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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.

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Crop Diversity Effects on Productivity and Economics

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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.

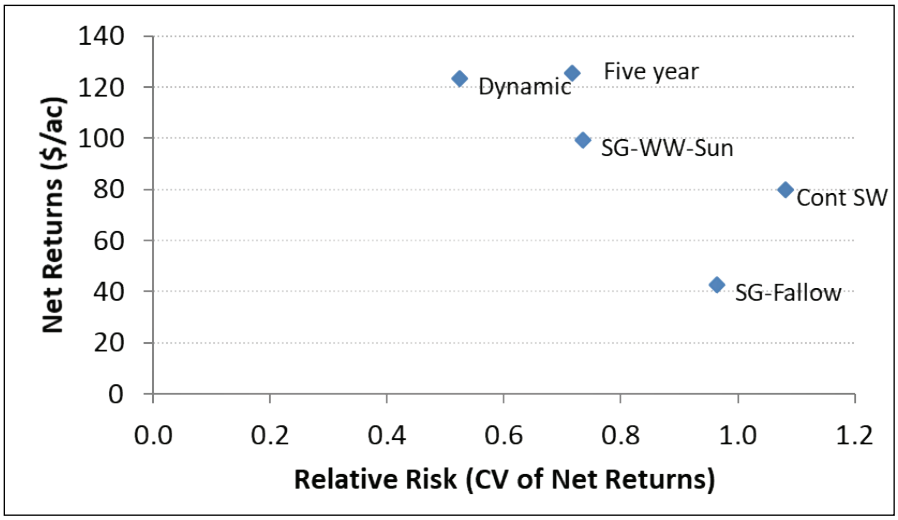

Fig. 1. Tradeoffs between average net returns and relative risk for each crop rotation.

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.

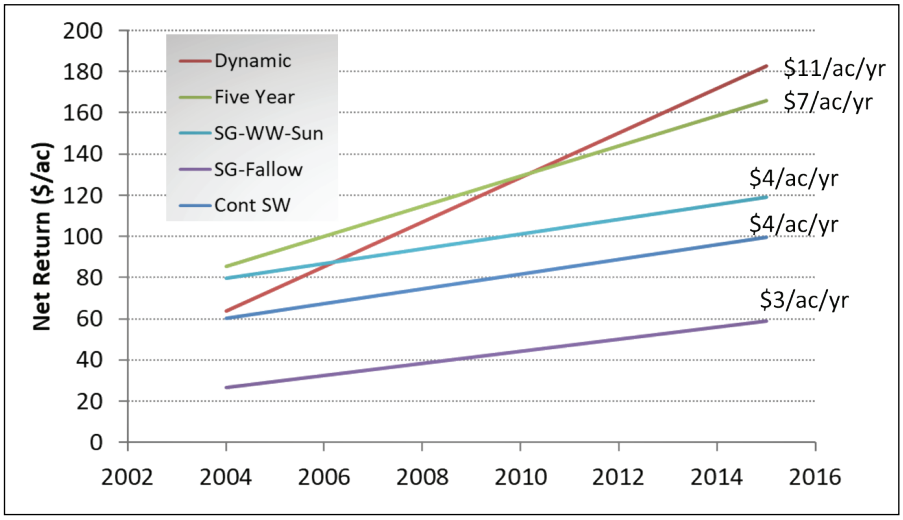

Fig. 2. Trends in annual net returns for each crop rotation.

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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Message from Dave

Dr. David Archer, Research Leader

I was recently asked how we develop our research plans. While our scientists and staff bring their own research ideas to the table, a primary source of ideas is our stakeholders. The NGPRL has a Customer Focus Group that meets two times each year, in February and July. These meetings provide an opportunity for us to give updates on our research, and to get feedback on research direction and ideas on high priority research needs.

This input feeds into the formal research planning process for a project, which is on a five-year cycle. Our research had been organized under three different projects, each on their own five-year cycle. However, we have just finished consolidating all of our research into one project "Sustainable Agricultural Systems for the Northern Great Plains", which officially began in October, 2018.

The studies within this project are grouped under four inter-related objectives. Objective 1 focusses on development of management strategies to improve sustainability. The goal is to increase production and economic performance of these systems while improving ecosystem services. This includes management strategies for grazing, crop, and integrated crop/livestock systems. Objective 2 is targeted toward assessing and developing options to better withstand or adapt systems to extreme weather events, and begins to scale-up our research to a broader region. Objective 3 is designed to see if the strategies that are designed to increase overall sustainability can also increase the nutrient content of crop and livestock products. Finally, Objective 4 expands our research to a national scale through participation in research networks, including the Long-Term Agroecosystem Research Network (LTAR).

Please do not hesitate to contact us if you would be interested in participating in the Customer Focus Group or have feedback on our research.

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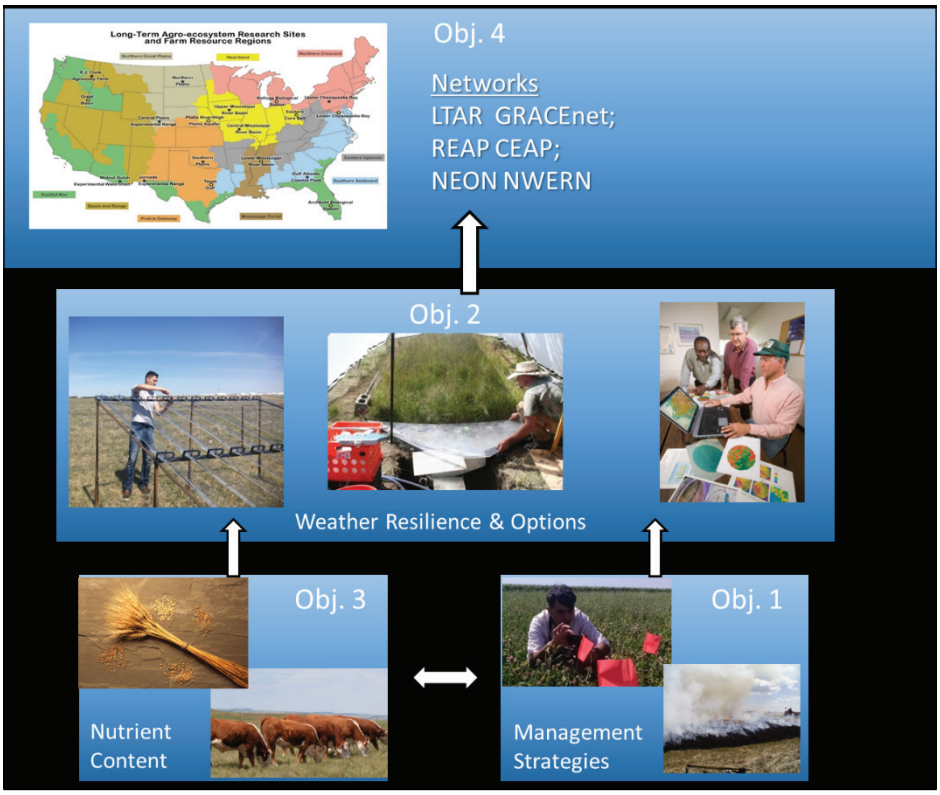

