted in the conversion of many acres of crop and conservation land to corn and soybean production. This has led to a reduction in floral resources across the landscape with consequences for both managed and wild pollinators.

The strategic introduction of cover crops across the landscape is one way of diversifying floral resources to benefit pollinators. In addition to providing resources for wildlife, suppressing weeds, reducing soil erosion, improving soil fertility and providing supplemental farm income through grazing opportunities, cover crops can provide season-long forage resources necessary for bee winter survival. In contrast to perennial wildflower conservation plantings, annual cover crops are often less expensive and quick to flower. This makes them ideal to use as a temporary planting as part of a crop rotation, on fallow fields, or on prevented planting acres.

The conservation value of planting annual cover crops will depend on several factors. Such factors include floral density, diversity of cover crops and,

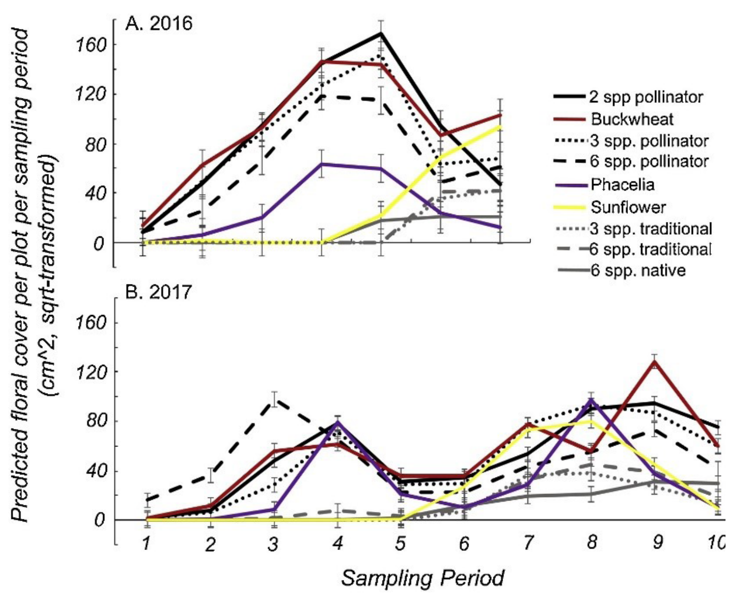

Fig. 2. Floral cover per plot per sampling period over the growing season for different plant treatments in 2016 (A) and 2017 (B).

consequently, diversity of floral resources throughout the growing season, and whether they provide resources for common bee species thriving in the landscape or provide resources for rare or threatened species. There is a need to better understand the role annual cover crops play in providing resources for both managed and wild pollinators in this agriculture-rich region.

To help address this, scientists from two North Dakota USDA labs conducted a study at the Northern Great Plains Research Lab to evaluate the potential for cover crops to provide supplemental floral resources throughout the growing season. Cover crops were planted in 1, 2, 3, and 6-species "pollinator" mixes (cover crops selected for their potential attractiveness to pollinators) and in 3 and 6-species "traditional" mixes (cover crops typically used in the region for soil, grazing, and other benefits). A native annual wildflower mix was planted for comparison. Bee visitation on cover crop treatments was also compared with bee visitation on an adjacent grassland. Floral density throughout the season, total bee visitation rates and bee visitation rates throughout the season, and attractiveness of plants to bee species of conservation concern were compared.

Results from the study found that annual cover crop mixes designed to attract pollinators can provide abundant summer-long floral resources for bees, but there is an overall trade-off between attracting many bees of common species versus attracting fewer individuals of conservation concern. "Pollinator" mixes containing buckwheat generally provided greater season-long floral density than other treatments (Fig. 2), and high floral density resulted in high bee visitation rates (Fig. 3). Phacelia was most attractive to social generalist pollinators (honey bees and bumble bees) and cultivated sunflower and native wildflowers were more attractive to solitary bees (rare and specialist bee species). The inclusion of cultivated sunflower in a mix generally resulted in lower overall floral display due to the short bloom period of cultivated sunflowers. This led to the displacement of other longer-blooming plants like buckwheat and phacelia resulting in lower bee visitation rates (Fig. 4).

Poor stand establishment of the native annual wildflower mix made it difficult to compare floral

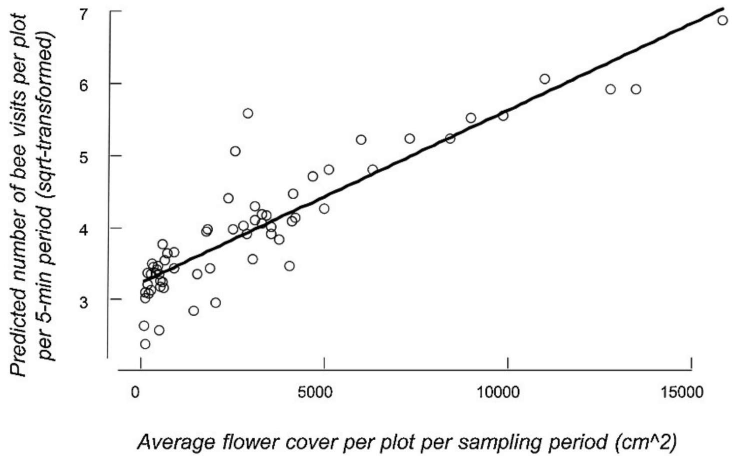

Fig. 3. Relationship between average bee visitation rate and average floral cover per plot.

cover and bee visitation with annual cover crop mixes. When comparing the number of bee species found in an adjacent grassland to cover crop treatments, 30 species were collected from within cover crop plots, 48 species were collected in the grassland, and 21 species were found in both areas. The dominant flowering plants in our cover crop treatments (buckwheat, phacelia, and cultivated sunflower) attracted between 12 and 14 bee species each, while flowering plants attracting the highest number of bee species in the grassland (milk thistle, western snowberry, and bee balm) attracted 13 bee species each. Fifteen of the bee species collected are thought to be "declining", with 4 of those species declining to the extent that they are considered threatened. Of the 15 "declining" species, 5 were found in the adjacent grassland, 2 were found in cover crop plots, and 8 were found across both habitat types.

To summarize, diverse cover crop mixes may support a broad community of pollinators, but these diverse plantings may be less likely to attract a high number of bees of a given species. A trade-off exists between attracting managed and common bees such as bumble bees and honey bees versus attracting wild bees of conservation concern. Therefore, optimal plantings will depend on management goals. Of the treatments used in the study, the three-species mix containing buckwheat, phacelia, and cultivated sunflower may be the best approach for attracting both managed and wild bees in this region.

Adapted from Mallinger, R.E., J.G. Franco, D.A. Prischmann-Voldseth, and J.R. Prasifka. 2019. Annual cover crops for managed and wild bees: Optimal plant mixtures depend on pollinator enhancement goals. Agriculture, Ecosystems and Environment 273:107-116.

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Understanding the role of prescribed fire in the northern Great Plains

Dr. David Toledo

Re-introduction of prescribed fire may be one of the best ways to combat Kentucky bluegrass invasion in the Northern Great Plains, but physical and societal constraints currently limit its use. Our research aims to address constraints to fire application and identify pathways for increased prescribed fire application.

To address societal constraints we mailed a self-administered questionnaire to 460 landowners in North Dakota to identify landowner attitudes and perceptions towards prescribed fire and understand major factors that limit the use of fire in rangeland management of this area.

Our results indicate that in general, survey respondents had positive attitudes towards prescribed fire and believe prescribed fire is a beneficial tool for restoring rangelands with 22% of respondents having performed a prescribed fire on their land. Many respondents also agreed that they were concerned about the potential negative effects of a prescribed fire on their neighbor's property.

Once respondents have decided to include the periodic use of prescribed burns as part of their management plans there is a strong likelihood that they will perform a prescribed fire. However, there is also a moderately strong likelihood that if the landowner perceives constraints, the prescribed burn will not be implemented. We found that financial resources, and to a lesser extent, time and equipment, were seen as limitations to implementing prescribed burns in our study area.

Our research identifies a gap between respondents agreeing that fire is a beneficial tool for rangeland management and actual fire implementation. We propose that focusing on indirect factors influencing burn intention (e.g. attitudes, norms, and knowledge), reducing direct constraints (labor and equipment), and increasing outreach on the benefits of prescribed fire to ranchers, will be most effective at changing burn behavior in the study area.

Research by others has shown that ranchers tend to rank forage production as one of their main objectives, the potential of fire to increase crude-protein and forage value suggests another potential avenue to increased adoption.

To address some of the more tangible constraints to fire application identified by our respondents, the development of prescribed burn associations can be a compelling approach.

Prescribed burn associations have been identified as a very effective institutional structure for promoting the use of prescribed fire at a landscape scale; therefore, they can provide a critical role in maintaining or restoring ecosystem integrity. Prescribed burn associations create networks that strengthen social capital, can change attitudes towards the use of prescribed fire, and have been shown to enhance the social acceptability of prescribed burning as a management practice. Most importantly for North Dakota landowners, prescribed burn associations also provide educational opportunities, training, equipment, and labor.

Use of prescribed fire to manage grasslands is also limited by local weather conditions. To use this practice successfully, managers must understand the seasonal windows within which prescribed fire can be applied and how fire behavior could potentially vary among these windows.

To characterize prescribed fire windows within the northern Great Plains of North America we collected data from 20 remote weather stations positioned across North Dakota and northwestern Minnesota, USA from station inception to 2015. We performed an hourly analysis for each station to determine if air temperature (2 - 43 °C), relative humidity (25- 80%), and wind speed (6.44 – 24.12 km h-1) conditions were within acceptable ranges for at least six contiguous precipitation-free hours from 8:00 to 18:00 hrs.

We summarized acceptable conditions over five half-season windows and then used the Rothermel fire spread equation to simulate fire behavior within these half-season windows based on average, minimum and maximum conditions for seasonally appropriate live herbaceous to fine dead fuel ratios. While the number of acceptable prescribed fire days did not change from early spring (21 March) to early fall (6 November), the number of acceptable days for conducting spring fires decreased and the number of acceptable days for conducting late summer to early fall fires increased over the study period. Prescribed fire planning needs to take into account when fire windows exist within a year and how these conditions affect fire behavior.

In the northern Great Plains, there is ample opportunity for grassland managers to use summer and fall prescribed fires and managers should expect to get variable fire behavior results when prescribed fires are applied in more extreme conditions throughout the year.

Cayla Bendel, David Toledo, Torre Hovick, Devan McGranahan. In review. Identifying strategies to affect burn behavior by studying factors influencing prescribed fire application in North Dakota. Rangeland Ecology and Management.

Kathryn A Yurkonis, Josie Dillon, Devan McGranahan, David Toledo, Brett Goodwin. In Press. Seasonality of prescribed fire weather windows and predicted fire behavior in the northern Great Plains. Fire Ecology.

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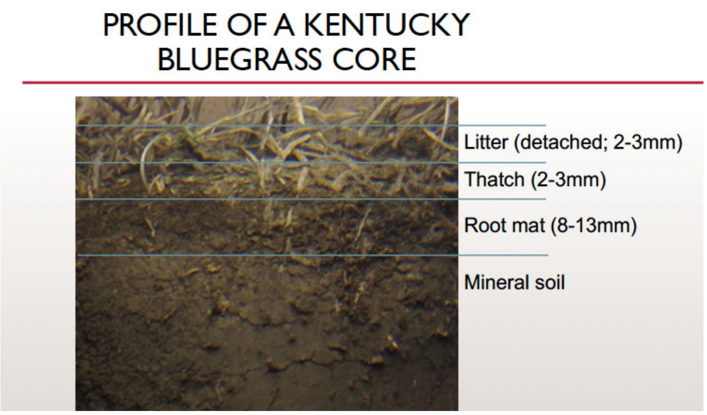
Hydrologic effects of grazing and prescribed fire on Kentucky bluegrass dominated rangelands

Dr. David Toledo

Kentucky bluegrass is in over 85% of the areas sampled in the U.S. northern Great Plains. This grass can develop a dense thatch layer and root mat near the soil surface, which can affect how water infiltrates and runs off of a site. Thatch is a tight layer of living and dead plant material that accumulates between the plant canopy and the soil surface of perennial grasses and results from an imbalance between production and decomposition of organic material. Various thatch management strategies have been proposed to mitigate thatch accumulation and reduce soil hydrophobicity but these techniques have predominantly focused on turf systems not rangelands. In natural ecosystems, grazing and prescribed fire have been proposed as management strategies to reduce thatch accumulation.



Our objective was to combine data from rainfall simulation experiments, water droplet infiltration time tests, and molarity of ethanol droplet tests to determine whether the presence of Kentucky bluegrass litter, thatch, and root mat layers affect water infiltration and therefore hydrologic function of Kentucky bluegrass-dominated ecosystems of the Northern Great Plains. These data also present the opportunity to investigate how management by grazing and burning affect the hydrologic response in systems invaded by Kentucky bluegrass.

Rainfall simulation experiments were conducted at three sites in the northern Great Plains. Two study sites were located at the USDA Agricultural Research Service Northern Great Plains Research Laboratory and the third site was located at The Nature Conservancy's Cross Ranch Preserve near Center, ND.

Rainfall simulation on dry soils (less than 20% volumetric water content) revealed that the time needed to initiate runoff was shortened by 5 minutes and the runoff ratio increased by 0.004 for every percentage point increase of Kentucky bluegrass in the vegetation cover. On dry soil strata, water drop penetration time increased by 20 seconds on litter and 3 seconds on thatch for every percentage point increase in Kentucky bluegrass in the vegetation, confirming the close association between this grass species and the development of soil hydrophobicity. However, bluegrass litter is less water repellant after it has been wetted. Hydrophobicity dramatically declined in the thatch layer by a factor of 4 and was completely absent from the litter layer after wetting. In contrast to the rainfall simulations on dry soils, wet runs (volumetric water content ≥ 20%) showed a beneficial effect of Kentucky bluegrass on hydrologic response with delayed runoff by 5 minutes and reduced runoff ratios by 0.003 for every 1% increase in Kentucky bluegrass in the vegetation cover.

Grazing and burning were accompanied by an increase in hydrophobicity but did not adversely impact hydrologic function (discharge or cumulative runoff). The nuanced relationship found between Kentucky bluegrass invasion and hydrophobicity and runoff production suggests the need for a risk assessment approach to invasion effects on rangeland hydrology that incorporates the probability and outcome of intense rainfall events. This approach requires comparative research on paired invaded and native rangeland sites -- a difficult objective considering the ubiquity of Kentucky bluegrass on the NGP.

Sayjro Kossi Nouwakpo, David Toledo, Mark Weltz, Matt Sanderson. In Press. Understanding the Effects of Grazing and Prescribed fire on Hydrology of Kentucky Bluegrass Dominated Rangelands in the Northern Great Plains. Journal of Soil and Water Conservation.

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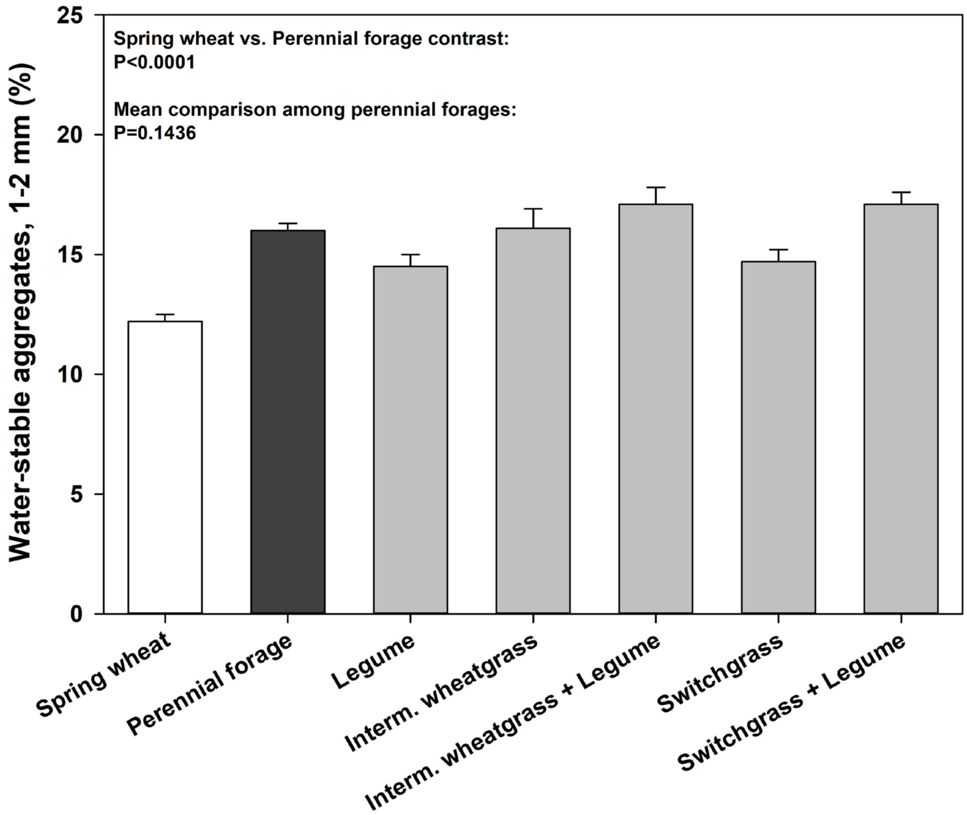
Perennial forages important for improving soil health

Dr. Mark Liebig

Adding perennial forages in annual cropping systems can offer significant benefits to agricultural landscapes. In addition to providing feed for livestock, perennial forages improve nutrient and water cycling, increase wildlife habitat, and provide novel educational and recreational opportunities for people of all ages.

