2020 Research Results

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Virtual Conference

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

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Northern Great Plains Research Laboratory Report

Area 4 SCD Research Farm Report

Message from the Research Leader

In our research, we have been interested in agricultural systems that are resilient to "shocks" that might occur. Often, we have thought about this in terms of variable weather conditions, as we are all familiar with how events like drought or excessive wet conditions or even individual storm events can affect production and livelihoods of farms, ranches, and rural communities. However, this past year has shown that there can be other shocks that can affect everything from markets and our ability to sell products, to availability of inputs that we use for production. Given these additional shocks, anything we can do to manage weather-related risks becomes even more important. I have talked about the importance of managing for stored soil moisture in previous columns. But, 2020 was probably one of the best examples I have seen for how rapidly conditions can change, and how stored soil moisture can help ensure we can produce a crop when the rain shuts off.

At the Area 4 farm, we went into 2020 after dealing with extreme wet conditions in the fall of 2019. Precipitation for the 2019 April-September growing season was over 6 inches above the long-term average, with 6.6 inches of precipitation in September followed by an early October snowstorm that left around a foot of snow in the fields. As a result, much of the 2019 corn crop could not be harvested until spring. Many of our discussions going into winter focused on how we would deal with the anticipated wet conditions in the spring. However, 2020 turned out to be a complete reversal, with precipitation during the 2020 April-September growing season below average in every month and the seasonal total 8.6 inches below the long-term average.

We are always looking for ways to better store and retain moisture in the field, so it is available to support crop production. With only a few exceptions for research comparison, all of the fields on the Area 4 farm are managed using no-till in order to reduce soil disturbance and keep good residue cover. We also focus on diversifying crop rotations and including perennials in our systems to improve soils and soil water holding capacity. In addition, we have been looking at additional ways to increase soil cover including using a stripper head for wheat harvest and including cover crops in our cropping systems.

Given, the lack of growing season precipitation in 2020, my expectations for crop yields were pretty low. However, results were not as bad as I thought they may be. Corn, soybean, field pea, and buckwheat yields were all somewhat low. But, spring wheat generally did pretty well, with some fields a bit below average and some a bit above average. Sunflower yields were above average, likely due to the water that was "banked" in the soil and the ability of sunflowers to utilize moisture deep in the soil profile. We share the results in this report showing what worked and what didn't work, so you can learn the lessons that we learn about how to better manage our systems. We hope you enjoy this issue.

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Exploring the cultural language of soil: North American Soil Proverbs

Dr. Mark Liebig

Soils are fundamental to life on earth, serving as the source for most of our food and contributing to the delivery of multiple ecosystem services affecting the quality of the air we breathe and the water we drink. Soils are also closely connected to human culture and civilization as conveyed through oral traditions and philosophical, religious, and popular literature. Despite the central role of soils to human existence and identity, much of society fails to recognize their contributions to food security and environmental quality. Therefore, novel approaches are needed to communicate the importance of soils to humanity.

Proverbs have been used for millennia to effectively communicate thematic messages to society. Soil proverbs, specifically, are deeply ingrained in the natural culture of a region and can enhance society's understanding and appreciation for soil and its many contributions to humankind.

To increase awareness of the importance of soil, a small group of active and retired USDA soil scientists recently assembled classic soil proverbs with roots in North America (Reicosky et al., 2019). Select proverbs from the compilation are shared below.

- "Treat the Earth well: it was not given to you by your parents, it was loaned to you by your children."
  – Native American proverb
- "When the earth is hot, the worm stays in the ground."
  – Native American proverb
- "Since the achievement of our independence, he is the greatest Patriot, who stops the most gullies."
  – Patrick Henry
- Civilization itself rests upon the soil."
  – Thomas Jefferson
- "Plant in the dust and the bin will bust; plant in the mud and the crop is a dud."
  – Minnesota Farmer proverb
- "There can be no life without soil and no soil without life."
  – Charles Kellogg
- "To skin and exhaust the land will result in undermining the days of our children."
  – Theodore Roosevelt
- "Certainly all the capital in all the banks cannot substitute for the soil of the land."
  – William A. Albrecht
- "A nation that destroys its soil, destroys itself."
  – Franklin D. Roosevelt
- "Soil is not lost because we farm. Soil is lost because of how we farm."
  – David Montgomery
- "The health of the soil, plants, animals, people and ecosystems are interdependent, interconnected and indivisible." – Rattan Lal

Reference: Reicosky, D.C., D.L. Karlen, M.A. Liebig, and M.J. Levin. 2019. 21st Century Perspectives on North American Soil Proverbs. Chapter 30, pp 213-230. In Yang, J.E., Kirkham, M.B., Lal, R., Sigbert, H. (Eds.). Global Soil Proverbs: Cultural Language of the Soil. 2019. Schweizerbart Science publishers, Germany, 275 pp.

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Global analysis highlights perennial crop effects on soil carbon

Dr. Mark Liebig

Agricultural lands have the potential to sequester up to two-thirds of historical soil carbon loss if managed properly. Perennial crops may be one way to sequester carbon without the loss of productive land. Perennial crops can generate food, fiber, and/or energy along with other goods and services, making them a promising strategy to balance needs of increased agricultural production with improved environmental quality.

Unfortunately, there is limited evidence on the capacity of perennial crops to store soil carbon. Previous studies on perennial crops have been conducted across a range of locations, using different experimental designs and analytical methods, and for a wide variety of crops. As a result, outcomes are not directly comparable, and conclusions about perennial crops and soil carbon are not easily derived. Accordingly, there is a need to conduct a standardized analysis and synthesis of results from the previous studies to better understand the global impacts of perennial crops on soil carbon.

Given this context, researchers from 10 countries collaborated to generate a harmonized global dataset containing values of soil organic carbon under different perennial crops with different end-uses, including bioenergy, food, and other bio-products (dataset reviewed in the February 2020 edition of the Integrator). Led by Dr. Alicia Ledo - formerly at the Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen, UK - the research team sought to answer three important questions associated with perennial crops and soil organic carbon dynamics: 1) What are the changes in soil organic carbon following a transition to perennial crops? 2) How does soil organic carbon change over the lifespan of perennial crops? and 3) What are the main factors that influence soil organic carbon dynamics under perennial crops?

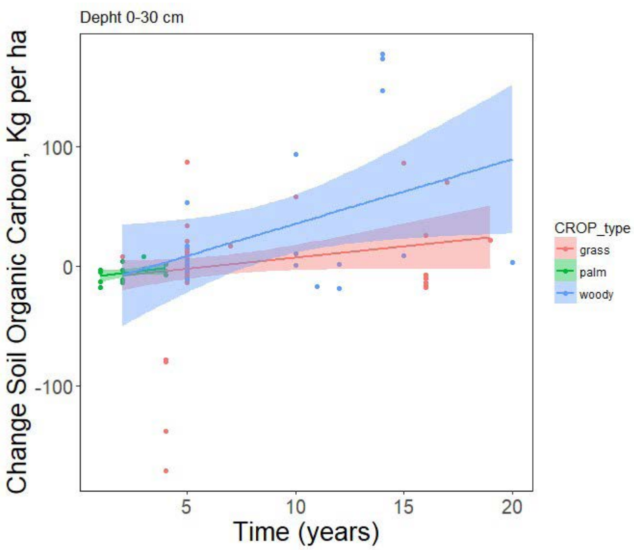
Perennial crops in the study were defined as crops that are planted, but not replanted and/or fully harvested annually to obtain goods. Perennial crops were categorized into two main groups: woody plants, such as fruits and nut crops (e.g., apple trees, citrus, almond), beverage crops (e.g., coffee, tea, cocoa), oil crops (e.g., palms), or short rotation coppices (e.g., poplar, willow); and perennial grasses such as sugarcane, switchgrass, and Miscanthus.

The research team found that a change from annual to perennial crops led to a 20% increase in soil organic carbon at 0-12” and an 11% increase over the 0-40” depth (Table 1). However, a change from grassland to perennial crops decreased soil organic carbon by an average of 1% over 12” and 10% over 0-40”. The effect of a land use change from forest to perennial crops did not have significant impacts, but the data indicated soil organic carbon increased at 0-12” but decreased across the 0-40” depth. These findings highlighted critical tradeoffs associated with land use, suggesting the greatest soil-derived benefit from perennial crops could occur on land previously planted to annual crops.

Table 1. Mean values of soil organic carbon (SOC) stocks (Ton ac^{-1}) before and after conversion to perennial crops for three previous land uses (annual crops, grassland, forest) and two depths (0-12 and 0-40”) (adapted from Ledo et al., 2020).

PREVIOUS LAND USE	SOC before conversion (Ton ac^{-1})	SOC after conversion (Ton ac^{-1})	$\Delta\ SOC_{stock}$ (Ton ac^{-1})	Gain/Loss	% change
Depth 0-12”					
Annual crop	18	21	3	Gain	20
Grassland	26	25	-1	Loss	-1
Forest	38	45	7	Gain	2
Depth 0-40”					
Annual crop	62	65	3	Gain	11
Grassland	54	48	-6	Loss	-10
Forest	77	59	-18	Loss	-24

Figure 1. Soil organic carbon stock change over time for perennial grass, palm, and woody crops at 0-12” (adapted from Ledo et al., 2020). Note: 100 kg/ha = 89 lb/ac.



Overall, perennial crops generally accumulated soil organic carbon over time (Figure 1). While the trend was consistent across all perennials over a 20-year period, increases in soil organic carbon were greatest under woody crops.

Temperature was the main factor explaining differences in soil organic carbon dynamics under perennial crops, followed by crop age, soil bulk density, clay content and soil depth. Temperature was negatively correlated with soil organic carbon change, indicating that in warmer, tropical areas the relative change in soil carbon was lower than in cooler, temperate/boreal areas. This finding suggests the potential for positive soil carbon balances will be limited in warmer conditions.

Outcomes from the study highlighted the potential of perennial crops to sequester carbon, though previous land use must be considered if greenhouse gas mitigation is a management goal. Recommendations included the need for more long-term trials with perennial crops (especially woody crops), and the need for future assessments to quantify soil carbon stocks to at least the 40” depth.

Adapted from Ledo, A., P. Smith, A. Zerihun, J. Whitaker, J.L. Vicente-Vicente, Z. Qin, N. McNamara, Y. Zinn, M. Llorente, M. Liebig, M. Kuhnert, M. Dondini, A. Don, E. Diaz-Pines, A. Datta, H. Bakka, E. Aguilera, J. Hillier. 2020. Changes in soil organic carbon under perennial crops. Global Change Biol. 26(7):4158-4168. doi:10.1111/gcb.15120.

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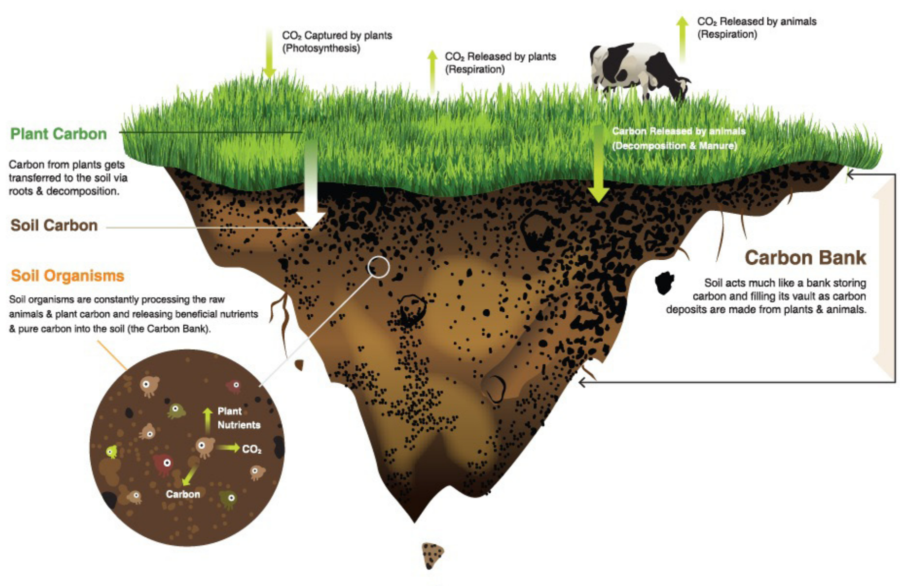

Managing carbon is key to soil health.
(*From http://australiansoil.com.au/soil-management-bebefits/*)

ARS scientists use soil archives to examine patterns of water-extractable soil organic matter associated with long-term soil change in the Great Plains

Drs. Jonathan Halvorson, Mark Liebig, Angela Hansen, California Water Science Center, USGS, Sacramento, CA

Carbon and nitrogen extracted from soil with water, are believed to originate from important pools of labile organic matter associated with available plant nutrients and soil microorganisms.

While routinely used to assess soil health, less is known about changes in the quantity and quality of water-extractable C and -N over space and time.

We used cool (23°C) and hot (80°C) water extracts of historic archived (1947) and contemporary (2018) soil samples, collected at locations in the northern (Moccasin, MT), central (Akron, CO), and southern (Big Spring, TX) Great Plains to quantify the impacts of long-term management on labile soil organic matter.

Significant quantities of C and N were extracted with cool water however, even greater amounts were removed with hot water. Both should probably be considered together.

In 1947 samples, extractable -C and -N were highest at Moccasin > Akron > Big Spring. However, in 2018 samples, values for Akron ≥ Moccasin > Big Spring. Shifting patterns were due to losses of extractable C and N in Moccasin soil, between 1947 and 2018. Conversely, 2018 values were not significantly changed from 1947 at Akron. Similarly, samples from 2018 were generally comparable to those from 1947 at Big Spring, but contained significantly less cool water extractable-C.

Further work is examining patterns of water-extractable organic matter using excitation emission matrices (EEM) constructed using spectroscopic techniques.

Preliminary results have identified distinct patterns of humic-like and fresh-like compounds in soil extracts influenced by location and date of sample collection (Figure 1).

We anticipate that EEM methods will be useful as a means for "fingerprinting" water-extractable organic matter from soil to distinguish differences related to site description and prescriptive management or across gradients of space, and time.

The work on extractable soil organic matter is just one part of a group effort by ARS scientists from several locations, and coordinated by Dr. Mark Liebig, to use historic soil archives to examine long-term soil change in the Great Plains.

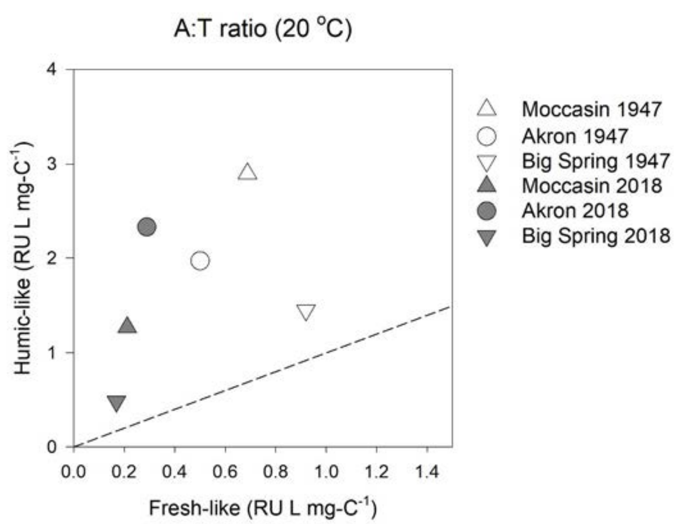

Figure 1. The proportion of stable "Humic" soluble organic matter to more recent "Fresh" organic matter in soil varies with location and sample date.

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Perennial forages influence mineral quality inannual cropping systems

Drs. Andrea Clemensen, Michael Grusak, Sara Duke, John Hendrickson, José Franco, David Archer, James Roemmich, and Mark Liebig

There is increasing interest in the potential impact of agricultural land management on food nutritional quality. Few studies have attempted to make connections between food quality and land management practices. A no-till experiment in Mandan, ND looked at wheat yield differences between continuous annual fertilized spring wheat and unfertilized spring wheat planted following 2-5 years of perennial forages such as alfalfa and intermediate wheatgrass. Spring wheat yield increased by 19 and 41% following 3 and 4 years of alfalfa, respectively, and yield benefits lasted for 3-4 years. In addition, including perennials improved near-surface soil qualities by increasing pH, reducing soil bulk density, and increasing particulate organic matter and water stable aggregates. Since this study comparing continuous annual fertilized wheat with wheat following perennial forages affected both wheat productivity and soil characteristics, we analyzed the wheat grain archive samples for minerals and protein to see if there was an influence on food quality.

Mineral and Protein Relationships to Wheat Yield.

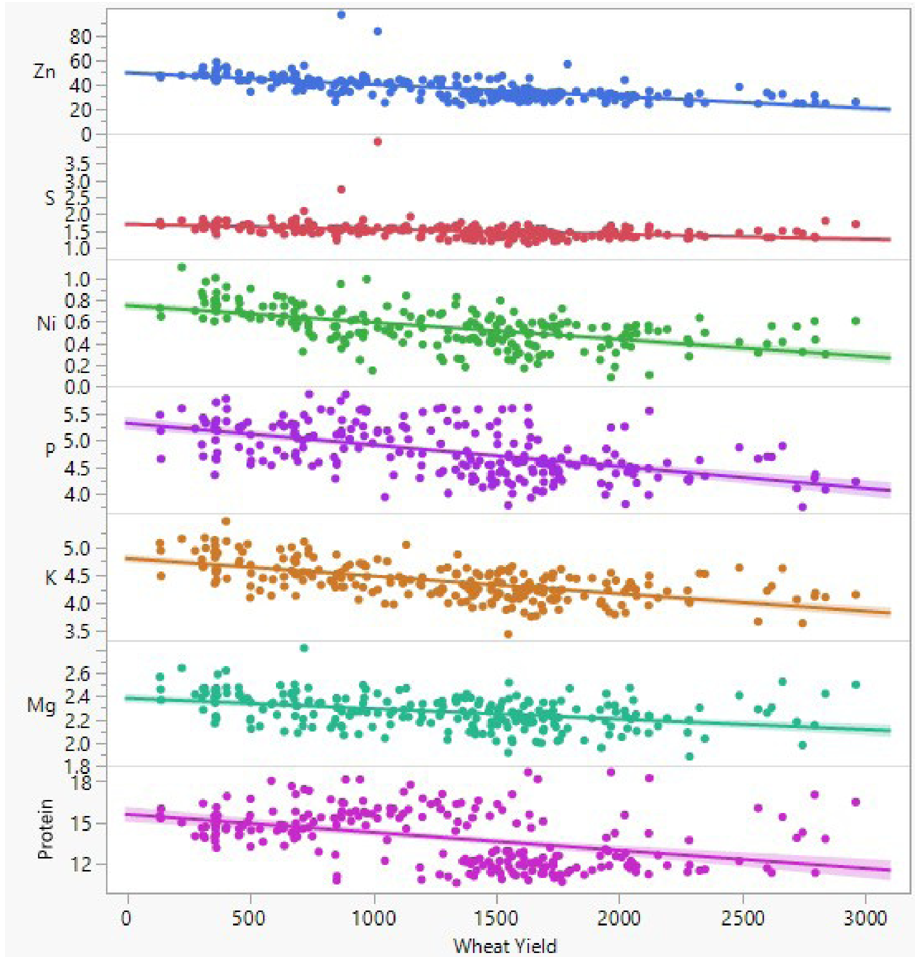

Figure 1. With increasing wheat yield (in kg / hectare), protein (%) and mineral concentrations zinc (Zn) and nickel (Ni), in micrograms / gram dry weight, and sulfur (S), phosphorous (P), potassium (K), and magnesium (Mg), in milligrams / gram dry weight, decrease. Data shown combines all four years (2011-2014) and includes all treatments.

We found that when wheat yield increased, protein and mineral concentration of zinc, sulfur, nickel, phosphorous, potassium, and magnesium decreased (Figure 1).

There were comparable concentrations of protein and minerals in wheat grain between a cropping system of continuous annual fertilized wheat, and wheat following perennial forages that received no fertilization for the duration of the study. Even without added fertilizers, the protein and mineral concentrations were similar between continuous annual fertilized wheat and wheat following perennial forages. This suggests that utilizing perennial forage phases in wheat production may reduce the need for fertilizer inputs, while maintaining food nutritional quality.

The differences observed in protein and mineral concentrations were largely driven by the year in which wheat samples were harvested (Table 1) suggesting the environment plays a significant role in determining protein and mineral concentrations of wheat grain.

Grain weight (TKW) was also different between years of harvest (Table 1; Image 2), and as grain weight increased, protein concentration and grain mineral concentrations for zinc, potassium, magnesium, phosphorous, and sulfur decreased (Table 1).

Total growing season rainfall was different each year between 2011-2014 (Table 1; Figure 2). Wheat was harvested August 26, 2011; August 17, 2012; September 3, 2013; and September 4, 2014.

A hailstorm in early August 2013 likely reduced wheat grain yield of that year, while heavy rainfall before the harvest in 2014 likely contributed to increased grain size.

Take home message

We observed comparable wheat grain protein and mineral concentrations between continuous annual fertilized wheat and wheat following perennial forages. As the system integrating perennial phases was not fertilized, and the wheat grain had similar concentrations of protein and minerals as the fertilized wheat, this suggests that implementing perennial forage phases in annual cropping systems may reduce the need for fertilizers without affecting food nutritional quality.

Differences observed in wheat grain weight, and wheat grain mineral and protein concentrations were largely driven by the year of harvest, indicating that environmental factors should be considered when assessing food quality.

Growing Season Precipitation

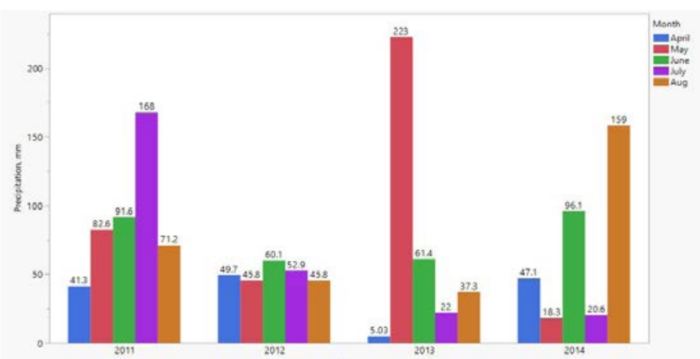

Figure 2. Monthly precipitation totals, in millimeters (mm), from April through August over four years (2011-2014).

Image 1. Plots showing field study

Image 2. Differences in grain size between 2011 and 2014. Photo courtesy of Michael Grusak.

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Year of Harvest	Rainfall (mm)	Grain weight (TKW in g)	Wheat Yield (kg/ha)	Protein % DW	Zn (µg/g DW)	K (mg/g DW)	Mg (mg/g DW)	P (mg/g DW)	S (mg/g DW)
2011	455	23	1119	16	42	4.5	2.3	5.3	1.6
2012	254	27	1851	13	30	4.2	2.3	4.4	1.4
2013	349	25	533	15	46	4.7	2.4	5.1	1.7
2014	341	31	1668	12	32	4.2	2.2	4.4	1.4

Table 1. Between years of harvest from 2011-2014, data showing growing season precipitation totals, grain size measured by thousand kernel weight (TKW), wheat grain yield, and protein, zinc (Zn), potassium (K), magnesium (Mg), phosphorous (P), and sulfur (S) measured on a dry weight basis (DW).

Integrating perennial forages into annual cropping systems: influence on soil and grain quality

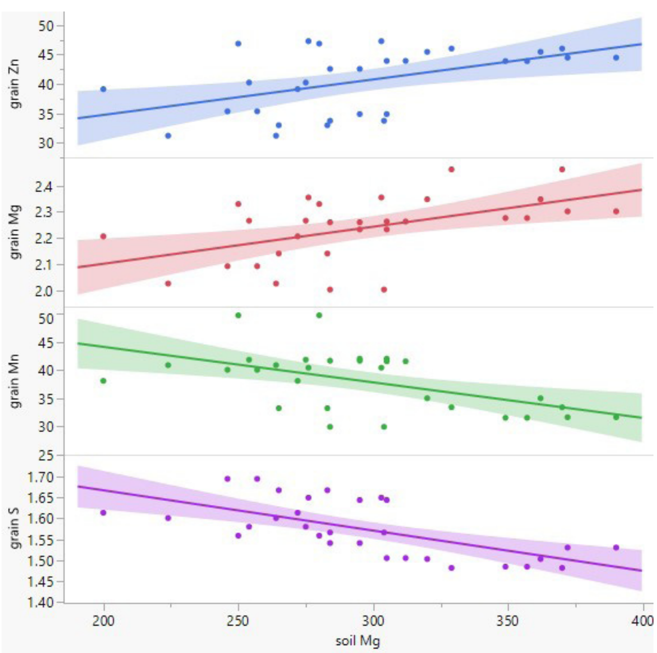
Drs. Andrea Clemensen, Mark Liebig, Michael Grusak, Sara Duke, José Franco, John Hendrickson, and David Archer

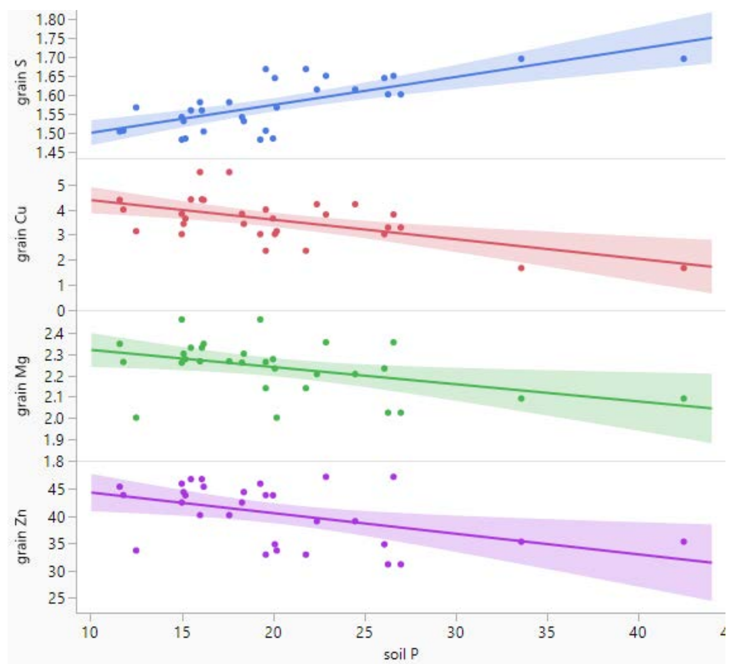
A no-till experiment in Mandan, ND introduced perennial forages into annual cropping systems. Wheat yield was greater when wheat followed 2-5 years of perennial forages such as alfalfa and intermediate wheatgrass compared to wheat yield in a continuous annual and fertilized system. Wheat grain also had greater protein (15.5%) when it followed 5 years of alfalfa (unfertilized) compared to wheat in continuous annual wheat systems with fertilizer inputs, where protein in wheat grain averaged 14.9%. In addition, including perennials improved near-surface soil qualities by increasing pH, reducing soil bulk density, and increasing particulate organic matter and water stable aggregates. Here, we analyzed wheat grain and soil samples from 2011 to determine the relationship between plant available soil minerals and grain minerals.

Image 1. Plots showing field study

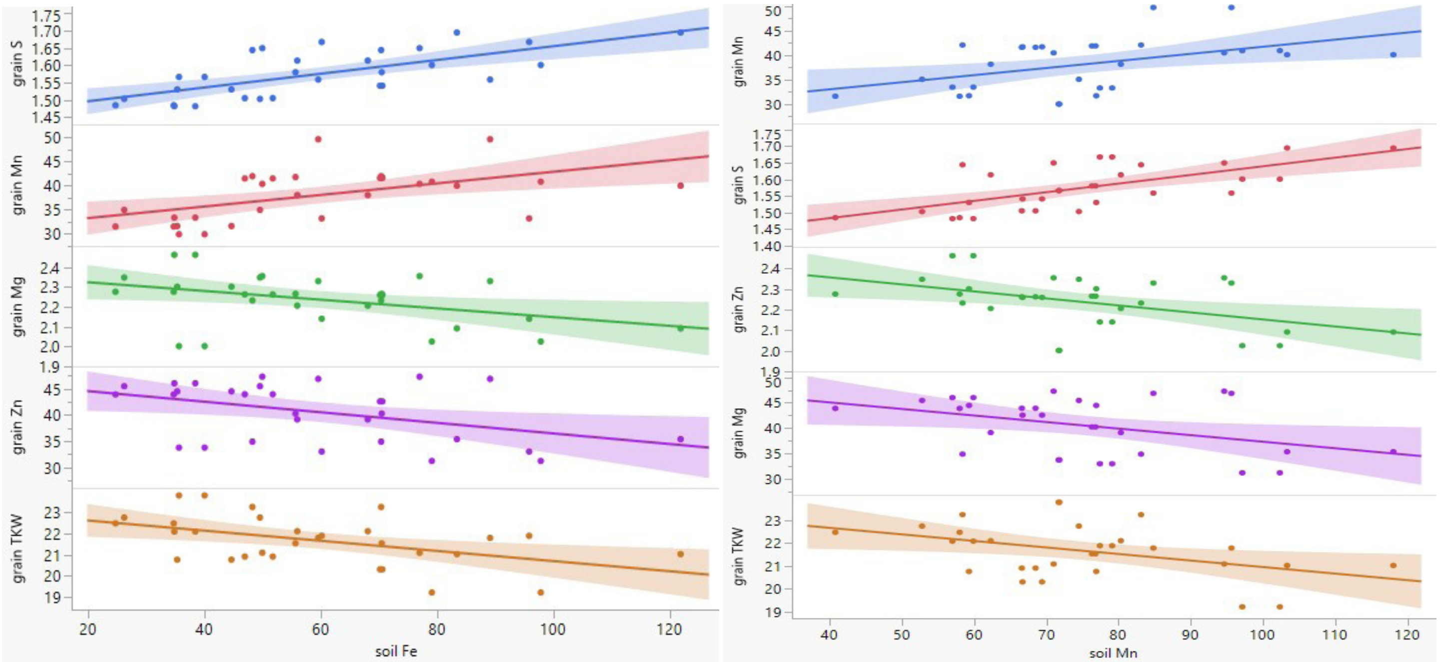
We focused on wheat grain samples from spring wheat planted following 2-5 years of three different perennial treatments; 1- alfalfa, 2- intermediate wheatgrass, and 3- alfalfa / intermediate wheatgrass mixture. No fertilizers were applied to wheat that was planted, after the perennial forages were terminated. These treatments were compared to a continuous annual wheat cropping system that received fertilizers annually.

We saw both positive and negative correlations between grain yield, thousand kernel weight, protein concentration, and grain mineral concentrations with increasing plant available soil mineral concentrations (Figs. 1-6). The shaded areas represent confidence intervals, which measure the degree of uncertainty (wider band) or certainty (narrower band) in trends.

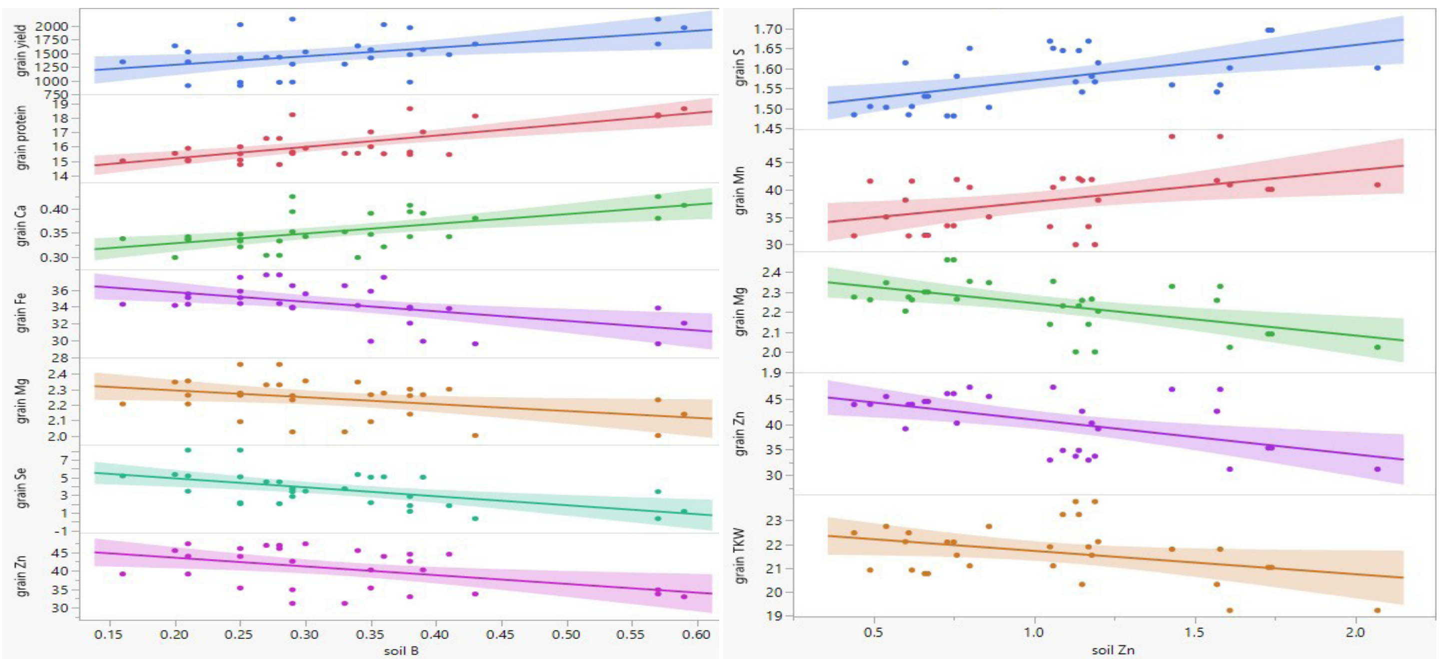




Figures 1 & 2. Relationships showing, on a dry weight basis, grain mineral concentrations Zn, Cu, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil magnesium or soil phosphorous (µg g^{-1}).