Farming and Ranching for the Bottom Line

Healing the Land & Ourselves with Livestock

February 26 & 27, 2019

National Energy Center for Excellence
Bismarck State College
1200 Schafer St. Bismarck, ND

AGENDA:

DAY 1: Tuesday, Feb 26

8 to 9 am	Registration
9 to 9:15	Welcome
9:15 to 9:45	Area 4 Farm Overview – Mark Liebig
9:45 to 10:45	Cover Crops On My Land? – Dave Archer, Jay Fuhrer
10:45 to 11	Break
11 to 12	Animal Behavior – Temple Grandin
12 to 1 pm	Lunch
1 to 2	Drought Conditions: Will They Return? – Henry Blakes
2 to 3:15	Livestock Handling Systems – Temple Grandin
3:15 to 3:30	Break
3:30 to 4:30	Impacts of Bale Grazing – Kevin Sedivec, Michael Undi
5 to 7	Poster Sessions, Table Talks & Social

Sponsored by ND Stockmen's Association

DAY 2: Wednesday, Feb 27

8 to 9 am	Registration
9 to 9:15	Welcome
9:15 to 10:40	Building Healthy Soil & Profits with Planned Grazing – Greg Judy
10:40 to 11	Break
11 to 12	The Dorito Effect: The Surprising New Truth About Food & Flavor – Mark Schatzker
12 to 1 pm	Lunch – Guest Speaker
1 to 1:30	The Banker's Perspective – Don Morgan, Starion Financial
1:30 to 2:30	Couples Panel Annie & John Carlson, Morning Joy Farm Krista & Jay Reiser, Reiser Ranch Molly & Justin Zahradka, Coop & Poop
2:30 to 3	All Speakers Q&A Wrap-Up

- Area Four Research Farm
- Bismarck State College
- Burleigh County Soil Conservation District
- Menoken Farm

SPONSORS & PARTNERS

- Morton County Soil Conservation District
- ND Grazing Lands Coalition
- NDSU Extension
- USDA Agricultural Research Service
- USDA Natural Resources Conservation Sevice

REGISTRATION: There is no cost to attend this event. However, due to limited seating, please RSVP by Feb 19th. To register, contact Cindy at 701-221-6865, or menokenfarm@gmail.com. For hotel reservations, please call the Hampton Inn and Suites at (701) 751-5656 & mention this conference to receive a discounted rate.

NGPRL shortcourse explores value of visual soil health assessments

Dr. Mark Liebig

Interest in soil health among farmers and ranchers has contributed to the development of new soil health tests. Broadly, these soil tests are intended to shed light on the 'soil's capacity to function', whether for agricultural production, environmental protection, habitat restoration, or some combination thereof. When applied and interpreted appropriately, soil health tests can provide valuable information to help guide decisions related to soil management.

Not surprisingly, as soil health tests have expanded in number, so have their complexity. Some laboratory-based soil health tests are so complex the outcomes are difficult to interpret. As a result, the tests may have limited application in helping producers make informed decisions about managing their soil.

Approaches to soil health assessment are needed to link the new and exciting laboratory tests with field tests that can be easily conducted and interpreted.

Fortunately, hands-on soil health tests have been developed to meet this need. One such test, called VESS [Visual Evaluation of Soil Structure; Ball et al. (2017)] uses a straightforward method that involves digging a hole and evaluating the soil's aggregation, porosity, and rooting characteristics. When complete, the evaluator assigns a score to the soil ranging from one to five.

In an effort to explore the value of VESS and other visual soil health assessments, a shortcourse for producers and conservationists was held on September 6th at the Northern Great Plains Research Laboratory (NGPRL) called Soil Health Connections. Over an afternoon, attendees learned the VESS method and applied it to seven NGPRL fields that differed in management. Each field was also evaluated for several laboratory-based soil health assessments earlier in the year, thereby allowing outcomes from VESS method to be compared to laboratory tests.

Average participant scores derived from the VESS method were found to be correlated to several common soil tests (e.g., soil organic matter, soil bulk density) as well as some somewhat specialized tests (e.g., soluble organic carbon, mineralizable nitrogen). Overall, the VESS method, requiring only a shovel and a laminated score sheet for guidance, served as a promising approach to easily relate the soil's condition in the field to laboratory measurements.

Evaluation of the VESS method will continue at NGPRL as we seek to better understand how long-term management systems affect the soil resource. A second shortcourse is planned for later this year. If you are interested in attending, please look for a formal announcement in the July edition of the NGPRL Integrator.