Some landscape-scale benefits associated with perennial forages are due to changes in soil properties. Under perennials, limited soil disturbance and increased organic matter inputs from roots lead to changes in soil properties which can improve soil health.



Despite this logical connection, management guidance for producers regarding use of perennial forages in annual cropping systems is lacking. Specifically, the length of time needed for soil health improvements to occur under perennial forages is unclear. In part, this is due to differences in forage types and productivity across regions.

To address this need, NGPRL scientists conducted a multi-year study to measure changes in soil properties under perennial grasses, legumes, and grass-legume mixtures at an experimental site near Mandan, North Dakota. Soil measurements were made over a five-year period, and included continuous spring wheat as an annual crop control.

Relative to continuous spring wheat, perennial forages reduced soil acidification and soil bulk density, and increased aggregate stability (Fig. 1) and a moderately-degradable pool of soil organic matter.

Results suggested that soil responses to perennial forages occurred as soon as two years after forage establishment, but peaked four years after establishment.

Among perennial forages, intermediate wheatgrass alone or mixed with alfalfa reduced soil bulk density and increased moderately-degradable organic matter compared to alfalfa, but such differences took four to five years to be detected.

Outcomes from the study suggested perennial forages maintained or improved near-surface soil health, but effects were subtle and were generally slow to occur. Results also showed the importance of strategic management (e.g., no-till, cover crops, increased residue retention) to ensure improvements in soil heath are preserved between perennial-annual transitions

Adapted from Liebig, M.A., J.R. Hendrickson, J. Franco, D.W. Archer, K. Nichols, and D.L. Tanaka. 2018. Near-surface soil property responses to forage production in a semiarid region. Soil Sci. Soc. Am. J. 82:223-230.

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Soil quality and water redistribution influences on plant production over low hillslopes of reclaimed mined land

Dr. Steve Merrill

Understanding interactions among plant growth, soil quality (SQ), and landscape hydrology can serve to guide management decisions for optimizing ecosystem services on agricultural landscapes.

We applied both SQ assessment and an index of water redistribution to resolve the influence of soil and land factors on plant productivity for mined land reclamation sites in central North Dakota.

At one site near Zap, North Dakota, cool-season forage grasses were more influenced by hillslope water redistribution while spring wheat yield showed influence of SQ and depth in the lower part of the hillslope and water redistribution in the upper part of the hillslope. At the site near Stanton, North Dakota, perennial forages and spring wheat showed similar patterns of growth response, with SQ and depth effects lower on the hillslope and water redistribution effect on the upper part.

Results of this study suggest plant community and soil characteristics on reclaimed, disturbed lands can alter the relative influence of SQ factors and water distribution effects on hillslope production patterns.

This outcome is relevant to not only land managers dealing with reclamation of disturbed lands, but to agricultural producers in general.

A basic part of soils' delivery of ecosystem services is the interaction between plant growth response to soil quality (SQ) factors at point scale and water redistribution effects at hillslope scale.

To study the influence of SQ-indicator properties and water redistribution, we examined hillslope production patterns of perennial forage species and spring wheat, and the relationships of such yield patterns with respread soil depth (RSD), SQ index (SQI) and hillslope wetness from catchment area (HW(a)) within two mined land reclamation experiments in central North Dakota (Zap and Stanton).

At Zap, yield of cool-season forages crested wheatgrass and Russian wildrye increased about 10% with increasing RSD from toeslope to about 10 m upslope, and then declined by greater amounts further upslope.

These hillslope patterns appeared dominated by water redistribution effects, reflecting response of cool-season forages to springtime water availability.

Forage species at Stanton included alfalfa, native grass mix, and crested wheatgrass. Growth of these increased 70% from toe to midslope, and then decreased 20% towards summit, indicating a greater response to RSD and SQ factors downslope and lesser response to water redistribution upslope.

Hillslope patterns of spring wheat seed yields at both sites were similar to those of forages at Stanton, showing greater response to SQ metrics.

Factors likely to be involved in production patterns at Stanton exhibiting greater response to SQ measures than at Zap were, (a) indications that hydraulic conductivity in the mine spoil at Stanton was lower than at Zap, and (b) Stanton had south aspect only, while Zap had north and south aspects. Regressions of perennial biomass yields vs. soil characteristics were consistent with hillslope production results, with positive responses to HW(a) and negative responses to RSD and SQI for forages at Zap, but positive responses to SQ measures for forages at Stanton.

Results indicate that plant community and soil characteristics on reclaimed, disturbed lands can cause a shift in the relative influence of SQ factors vs. water redistribution on hillslope production patterns .

Merrill, S.D., Liebig, M.A., Hendrickson, J.R., Wick, A. 2018. Soil quality and water redistribution influences on plant production over low hillslopes on reclaimed mined land. International Journal of Agronomy. Vol. 2018, Article ID 1431054, 12 pages. doi.org/10.1155/2018/1431054

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Fetal programing and winter feeding

Dr. Rachael Christensen

Feeding beef cows farm-raised forage to supplement winter pasture in the Northern Great Plains effects feed costs. In addition, cold weather in winter forces producers to strive to feed enough to maintain a consistent body weight or condition (also known as BCS, body condition score, a visual assessment of fat and muscle ratio in the cow mass). Increased exposure to cold winter conditions can reduce cow body weight, and excessively thin cows face increased stress during bad weather.

In these situations, it takes more feed to put weight back on a cow during cold weather and feeding in winter increases labor. Of keen interest is the effect of the cow's weight loss on the fetal calf, since the second trimester of pregnancy in cattle has been shown to be a critical time for maternal programing of fetal development of skeletal muscle and adipose tissue.

Winter feed management is a tool to conserve feed while maintaining cow health and productivity. Producers can meet goals of a good calf crop that performs well in the feedlot and has good carcass quality. Questions often arise, how much cow weight could be lost, and what is the effect of the weight loss on the cow and subsequent offspring?

Results from a study I was a part of at Utah State University suggest that reducing feed supplementation during the second trimester of gestation might not have dire consequences on future calf growth and development. Though this study was a one-year snap shot where long-term effects were not evaluated, valuable insight was gained. Pregnant cows were sorted into two groups with similar initial body weight. During the second trimester of pregnancy, one group of cows (restricted) were housed in a small pasture with limited availability of forage, wherein they lost on average one BCS. In contrast, the control group was provided a larger pasture treatment, supplemented with hay, and otherwise managed to experience no change in body condition during that same time. In the third trimester of pregnancy, all cows grazed together in a supplemented pasture, where the restricted cows were able to gain back the weight. Seven weeks after the end of treatment,

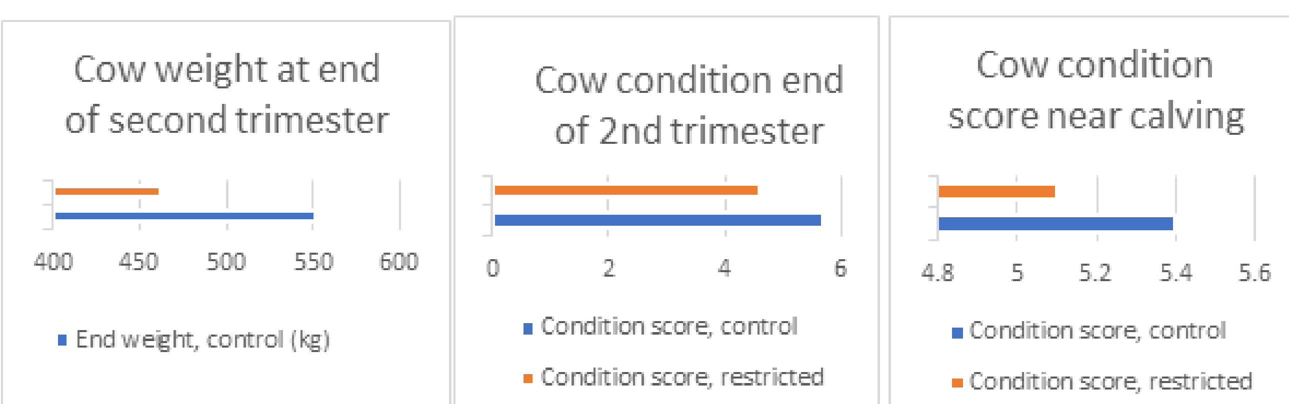

Fig. 1. Comparison of cow body weight and condition between two groups fed differently during the second trimester of pregnancy

there was no difference in BCS between the two treatment groups (Figure 1). The study revealed that a significant loss of weight occurred in restricted cows during this period of pregnancy, but that restricted cows recovered adequately before calving.

But what about the calves? Were they affected? Weaned calves from both groups of cows were fed a typical background ration in the same pen for 7 weeks. The calves were then sorted into individual pens, fed a grower ration for the first 84 days, then each week's diet calorie amount slowly increased until reaching a final high energy ration with daily measurement of individual feed intakes. Calves were weighed periodically and were shipped to a commercial harvest facility once an average backfat thickness of 7.0 mm was reached. Average daily gain, gain: feed, and feed intakes were not different between calves from each group of cows. Carcass quality was evaluated and was not different.

Blood was sampled 7 days after weaning and 84 days into the feedlot phase. These blood samples were analyzed to monitor growth factors and parameters that might indicate stress or poor well- being. Despite differences in maternal body condition during pregnancy, during the finishing feeding of calves there was no difference ($P > 0.10$) in calves' blood concentrations of glucose, cortisol, insulin or insulin-like growth factor-1 (IGF-1: see table).

It seems therefore that cows might be able to lose some body condition in the second trimester of pregnancy, and yet have successful outcomes in their calf crop. In this study, cows gained back their body condition in the third trimester, long before the breeding season. Producers could conserve feed and reduce labor by feeding less to the cows during winter with little effect on cow condition and calf growth and health.

Item, unit of measurement	Control	Restricted	P-Value
Plasma glucose, mg/dL	73.75	76.78	0.50
Plasma IGF-1, ug/L	178.84	162.84	0.53
Plasma Insulin, ug/L	0.74	0.94	0.44
Serum cortisol, ug/dL	2.73	2.59	0.71

Table 1. Serum and plasma values of various metabolic markers taken from calves at the beginning of feedlot phase. Calves were born of dams that maintained (control) or lost body condition (restricted) during the second trimester of pregnancy.

I am planning future studies of sustainable feeding of harvested forages, native prairie pasture, and pastured and harvested cover crops that will increase our understanding of cost-effectively feeding wintering beef cows while producing a hardy and efficient calf crop.

Source: The influence of maternal dietary intake during mid-gestation on calf growth, feedlot performance, and miRNA expression in skeletal muscle of the resultant offspring. (In review process)

*N.E. Inecka, J.M. Gardnerb, S.M. Quarnbergb, R.G. Christensena, C.E. Carpenterb, K.A. Rooda, D. Zobella, J.F. Legakoc, K.J. Thorntona,**

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A potentially easier way to determine daily forage intake of grazing cattle for various purposes

Dr. Scott Kronberg

If we had a simpler and less expensive way to determine how much forage individual cattle graze each day, more rangeland and cattle managers could obtain this information to use in a variety of ways to improve their management of land and/or cattle. For example, cattle producers and breeders could use the information to help determine which animals to keep and which to cull and scientists could use this information for various research projects. So, what if we could collect a sample of fresh feces from each animal of interest, dry the feces then scan it with a near-infrared spectrometer (NIRS) and use the data output from the scanned feces to develop an equation to accurately predict each animal's daily dry forage intake? Near-infrared spectroscopy is used for many purposes including predicting the quality of forages, grains, oilseeds, and other agricultural products. It has also been used to predict diet quality of grazing cattle, sheep and goats by scanning small samples of their dried feces and entering the NIRS output data into a prediction equation to predict the percentage of crude protein and digestible matter in their diets.

Photo of forage auto-feeders

A prediction equation is developed with pen-fed animals with diets of known forage quality and daily feed intake.

What we plan to do over the next few years is use low-labor auto-forage feeding and measuring equipment with penned cattle to develop prediction equations with fecal NIRS for different types of forage and cattle and determine if we can accurately predict daily forage dry matter intake for individual cattle while they consume different types and qualities of forage.

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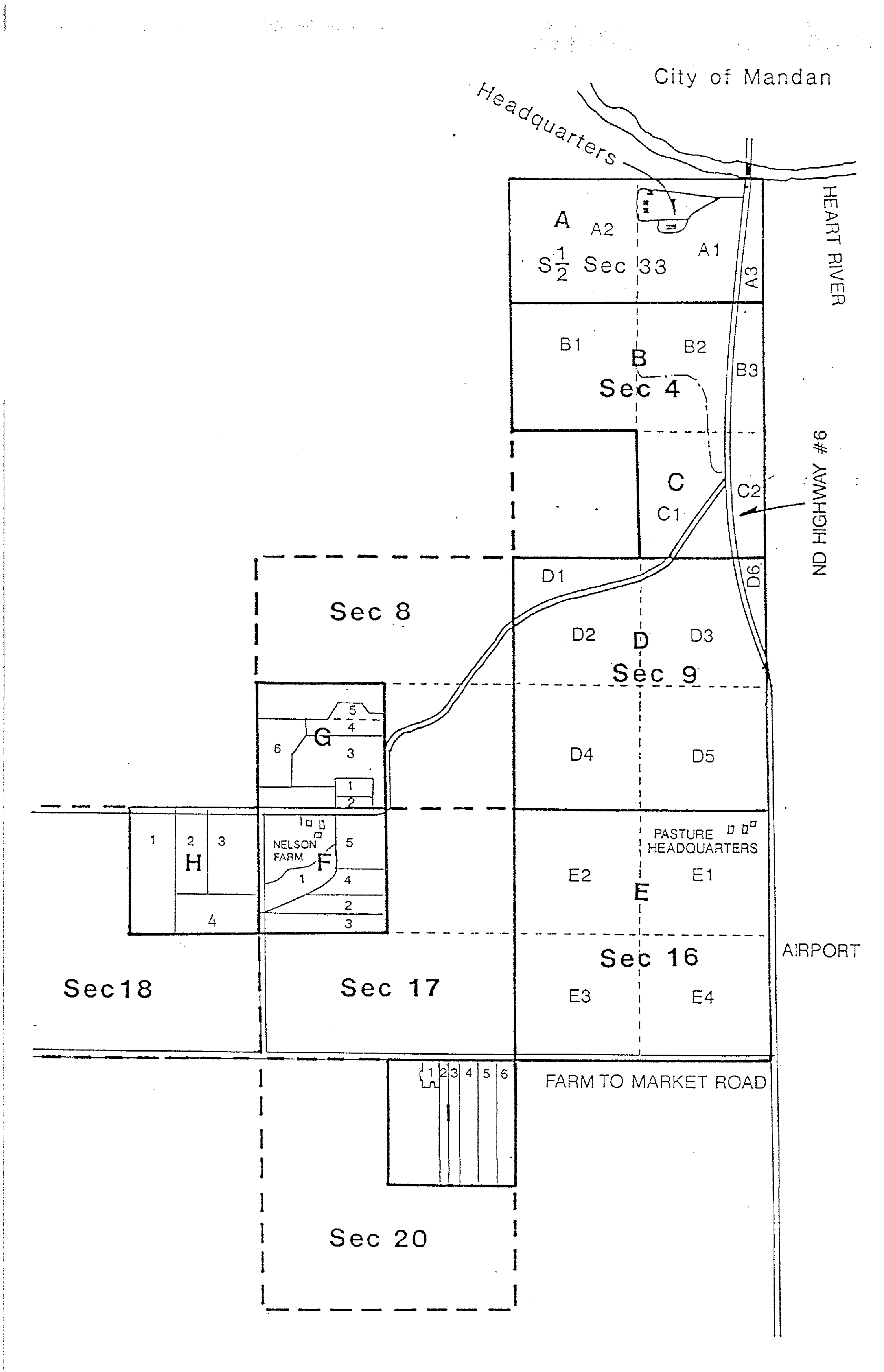
USDA-ARS LAND RESOURCES (FEDERAL & STATE) A, B, C, D, AND E

AREA 4 SCD COOPERATIVE RESEARCH FARM

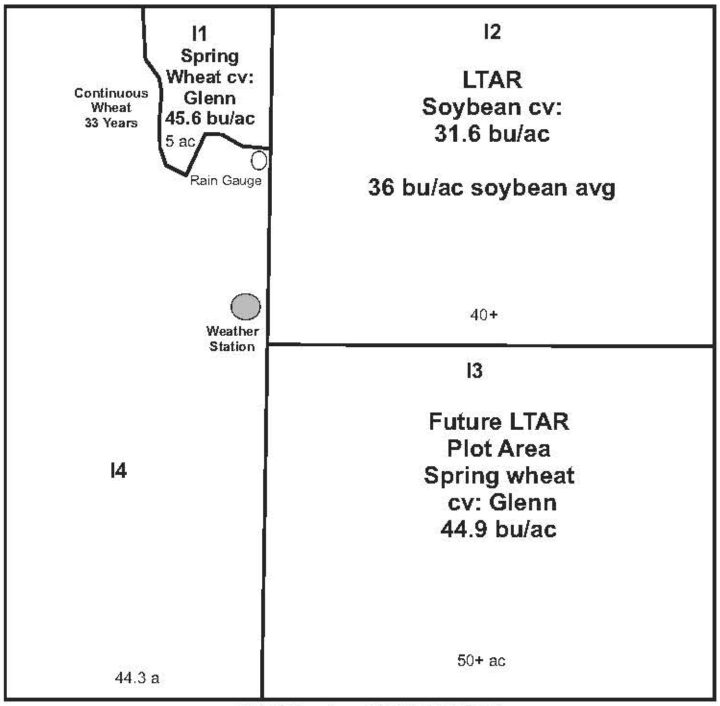
LAND RESOURCES F, G, H, AND I



2018 Area IV Research Farm

(11-14-18)