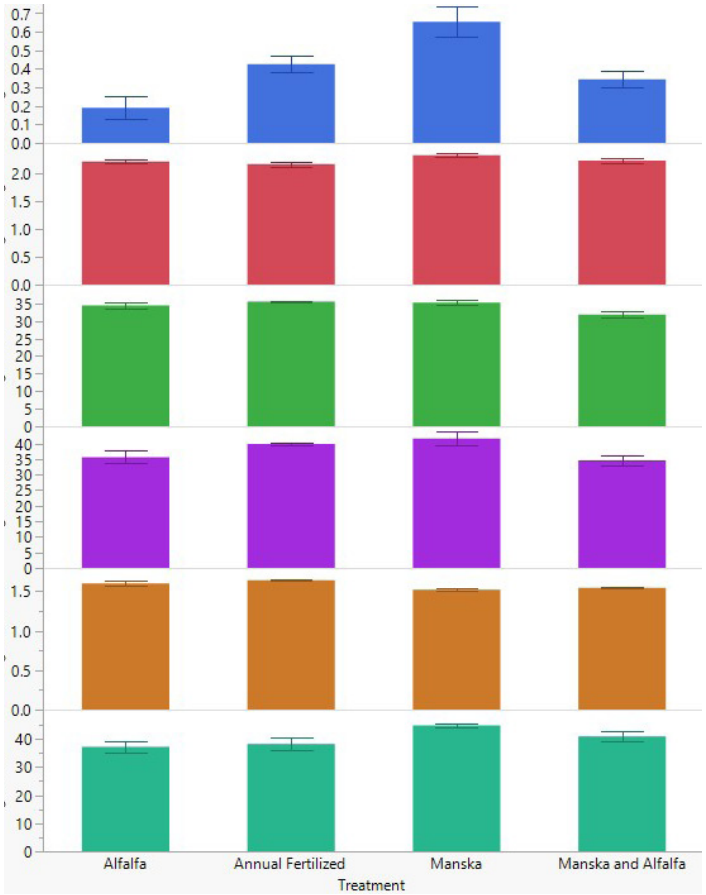
Figures 3 & 4. Relationships showing TKW (thousand kernel weight) and mineral concentrations Zn, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil iron or soil manganese (µg g^{-1}).

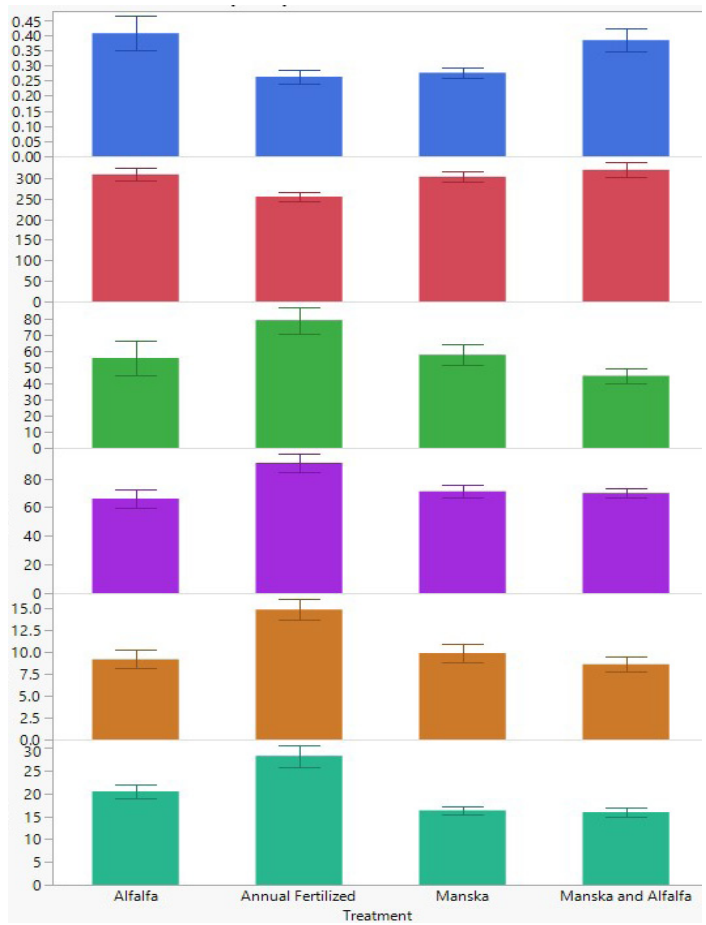


Figures 5 & 6. Relationships showing grain yield (kg ha^{-1}), TKW (thousand kernel weight), protein concentration (%), and mineral concentrations Fe, Se, Zn, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}) with increasing soil boron or soil zinc (µg g^{-1}).

Differences between treatments showed that continuous annual and fertilized wheat plots had greater plant available soil mineral concentrations P, S, and Mn than the perennial treatment plots. Also, the continuous annual plots had greater plant available soil Fe than the alfalfa/intermediate wheatgrass mixture treatment plots (Figure 7). Alfalfa treatment plots had greater plant available soil B than continuous annual wheat plots, while alfalfa / intermediate wheatgrass mixture plots had greater plant available soil Mg than continuous annual wheat plots (Figure 7).

Grain mineral concentrations were different between treatments, showing greater concentrations of Mg, Mn, Zn, and Ni in intermediate wheatgrass plots than all other treatments (Figure 8). Grain protein was greater in wheat from alfalfa treatments than intermediate wheatgrass and continuous annual wheat treatments. Thousand kernel weight (TKW) was greater in wheat from alfalfa and mixture treatments than continuous annual wheat treatments, while grain Fe concentration was greater in continuous annual and intermediate wheatgrass treatments than the mixture treatments.





Figures 7 & 8. Treatments alfalfa, continuous annual fertilized wheat, intermediate wheatgrass (Manska), and alfalfa / intermediate wheatgrass mixture (Manska and Alfalfa) showing differences, and standard error bars, of grain mineral concentrations, on a dry weight basis, Zn, Ni, Fe, Mn (in µg g^{-1}), S and Mg (in mg g^{-1}). The same treatments showing differences of plant available soil mineral concentrations P, S, Mn, Fe, Mg, and B (µg g^{-1}), with standard error bars.

Soil organic carbon and soil total N showed a negative relationship with grain mineral concentrations Cu and Se. We did not observe any relationship, whether positive or negative, between soil particulate organic matter and grain quality.

In summary, this study showed that increased plant available soil mineral concentrations do not always increase mineral concentrations in spring wheat grain. The observed negative correlations between plant available soil minerals and grain minerals, such as Zn, could be due to soil depth, with the active root zone of nutrient assimilation in deeper soil depths. In all, we observed differences in wheat grain and soil mineral concentrations between the treatments, which indicates that implementing perennial forages into annual cropping systems influences soil and grain nutrient concentrations.

Perennial forages influence mineral and protein concentrations in annual wheat cropping systems. Clemensen, A.K., M.A. Grusak, S.E. Duke, J.R. Hendrickson, J.G. Franco, D.W. Archer, J.N. Roemmich, and M.A. Liebig. 2020. Crop Science, under review.

Spring Wheat Yields Following Perennial Forages in a Semiarid No-Till Cropping System. J.G. Franco, S.E. Duke, J.R. Hendrickson, M.A. Liebig, D.W. Archer, D.L. Tanaka. 2018. Agron. J. 110:1-9. https://acsess.onlinelibrary.wiley.com/doi/pdfdirect/10.2134/agronj2018.01.0072

Near-Surface Soil Property Responses to Forage Production in a Semiarid Region. Soil Sci. Soc. Am. J. 82:223-230. M.A. Liebig, J.R. Hendrickson, J.G. Franco, D.W. Archer, K. Nichols, D.L. Tanaka. 2018. https://doi.org/10.2136/sssaj2017.07.0237

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Plant stand spatial distribution analysis from UAS imagery using ImageJ plugin and uniformity index

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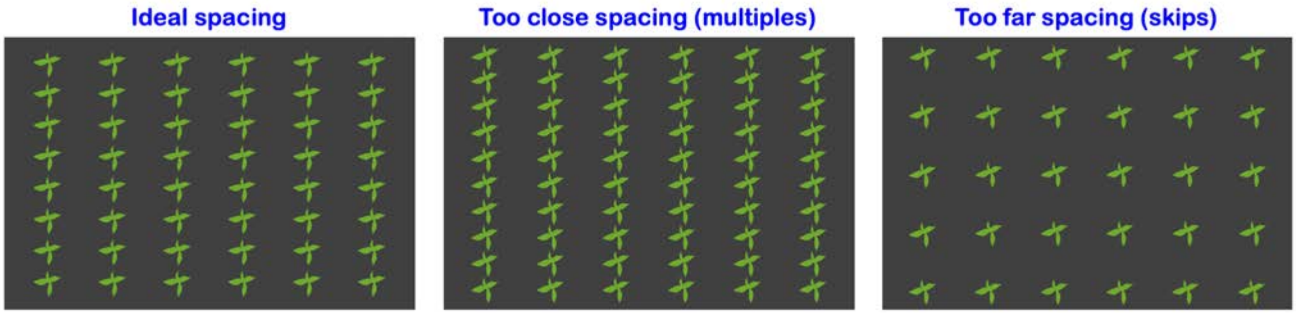

Figure 1. Simulated plants arrangement showing three different scenarios to demonstrate the lacuna of the existing spatial distribution measure such as standard deviation (SD). All these scenarios produce zero SD even though they deviated from the desired ideal plant spacing.

Logistic operations for agricultural biomass, including collection, handling, storage, and transport require substantial amounts of energy. Bale logistics in the field which includes aggregating bales in the field and transporting them to the field outlet significantly contributes to the overall logistics cost. But studies on the energy involved (or fuel consumption) in bale aggregation logistics within a field are not available. Therefore, a study was conducted to predict fuel consumption during bale aggregation with varying load scenarios and using fuel efficiency and operational time to help producers make efficient management decisions and cut down on cost.

Reducing the time spent in collecting bales within a field can reduce costs. Increasing the number of bales/trip (BPT), by using modern equipment such as an automatic bale picker (ABP; also known as "self-loading bale carrier") which is capable of handling multiple BPT, reduced operation time thus enabling improved logistics efficiency and reduced logistics cost (Figure 1).

One of the primary contributors to logistics cost is the fuel consumption of the equipment operating on the field. Many studies have been conducted to predict tractor fuel consumption during various field operations such as tillage, fertilizer and chemical application, planting, cultivation, and forage harvesting. Fuel efficiency, an essential aspect of a tractor engine, directly influences fuel consumption. Variable load characteristics, comparable to the different number of bales handled in logistics, is one of the significant parameters that affect fuel efficiency.

A novel mathematical simulation was developed to compare the bale aggregation logistics and fuel consumption between the traditional tractor and ABP. The conventional method for bale aggregation is using a tractor and was considered the "control" method in this study. This was compared to the ABP, which aggregates and transports bales to the stack location or outlet in a single trip.

The ABP is a trailer attached to the tractor with a bale picking arm on its side. Unlike the tractor, which can usually handle only 1 or 2 BPT, the ABP can handle 8-23 BPT (Figure 1). The logistics distance traveled by the equipment (tractor and ABP) was simulated using geometric principles to achieve a realistic turning paths. Fuel consumption was estimated using the (1) ASABE standard and (2) fuel efficiency method. The ASABE method uses rated and available PTO, while the fuel efficiency method uses bale load and fuel efficiency to calculate the fuel consumption. Several logistics scenarios (36,390 scenarios) using field area (8 - 259 ha), BPT (tractor: 1 and 2; ABP: 8 - 23), biomass yield (3 - 40 Mg/ha), equipment speed (6.4 - 10.5 km/ha), bale mass (500 kg), swath width (9 m), and windrow variation (5, 10, and 15 %) were studied. The operation time was determined using the logistics distance results and the equipment speed. The logistics distance simulation for tractor and ABP can be seen in Figure 2.

Fuel consumption analysis results during bale aggregation showed that the field area ≥32 ha displayed a significant difference with higher ABP bale capacity of 17 and 23 BPT. A steep drop in fuel quantity was observed between tractor (1 and 2 BPT) and ABP (8 -23 BPT). This fuel quantity reduction

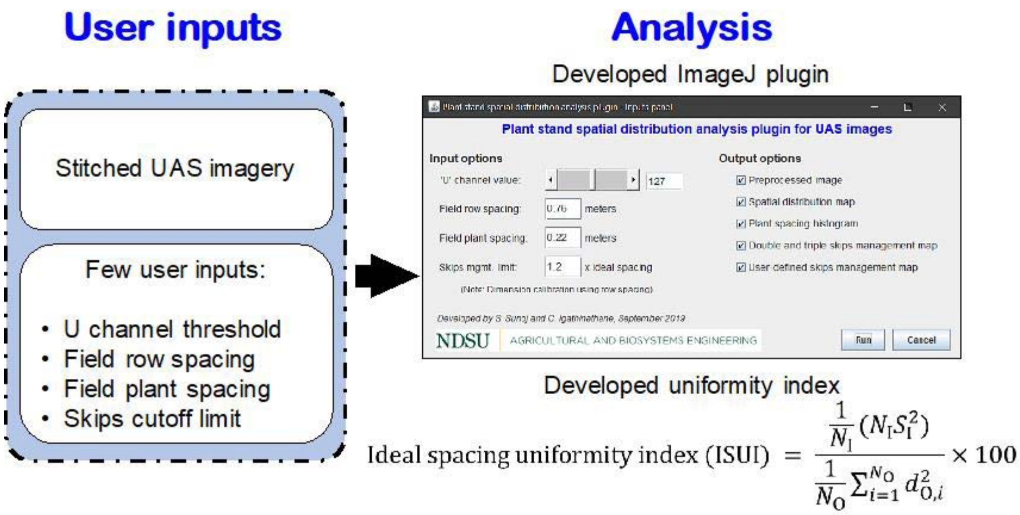

Figure 2. Plant stand spatial distribution analysis user inputs, the front panel of the developed ImageJ plugin, and ideal spacing uniformity index equation

trend was similar across all the field areas but more pronounced with larger fields (Fig. 3). Average fuel consumption decreased by 72 % and 53 % for ABP with 8 and 11 BPT compared to the tractor with 1 and 2 BPT, respectively. An increase in biomass yield (more bales/ha) resulted in an increase in fuel use (prominent only between 8 and 40 Mg/ha). Equipment speed did not have any significant effect on fuel consumption for field areas of 8 - 259 ha.

Specific fuel quantity models with very good fit ($R^2 > 0.99$) were developed for tractor and ABP with the field area, biomass yield, and equipment speed as variables: where, QF is the fuel quantity utilized in bale aggregation (L); AF = field area (ha); YB = biomass yield (Mg/ha); and SP = equipment speed (km/h).

A non-linear combined multivariate model called “Biomass Infield Bale Logistics Multivariate Model” (BIBLMM) was developed. These models predicted the fuel consumption exclusively for tractor and ABP using the variables field area, BPT (BT = bales/trip), biomass yield, and equipment speed.

This novel study successfully generated logistics distance and fuel consumption prediction models developed from 36,960 bale aggregation scenarios. The results of this study could serve as a tool for farmers/producers to decide between the traditional tractor and ABP, based on fuel consumption for efficiently aggregating bales within a field. Besides, the direct use, the developed multivariate models can serve as a basis to build more complex models in various fields, such as agriculture, supply chain logistics, economics, and environment that could potentially impact conventional practices and influence policy decisions.

Crop growers prefer uniform plant-to-plant spacing in the field because it is proven to produce better yield and is aesthetically pleasing. Uniform plant spacing is one of the factors from early growth stages that influence crop yield. Possible reasons for non-uniform plant stand spacing are irregular seed size, planter mechanism type, planter operation speed, soil moisture, and residue distribution. The uniformity or lack of it in plant spacing, also called plant stand spatial distribution, is traditionally analyzed by manually measuring the plant-to-plant distances (using tapes or rulers) on a few selected rows along manageable short known row length (e.g., 30-60 m) and reported as the mean spacing with standard deviation (SD) of the distances. A lower SD means a better spacing uniformity.

While the SD provides a measure of the uniformity of the stand, the mean is needed to identify if the desired plant spacing is achieved. For example, in the simulated plants arrangement - showing ideal, too close, and too far spacing (Figure 1), the SD value will be zero for all these scenarios. Although the plants are uniformly spaced, the desirable plant spacing is not achieved. A single index that provides a measure of the uniformity compared to the desired spacing would be helpful.

Another issue is that the manual distance measurements are performed only for a small portion at a few locations of the field, which might not sufficiently represent the overall spacing distribution.

Nowadays, unmanned aerial system (UAS) images are increasingly being used in agriculture to obtain plant emergence status, stand count, growth characteristics, and crop health on a field scale. Therefore, we used UAS images collected at the crop emergence stage and developed an image processing pipeline to analyze the whole field's crop spatial distribution. We further developed a novel spatial uniformity index that represents the distribution with respect to the ideal plant spacing.

The UAS image was obtained from a sunflower experimental field (area = 0.25 acres) at the Carrington Research and Extension Center, Carrington, ND. The images were captured using the DJI Phantom 4 Pro flown at 40 ft above ground level. The UAS was equipped with a 20 MP color digital camera. The built-in DJI's flight mission software automatically generated a flight pattern once the field area was delineated. The images were stitched using Pix4D mapper Pro software to produce a single image of the whole field. The resolution of the stitched image was 3.31 mm/pixel.

An image processing plugin was developed in ImageJ, a free and open source software, for analyzing the stitched UAS image for the plant stand spatial distribution analysis. The plugin takes the stitched image and a few user inputs and performs a sequence of image analysis operations. The plugin was programmed to automatically process the UAS image with minimal user inputs, irrespective of the row orientation and image resolution, to produce a suite of outputs (Figure 2).

We developed a new uniformity index that allows for assessment of the spatial distribution compared to the desired spacing, called the "ideal spacing uniformity index" (ISU) (equation in Figure 2). If all the seeds are perfectly placed at the ideal spacing, the ISUI will result in 100 %, while any deviation from the ideal spacing will be penalized and result in a lower ISUI value, which is the desired and expected from a spatial distribution index. The performance of ISUI was compared with five other uniformity indices and was superior compared to others.

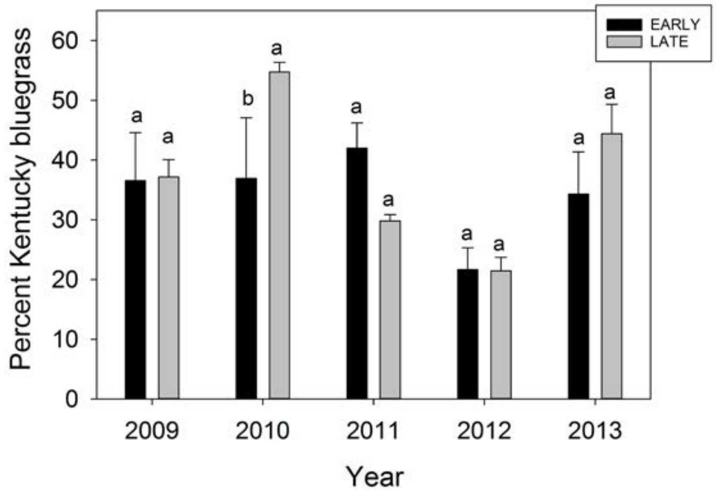

Figure 3. Plant stand spatial distribution analysis plugin output maps.

Along with these uniformity indices, the plugin also produced two maps to visually represent the spacing variation in the field (Figure 3). A color-coded spatial distribution map, which displayed the different categories in plant spacing (e.g., ideal, multiples, single-, double-, and triple-skips). Another was the black and white (binary) management map representing only the double- and triple-skips present in the field based on user's spacing tolerance. This map provides a useful tool to use in making management decisions such as replanting and nutrient application decisions.

The study results showed that the open-source ImageJ plugin using UAV imagery provided accurate assessments of plant spacing, using only a few user inputs. The developed uniformity index provides a simple measure of plant spacing uniformity compared to the planned ideal spacing, and the map outputs provide an intuitive visual tool for use in identifying problem areas and in making management decisions.

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Ecological implications of plant secondary metabolites – enhancing agricultural sustainability through plant biochemical diversity

Drs. Andrea Clemensen, Frederick Provenza, John Hendrickson, and Michael Grusak

Agricultural production, although efficient in feeding an expanding human population, often has negative environmental impacts that are diminishing the sustainability of natural resources. Producers and consumers are increasingly interested in understanding how land management practices can enhance agricultural sustainability and improve human health. Crop and forage (hay or silage) production often uses synthetic pesticides, herbicides, and fertilizers, and livestock production often uses vaccines, antibiotics, medicated feeds, and growth hormones.

Although these agrochemicals and medicines have widened the ability of large-scale production, these inputs are proving to have a range of negative environmental impacts that are reducing the sustainability of agroecosystems. Recommended strategies to reduce the negative environmental impacts include crop rotation, cover crops, reduced and/or no-tillage, integrated pest management, precision farming, diversification of farm enterprises, genetically modified crops, and agricultural conservation management practices.

Here, we discuss an additional strategy to reduce the negative environmental impacts of agriculture, that being, to utilize crops and forages with diverse plant secondary metabolites (PSMs).

Using biodiverse crops and forages with different biochemistries can reduce input requirements such as pesticides and fertilizers and reduce the need for medication and parasiticides in animal production, thus reducing negative impacts from these inputs on the environment.

Besides producing the primary compounds necessary for growth, plants produce a diverse assortment of secondary metabolites. Research over the last several decades has highlighted the ecological importance of PSMs. Plants produce tens of thousands of PSMs to communicate with organisms in their environment, both above and belowground. Plants use these metabolites to modify the rhizosphere and acquire nutrients, which in turn can influence the chemical, physical, and biological qualities of soil. Plants also use these metabolites to defend themselves against herbivores, fungi, bacteria, viruses, and other plants. Plant secondary metabolites are used by plants to attract pollinators and seed dispersers, while also protecting plants from extreme UV-light, excessive evaporation, temperature extremes, and drought.

In pastures and rangelands, PSMs can act as medicines to animals foraging on different plants which contain various PSMs, and animal production can increase when animals ingest forages with different PSMs. This leads to implications for enhancing the biochemical richness of meat and dairy products for human consumption. In addition to improving the health of foraging animals, ingesting various PSMs enhances the biochemical richness, flavor, and quality of cheese, milk, and meat for human consumption.

Our health is thus linked with the diets of livestock through the chemical characteristics of the plant species they eat. Through their anti-inflammatory, immunomodulatory, antioxidant, anti-bacterial, and anti-parasitic properties, PSMs in plants protect livestock and humans against diseases and pathogens. Historically, plants were the source of medicine for all animals, including humans. Today, various drugs (antibiotics, pain killers, fever reducers, etc.) are derived from plants that produce these chemicals naturally. The opportunity is to reconsider the fundamentally important roles these compounds played in health before the advent of modern medicine, while integrating plants with diverse PSMs back into our crops and forages.

A deeper understanding of PSMs, and their functional roles in agroecology, may help producers better manage their lands, reduce inputs, and minimize negative environmental impacts. Enhancing plant biodiversity and associated plant secondary metabolite biochemical diversity offers a logical progression to improve agricultural resilience while providing ecosystem services that also benefit the health of herbivores and humans.

Clemensen AK, Provenza FD, Hendrickson JR, and Grusak MA (2020) Ecological Implications of Plant Secondary Metabolites – Phytochemical Diversity Can Enhance Agricultural Sustainability. Front. Sustain. Food Syst. 4:547826. doi: 10.3389/fsufs.2020.547826

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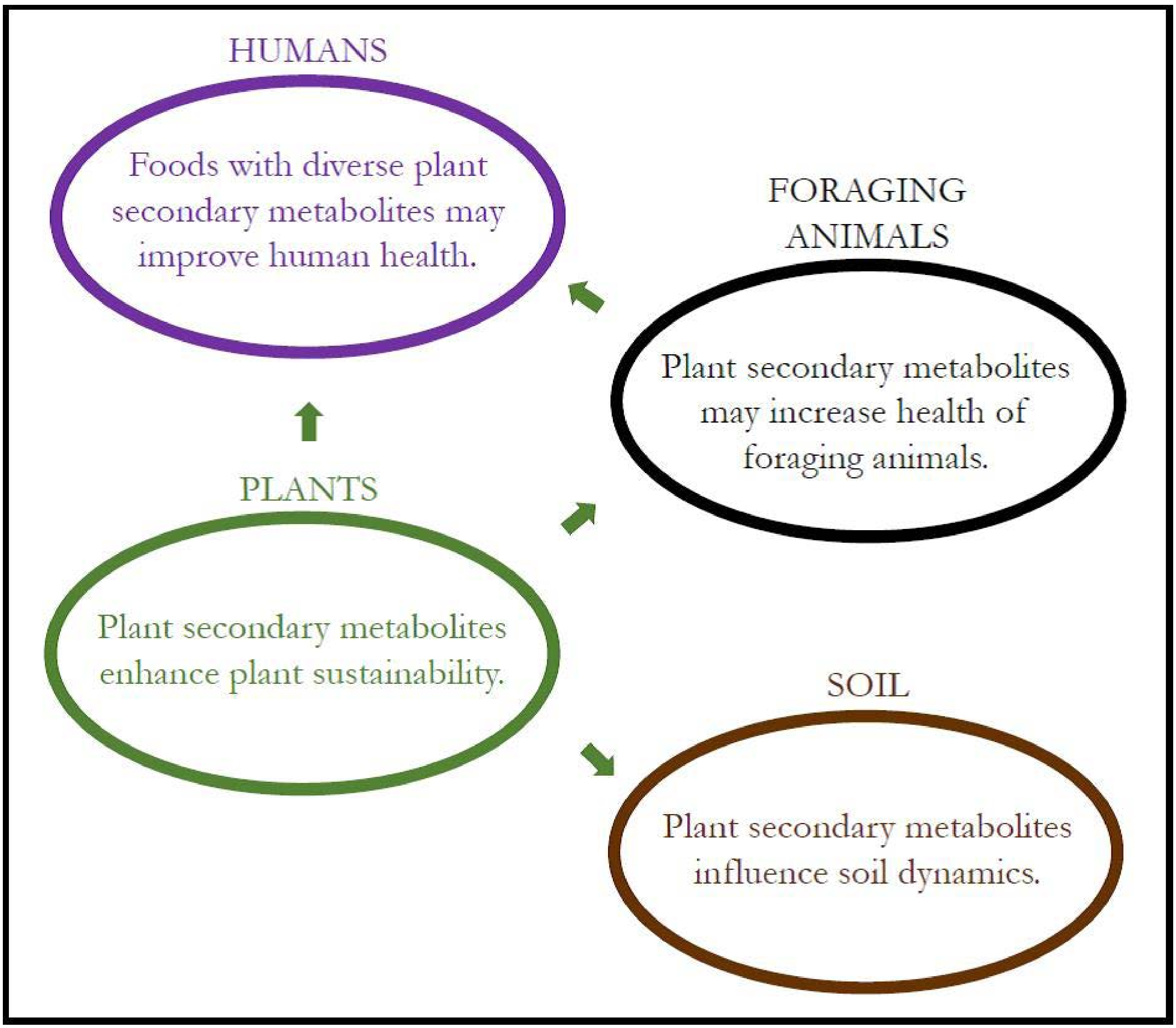

What has been the focus of research into Integrated Crop-Livestock Systems (ICLS)?

Dr. John Hendrickson

The Northern Great Plains Research Laboratory (NGPRL) has had an integrated crop-livestock system (ICLS) project since 1999. At that time, this was one of the few ICLS projects in the nation and also has included some of the earliest work on cover crops used as forage in ICLS. While NGPRL has continued to conduct research into ICLS, interest in these systems is increasing and other researchers are starting to study these systems. It is important to understand what is known about ICLS and to identify the research gaps to better design research into ICLS.

Hummel 2016. https://nexuspointblog.wordpress.com/2016/02/01/social-sustainability-the-shorter-leg/

One reason many researchers are interested in ICLS is that it may provide a way to enhance the sustainability of agricultural systems while still maintain their productivity. A review of 116 recently published research articles on ICLS looked at how many focused on the environmental, economic or social aspects of sustainability. The table below shows how the research articles were divided between the various aspects of sustainability. For example, there were 77 articles that mentioned environmental and 72 that mentioned economic, but only 32 that mentioned social aspects of sustainability. Also, there were 42 articles that mentioned both environment and economic aspects but only 13 that mentioned economic and social. Of the 116 articles, there were only 9 that mentioned all three (environmental, economic and social).

This information suggests that the primary focus of most research into ICLS has been environmental and economic aspects. However, for ICLS to realize its potential, more research needs to be done on the social aspect which is critical for the adoption and use of these systems. For example, there may be certain types or age groups of farmers who may be more willing to adopt ICLS and adoption efforts should be focused there.

The research review does show that to get the maximum benefit of ICLS to producers, more research is needed that integrates the social aspects with the environmental and economic aspects.

Topics	Environmental	Economic	Social
Environmental	**77**	42	17
Economic	42	**72**	13
Social	17	13	**32**

Hendrickson, J.R. 2020. Crop-livestock integrated systems for more sustainable agricultural production: A review. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 15 (12), art. no. PAVSNNR202015012, DOI: 10.1079/PAVSNNR202015012

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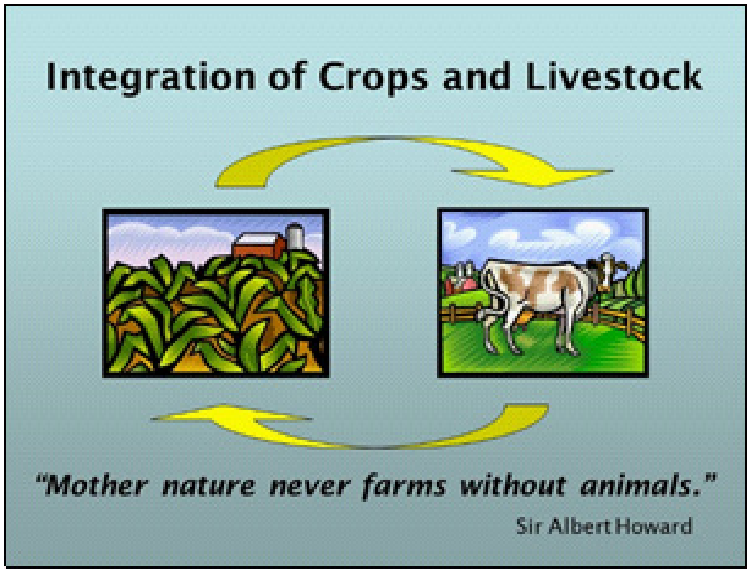
Integrated Crop-Livestock Systems and soil carbon: the importance of grazing and residue retention

Drs. Mark Liebig, Derek Faust, David Archer, Scott Kronberg, John Hendrickson, and Don Tanaka



Integrated crop-livestock (ICL) systems have the potential to balance production and environmental goals by improving soil quality. Soil organic carbon is an important property often measured when assessing soil quality in agricultural systems, as its status provides insight into a soil's capacity to efficiently cycle nutrients, retain water, and support soil biota.

Previous research has shown soil carbon to decrease, increase, or not change under ICL systems in South America. Variable responses in previous studies have been due to differences in weather and soil characteristics, historical land use, and management practices, underscoring the importance of framing ICL outcomes within specific ecoregions, site history, and over time. Unfortunately, few ICL studies have documented soil carbon over the long term (>10 years), especially in North America.

In response to this need, soil carbon changes were documented in an ICL experiment conducted at the USDA-ARS Northern Great Plains Research Laboratory near Mandan, ND.

Three treatments in the ICL experiment were evaluated for their effect on soil carbon:

GRAZED, residue removal by livestock grazing following haying or grain harvest

REMOVED, residue removal with a baler following haying or grain harvest

CONTROL, no residue removal, with residue left in place following haying or grain harvest

Soil carbon was measured in 1999 at the beginning of the experiment, and again in 2014. Measurements were made in all treatments to a depth of three feet in increments of 0-3", 3-6", 6-12", 12-24", and 24-36".

Soil carbon did not differ among treatments at the beginning of the experiment. In 2014, soil carbon was greater under the GRAZED and CONTROL treatments compared to the REMOVED treatment at 0-3 and 3-6" depths, with no differences among treatments below 6".

Soil carbon was found to increase significantly over 15 years for the GRAZED and CONTROL treatments (4.5 and 5.0 tons/ac, respectively), but only in the 0-3" depth (Fig. 1). Soil bulk density also increased in these treatments between 1999 and 2014, contributing to the change in soil carbon stocks. No changes in soil carbon over time were detected below 3".

Treatment and time effects on soil carbon were confined to the soil surface, where effects from roots, residue, and – in the case of the GRAZED treatment – manure and hoof action were concentrated. The absence of physical disturbance by tillage also likely contributed to the prevalence of near-surface treatment effects on soil carbon, since no-till

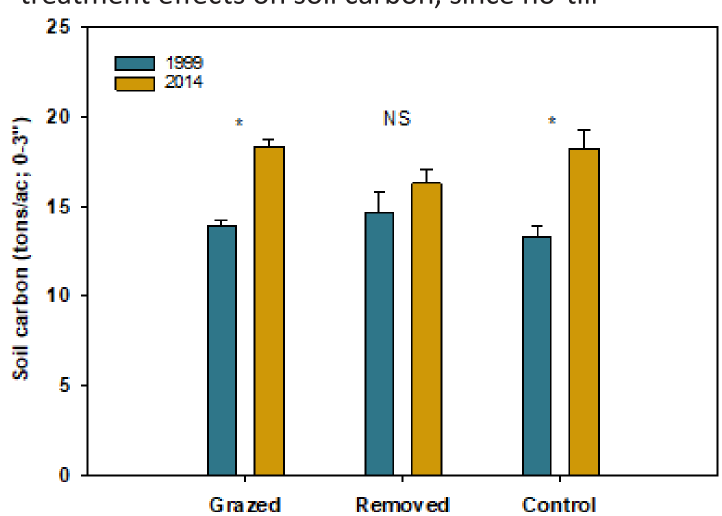


Figure 1. Soil carbon at 0-3" for integrated crop-livestock treatments differing in residue management (residue grazed, removed, or retained as a control). Stars (*) above bars signify a significant change in soil carbon between 1999 and 2014 (P<0.1). NS indicates the difference was not significant.

Collecting samples for soil carbon measurements

management (as used in this study) can strongly stratify soil properties with depth compared to tilled production systems.

Removal of crop residue from the soil surface is well documented to decrease soil carbon, as less residue returned to the soil equates to lower carbon inputs. Residue removal can also expose more bare soil, thereby contributing to increased soil temperatures and higher carbon mineralization rates.