For an excellent review of the VESS method, see *Ball et al. (2017). Visual soil evaluation: A summary of some applications and potential developments for agriculture. Soil Tillage Res. 173:114-124. https://doi.org/10.1016/j.still.2016.07.006*

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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,

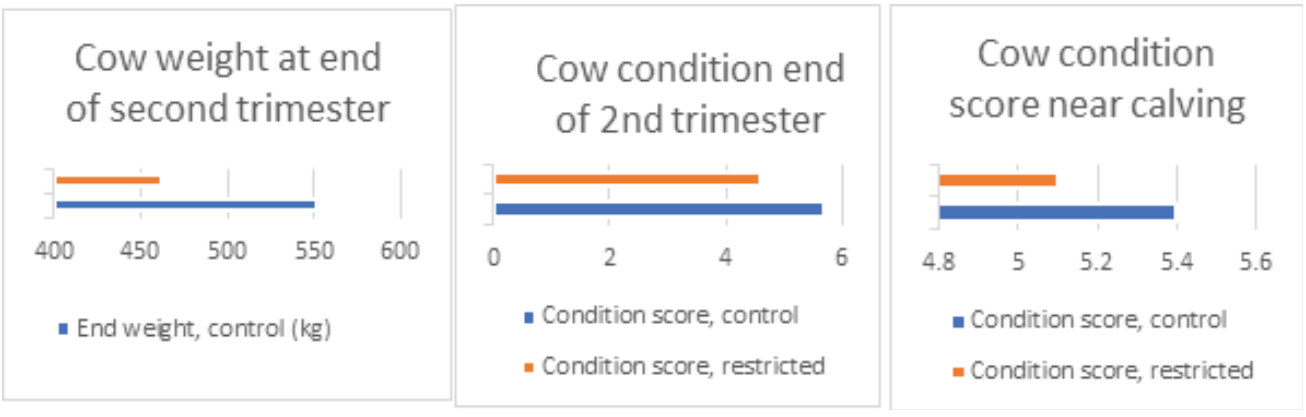

Fig. 1. Comparison of cow body weight and condition between two groups fed differently during the second trimester of pregnancy

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Fetal programing and winter feeding

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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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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, a self-administered questionnaire was mailed 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

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Understanding the role of prescribed fire in the northern Great Plains

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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.

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

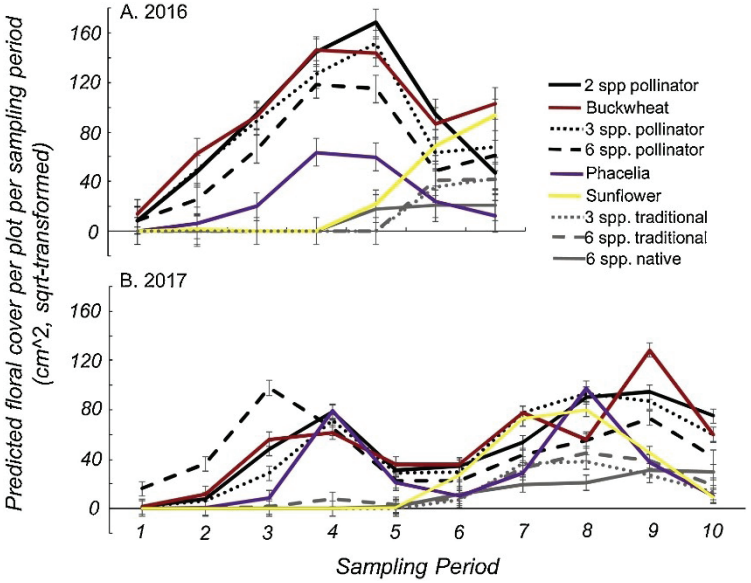

Fig. 2. Floral cover per plot per sampling period over the growing season for different plant treatments in 2016 (A) and 2017 (B).

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

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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, 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 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.

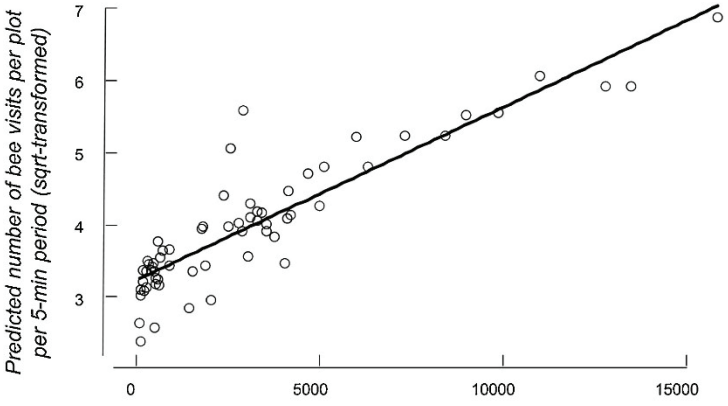

Fig. 3. Relationship between average bee visitation rate and average floral cover per plot.

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

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

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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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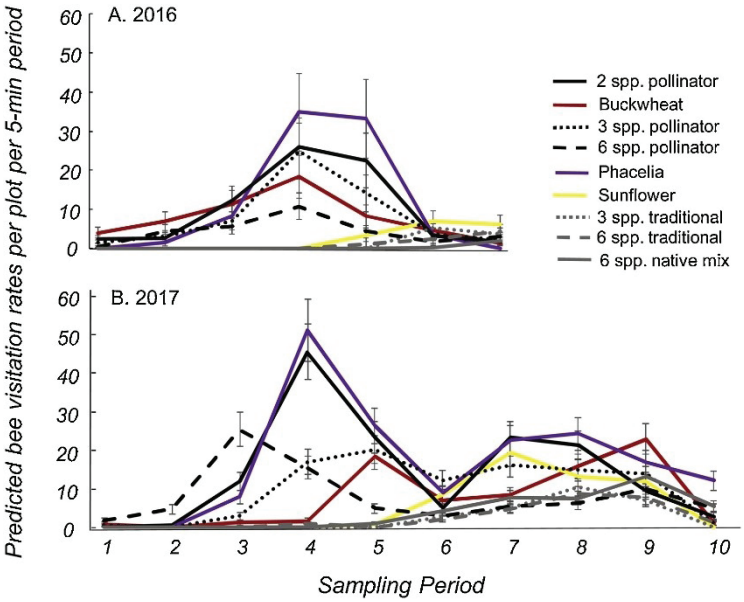

Fig. 4. Bee visitation rates per plot per sampling period over the growing season for different plant treatments in 2016 (A) and 2017 (B).