Area I



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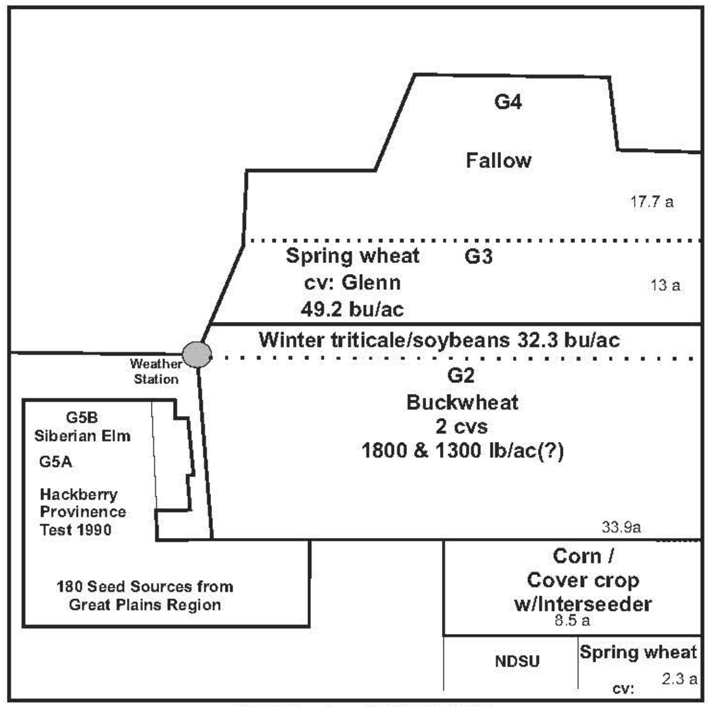
Area G



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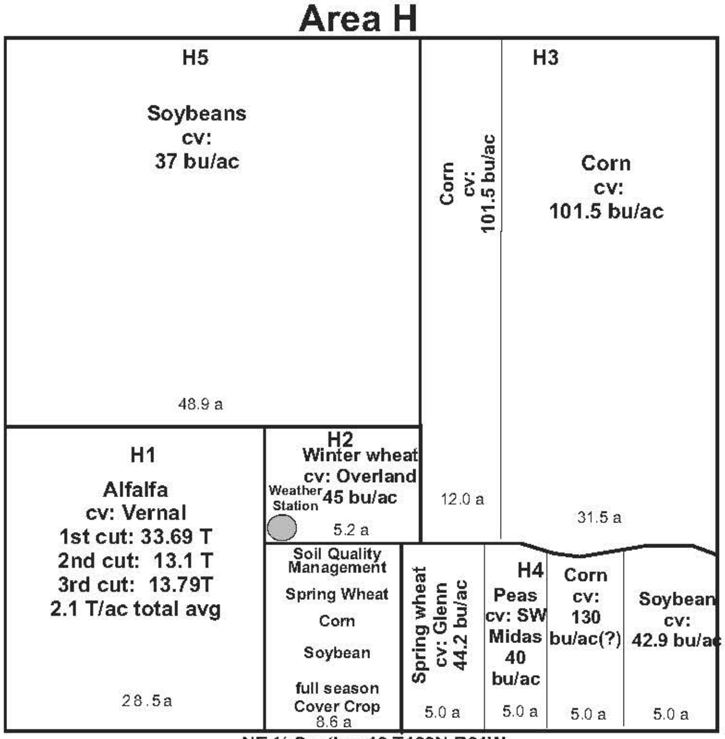
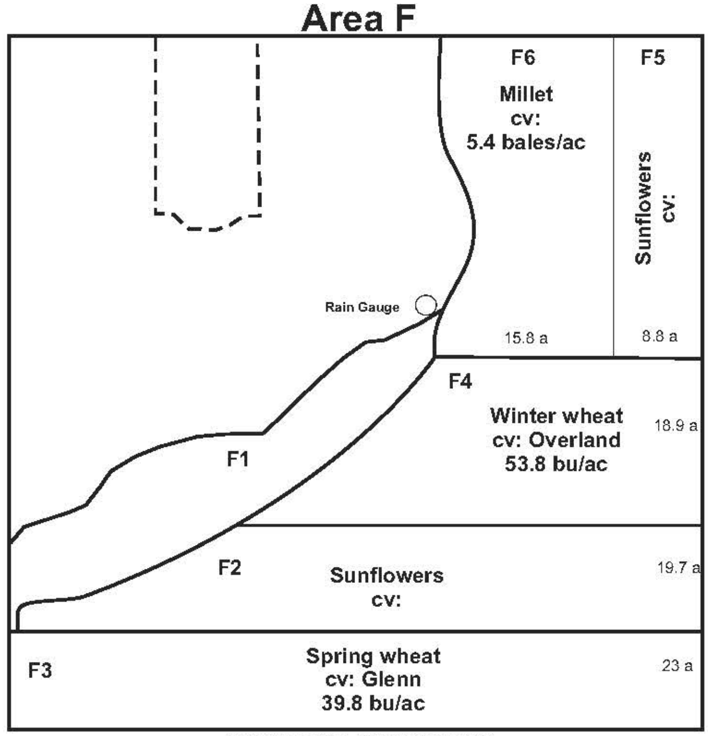
Area H



NE ¼ Section 18 T138N R81W

Area F



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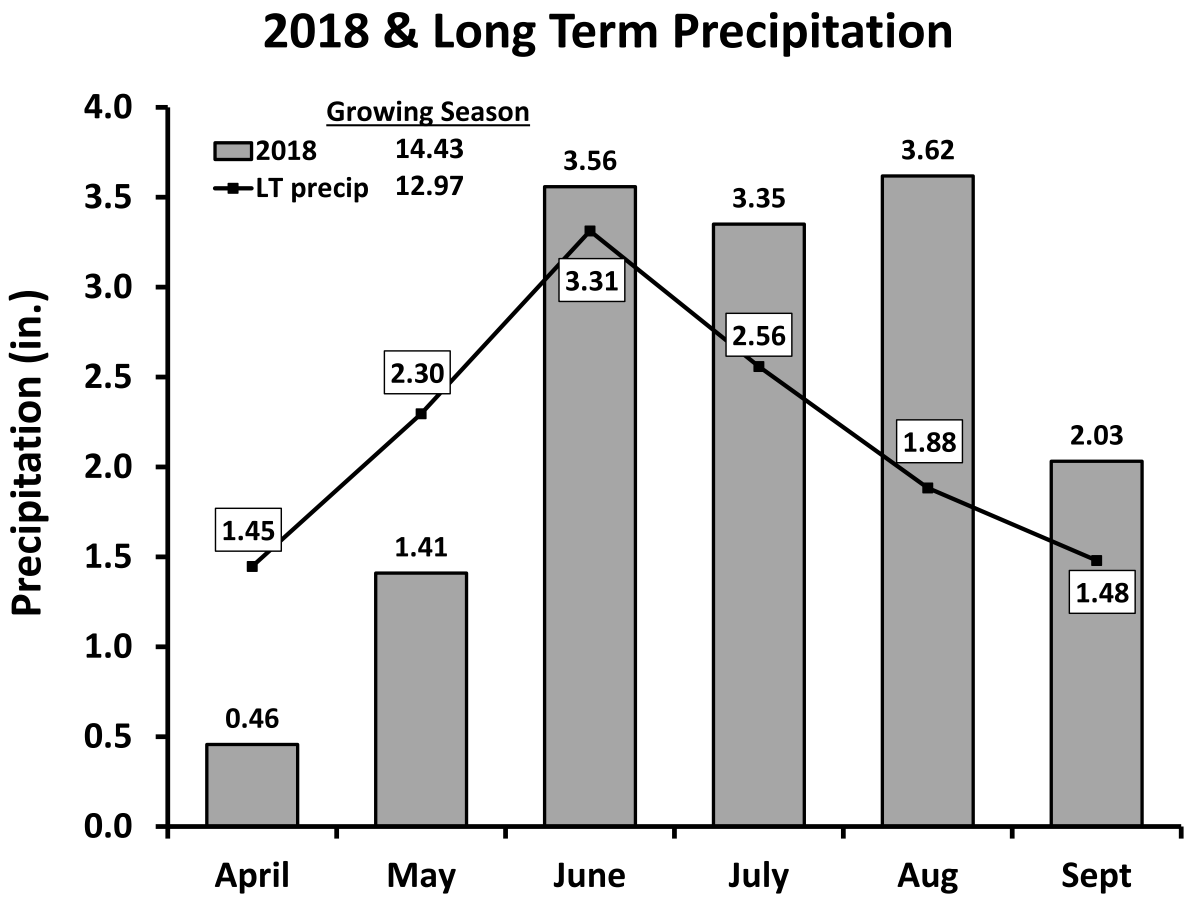


Fig 1. Seasonal precipitation for 2018 and long term average.

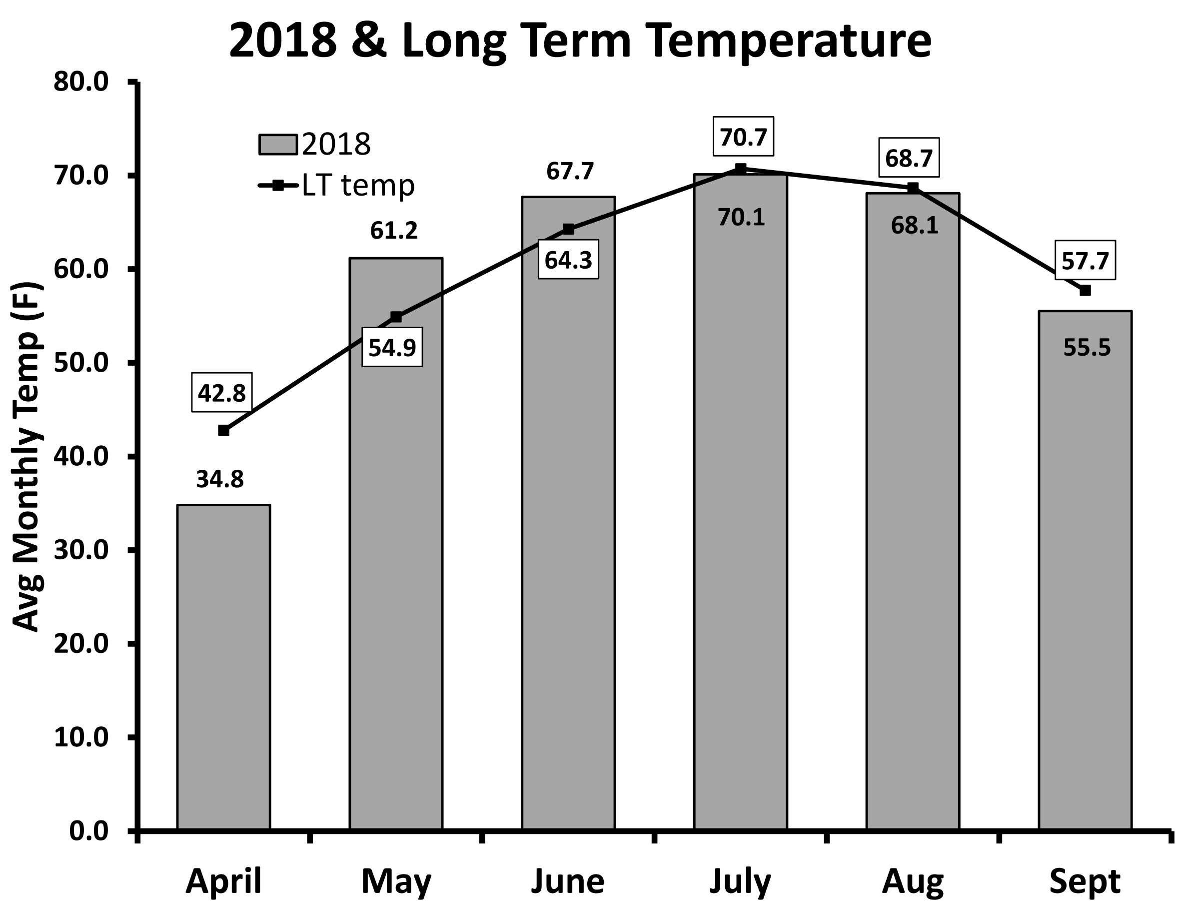


Fig 2 Seasonal monthly average temperature for 2018 and the long term average.

AREA-F FIELD OPERATIONS, NW ¼ Section 17 T138N R81W

FIELD F1 This area has been excluded from the total acreage leased by AREA IV SCDs since 1987.

FIELD F2, SUNFLOWERS

Previous crop – Overland winter wheat

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/13/18 Contractor sprayed w/Spartan Charge @ 4 oz/ac + Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

05/21/18 Field planted w/JD MaxEmerge XP planter @ 24,000 seeds/ac.

06/21/18 Contractor sprayed field w/Volunteer @ 7 oz/ac + Express @ 0.5 oz/ac + Destiny @ 2 qt/100 gal.

07/26/18 Contractor sprayed field w/Paradigm @ 4 oz/ac + Cerium Elite @ 1 qt/100 gal.

12/05/18 Field harvested w/JD 6620 and 6-row all-crop head (2500 lb/ac).

FIELD F3, GLENN SPRING WHEAT

Previous crop – Sunflowers

05/02/18 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 85 lb/ac 11-52-0.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/09/18 Field harvested w/JD 9650 combine and 35 ft straight head (39.8 bu/ac).

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

09/18/18 Field seeded to Overland winter wheat @ 120 lbs/ac.

FIELD F4, OVERLAND WINTER WHEAT

Previous crop- Spring wheat

09/19/17 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/21/18 Contractor sprayed field w/Propimax @ 4 oz/ac + Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac.

07/30/18 Field harvested w/JD 9650 and 35 ft. straight head (53.8 bu/ac).

08/21/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Jackhammer @ 2 qt/100 gal.

09/26/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD F5, SUNFLOWERS

Previous crop – Corn

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/13/18 Contractor sprayed w/Spartan Charge @ 4 oz/ac + Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

05/21/18 Field planted w/JD MaxEmerge XP planter @ 24,000 seeds/ac.

06/21/18 Contractor sprayed field w/Volunteer @ 7 oz/ac + Express @ 0.5 oz/ac + Destiny @ 2 qt/100 gal.

07/26/18 Contractor sprayed field w/Paradigm @ 4 oz/ac + Cerium Elite @ 1 qt/100 gal.

11/29/18 Field harvested w/JD 9650 combine and 6-row all-crop head (2500 lb/ac).

FIELD F6, GOLDEN GERMAN FOXTAIL MILLET

Previous crop – Sunflowers

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

06/09/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Vida @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

06/18/18 Field planted w/ JD 30ft. 1890 drill @ 20 lbs/ac.

08/30/18 Field cut w/MacDon swather (12 ft.).

09/19/18 Field baled w/New Holland BR790 round baler (3.2 T/ac).

AREA-G FIELD OPERATIONS, SW ¼ Section 8 T138N R81W

FIELD G1 (FORMER TREE PLOT), CORN (INTERSEEDER TRIAL) on page 48

Previous crop – Spring wheat

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/16/18 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

06/14/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Class Act @ 2 qt/100 gal.

06/15/18 Planted first treatment of interrow cover crops w/Interseeder drill.

06/22/18 Planted second treatment of interrow cover crops w/Interseeder drill.

06/28/18 Planted third treatment of interrow cover crops w/Interseeder drill.

11/16/18 Field harvested w/JD 9650 and 6-row corn header (125.0 bu/ac).

FIELD G1, GLENN SPRING WHEAT

Previous crop – Spring wheat

04/30/18 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/10/18 Field harvested w/JD 9650 and 35 ft. straight header (41.9 bu/ac).

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD G2, GREEN TESTA BUCKWHEAT (2 separate lots)

Previous crop – Spring wheat

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

06/13/18 Field seeded w/JD 1890 30 ft. drill @ 60 lb/ac + 60 lb/ac 11-52-0.

07/09/18 Contractor sprayed field w/Poast @ 7 oz/ac + Trophy Gold @ 1 qt/100 gal.

09/26/18 Field cut w/MacDon swather (12 ft.).

10/23/18 Field harvested w/JD 9650 and pickup head (2920 lb/ac).

FIELD G3, GLENN SPRING WHEAT

Previous crop – Fallow

04/30/18 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/10/18 Field harvested w/JD 9650 and 35 ft. straight header (49.2 bu/ac).

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD G4, FALLOW

Previous management – Spring wheat

06/09/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Vida @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

07/26/18 Contractor sprayed w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Class Act @ 2 qt/100 gal.