Overall, the changes in soil carbon found in this study underscored the importance of residue retention and livestock grazing for ICL systems in semiarid regions. These findings also highlighted the role of ICL practices to influence the top-most portion of the soil profile, where the impacts of weather and management are most pronounced.

Adapted from Liebig, M.A., D.R. Faust, D.W. Archer, S.L. Kronberg, J.R. Hendrickson, and D.L. Tanaka. 2020. Integrated crop-livestock effects on soil carbon and nitrogen in a semiarid region. Agrosys. Geosci. Environ. http://dx.doi.org/10.1002/agg2.20098.

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Simple organic compounds related to benzoic acid may affect the amount of nitrogen bound to manure fiber

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Polyphenolic plant secondary compounds such as tannins are known to increase the total amount of nitrogen excreted in feces when fed to ruminants but less often noted is an accompanying increase in the amount of nitrogen recovered in fecal acid detergent fiber (ADF-N). Relatedly, tannins, associated monomers (gallic acid) and even simple compounds like benzoic acid are known to reduce nitrogen solubility when added to soil presumably through mechanisms that bind unspecified forms of nitrogen to soil organic matter or inorganic soil matrix.

Because complex polyphenolic plant secondary compounds like tannins are not usually associated with annual crops in the northern Great Plains, We hypothesized that topical applications of simple aromatic organic acids, representative of compounds found in annual crops, would increase the amount of nitrogen affixed to the cellulose and lignin fibers in manure and expressed as ADF-N.

Samples of dry, ground manure from cows fed two diets (low and high protein) were treated with aqueous solutions of six treatment compounds applied at three concentrations (0.001 M, 0.01 M, and 0.1 M).

Treatment compounds were selected to evaluate the effects of hydroxybenzoic acids of varying substituent configurations. Hydroxybenzoic acids together with cinnamic acids are common in food crops and are more likely to be consumed by animals grazing on cover crops or crop residues than more complex polyphenolic secondary compounds like tannins that have received recent attention. For this study we evaluated sodium benzoate (aromatic ring, B0), sodium 4-hydroxybenzoic acid (aromatic ring with a single OH group, B1), 3,4, dihydroxybenzoic acid (aromatic ring with 2 OH groups, B2), 3,4,5-trihydroxybenzoic acid monohydrate (aromatic ring with 3 OH groups, B3), ammonium benzoate (aromatic ring + NH_4+, AB), and ammonium chloride (an inorganic salt, AC).

Chemical analyses were conducted on diet components and untreated manure samples by a commercial lab (Ward Laboratories Inc., Kearney, NE). Total soil C and N was determined by dry combustion using a LECO FP-2000 CN analyzer (LECO Corporation, St. Joseph, MI). The concentrations of total P (P_2O_5), K (K_2O), S, Ca, Mg, Na, Zn, Fe, Mn, Cu, and B in feed and manure were determined by Inductively Coupled Argon Cooled Plasma Spectrometry (ICAP, Thermo) after acid digestion of samples.

The effects of treatment solutions on fiber-bound N in manure were determined from the amount of N (LECO) retained in acid detergent fiber (ADF-N). Acid detergent fiber was measured by the Van Soest technique following the Ankom method, using a Fiber Analyzer 220 (Ankom Technology, Fairport, NY), and using the customary acid detergent solution.

Our results did not entirely support our hypothesis. However, they clearly showed there is considerable variability in the concentration of manure ADF-N, even among animals fed the same ration, and revealed concentrations of manure ADF-N could be readily affected by the treatment solutions.

Alfalfa hay supplied more protein to animals than the oat hay ration (Table 1) but manure from both diets contained similar amounts of N (Table 2). Despite

Figure 1

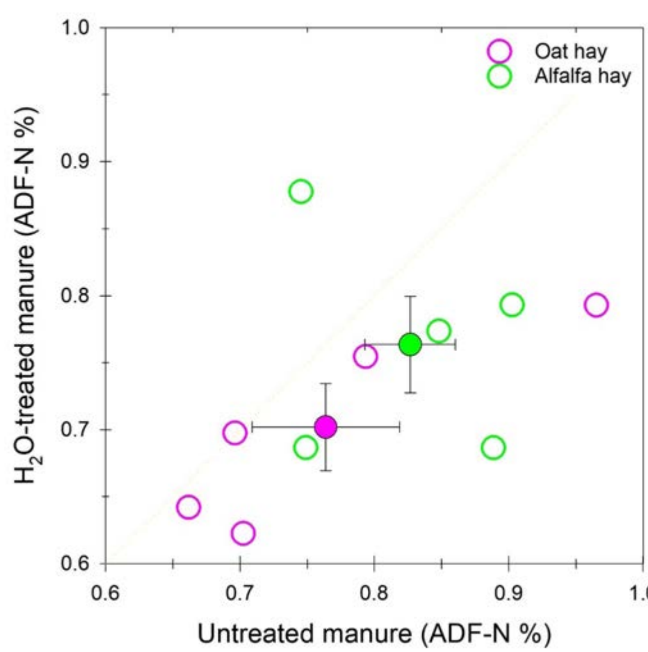


Figure 1. Manure ADF-N (%) for individual cows (open symbols). Samples were analyzed after treatment with water or without treatment (sample handling only). Filled symbols indicate arithmetic mean values (n=5). Error bars indicate the standard error of the mean. The same five animals were used to produce the manure for each diet.

appearing slightly higher for alfalfa hay, mean ADF-N in untreated and water-treated samples did not differ between the two diets (Figure 1). Similarly, mean ADF-N in water-treated manure did not differ from that in untreated manure from either the alfalfa or the oat hay mixed ration. Notably, the amount of variation observed in untreated manure ADF-N among individual cows as well as differences between untreated manure and the H_2O-treated control samples were unexpected. Future work will employ more animals and longer exposures to treatment solutions to clearly detect treatment and concentration effects.

Significant treatment effects on manure ADF-N were complex, influenced by diet, compound, and concentration. For example, alfalfa hay resulted in manure in which ADF-N concentration was positively related to the number of OH functional groups on the phenolic treatment compounds (B1-B3 in Figure 2a), but this pattern was observed only at the lowest (0.001 M) treatment concentration. No treatment differences were observed for the other concentrations.

In contrast, the oat hay ration resulted in manure in which ADF-N concentration was negatively related to the number of OH functional groups on the phenolic treatment compounds (B1-B3 in Figure 2b) but this pattern was observed only at the highest (0.1 M) concentration. At other concentrations, the relationship between ADF-N and OH functional groups was inconsistent.

Both low-(oat hay) and high-(alfalfa) protein diets resulted in manure with similar concentrations of N (Tables 1,2). Different responses to treatment solutions observed between diets (Figures 2a,b) suggest a) innate differences in ADF composition of different forages or in the manure derived from them, and/or b) different quantities and composition of the unspecified forms of organic N in manure, able to complex or be retained by with fibers.

This work suggests that secondary plant compounds might indirectly influence nutrient cycling in integrated crop livestock systems. Manure ADF-N, affected by solution concentration and varying by treatment suggest that some of changes to manure composition associated with dietary tannins or related phenolic compounds do not depend on rumen fermentation and subsequent digestion. Mineralization kinetics of manure may be impacted by increasing or decreasing the amount of nitrogen bound to manure fibers but if our observations are true in a broader sense, effects of simple organic compounds on ADF-N may also affect estimates of heat damaged protein typically included in forage analyses.

Figure 2a

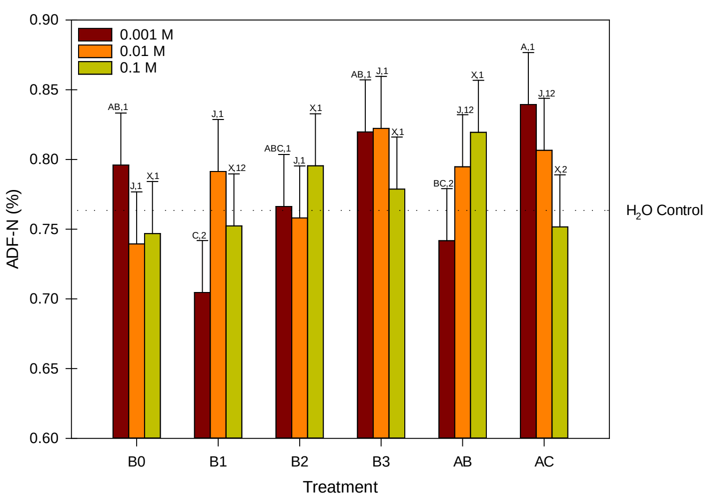


Figure 2b

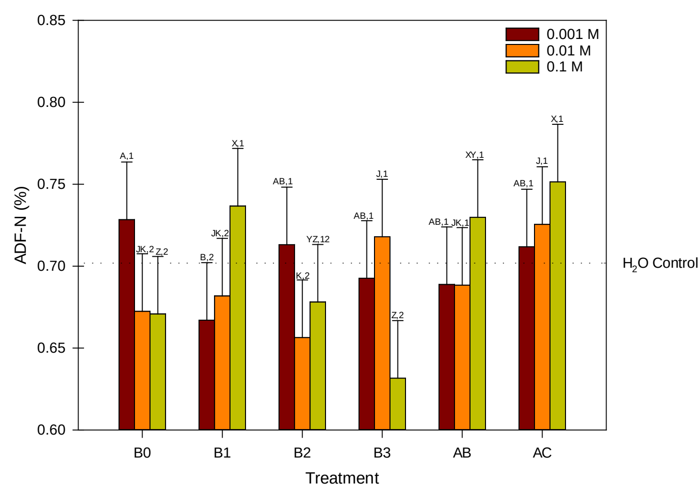


Figure 2. Manure ADF-N (%) for cows fed a) alfalfa hay, and b) oat hay mixed ration. For each diet, we applied a linear mixed model using PROC GLIMMIX to examine the influence of treatment compound (TRT) and concentration (CONC) on ADF-N. Both TRT and CONC were classed as fixed effects while animals were assumed random. Bars show LSMEANS (n=5) and error bars indicate the standard error calculated by the model. Post hoc comparisons between means were considered significant at Tukey-Kramer adjusted P-values of ≤0.05. At each concentration, different treatments are denoted by letters. Within each treatment, different concentrations are denoted by number.

Table 1. Feed analysis[a]

	DM	CP	ADF	NDF	TDN	NEm	NEg	Nel	RFV	Ca	P	K	Mg	Na	S	Cu	Fe	Mn	Mo	Zn
										Macrominerals						Micronutrients				
	--------%--------					---Mcal cwt^{-1}---				--------%--------						--------ppm--------				
Diet 1[b]																				
Oat Hay	88.6	7.0	36.9	58.3	60.4	60.1	34.0	63.2	96	0.18	0.10	1.48	0.14	0.18	0.12	2.1	106	28	1.65	43.7
Corn	86.8	8.6	2.9	9.2	87.8	98.6	67.7	89.7	880	0.04	0.21	0.37	0.13	0.04	0.10	0.4	44	6	0.63	39.1
Peas	90.1	19.7	17.0	23.3	66.2	68.6	41.7	86.1	302	0.22	0.33	0.91	0.17	0.05	0.15	3.9	129	13	0.89	67.0
Ration Mix	88.6	8.2	32.6	51.6	63.0	63.8	37.3	67.1	174	0.17	0.13	1.35	0.14	0.16	0.12	2.1	103	25	1.51	45.2
Diet 2[b]																				
Alfalfa Hay	88.0	22.9	34.8	46.3	56.3	53.7	28.2	62.6	124	1.08	0.25	2.74	0.33	0.04	0.22	6.4	233	42	1.81	44.1

a) Manure pH determined with DM, Dry Matter, (%); Ntot, Total N, (%); Norg, Organic N, (%); P_2O_5, Phosphorus, (% P_2O_5); K_2O, Potassium, (% K_2O); S, Sulfur, (%) ; Ca, Calcium, (%); Mg, Magnesium, (%); Na, Sodium, (%); Zn, Zinc (ppm); Fe, Iron, (ppm); Mn, Manganese, (ppm); Cu, Copper, (ppm); B, Boron, (ppm) .

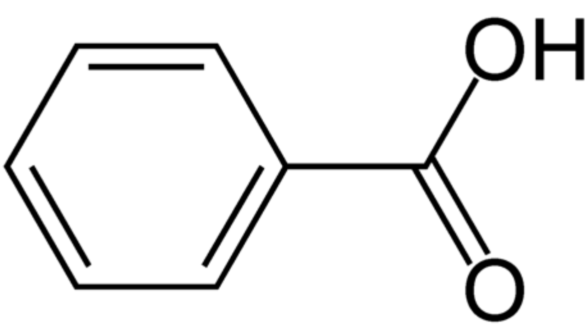
b) Diet 1: Animals, fed collectively, were supplied with a mixed daily ration composed of 21 lb. oat hay (84% DM), 2 lbs. of corn (7.8% DM) and 2 lbs. of peas (8.1% DM), $animal^{-1}$ day^{-1}. Diet 2: Animals were fed ad libitum on alfalfa hay.

Table 2. Manure composition[a]

	Cow	pH_w	DM	N_{tot}	N_{org}	P_2O_5	K_2O	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B
				---------------%---------------								--------Mg kg^{-1}--------				
	A	5.5	94.3	2.44	2.37	0.86	0.71	0.21	0.41	0.38	0.16	99	386	82	7	7
	B	8.8	94.2	1.98	1.96	1.02	2.51	0.25	0.56	0.35	0.58	105	329	84	8	10
	C	8.2	93.9	2.04	2.02	0.63	0.96	0.23	0.52	0.40	0.54	137	694	134	17	8
	D	8.8	93.8	2.50	2.48	0.91	1.13	0.29	3.37	0.76	0.24	107	1331	142	19	33
	E	8.1	94.5	2.06	2.03	0.86	1.62	0.23	0.57	0.40	0.17	87	343	91	6	10
	Avg.	**7.9**	**94.1**	**2.20**	**2.17**	**0.86**	**1.39**	**0.24**	**1.09**	**0.46**	**0.34**	**107**	**617**	**107**	**11**	**14**
	SEM	0.6	0.1	0.11	0.11	0.06	0.32	0.01	0.57	0.08	0.09	8	191	13	3	5
Diet 1[b]	CV %	17	<1	11	11	17	51	13	118	37	61	17	69	27	55	80
	A	8.5	95.1	2.52	2.50	0.67	1.19	0.30	2.81	0.72	0.20	86	1140	142	19	36
	B	8.6	94.3	2.16	2.16	0.81	0.75	0.28	2.93	0.55	0.17	103	1559	155	17	30
	C	9.0	94.1	2.12	2.11	1.06	0.67	0.24	3.05	0.71	0.12	92	1453	122	15	27
	D	7.8	94.8	2.02	2.01	0.82	1.44	0.24	0.48	0.35	0.35	80	348	76	7	8
	E	8.9	94.6	2.03	2.03	1.16	0.69	0.29	3.07	0.73	0.09	101	1803	160	20	28
	Avg.	**8.6**	**94.6**	**2.17**	**2.16**	**0.90**	**0.95**	**0.27**	**2.47**	**0.61**	**0.19**	**92**	**1260**	**131**	**16**	**26**
Diet 2[b]	SEM	0.2	0.2	0.09	0.09	0.09	0.16	0.01	0.50	0.07	0.05	5	252	15	2	5
	CV %	6	<1	9	9	22	37	10	45	27	54	11	45	26	32	41

a) DM, Dry Matter, (%); CP, Crude Protein, (%); ADF, Acid Detergent Fiber, (%); NDF, Neutral Detergent Fiber, (%);TDN, Total Digestible Nutrients, (%); NEm, Net Energy Maint, (MCal/cwt); NEg, Net Energy Gain, (MCal/cwt); NEl, Net Energy Lact, (MCal/cwt); RFV, Relative Feed Value (dimensionless); Ca, Calcium, (%); P, Phosphorus, (%); K, Potassium, (%); Mg, Magnesium, (%); Na, Sodium, (%); S, Sulfur, (%); Cu, Copper, (ppm); Fe, Iron, (ppm); Mn, Manganese, (ppm); Mo, Molybdenum, (ppm); Zn, Zinc (ppm).

b) Diet 1: Animals, fed collectively, were supplied with a mixed daily ration calculated as 21 lb. oat hay (84% DM), 2 lbs. of corn (7.8% DM) and 2 lbs. of peas (8.1% DM). Diet 2: Animals were fed ad-libitum on alfalfa hay. Both oat hay and alfalfa were locally sourced, near Almont, ND and Hannover ND, respectively.



Benzoic Acid

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Spinach response to salinity: nutritional Value, physiological parameters, antioxidant capacity, and gene expressione

Dr. Jonathan Halvorson , Jorge F. S. Ferreira, Devinder Sandhu, and Xuan Liu

Commercial spinach cultivated today probably originated from Spinacia tetranda L., a wild edible green found in Nepal. In 647 AD spinach was taken from Nepal to China where it was referred to as the "Persian green." Spinach was introduced by the Moors of North Africa to Spain in the 11th century. By the Middle Ages, spinach was grown and sold throughout the rest of Europe, and it was known in England as the "Spanish vegetable". It was not until the 1400's that spinach became a staple in Mediterranean cooking.

According to the National Nutrient Database for Standard Reference, fresh spinach is rich in the minerals potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), phosphorus (P), iron (Fe); and vitamins C, betaine, lutein and zeaxanthin, B-carotene, vitamins E, A, and K (a.k.a. phylloquinone), folate, and protein. However, due to the high concentration of oxalates and phytates in spinach leaves, only 2-5% of its Ca or P is bioavailable to humans.

Lack of good-quality irrigation water is a limitation for producing food to feed a growing world population. Recycled waters may be available locally, but their higher salinity is a concern. Effects of using saline water on spinach, including effects on mineral and antioxidant levels, photosynthesis, and gene expression have not been established. Spinach (cv. Raccoon) was greenhouse-grown and irrigated with four levels of water salinity combined with three levels of K (3, 5, and 7 meq L^{-1}). Salinity levels included electrical conductivities (ECiw) ranging from 1.4 (control) to 9.8 dS m^{-1}, and with NaCl levels of 2, 20, 40, and 80 meq L^{-1}.

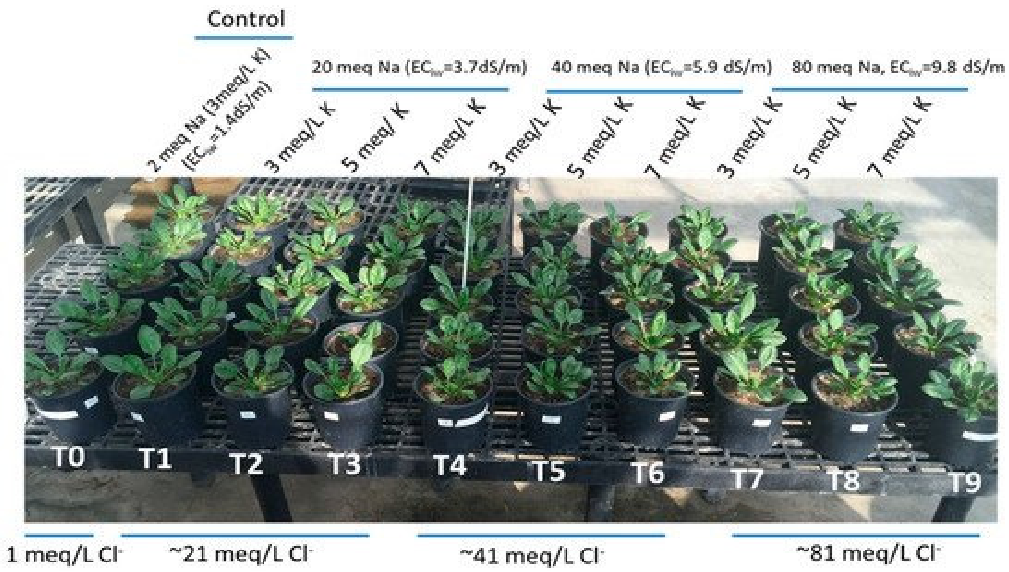

Figure 1. Spinach plants of the cultivar Raccoon 23 days after exposure to irrigation water salinities with electrical conductivities (ECiw) ranging from 1.4 dS m^{-1} (2 meq L^{-1} NaCl) to 9.8 dS m^{-1} (80 meq L^{-1} NaCl). NO_3^- and SO^{-2} were kept constant at 7.5 and 2.0 meq L^{-1}, respectively, and pH = 7.3. Treatments were labeled T0 (control, 2 meq L^{-1} Na^+, 1 meq L^{-1} Cl^-, 3 meq L^{-1} K^+) to T9 (80 meq L^{-1} NaCl:7 meq L^{-1} K^+).

After 23 treatment days, plants had more Na and chloride (Cl) in shoots and roots with increasing salinity, regardless of the K concentration in the irrigation water. Plants showed no visual symptoms of salt toxicity and there were no differences in shoot growth. Plants maintained their overall concentrations of mineral nutrients, physiological parameters, and oxalic acid across salinity treatments. Leaves retained all their antioxidant capacity at 20 meq L^{-1} NaCl, and 74% to 66% at 40 and 80 meq L^{-1} NaCl, respectively.

Expression analyses of ten genes, that play important roles in salt tolerance, indicated that although some genes were upregulated in plants under salinity, compared to the control, there was no association between Na or K tissue concentrations and gene expression.

Excerpted from: Spinach (Spinacea oleracea L.) Response to Salinity: Nutritional Value, Physiological Parameters, Antioxidant Capacity, and Gene Expression. Jorge F. S. Ferreira 1, Devinder Sandhu, Xuan Liu, and Jonathan J. Halvorson. Agriculture 2018, 8(10), 163; https://doi.org/10.3390/agriculture8100163

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Can time of grazing reduce Kentucky bluegrass in your pastures?

Drs. John Hendrickson and Scott Kronberg

Kentucky bluegrass has dramatically increased across the Northern Great Plains over the last 30 years. The increase in Kentucky bluegrass has had many impacts but one of the primary impacts on producers has been a change in the forage cycle. Kentucky bluegrass starts growing earlier in the season and matures earlier than most native grasses. However, it is often unpalatable after maturity, especially if there is little or no rain, and cattle may avoid grazing it and instead repeated graze native grasses.

Targeted grazing is grazing a specific livestock species at a specific time with enough duration and intensity to change the vegetation species mixtures. An example of targeted grazing that many people in the Northern Plains may remember is the use of sheep to eat leafy spurge. In the case of Kentucky bluegrass, we wanted to see if early spring grazing by cattle (Targeted grazing of Kentucky bluegrass) would reduce the amount of Kentucky bluegrass and increase the amount of native grasses on the rangeland. Kentucky bluegrass starts growth in the spring earlier than many native grasses which may provide an opportunity to reduce it by using targeted grazing in the spring.

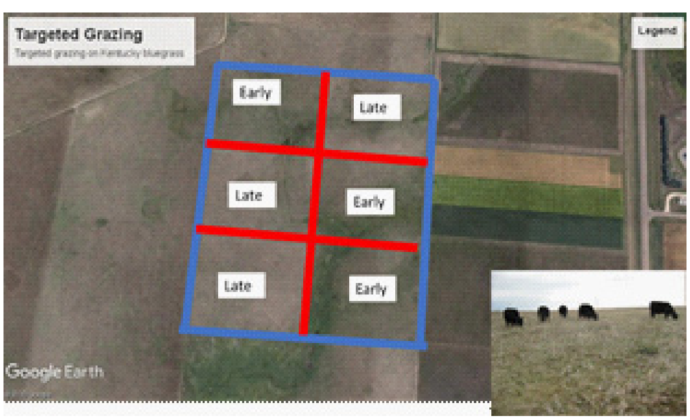

Figure 1. The layout of the pastures used in the study. The pastures were split in half and each half was assigned to either an Early or a Late grazing treatment. The inset shows cattle grazing on the Early grazed treatments.

To see if targeted grazing could help reduce Kentucky bluegrass and increase native grasses, we started a 5-year project in the spring of 2009 and ended it in the fall of 2013. We utilized three 15-acre native grass pastures for this project. Each pasture was split in half and each half was assigned to either early grazing (Early) or late grazing control (Late). Figure 1 shows the pasture layout and the cattle grazing on the early grazed plots. The early plots were grazed with 10 cow-calf pairs with grazing starting as soon as we estimated there was a week of forage to carry them through. The start of grazing in the early plots varied with the year and ranged from April 30 in 2012 to May 16 in 2011. Grazing continued on the Early plots until approximately 30% of the native plants were grazed by cattle. This was determined by locating 50 random points throughout the pasture and determining if the nearest native plant to that point was grazed. The number of days of grazing on the Early plots ranged from 23 days in 2010 and 2012 to a low of 14 days in 2009.

After June first, the Late plots were grazed. We grazed the late plots with 5 cow-calf pairs for twice as long as we had grazed the Early plots using some of the same cow-calf pairs. By halving the number of pairs and grazing them for twice as long, we did two things that were important for the project. First, the longer grazing period is more representative of the grazing in the region and second, it allowed us to keep the stocking rate the same between the two treatments. If we hadn't kept the stocking rates the same, we would be unable to know if any changes in the plant community were due to a heavier stocking rate or due to the time of grazing.

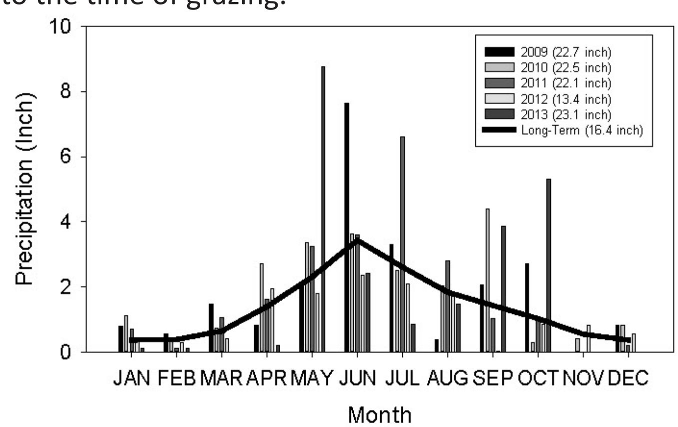

Figure 2. Monthly precipitation by year (bars) of the study and long-term average for NGPRL (Line).

Rainfall was greater than the long-term average every year except for 2012. Figure 2 shows monthly precipitation by year for the study. Monthly precipitation during the growing season (April through September) ranged from a high of 8.8 inches in May 2013 to a low of 0.03 inches in September 2012.

We used a couple of methods to evaluate the impact of grazing treatment on the pastures. We clipped the pastures to determine if grazing treatment had any impact on productivity and then measured species composition in the fall of each year. The grazing treatments had minor impact on forage production. We measured forage production in 3 of the 5 years of the study with forage production differing in only 1 of the 3 years. In that year, 2010, the Early grazed plots produced more forage than the Late plots.

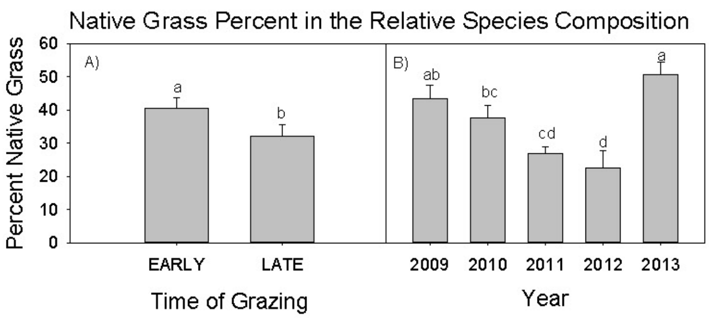

Figure 3. The percent of the rangeland vegetation made up of native grasses for the Early and Late treatments and for each year.

The Early grazing treatment did increase the amount of native grasses in the species composition (Figure 3). In the Early grazed pastures, native grasses made up about 40% of the species compared to 32% in the Late grazed treatments. Year also made difference in percent of native grass in the pastures. The percent of native grass decreased between 2009 and 2012 and then rapidly increased in 2013. The drought in 2012 combined with increased precipitation in 2013 may have helped increase the amount of native grasses in pastures in 2013.

The impact of the Early treatment on Kentucky bluegrass was less clear than with native grasses. The percent of Kentucky bluegrass in the species composition was generally the same between treatments except for 2010 when the Early grazed treatment had less Kentucky bluegrass than did the late grazed treatment. Most years of the study had above average precipitation which may overridden any effects of the Early grazing treatment.

Cattle producers in the Northern Great Plains have often been advised to delay grazing until late May or early June to limit harming native grasses. This concern is justifiable but the increase in Kentucky bluegrass on rangelands suggests that we need to adjust our management strategy. Early spring grazing, where the cattle are removed before damage is done to the native grasses, is an alternative grazing management strategy for producers improving their rangelands.

Hendrickson, John R., Scott L. Kronberg, and Eric J. Scholljegerdes. "Can targeted grazing reduce abundance of invasive perennial grass (Kentucky bluegrass) on native mixed-grass prairie?." Rangeland Ecology & Management 73: 547-551. (2020).

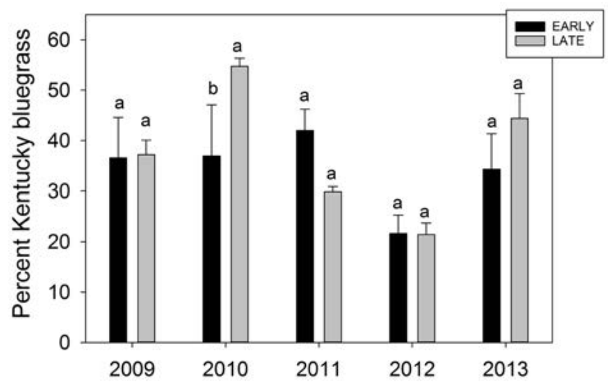

Figure 4. Impacts of grazing treatment on the amount of Kentucky bluegrass in the rangeland vegetation.

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Prescribed fire perceptions and potential management alternatives to prescribed fire

Dr. David Toledo

Kentucky bluegrass is a concern on many rangelands in the Northern Great Plains of North America. Re-introducing fire may be one of the best ways to combat bluegrass invasion in the Northern Great Plains. But, people's ideas about risks and barriers currently limit its use. We report findings of a project to identify the human aspects of using prescribed fire in North Dakota. We implemented a mail survey in November of 2016 by mailing 460 self-administered questionnaires. The survey sample included 50 landowners in each of six randomly selected counties, as well as all registered beekeepers in North Dakota. Our results show that fire is generally acceptable to many North Dakota landowners. Our respondents generally agreed with the use of prescribed fire but their behavior did not necessarily reflect those attitudes. Respondents reported several factors posed constraints toward potential fire application. Knowledge and experience was a weak constraint (25% of ranchers and 23% of non-ranchers see it as a constraint). Larger constraints included time constraints (50% of ranchers and 47% of non-ranchers see time as a constraint) and financial resources (56% of ranchers and 67% of non-ranchers see financial resources as a constraint). Labor and equipment varied between ranchers and non-rancher landowners with 65% of ranchers seeing it as a constraint and only 33% of non-ranchers agreeing. Previous research shows that prescribed burn associations are an effective approach to overcoming barriers to prescribed fires. Prescribed burn associations may help gain support for prescribed fires in North Dakota and may provide the resources to safely and effectively conduct prescribed fires.

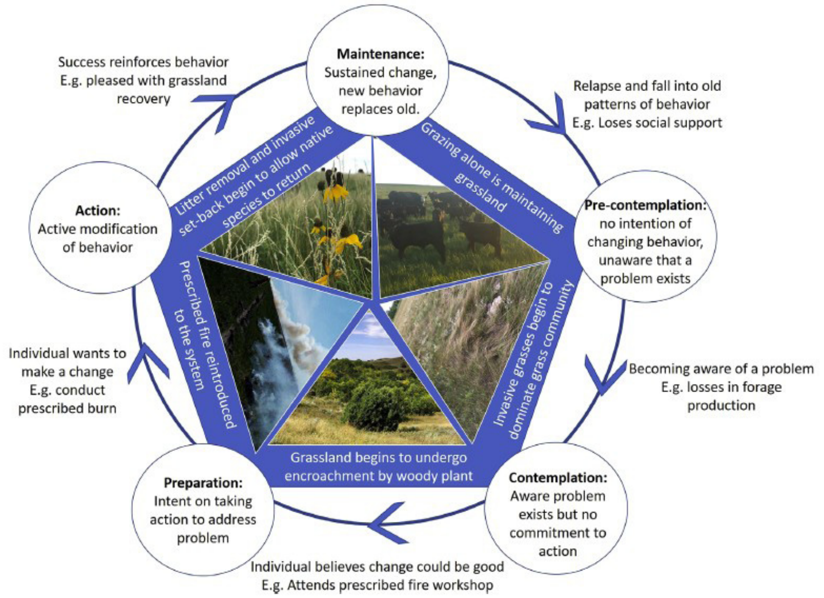

Figure. Model depicting stages of behavioral change in relation to current understanding of grassland succession and the role of prescribed fire. The model is useful for making inferences about landowner attitudes and behavior and for forming strategies to stimulate behavioral change that will result in positive impacts on the landscape (Bendel et al. 2019).

Currently, Audubon Dakota is organizing a ND Prescribed Fire Cooperative, the objective of this cooperative is to help private landowners conduct prescribed burns. The burn would be conducted with a contractor to facilitate knowledge exchange and provide the support needed. The idea is that this will empower landowners to then be able to burn on their own. For more information on the ND Prescribed Fire Cooperative, please contact Julianna Bosmoe at julianna.bosmoe@audubon.org or Lucy Britton at lucy.britton@audubon.org.

In 2017, the NGPRL customer focus group suggested mob grazing and/or multi-species grazing as an alternative to fire for managing grassland productivity and plant species composition. Based on this feedback, scientist at the NGPRL started a long-term multi-species grazing and burning experiment. The objective of the experiment is to sustainably intensify forage and livestock production on semiarid grazing land by using alternative land management practices including multi-species grazing and prescribed fire. This project will have five treatments that include fire, grazing, small ruminants, and a combination of fire and grazing. This study will provide valuable information regarding treatments for controlling Kentucky bluegrass and will also help determine whether the management induced vegetation changes that result from our treatments can help intensify livestock management operations. This experiment started in 2019. We look forward to sharing results from this experiment with you over the coming years.

Bendel, C., Toledo, D., Hovick, T., McGranahan, D. 2019. Using behavioral change models to understand private landowner perceptions of prescribed fire in North Dakota. Rangeland Ecology and Management 73:194-200.