Crew working in the Organic Transition Study taken with the new NGPRL drone in August 2018

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.

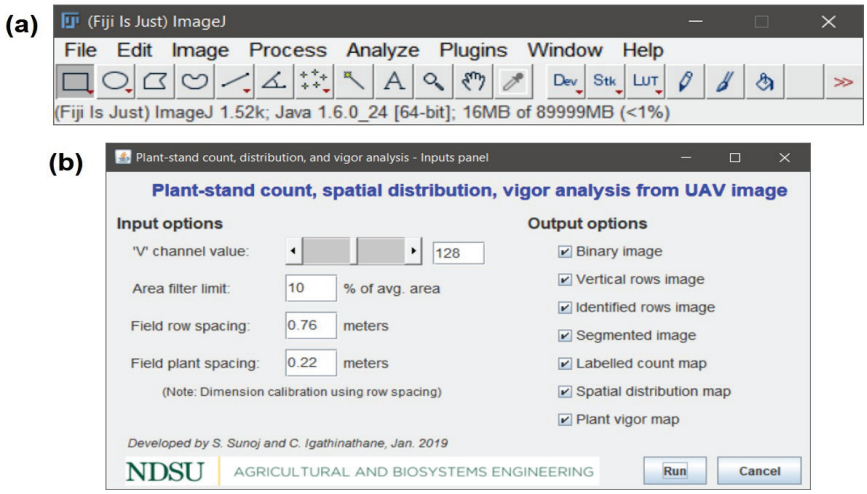

Fig. 1. The open-source and free Fiji software and the front panel of the developed plugin. (a) The simple interface of the Fiji software (Ver. ImageJ 1.52k; Java 1.6.0_24); (b) The front panel of the developed plugin with various input and output options.

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 works with minimum user input requirements is not available. The basic commercial software itself is expensive and carries 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 and performs plant-stand count, spatial distribution, and vigor (foliage growth) analysis from UAV images. The plugin starts with a custom-designed front panel (Fig. 1b) that has 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 is 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

continued on page 13

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

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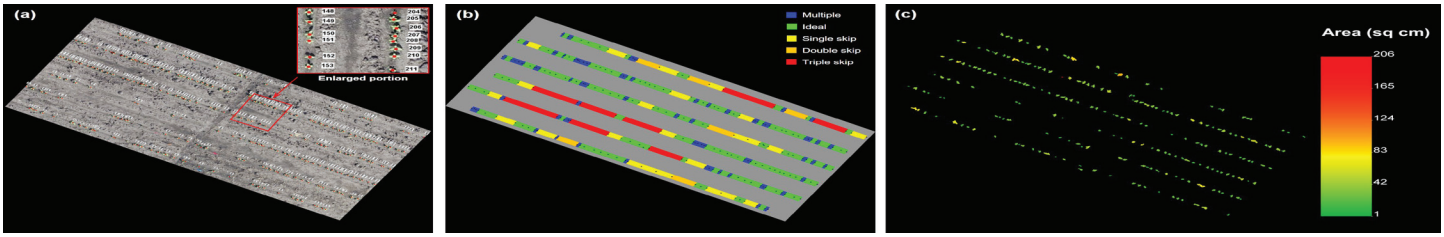

Fig. 2. Few outputs from the developed ImageJ plugin using the inclined field image as input. (a) Row-wise sequentially counted plants; (b) Plant spatial distribution map classified into five spacing classes – multiple, ideal, single skip, double skip, and triple skip; and (c) Plant vigor map with the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

were captured when sunflower plants were in V2 and V4 stages. The UAV image used in this study 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 row 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 row orientation determination – A simple and less computationally intensive method using profile was developed, unlike Hough transform.

iv. Crop row identification – A fully automatic crop row 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 plants.

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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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 could be widely adopted as it possesses multiple agronomical and social-economic benefits.

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

Cover 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

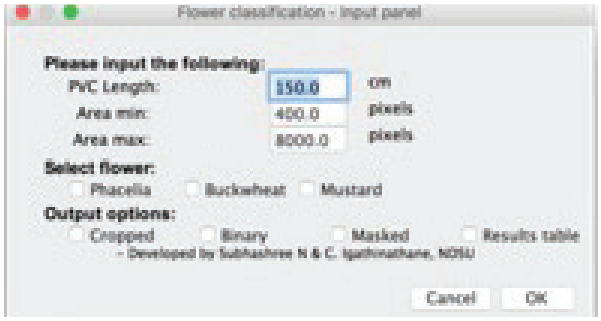

Fig. 2. Front panel of the developed plugin.

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 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 flower classification and quantification in terms of floral

Fig. 3. Equipment used for image acquisition.

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).

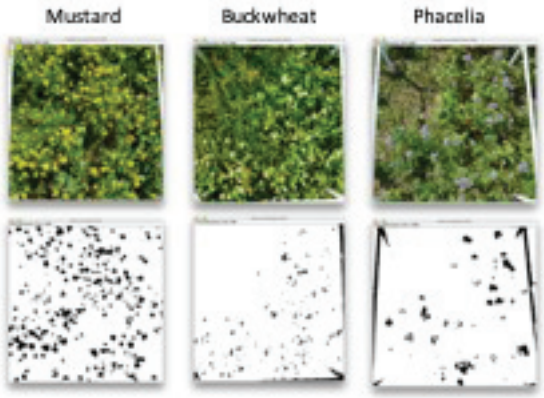

Fig. 4. Conversion of RGB to binary image through pre-processing and thresholding techniques.

A color DSLR camera and custom designed frame (1.5 m × 1.5 m) with legs were used in the test plots for capturing the inflorescence images (Fig.3). The images were captured weekly for a duration of

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Digital image processing for classification and quantification of cover crop flowers

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about three months (June – August 2017), a total of 192 sample images (4 main plots × 16 subplots × 3 replications) were captured in a visit.