09/26/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

AREA-H FIELD OPERATIONS, NE ¼ Section 18 T138N R81W

FIELD H1, VERNAL ALFALFA

Previous crop – Alfalfa

06/13/18 First cutting done by Northern Lights Dairy (1.21 ton/ac).

07/15/18 Second cutting done by Northern Lights Dairy (0.47 ton/ac).

08/16/18 Third cutting done by Northern Lights Dairy (0.50 ton/ac).

09/10/18 Contractor terminated stand w/Durango @ 32 oz/ac + Detonate @ 10 oz/ac + Class Act @ 2 qt/100 gal.

FIELD H2, OVERLAND WINTERWHEAT

Previous crop – Spring wheat

09/19/17 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/21/18 Contractor sprayed field w/Propimax @ 4 oz/ac + Perfect Match @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac.

07/31/18 Field harvested w/JD and 35 ft. straight head (45.0 bu/ac).

08/21/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Jackhammer @ 2 qt/100 gal.

09/26/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD H3 WEST, CORN

Previous crop – Sunflowers

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/15/18 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/09/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Atrazine @ 8 oz/ac + Vida @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

10/29/18 Field harvested w/JD 9650 and 6-row corn head (101.5 bu/ac).

FIELD H3 EAST, CORN

Previous crop – Buckwheat

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/15/18 Field seeded w/JD 1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/09/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Atrazine @ 8 oz/ac + Vida @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

10/30/18 Field harvested w/JD 9650 and 6-row corn head (101.5 bu/ac).

FIELD H4, SOIL QUALITY MANAGEMENT

See ‘Management strategies for soil quality’ on page 37

FIELD H4, GLENN SPRING WHEAT

Previous crop – Soybeans

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/02/18 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/10/18 Field harvested w/JD 9650 and 35 ft. straight header (44.2 bu/ac).

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD H4, FIELD PEAS

Previous crop – Winter wheat

04/30/18 Field seeded w/JD750 drill @ 180 lb/ac + 50 lb/ac 11-52-0.

05/02/18 Field sprayed w/Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

07/26/18 Contractor sprayed w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Class Act @ 2 qt/100 gal.

08/08/18 Field harvested w/JD 6620 combine and 15ft. flex head (32.6 bu/ac).

FIELD H4, CORN

Previous crop- Field Peas

05/02/18 Contractor banded liquid N 27-0-0-1 @ 20 gal/ac.

05/15/18 Field planted w/JD MaxEmerge XP planter @ 24,000 seeds/ac.

06/09/18 Contractor sprayed field w/Durango @ 32 oz/ac + Detonate @ 8 oz/ac + Atrazine @ 8 oz/ac + Vida @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

10/31/18 Field harvested w/JD 9650 and 6-row corn head (143.8 bu/ac).

FIELD H4, SOYBEANS

Previous crop- Corn

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

05/31/18 Field planted w/JD 1750 MaxEmerge II planter @ 180,000 seeds/ac.

06/27/18 Contractor sprayed field w/Durango @ 32 oz/ac + Targa @ 7 oz/ac + Prefer90 @ 2 qt/100 gal + Jackhammer @ 2 qt/100 gal.

10/17/18 Field harvested w/JD 9650 combine and 35 ft flex head (42.9 bu/ac).

FIELD H5, SOYBEANS

Previous year – Corn

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

05/30/18 Field planted w/JD 30 ft 1890 drill @ 220,000 seeds/ac.

06/05/18 Field was rolled.

06/27/18 Contractor sprayed field w/Durango @ 32 oz/ac + Targa @ 7 oz/ac + Prefer90 @ 2 qt/100 gal + Jackhammer @ 2 qt/100 gal.

10/17/18 Field harvested w/JD 9650 and 35 ft flex head (34.2 bu/ac).

AREA-I FIELD OPERATIONS, NE ¼ Section 20 T138N R81W

FIELD I1, GLENN SPRING WHEAT (Continuous spring wheat 33 yrs).

This field will remain as a continuous spring wheat treatment.

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/02/18 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/16/18 Field harvested w/JD 9650 and 35 ft straight header (45.6 bu/ac)

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

FIELD I2, SOYBEANS

Previous crop – Corn

05/22/18 Contractor sprayed w/Durango @ 32 oz/ac + Authority Assist @ 7 oz/ac + Aim @ 1 oz/ac + Jackhammer @ 2 qt/100 gal + Downdraft @ 4 oz/ac.

05/31/18 Field planted w/JD 30 ft 1890 drill @ 220,000 seeds/ac.

06/05/18 Field was rolled.

06/27/18 Contractor sprayed field w/Durango @ 32 oz/ac + Targa @ 7 oz/ac + Prefer90 @ 2 qt/100 gal + Jackhammer @ 2 qt/100 gal.

10/16/18 Field harvested w/JD 9650 and 6-row corn head (31.6 bu/ac).

FIELD I3, GLENN SPRING WHEAT

Previous crop – Oats

05/02/18 Contractor banded liquid N 27-0-0-1 @ 16 gal/ac.

05/02/18 Field seeded w/JD 30 ft 1890 drill @ 96 lb/ac.

06/07/18 Field sprayed w/Axial XL @ 16.4 oz/ac + WideMatch @ 16 oz/ac.

08/13/18 Field harvested w/JD 9650 and 35 ft straight header (44.9 bu/ac)

09/05/18 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @16 oz/ac + Class Act @ 2 qt/100 gal.

Summary of Area IV Research Farm yields.

Field	Crop	Variety	Yield
			(per ac)
F2	Sunflowers	Croplan 432E	2500 lb
F3	Spring wheat	Glenn	39.8 bu
F4	Winter wheat	Overland	53.8 bu
F5	Sunflower	Croplan 432E	2500 lb
F6	Millet	Golden German	3.2 T
G1	Corn	Mycogen 2R158	125 bu
G2	Buckwheat	Green Testa	2920 lb
G3	Spring wheat	Glenn	49.2 bu
G4	Fallow	------	-----
H1	Alfalfa	1st cutting	1.21 T
		2nd cutting	0.47 T
		3rd cutting	0.50 T
H2	Winter wheat	Overland	45.0 bu
H3 west	Corn	Mycogen 2R158	101.5 bu
H3 east	Corn	Mycogen 2R158	101.5 bu
H4 (a)	Spring wheat	Glenn	44.2 bu
H4 (b)	Dry Peas	Nette	32.6 bu
H4 (c)	Corn	Mycogen 2R158	143.5 bu
H4 (d)	Soybeans	Mycogen 5B024	42.9 bu
H5	Soybeans	Mycogen 5B024	34.2 bu
I1	Spring wheat	Glenn	45.6 bu
I2	Soybeans	Mycogen 5B024	31.6 bu
I3	Spring wheat	Glenn	44.9 bu

Evaluation of 'Business as Usual' Cropping Practices, 2016-2018

Overview

In preparation for the Long-term Agroecosystem Research (LTAR) network Common Experiment at NGPRL, two field sites on the Area IV SCD Cooperative Research Farm have been managed similarly since 2016 to assess previous land use effects on a range of vegetation, soil, and gas flux properties and processes. The sites – Fields H5 and I2 – have been managed under no-till continuous cropping since 2002, but under different crop rotations (Fig. 1). Prior to initiating the Common Experiment, normalizing differences in previous land use between fields will be important to ensure both fields are at a similar 'starting point' prior to deploying 'Business as usual' (Field H5) and 'Aspirational' (Field I2) practices in 2019.

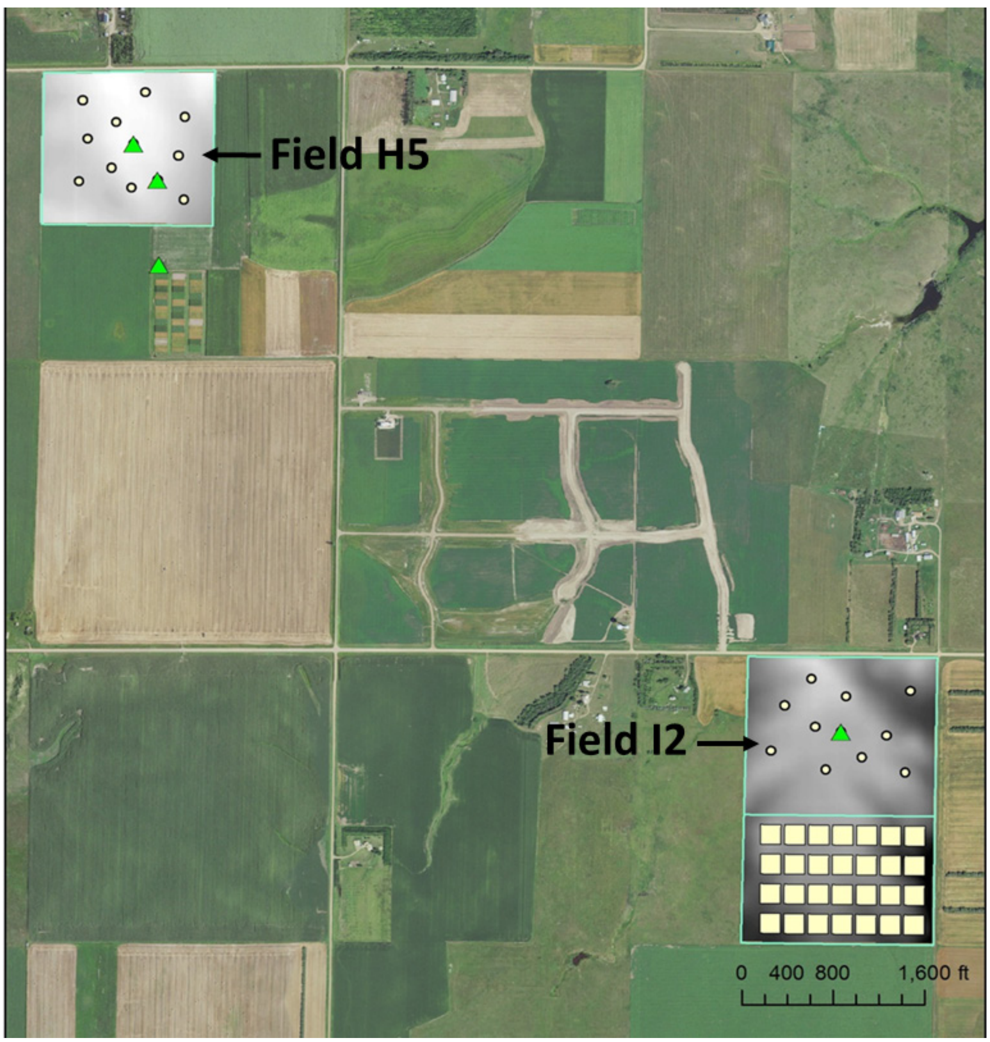


Fig 1. Field site locations for LTAR Common Experiment at the Area IV SCD Cooperative Research Farm.

Preliminary Findings - Carbon, Water and Heat Fluxes

Grain yields were comparable between fields, with the notable exception of 2017 when two July storms with high winds and hail damaged crops in fields G and H (Table 1). Measurements of net ecosystem exchange (NEE) for CO_2, evapotranspiration (ET), and sensible heat (H) fluxes found close agreement between fields over the 3-year measurement period (Table 2; Fig. 2). Daily average NEE and ET, however, were different between fields during the corn (2017) phase of the rotation. Among crops, annual carbon fluxes were negative for corn (implying net carbon uptake by the ecosystem) and positive for spring wheat and soybean (implying net carbon loss to the atmosphere).

Table 1. Combine grain yields for spring wheat (2016), corn (2017), and soybean (2018) for fields H5 and I2, Area 4-SCD Cooperative Research Farm.

Year / Crop	**Field**	**Grain yield (bu/ac)**
2016 / Spring wheat	H5	49
	I2	41
2017 / Corn	H5	88
	I2	120
2018 / Soybean	H5	37
	I2	32

Table 2. Field-scale net ecosystem exchange (NEE) for CO_2, evapotranspiration (ET), and sensible heat (H) fluxes from 'Business-As-Usual' practices at fields H5 and I2 in 2016–2018. Values for NEE and ET are totals, while values for H are daily averages.

Field	Year	Crop	Annual Fluxes			Growing Season Fluxes			
			NEE	ET	H	Period	NEE	ET	H
			g C m^{-2} yr^{-1}	mm yr^{-1}	W m^{-2}		g C m^{-2} $season^{-1}$	mm $season^{-1}$	W m^{-2}
H5	2016	Spring Wheat	57	377	22	6/15 - 8/15	-159	183	26
	2017	Corn	-73	431	21	5/20 - 10/20	-189	352	35
	2018	Soybean	49	392	16	6/15 - 9/15	-147	251	21
		Mean	11	400	20	Mean	-165	262	27
		Std. Error	42	16	2	Std. Error	12	49	4
I2	2016	Spring Wheat	16	407	21	6/15 - 8/15	-171	201	16
	2017	Corn	-162	494	23	5/20 - 10/20	-273	408	37
	2018	Soybean	61	404	15	6/15 - 9/15	-134	247	20
		Mean	-28	435	20	Mean	-193	285	25
		Std. Error	68	29	2	Std. Error	42	63	7

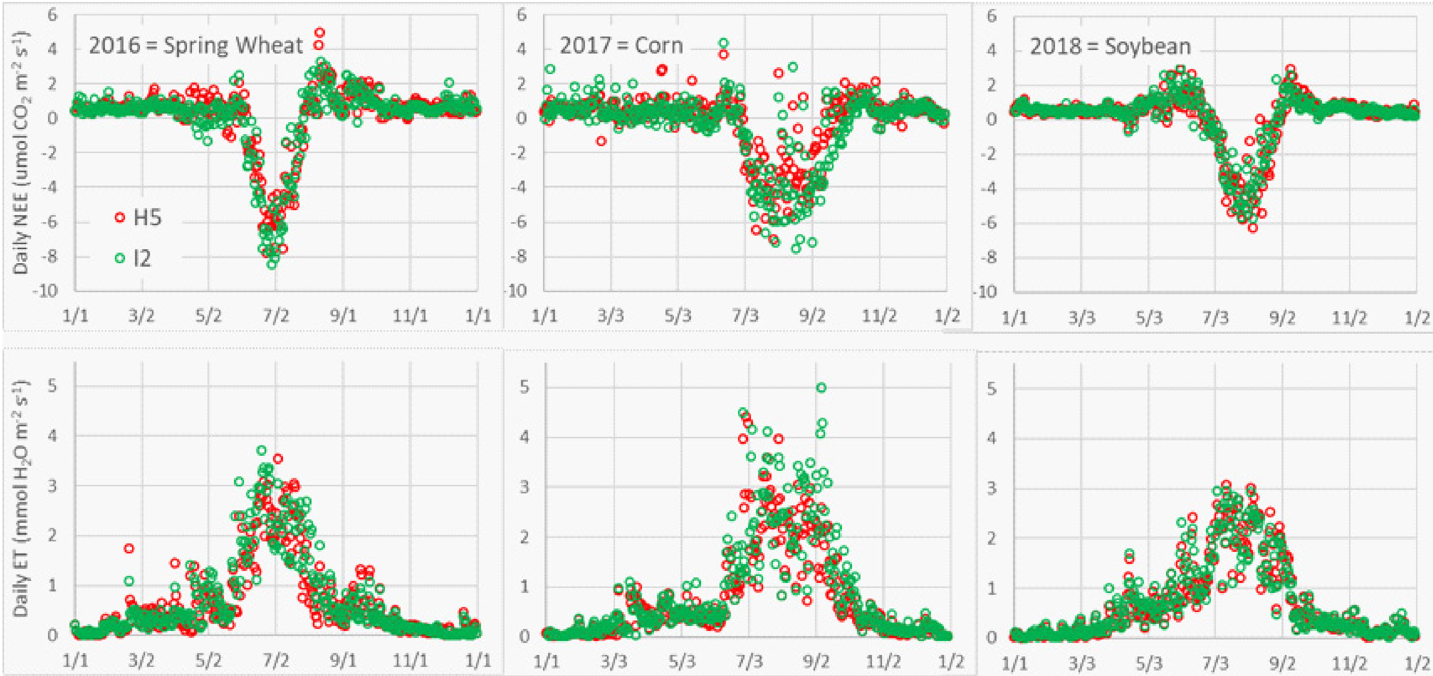
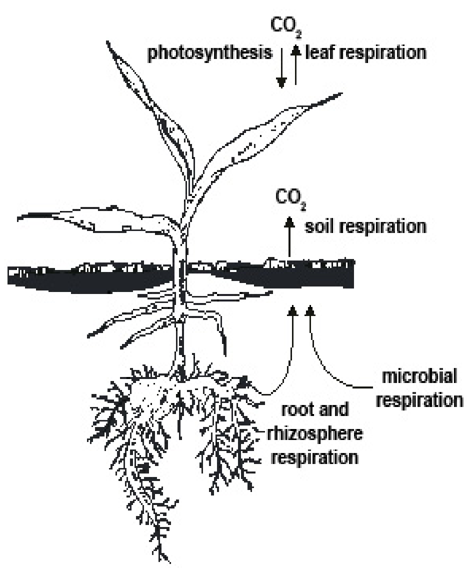


Fig 2. Daily averages of carbon and water fluxes for the three-year (2016 - 2018) crop rotation of spring wheat – corn – soybean at fields H5 and I2. Negative values for carbon flux represent CO_2 uptake by the ecosystem, while positive values denote CO_2 emission. Each point is the mean of half-hourly observations for a 24-hour period (n = 48).