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Forage economics calculator – a web tool

Subhashree N Srinivasagan and Dr. Cannayen Igathinathane, Agricultural and Biosystems Engineering, NDSU, Drs. John Hendrickson, David Archer, Mark Liebig, Jonathan Halvorson, Scott Kronberg, and David Toledo, USDA-ARS

Forage economics analysis is critical for performing agricultural enterprise and risk evaluation. Estimates of forage economics provide a way of making an educated decision related to growing or buying forage, purchasing machinery, and fixing forage prices. Economics analysis of forage involves working with various parameters such as the costs associated with forage production, harvesting, collection, labor, fuel, and the revenue generated by selling the forage (as bales).

Manual calculation of the economics using these parameters is highly complex, tedious, and time-consuming. Therefore, a web-based (multi-browser and multi-device) tool with 21 inputs and 23 output results was developed that computes and generates various economic result scenarios built from mathematical simulation and scientific procedures using HTML, CSS, and Javascript.

The tool emphasized the bale collection operation cost while the harvesting and baling costs are provided as direct inputs. Bale collection is commonly performed using a tractor with grapple or spear attachment; or using an efficient "automatic bale picker" (ABP), which collects and transports multiple bales in a single trip.

Figure 1. Forage economics calculator web tool is compatible across web browsers and device screen sizes.

The tool included both types of bale collection machinery (tractor and ABP) forcomparison. The web tool is compatible across major web browsers such as Safari, Chrome, and Firefox (Figure 1). It is also designed to accommodate different screen sizes such as desktop, laptop, smartphone, and iPad/tablet.

The forage economics web tool consists of three main sections: (i) home, (ii) user instructions & manual,

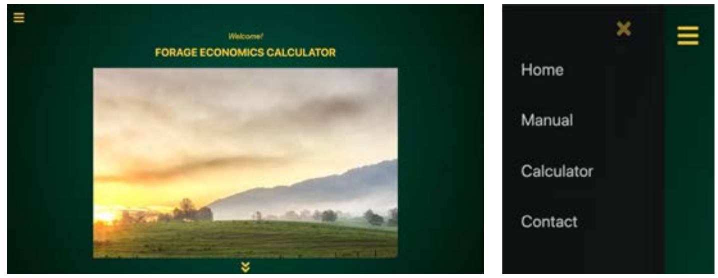

Figure 2. Home/welcome page of the forage economics calculator web tool (left). A collapsible navigation sidebar enables a smooth transition between sections (right).

and (iii) calculator section. The first section is the home page that welcomes the user to the forage economics web tool (Figure 2). Each section consists of a collapsible navigation sidebar at the top-left corner that enables a smooth transition between the sections. The second section consists of short 6-step user instructions and a detailed manual (Figure 3). The user instructions include a friendly step-by-step

Figure 3. User instructions and manual section contains downloadable (i) short 6-step user instructions and (ii) detailed user manual.

guide for the user, while the detailed manual contains comprehensive information about the various inputs, region-specific forage and economics data, forage bale collection logistics models, standard economics calculations that run at the background of the web tool, and the generated outputs. The third section is the actual forage economics calculator section, which consists of 21 inputs and 23 output results (Figures 4 and 1). The input values are provided as default and can be modified using sliders or drop-down boxes. The features of the calculator tool are as follows (list order corresponds to numbers in Figure 4):

1. Tooltip provides brief information about the item on hover.

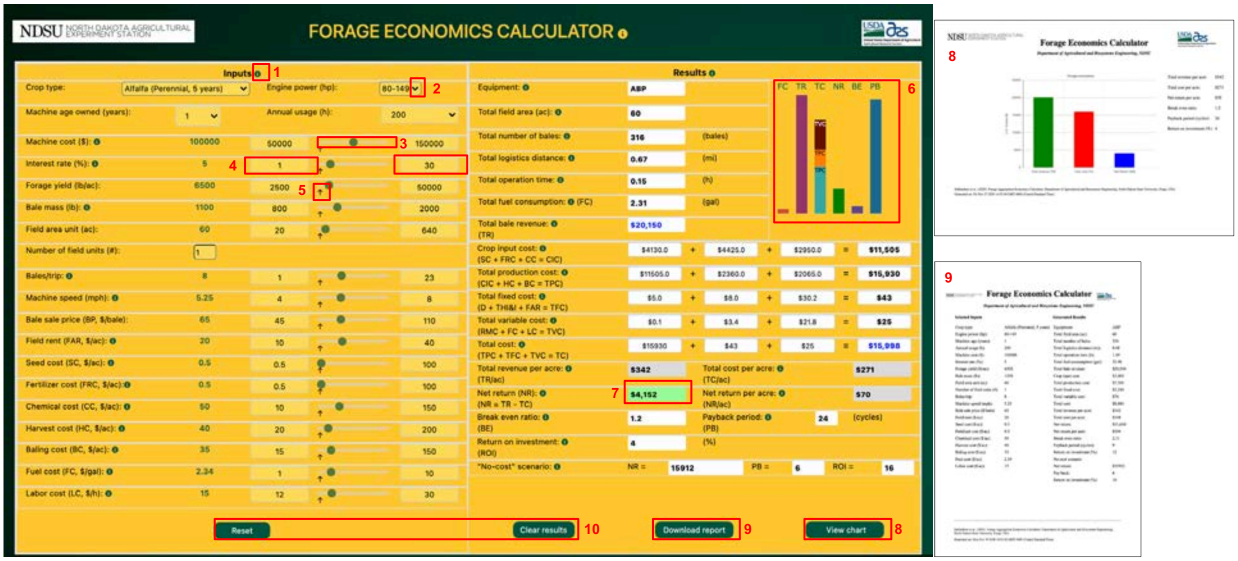

Figure 4. Calculator section contains 21 inputs and 23 output results including a dynamic and downloadable chart and report

2.Drop-down input options (e.g., crop, machine information) allow selecting an item from the provided list.

3. Slider input option allows selecting a value between the range.

4. User-input boxes allow editing the minimum and maximum values of the range.

5. Markers below sliders provide sensitivity analysis.

6. Dynamic chart visualization based on the inputs provided and results generated automatically.

7. Colored text boxed for “Net return” result; green indicates profit and red indicates loss.

8. “View chart” button opens a downloadable bar chart of total revenue, total cost, and net profit.

9. “Download report” button generates a report with inputs and generated outputs.

10. “Reset” and “Clear results” buttons reset the inputs to default and clears results, respectively.

A case study was carried out to demonstrate the functionality and applicability of the forage economics calculator web tool. The case study focused on estimating the economics of the alfalfa, a perennial forage crop, in a field area of 80 ac. The calculator estimated the cost for collecting the bales using a tractor with 2 bales/trip capacity. The seed cost was fixed at $25/ac while the fertilizer and chemical cost was set at the minimum. Harvest and baling costs are provided as direct inputs. Other costs include machinery, field rent, fuel, and labor. The inputs were fed to the calculator using drop-down options, sliders, and minimum input boxes. Three non-linear regression models (R^2 = 0.98) that estimate the total logistics distance, operation time, and fuel quantity during bale collection operation runs in the background of the calculator web tool. Eight standard economic analysis equations were included to generate the rest of the results (economics-based). Various economic analysis results include net return, break-even ratio, payback period, and return on investment. The results include a “no-cost” scenario where the net return, payback, and return on investment are estimated when field area rent, fertilizer, chemical, and labor costs are zero. Detailed information on the inputs fed into the tool and the results generated are presented in Table 1.

Potential users of this web tool are farmers, hay producers, custom hay operators, agricultural extension and financial personnel, and general users handling bales. The tool is continuously improved based on stakeholder inputs.

Table. 1. Input parameters and output results of the forage economics calculator (example case study).

Inputs		Results	
Parameter	**Value**	**Parameter**	**Value**
Crop type	Alfalfa (perennial, 5 years)	Equipment	Tractor
Engine power (hp)	80-140	Total field area (ac)	80
Machine age owned	10	Total number of bales (bales)	223
Annual usage (h)	200	Total logistics distance (mi)	2.99
Machine cost ($)	50000	Total operation time (h)	0.78
Interest rate (%)	5	Total fuel consumption (gal)	2.30
Forage yield (lb/ac)	5000	Total bale revenue ($)	16, 725
Bale mass (lb)	1500	Total production cost ($)	5,640
Field area unit (ac)	80	Total fixed cost ($)	2,824
Number of field units	1	Total variable cost ($)	20
Bales/trip	2	Total cost ($)	8,484
Machine speed (mph)	5.25	Net return ($)	8,241
Bale sale price ($/bale)	75	Total revenue per acre ($/ac)	209
Field rent ($/ac)	35	Total cost per acre ($/ac)	106
Seed cost ($/ac)	25	Net return per acre ($/ac)	103
Fertilizer cost ($/ac)	0	Break even ratio	1.97
Chemical cost ($/ac)	10	Payback period (cycles)	6
Harvest cost ($/ac)	20	Return on investment (%)	16
Baling cost ($/ac)	15	No-cost scenario net return ($)	13, 868
Fuel cost ($/gal)	2	No-cost scenario payback (cycles)	4
Labor cost ($/h)	20	No-cost scenario return on investment (%)	28

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Fuel consumption comparison in logistics of aggregation of biomass bales - tractor vs. automatic bale pickers

Subhashree N Srinivasagan and Dr. C. Igathinathane, Agricultural and Biosystems Engineering, NDSU,
Drs. Mark Liebig, Jonathan Halvorson, David Archer, John Hendrickson, and Scott Kronberg, NGPRL, USDA-ARS.

Logistic operations for agricultural biomass, including collection, handling, storage, and transport require substantial amounts of energy. Bale logistics in the field which includes aggregating bales in the field and transporting them to the field outlet significantly contributes to the overall logistics cost. But studies on the energy involved (or fuel consumption) in bale aggregation logistics within a field are not available. Therefore, a study was conducted to predict fuel consumption during bale aggregation with varying load scenarios and using fuel efficiency and operational time to help producers make efficient management decisions and cut down on cost.

Reducing the time spent in collecting bales within a field can reduce costs. Increasing the number of bales/trip (BPT), by using modern equipment such as an automatic bale picker (ABP; also known as "self-loading bale carrier") which is capable of handling multiple BPT, reduced operation time thus enabling improved logistics efficiency and reduced logistics cost (Figure 1).

Figure 1. Examples of common and modern bale aggregation equipment: (A) Tractor equipped with bale spears at the front and rear (capacity = 1–2 bales); and (B) An automatic bale picker (ABP) with loading arm (capacity up to 23) - Image sources: https://www.himac.com.au and https://www.farm-king.com.

One of the primary contributors to logistics cost is the fuel consumption of the equipment operating on the field. Many studies have been conducted to predict tractor fuel consumption during various field operations such as tillage, fertilizer and chemical application, planting, cultivation, and forage harvesting. Fuel efficiency, an essential aspect of a tractor engine, directly influences fuel consumption. Variable load characteristics, comparable to the different number of bales handled in logistics, is one of the significant parameters that affect fuel efficiency.

A novel mathematical simulation was developed to compare the bale aggregation logistics and fuel consumption between the traditional tractor and ABP. The conventional method for bale aggregation is using a tractor and was considered the "control" method in this study. This was compared to the ABP, which aggregates and transports bales to the stack location or outlet in a single trip.

The ABP is a trailer attached to the tractor with a bale picking arm on its side. Unlike the tractor, which can usually handle only 1 or 2 BPT, the ABP can handle 8-23 BPT (Figure 1). The logistics distance traveled by the equipment (tractor and ABP) was simulated using geometric principles to achieve a realistic turning paths. Fuel consumption was estimated using the (1) ASABE standard and (2) fuel efficiency method. The ASABE method uses rated and available PTO, while the fuel efficiency method uses bale load and fuel efficiency to calculate the fuel consumption. Several logistics scenarios (36,390 scenarios) using field area (8 - 259 ha), BPT (tractor: 1 and 2; ABP: 8 - 23), biomass yield (3 - 40 Mg/ha), equipment speed (6.4 - 10.5 km/ha), bale mass (500 kg), swath width (9 m), and windrow variation (5, 10, and 15 %) were studied. The operation time was determined using the logistics distance results and the equipment speed. The logistics distance simulation for tractor and ABP can be seen in Figure 2.

Fuel consumption analysis results during bale aggregation showed that the field area ≥32 ha displayed a significant difference with higher ABP bale capacity of 17 and 23 BPT. A steep drop in fuel quantity was observed between tractor (1 and 2 BPT) and ABP (8 -23 BPT). This fuel quantity reduction trend was similar across all the field areas but more pronounced with larger fields (Fig. 3). Average fuel consumption decreased by 72 % and 53 % for ABP with 8 and 11 BPT compared to the tractor with 1 and 2 BPT, respectively. An increase in biomass yield (more bales/ha) resulted in an increase in fuel use (prominent only between 8 and 40 Mg/ha). Equipment speed did not have any significant effect on fuel consumption for field areas of 8 - 259 ha.

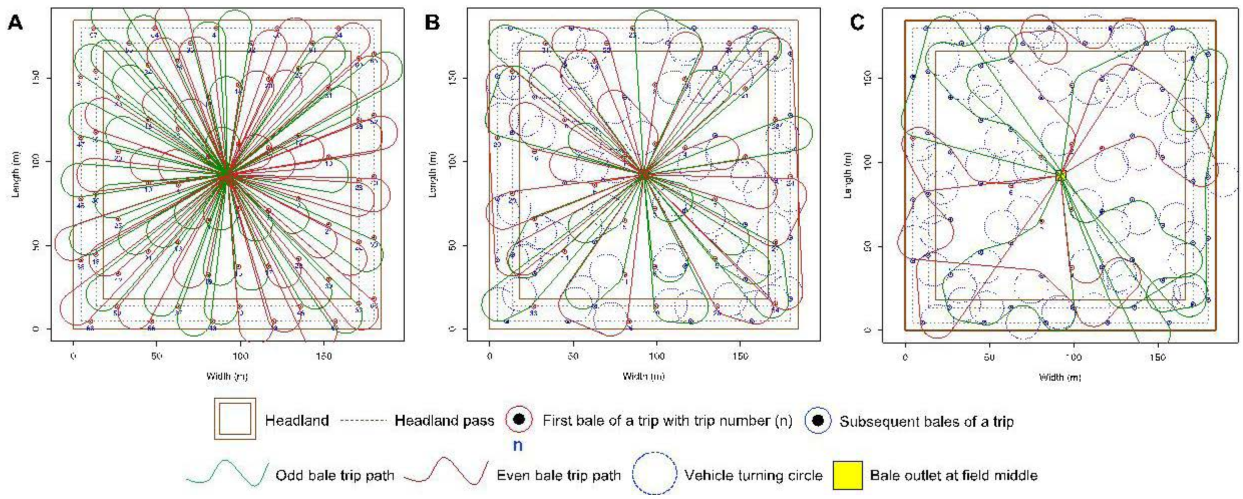

Figure 2. Bale aggregation equipment path simulation results: (A) Tractor, BPT (bales/trip) = 1; (B) Tractor, BPT = 2; and (C) Automatic bale picker, BPT = 8; Simulation data: area = 4 ha; turning radius = 10 m; biomass yield = 10 Mg/ha; bale mass = 500 kg; harvester swath = 9 m; field aspect ratio = 1.0 ; random variation in biomass yield = 15 %; and random number seed used = 2016.

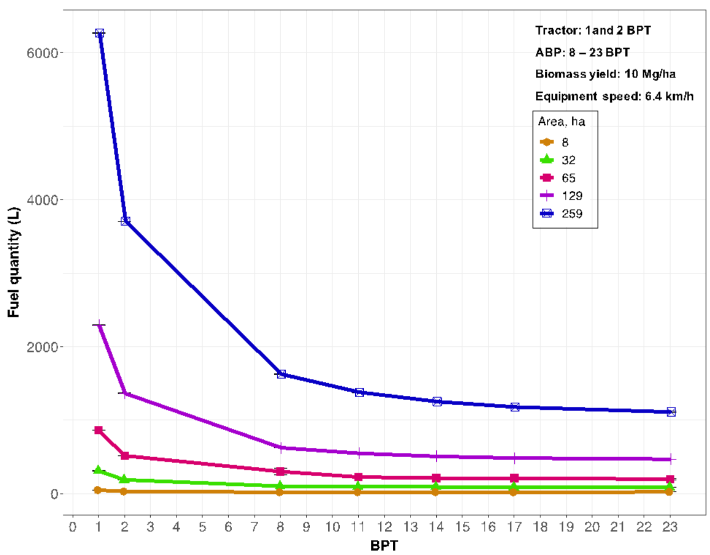

Figure 3. Effect of BPT (bales/trip) on the fuel quantity required by tractor and ABP (automatic bale picker) for aggregating 1–23 BPT for selected field areas of 8, 32, 65, 129, and 259 ha with 10 Mg/ha biomass yield.

Logistic operations for agricultural biomass, including collection, handling, storage, and transport require substantial amounts of energy. Bale logistics in the field which includes aggregating bales in the field

$$\text{Tractor (1 bale)}: Q_\mathrm{F} = 0.458 \times {A_\mathrm{F}}^{1.527}\, {Y_\mathrm{B}}^{1.345}\, {S_\mathrm{P}}^{-0.999}$$

$$\text{Tractor (2 bales)}: Q_\mathrm{F} = 0.280 \times {A_\mathrm{F}}^{1.523}\, {Y_\mathrm{B}}^{1.338}\, {S_\mathrm{P}}^{-0.999}$$

$$\text{ABP (8 bales)}: Q_\mathrm{F} = 0.340 \times {A_\mathrm{F}}^{1.435}\, {Y_\mathrm{B}}^{1.179}\, {S_\mathrm{P}}^{-1.000}$$

$$\text{ABP (23 bales)}: Q_\mathrm{F} = 0.506 \times {A_\mathrm{F}}^{1.313}\, {Y_\mathrm{B}}^{1.135}\, {S_\mathrm{P}}^{-0.997}$$

and transporting them to the field outlet significantly contributes to the overall logistics cost. But studies on the energy involved (or fuel consumption) in bale aggregation logistics within a field are not available. Therefore, a study was conducted to predict fuel consumption during bale aggregation with varying load scenarios and using fuel efficiency and operational time to help producers make efficient management decisions and cut down on cost.

$$\text{Tractor (1 to 2 bales)}: \quad Q_\mathrm{F}\left[\frac{A_\mathrm{F} Y_\mathrm{B}}{-1.155 + 2.548 B_\mathrm{T} + 0.544 S_\mathrm{P}}\right]^{1.414} \quad (R^2 = 0.98)$$

$$\text{ABP (8 to 23 bales)}: \quad Q_\mathrm{F}\left[\frac{A_\mathrm{F} Y_\mathrm{B}}{-0.782 + 0.184 B_\mathrm{T} + 0.759 S_\mathrm{P}}\right]^{1.243} \quad (R^2 = 0.98)$$

Reducing the time spent in collecting bales within a field can reduce costs. Increasing the number of bales/trip (BPT), by using modern equipment such as an automatic bale picker (ABP; also known as “self-loading bale carrier”) which is capable of handling multiple BPT, reduced operation time thus enabling improved logistics efficiency and reduced logistics cost (Figure 1).

One of the primary contributors to logistics cost is the fuel consumption of the equipment operating on the field. Many studies have been conducted to predict tractor fuel consumption during various field operations such as tillage, fertilizer and chemical

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Influence of Big Data on agricultural practices

Harsh Pathak and Dr. Cannayen Igathinathane, Agricultural and Biosystems Engineering, NDSU

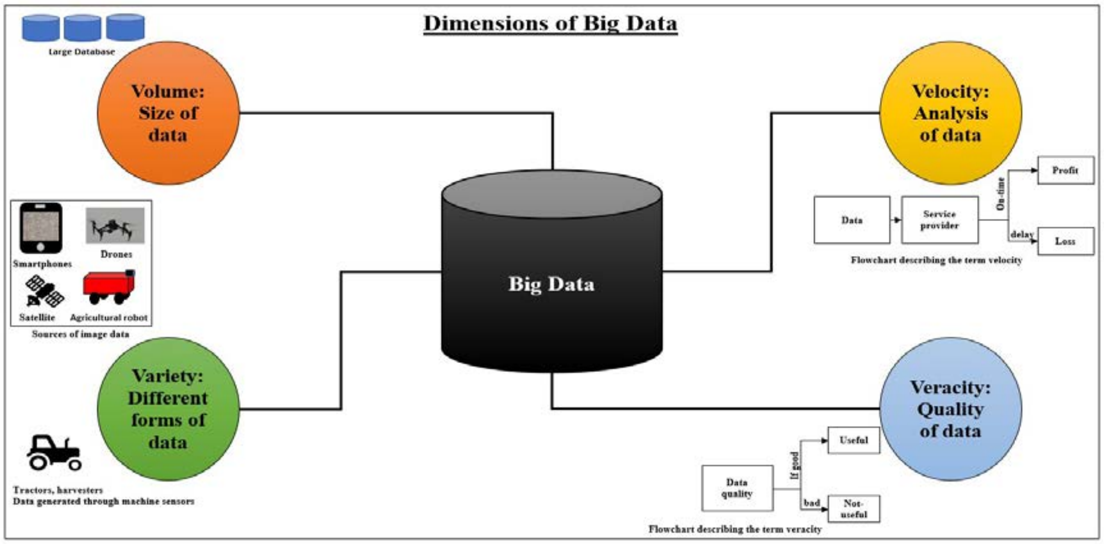

Figure 1. Dimensions of big data showing its characteristics.

As per the Food and Agriculture Organization (2009) report, the global population will increase to more than 30% by 2050, which will require 70% more food. Urbanization, land degradation, water contamination, sudden climate changes, market fluctuations, and many more factors have added uncertainties to food security. These uncertainties challenge agriculture to improve productivity with a limited amount of resources. To address agricultural production challenges and efficiently use limited resources such as land, water, and many more, precision agriculture (PA) has been implemented. The PA helps to achieve sustainability with automation and technological involvement to improve the use of resources. Nowadays, emerging digital technologies such as remote sensing, the internet of things, cloud computing, and new information and communication technologies for farm management extend the PA concept. These digital technologies continuously monitor the physical environment and generate a large quantity of data at an unprecedented rate (big data). This big data should be processed, which is always a challenge, to derive meaningful results.

Characteristics of big data and potential agriculture use

Big data refers to large, diverse, complex sets of data generated at different places by different sensing devices such as image data collected by a digital camera, data collected from different ground sensors, data measurement streams from farm machinery, and equipment data. Following are the four major dimensions that characterize big data (Figure 1):

1. Volume: amount/size of data; sensers and remote sensed images tend to produce large volumes of data,

2. Velocity: the time frame untill which data is useful,

3. Variety: data collected in different formats from different places, and

4. Veracity: quality and potential use of data.

Although these four V's describe big data, big data analysis in agriculture does not need to satisfy all these four dimensions at one time. For problems that need urgent action to be taken, such as disease detection, systems need a high velocity not a high variety of data. While producing yield maps or evaluating plant stand count, applications need a high volume of data. The typical data elements in agriculture and their potential uses are outlined in Table 1.

Table 1: Typical data elements in agriculture and their potential use

Data elements	Some example of potential use
Imagery (RGB, multispectral, hyperspectral, NDVI, and thermal images)	For field scouting, estimating soil water status and crop water status, crop growth monitoring, yield prediction, and classification of healthy and unhealthy crops
Machine sensors (fuel consumption, battery status, slip, and speed)	For improving control, and machine efficiency
Soil sensors (moisture, temperature, chemical, and biological sensors)	For automating different farm management processes such as irrigation in the field

Flow of big data

The data collected by the ground sensors, drones or agriculture equipment are uploaded by the farmer and are further analyzed by the technology provider on the cloud platform using different algorithms (Figure 2). Once the analysis is performed

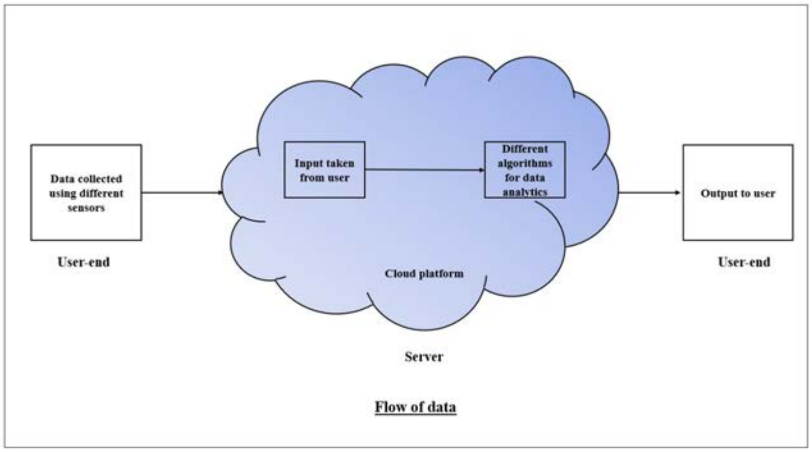

Figure 2. Flow of big data from users to processing and results back to users.

a customized solution is given back to the farmers, which can help them to make farm management decisions.

Benefits of employing big data in agriculture

The agricultural ecosystem is highly complex and unpredictable. It has big risk factors that are out of the control of farmers, such as unexpected weather conditions, crop diseases, or even natural disasters such as drought. Predicting such events was no longer possible without the use of big data, as the systems are complex and involve numerous variables. Big data analytics finds applications in a variety of farm management aspects (e.g., crop yields, disease control, farm animal husbandry).

It is often hard for farmers to know the market demand, so it becomes challenging for farmers to decide which crop to grow. Big data enables farmers to predict the demand of the market and cut excess waste by growing crops that have a higher market demand. Big data also helps with equipment management to reduce downtime and keep everything productive and efficient. By logging into their equipment agencies' accounts, farmers can know when their equipment needs maintenance service.

Challenges

Despite the many benefits, many challenges exist in the adoption of big data. One of the major issues that limit the adoption of big data in agriculture is internet speed, specifically the uploading speed. The inputs needed by the cloud computing algorithm require a high volume of data such as images collected by drones, and hence, it requires high uploading speed. However, the control files/output given by the cloud platform are of relatively small size and therefore are of less concern. Moreover, combining the data collected from a variety of sources affects data quality and raises concerns about data fusion, data security, and privacy. Another challenge related to big data is the high memory and computational cost to store and analyze the huge data volume. Furthermore, the results from the analysis should be clearly communicated so that the producer does not need to hire predictors, analysts, and decision-makers for their fields.

Big data product illustration - Plantix

Plantix is the pest and disease management tool that allows farmers to identify pests and diseases using mobile phones and can give remedial measures (Figure 3). This tool can be considered as an application

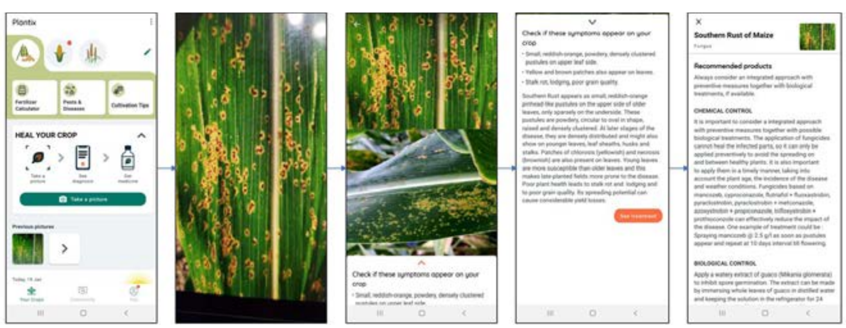

Figure 3. Plantix application interface – a big data illustration.

of big data. In this app, farmer uploads the photo of their infected crop, and the in-return app provides a diagnostics report. Apart from this, it also provides a prescription to mitigate diseases. Its database contains 60,000 images and covers 60 crop varieties all across the globe. For areas that face connectivity issues, the app features a library of disease images that can be referred by the farmer.

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Data security and privacy in precision agriculture - is open source software a possible solution?

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Precision agriculture (PA) is a data-driven management system. The ability to collect and analyze more data about the operations permits the producer to make better management decisions and improve crop production in their fields. Data is collected through sources such as sensors, farm equipment, satellites, and unmanned aerial vehicles (UAVs). Much farm equipment such as tractors, combines, and sprayers is now equipped with PA technology sensors and GPS systems to collect data. Data is also collected in the form of images through satellites and UAVs. Satellites provide larger-scale imagery of the farm weekly. Some of the limitations of the satellite imagery are low spatial resolution, expense, and cloud cover interference. Conversely, small UAVs are an economical solution for the producers and can produce high-quality images.

Images collected through UAVs need to be stitched, processed, and analyzed to derive the desired output. Commercial software is available on the market to perform these tasks. The annual subscriptions to commercial software can be costly. The Purdue University's "Center for Commercial Agriculture" conducted a survey with the producers who have abandoned agriculture software usage*. This survey reported that 40 % of producers' primary reason for discontinuing the software was the subscription cost, while 12% of the users cited privacy concerns as the reason for not using farm data software. As most of the third-party software works on a cloud platform using some cloud computational techniques, the data need to be in the cloud. Another related general concern among the producers is based on the fact that the commercial software and third-parties have access to their data for data analysis, visualization, and other commercial purposes.

Cloud computing comprises of three things: (1) clients or the user, (2) distributed server, and (3) cloud databases (Figure 1). For agricultural image processing software, the user requests the server to perform a specific function like evaluating the plant count, monitoring crop health, and many more by uploading the images and data of their field. The images provided by the user are stored on the cloud

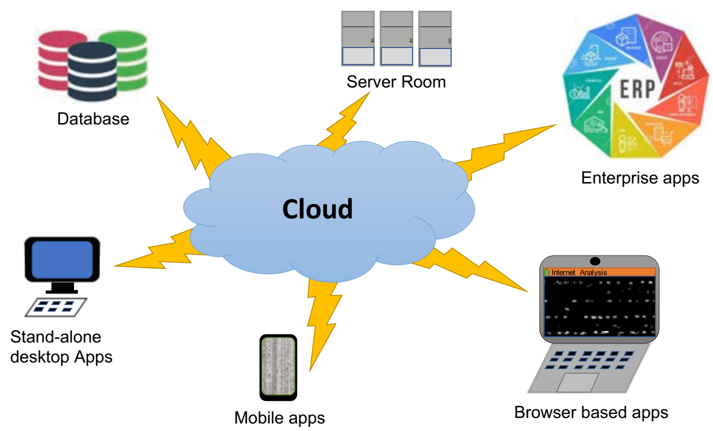

Figure 1. Components of cloud computing (Source of some imagies: google images).

databases while the distributed server does the processing of those images, and the result is sent back to the user.

One of the major limitations of using a cloud platform is the risk of data security. There are distributed servers for processing the data therefore a trustworthy supply chain and compliance are required. Other limitations include (i) while cloud services can access more computing resources, processing time can be delayed depending upon the analysis and priority of the user, and a delay in the processing time might lead to missed management opportunity resulting in possible yield and profit reduction; (ii) user is unaware of the logic behind the scene or the architecture of the cloud platform; and (iii) a reliable internet connection is essential for the efficient use of the software. Producers nowadays are aware of the importance of owning the data rights and are concerned about data security.

A cost-effective approach to address this issue is to develop tools using "open-source" software. The term "open" means that the tool is available free of cost to view and use, while the "source" refers to the main computer program (source codes) that makes the software. At present - open source projects, products, or initiatives embrace and celebrate principles of open exchange, collaborative

*Purdue Center for Commercial Agriculture, Producer Survey, April 2019 participation, rapid prototyping, transparency, meritocracy, and community-oriented development. Some of the advantages of using open source software are (i) no cost involved in software and their updates, (ii) latest developments are made readily available, (iii) a huge community of developers and users contribute to the software, (iv) several well-tested routines/module have been developed and available for use, (v) the user-developed software can be readily shared and others can use them anywhere in the world, and (vi) it promotes data control and security. Along with the developed tool, the users own the data and do their analysis "on-demand" rather than upload their data, go through the waiting time, and get them analyzed by others. With this approach, the user retains control and responsibility for maintaining security of their data through regular back-up. One advantage of the paid cloud storage is that it is typically automatically backed up.

Some of the open source software used in agricultural applications are OpenCV, Python, R, and ImageJ. Even though these software are free to download, develop, and use, they can be comparable or even better and more sophisticated than their commercial counterparts. The tools developed using these software aid in practicing precision agriculture at no cost. Even though the open source software ensures data privacy, it should be noted that they do not eliminate all the security risks as the software are distributedon an "as is" basis and there might be risks with the software itself. However, proper testing and validation would minimize the associated risks.

Following is an example of image processing performed in an agricultural application of plant stand count using open source ImageJ.

Plant stand count is an important measure in the early growing season to determine if a target plant population was attained, obtain seed emergence characteristics, and evaluate planter performance. An open-source ImageJ plugin termed "RIAPCP" was developed to perform plant stand counting from UAV images (Figure 2).

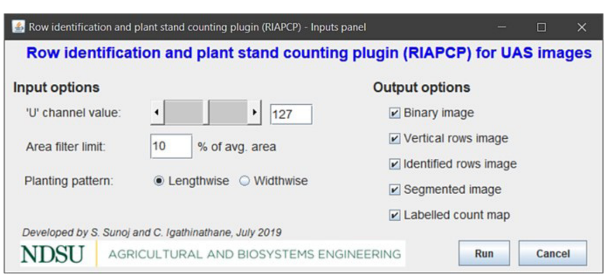

Figure 2. The front panel of the developed row identification and plant stand counting ImageJ plugin (RIAPCP).

The RIAPCP can produce row-wise and overall stand count that can be compared with the manual visual count in the image for validation. The plant stand count graphical output from the plugin provides the labeled plants count numbered sequentially (top to bottom) in rows from left to right (Figure 3). The original ImageJ software and the developed plugin with the input images can reside in the user's computer and can be analyzed securely and rapidly at the user's convenience with no fear of security or privacy breach.

This example shows how open source software can open doors to solving agriculture problems such as data security and developing affordable products for producers.