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

A sequence of image pre-processing and thresholding techniques was employed for the segmentation of flowers from the background (soil and plant material

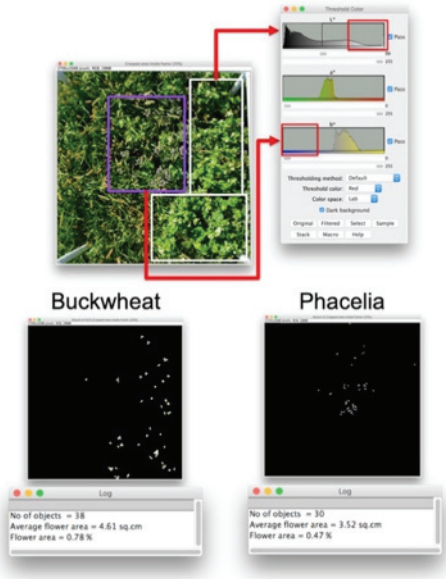

Fig. 6. Flower classification results – buckwheat and phacelia

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.

Based on preliminary analysis it can be concluded

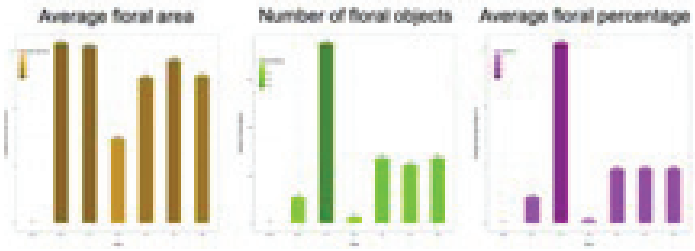

Fig. 7. Flower quantification results

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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Congratulations Sunoj Shajahan

Sunoj Shajahan, a doctoral candidate in Agricultural and Biosystems Engineering, NDSU, under the supervision of Dr. Igathinathane Cannayen working in collaboration with NGPRL, Mandan received the American Society of Agricultural and Biosystems Engineers' Superior Paper Award. He was recognized with a certificate during the society's Annual International Meeting held July 29-Aug 1, 2018, in Detroit, MI. Of the 300 articles published in the society's three peer-reviewed journals during 2017, about 15 are selected for the annual superior paper award. The papers were judged on timeliness, value, originality and benefits to society. In this paper, an image processing-based method of assessing the number of aphids, while differentiating from the exoskeletons and leafspots, from the digital image of soybean leaves for rapid quantification of pest infestation was developed. *Sunoj, S., Sivarajan, S., Maharlooei, M., Bajwa, S. G., Harmon, J. P., Nowatzki, J., and Igathinathane, C. 2017. Identification and counting of soybean aphids from digital images using shape classification. Transactions of the ASABE, 60: 1467-1477 (https://elibrary.asabe.org/abstract.asp?aid=48461).*

NGPRL organizes and contributes to special issue of rangelands

Dr. John Hendrickson

The Society for Range (SRM) Management Annual Meetings were held in Minneapolis, MN from February 10-14, 2019. Because of the Minneapolis location, the Northern Great Plains Section of SRM, which includes North Dakota, helped host the meetings. As hosts, the Northern Great Plains Section was encouraged to develop a special issue of Rangelands focusing on rangeland issues in the region.

Scientists from NGPRL were asked to organize and contribute to this special issue. Articles contained in the issue included the following:

1) Threats to soil function in Northern Great Plains grazing lands,

2) Vegetation in the Northern Great Plains and North Central Region

3) History of plant breeding in the Northern Great Plains,

4) US Fish and Wildlife Service land management in the prairie pothole region,

5) Wetland ecology in the region, and

6) Challenges facing rangelands in the Northern Great Plains and North Central Regions.

In addition to organizing the issue, NGPRL scientists authored or co-authored the articles on soil function, vegetation, plant breeding history and challenges to rangelands. The special issue is an important contribution to recognizing the benefits and challenges common to grazing and wildlands in the region.

Copies of the articles that NGPRL scientist were involved in will be available after publication.