Management strategies for soil quality – 2018 crop summary

Drs. Donald Tanaka (retired), Mark Liebig, and David Archer

Introduction

The 'Management Strategies for Soil Quality' study was established in 1993 by Dr. Don Tanaka to evaluate long-term impacts of minimum and no-till cropping systems on crop yield, precipitation use, and soil properties. The study was designed with six crop sequences (whole plot) each split by tillage type (split plot). All phases of each crop sequence are present every year, and treatments are replicated three times.

Beginning in 2012, three crop sequences were adjusted to reflect changing cropping practices in the northern Great Plains. Specifically, millet and safflower were replaced with corn and soybean, and rye (partial fallow) was replaced with a full-season cover crop mixture (Table 1). Tillage treatments were left unchanged.

Table 1. Changes to crop sequences in Management Strategies for Soil Quality study.

Sequence	Previous (1993-2011)	Present (beginning 2012)
1	Continuous spring wheat, straw chopped and spread	Unchanged (CSW+)
2	Continuous spring wheat, stubble left in place, straw removed	Unchanged (CSW-)
3	Spring wheat – millet	Spring wheat – soybean (SW-S)
4	Spring wheat – safflower - fallow	Spring wheat – corn – soybean (SW-C-S)
5	Spring wheat – safflower – rye (partial fallow)	Spring wheat – corn – cover crop, full season (SW-C-CC)
6	Spring wheat – fallow	Unchanged (SW-F)

Field Activities

Plots planted to wheat were sprayed May 6 with Durango (24 oz/ac) and surfactant. Corn, soybean and fallow plots were sprayed May 13 with Durango (24 oz/ac) and 2,4-D LV6 (12 oz/ac) plus surfactant. Spring wheat was sprayed post-emergent on June 3 with Tacoma (10 oz/ac) and Widematch (16 oz/ac). Corn plots were sprayed June 6 with Barbarian Max (32 oz/ac) and surfactant. Soybean and fallow plots were sprayed June 14 and July 13 with Durango (28 and 32 oz/ac, respectively) plus surfactant. Minimum tillage treatment plots for each crop were tilled with a 14.5 ft. Mulch Master cultivator just prior to planting to a depth of 3 to 4 inches.

Table 2. Planting, fertilizer, and harvest documentation for 2018 crop year.

Crop	Planting date	Cultivar/ type	Planting rate – seeds/ac	Fertilizer – Urea & 11-52-0	Drill/ Planter	Harvest
Spring wheat	5/8/18	Glenn	1.3 million	60 lb N/ac recrop; 30 lb N/ac fallow + 10 lb P/ac.	JD 750	8/6/18 hand harv. 8/15/18 combined
Corn	5/17/18		24,500	90 lb N/ac + 10 lb P/ac	JD 1750	9/26/18 biom. harv. 10/25/18 combined
Soybean	5/24/18	Mycogen 5B024 R2	180,000	100 lb/ac 11-52-0	JD 1750	10/2/18 biom. harv. 10/18/18 combined
Cover crop	6/5/18	7-way mix*	34 lb (total seed)	60 lb N/ac + 10 lb P/ac as 11-52-0	JD 750	8/14/18 sampled 8/15/18 swathed 8/23/18 baled

* 7-way mix composed of triticale, proso millet, winter canola, sunflower, forage pea, soybean, and pasja turnip.

Crop Yield Summary

1. Early season precipitation in April and May was half of the long-term average (1.87 vs. 3.75 in., Fig. 5) while the average temperature for April was 8 degrees cooler than the long-term average followed by over 6 degrees warmer in May (Fig. 6). The remaining season's precipitation (June through Sept) saw a 36% increase over the long-term average with monthly temperatures close to the long-term average.

2. Significant differences in spring wheat yields among the rotations have not occurred to this degree since the beginning of the study (Fig. 1). Although analysis of soil water data among the rotations showed similar in-season water use across the study, it is thought that SW following cover crops (SW-C-CC rotation) yielded the lowest because of continued cover crop growth through late fall, which led to lower water reserves. This was compounded by the low spring precipitation during the 2018 growing season. Continuous SW rotations were also low largely due to more severe weed pressure as weeds emerged with June precipitation occurring after herbicide application.

3. Corn and soybean yields did not show any significant treatment effects (Figs. 2 & 3).

4. Cover crop production was the highest since this treatment was started but it appears to be leveling off with comparable production to that in 2016 (Fig. 4).

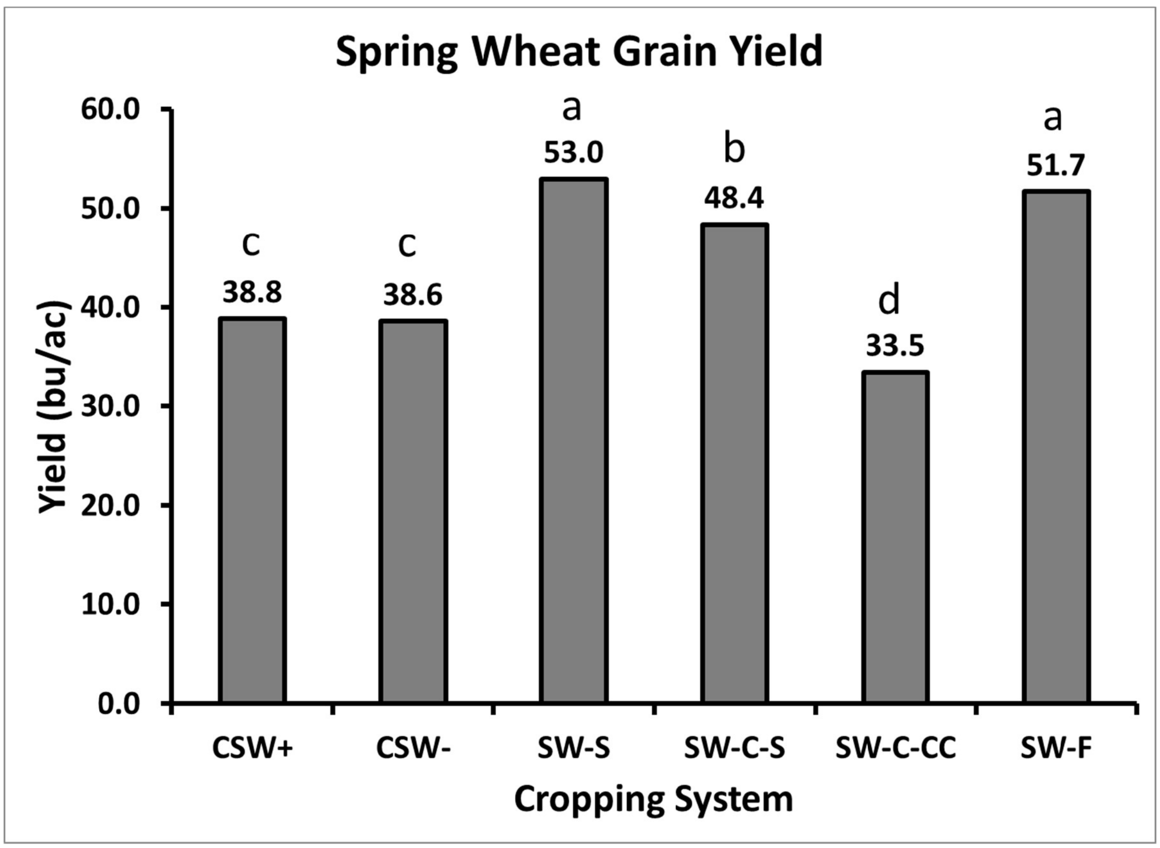


Fig1. Spring wheat seed yield as influenced by cropping system. Yields are the average of minimum and no-till.

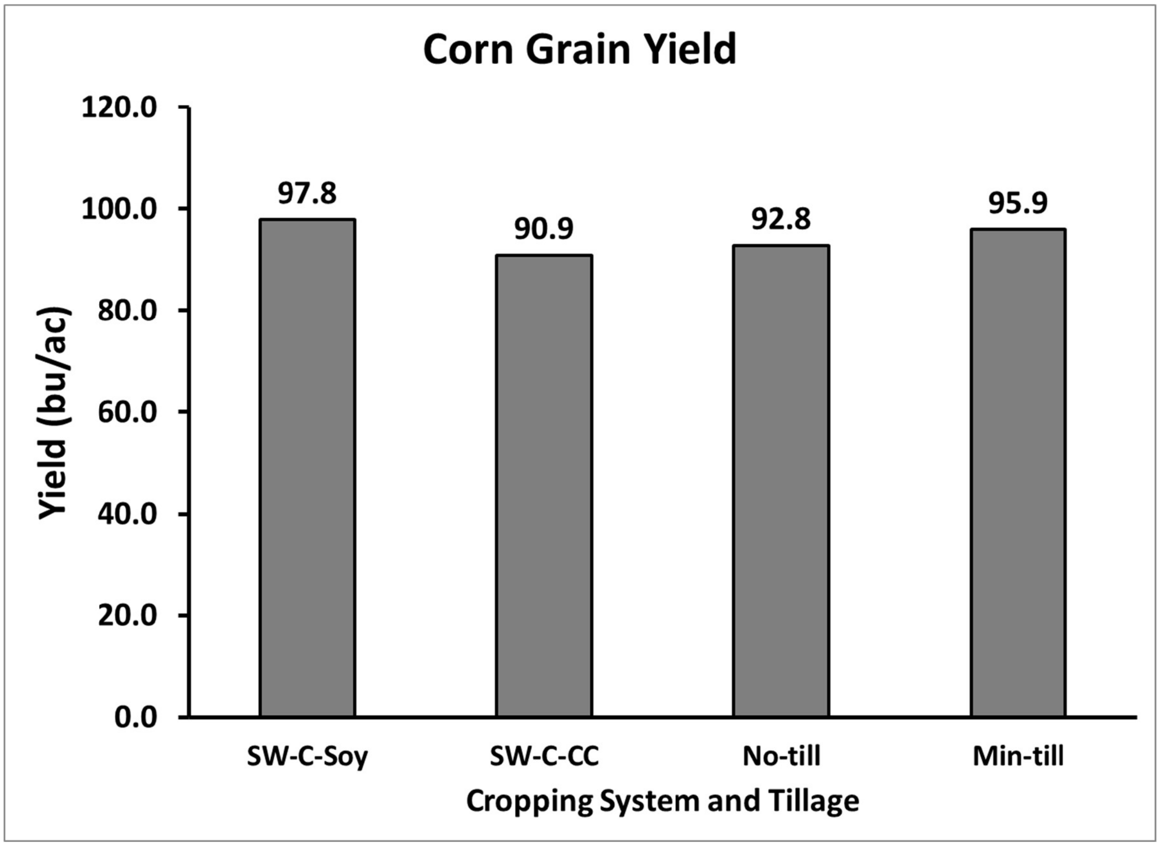


Fig 2. Corn grain yield showing cropping system and tillage comparisons. Yields of cropping system are averaged across tillage and vice versa.

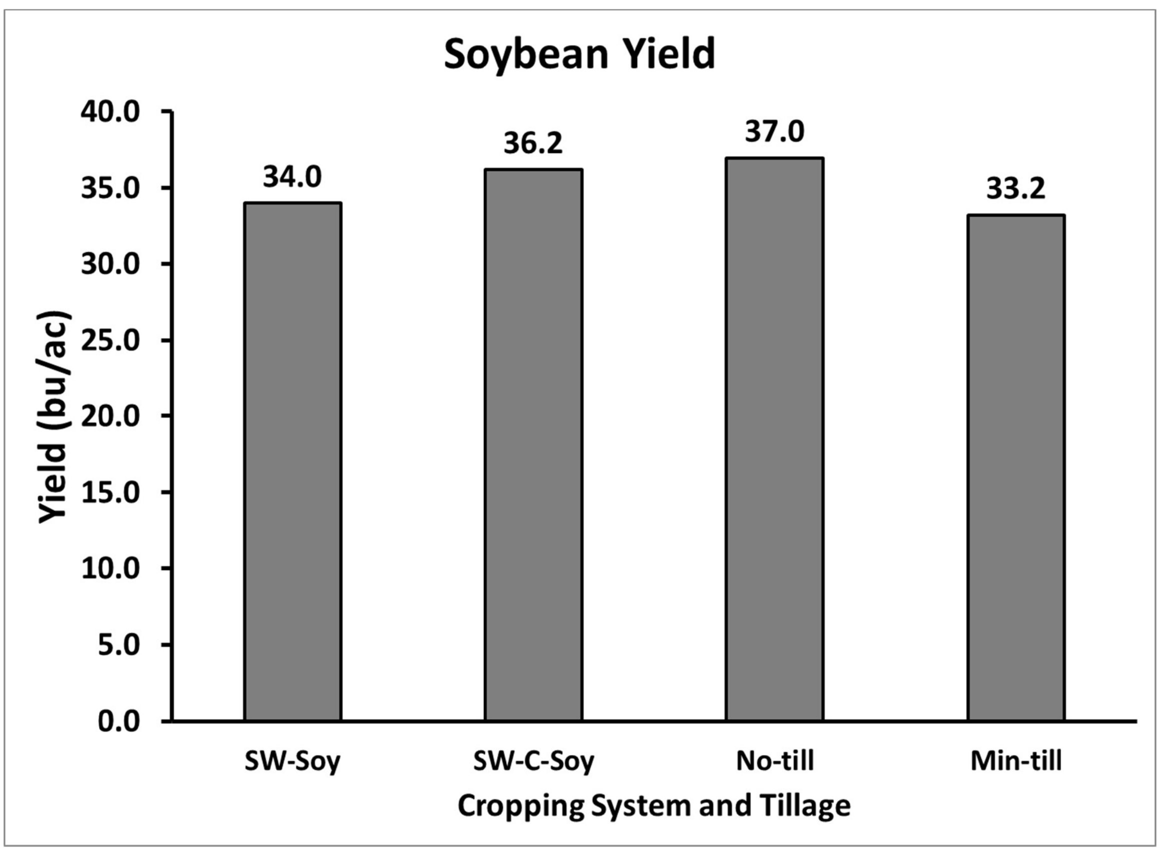


Fig 3. Soybean yield showing cropping system and tillage comparisons. Yields of cropping system are averaged across tillage and vice versa.

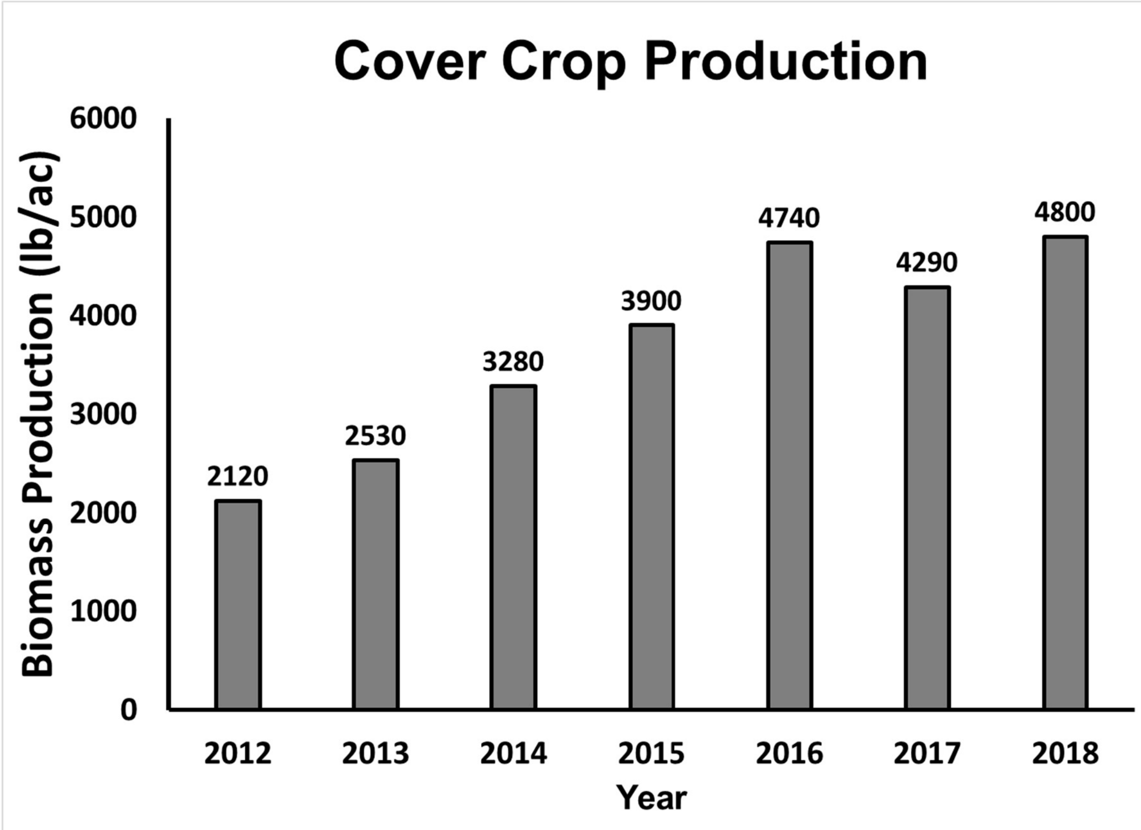


Fig 4. Production over time of cover crop treatment in the SQM study.