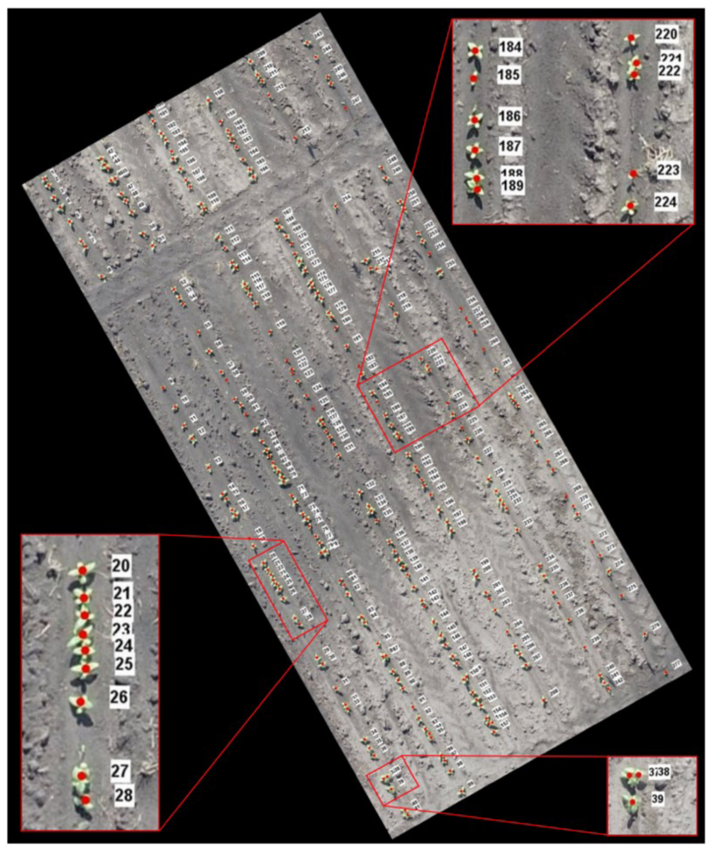
Figure 3. Plant stand count sequentially labeled along the rows from top to bottom and from left to right (Insets: zoomed portions to show the plants, markers, and labels clearly).

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Made from plants?

Dr. Scott Kronberg

Plant-based meat alternatives, which are designed to imitate the sensory experience and nutritional characteristics of meat are available to consumers and are marketed as better for human and environmental health.

We reviewed the scientific literature in respect to the nutritional and environmental impacts of eating plant-based meat alternatives versus animal-based meats.

Most people satisfy some of their nutritional requirements from eating plant foods while satisfying other nutritional requirements better by eating animal foods.

Animal foods facilitate the uptake of several plant-based nutrients such as zinc and iron, while nutrients and other compounds in plants can provide protection against potentially harmful compounds in cooked meat.

Ingested plant and animal foods interact in symbiotic ways to improve human health. Mimicking animal-based foods using mixtures of isolated plant proteins, fats, vitamins, and minerals probably underestimates the actual nutritional value of meat because of the nutritional complexity of whole foods in their natural state.

Whole foods in their natural state contain hundreds of nutrients and other compounds that impact human health. Plant-based meat alternatives may imitate the sensory experience of eating meat, but are not a true meat replacement in respect to human nutrition.

Replacement of some, but not all meat in the diet with plant-based meat alternatives will probably not have a negative impact on overall nutritional status, but this depends on what other foods are in the diet and the live state of the individual.

In respect to greenhouse gases and climate change, plant-based meat alternatives may have a lower overall greenhouse gas output compared to feedlot-fed and fattened beef, well-managed pasture-based beef production can in some cases be neutral in respect to overall greenhouse gas production or even have a net negative greenhouse gas footprint because overall more greenhouse gas is stored (carbon sequestration in soil) than is emitted to the atmosphere.

While some have argued that we can't produce enough grass-fed beef in the US to meet current overall beef consumption, others have argued that we can. Additionally, the potential to produce more red meat with multi-species grazing (e.g. cattle, sheep and goats) is greatly underappreciated and underutilized.

Moreover, the potential to mitigate nutritional deficits, enhance use of less palatable vegetation, reduce overgrazing and reduce methane production by supplementing grazing livestock with by-products of agricultural production is also underappreciated and underutilized. Also, increased consumption of organ meats by people, which are often denser in vitamins and minerals compared to muscle meat has been found to reduce meat associated greenhouse gas production by 14%, but this is seldom considered in respect to beef production and consumption.

Lastly, integration of crop and livestock production can improve crop yield and soil fertility and simulation of various diet patterns suggest that a healthy omnivorous diet, which is rich in whole plant and animal foods, has the greatest capacity for feeding people in diverse regions of the world.

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Producers can watch crop develop through ARS cameras

By Sue Roesler, Farm & Ranch Guide, Jul 17, 2020 (Updated Jul 24, 2020)

MANDAN, ND - Scientists at the Northern Great Plains Research Laboratory (NGPRL) in Mandan, N.D., will be conducting further research on interseeding cover crops into grain corn this summer, so producers will want to tune in.

For the past three years, Mark Liebig, USDA-ARS research soil scientist at NGPRL, and other scientists, have been studying interseeding a cover crop mix into grain corn at specific growth stages.

The premise of the study is: Can producers come out ahead and in good shape in terms of soil health by interseeding cover crops into grain corn without losing yield on the commodity crop?

Mark Liebig, USDA-ARS Research Soil Scientist at NGPRL, Talks to Producers at Friends and Neighbors Day Last Year

"Our central question is if we do this interseeding in a drier part of North Dakota, is there going to be a yield penalty to the commodity crop?" Liebig said.

In 2020, the ARS farm crew will be interseeding the cover crops into the corn in a larger field than they used during the previous two years of the study.

"What is really exciting is we are going to be doing the interseeding on a larger field – a 50-acre field – this year," he said.

The larger field will allow ARS scientists to do additional studies, in real-time, as part of the Long-Term Agroecosystem Research Network (LTAR).

"We are going to be able to see what is happening in fine detail in a cornfield that has the intercrop and in a cornfield that doesn't," Liebig said. "It will be a fantastic comparison to see how that intercrop affects these other things that are important for us to understand crop performance in the crop rotation."

ARS has an instrument tower, which measures carbon dioxide and water fluxes in real-time on fields with and without the cover crops in corn.

In addition, there are soil moisture sensors, which are able to see the differences in soil moisture depletion down to about 6 feet, along with other measurements.

Producers and scientists will be able to check on the crop as it develops through the LTAR PhenoCam Network, a camera system that is set up and pointed at the crop canopy, where a photo is taken every 30 minutes.

"Producers can watch the crops grow in real-time over the season," Liebig said.

Interseeding study

Liebig explained the importance for interseeding cover crops into a commodity crop.

"Interseeding is a way to increase the soil cover, and the biomass (from the cover crops) can be utilized as a forage resource after the commodity crop is harvested," Liebig said.

Soil cover is "important" to the study.

"Covering the soil reduces the potential risk of erosion from the field, but cover crops are widely recognized to provide multiple benefits to the soil in cropping systems," he said. "Cover crop biomass is also effective at taking up any excess nutrients in the soil."

Later, the biomass can slowly decompose and be available for the following crop, allowing for a more efficient use of nutrients.

Planting with no-till interseeder

Using a specially-made no-till interseeder, the ARS farm crew seeded cover crops in corn in 2018 for the first time. According to the website, the no-till interseeder can sow three rows of standing cover crops, and it also works as a multi-function no-till grain drill.

"We have had good subsoil moisture this spring, although it has been a little dry like most places in southwestern to south central North Dakota," he said. "All the corn is in and we will be interseeding the cover crops soon."

In 2019, the crews weren't able to interseed the cover crops until July.

"Seeding was late last year, as we had persistent wet conditions in the field early in the growing season," Liebig said. "The corn really didn't start to take off until the first week in July."

The ARS farm crew targets the interseeding when the corn is at the V4, V6, and V8 vegetative stages.

The cover crop seed mix the farm team interseeds includes: 17.8 pounds per acre of rye, 3.2 pounds per acre of triticale, 18.9 pounds per acre of cowpea and 2.1 pounds per acre of purple-top turnips.

"The different seeding times allow us to evaluate potential tradeoffs from earlier establishment," Liebig said. "To me, success would be getting good biomass early and not suffering from a yield penalty."

Cover crop biomass, corn yields

In 2019, cover crop biomass from the first seeding time (about 600 pounds per acre) was significantly greater than cover crop biomass from the second and third seeding times (averaging about 355 pounds per acre).

Cover crop biomass was on average 81 percent greater in 2019 compared to 2018.

The grain yields did not differ across treatments, with yields ranging from about 120-130 bushels per acre.

"We didn't finish harvesting the corn until this spring because of the snowstorm we had last October," he said.

While the third year is not finished and there are no official results, Liebig said the study looks promising.

"The preliminary results point toward this being a promising practice in drier parts of the state," he said. "We haven't observed a yield penalty from intercropping and the cover crops over the first two years, but we'll have to see how the third year shakes out," he said.

Roberto Luciano, who works for NRCS as an agronomist, works as a liaison between the NRCS state office and ARS in Mandan. He helps document the growth of the cover crop throughout the season.

"Luciano has cameras set up in each treatment to see how the cover crop develops over time," he said. Luciano also does several measurements on the farm related to soil health.

Commodity crop: Sunflower

While grain corn is not bringing a high price in the current market, the ARS team is planning to run the treatment in 2020 with sunflowers. Sunflowers may bring a better commodity price.

"Some of the same issues with corn may exist with sunflowers, but there are different root and canopy attributes with sunflower," Liebig said. "We may minimize competition with sunflower because it is a taproot species, but there could be more shading with sunflower. We don't know how the cover crops could handle that."

After harvesting sunflowers, biomass tends to decompose quickly, and that residue could partially disappear. That could create issues with soil conservation efforts.

But after harvesting sunflowers, Liebig is hoping biomass left by the cover crops will be a good soil cover for the field. Soil health is one of the main parameters to the study.

Would the study encourage more producers to grow more sunflowers?

"If we could show that cover crops could be incorporated without a yield penalty in sunflowers, then it would be a win-win," he said.

Cover crops are gaining in importance in the drier parts of the state. The Mandan ARS station has been raising and researching cover crops for about 15 years.

"It is our role to do research on cover crops and help producers understand the trade-offs associated with their use," Liebig said.

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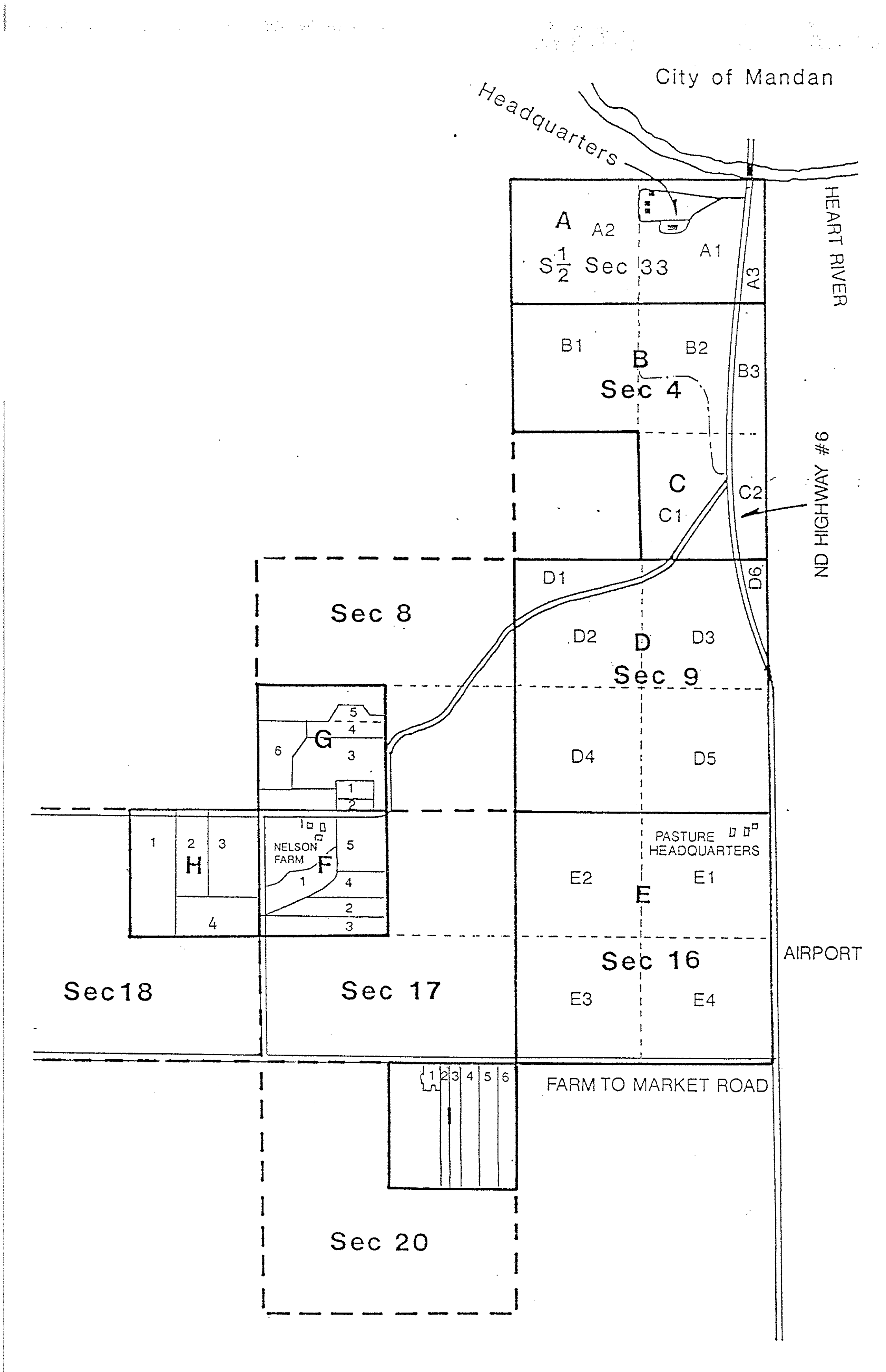
USDA-ARS LAND RESOURCES (FEDERAL & STATE) A, B, C, D, AND E

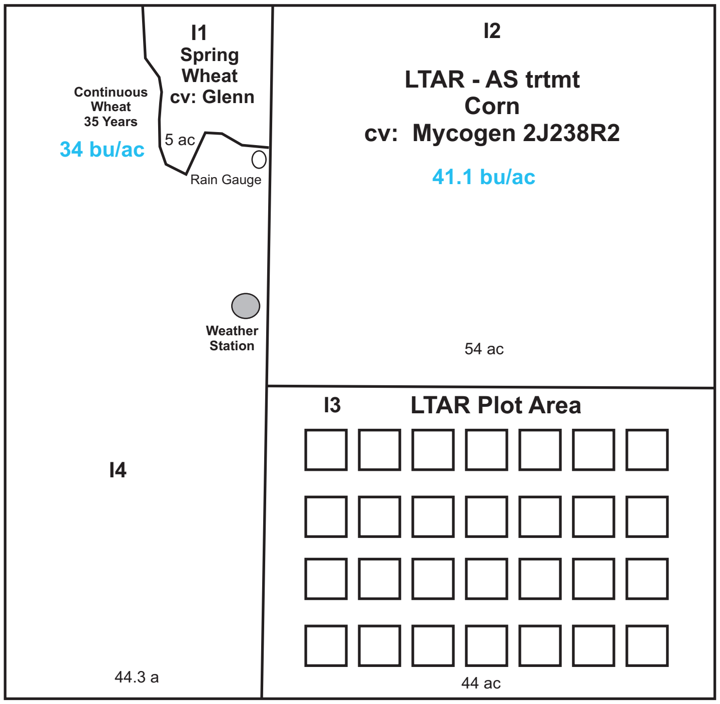
AREA 4 SCD COOPERATIVE RESEARCH FARM

LAND RESOURCES F, G, H, AND I



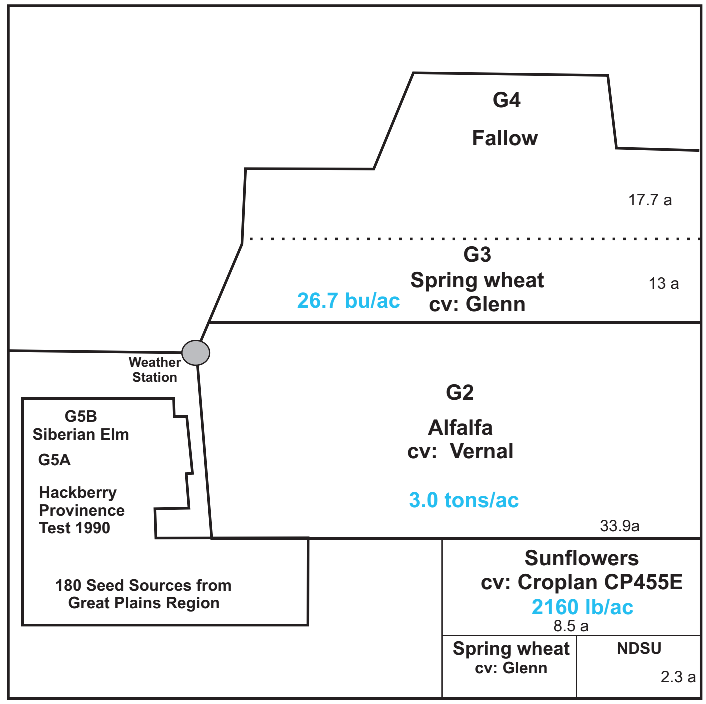
2020 Area IV Research Farm
(1-22-2021)

Area I



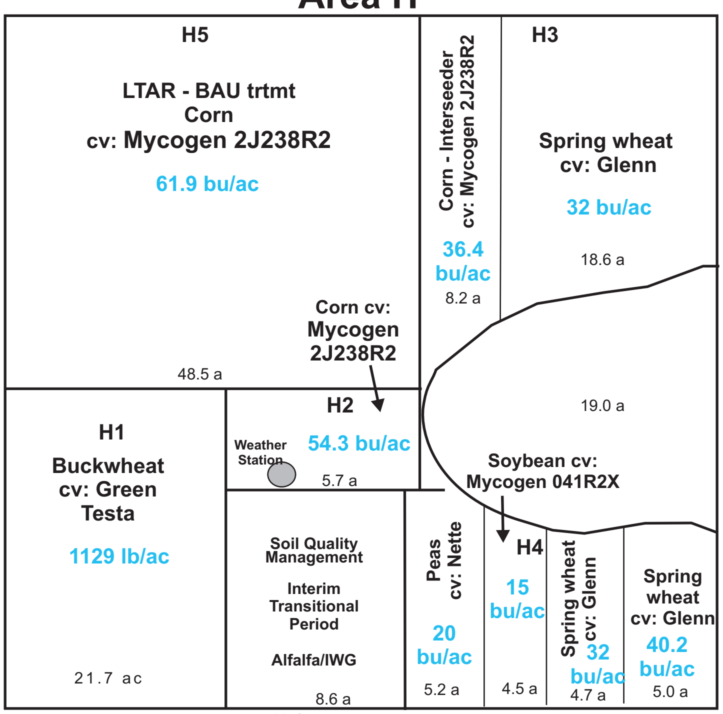
NE ¼ Section 20 T138N R81W

Area G



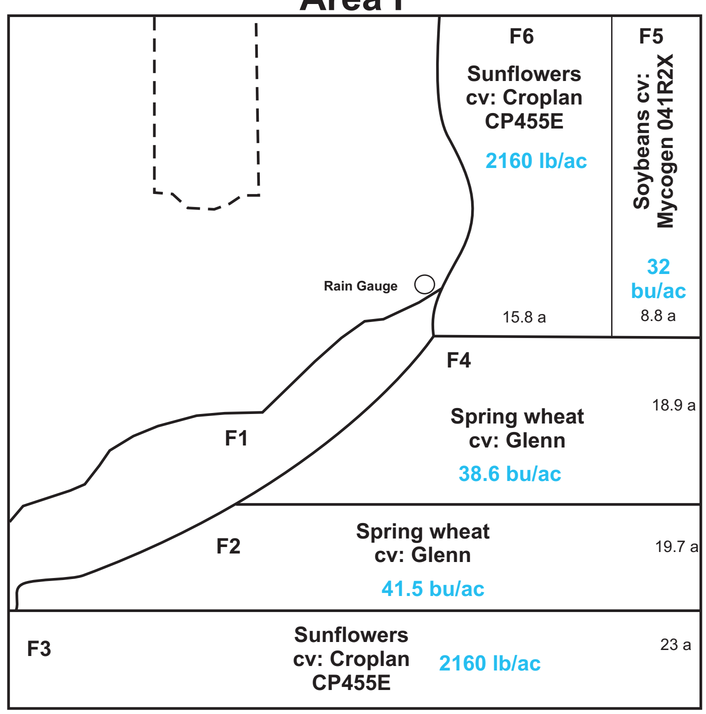
SW ¼ Section 8 T138N R81W

Area H



NE ¼ Section 18 T138N R81W

Area F



NW ¼ Section 17 T138N R81W

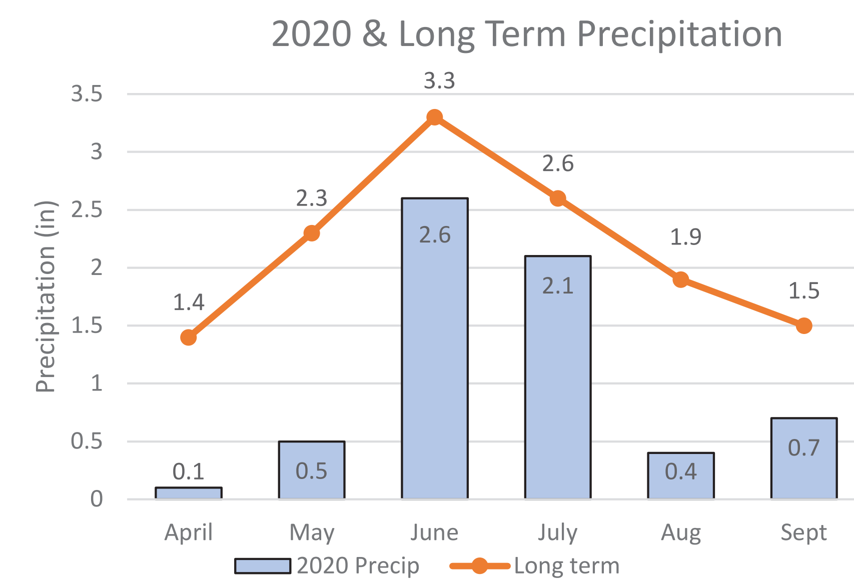


Figure 1. Seasonal precipitation for 2020 and long term average.

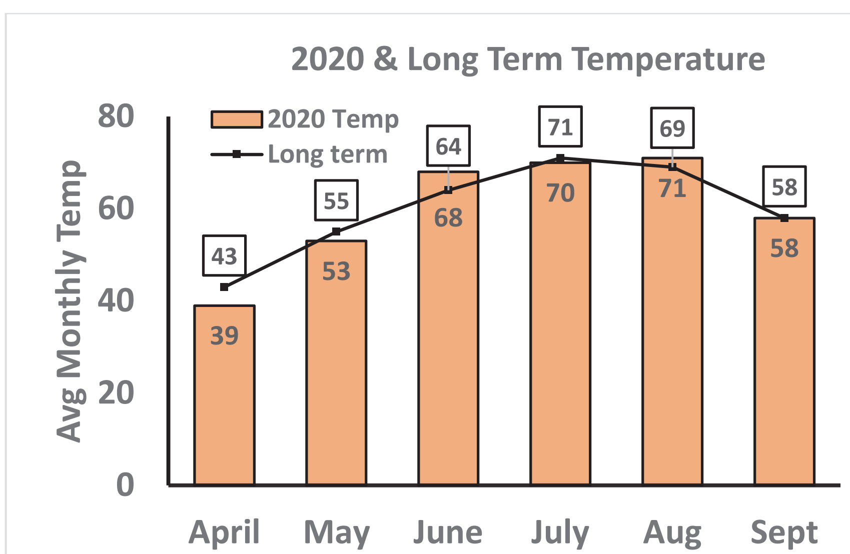


Figure 2. Seasonal monthly average temperature for 2020 and the long term average.

Management practices of Area IV SCD Cooperative Research Farm – 2020 summary

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, GLENN SPRING WHEAT

Previous crop - Spring wheat

Wet conditions in the fall of 2019 did not allow planting of winter wheat for this year.

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/05/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Contractor sprayed field w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/19/20 Field harvested w/JD 9650 combine and 32 ft stripper head (41.5 bu/ac).

09/15/20 Field planted to winter wheat (cv Keldin) w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

FIELD F3, CROPLAN CP455E SUNFLOWERS

Previous crop - Winter wheat

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spartan Charge @ 4 oz/ac + Jackhammer @ 2 qt/100 gal.

06/02/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/25/20 Contractor sprayed field w/Express @ 0.5 oz/ac + Volunteer @ 8 oz/ac + Veracity Elite @ 2 qt/100 gal.

08/10/20 Contractor aerial sprayed field w/Lambda-CY AG @ 4 oz/ac + Cerium Elite @ 3 oz/ac.

11/2-3/20 Field harvested w/JD 9650 combine and 6-row all crop head (2160 lb/ac).

FIELD F4, GLENN SPRING WHEAT

Previous crop - Sunflowers

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/07/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Contractor sprayed field w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/19/20 Field harvested w/JD 9650 and 32 ft stripper head (38.6 bu/ac).

FIELD F5, MYCOGEN MY041R2X SOYBEANS

Previous crop - Corn

05/04/20 Contractor banded liquid N 27-0-0-1 @ 40 lb N/ac.

05/16/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

06/02/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

07/10/20 Field sprayed w/Cornerstone 5 Plus @ 30 oz/ac + Jackhammer @ 2 qt/100 gal.

10/07/20 Field harvested w/JD 6620 combine and 15 ft flex head (15 bu/ac).

FIELD F6, CROPLAN CP455E SUNFLOWERS

Previous crop - Buckwheat

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spartan Charge @ 4 oz/ac + Jackhammer @ 2 qt/100 gal.

06/02/20 Field seeded w/750 drill @ 47 lb/ac.

06/25/20 Contractor sprayed field w/Express @ 0.5 oz/ac + Volunteer @ 8 oz/ac + Veracity Elite @ 2 qt/100 gal.

08/10/20 Contractor aerial sprayed field w/Lambda-CY AG @ 4 oz/ac + Cerium Elite @ 3 oz/ac.

11/04/20 Field harvested w/JD9650 and all crop header (2160 lb/ac).

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

FIELD G1 (FORMER TREE PLOT), CROPLAN CP455E SUNFLOWERS (INTERSEEDER TRIAL)

Previous crop - Spring wheat

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spartan Charge @ 4 oz/ac + Jackhammer @ 2 qt/100 gal.

06/03/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/25/20 Contractor sprayed field w/Express @ 0.5 oz/ac + Volunteer @ 8 oz/ac + Veracity Elite @ 2 qt/100 gal.

07/02/20 Seeded cover crop mixture w/Interseeder drill (1st treatment).

07/09/20 Seeded cover crop mixture w/Interseeder drill (2nd treatment).

07/13/20 Seeded cover crop mixture w/Interseeder drill (3rd treatment).

08/10/20 Contractor aerial sprayed field w/Lamda-CY AG @ 4 oz/ac + Cerium Elite @ 3 oz/ac.

11/05/20 Field harvested w/JD9650 and all crop head (2160 lb/ac).

FIELD G2, VERNAL ALFALFA

Previous crop - Alfalfa, initial year

06/20/20 First cutting done by Northern Lights Dairy (1.4 ton/ac).

07/24/20 Second cutting done by Northern Lights Dairy (1.6 ton/ac).

FIELD G3, GLENN SPRING WHEAT

Previous crop - Fallow

04/17/20 Contractor banded liquid N 27-0-0-1 @ 70 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/07/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Field sprayed w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/24/20 Field harvested w/JD 9650 combine and 32 ft stripper head (26.7 bu/ac).

FIELD G4, FALLOW

Previous management - Spring wheat

05/16/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

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

FIELD H1, GREEN TESTA BUCKWHEAT

Previous crop - Corn

05/02/20 Contractor banded liquid N 27-0-0-1 @ 65 lb N/ac.

05/22/20 Contractor sprayed field w/Durango @ 32 oz/ac + Vida @ 1.5 oz/ac + Jackhammer @ 2 qt/100 gal.

06/11/20 Contractor sprayed field w/Durango @ 32 oz/ac + Dicamba @ 6 oz/ac + Interlock @ 4 oz/ac + Jackhammer @ 2 qt/100 gal.

06/15/20 Field seeded w/JD 30ft. 1890 drill @ 50 lb/ac + 60 lb/ac 11-52-0.

07/09/20 Contractor sprayed field w/Poast @ 9 oz/ac + Cerium Elite @ 2 qt/100 gal.

09/09/20 Field swathed w/20 ft Versatile swather.

09/24/20 Field harvested w/JD 9650 combine and a pickup head (1129 lb/ac).

FIELD H2, MYCOGEN 2J238R2 CORN

Previous crop - Peas

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/19/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/11/20 Contractor sprayed field w/Durango @ 32 oz/ac + Dicamba @ 6 oz/ac + Interlock @ 4 oz/ac + Jackhammer @ 2 qt/100 gal.

06/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

10/06/20 Field harvested w/JD 9650 combine and 6-row head (54.3 bu/ac).

FIELD H3 EAST, GLENN SPRING WHEAT

Previous crop - Sunflowers

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/07/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Field sprayed w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/21/20 Field harvested w/JD 9650 and 32 ft stripper head (32.0 bu/ac).

FIELD H3 WEST, MYCOGEN 2J238R2 CORN (INTERSEEDER TRIAL)

Previous crop - Sunflowers

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/16/20 Field sprayed w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

05/19/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/23/20 Field sprayed w/Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

06/24/20 Seeded cover crop mixture w/Interseeder drill (1st treatment).

07/02/20 Seeded cover crop mixture w/Interseeder drill (2nd treatment).

07/09/20 Seeded cover crop mixture w/Interseeder drill (3rd treatment).

10/08/20 Field harvested w/JD 9650 combine and 6-row head (36.4 bu/ac).

FIELD H4, SOIL QUALITY MANAGEMENT

This study was seeded to a homogeneous stand of alfalfa/intermediate wheatgrass to look at effects of previous long-term rotation treatments.

FIELD H4, NETTE PEAS

Previous crop - Winter wheat

05/07/20 Field seeded w/JD 750 drill @ 350,000 seeds/ac + 50 lb/ac 11-52-0.

07/28/20 Contractor sprayed field w/Aim @ 6 oz/ac + Destiny @ 2 qt/100 gal.

08/10/20 Field harvested w/JD 6620 and 15 ft flex head (20.0 bu/ac).

FIELD H4, MYCOGEN MY041R2X SOYBEANS

Previous crop - Corn

05/04/20 Contractor banded liquid N 27-0-0-1 @ 40 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/16/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

06/01/20 Field seeded w/JD 750 drill @ 47 lbs/ac.

07/10/20 Field sprayed w/Cornerstone 5 Plus @ 30 oz/ac + Jackhammer @ 2 qt/100 gal.

10/07/20 Field harvested w/JD 6620 combine and 15 ft flex head (15 bu/ac).

FIELD H4, GLENN SPRING WHEAT

Previous crop - Soybeans

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/07/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Field sprayed w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/21/20 Field harvested w/JD 9650 combine and 32 ft stripper head (32.0 bu/ac).

09/15/20 Field planted to winter wheat (cv Keldin) w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

FIELD H4, GLENN SPRING WHEAT

Previous crop - Spring wheat

Wet conditions in the fall of 2019 did not allow planting of winter wheat for this year.

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/06/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Field sprayed w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/24/20 Field harvested w/JD 9650 combine and 32 ft stripper head (40.2 bu/ac).

FIELD H5 – LTAR PROJECT (BAU TRTMT), MYCOGEN 2J238 CORN

Previous year - Spring wheat

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/16/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

05/20,21/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

10/05/20 Field harvested w/JD 9650 combine and 6-row head (61.9 bu/ac).

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

FIELD I1, GLENN SPRING WHEAT (Continuous spring wheat 35 yrs).

This field will remain as a continuous spring wheat treatment.

04/17/20 Contractor banded liquid N 27-0-0-1 @ 80 lb N/ac.

05/06/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 8 oz/ac + Jackhammer @ 2 qt/100 gal.

05/07/20 Field seeded w/JD 30ft. 1890 drill @ 1.3 million seeds/ac + 70 lb/ac 11-52-0.

06/11/20 Contractor sprayed field w/Widematch @ 16 oz/ac + 2,4-D LV6 @ 8 oz/ac + PropiStar @ 4 oz/ac + Everest 3.0 @ 0.5 oz/ac.

08/24/20 Field harvested w/JD 9650 combine and 32 ft stripper head (34.0 bu/ac).

FIELD I2 – LTAR PROJECT (ASPIRATIONAL TRTMT), MYCOGEN 2J238R2 CORN

Previous crop - Spring wheat

04/17/20 Contractor banded liquid N 27-0-0-1 @ 90 lb N/ac.

05/16/20 Contractor sprayed field w/Durango @ 32 oz/ac + Spitfire @ 16 oz/ac + Jackhammer @ 2 qt/100 gal.

05/22,25/20 Field seeded w/1750 MaxEmerge XP planter @ 24,000 seeds/ac.

06/23/20 Contractor sprayed field w/Durango @ 32 oz/ac + Jackhammer @ 2 qt/100 gal.

10/8-16/20 Field harvested w/JD 9650 combine and 6-row head (41.1 bu/ac).