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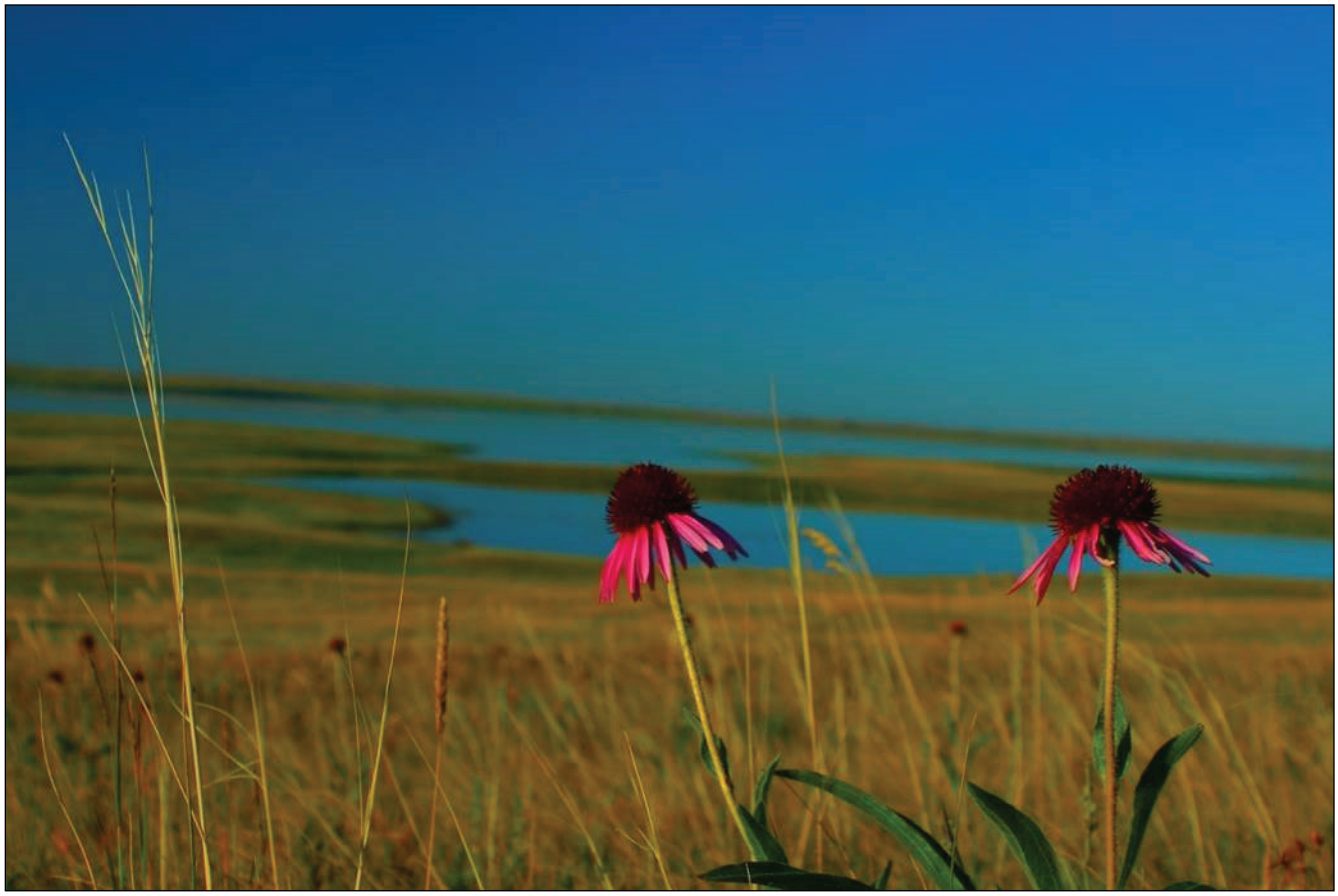
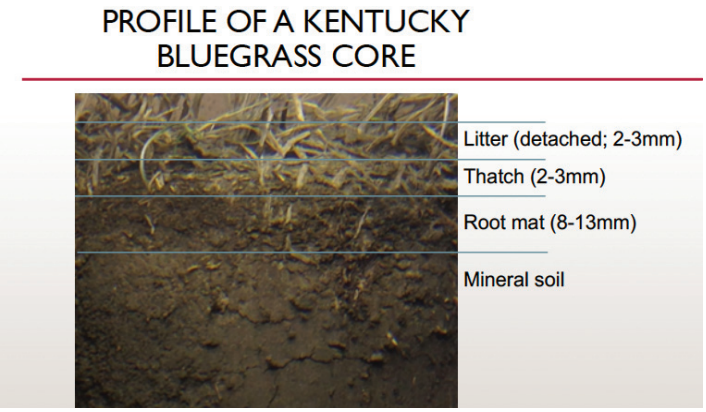


Hydrologic effects of grazing and prescribed fire on Kentucky bluegrass dominated rangelands

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 (tending to repel or fail to mix with water), 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 layers, 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 that Kentucky bluegrass is common across the Northern Great Plains.

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.

David Toledo 701.667.3063 david.toledo@usda.gov

Presentations of NGPRL science

Since the last issue:

On September 10-13, 2018, ARS Research Soil Scientist Mark Liebig, of the Northern Great Plains Research Laboratory in Mandan, ND, attended the International Conference on Agricultural Greenhouse Gas Emissions and Food Security in Berlin, Germany to present the abstract and poster, "*MAGGnet: A Meta-Database to Support Greenhouse Gas Mitigation Research*".

Dr. David Archer discusses northern soybean production with farmers from Argentina

On September 10, 2018, ARS staff at the Northern Great Plains Research Laboratory in Mandan, ND hosted a research tour for a group of innovative farmers and agribusiness professionals from Argentina sponsored by Fundación Producir Conservando. The tour led by NGPRL Research Leader David Archer and Range Scientist John Hendrickson highlighted NGPRL long-term conservation cropping systems and integrated crop-livestock systems research.

October 5, 2018, ARS Research Ecologist Jose Franco, of the Northern Great Plains Research Laboratory in Mandan, ND, presented a seminar for students at the United Tribes Technical College in Bismarck, ND entitled "*Diversification strategies for sustainable crop production*".

November 4-7, 2018, NGPRL Research Leader David Archer and Research Ecologist Jose G. Franco, attended the American Society of Agronomy and Crop Science Society of America Meeting in Baltimore, MD to give invited presentations "*Cover Crops Systems for the Northern Great Plains: Long-Term Performance and Economics*" (Archer), "I*nter-annual rainfall variability impacts on cover crop productivity during the organic transition period*" (Franco), and "*Multi-species and monoculture cover crop productivity under contrasting management systems and climates in the Northern Great Plains*" (Franco). Franco also moderated an oral presentation session, and served as judge for the Students of Agronomy, Soils, and Environmental Sciences speech contest.

On November 1, 2018, Mark Liebig provided four tours for BSC soils students. In each tour students reviewed protocols for soil sampling, processing, analysis, and archiving. Each group of students toured soils research facilities in Building 28, 1, and 24 at NGPRL. Fifty-two students attended the tours (a record), along with their instructor, Dr. Marko Davinic.