Bioenergy cropping systems study – 2018 summary

Drs. David Archer, Scott Kronberg, and Mark Liebig

Treatments (all combinations of the following crop rotation and residue removal treatments, all no-till)

Rotations:

1. Spring Wheat – Dry Pea (W-P)
2. Spring Wheat – Dry Pea/ Cover Crop mix (W-P/CC)
3. Spring Wheat – Dry Pea - Corn (W-P-C)

Residue Removal:

A. No residue removed

B. Wheat straw baled and removed

C. Wheat straw, corn stover, and pea residue baled and removed

D. Wheat straw, corn stover, and peas residue grazed

2018 Planting Dates, Seed, and Fertilizer Rates:

Crop/ Rotation	Planting Date	Cultivar/ Type	Planting Rate	Fertilizer (lb material)	Drill/ Planter	Harvest Date
Spring Wheat W-P-C	5/07/2018	WB 9653	130 lb/ac	199 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/16/2018
Spring Wheat W-P	5/07/2018	WB 9653	130 lb/ac	22 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/16/2018
Spring Wheat W-P/CC	5/07/2018	WB 9653	130 lb/ac	130 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/16/2018
Dry Pea W-P, W-P/CC, W-P-C *Reps 3 & 4*	5/04/2018	Nette 2010	150 lb/ac	0 lb/ac urea 50 lb/ac 11-52-0	JD 750	7/31/2018
Dry Pea W-P, W-P/CC, W-P-C *Reps 1 & 2*	5/04/2018	SW Midas	150 lb/ac	0 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/06/2018
Corn W-P-C	5/14/2018	Proseed 1280	24,300 seeds/ac	59 lb/ac urea 50 lb/ac 11-52-0	JD Max Emerge II	10/31/2018
Cover Crop W-P/CC	8/07/2018	Mix	34 lb/ac	----	JD 750	----

Fertilizer rates based on soil test and NDSU fertilizer recommendations. Cover crop mix consisted of: 4.7 lb/a forage soybean, 11.2 lb/a spring triticale, 10.4 lb/a Arvika pea, 6 lb/a lentil, 1.6 lb/a red clover, and 0.13 lb/a purple top turnip.

2018 Spray Dates, Pesticides Used, & Rates:

Crop	Date	Plot Areas	Chemical	Rate
Peas	5/04/2018	All pea rotations/plots	Durango Jackhammer	24 oz./a 6.4 oz/a
	6/4/2018	Pea rotations/plots: W-P, W-P-C	Basagran Pursuit Section	25 oz./a 2 oz./a 8 oz./a
	6/4/2018	Pea rotations/plots: W-P/CC	Basagran Pursuit	25 oz./a 2 oz./a
	7/27/2018	Pea rotations in Rep 1 and 2 from removal treatments A, B, C	Durango Class Act	32 oz./a 64 oz./100 gallon
	8/10/2018	Pea rotations in Rep 3 and 4 from removal treatments A, B, C	Durango Class Act	32 oz./a 64 oz./100 gallon
Spring Wheat	5/06/2018	All wheat rotations/plots	Durango Jackhammer	24 oz./a 6.4 oz/a
	5/31/2018	All wheat rotations/plots	Tacoma Widematch	10 oz./a 16 oz./a
	8/28/2018	All wheat plots from removal treatments A, B, C	Durango 2,4-D LV6 Class Act	28 oz./a 12 oz./a 64 oz./100 gallon
Corn	5/13/2018	All corn rotations/plots	Durango Jackhammer 2,4-D LV6	24 oz./a 6.4 oz/a 12 oz./a
	6/06/2018	All corn rotations/plots	Barbarian Max Class Act	32 oz./a 64 oz./100gallons

Summary:

- Spring wheat yields were significantly higher for the W-P than for the W-P/CC and W-P-C rotations (Figure 1). Yield was significantly lower where residue had been harvested and removed every year (C) than for no residue harvest (A).

- Dry pea yields were significantly lower for the W-P/CC rotation than for either the W-P or the W-P-C rotation (Figure 2). There were no significant differences in pea yields among residue removal treatments. Two replications of peas were planted using the SW Midas variety and two replications were planted using the Nette 2010 variety. Powdery mildew was common in the SW Midas areas but was not apparent in the Nette 2010 areas.

- There was some indication that corn yield was lower where residue had been harvested and removed every year (C) and where residue had been grazed (D) than for the no residue harvest treatment (A). However, the differences were not statistically significant (Figure 3).

- Grazing days were good for all treatments, except grazing was very limited after peas in the W-P-C rotation with little volunteer pea or weed growth occurring in this treatment.

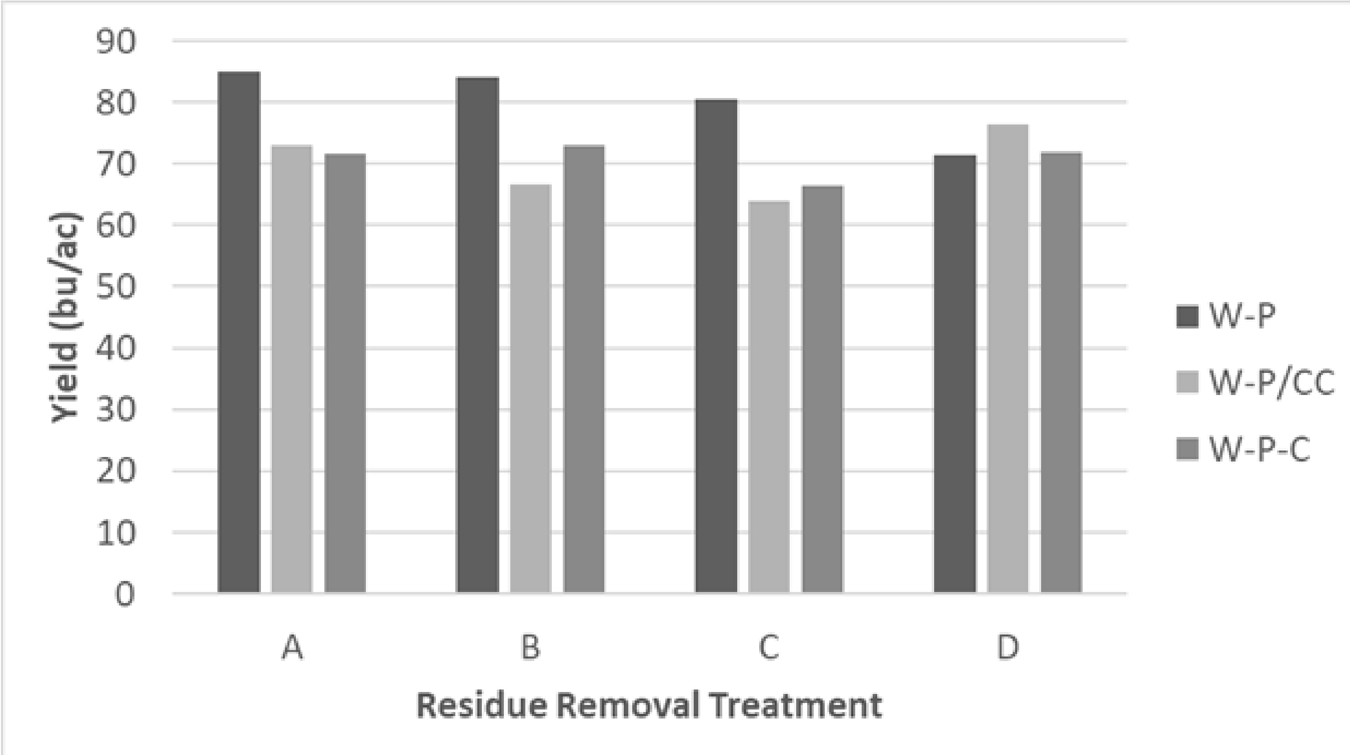


Fig 1. 2018 spring wheat seed yield as influence by crop rotation and residue removal treatments.

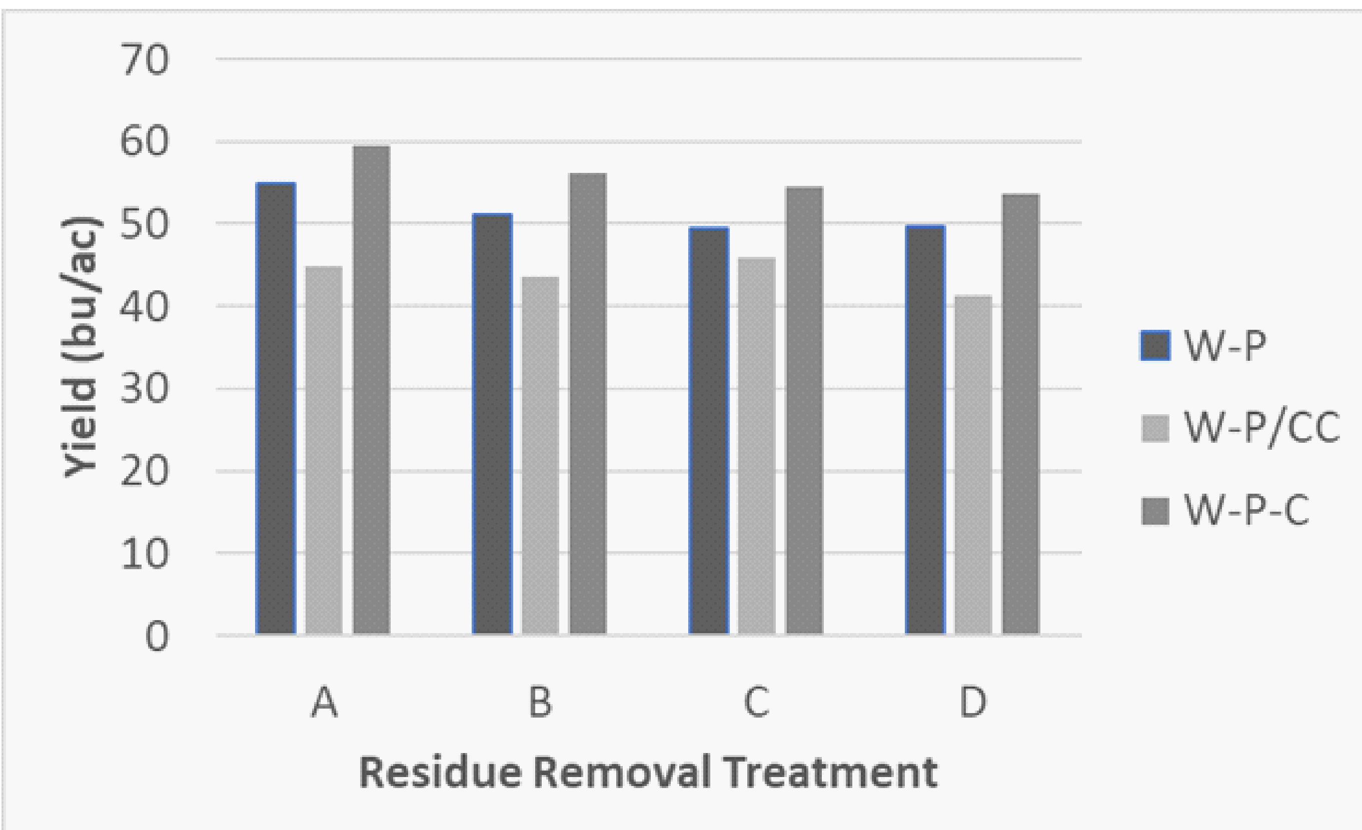


Fig 2. 2018 dry pea seed yield as influenced by crop rotation and residue removal treatments.

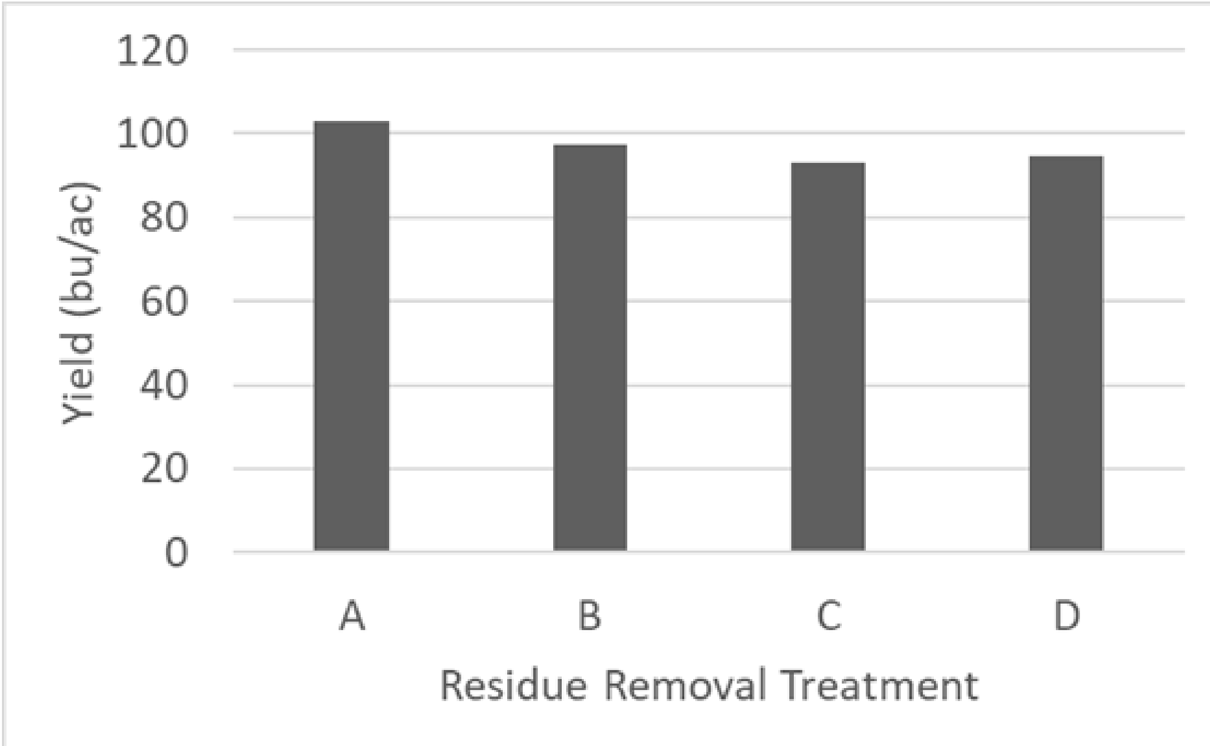


Fig 3. 2018 corn seed yield as influenced by residue removal treatments.

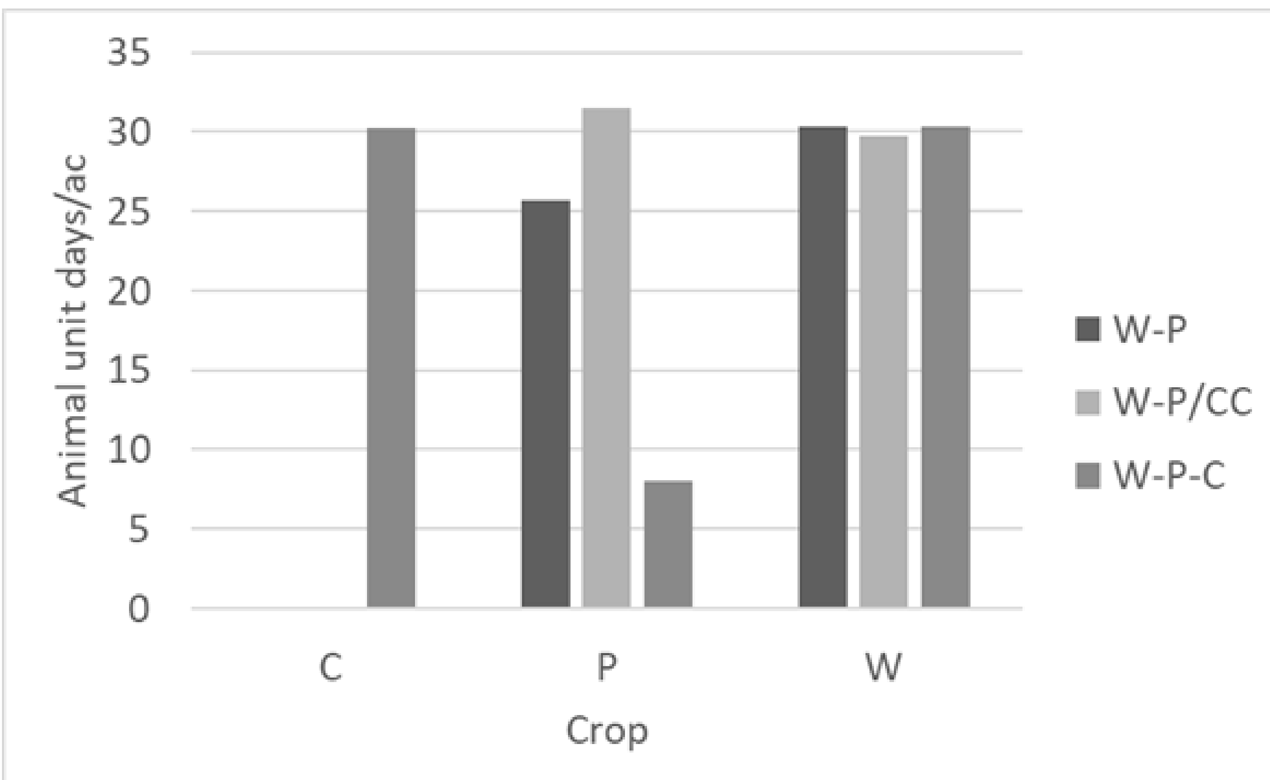


Fig 4. 2018 grazing amount (1000 lb AU days/ac) by crop and rotation.