FIELD I3, LTAR PLOT STUDY

Previous crop - Spring wheat

Summary of Area 4 Research Farm yields and economic returns based on February 2021 crop prices

Field	Crop	Variety	Yield	Gross Return	Cost	Net Return
			(per ac)	($/ac)	($/ac)	($/ac)
F2	Spring wheat	Glenn	41.5 bu	231	173	59
F3	Sunflowers	Cropland CP455E	2160 lb	383	162	221
F4	Spring wheat	Glenn	38.6 bu	215	133	82
F5	Soybeans	Mycogen Y041R2X	15.0 bu	191	87	104
F6	Sunflowers	Cropland CP455E	2160 lb	383	175	208
G1	Sunflowers	Cropland CP455E	2160 lb	383	223	160
G2	Alfalfa	Vernal		264	39	225
G3	Spring wheat	Glenn	26.7 bu	149	130	19
G4	Fallow	---------	-----	0	15	-15
H1	Buckwheat	Green Testa	1129 lb	237	154	83
H2	Corn	Mycogen 2J238R2	54.3 bu	267	167	99
H3 East	Spring wheat	Glenn	32.0 bu	178	120	58
H3 West	Corn	Mycogen 2J238R2	36.4 bu	179	203	-25
H4 (a)	Dry Peas	Nette	20.0 bu	135	133	2
H4 (b)	Soybeans	Mycogen Y041R2X	15.0 bu	191	102	89
H4 (c)	Spring wheat	Glenn	32.0 bu	178	173	6
H4 (d)	Spring wheat	Glenn	40.2 bu	224	133	91
H5	Corn	Mycogen 2J238R2	61.9 bu	304	153	150
I1	Spring wheat	Glenn	34.0 bu	189	133	56
I2	Corn	Mycogen 2J238R2	41.1 bu	202	153	48

Long-term Agroecosystem Research Network (LTAR)

Scientists: Mark Liebig, David Archer, Nicanor Saliendra, Igathi Cannayen (NDSU), David Toledo

Support staff: Robert Kolberg, Justin Feld, Raina Hanley, Marvin Hatzenbuhler, Eric Antosh, Chantel Kobilansky, Robert Pennington

In a Nutshell

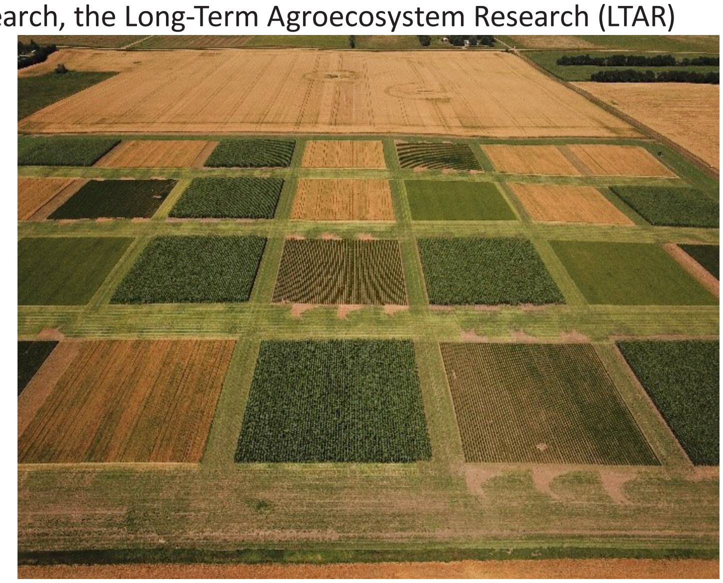
- 2020 was the second year of the LTAR Northern Plains Croplands Common Experiment, where common cropping practices ('Business as Usual'; BAU) are compared to dynamic/adaptive cropping practices using no-till management, integrated cropping, and cover crops ('Aspirational'; ASP) at plot- and field-scales.
- Annual precipitation in 2020 was less than half of the long-term mean (7.2" vs. 16.3"). Accordingly, crop yields suffered.
- Corn grain yield was significantly lower in the ASP treatment (with interseeded cover crops) c compared to BAU (without cover crops) at plot- and field-scales.
- Cover crop biomass production in ASP corn peaked in October at 612 lbs/ac.
- The field-scale ASP treatment was a carbon sink in 2020 (-633 lbs CO_2-C/ac), while the BAU treatment was a carbon source (204 lbs CO_2-C/ac). Carbon allocation to belowground biomass likely contributed to carbon uptake in the ASP treatment.

Background

Contemporary cropland agriculture in the United States is dominated by an emphasis on provisioning services by applying energy-intensive inputs through uniform production systems across variable landscapes. This approach to cropland use is not sustainable and has contributed to many negative impacts related to yield, soil health, and water and air quality.

Despite this challenging context, cropland agriculture has the potential to provide many ecosystem services in addition to yield, including pollinator habitat, flood protection, pest/disease suppression, soil fertility, etc. Understanding how cropland agriculture affects the balance of ecosystem services under different forms of management over the long-term is a research area largely unexplored.

Through long-term observational and experimental research, the Long-Term Agroecosystem Research (LTAR) Croplands Common Experiment (CCE) will generate critical information to facilitate the adoption of cropland practices that support the delivery of multiple ecosystem services for improved economic, social, and environmental outcomes. More information about the CCE is available at https://ltar.ars.usda.gov/.



LTAR Northern Plains Croplands Common Experiment

The LTAR CCE at NGPRL will generate data for the evaluation of alternative management strategies for cropland agriculture in the northern Great Plains. Specifically, the CCE will contrast common cropping practices in central North Dakota ('Business as Usual'; BAU) with dynamic/adaptive cropping practices using no-till management, integrated cropping, cover crops, and eventually, livestock integration ('Aspirational'; ASP) (Table 1). For the initial phase of the experiment (2019-2024), a spring wheat – corn – soybean rotation with and without cover crops will be evaluated at two spatial scales, plot and field (Figures 1 & 2). The experiment is conducted on the Area 4 SCD Cooperative Research Farm on Temvik-Wilton silt loam soils.

Summary of field activities

Spring wheat plots were seeded with a JD 750 drill on May 19 and sprayed pre-emergent on May 22 (Buccaneer 5 Extra @ 24 oz/ac + Sharpen @ 2 oz/ac + Destiny @ 12 oz/ac + Class Act @ 1 qt/100 gal). These plots were sprayed post-emergent on June 5 (GoldSky @ 16 oz/ac + Shredder @ 16 oz/ac). A preplant burndown application of corn and soybean plots was done on May 26 with the same mix as the pre-emergent wheat. Corn plots were planted May 28 with a JD MaxEmerge XP planter. The ASP1 treatment of corn was sprayed post-emergent June 22 (Buccaneer 5 Extra @ 32 oz/ac + surfactant) and BAU treatment June 23 with the addition of Status (10 oz/ac). The ASP1 treatment of corn was seeded with a cover crop mixture July 2 with the Interseeder drill which places three rows (7.5 in. spacing) between each corn row. Soybean plots were planted May 29 with a JD MaxEmerge XP planter and sprayed post-emergent July 5 (Buccaneer 5 Extra @ 28 oz/ac and surfactant) with a second application on July 30 (Cornerstone 5 Plus @ 32 oz/ac and surfactant). Additional field activities are outlined in Table 2.

Spring wheat plots were sampled Aug 17 for yield measurement with a Wintersteiger plot combine. Corn plots were sampled Oct 8 for yield measurement and cleared with a JD 9650 combine and a six-row head. Soybean plots were sampled Oct 9 for yield and cleared with a JD 6620 combine and a flex head.

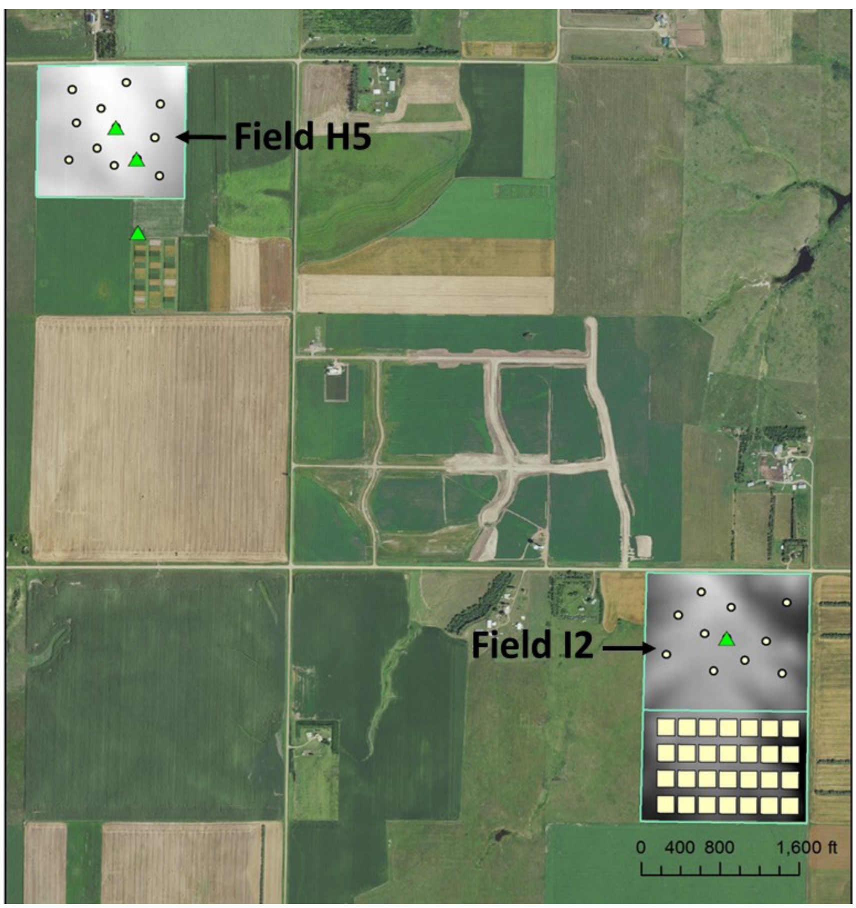


Figure 1. Field site locations for LTAR-NP Croplands Common Experiment on the Area 4 SCD Cooperative Research Farm. Fields H5 and I2 represent the 'Business as Usual' (BAU) and 'Aspirational' (ASP1) treatments, respectively.

Table 1. Generalized treatment descriptions for the LTAR Croplands Common Experiment at NGPRL, 2019-2024.

	Component	Description
Prevailing Practice ('BAU')	Crop rotation	Spring wheat-Corn-Soybean
	Cover crop	None
	Tillage	No-till/Minimum-till
	Nutrient management	NDSU recommendation; Uniform application
	Pest management	Proactive herbicide/insecticide use
	Other	Residue removal following spring wheat phase (harvest without chopper; bale and remove straw). Chisel tillage (Mulch Master) prior to soybean.

	Component	Description
Alternative Practice ('ASP1')	Crop rotation	Spring wheat/cover crop - Corn/interseeded cover crop - Soybean (planted into residual rye)
	Cover crop	Post-harvest in spring wheat phase (winter wheat/oilseed radish/pea); Intercrop (V4) in corn phase (rye/spring triticale/cowpea/purple top turnip).
	Tillage	No-till
	Nutrient management	Recommendation based on pre-plant N&P status (fall soil collection to 2'); Split nutrient application; Precision/variable application (employed when available)
	Pest management	IPM and precision/variable rate technology (employed when available)
	Other	No residue removal.

	Component	Description
Alternative Practice ('ASP2')	Type	Alfalfa (*Medicago sativa* L.) + Intermediate wheatgrass
	Nutrient management	NDSU recommendation at planting
	Management	Harvest as hay (1-2 cuttings per year)

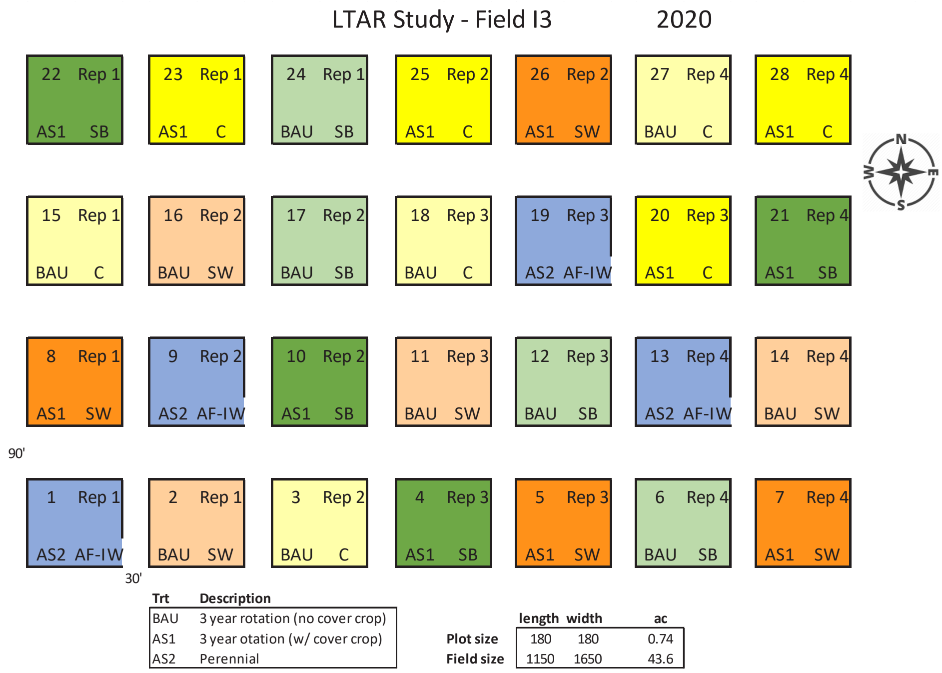


Figure 2. Treatment assignments by plot for the LTAR-NP Croplands Common Experiment, 2020.

Table 2. Crop, fertilizer, and harvest information for plot-scale treatments included in the LTAR-NP Croplands Common Experiment, 2020.

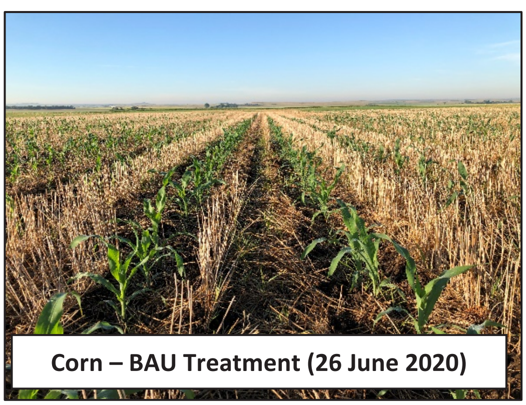
Crop	Cultivar or type	Planting Date	Planting rate	Fertilizer	Harvest Date
Aspirational (ASP1)					
Spring wheat	Glenn	5/19/20	90 lb/ac	Urea - 50 lb N/ac MAP - 133 lb mat./ac	Hand 8/12/20 Comb 8/17/20
Cover crop mix:		8/21/20			
• Pea	Vine		12.9 lb/ac		
• Wheat	Winter		12.9 lb/ac		
• Radish	Oilseed		0.4 lb/ac		
Corn	Mycogen 2J238R2	5/28/20	24,500 seeds/ac	Urea - 50 lb N/ac MAP - 133 lb mat./ac	Hand 9/30/20 Comb. 10/8/20
Cover crop mix:		7/2/20	42.0 lb/ac	None	
• Rye	Winter		17.8 lb/ac		
• Triticale	Spring		3.2 lb/ac		
• Cowpea	common		18.9 lb/ac		
• Purple-top turnip	common		2.1 lb/ac		
Soybean	Mycogen MY041 R2X	5/29/20		MAP – 66 lb mat./ac	Hand 9/30/20 Comb. 10/9/20
Business as Usual (BAU)					
Spring wheat	Glenn	5/19/20	90 lb/ac	Urea - 80 lb N/ac MAP - 133 lb mat./ac	Hand 8/12/20 Comb. 8/17/20
Corn	Mycogen 2J238R2	5/28/20	24,500 seeds/ac	Urea - 120 lb N/ac MAP - 133 lb mat./ac	Hand 9/30/20 Comb. 10/8/20
Soybean	Mycogen MY041 R2X	5/29/20	180,000 seeds/ac	MAP - 66 lb mat./ac	Hand 9/30/20 Comb.10/9/20
Aspirational (ASP2)					
Intermediate wheat grass + Alfalfa	Manska Vernal	6/11/19 (2^{nd} year)	5 lb/ac 5 lb/ac	MAP - 133 lb mat./ac (in 2019)	Swath 6/18/20, 7/27/20 Hand 6/18/20, 7/23/20, 9/10/20

Plot-scale summary

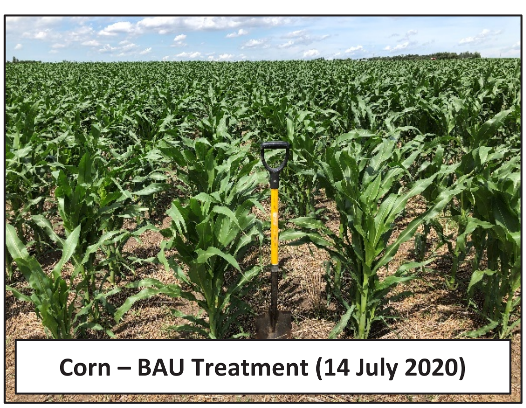
Interseeded cover crops affected corn grain yield, with 39% lower grain yield in the ASP treatment compared to the BAU treatment (Table 3). Cover crop biomass in corn increased throughout the growing season (Figure 3), with maximum biomass achieved on 10/24/20 (612 lb/ac). Soybean grain yield was nearly 5 bu/ac greater in the ASP treatment compared to BAU, while spring wheat grain yields were low in both treatments (<16 bu/ac). Two cuttings of alfalfa + intermediate wheatgrass were made during the growing season, with modest cumulative harvested biomass (3.1 ton/ac).

Table 3. Grain yield, stover, aboveground biomass, and harvest index (± standard error) for Business-As-Usual (BAU) and Aspirational (ASP) treatments in the LTAR-NP Croplands Common Experiment, 2020.

Treatment-Crop Phase	Grain yield - - - bu/ac - - -	Stover - - - ton/ac - - -	Aboveground biomass - - - ton/ac - - -	Harvest index
BAU-Spring wheat	15.7 ± 1.6	0.8 ± 0.1	1.3 ± 0.1	0.37 ± 0.01
ASP1-Spring wheat	14.1 ± 2.0	0.8 ± 0.1	1.2 ± 0.1	0.32 ± 0.03
BAU-Corn	80.5 ± 4.6	3.1 ± 0.2	5.3 ± 0.3	0.43 ± 0.01
ASP1-Corn	49.0 ± 5.5	2.4 ± 0.2	3.7 ± 0.3	0.36 ± 0.02
BAU-Soybean	15.7 ± 1.5	0.6 ± 0.1	1.0 ± 0.1	0.45 ± 0.01
ASP1-Soybean	20.4 ± 1.5	0.7 ± 0.1	1.3 ± 0.1	0.47 ± 0.01
ASP2-Alfalfa/Intermediate wheatgrass			3.1 ± 0.8	


Corn – BAU Treatment (26 June 2020)


Corn – ASP Treatment (26 June 2020)


Corn – BAU Treatment (14 July 2020)


Corn – ASP Treatment (14 July 2020)

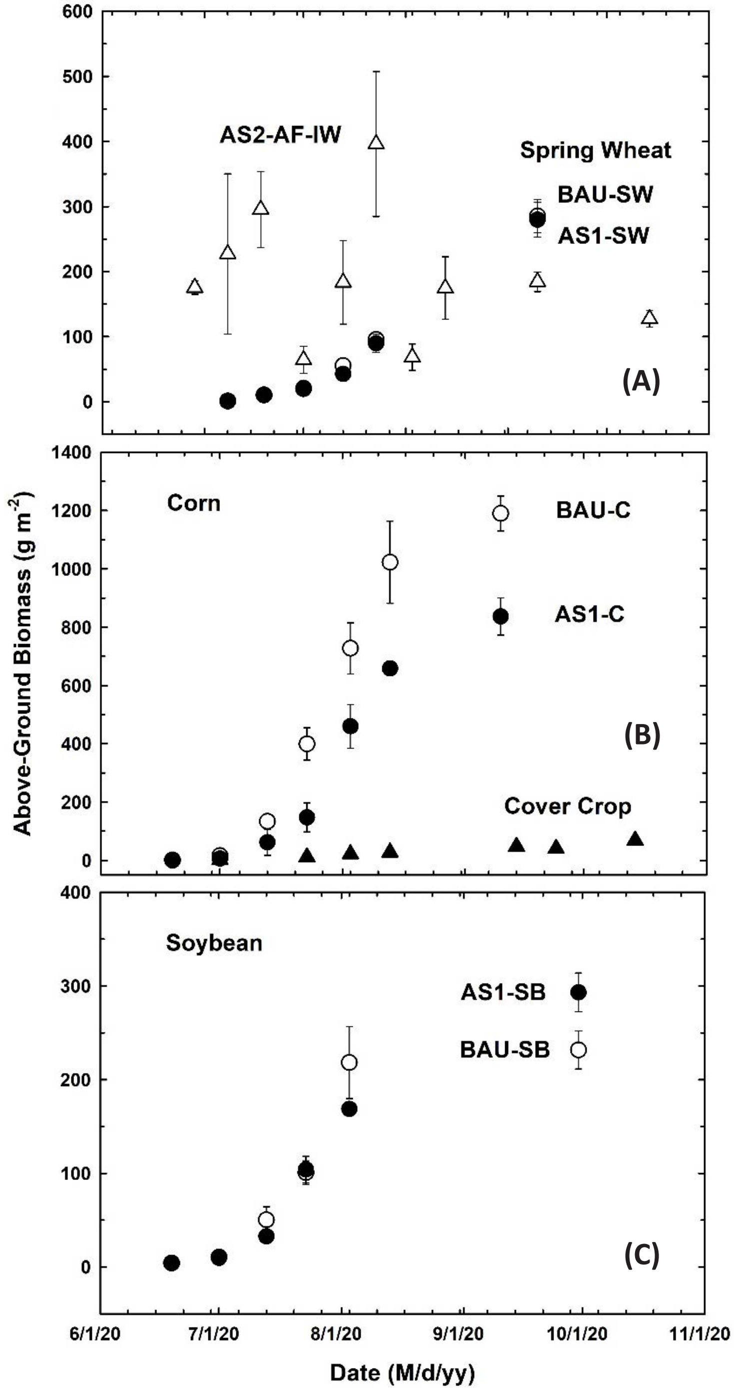


Figure 3. Growing season above-ground biomass (AGB, g m-2) for the aspirational (AS1 and AS2) and business-as-usual (BAU) treatments at the plot-scale within the LTAR-NP Cropland Common Experiment, 2020: (A) perennial system (triangles, AS2-AF-IW, alfalfa-intermediate wheatgrass) and spring wheat phase (circles), (B) corn phase (circles) and cover crop (triangles) in AS1-C, and (C) soybean phase in the second year of a 3-year rotation.

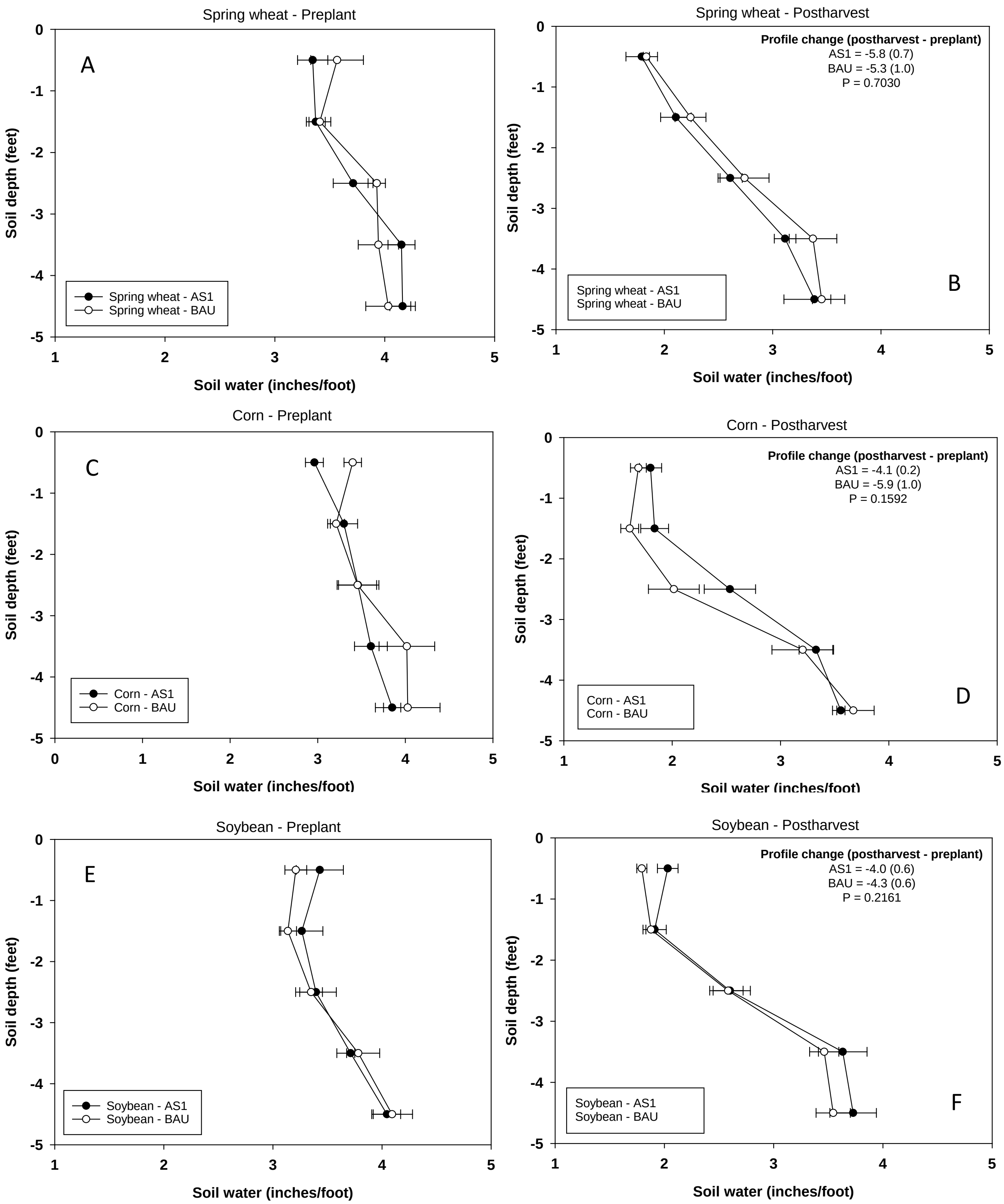


Figure 4. Profile soil water status before planting and after harvest for the aspirational (AS1 and AS2) and business-as-usual (BAU) treatments at the plot-scale within the LTAR-NP Cropland Common Experiment, 2020: spring wheat (A, B), corn (C, D), and soybean (E, F).

Differences between treatments in soil water status prior to planting was limited to corn, where growth by the previous year's cover crop decreased soil water content in the 0-1 ft depth of the ASP treatment (Figure 4c). Soil water status decreased over the course of the growing season, with depletion between planting and harvest ranging from 4.0 to 5.9 inches of water over the 5 ft depth. Change in profile soil water status did not differ between treatments for any crop (Figure 4).

Measurements of soil biological properties and greenhouse gas fluxes were not conducted on the LTAR-NP plot-scale study in 2020.

Field-scale summary

Growing conditions at fields H5 (BAU) and I2 (ASP) were similar in 2020 (Tables 4 & 5; Figure 6). Precipitation at both fields was well below the long-term mean of 16.3". Near-surface soil water content (2" depth) was greater in the ASP treatment compared to BAU in both growing and dormant seasons (Table 5).

Combined corn grain yield was over 20 bu/ac lower in the ASP treatment (41 bu/ac) compared to the BAU treatment (62 bu/ac) (see Area 4 SCD Research Farm bulk field summaries for details). Hand samples collected at 10 locations in each treatment confirmed the combine harvest, with significantly greater grain yield, total aboveground biomass, and harvest index in BAU compared to ASP (P=0.0001, 0.0008, and 0.0004, respectively; data not shown).

CO^2 uptake was observed in the ASP treatment in 2020, while the BAU treatment was a CO2 source (Table 6; Figure 5). Daily CO2 fluxes in the ASP and BAU treatments during the growing season were -7.8 ± 1.3 and 2.6 ± 1.3 lbs CO2-C/ac/d, respectively (Table 7). Given the lower aboveground biomass production in the ASP treatment compared to BAU, this result suggests substantial carbon allocation to belowground biomass in the ASP treatment.

Cover crop growth throughout the year contributed to greater evapotranspiration (ET) in the ASP treatment compared to BAU (Tables 6 & 7; Figure 5).

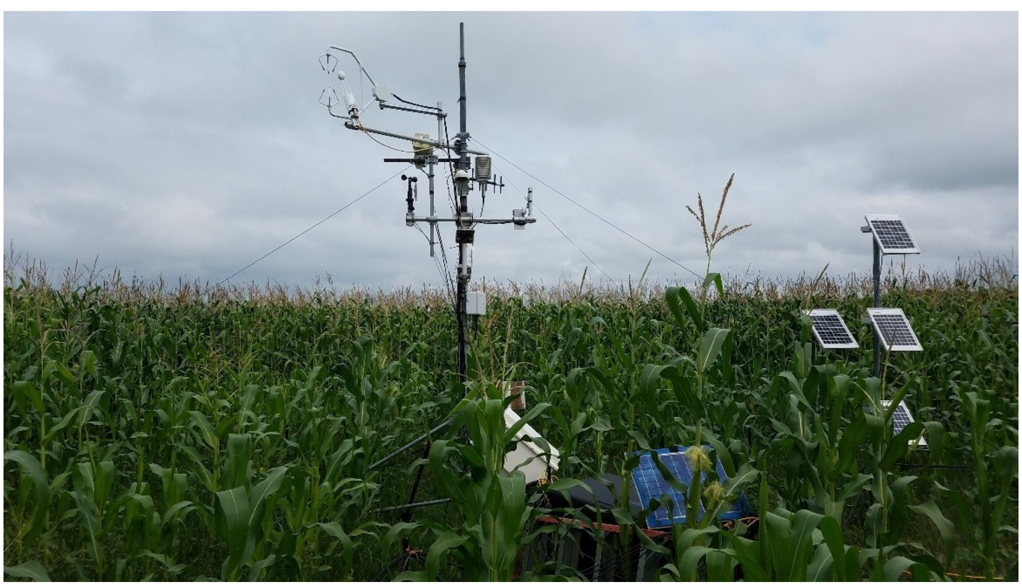


Table 4. Annual averages (± standard error) of incoming or global solar radiation (Rg), vapor pressure deficit (VPD), relative humidity (RH), air (Tair) and soil (Tsoil) temperature, soil water content (SWC), and total precipitation (PCPN) in two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU) and ASPirational (ASP). Soil temperature and water content measurements taken at the 2" depth.

Treatment (Field)	n Days	R_g W m^{-2}	VPD hPa	RH %	T_{air} °C	T_{soil} °C	SWC %, v/v	PCPN in yr^{-1}
BAU (H5)	366	167 ± 5	5.3 ± 0.3	70.0 ± 0.8	6.6 ± 0.6	8.8 ± 0.5	15.4 ± 0.2	7.33
ASP (I2)	366	171 ± 5	5.4 ± 0.2	68.7 ± 0.7	6.6 ± 0.6	8.2 ± 0.5	18.0 ± 0.4	7.19

Table 5. Seasonal averages (± standard error) of incoming or global solar radiation (Rg), vapor pressure deficit (VPD), relative humidity (RH), air (Tair) and soil (Tsoil) temperature, soil water content (SWC), and total precipitation (PCPN) in two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU) and ASPirational (ASP). Soil temperature and water content measurements taken at the 2" depth.

Season (Period)	Treatment (Field)	n Days	R_g W m^{-2}	VPD kPa	RH %	T_{air} °C	T_{soil} °C	SWC %, v/v	PCPN in $season^{-1}$
Growing (May-Oct)	BAU (H5)	184	222 ± 6	8.5 ± 0.3	64.4 ± 1.0	15.4 ± 0.6	17.2 ± 0.4	16.0 ± 0.4	6.58
	ASP (I2)		224 ± 6	8.5 ± 0.3	63.8 ± 1.0	15.5 ± 0.6	16.7 ± 0.4	18.4 ± 0.4	6.45
Dormant (Nov-Apr)	BAU (H5)	182	112 ± 6	2.0 ± 0.3	75.7 ± 1.0	-2.4 ± 0.6	0.3 ± 0.4	14.9 ± 0.4	0.75
	ASP (I2)		117 ± 6	2.2 ± 0.3	73.6 ± 1.0	-2.3 ± 0.6	-0.3 ± 0.4	17.6 ± 0.4	0.74

Table 6. Annual averages (± standard error) of net ecosystem exchange for CO2 (NEE), ecosystem respiration (ER), gross ecosystem production (GEP), evapotranspiration (ET), and sensible heat flux (H) and their annual totals in two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU) and ASPirational (ASP).

Treatment	n	NEE	ER	GEP	ET	H	NEE	ER	GEP	ET	H
(Field)	Days	--------- lbs C $acre^{-1}$ d^{-1} ---------			in d^{-1}	MJ m^{-2} d^{-1}	lbs C $acre^{-1}$ yr^{-1}			in yr^{-1}	MJ m^{-2} yr^{-1}
BAU (H5)	366	0.56 ± 0.94	16.4 ± 1.2	15.8 ± 1.8	0.045 ± 0.003	2.29 ± 0.15	204	5984	5781	16.4	839
ASP (I2)	366	-1.73 ± 1.02	17.1 ± 1.3	18.8 ± 2.1	0.056 ± 0.004	2.15 ± 0.15	-633	6266	6899	20.6	787

Table 7. Seasonal averages (± standard error) of net ecosystem exchange for CO2 (NEE), ecosystem respiration (ER), gross ecosystem production (GEP), evapotranspiration (ET), and sensible heat flux (H) and their seasonal totals in two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU) and ASPirational (ASP).