On September 25-26, 2018, NGPRL hosted 20 North Dakota National Guard personnel on site to conduct a 'scenario-based' emergency response training exercise. They worked mainly out of three trailers and a few trucks

New science published

Annual cover crops for managed and wild bees: optimal plant mixtures depend on pollinator enhancement goals

Mallinger, R., Franco Jr, J.G., Prischmann-Voldseth, D.A., Prasifka, J.R. 2018. Annual cover crops for managed and wild bees: optimal plant mixtures depend on pollinator enhancement goals. Agriculture, Ecosystems and Environment. 273(1):107-116. https://doi.org/10.1016/j.agee.2018.12.006

Effects of feeding Lespedeza cuneata pellets with Medicago sativa hay to sheep: Nutritional impact, characterization and degradation of condensed tannin during digestion

Kronberg, S.L., Zeller, W.E., Waghorn, G., Grabber, J.H., Terrill, T.H., Liebig, M.A. 2018. Effects of feeding Lespedeza cuneata pellets with Medicago sativa hay to sheep: Nutritional impact, characterization and degradation of condensed tannin during digestion. Animal Feed Science And Technology. 245:41-47. https://doi.org/10.1016/j.anifeedsci.2018.08.011

Effects of storage time and temperature on greenhouse gas samples in Exetainer vials with chlorobutyl septa caps

Faust, D.R., Liebig, M.A. 2018. Effects of storage time and temperature on greenhouse gas samples in Exetainer vials with chlorobutyl septa caps. MethodsX (2018). https://doi.org/10.1016.j.mex.2018.06.016

Spring wheat yields following perennial forages in a semiarid no-till cropping system

Franco Jr, J.G., Duke, S.E., Hendrickson, J.R., Liebig, M.A., Archer, D.W., Tanaka, D.L. 2018. Spring wheat yields following perennial forages in a semiarid no-till cropping system. Agronomy Journal. 110(5):1-9. https://doi.org/10.2134/agronj2018.01.0072

Sunflower floral dimension measurements using digital image processing

Shajahan, S., Navaneeth, S., Babu, D., Cannayen, I., Franco Jr, J.G., Mallinger, R.E., Prasifka, J.R., Archer, D.W. 2018. Sunflower floral dimension measurements using digital image processing. Computers and Electronics in Agriculture. 151:403-415. https://doi.org/10.1016/j.compag.2018.06.026

Crop diversity effects on productivity and economics: A Northern Great Plains case study

Archer, D.W., Liebig, M.A., Tanaka, D.L., Pokharel, K.P. 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

The use of biogeochemical models to evaluate mitigation of greenhouse gas emissions from managed grasslands

Sandor, R., Ehrhardt, F., Brilli, L., Carozzi, M., Recous, S., Smith, P., Snow, V., Soussana, J., Dorich, C., Fuchs, K., Fitton, N., Gongadze, K., Klumpp, K., Liebig, M.A., Martin, R., Merbold, L., Newton, P.C., Rees, R.M., Rolinski, S., Bellocchi, G. 2018. The use of biogeochemical models to evaluate mitigation of greenhouse gas emissions from managed grasslands. Science of the Total Environment. 642:292-306. https://doi.org/10.1016/j.scitotenv.2018.06.020

Long term soil pH change in rainfed cropping systems: is acidification systemic?

Liebig, M.A., Reeves, J.L., Osborne, S.L., Riedell, W.E., Schmer, M.R., Jin, V.L., Sainju, U.M. 2018. Long term soil pH change in rainfed cropping systems: is acidification systemic?. Proceedings of Great Plains Soil Fertility Conference. Vol. 17/pp. 210-214.

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New science published

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The impact of size and specialization on the financial performance of agricultural cooperatives

Meeting Proceedings. Proceedings of the Agricultural and Applied Economics Association (AAEA) Annual Meeting, Washington, D.C. August 5-7, 2018.

Estimating economic efficiency under risk for agricultural cooperatives

Pokharel, K.P., Featherstone, A.M., Archer, D.W. 2018. Estimating economic efficiency under risk for agricultural cooperatives. Proceedings of the Southern Agricultural Economics Association Annual Meeting, February 2-6, 2018, Jacksonville, FL.

Integrated farming systems - book chapter

Archer D.W., Franco J.G., Halvorson J.J., and Pokharel K.P., Encyclopedia of Ecology 2nd Edition January 2019, https://www.sciencedirect.com/science/article/pii/B9780124095489105627?via%3Dihub

Color calabration of digital images for agriculture and other applications

S. Sunoj, C. Igathinathane, N. Saliendra, J. Hendrickson, D. Archer, Color calibration of digital images for agriculture and other applications, ISPRS Journal of Photogrammetry and Remote Sensing, Volume 146, December 2018, Pages 221-234, https://doi.org/10.1016/j.isprsjprs.2018.09.015, https://www.sciencedirect.com/science/article/pii/S0924271618302600

Exammining the financial performance of cooperatives in the USA

Krishna Prasad Pokharel, Madhav Regmi, Allen M. Featherstone, David W. Archer, Examining the financial performance of agricultural cooperatives in the USA, Agricultural Finance Review. 16 November 2018, https://doi.org/10.1108/AFR-11-2017-0103, https://www.emeraldinsight.com/doi/abs/10.1108/AFR-11-2017-0103?journalCode=afr

Spinach (Spinacea oleracea L.) response to salinity: nutritional value, physiological parameters, antioxidant capacity, and gene expression

Jorge F. S. Ferreira, Devinder Sandhu, Xuan Liu, and Jonathan J. Halvorson, Agriculture, 17 October 2018, *https://doi.org/10.3390/agriculture8100163*

Agricultural Collaborative Research Outcomes System (AgCROS): A network of networks connecting food security, the environment, and human health

Jorge A. Delgado, Bruce Vandenberg, Nicole Kaplan, Donna Neer, Greg Wilson, Robert D'Adamo, Jennifer Carter, Laura O'Gan, Nadene Grow, Roger Marquez, Dan Arthur, Marlen Eve, Stephen J. Del Grosso, Jane M.F. Johnson, Douglas L. Karlen, Lisa Durso, John Finley, Veronica Acosta-Martinez, *David B. Knaebel, Daren Harmel, and Justin D. Derner, doi: 10.2489/jswc.73.6.158A Journal of Soil and Water Conservation November/December 2018 vol. 73 no. 6 158A-164A http://www.jswconline.org/content/73/6/158A.short*

Welcome International Interns

Hello everyone! We are Emilie Tourlet (22 years old) and Rémi Richard (23 years old). We are two French students studying biology and agronomy at ENSAT (École Nationale Supérieure Agronomique de Toulouse or the National Institute of Agronomy) located in Toulouse, France. Toulouse is in the south-west of France. As part of our education, we are planning on doing a 5 months internship which is included in our gap year. Our internship at NGPRL will start on March 4th and end on July 14th.