Integrated crop / livestock systems study - 2018 summary

Drs. Dave Archer, Scott Kronberg, John Hendrickson, and Mark Liebig

Late summer and fall grazing (Phase 3)

Phase 3 of the Integrated Crop/Livestock (ICL) systems project was initiated in 2015 focusing on providing forages at times when native range may not be of adequate quality to maintain the rate of animal weight gain. Previous phases looked at the late fall (Phase II) and winter periods (Phase I). In this phase, we continue to focus on the late fall grazing period, but also include potential needs during the late summer. In Phase 3, we are also looking to increase grain production while meeting critical forage needs, so harvestable grain crops are included for two years out of a three year rotation.

Cropping system – integrated treatments:

1. Spring wheat, which is inter-seeded at or around the 4-leaf stage with a 7-way mixture of intermediate wheatgrass, timothy, alfalfa, hairy vetch, red clover, daikon radish, and chicory.

2. Inter-seeded mix from previous spring wheat allowed to grow, then hayed during the growing season.

3. Corn for grain inter-seeded with soybean.

Check strips – grain-only treatments:

1. Spring wheat

2. Soybean

3. Corn

Grazing treatments – 20 yearling steers in each group (5 per replication):

1. Graze cropping system grazing treatment strips beginning in the fall. Hay harvested from the strips fed to the steers on those strips.

2. Graze native and introduced pastures and feed hay as needed.

Summary

Spring wheat strips were sprayed May 2 with Durango (24 oz/ac) + 2,4-D LV6 (10 oz/ac) and surfactant, and were seeded with a JD 750 drill on May 3. Spring wheat was sprayed post-emergent May 31 with Tacoma (10 oz/ac) and Bison (16 oz/ac). The spring wheat integrated treatment was inter-seeded May 25. Corn strips were sprayed preplant May 13 with Durango (24 oz/ac) + 2,4-D LV6 (12 oz/ac). An 11-row JD MaxEmerge II planter with 15 inch row spacing was used to plant the interseeded corn and soybean “integrated” treatment, with corn seed and soybean seed loaded in alternating planter boxes (6 rows of corn, 5 rows of soybean). The corn strips (integrated and check treatments) were planted May 22. Soybean check strips were planted May 23. Both corn treatments and soybean check strips were sprayed post-emergent June 27 (Durango @32 oz/ac + surfactant) and just soybeans on July 17 (Durango @28 oz/ac + surfactant).

Both treatments of spring wheat were combined Aug 30. Soybean check strips were combined Oct 19. The corn check strips were combined Oct 25 and the integrated strips on Oct 29. Grain yields are shown in Figure 1. Spring wheat yield was higher in the check strip than in the integrated strip where cover crops had been interseeded. Corn yield was drastically lower for the integrated treatment compared to the check treatment. This likely reflects the greater depletion of soil moisture by the forage crop mix compared to soybean, with the forage crops terminated just 8 days before corn planting. It also likely reflects the additional water use by the interseeded soybeans in the integrated treatment. Although both wheat and corn yields were lower in the integrated treatments than in the respective check treatments, protein content was higher in the integrated treatments (Figure 2).

The chopper was left off for the integrated strips, and the corn stover was baled (1200 lb/ac). The full season cover crop strips (seeded in 2017) were mowed with a 9 ft. sickle mower to facilitate drying on June 21 & 22, raked on the 25th and baled. Prior to mowing, the cover crop biomass was estimated using a Swift Current® forage harvester mowing at a 4-inch stubble height. Average biomass production from the cover crop strips in June was 1822 lbs. per acre.

The ICL and nearby grass control pastures were grazed for 26 days (September 27 to October 23) with 4 yearlings in each pasture. The grass control pastures were 7.5 acres in size but grazing was only done on the cover crop portion of the ICL which was approximately 2.5 acres in size. Average daily gain was greater on the grass control pasture (2.23 lbs. per day) than on the ICL (1.84 lbs. per day). However, the total gains of the 4 steers per acre was greater for the ICL (76.45 lbs. per acre) then for the grass control pasture (30.97 lbs. per acre).

Establishment of the cover crops seeded into the spring wheat was recorded in September 2018 using a frequency grid. This is a simple technique where the presence or absence of cover crop species is recorded within 25 squares on a grid. The number of squares where cover crops are recorded provides and estimation of establishment. Stand establishment was low in 2018 averaging only 7.8% suggesting that climatic conditions were not conducive to establishment. In contrast, average stand establishment in 2017 was 76% indicating a successful cover crop seeding.

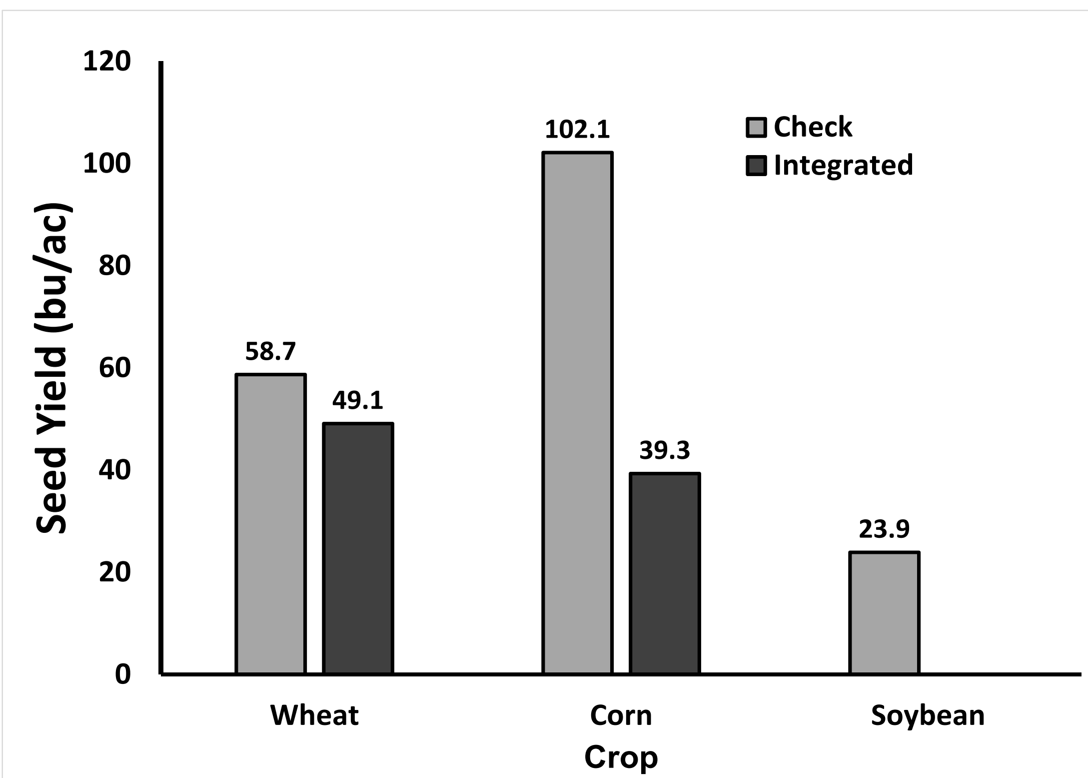


Fig 1. 2018 grain/seed production for the grazed (Integrated) and grain crop check (Check) strips.

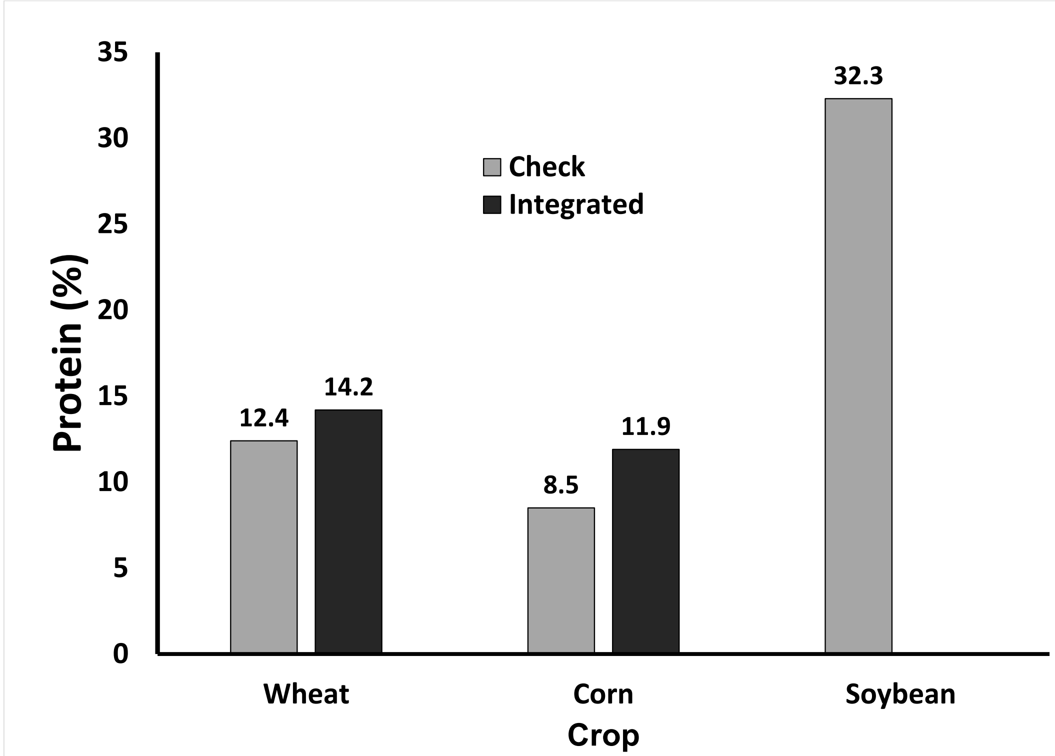


Fig 2. 2018 grain/seed protein for the grazed (Integrated) and grain crop check (Check) strips.

Table 1. Crop parameters for 2018.

Crop	Cultivar or type	Planting	Planting rate	Fertilizer	Harvest
Spring wheat	Glenn	5/2/18	100 lb/ac	Urea - 30 lb N/ac MAP - 30 lb mat/ac	8/30/18
Cover crop mix:		5/25/18	26.5 lb/ac	None	
Intermediate Wheatgrass	Manifest		6 lb/ac		
Timothy grass			6 lb/ac		
Alfalfa	Vernal		6 lb/ac		
Red clover	common		3.5 lb/ac		
Hairy vetch	Haymaker		1 lb/ac		
Radish	Daikon		3.5 lb/ac		
Chicory	common		0.5 lb/ac		
Corn	ProSeed 1280	5/22/18	24,500 seeds/ac	Urea - 40 lb N/ac MAP - 30 lb mat/ac	9/19/18 10/29/18
Interseeded w/ Soybean		5/22/18	80,200 seeds/ac		
Check strips					
Spring wheat	Glenn	5/2/18	90 lb/ac	Urea - 30 lb N/ac MAP - 30 lb mat/ac	8/30/18
Corn	ProSeed 1280	5/22/18	24,500 seeds/ac	Urea - 40 lb N/ac MAP - 30 lb mat/ac	9/19/18 10/25/18
Soybean	Mycogen 5B024 R2	5/23/18	180,000 seeds/ac	None	9/20/18 10/19/18

Cover Crop Interseeding Study – 2018 Summary

Dr. Mark Liebig, Dr. Dave Archer, Roberto Luciano (NRCS)

Establishing cover crops in row crops can be challenging in short-season northern regions. Interseeding cover crops into a standing crop can help cover crop establishment while limiting competition with the cash crop. This approach has been used in wetter areas of North Dakota, but performance in the western part of the state has not been widely tested. With drier conditions, it is particularly important to place cover crop seed into the soil rather than broadcast on the soil surface to improve the likelihood of germination and growth.

Approach:

- Plant cover crop mix in standing corn at different planting dates, using a no-till interseeder
- Cover crop seed mix: 17.8 lb rye, 3.2 lb triticale, 18.9 lb cowpea, 2.1 lb purple-top turnip
- Cover crop planting dates: June 15 (corn V4), June 22 (corn V5), June 28 (corn V6). Also, included a no-cover control.

Summary

There were no significant differences in grain yield for any of the treatments (Figure 1), so cover crop interseeding and interseeding date had no significant effect on grain yield.

Biomass of cover crops and weeds were sampled on Oct 15. Cover crop biomass was relatively small and only slightly more than the weed biomass that was observed in the Control treatment (Figure 2). Cover crop biomass was higher for the first cover crop planting date than for the control and for the second planting date, but was not different from the third planting date.

This study will be repeated on Field F5 in 2019.

Interseeder Corn Trial

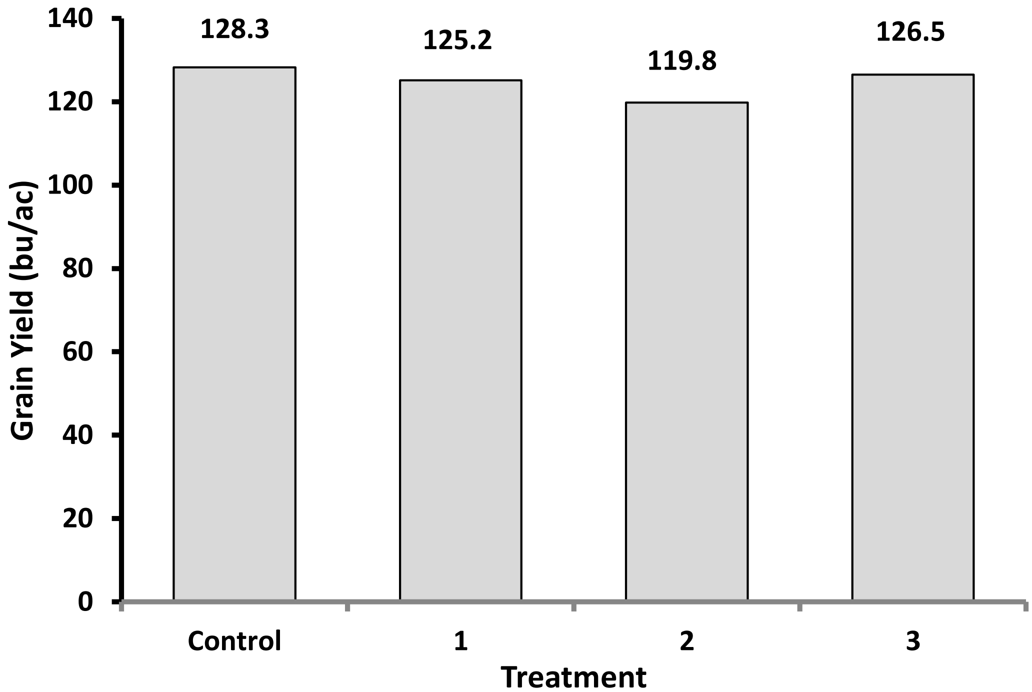


Fig 1. Corn grain yield for cover crop interseeding treatments: Control (no cover), 1 (June 15; corn V4), 2 (June 22; corn V5), 3 (June 28; corn V6)

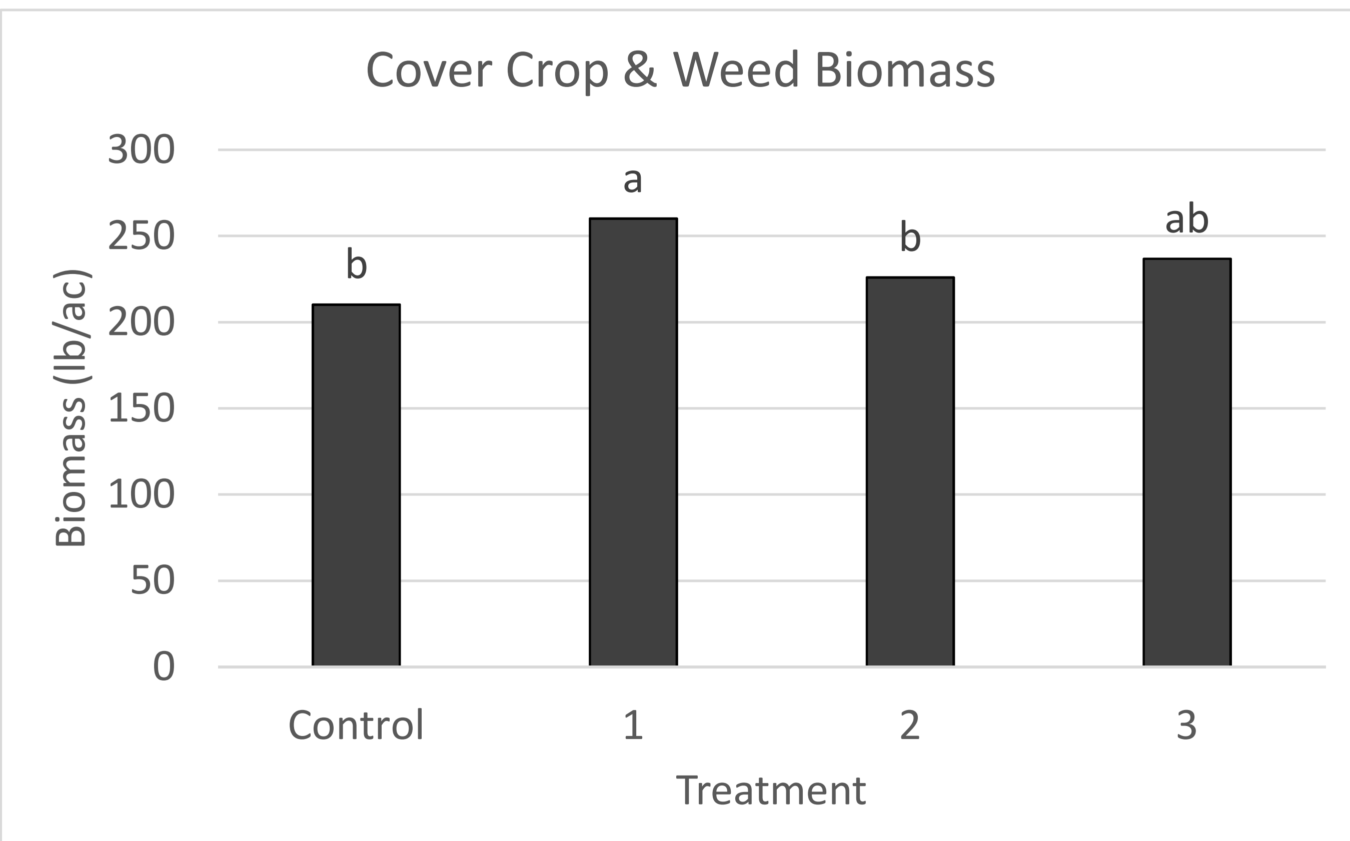


Fig 2. Total cover crop and weed biomass on Oct 15 for cover crop interseeding treatments: Control (no cover), 1 (June 15; corn V4), 2 (June 22; corn V5), 3 (June 28; corn V6).