Season	Treatment	n	NEE	ER	GEP	ET	H	NEE	ER	GEP	ET	H
(Period)	(Field)	Days	--------------- lbs C $acre^{-1}$ d^{-1} --------------			in d^{-1}	MJ m^{-2} d^{-1}	-- lbs C $acre^{-1}$ $season^{-1}$ --			in $season^{-1}$	MJ m^{-2} $season^{-1}$
Growing (May-Oct)	BAU (H5)	184	2.62 ± 1.34	28.8 ± 1.5	31.4 ± 2.5	0.078 ± 0.004	3.54 ± 0.19	482	5299	5781	14.3	652
	ASP (I2)		-7.80 ± 1.34	29.7 ± 1.5	37.5 ± 2.5	0.096 ± 0.004	3.26 ± 0.19	-1435	5464	6899	17.7	600
Dormant (Nov-Apr)	BAU (H5)	182	3.77 ± 1.34	3.8 ± 1.5	0	0.011 ± 0.004	1.03 ± 0.19	686	686	0	2.1	187
	ASP (I2)		4.41 ± 1.34	4.4 ± 1.5	0	0.016 ± 0.004	1.03 ± 0.19	802	802	0	2.9	188

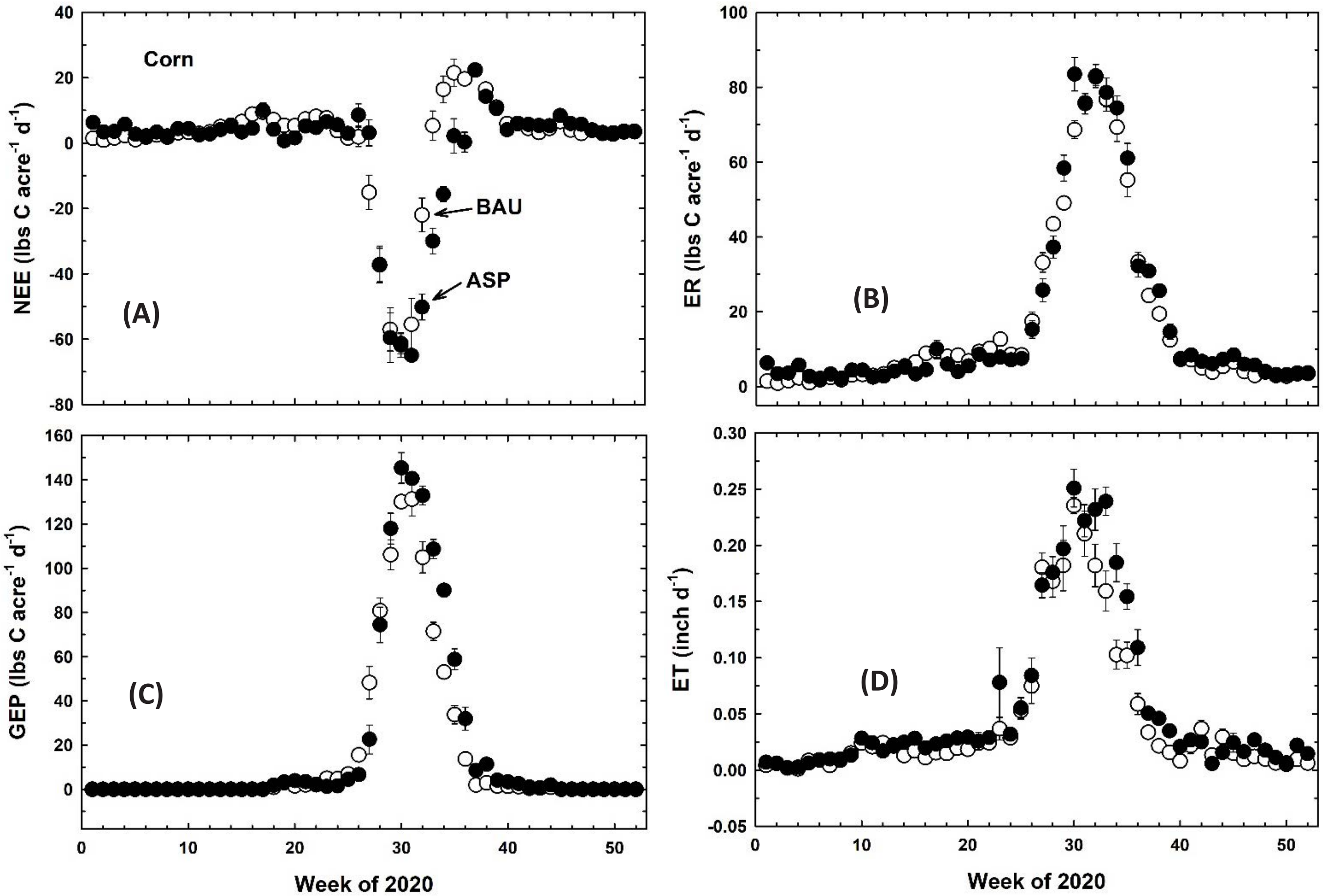


*Figure 5. Weekly averages (± standard error) of (A) net ecosystem exchange for CO2 (NEE), (B) ecosystem respiration (ER), (C) gross ecosystem production (GEP), and (D) evapotranspiration (ET) as obtained from half-hourly eddy covariance measurements in the second (corn) phase of a 3-year crop rotation in the LTAR-NP Cropland Common Experiment. Each data point is the mean of 336 observations (n = 48/day * 7 days) from two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU, open circles) and ASPirational (ASP, filled circles).*

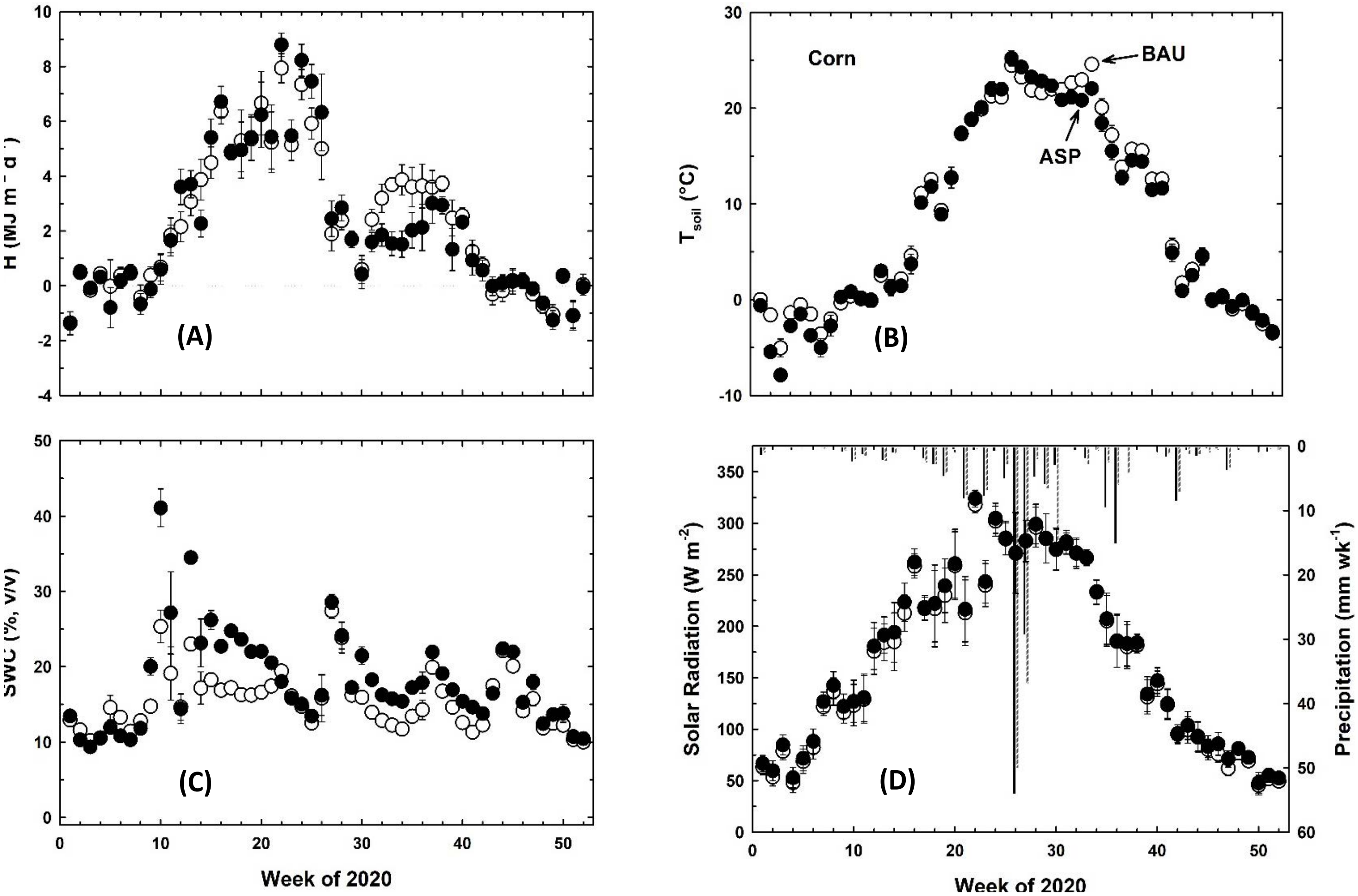


*Figure 6. Weekly averages (± standard error) of (A) sensible heat flux (H), (B) soil temperature (Tsoil), (C) soil water content (SWC), and (D) solar radiation and precipitation (solid bars = BAU, dashed bars = ASP) as obtained from half-hourly eddy covariance measurements in the second (corn) phase of a 3-year crop rotation in the LTAR Cropland Common Experiment. Each data point is the mean of 336 observations (n = 48/day * 7 days) from two fields (>20 ha) with contrasting cropping systems, Business-As-Usual (BAU, open circles) and ASPirational (ASP, filled circles).*

Table 7. Glossary of terms associated with field-scale measurements.

Abbreviation	Description
C	Carbon; the proportion of C in CO_2 = 12/44 = 0.273
CO_2	Carbon dioxide; molecular weight = 44 g mol^{-1}
ER	Ecosystem respiration; measured as night-time NEE from eddy covariance
ET	Evapotranspiration; calculated from latent heat flux, LE, measured from eddy covariance
H	Sensible heat flux; measured from eddy covariance
GEP	Gross ecosystem production, GEP = ER – NEE
NEE	Net ecosystem exchange for CO_2; negative (–) is C gain/uptake; positive (+) is C loss/emission

Organic Transition Study – 2019 summary

Scientists: Andrea Clemensen, John Hendrickson, Dave Archer, Rachael Christensen

Support staff: Andrew Carrlson, Raina Hanley, Holly Johnson

Description

An area approximately 7 acres was transitioned and certified for organic research. After the first organic study experimental phase (2016-2019), a new phase of research treatments were implemented in 2020. Organically grown, perennial crops are of great interest to producers in the Northern Plains. This type of crop may provide options for producers and introduce greater diversity to current cropping systems. Financially, if these systems can be proven sustainable, they may provide economic returns. Kernza® (Thinopyrum intermedium), a perennial intermediate wheatgrass, might provide an alternative cropping option but additional research is needed to address concerns with establishment, grain yield, and responses to grazing pressure.

Hypotheses:

1. Kernza yield will be similar between the solid seeded and inter-seeded treatments.
2. The length of Kernza grain production will be longest in the cultivated widely spaced Kernza rows followed by the inter-seeded treatments and least in the solid seeded treatment.
3. Inter-seeding alfalfa will improve selected soil parameters compared to the other treatments.

Treatments:

Seeding:

1. Solid-seeded - Kernza drilled at 7.5” row spacing
2. Inter-seeded – Kernza planted at 30” spacing with falcata Alfalfa seeded between Kernza rows in 2021
3. Cultivated – Kernza planted at 30” spacing with cultivation used between rows to keep inter-row spaces clear of volunteer crops and/or weeds

Grazing:

1. Grazed
2. Ungrazed

Summary

Winter rye was planted as cover-crop in fall 2019. An undercutter was used to terminate the winter rye and weeds (mostly cheatgrass) on June 4. Due to dry soil conditions, it was difficult to keep the undercutter below the soil surface to sever roots and minimize disturbance of the above ground biomass. Patches of Canada thistle were hand weeded on June 15. Plots were disced July 13-16 and tilled with a Will Rich cultivator August 26. Kernza was seeded (26.7 lb/ac) using a John Deere 750 drill, with the solid-seeded treatment drilled on August 31, and the interseeded and cultivated treatments drilled on September 1.

Borders/alley areas were seeded using a Great Plains drill with a mix of rye (21.4 lb/ac), Organic DS Admiral Field Pea (21.4 lb/ac), Organic Proso Millet (14.3 lb/ac), and buckwheat (2.9 lb/ac).

Bioenergy Cropping Systems Study – 2020 summary

Scientists: David Archer, Scott Kronberg, and Mark Liebig
Support staff: Holly Johnson, Robert Kolberg, Eric Antosh, Raina Hanley

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

2020 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	5/11/2020	WB 9653	130 lb/ac	229 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/27/2020
Spring Wheat W-P	5/11/2020	WB 9653	130 lb/ac	145 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/27/2020
Spring Wheat W-P/CC	5/11/2020	WB 9653	130 lb/ac	164 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/27/2020
Dry Pea W-P, W-P/CC, W-P-C	5/01/2020	SW Midas	180 lb/ac	0 lb/ac urea 50 lb/ac 11-52-0	JD 750	8/03/2020
Corn W-P-C	5/20/2020	Proseed 1979RR	24,500 seeds/ac	0 lb/ac urea 50 lb/ac 11-52-0	JD Max Emerge II	9/24/2020
Cover Crop W-P/CC	8/06/2020	Mix	34 lb/ac	0 lb/ac urea 0 lb/ac 11-52-0	JD 750	

Fertilizer rates based on 2019 soil tests 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.

2020 Spray dates, pesticides used, & rates:

Crop	Date	Plot Areas	Chemical	Rate
All Crops	04/29/2020	*Spring Burndown:* All rotations/crops/plots	Buccaneer 5 Extra Destiny Sharpen Class Act	24 oz./a 12 oz./a 2 oz./a 128 oz./100gallons
Peas	6/03/2020	W-P and W-P-C rotations: All plots/residue removals	Basagran Section 3 Pursuit Class Act	32 oz./a 8 oz./a 2 oz./a 1 qt/100 gallon
	6/04/2020	W-P/CC rotation: All plots/residue removals	Basagran Section 3 Class Act	32 oz./a 8 oz./a 1 qt/100 gallon
	8/11/2020	All rotations - burndown	Buccaneer 5 Extra Class Act Jackhammer	32 oz./a 2.5 gal/100 gallon 2 qt/100 gallon
		All Rotations [A, B, C residue removals only]	Express 2,4-D LV-6 Buccaneer 5 Extra Class Act Jackhammer	0.5 oz./a 12 oz./a 16 oz./a 2 qt/100 gallon 2 qt/100 gallon
Spring Wheat	6/05/2020	All rotations	Tacoma Widematch	10 oz./a 16 oz./a
		All Rotations [A, B, C residue removals only]	Express 2,4-D LV-6 Buccaneer 5 Extra Class Act Jackhammer	0.5 oz./a 12 oz./a 16 oz./a 2 qt/100 gallon 2 qt/100 gallon
Corn	6/19/2020	All rotations	Buccaneer 5 Extra Class Act Jackhammer	20 oz./a 2.5 gal/100 gallon 2 qt/100 gallon
	6/23/2020	All rotations	Buccaneer 5 Extra Class Act Jackhammer	20 oz./a 2.5 gal/100 gallon 2 qt/100 gallon

Summary:

- Spring wheat yield was significantly lower ($\alpha = 0.10$) where residue had been harvested and removed in previous years (B) and (C) than where grazing (D) or no residue harvest (A) had occurred (Figure 1). There were no significant wheat yield differences among the rotations.

- No significant differences in Pea yield were observed among any of the treatments (Figure 2).

- Corn yield appeared to be lower where wheat straw had been harvested (B) or grazing occurred (D) than where no residue harvest had occurred (A) or where residues from all crops had been harvested (C). However, the differences were not significant.

- Plots were grazed with heifers. Due to drought, it was decided to only graze the corn plots. The corn plots were 10/5/2020-10/7/2020 with four heifers per plot, so approximately 58 animal unit day per acre.

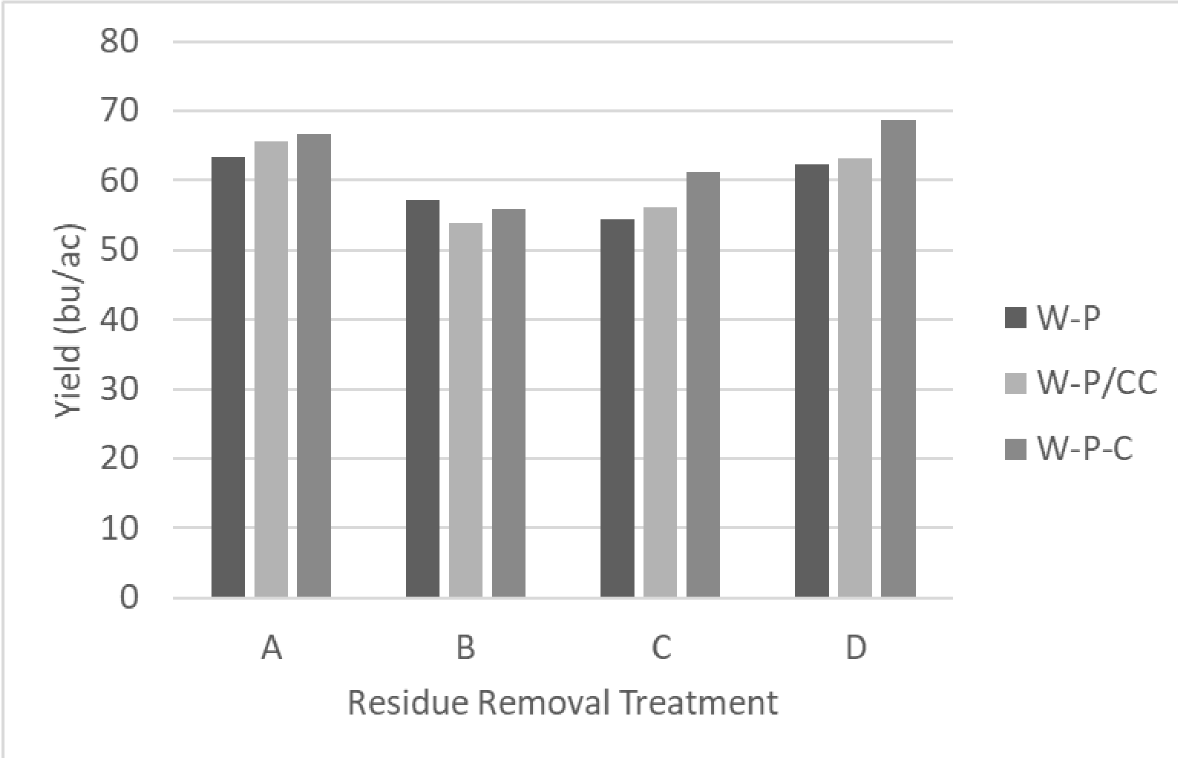


Figure 1. 2020 spring wheat seed yield as influence by crop rotation and residue removal treatments.

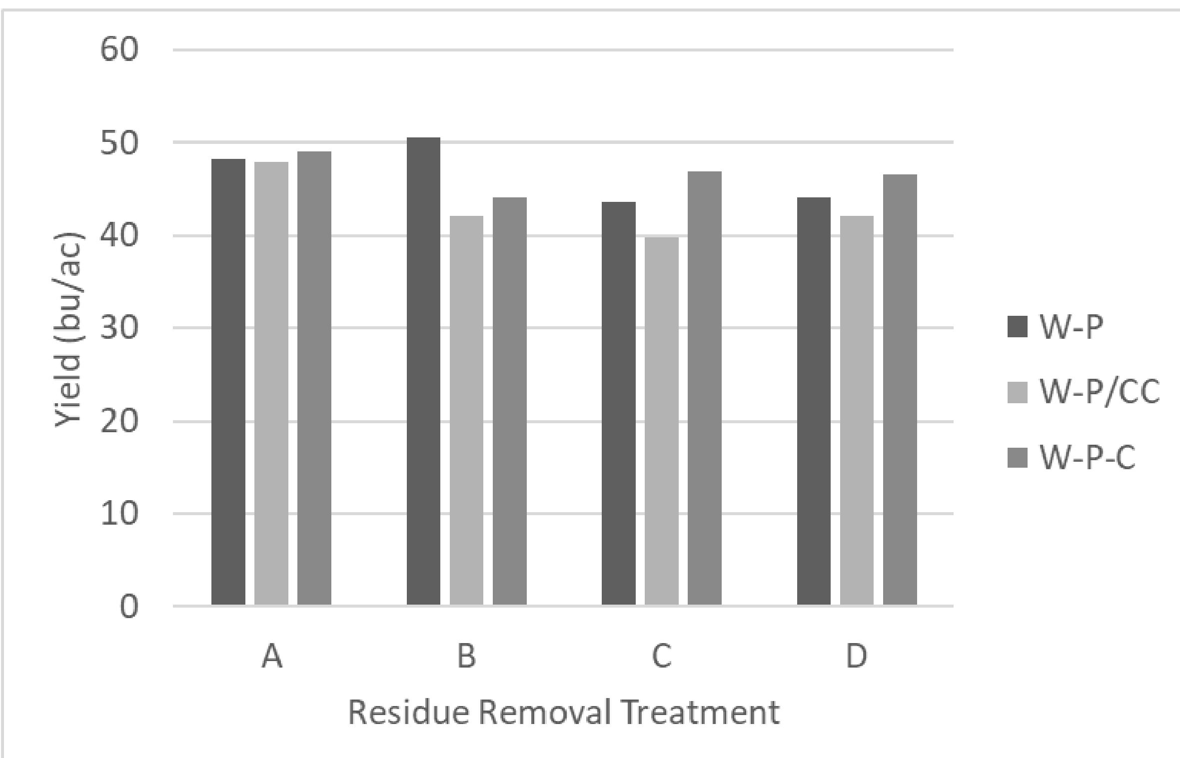


Figure 2. 2020 dry pea seed yield as influenced by crop rotation and residue removal treatments.

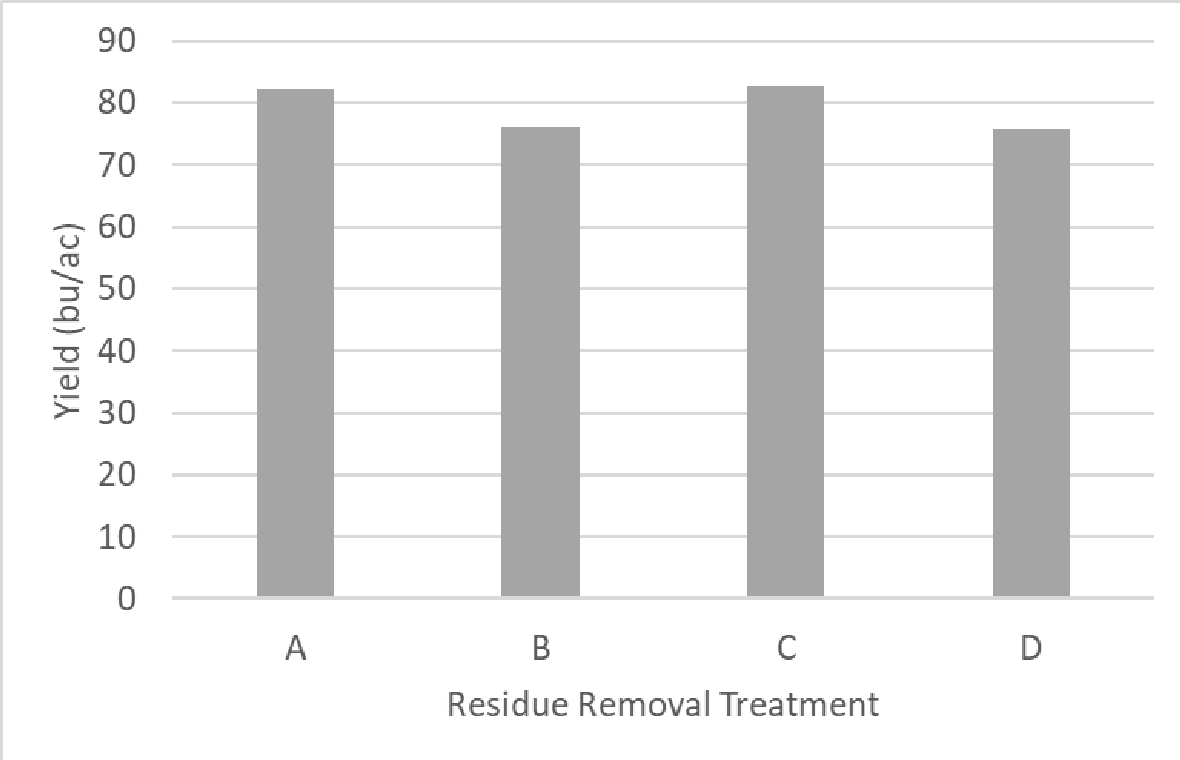


Figure 3. 2020 corn seed yield as influenced by residue removal treatments.

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, with a 7-way mixture of intermediate wheatgrass, timothy, alfalfa, hairy vetch, red clover, daikon radish, and chicory planted after harvest.

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

Planned fall grazing of corn in 2019 could not be done due to very wet conditions. The standing corn was harvested on April 21 with a JD6620 combine and an all crop header. There was some yield reduction due to stand loss from snow, wildlife, and incomplete crop maturity. Wheat strips were planted May 14 with a JD 750 drill. Wheat and corn strips were sprayed May 15 with Buccaneer 5 Extra (24 oz/ac) + Sharpen (2 oz/ac) + conditioner and surfactant. Wheat strips were sprayed post-emergent on June 5 with Widematch (16 oz/ac) and Tacoma (10 oz/ac).

An 11-row JD MaxEmerge II planter with 15-inch row spacing was used to plant the interseeded corn and soybean grazed treatment, with corn seed and soybean seed loaded in alternating planter boxes (6 rows of corn, 5 rows of soybean). Grazed corn and check strips were planted May 21 with the latter seeded conventionally. Soybean check strips were planted June 2 and sprayed June 4 with Durango (32 oz/ac), conditioner and surfactant. They were sprayed post-emergent on June 19 (Buccaneer 5 Extra @ 32 oz/ac + conditioner and surfactant) and July 30 (Cornerstone 5 Plus @ 32 oz/ac + conditioner and surfactant). Grazed corn strips were also sprayed on June 19 with Buccaneer 5 Extra @ 32 oz/ac as well as the check strips with the addition of Status @ 10 oz/ac + surfactant.

Both treatments of spring wheat were combined Aug 21 with the cover crop mix seeded into the stubble Aug

26 with a JD 750 drill and subsequently sprayed Aug 29 with Durango (24 oz/ac) and surfactant. The corn check strips were harvested Sep 25 with a JD 6620 combine and an all crop header with residue chopped and spread. Grazed corn strips were harvested Sep 29 with a picker header and residue placed in a swath. Soybean check strips were combined Oct 6. Grain yields are shown in Figure 1.

Differences in soil water status were limited to the soybean and cover crop phases, with significantly lower soil water under the cover crop prior to planting (0-1’) and after harvest (3-4’ and 4-5’) (Fig. 4). All crops exhibited substantial soil water depletion between planting and harvest, ranging from -5.1 to -8.1 inches of water over a five-foot depth (Table 2). Soil water depletion did not differ between crop phases.

Yearling black angus (5 animals per replication) were allowed to graze the 2020 cover crop strips and corn/ soybean residue for 95 days (Sep 24 to Dec 28). Free choice supplemental feed was also given consisting of 2019 baled millet and 2020 cover crop balage with added corn as needed. Average daily gain across all reps was 1.1 lb/day.

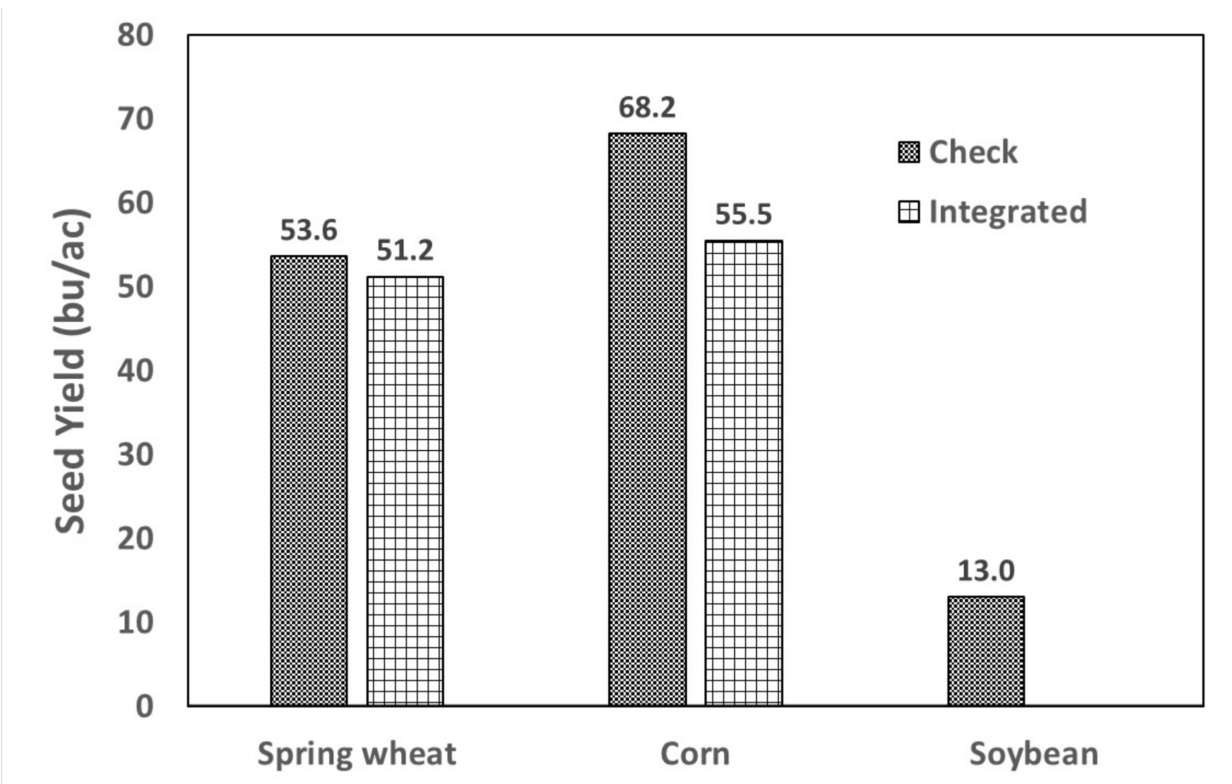
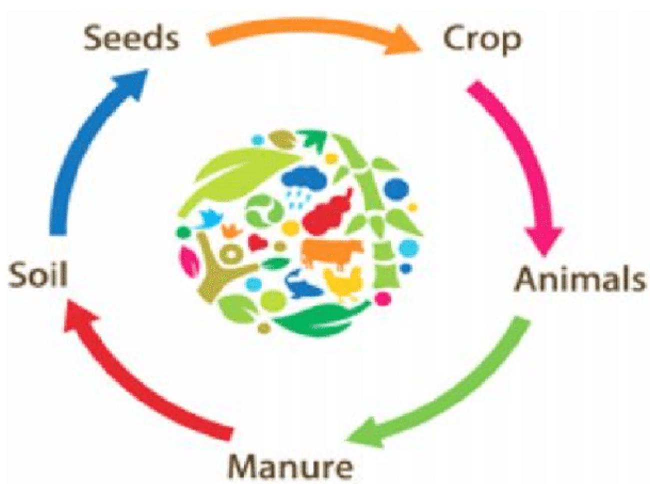


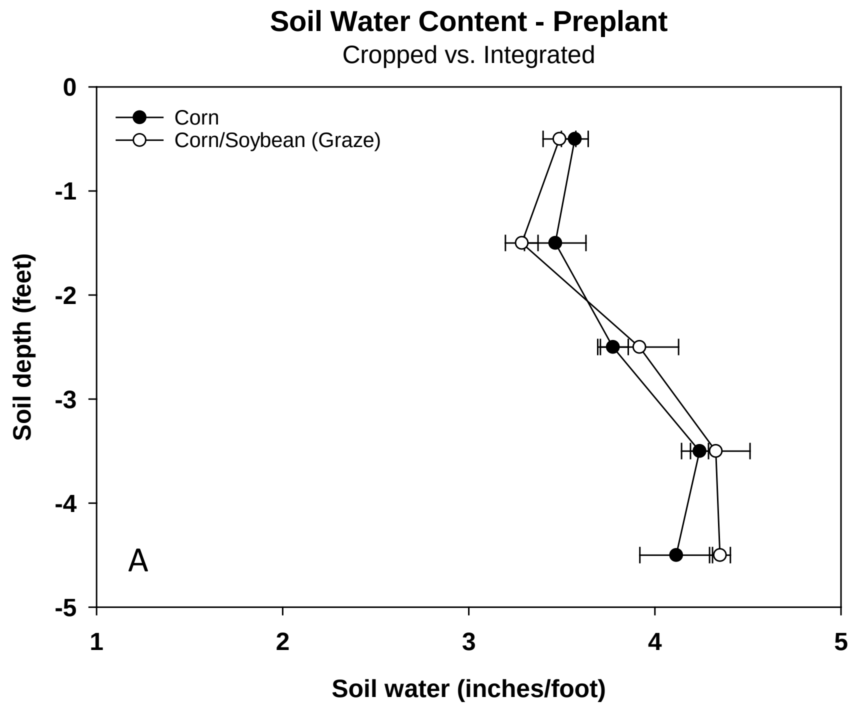
Figure 1. 2020 grain/seed production for the grazed (Integrated) and grain crop check (Check) strips.

Table 1. Crop parameters for 2020.