We chose this internship to learn more about agroecology and US farming. We are interested looking at organic transitions and the link between animals and their environment. We are interested in obtaining different knowledge from around the world. We already have, or we will travel in other countries to improve our understanding of agroecology.

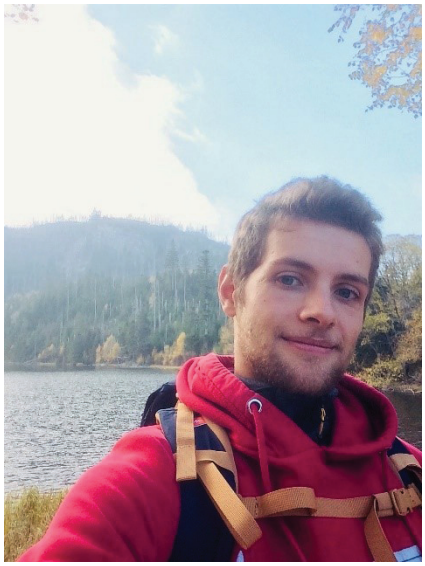
The opportunity offered by this internship will also allow us to discover new landscapes and a new culture. We are excited to visit you and discover the famous United States of America!

More about our hobbies:

Emilie

I have been riding horses since I was 7 years old. I ride in the forest of my region (Loir-et-Cher). I have the opportunity to live in the countryside which allows me to take care of my horses and my cat. As you might guess, I am a nature and animal lover!

I love to travel but it is my first trip so far from my country. I am very excited to meet you and to exchange experiences with you. I look forward to beginning this great adventure!



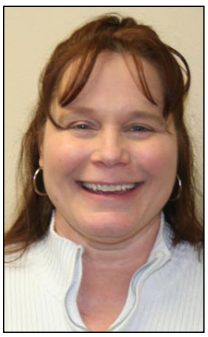
Rémi

Like Emilie, I am a nature lover and every kind of outside activities can motivate me! I like all kinds of animals, but dogs are my passion. I love to cook, and it will be a pleasure for me to let you taste the French food.

I travelled in Central Europe last year, but discovering North America is one of my oldest dreams. I am eager to see your Plains, your parks, and the wildlife of your country!

Feel free to pass on this issue of Northern Great Plains Integrator to others interested in agricultural research in the northern Great Plains. Northern Great Plains Integrator is published and distributed by the USDA-ARS, Northern Great Plains Research Laboratory, PO Box 459, Mandan, ND 58554. To be added to our mailing list, request a copy through our website or contact editor: Cal Thorson, Technical Information Specialist, USDA-ARS Northern Great Plains Research Laboratory, PO Box 459, Mandan, ND 58554. Office:701 667-3018 FAX:701 667-3077 Email: cal.thorson@usda.gov

New faces



Julie Meissner, Program Support Assistant: While Julie was in the the Navy Reserves, she traveled the United States, as well as, Korea, Kuwait, and Saudi Arabia. She continued service in the Coast Guard, traveling across the country until retirement in 2017. Her favorite adventures include traveling to Antarctica, Australia, the island of Tasmania, and assisting the National Science Foundation. Julie, originally from Circle, MT, appreciates spending time with family and friends, and enjoys hiking, biking, kayaking, paddle boarding, and snowshoeing (and a nice cup of coffee and a book somedays). Her little sidekick pup, named Sable, has been with her since 2016. They can often be seen running errands and walking the beautiful USDA campus in Mandan together.

Yssi Cronquist, Agricultural Science Research Technician: Originally from Luverne, MN, Yssi, attended Hamline University pursuing a degree in International Business, but switched majors and schools after interning at Grazix Animal Health and developing a love for research and bottle calves. She received her B.S., magna cum laude, from NDSU in Animal Science. While at NDSU she was a member of Sigma Alpha, Gamma Sigma Delta, National Wildlife Society, and Dairy Club. She also worked for the Soybean Department where she learned to cross pollinate soybeans and pull weeds. She enjoys hiking, biking, and swimming, but also reading and learning (esp. Fun Facts).

Dr. Rachael Christensen, Research Animal Scientist: Rachael's curiosity about the living world began while growing up on the family dairy farm. Intending to be a veterinarian, her experiences with research in high school competitions and as an undergraduate led her to pursue nutrition. She received her BS from BYU in Cellular Physiology and Genetics, M.S. at Utah State in Dairy Science Nutrition, and her PhD at USU in Ruminant Nutrition. She has had extensive industry experience in nutrition consultation and sales; as owner of her own independent nutrition company, working for Cargill Animal Nutrition, a local feed Co-op (IFA), and Renaissance nutrition, She enjoyed teaching college-level classes ranging from a dairy herdsman nutrition course to introductory animal nutrition for veterinary students. She delights in working with youth through Cub and Boy Scouts. She enjoys gardening, honing homesteading skills, hiking, backpacking, fishing, hunting, and all things outdoors (usually with one or more of her five children in tow). Her husband, Clay, is her favorite hiking buddy.

Shannan Carrig, Financial Technician: Shannon and her husband moved to North Dakota from Alaska in August. She grew up in Washington State but in the last fifteen years has moved all over the U.S. She has lived in all U.S. time zones except for Hawaii (but visited once). She also lived in Guam for a year. She hopes to be stay here for a while. She is a devoted Seattle Seahawks fan (and has been forever). She was even able to watch a couple of games this season…and they made the playoffs!

Congratulations Dr. Toledo

Dr. David Toledo, Research Rangeland Management Specialist at the USDA-ARS Northern Great Plains Research Laboratory was elected to the Board of Directors of the Society for Range Management in October 2018. Toledo joined the NGPRL staff in 2013 as a Postdoc and the permanent staff in 2015. His primary responsibilities are in developing integrated grazingland assessment for use in management and conservation planning. His previous research includes working at the USDA-ARS Jornada Experimental Range in Las Cruces, NM working on the development and application of indicators for monitoring soil and vegetation attributes and assessment of rangeland health.