USDA-ARS Northern Great Plains Research Laboratory Research Network Involvement - 2018

Drought-Net - Fields S13, S14, SlS.
Drought-Net is a global network focused on assessing terrestrial ecosystem sensitivity to drought. To effectively forecast terrestrial ecosystem responses to drought, ecologists must determine the mechanisms underlying ecosystem sensitivity to drought across a range of different ecosystem types, and then improve existing modeling frameworks by incorporating such variation within the context of broader environmental gradients.

Drought-Net will advance understanding of the determinants of terrestrial ecosystem sensitivity to drought by bringing together an international cadre of scientists with expertise that spans a wide range of terrestrial ecosystems, but with a common interest in drought, to design and coordinate three complementary research coordination activities: 1) Planning and coordinating new research utilizing standardized measurements to leverage the value of existing drought experiments across the globe, 2) Finalizing the design and facilitating the establishment of a new international network of coordinated drought experiments, and 3) Training highly motivated graduate students to conduct synthetic and network-level research through Distributed Graduate Seminars focused on drought. *http://wp.natsci.colostate.edu/droughtnet/*

RISK (Rain Intercept Shelters for Kentucky bluegrass) - Fields S13, Sl4, SlS.
There is concern over Kentucky bluegrass (*Poa pratensis*) cover increase throughout the northern Great Plains of the USA and little information is available regarding effects of drought on this species and potential bluegrass control treatments. The RISK project will test the response of Kentucky bluegrass to three different levels of precipitation (ambient, 30% interception, and 60% interception). Three hypotheses guide the project: 1) Decreased precipitation will reduce the relative abundance of Kentucky bluegrass in comparison to associated native grasses, 2) Burning will decrease the relative abundance of Kentucky bluegrass under all precipitation regimes, and 3) Increased stress through burning and simulated drought will decrease Kentucky bluegrass abundance and increase native species richness while wetter unburnt plots will remain dominated by Kentucky bluegrass.

NEON (National Ecological Observatory Network) - Field S66 and peripheral sites on NGPRL land.
NEON is a continental-scale ecological observation facility, sponsored by the National Science Foundation and operated by Battelle, that gathers and synthesizes data on the impacts of climate change, land use change and invasive species on natural resources and biodiversity.

The NEON observatory is designed to collect high-quality, standardized data from 81 field sites (47 terrestrial and 34 aquatic) across the U.S. (including Alaska, Hawaii and Puerto Rico). Data collection methods are standardized across sites and include in situ instrument measurements, field sampling and airborne remote sensing. Field sites are strategically selected to represent different regions of vegetation, landforms, climate, and ecosystem performance. NEON data and resources are freely available to enable users to tackle scientific questions at scales not accessible to previous generations of ecologists. *www.neonscience.org*

IPICL (Improving Production with Integrated Crop Livestock Systems) - Fields S6, S12, S13, Sl4.
IPICL is a USDA-funded research and extension project focused on increasing the diversity of farm production systems that conserve soil resources, increase resilience of farm operations, moderate risk against a changing climate, and improve nutrient cycling, thereby enhancing sustainable food production and maintenance of farm-based communities and livelihoods of the region. The project involves a team of 26 scientists across three states (ND, SD, NE) with research expertise in crop performance, livestock health, soil quality, greenhouse gas flux, and nutrient management. *http://www.ipicl.org/*

LTAR (Long-Term Agroecosystem Research Network)- Fields HS, 12, 13.
The Long-Term Agroecosystem Research (LTAR) Network is a partnership among 18 premier long-term research sites across the United States. LTAR was established to build the knowledge required for sustainable intensification of agriculture, increasing yields from the current agricultural land base while minimizing or reversing agriculture's adverse environmental impacts. Network research is organized around topics of sustainability of regional or national consequence, relying upon long-term databases, cross-site experiments, and computational modeling to tie experimental and monitoring conclusions from diverse locations to a broader vision of agriculture for the United States.

https://ltar.nal.usda.gov/

NWERN (National Wind Erosion Research Network) - Field HS.
The National Wind Erosion Research Network was established in 2014 as a collaborative effort led by the US Department of Agriculture Long Term Agro-Ecosystem Research network and the Bureau of Land Management to address the need for a long-term research program to meet critical challenges in wind erosion research and management in the United States. The Network has three aims: (1) provide data to support understanding of basic aeolian processes across land use types, land cover types, and management practices, (2) support development and application of models to assess wind erosion and dust emission and their impacts on human and environmental systems, and (3) encourage collaboration among the aeolian research community and resource managers for the transfer of wind erosion technologies. The Network currently consists of thirteen intensively instrumented sites providing measurements of aeolian sediment transport rates, meteorological conditions, and soil and vegetution properties thut influence wind erosion. Network sites are located across rangclands, croplands, and deserts of the western US. The Network provides a mechanism for engaging national and international partners in a wind erosion research program that addresses the need for improved understanding and prediction of aeolian processes across complex and diverse land use types and management practices.

https://winderosionnetwork.org/

GRACEnet (Greenhouse gas Reduction through Agricultural Carbon Enhancement network) - Multiple fields.
The objective of GRACE net is to identify and further develop agricultural practices that will enhance carbon sequestration in soils, promote sustainability and provide a sound scientific basis for carbon credits and trading programs. This program will generate information concerning carbon storage in agricultural systems that is needed by producers, program managers and policy makers. Agricultural lands to be studied by GRACEnet scientists include both grazing lands (range and pasture) and crop lands (irrigated and dryland). Coordinated multi-location field studies will follow standardized protocols to compare net GHG emissions (CO_2, CH_4, N_20), carbon sequestration, and broad environmental benefits under different management systems.

www.ars.usda.gov/anrds/gracenet/

REAP (Resilient Economic Agricultural Practices) - Multiple fields.
REAP is a cross-location research project involving ARS units nationwide that recognizes and strives to enhance diverse and precious soil resources through trans-disciplinary, multi-location research and technology transfer. Project goals include, 1) Identify physical, chemical, or biological parameters and index tools that quantify management effects on carbon sequestration and soil health, and 2) Conduct multi-location comparisons of business as usual (BAU) versus management practices designed to enhance soil health. Efforts within REAP provided critical data to meet the ARS Grand Challenge of transforming agriculture to deliver a 20% increase in Quality Production with 20% lower environmental impact by 2025.

www.ars.usda.gov/natural-resources-and-sustainable-agricultural-systems/soil-and-air/docs/reap-2/

CEAP (Conservation Effects Assessment Project) - Multiple fields.
CEAP is a multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Project findings will be used to guide USDA conservation policy and program development and help conservationists, farmers and ranchers make more informed conservation decisions. Assessments in CEAP are carried out at national, regional and watershed scales on cropland, grazing lands, wetlands and for wildlife. The three principal components of CEAP-the national assessments, the watershed assessment studies, and the bibliographies and literature reviews- contribute to building the science base for conservation. That process includes research, modeling, assessment, monitoring and data collection, outreach, and extension education. Focus is being given to translating CEAP science into practice.

www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

NDSU Hettinger Research Extension Center

Hard Red Spring Wheat - 2018	**Mandan, ND**

Variety	Plant Height	Plant Lodge	Test Weight	Grain Protein	----- Grain Yield ----- 2016	2017	2018	Average Yield 2 yr	3 yr
	inches	0-9*	lbs/bu	%	------------ Bushels per acre ------------				
AAC Brandon	28	0	54.4	12.4	--	--	41.7	--	--
AAC Goodwin	31	0	55.4	12.6	--	--	50.9	--	--
AAC Penhold	30	0	54.6	12.4	--	--	49.0	--	--
Barlow	28	0	54.7	13.1	60.9	16	46.2	31.1	41.0
Bolles	27	0	55.3	13.2	--	7.5	48.6	28.1	--
Boost	28	0	54.5	12.8	--	16.0	50.5	33.3	--
DynaGro Ambush	26	0	56.1	12.1	--	--	50.5	--	--
DynaGro Caliber	29	0	55.9	14.2	--	--	52.7	--	--
Elgin-ND	27	0	55.8	12.7	65.3	17.4	48.9	33.2	43.9
Faller	29	0	55.6	11.3	--	--	45.6	--	--
Glenn	30	0	54.9	13.1	62.6	11.1	56.0	33.6	43.2
HRS 3100	29	0	54.5	12.5	--	--	52.4	--	--
HRS 3419	30	0	54.9	10.5	73.5	18.3	51.2	34.75	47.7
HRS 3504	27	0	53.4	11.7	--	--	46.2	--	--
HRS 3530	25	0	55.3	12.9	70.6	18.3	48.2	33.3	45.7
HRS 3616	27	0	55.9	13	--	--	46.5	--	--
HRS 3888	30	0	54.5	12.5	--	--	51.5	--	--
Lang-MN	28	0	55.3	12.0	--	21.1	51.3	36.2	--
Lanning	28	0	55.1	12.8	--	--	46.3	--	--
LCS Breakaway	28	0	54.3	13.1	--	--	49.6	--	--
LCS Cannon	30	0	54.1	13.1	--	--	50.0	--	--
LCS Rebel	27	0	55.4	12.9	--	--	52	--	--
LCS Trigger	29	0	54.0	10.2	--	28.7	43.5	36.1	--
Linkert	29	0	54.9	13.1	--	--	45.9	--	--
Mott	28	0	54.1	12.9	61.3	18.2	45.1	31.65	41.5
MS Camaro	26	0	55.0	13.7	--	--	51.6	--	--
MS Chevelle	29	0	54.0	12.0	--	22.6	49.8	36.2	--
MS Barracuda	29	0	55.3	12.3	--	--	50.2	--	--
ND VitPro	29	0	55.2	13.7	--	16.2	47.1	31.7	--
Prestige	29	0	55.5	12.6	--	--	46.5	--	--
Prosper	31	0	54.3	11.2	--	--	53	--	--
Redstone	26	0	55.4	10.9	--	22.3	44.7	33.5	--
Rollag	29	0	54.6	13.7	--	--	48.6	--	--
Shelly	28	0	54.7	11	--	15	51.8	33.4	--
Surpass	30	0	54.8	11.8	--	17.4	51.4	34.4	--
SY Ingmar	29	0	55.2	12.5	58.8	20.5	55.4	38.0	44.9

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NDSU Hettinger Research Extension Center

Hard Red Spring Wheat - 2018									**Mandan, ND**
	Plant	Plant	Test	Grain	----- Grain Yield -----			Average Yield	
Variety	Height	Lodge	Weight	Protein	2016	2017	2018	2 yr	3 yr
	inches	0-9*	lbs/bu	%	------------ Bushels per acre ------------				
Table continues from previous page									
SY Rockford	27	0	54.6	11.9	--	--	46	--	--
SY Soren	30	0	54.6	12.7	59.4	18.3	48.0	33.2	41.9
SY Valda	31	0	56.0	11.6	--	19.1	46.0	32.6	--
TCG Climax	29	0	54.6	12.7	--	--	54.8	--	--
TCG Glenville	30	0	55.2	13.6	--	--	53.3	--	--
TCG Sptifire	29	0	55.2	11.4	--	23.2	49.2	36.2	--
WB9479	30	0	55.8	13.1	--	--	51.9	--	--
WB9590	27	0	54.1	12.8	--	--	52.2	--	--
WB9653	29	0	54.2	11.1	70.1	23.7	45.3	34.5	46.4
WB9719	31	0	54.7	11.3	--	--	49.9	--	--
Trial Mean	29	0	54.9	12.5	64.2	18.5	49.3	33.1	43.8
C.V. %	7.6	--	2.2	6.0	7.6	15.7	12.2	--	--
LSD 5%	3.0	NS	1.7	1.0	6.9	4.1	8.4	--	--
LSD 10%	2.6	NS	1.4	0.9	5.7	3.4	7.0	--	--

* 0 = no lodging, 9 = 100% lodged.

Planting Date: May 9

Harvest Date: September 6

Previous Crop: Spring Wheat

NDSU Hettinger Research Extension Center

Durum Wheat - 2018									**Mandan, ND**
	Plant	Plant	Test	Grain	----- Grain Yield -----			Average Yield	
Variety	Height	Lodge	Weight	Protein	2016	2017	2018	2 yr	3 yr
	inches	0-9*	lbs/bu	%	------------ Bushels per acre ------------				
Alkabo	27	0	57.9	12.8	62.5	20.2	33.6	26.9	38.8
Carpio	31	0	57.2	11.6	70.2	21.6	36.4	29.0	42.7
Joppa	31	0	57.8	12.2	69.8	24.9	34.9	29.9	43.2
ND Grano	31	0	58.1	11.3	--	23.7	32.1	27.9	--
ND Riveland	32	0	58.6	11.0	--	18.8	36.4	27.6	--
Tioga	34	0	58.2	12.0	72.9	19.9	34.0	27.0	42.3
Trial Mean	31	0	57.9	11.8	70.0	21.3	34.6	28.0	41.7
C.V. %	8.0	--	1.1	7.0	4.8	12.3	7.7	--	--
LSD 5%	2.7	NS	0.9	1.2	5.1	3.9	4.0	--	--
LSD 10%	2.3	NS	0.8	1.0	4.2	3.2	3.3	--	--

* 0 = no lodging, 9 = 100% lodged.

Planting Date: May 9

Harvest Date: September 6

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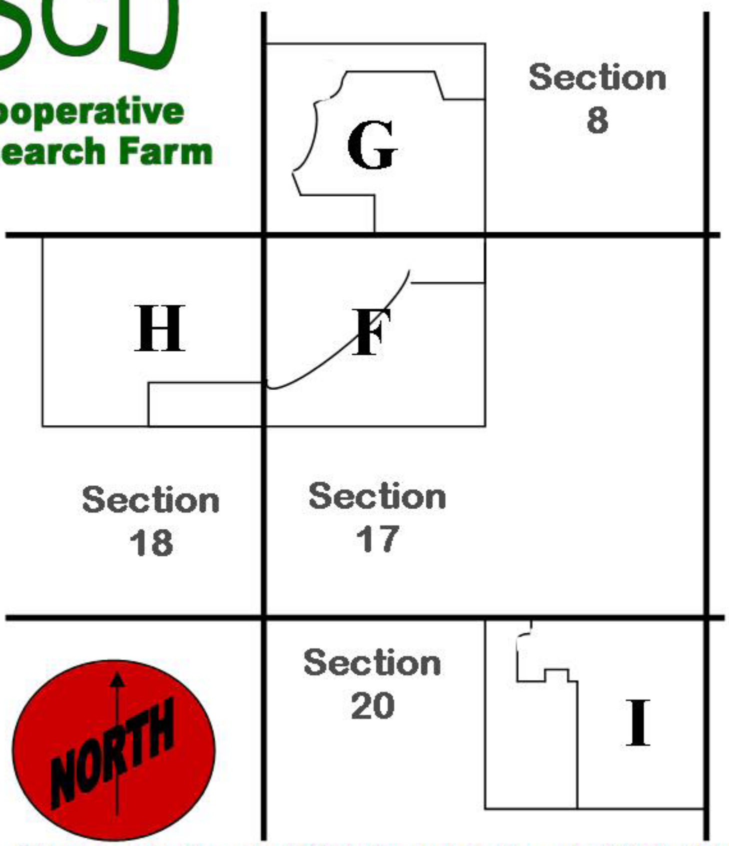

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