Crop	Cultivar or type	Planting	Planting rate	Fertilizer	Harvest
Grazed strips: Spring wheat	Glenn	5/14/20	100 lb/ac	Urea - 30 lb N/ac MAP - 30 lb mat/ac	8/21/20
Cover crop mix:		8/26/20	26.5 lb/ac	None	
Intermediate Wheatgrass	Manifest		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	5/21/20	24,500 seeds/ac	Urea - 40 lb N/ac MAP - 30 lb mat/ac Banded 5/21/20	9/29/20
Interseeded w/ Soybean	Mycogen 5B024 R2	5/21/20	80,200 seeds/ac		
Check strips: Spring wheat	Glenn	5/14/20	90 lb/ac	Urea - 30 lb N/ac MAP - 30 lb mat/ac	8/21/20
Corn	ProSeed 1280	5/21/20	24,500 seeds/ac	Urea - 40 lb N/ac MAP - 30 lb mat/ac	9/25/20
Soybean	Mycogen 5B024 R2	6/2/20	180,000 seeds/ac	None	10/6/20



Choudhary, Anil. (2013). Integrated farming systems for enhancing productivity and profitability under hill and mountain agro-ecosystems. https://www.researchgate.net/publication/308624784_Integrated_farming_systems_for_enhancing_productivity_and_profitability_under_hill_and_mountain_agro-ecosystems



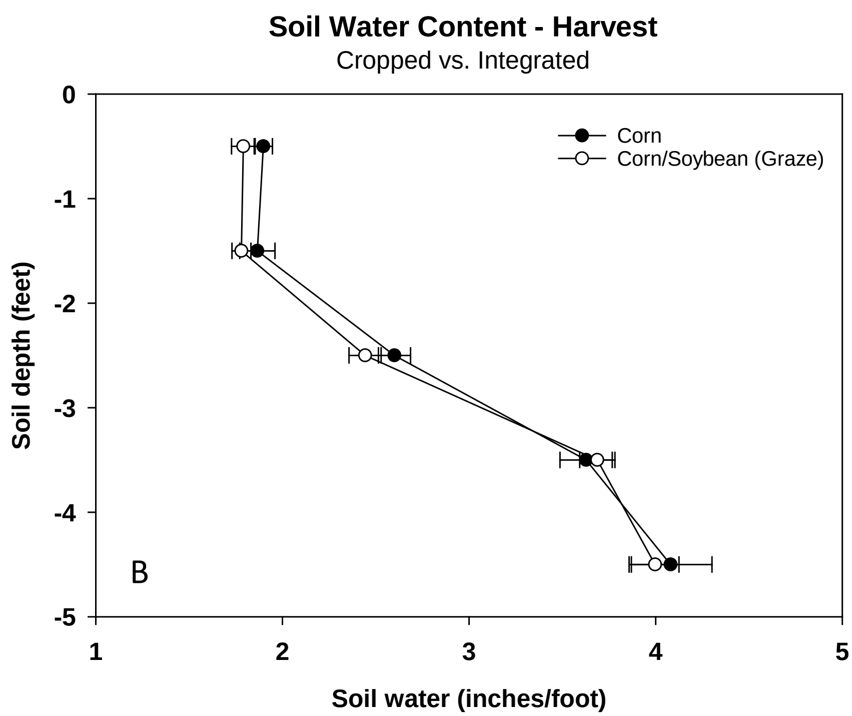
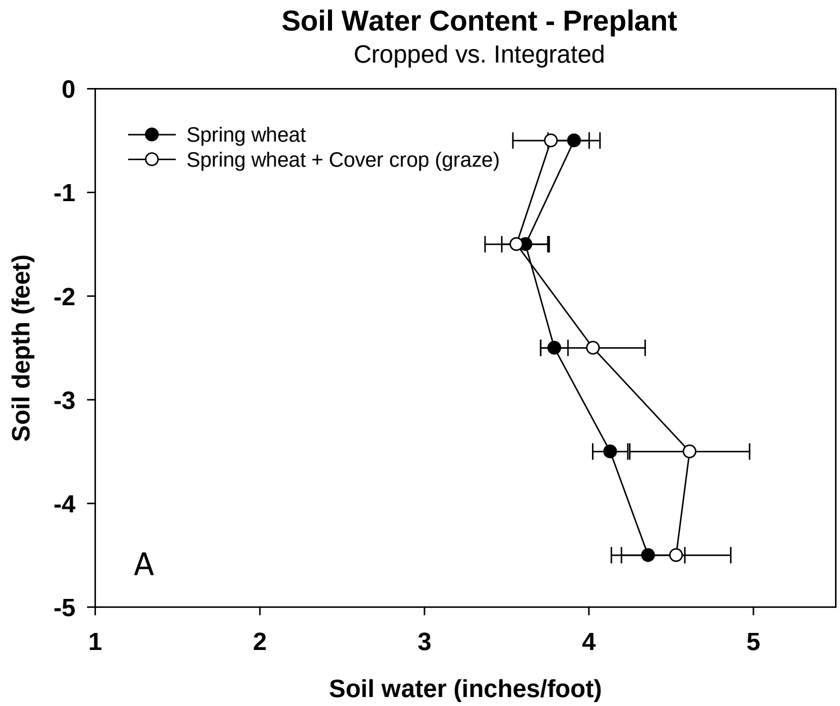


Figure 2. Profile soil water status for corn and corn interseeded with soybean prior to planting (A) and after harvest (B), 2020. Bars reflect mean standard error.



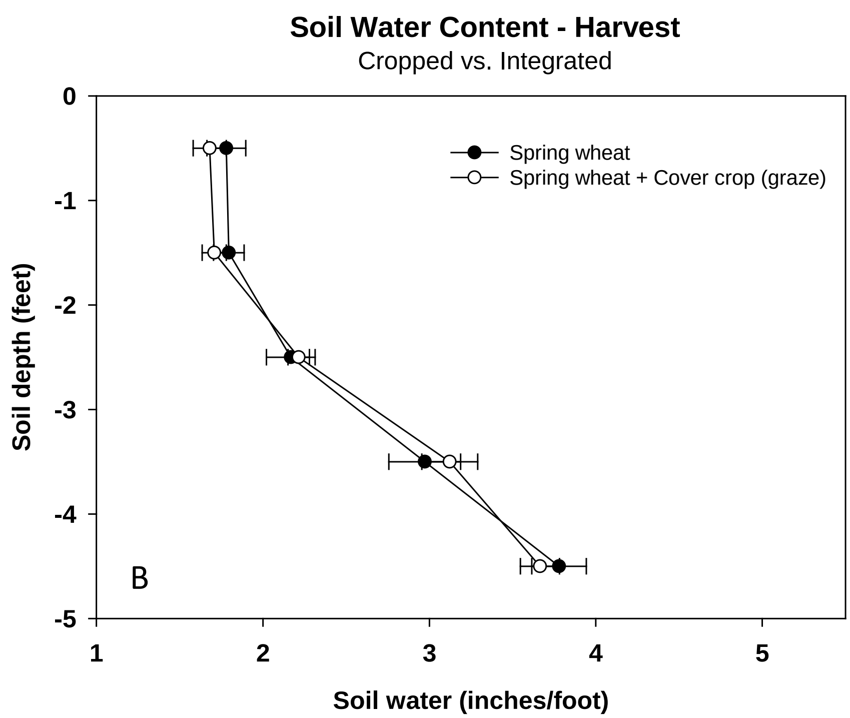


Figure 3. Profile soil water status for spring wheat and spring wheat + cover crop prior to planting (A) and after harvest (B), 2020. Bars reflect mean standard error.

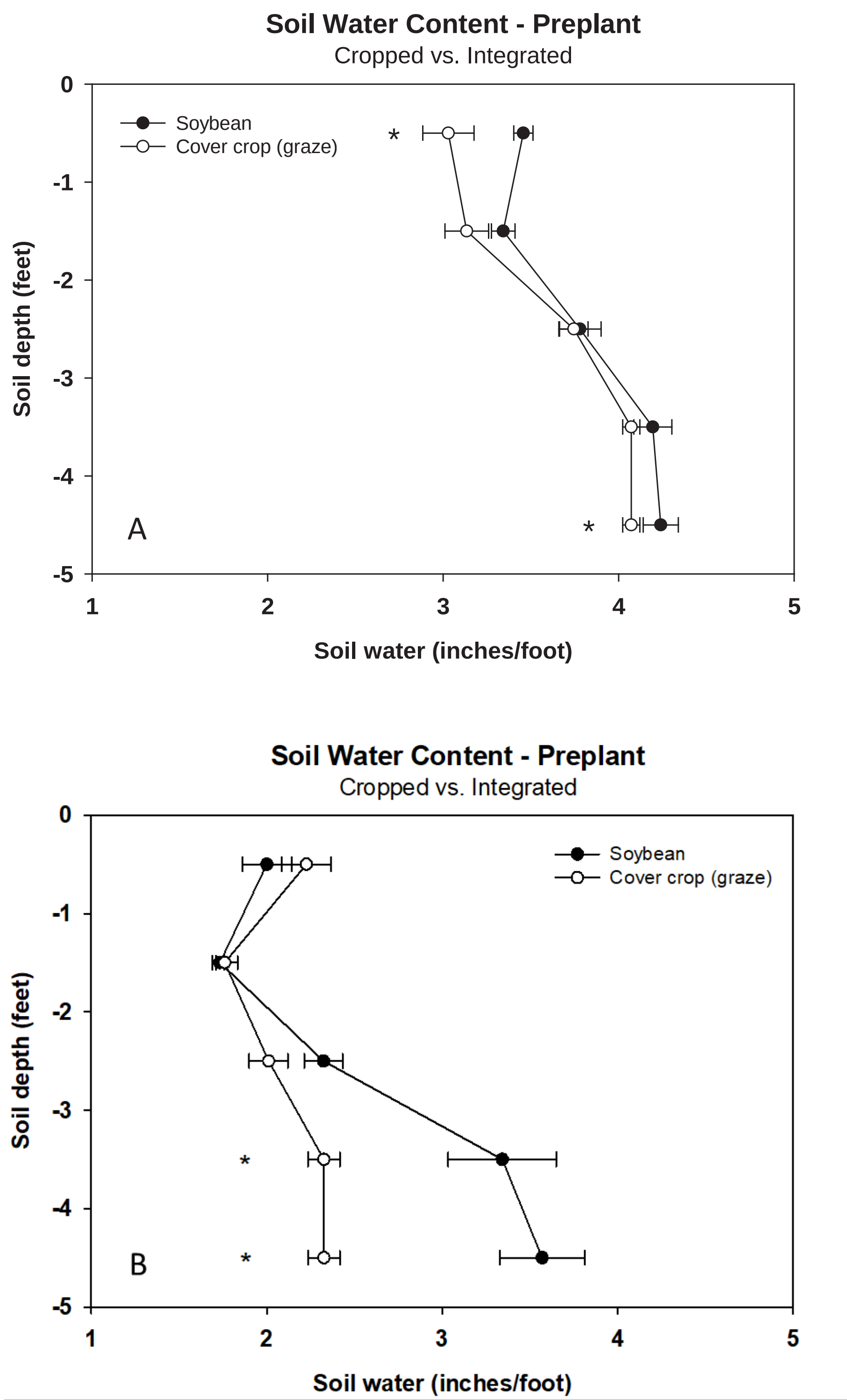


*Figure 4. Profile soil water status for soybean and cover crop prior to planting (A) and after harvest (B), 2020. Bars reflect mean standard error. Significant differences at P<0.05 designated by *.*

Table 2. Cumulative change in soil profile water status between planting and harvest, 2020.

Values reflect change over a five-foot soil depth.

Integrated crop-livestock treatment	Crop	Change in soil water (inches)
Ungrazed	Corn	-5.1
Grazed	Corn + Soybean	-5.7
		P=0.1952
Ungrazed	Spring wheat	-7.3
Grazed	Spring wheat + cover crop	-8.1
		P=0.5482
Ungrazed	Soybean	-6.0
Grazed	Cover crop	-7.0
		P=0.2638

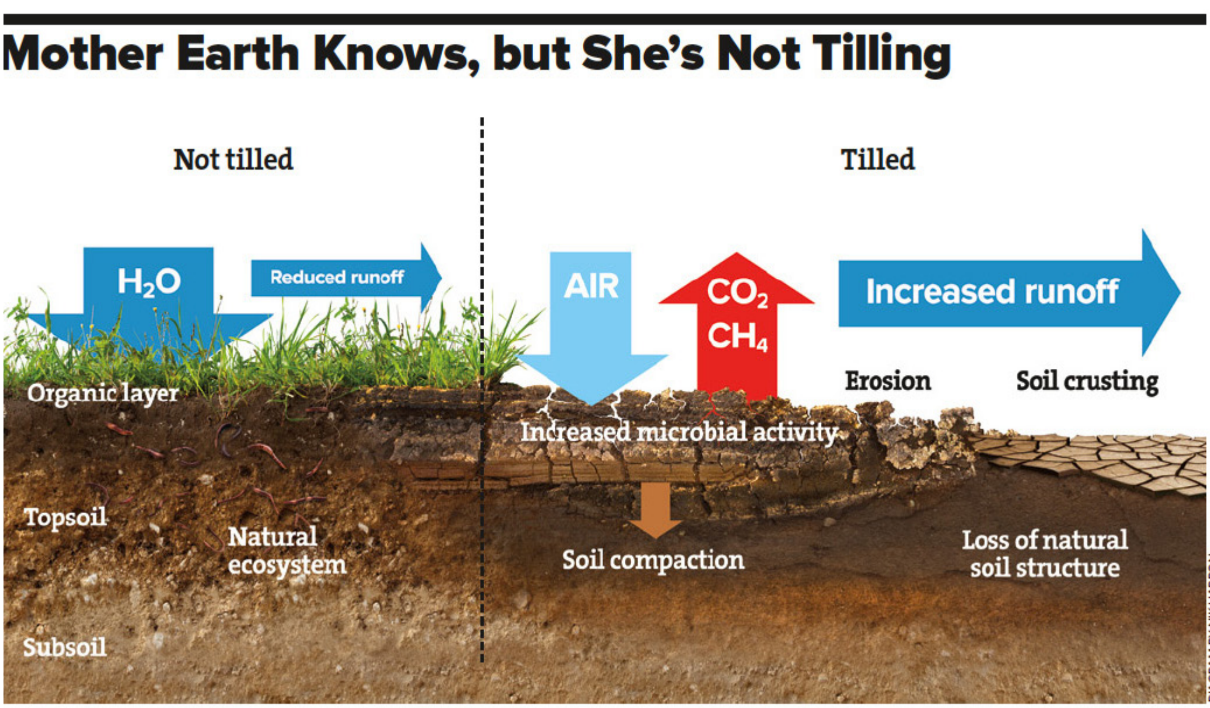


Diagram by nik harron.

Cover Crop Interseeding Study - 2020

Scientists: Dr. Mark Liebig, Dr. David Archer, Roberto Luciano (NRCS)
Support staff: Eric Antosh, Robert Kolberg, Raina Hanley, Marvin Hatzenbuhler

Interseeding cover crops into a standing crop can improve soil cover, enhance nutrient retention, and provide nutritious forage for livestock later in the season. This approach to cover crop establishment has been used in wetter areas of North Dakota, but performance in the western part of the state – where conditions are typically drier – has not been widely tested. Therefore, a three-year study was undertaken to determine the optimum time to interseed cover crops in corn. The study was conducted on the Area 4 SCD Cooperative Research Farm.

Background

• Approach: Plant cover crop mix in standing corn at three different planting dates, using a no-till interseeder.

• Treatments (replicated five times on Field H3 west):
    * No cover crop control, Time 0 (corn only, planted on May 26th)
    * First cover crop seeding time, Time 1 (corn at V4, June 24th)
    * Second cover crop seeding time, Time 2 (corn at V6, July 2nd)
    * Third cover crop seeding time, Time 3 (corn at V8, July 9th)

• Cover crop seed mix: 17.8 lb rye, 3.2 lb triticale, 18.9 lb cowpea, 2.1 lb purple-top turnip

• Data collection: Cover crop biomass and corn grain was harvested on October 9th.

Findings

Cover crop biomass from the first seeding time (348 lbs/ac) was significantly greater than cover crop biomass from the second and third seeding times (Avg. = 102 lbs/ac) (Figure 1). Weed biomass harvested in the no cover crop control (88 lbs/ac) was not different from biomass harvested from the second and third seeding times. Corn grain yield was not different between planting times (Avg. = 46 bu/ac) compared to the no cover crop control (48 bu/ac) (Figure 2).

This was the final year of this three-year study. Study results are being summarized for journal submission.

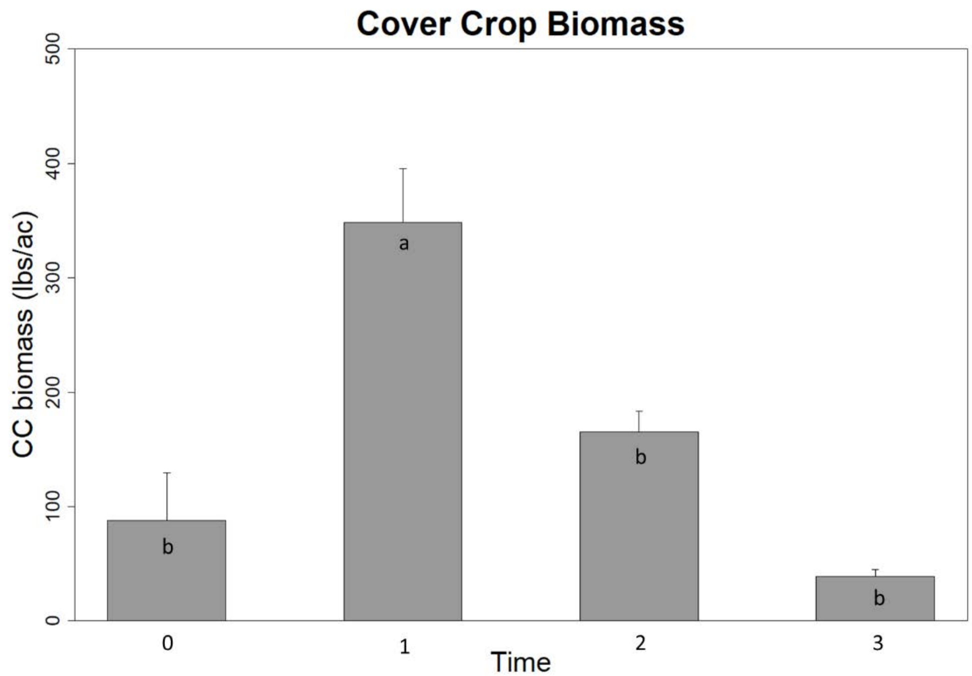


Figure 1. Cover crop and weed biomass for cover crop Interseeding treatments. Bars with unlike letters are significantly different at P<0.05. Time 0 is the control (corn only), time 1 is the first cover crop interseeding time and so on.

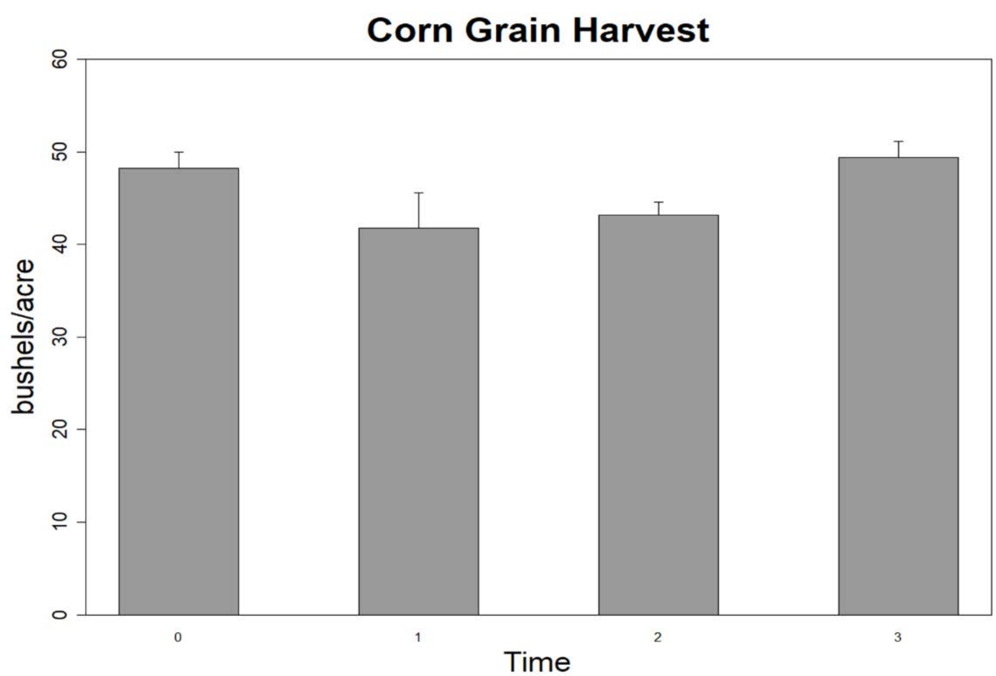


Figure 2. Corn grain yield for cover crop Interseeding treatments. No treatments were significantly different at P<0.05. Time 0 is the control (corn only), time 1 is the first cover crop interseeding time and so on.

Hettinger Soybean Seeding Rate Study

John Rickertsen & Michael Wells, Hettinger Research Extension Center, 2018 - 2020

Over the past decade soybean seeding rate recommendations in the corn-soybean belt have been reduced from 180,00 - 240,000 seeds per acre to 125,000 - 170,000. Much of this is due to increasing cost of soybean seed and soybeans tremendous ability to compensate for lower densities with increased branching and pod number. Yield per acre for soybeans remains relatively constant across population. This is because the number of seeds produced per plant is inversely related to the number of plants per acre. In general, numerous studies in the Midwest have shown 100,000 relatively uniformly spaced plants at harvest will produce the maximum economic return under most conditions. There have been many studies on soybean seeding rates in the Midwest, but there is little information on seeding rates for dryland soybeans in the semi-arid high plains.

A study was initiated in 2018 with nine seeding rates, 20,000 to 180,000 in 20,000 increments in both drilled (7”) and row (30”) configurations at Hettinger, ND and just 30” rows at Mandan, ND. In 2020 the Hettinger trial was planted on May 19 and Mandan on May 20. The soybean variety ND19009GT was used at both locations. Trials were no-till planted with a 7 row 7” inch spacing plot drill equipped with Acra Plant ADU double disk openers and a two row plot planter equipped with John Deere 1700 row units on 30” inch spacing. Weed control was obtained by a pre-emergence herbicide application of BroadAxe and post-emergence application of glyphosate. The trials were harvested with a Kincaid 8XP small plot combine on September 16 at Hettinger and September 26 at Mandan. Data was recorded on flowering, height, maturity date, yield, test weight, seed protein and seed oil content.

The results showed that seeding rates of 100,000 – 180,000 were not significantly different in yield and even the extremely low rate of 20,000 yielded 65% of the 100,000 - 180,000 seeding rates. For seed protein and oil content, as seeding rate increased, oil content decreased and protein increased. At the very lowest populations, seed size increased and test weight decreased, but there was no significant difference in the 100,000 to 180,000 rates for seed size and no significant difference in 40,000 to 180,000 rates for test weight. In 2018 and 2020, there was no difference in yield between 7” and 30” rows, while in 2019, 7” rows yielded 5.5 Bu/Acre higher than 30” rows. Over the past three years the 120,000 seeds/acre rate has been the optimal seeding rate for southwest North Dakota.

NDSU Hettinger Research Extension Center

Hard Red Spring Wheat - 2020	**Mandan, ND**

Variety	Plant Height	Plant Lodge	Test Weight	Grain Protein	----- Grain Yield ----- 2018	2019	2020	Average Yield 2 yr	3 yr
	inches	0-9*	lbs/bu	%	------------ Bushels per acre ------------				
AAC Concord	28	0	60.3	14.5	--	--	45.5	--	--
AP Murdock	23	0	61.2	14.3	--	40.6	44.7	42.7	--
Barlow	26	0	62.1	14.8	46.2	34.4	43.0	38.7	41.2
Bolles	26	0	60.2	17.2	48.6	35.6	40.7	38.2	41.6
Boost	27	0	60.7	15.1	50.5	34.8	44.5	39.7	43.3
CP3530	28	0	62.2	14.7	48.2	38.8	45.9	42.4	44.3
CP3903	26	0	62.2	15	--	--	42	--	--
CP3910	24	0	63.1	15.1	--	33.6	45.3	39.5	--
CP3915	25	0	62.4	14.4	--	36.2	47.9	42.1	--
Dagmar	25	0	60.8	15.3	--	--	40.5	--	--
Driver	27	0	62.5	13.9	--	--	50.7	--	--
Dyna-Gro Ambush	25	0	61.5	14.3	50.5	36.2	42.9	39.6	43.2
Dyna-Gro Ballistic	27	0	61.7	13.9	--	31.9	52.6	42.3	--
Dyna-Gro Commander	25	0	61.0	14.7	--	35.0	44.5	39.8	--
Dyna-Gro Velocity	24	0	61.3	14.8	--	--	38.2	--	--
Elgin ND	28	0	61.8	14.2	48.9	38.7	51.6	45.2	46.4
Faller	25	0	61.5	13.8	45.6	42.1	48.3	45.2	45.3
Glenn	28	0	62.4	15.0	56.0	34.8	42.0	38.4	44.3
Lang MN	26	0	62	14.9	51.3	40	48.8	44.4	46.7
Lanning	24	0	61.1	14.9	46.3	36.7	47.4	42.1	43.5
LCS Buster	26	0	61.6	12.2	--	--	54.0	--	--
LCS Cannon	25	0	62.9	14.8	50	37.1	41.5	39.3	42.9
LCS Rebel	28	0	61.8	15.6	52.0	36.8	46.8	41.8	45.2
LCS Trigger	24	0	62.4	12.1	43.5	41.7	50.2	46.0	45.1
Linkert	24	0	62.1	15	45.9	35.5	45.1	40.3	42.2
MN Torgy	23	0	62.4	14.1	--	40.7	48.2	44.5	--
MN Washburn	24	0	61.6	13.7	52.4	35.4	40.4	37.9	42.7
MS Barracuda	24	0	60.6	16.3	50.2	34.7	43.6	39.2	42.8
MS Chevelle	23	0	61.5	13.7	49.8	36.3	41.7	39.0	42.6
MS Ranchero	24	0	60.4	14.3	--	--	49.1	--	--
ND Frohberg	26	0	61.6	15.2	--	32.1	45.2	38.7	--
ND VitPro	25	0	62.4	15.7	47.1	36.9	46.1	41.5	43.4
Shelly	23	0	60.1	14.1	51.8	37.2	48.7	43.0	45.9

Table continued on next page

Hard Red Spring Wheat - 2020	Mandan, ND

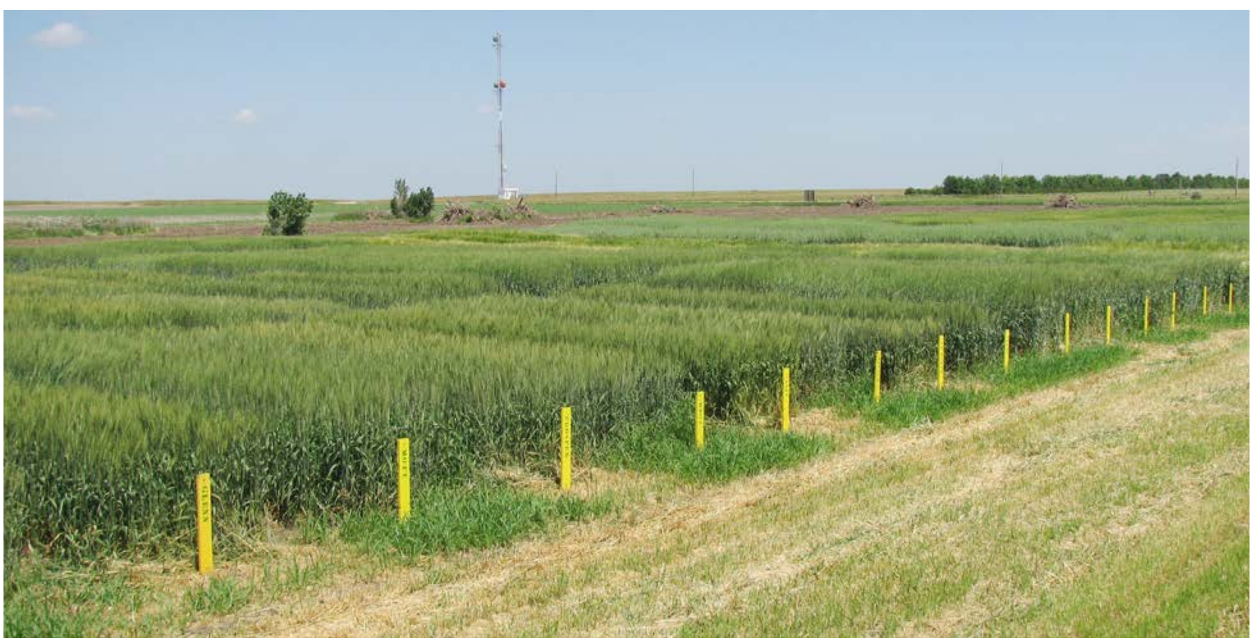
Variety	Plant Height	Plant Lodge	Test Weight	Grain Protein	----- Grain Yield ----- 2018	2019	2020	Average Yield 2 yr	3 yr
	inches	0-9*	lbs/bu	%	----------- Bushels per acre -----------				
Table continues from previous page									
SY 611 CL2	23	0	63.2	15	45.3	40.7	44.3	42.5	43.4
SY Ingmar	24	0	61.8	15.6	55.4	33.0	39.9	36.5	42.8
SY Longmire	25	0	62.3	15.4	52.6	32.6	45.1	38.9	43.4
SY McCloud	26	0	62.3	15.8	45.8	32.5	41.5	37.0	39.9
SY Rockford	26	0	60.1	15.2	46.0	38.2	49.6	43.9	44.6
SY Soren	23	0	61.9	15.0	48.0	30.4	39.4	34.9	39.3
SY Valda	25	0	61.8	14.1	46	41.5	51.5	46.5	46.3
TCG Heartland	24	0	62.6	15.3	--	30.9	42.1	36.5	--
TCG Sptifire	25	0	61.8	13.2	49.2	38.5	48.7	43.6	45.5
TCG Wildcat	25	0	61.9	15.6	--	--	38.9	--	--
Trial Mean	25	0	61.6	14.7	49.3	36.1	44.8	40.9	43.6
C.V. %	6.5	--	1.5	3.3	15.7	7.6	14.0	--	--
LSD 5%	2.3	--	1.3	0.7	4.1	3.8	8.8	--	--
LSD 10%	1.9	--	1.1	0.6	3.4	3.2	7.4	--	--

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

Planting Date: May 1

Harvest Date: August 26

Previous Crop: Soybean



NDSU Hettinger Reaserch Extension Center

Soybean - Conventional/LibertyLink - 2020									Mandan, ND
		Maturity	Plant	Test	Seed	Seed	Seed Yield		
Company/Brand	Variety		Height	Weight	Oil	Protein	2020	2-Yr	
			inches	lbs/bu	%	%	-----Bu/ac-----		
Conventional									
NDSU	ND Benson	0.4	32	57.5	16.9	35.0	31.9	--	
NDSU	ND Dickey	0.7	32	57.5	16.2	34.7	36.5	--	
RR Check #1		0.8	32	56.1	16.2	35.2	31.7	--	
RR Check #2		0.8	31	56.7	16.5	34.4	30.2	--	
LibertyLink									
Proseed	BX20-65	0.8	28	57.5	16.5	34.6	26.7	--	
Trial Mean			32	57.1	16.3	35.1	30.7	--	
C.V. %			5.2	0.6	2.1	1.3	9.8	--	
LSD 5%			2.5	0.6	0.5	0.7	4.5	--	
LSD 10%			2.0	0.5	0.4	0.6	3.7	--	

Planting Date: May 20
Harvest Date: September 24
Previous Crop: Spring Wheat

Soybean - Roundup Ready - 2020								
		Maturity	Plant	Test	Seed	Seed	Seed Yield	
Company/Brand	Variety		Height	Weight	Oil	Protein	2020	2-Yr
			inches	lbs/bu	%	%	-----Bu/ac-----	
NDSU	ND17009GT	00.9	38	59.3	17.0	36.1	38.6	--
Proseed	XT80-20N	0.2	35	57.2	17.7	30.7	35.0	--
INTEGRA	50309N	0.3	33	57.2	17.7	30.6	37.6	38.7
INTEGRA	40300N	0.3	32	57.2	17.7	30.6	40.4	--
REA Hybrids	RX0411	0.4	38	56.9	18.6	29.5	34.9	--
Proseed	XT60-40	0.4	29	56.8	18.5	31.1	32.0	35.9
REA Hybrids	RX0520	0.5	36	57.4	17.1	32.7	33.6	38.1
REA Hybrids	RX0721	0.7	34	57.1	17.6	32.3	36.4	--
RR Check #1		0.8	35	56.2	17.7	32.2	31.5	37.1
RR Check #2		0.8	33	57.0	18.6	29.9	31.5	38.3
			34	57.2	17.9	31.8	34.6	37.6
C.V. %			7.2	0.6	2.2	1.1	6.6	--
LSD 5%			3.4	0.5	0.5	0.6	3.2	--
LSD 10%			2.9	0.4	0.4	0.5	2.7	--

Planting Date: May 20
Harvest Date: September 24
Previous Crop: Spring Wheat

Northern Great Plains Research Laboratory Staff 2019

NGPRL Staff

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Cooperative Research Farm

Area IV Soil Conservation Districts*

USDA Agricultural Research Service

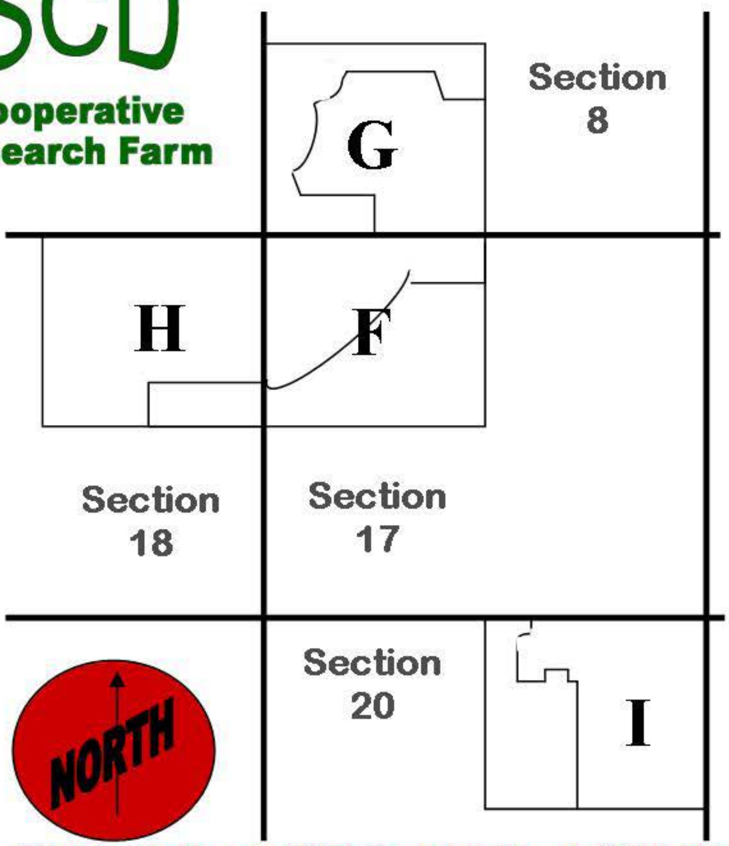
Founded 1983

AREA 4 SCD

Cooperative Research Farm

USDA Agricultural Research Service

Northern Great Plains Research Laboratory



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